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POPULATION TREND IN RIGHT WHALES OFF SOUTHERN AUSTRALIA 1993-2020

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Abstract

Annual aerial surveys of southern right whales have been conducted off the southern Australian coast, between Cape Leeuwin (W.A.) and Ceduna (S.A.) over a 28 year period between 1993 and 2020, to monitor the recovery of this species following commercial whaling. We conducted an aerial survey of southern right whales between the 20th and 24th August 2020, to continue these annual series of surveys and inform the long-term population trend. The comparable count for the 2020 survey utilised the maximum count for each leg and incorporated a correction for the unsurveyed area between Head of the Bight to Ceduna due to the inability to cover whole survey as a result of COVID-19 restrictions between State borders. This resulted in 384 individuals, consisting of 156 cows accompanied by calves of the year and 72 unaccompanied adults. Of these, 126 images of individual whales have been selected for photo-identification matching. This is a significant decrease in overall sightings that has not been observed for over 13 years when compared to long term trend data for the population; last seen in 2007 (N = 286 individuals). The subsequent population estimate for the Australian 'western' subpopulation is 2,585 whales, which is also a significant decrease in estimated population size from 3,164 in 2019 to 2,585 in 2020. The extremely low number of unaccompanied adults (N = 68) had the greatest impact on the overall number of sightings in 2020, and is the lowest number sighted since 1993 (N = 47). Previous surveys in 2007 and 2015 have been noted as years of low whale counts that had been deemed anomalous years, although the low numbers from this survey questions this and may suggest the 3-year female breeding cycle is becoming more unpredictable. Considerable inter-annual variation in whale numbers, and cycles in population growth, makes it difficult to detect consistent and reliable changes in abundance from one year to the next, or even over longer periods of time. This severely inhibits our ability to identify immediate threats to the population and strongly supports continued annual population surveys.

Introduction

Now classified as endangered under the Australian EPBC Act, unsustainable whaling during the 19th and 20th centuries reduced southern right whales (*Eubalaena australis*) almost to extinction (to a few hundred animals) throughout the southern hemisphere, including off Australia. 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. Specifically, this has been evident for waters off Western Australia (WA) and western South Australia (SA) which is referred to as the 'western subpopulation'.

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 intra- and inter-season coastal movement. The series from 1993 was 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 and range expansion.

In the south-east of the southern Australian coast there has been little sign of recovery in numbers; a working hypothesis assumes separation between two subpopulations – 'western' and 'eastern'. Given the relative paucity of animals that visit the remainder of the southern Australian coast, the 'western' subpopulation is considered to represent the majority of the 'Australian' population. A comprehensive understanding of the population abundance and degree of spatial connectivity of southern right whales in Australian waters is currently being addressed in a nationally funded project. It will provide an abundance estimate of the total Australian population of southern right whales for the first time and investigate the connectedness of whales that utilise breeding areas on the eastern, southern and western coasts of Australia. The count data from these aerial surveys provide estimates of population size and trend for the 'western' population and the associated photo-identification data provides information on connectivity between the 'western' and 'eastern' population and life history information (e.g. calving intervals).

Methods

Aerial surveys of southern right whales are undertaken following established protocols, using a high wing, single engine aircraft (Cessna 172) crewed by a pilot/observer and photographer/observer along the southern coast of Australia between Cape Leeuwin (Western Australia) and Ceduna (South Australia). The survey is undertaken during August/September when whale numbers are likely to be at close to the maximum given the known calving period, and flights are only conducted on 'good' days, when wind speeds are less than 15 knots. Most animals, particularly cows accompanied by their calves of the year, 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. Each flight surveys an area within *ca* one nautical mile of the coast, assuming all animals are close to the coast, at a survey altitude of 1000 ft, with photographs of the individual markings of the whales taken at 500 ft (Fig. 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.

As in previous years, direct counts were obtained of animals observed within the search area. However, this year it was not possible to survey the entire extent of the survey area to the eastern range of Ceduna due to COVID-19 restrictions regarding quarantine conditions for people crossing the Western Australia-South Australia border. The survey in 2020 was undertaken between Perth and the Head of the Bight (HOB), at the Nullarbor in South Australia, because WA government restrictions placed on the survey team stipulated the plane could not land in South Australia. Typically, refuelling of the aircraft occurs at the Nullarbor and Ceduna in South Australia, and so without this option the range of the aircraft only enabled surveying as far east as the HOB. Aviation fuel (avgas) was road transported to Eucla, located on the W.A. and S.A. border, and a single flight was conducted from Eucla to the HOB and back on 22nd August 2020.

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 C. 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 'western' subpopulation recorded between C 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 C. 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. For the 2020 aerial survey, it has been necessary to determine an estimate for the unsurveyed portion of the survey area in South Australia, between HOB and Ceduna. In this unsurveyed area, Fowlers Bay is a historically significant right whaling area that experiences the second highest (aside from HOB) numbers of southern right whales in S.A. On the 22nd August, the aerial survey team conducted a flight over the HOB while a land-based survey was concurrently undertaken by the team of the Great Australian Bight Right Whale Study (GABRWS). Additionally, a land based team (by GABRWS) also undertook a survey count at Fowlers Bay on the same day. A correction factor was calculated for the unsurveyed area, using the land-based day count data from Fowlers Bay and an average of whale numbers over the past decade (2010-2019; ~ three (three-year) calving cycles) for the remaining unsurveyed area between HOB and Ceduna. This correction factor was incorporated into an estimate of the long-term trend in abundance, which informs a population estimate for the 'western' subpopulation.

The total population size estimate for the 'western' subpopulation 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 from the flights are added to the 'WA' catalogue for computer-assisted 'matching' with those already identified. A computer-assisted comparison system (Hiby & Lovell 2001) is used to 'match' individual photographs obtained on the flights with those already available in the 'WA catalogue'. From late 2003 it replaced manual methods used previously. The system compares digitised extracts of overhead ('topside') photographs of individual head callosity patterns. 'Matched' individuals are then included in the 'WA catalogue', comprising animals from Western Australia and South Australia, as well as from some other eastern states, the southern Indian Ocean and the Antarctic. It is contained in an 'Individual Whale' database. Sightings information is added to the existing sightings database which relates detailed sightings information to individuals already identified photographically

Results

Aerial survey and whale distribution

An aerial survey of the 'western' population of Australian southern right whales was undertaken between C. Leeuwin (WA) and Head of the Bight (SA) over five days in total, from the 20th to 24th August 2020 during 32.7 flying hours. During the survey, 721 southern right whales were sighted consisting of 302 calves of the year. There were an additional six groups of humpback whales, totalling 14 individuals and two mother-calf groups (Table 1).
For comparison with counts from previous years, only the maximum counts of each leg, 'outwards' or 'inwards' are included. For the 2020 survey, the comparable count was obtained utilising the maximum count for each leg surveyed and a correction for the unsurveyed area. During the survey, there were a total 375 southern right whales sighted, consisting of 154 cow-calf pairs and 67 unaccompanied whales. On the 22nd August, the land-based team surveyed Fowlers Bay at the same time the aerial survey team surveyed the HOB. The land-based team recorded no southern right whales in Fowlers Bay, and consequently a value of zero was attributed to Fowlers Bay in the correction factor. For the remainder of the unsurveyed area between the HOB and Ceduna (excluding Fowlers Bay), the average whale counts were used for the period between 2010 and 2019. This resulted in an average of 2 cow-calf pairs and 5 unaccompanied adults (median of 2 and 3 and maximum of 4 and 15, respectively). The overall maximum counts used for comparison with the long term trend data totalled 384 southern right whales, consisting of 156 cow/calf pairs and 72 'unaccompanied' adults (Table 2).

Sightings of southern right whales during the 2020 aerial survey were consistent with the distribution of whales in previous years for both cow/calf pairs and unaccompanied animals, although were lower in number (Fig. 2). The distribution of cow/calf pairs and unaccompanied animals also appeared in similar areas, with sightings of both groups in similar places along the coast. Specifically, there were higher numbers of both groups 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. 1 & 2).

Population estimate

The number of whales sighted in 2020 were fewer than the numbers sighted in the past four years (since 2015) for both the total numbers of whales (N=577) and cow/calf pairs (N=221), based on the comparable maximum counts (Table 2). It is evident there is significant inter-annual variation in the numbers of whales sighted (Fig. 3a). Since 1993, this variation demonstrates a 2 to 4-year cycle in population growth for unaccompanied animals and a 3 to 5-year cycle for cow/calf pairs (Fig. 3b), which appears to deviate from the typical 3-year calving cycle. Considerable inter-annual variation in whale numbers, and cycles in population growth, 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.

Current population size is estimated using a simple model adopted at the International Right Whale Workshop held at Buenos Aires, Argentina, in September 2011 (IWC, 2013), based largely on evidence from increasing populations off Argentina and South Africa. This model uses the cow/calf count over three years (to allow for the 3-year periodicity in calving), which is multiplied by a factor of 3.94. For the Australian 'western' subpopulation, this results in a current population size (i.e. for the three-year rolling average period, 2018 to 2020) of 2,585 whales, which is a significant decrease from 3,164 whales in 2019. The implications for future population estimates over the next two years is that they will be significantly affected by the low whale count in 2020, as demonstrated in previous years of low whale counts (e.g. 2015, Table 2).

Trend analysis

An exponential regression analysis of the count data for '*all animals*' between 1993 and 2020 (excluding 1996/97) provides an exponential rate of increase over the period of 0.0440 (95% CI 0.029, 0.059), which is equivalent to an annual increase of 4.5% (95% CI 2.95, 6.09) (Table 3, Figure 4). The estimated exponential rate of increase based on counts of only cow/calf pairs was 0.0531 (0.034, 0.072) or an annual increase of 5.45% (95% CI 3.51, 7.43) (Table 3, Figure 5). The lower whale numbers from the 2020 survey has resulted in a decreased trend in the rate of population increase compared to previous years. For '*all animals*' there has between a decrease from 5.18% in 2019 to 4.5% in 2020 and for '*cow/calf pairs*' it has decreased from 6% in 2019 to 5.45% in 2020 (Table 3).

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 4). When we look at more recent data between the years 2007 to 2020, this relationship becomes non-statistically significant (Table 4).

Discussion

The comparable count for the 2020 survey utilised the maximum count for each leg and a correction for the unsurveyed area between Head of the Bight to Ceduna in South Australia. This resulted in 384 individuals, consisting of 156 cows accompanied by calves of the year and 72 unaccompanied adults. This is a significant decrease in overall sightings that has not been observed for over 13 years when compared to long-term trend data for the population; last seen in 2007 (N = 286 individuals). The population long-term trend data shows similarly low numbers in 2015, 2007 and 2003, demonstrating high inter-annual variability. Previous surveys in 2007 and 2015 have been noted as years of low whale counts that had been deemed anomalous years (Bannister 2007, Bannister et al 2015). The low count in whale numbers from 2020 combined with these previous years, suggests these may not be anomalous years and that the typical 3-year breeding cycle of females may be becoming more unpredictable. Inter-annual variation of cow/calf pairs is related to the female breeding cycle, although in some years many females that are 'due' to breed in a particular year actually avoid breeding ('skip-breed') until the subsequent year, leading to these unpredictable fluctuations in the cohort structure. Southern right whale breeding success, as exemplified by cohort strength from year to year, has been correlated with high sea surface temperatures related to El Nino events that have affected conception rates, with a resulting effect on pregnancy rate
(Leaper et al 2006; Seybooth).

In the 2020 survey, of considerable interest is the extremely low number of unaccompanied adults (N = 68), which had the greatest impact on the overall number of sightings and is the lowest number sighted since 1993. The current population size of the 'western' Australian subpopulation is estimated to be at 2,585 whales, which is a considerable decrease compared to the 2019 3-year rolling average estimate of 3,164 whales. As demonstrated in previous years of low whale counts (e.g. 2015), the population estimate is significantly affected by the low whale count in the current year, which will affect the estimate over the next couple of years. To evaluate the recovery of the southern right whale population, it will be critical to understand annual variability in whale numbers related to the typical 3-year 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. Furthermore, if detection of environmental linkages is considered an important aim of future surveys, then annual surveys would be essential rather than any reduced-frequency strategy.

ACKNOWLEDGEMENTS

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The flying was undertaken under relevant permits from the Western Australian Department of Parks and Wildlife (permit no. TFA 2020-0090), the South Australia Department for

Environment and Water (permit no. MR00060-5-R and U26871-2) and ethical approval from Murdoch University (permit no. O3031/18).

REFERENCES

Bannister, J L, 1998. Aerial survey of southern right whales off Western and South Australia, 1997 calving season: report on work undertaken to 31 January 1998. Final report to Biodiversity Group, Environment Australia, 18 pp (unpublished).

Bannister, J L, 2002. Southern right whale aerial survey and photoidentification, southern Australia, 2001 calving season. Final report to Environment Australia, 18pp (unpublished).

Bannister J L, 2008. Population dynamics of right whales off southern Australia, 2007. Final report to the Department of the Environment and water Resources, Canberra 19pp (unpublished).

Bannister J L, 2011. Southern Right Whale Aerial Survey, Southern Australian Coast, August 2010. Final Report on work funded by the Australian Government through the Australian Marine Mammal Centre (unpublished) 16pp.

Bannister J L, Hamilton, P S and Double, M, 2015. Population trend in right whales off southern Australia 1993-2015. Paper SC/66b/BRG09 submitted to the Scientific Com International Whaling Commission, Bled, June 2015, 7pp.

Hiby, L & Lovell, P, 2001. A note on an automated system for matching the callosity patterns on aerial photographs of southern right whales. Journal of Cetacean Research and Management (Special Issue 2): 291-295.

IWC, 2013. Report of the Workshop on the Assessment of Right Whales. Journal of Cetacean Research and Management 14 (Suppl.), 437-462.

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

Seyboth, E., K. R. Groch, L. Dalla Rosa, K. Reid, P. A. C. Flores and E. R. Secchi (2016). Southern right whale (*Eubalaena australis*) reproductive success is influenced by krill (*Euphausia superba*) density and climate. Scientific Reports 6. 28205

Table 1. Total comparable maximum counts of whales for each leg since 1993 for the Right whale aerial survey, C. Leeuwin WA-Ceduna SA.

Year	a. All animals	b. Unaccompanied animals	c. 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

Note: The 2020 survey only extended east to the Head of the Bight (HOB). To correct for the unsurveyed area, an average of whale sightings between HOB to Ceduna (excluding Fowlers Bay) for the years 2010-2019 were used. The number of whale sightings used for Fowlers Bay were based on the land-based whale count by the Great Australia Bight Right Whale Study team.

Table 2. Best fit regressions for the maximum counts of whales in each leg for 1993-2020 (excluding 1996 and 1997) for the Right whale aerial survey C. Leeuwin (WA) to Ceduna (SA).

Period	**1993 - 2020**		**1993 - 2019**	
Class	All animals	Cow/calf pairs	All animals	Cow/calf pairs
Exponential increase	0.0440	0.0531	0.0505	0.0582
SE	0.0073	0.0090	0.0067	0.0092
95% CI (Lower – Upper)	0.029 – 0.059	0.034 – 0.072	0.037 – 0.064	0.039 – 0.077
p-value	< 0.01	< 0.01	< 0.01	< 0.01
R^2	0.60	0.59	0.71	0.64
Percentage annual increase	**4.5**	**5.5**	**5.2**	**6.0**
SE	0.74	0.90	0.67	0.92
95% CI (Lower – Upper)	2.93 – 6.09	3.51 – 7.43	3.73 – 6.65	4.01 – 8.02

Table 3. Best fit regressions for the maximum counts of whales in each leg for 2000-2020 and 2007-2020 for the Right whale aerial survey C. Leeuwin (WA) to Ceduna (SA).

Period	**2000 - 2020**		**2007 - 2020**	
Class	All animals	Cow/calf pairs	All animals	Cow/calf pairs
Exponential increase	0.0342	0.0454	0.0077	0.0365
SE	0.0110	0.0140	0.0208	0.0301
95% CI (Lower – Upper)	0.011 – 0.057	0.016 – 0.075	-0.037 – 0.053	-0.029 – 0.102
p-value	< 0.01	< 0.01	0.717	0.248
R^2	0.34	0.36	0.01	0.11
Percentage annual increase	**3.5**	**4.6**	**0.8**	**3.7**
SE	1.11	1.41	2.10	3.05
95% CI (Lower – Upper)	1.11 – 5.90	1.62 – 7.75	-3.69 – 5.45	-2.86 – 10.73

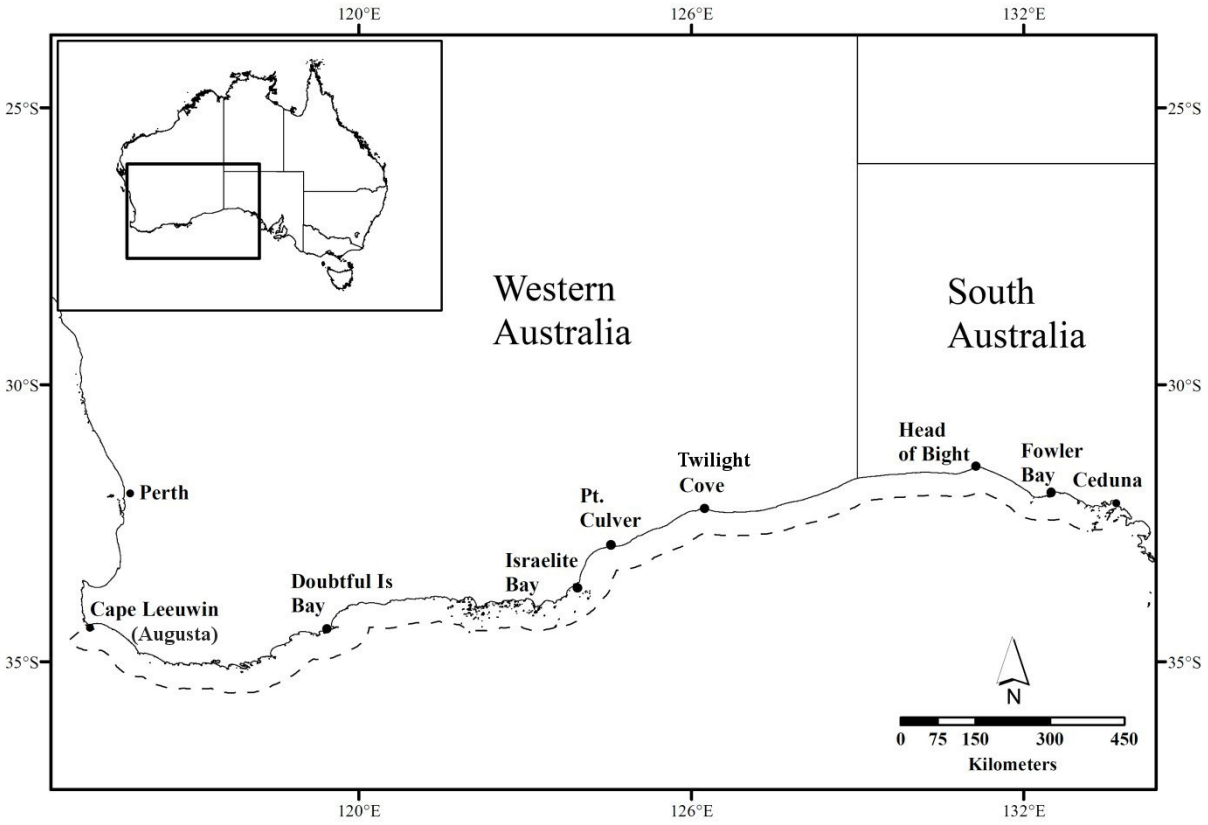
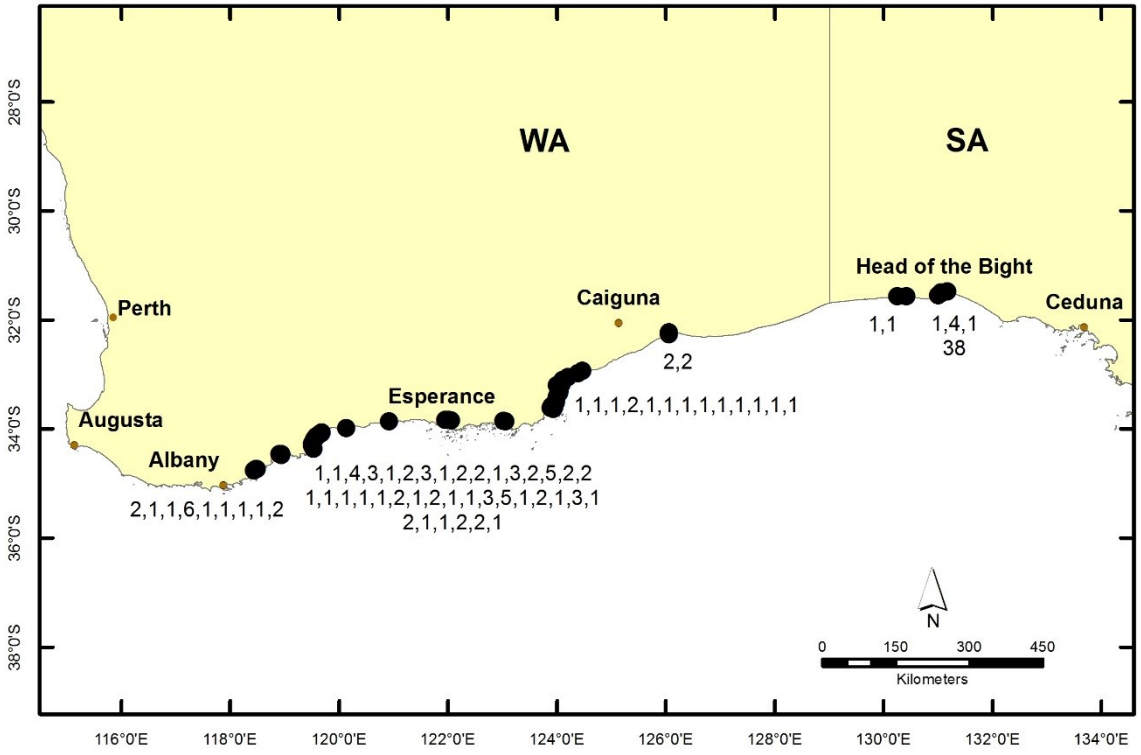


Figure 1 Right whale aerial survey off the coast of South West Australia in 2020. Dashed line represents the approximate survey area boundary.

a)



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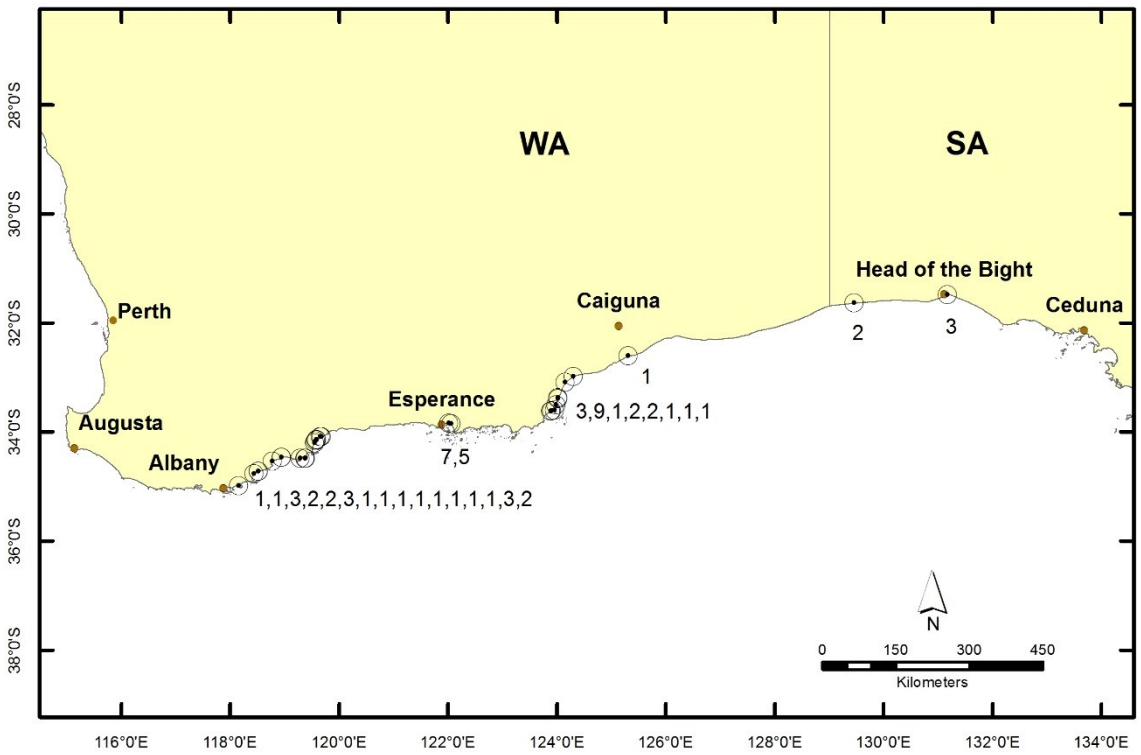
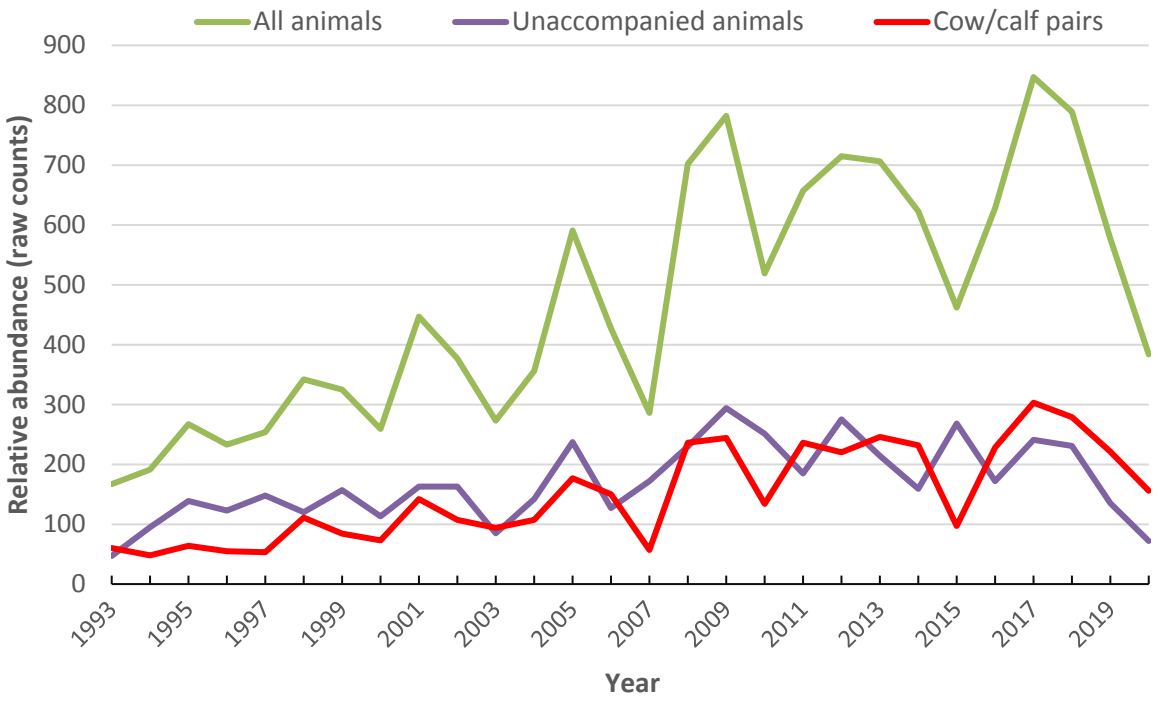


Figure 2 Aerial survey of WA-SA in Aug 2020. Approximate positions of right whale sightings on the flight and their associated group sizes.

a) Cow-calf pairs (●)

b) Unaccompanied animals (ʘ)

(a)



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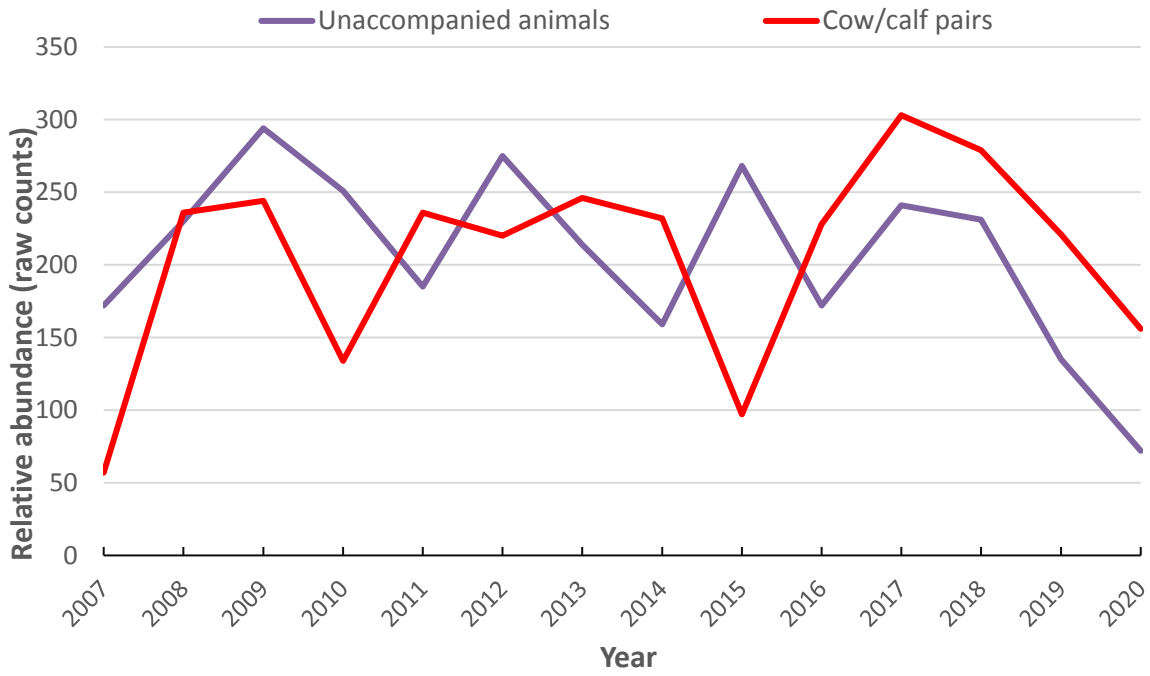
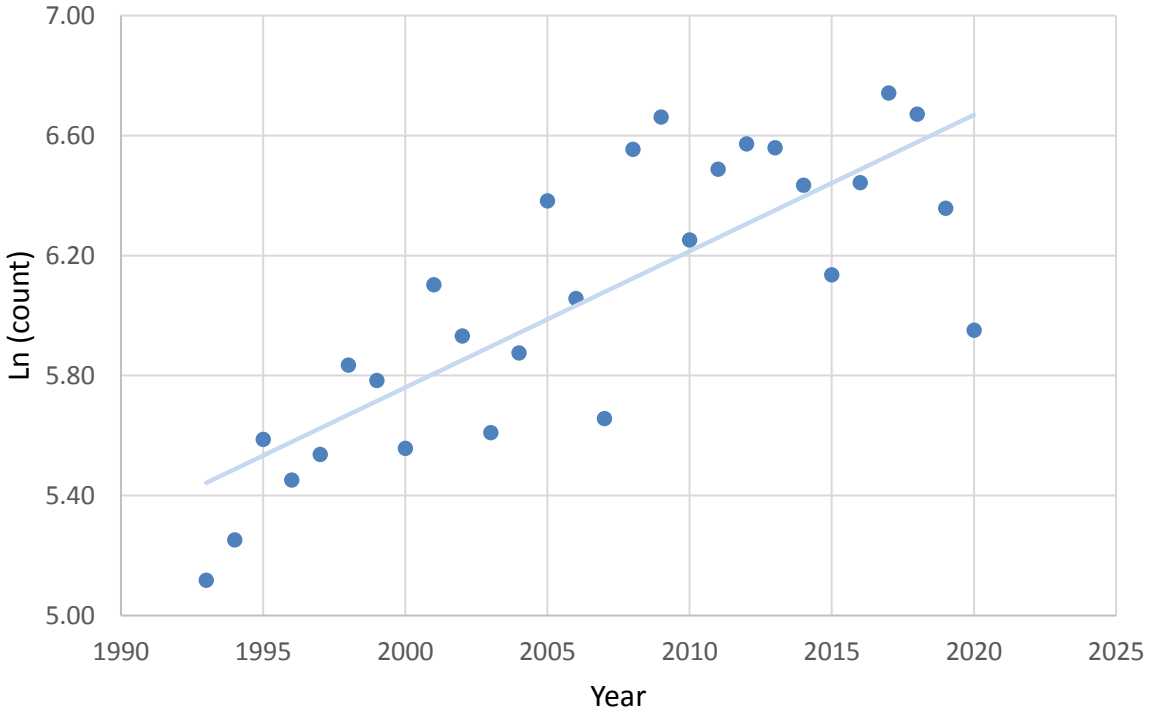


Figure 3. Graph of the relative abundance of the 'western' population of southern right whales for (a) all animals, unaccompanied animals and cow/calf pairs, between 1993 and 2020 and (b) unaccompanied animals and cow/calf pairs between 2007 and 2020.

(a)



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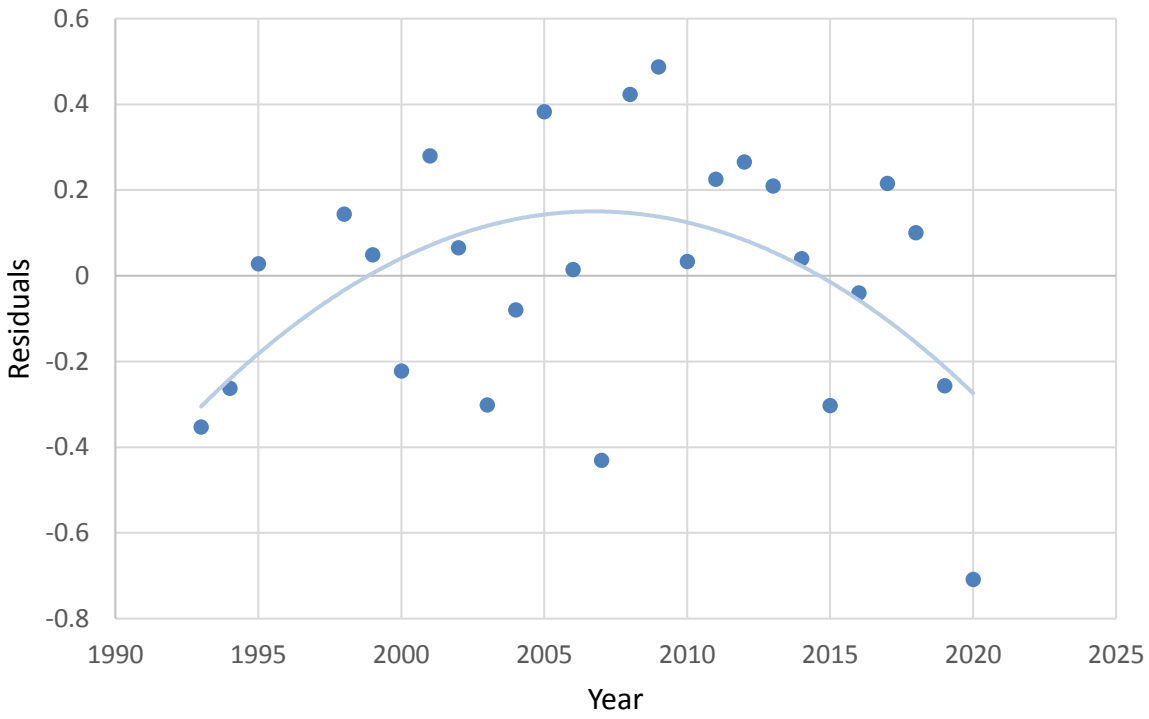
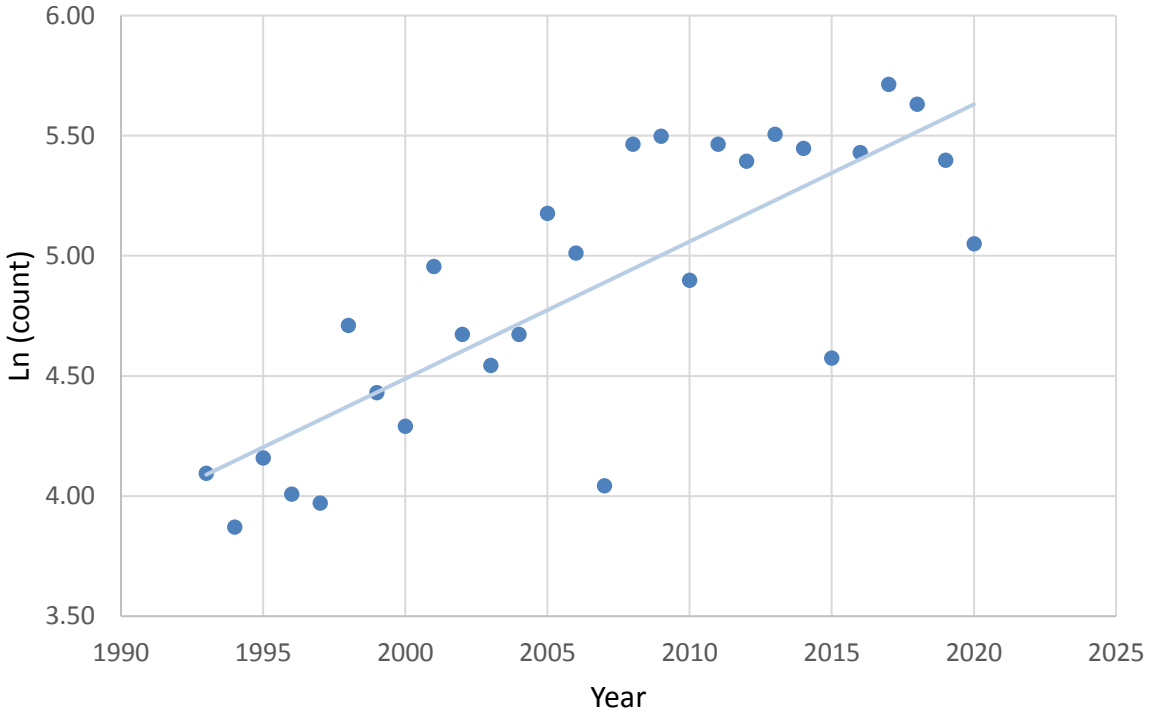


Figure 4. Plots of the fitted (a) linear regression and (b) residuals for the maximum counts of whales in each leg for 1993-2020 (excluding 1996 and 1997) for *All animals*.

(a)



(b)

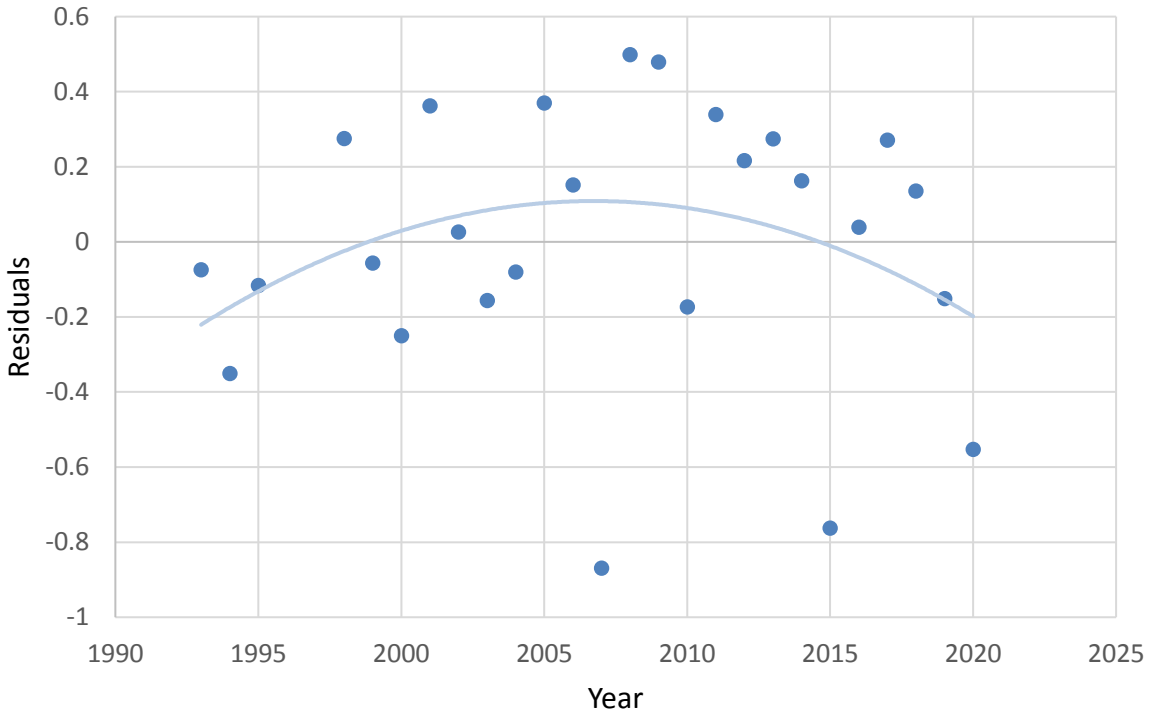


Figure 5. Plots of the fitted (a) linear regression and (b) residuals for the maximum counts of whales in each leg for 1993-2020 (excluding 1996 and 1997) for *Cow/calf pairs*.