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ABSTRACT

Residency, site fidelity and date of calving for southern right whales (*Eubalaena australis*) was assessed using 32 years of photo-identification mark-recapture data. Shore based count and photo-identification studies were undertaken annually at a significant reproductive area for southern right whales, at the Head of the Great Australia Bight (HOB), South Australia, between 1991 and 2022. Females with newborn calves spend up to four months residing in the wintering aggregation area, while unaccompanied adults are more transient with much shorter residency periods. The mean within-year residency of females with calves decreased across decades from 71 days (range 2–118) during 1992–1994 to 53 days (range 2–99) during 2016–2021. Mean residency for unaccompanied adults of 20 days (2–93) during 1992–1994 was recorded compared with 14 days (range 2-58) during 2016–2021. Site fidelity (individuals returning to the same site across years) was 58.4% of reproductive females (n = 524), compared with 92% reported for this population in the early 1990s (n = 61). Calving site fidelity was displayed for 44.7% (n = 524) of the total reproductive females observed, or 76.5% of the females that showed fidelity to the site (n = 234). Females returned to the study site to calve up to 11 times while the mean number of calves recorded for all reproductive females was 3 (SD = 1.96). Australian wintering grounds are clearly important for reproductive females and unaccompanied adults. A third of the reproductive females were observed in non-calving years. Site fidelity was 21% of non-calving females, sighted on average 1.47 times (SD=1.13, range 1-13) at HOB. Results highlight that inter-seasonal movement across the core use area in Australia is likely and an updated Australian-wide assessment is needed. The timing for calving for females that arrived pregnant at the site was consistent across three decades at HOB. The mean date of calving was 24 July (SD = 14.6). The HOB dataset provides the only known aged animals in Australia with evidence of natal site fidelity (n = 24). The probability of calves being resighted at HOB was greater six years after birth, supporting the theory that calves disperse to other areas and return to their site of birth at sexual maturity. Results highlight the importance of wintering aggregation areas and coastal connective habitat for behaviours critical to survival. As southern right whales recover from whaling and populations grow, habitat dispersal and increased inter and intra-seasonal movement into and out of primary reproductive areas has occurred. Conspecific attraction and spatial pressures may enhance movement out of the area and subsequently reduce the residency periods as population size continues to increase. Ongoing research into population demographics, coastal movement and connectivity are a national priority in Australia. Increased legislative protection across the marine park network in the coastal waters of Australia is needed for the management and recovery of the endangered southern right whale in Australia. This study highlights the importance of reproductive areas and the need to protect coastal habitats for their survival and recovery.

KEYWORDS: SOUTHERN RIGHT WHALE, SITE FIDELITY, RESIDENCY, PHOTO-IDENTIFICATION, REPRODUCTIVE AREAS, MOVEMENT, SOUTHERN HEMPISHERE, MANAGEMENT

INTRODUCTION

Southern right whales (SRWs), *Eubalaena australis*, have a circumpolar distribution between 16˚ and 65˚ S and migrate to the Southern Hemisphere aggregation areas in the Austral winter to early spring to calve, mate and rest. SRWs were protected from commercial whaling in Australia in 1935, although signs of population increase were delayed until the early 1970's when illegal pelagic catches by the Soviet Union ended (Tormosov *et al*., 1998). Signs of the return of SRWs to the Australian coastline were recorded in the late 1950s, 1960's and 1970's (Chittleborough 1956, Bannister, 1994).

Female SRWs typically show strong fidelity to calving and nursing grounds (Best and Scott, 1993; Burnell, 2001; Rowntree *et al*., 2001; Crespo *et al*., 2017). Long-term photo-identification (ID) studies show that females return to the same areas to calve over several decades (Bannister *et al*., 2011; Best *et al*., 2001; Burnell, 2001; Charlton, 2017). Early SRW sightings in Australia were restricted to areas where the largest remnant populations existed (Burnell, 2001;Bannister, 2001). Conspecific attraction and historic whaling effort combined with philopatry appear to be the main drivers of SRW calving ground occupation (Payne, 1986; Best *et al*., 2001; Burnell, 2001, Rowntree *et al*., 2001; Pirzl, 2008). While site fidelity of SRWs to calving grounds is typically high, there is evidence that SRWs can shift selected calving habitat and display flexibility in their philopatric behaviour (Best *et al*., 1993; Groch *et al*., 2005; Carroll *et al*., 2014; Charlton, 2017; Watson et al. 2021). Movement of calving and non-calving adults has been recorded across broad distances within and across seasons (Pirzl *et al*., 2009; Charlton, 2017; Roux *et al*., 2015; Watson et al. 2021).

The long-term relative abundance and distribution of SRWs in Australia is well understood through annual aerial studies undertaken by John Bannister of the Western Australian Museum (WAM) since 1976 (Bannister, 2001; Bannister *et al*., 2011; Bannister, 2017). The current population estimate for SRWs in Australia is 2,800, with approximately 2,500 in the western sub-population and less than 300 in the eastern sub-population (Smith *et al.*, 2022b; Stamation *et al.*, 2020). The western sub-population is showing signs of increase at a rate of approximately 5.4% per year, which is near the biological maximum for the species of 6–7% (Smith *et al*., 2022b; IWC, 2013), while the eastern sub-population is not showing any signs of increase in reproductive females (Stamation *et al.*, 2020). In Australia, SRW wintering aggregations are distributed between Albany in Western Australia (WA) and Warrnambool in Victoria, with rare sightings recorded as far north as Exmouth in WA and Moreton Bay, Queensland in eastern Australia (Smith *et al.,* 2022a). In Australia, SRWs have dispersed their winter habitat range into small and emerging aggregation areas with increased abundance in south-western Australia in recent years (Bannister, 2017; DSEWPaC, 2012; Charlton *et al.,* 2019b; Kemper *et al.,* 2022; Salgado Kent *et al.,* 2023).

Shore based research on the population biology and ecology of SRWs has been undertaken at one of Australia's most biologically important areas for reproduction and calving at the Head of the Great Australian Bight (HOB) in South Australia (SA) (31˚28'S, 131˚08'E) from 1991 to 2022 (Burnell, 2001; Burnell and Bryden, 1997; Charlton *et al.,* 2019a; Charlton *et al.,* 2022; O'Shannessy *et al.,* 2023). Coastal aggregation areas on the southern coast of Australia are occupied by SRWs between May and October with peak numbers recorded in August (Burnell, 2001; Charlton *et al.,* 2019a). Females with calves are known to reside in calving grounds for up to four months (Burnell, 2001). Information on residency and site fidelity for the Australian SRW population was reported for years 1991–1995 (Burnell and Bryden, 1997; Burnell, 2001). Mean residency periods of 70.9 days were recorded for female and calf pairs and 20.4 days for unaccompanied adults (individuals not accompanied by a calf of the year) (Burnell and Bryden, 1997). Site fidelity to the HOB aggregation area was reported for 92% (n = 56) of females with a calf sighted at HOB between 1991 and 1995 (n = 61) (Burnell, 2001). For unaccompanied adults, site fidelity to the HOB aggregation area was reported for 75.4=% (n = 46) of the total 61 individuals identified at HOB between 1991 and 1995 (Burnell, 2001). Of the 20 calves identified at HOB during 1991–1995, 17 (85%) displayed site fidelity to their place of birth as demonstrated by resights of these individuals in subsequent years. Natal site fidelity could not be assessed because at the time of the Burnell (2001) study, the calves identified in their year of birth (1991–1995) had not reached sexual maturity. The mean date of calving for SRWs was reported as 26 July (Burnell and Bryden, 1997). An additional 27 years of data is now available from annual research undertaken at HOB during 1996–2022 to update previous findings on residency, site fidelity and date of calving of SRWs in Australia (Burnell and Bryden, 1997; Burnell, 2001). During this time the abundance and number of photo-IDs in the HOB catalogue has significantly increased. Between 1991 and 1995 the mean maximum abundance recorded on a single day per year at HOB was 55 (SD = 9.1, range = 43–65) individuals and the number of individuals uniquely identified was 350 (Burnell, 2001). Charlton *et al.,* (2019a) reported a mean maximum abundance recorded on a single day per year at HOB between 1996 and 2016 of 105 (SD = 36.9, range = 49–172) individuals and the number of individuals identified was 836.

The long-term photo-ID study at HOB (1991–2022) provides an unbroken time series dataset with sighting histories of known individuals. The HOB photo-ID dataset provides information on known aged individuals photographed in the year of their birth to assess natal site fidelity for the Australian SRW population. With an increasing population and evidence of habitat dispersal of SRWs in south-western Australia, there is a need to assess residency and site fidelity to inform management of this endangered species. Recovery actions in the Commonwealth Conservation Management plan for the SRW include research into the population ecology, movements and connectivity of SRWs. This study aims to assess residency, site fidelity, natal site fidelity and date of calving of SRWs at the significant reproductive area at HOB in SA using 32 years of photo-ID mark-recapture data (1991–2022). With an increase in population size and habitat dispersal of SRWs along the Australian coast, it is hypothesised that residency and site fidelity of calving females and unaccompanied adults from the open population at HOB has decreased in recent years when compared to records from 1991–1995 (Burnell and Bryden, 1997).

METHODS

Study site

HOB is located within the Great Australian Bight (GAB) in the far west of SA (31°29'S, 131°08'E, Figure 1) approximately 270 km west of Ceduna and 210 km east of the WA border (using shortest swim distance). The study is completed on the Yalata Anangu Peoples land and on the land and sea country of the Far West Coast Aboriginal Peoples along the Bunda Cliffs of the Nullarbor Plain. The HOB aggregation area is within the Marine Mammal Protection Zone of the GAB Commonwealth Marine Reserve and the Far West Coast State Marine Park. The GAB Marine Reserve was established in 1995 to protect the wintering SRW aggregation at HOB. The study site is selected to include the primary aggregation area and extends approximately 15 km along the coast and 8 km offshore (Figure 1). Observations and photography was collected from the cliff top vantage points 33 m–53 m in elevation.

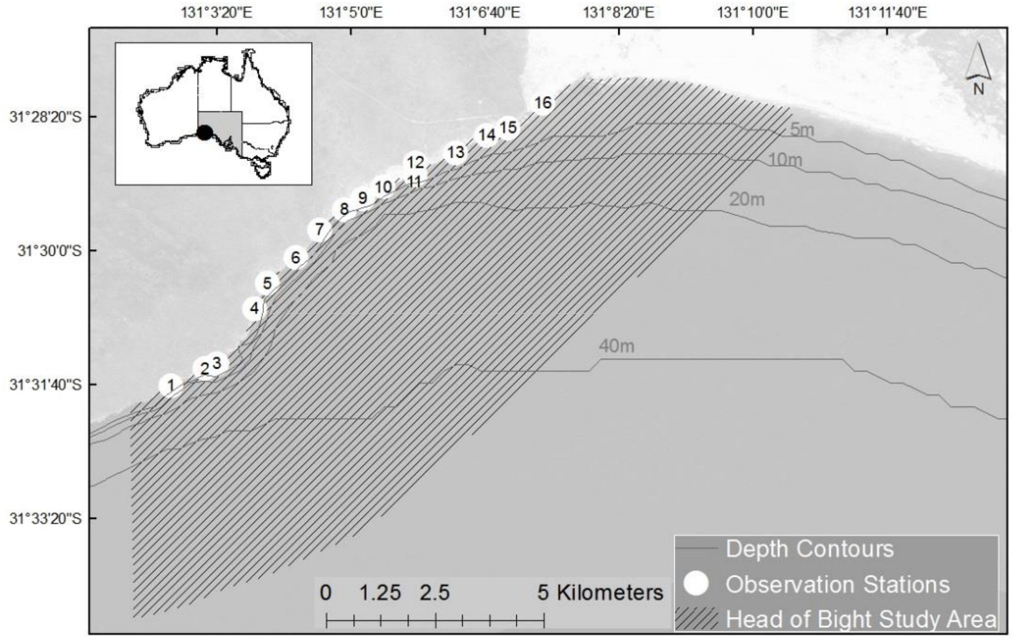

Figure 1. Boundaries of the study site and location of observation stations for southern right whales at Head of Bight in the central Great Australian Bight, South Australia.

Data collection

Study period

Field surveys were completed at HOB annually since 1991, between June and October. Study effort varied among years. However, for inter-annual comparison of maximum daily counts during the peak season, surveys were systematically completed between mid to late August. Outside of that period, the study effort varied across years (Table 1). During 1991–1997 and 2014–2021 (excluding 2020) surveys were undertaken between June and October and provide comparable data to assess SRW residency and date of calving. Site fidelity is assessed using 29 years of photo-ID life history data at HOB (1991–2019).

Photo identification

The study methods are consistent with the long-term shore-based population census and photo-ID study, completed annually at HOB between 1991 and current (Burnell and Bryden, 1997; Burnell, 2001; Charlton *et al.*, 2019a; O'Shannessy *et al.*, 2023).

Photo-ID of SRWs is achieved through photographing the callosity patterns on the rostrum of individual whales and resighting individuals over time. Callosity patterns are keratinised skin patches colonised by cyamids that form on the dorsal surface of the rostrum, the lip line of the lower jaw and just posterior to the blowhole on SRWs (Payne et al., 1983). Callosities provide individually unique markings on SRWs that persist throughout life (Payne *et al.*, 1983). To record callosity patterns and other unique identifying marks, high resolution telephoto images are taken from the cliff top vantage points at HOB. A Nikon 7100 or D100 digital SLR camera with a Nikon 500 mm (effective 750 mm) or Sigma 500 mm lens mounted on a Manfrotto tripod is used.

Dorsal and ventral photographs are obtained wherever possible. Left and right lateral perspectives of callosity patterns, as well as the size and shape of ventral pigmentation (also persistent and unique) and the ano-genital configuration (sex) are documented with opportunistic photographs. Markings and any scarring are likewise photographed. Photography was concentrated primarily on adults as callosity patterns are well developed. Photo-ID effort for calves was increased later in the season, as they are generally too young to distinguish unique callosity patterns for future identification early in the season.

Digital photo-ID images were sorted daily in the field, including within season cross matching of individuals to document the total number of individuals identified in that year. Individuals were then matched against the long-term catalogue (Big Fish v6 Microsoft Access), including all calves photographed in previous years to document previously sighted and newly sighted whales.

Photo-ID images were contributed by J. Bannister of the WAM and J. Smith of Murdoch University from annual aerial surveys completed at HOB (2014–2022) and the long-term HOB photo-ID catalogue includes sighting histories from matches completed with the WAM catalogue 1993–2007 and reproductive females to 2012

(Burnell, 2008, Charlton *et al.*, 2022). The methodology for collection of images during annual aerial surveys are outlined in Bannister (2017) and summarised in Charlton *et al.*, (2019a). Individual sighting records from aerial survey photo-ID images contribute to the assessment of site fidelity and residency. Because of the three to four month duration of the study period in 2014–2019, the aerial survey data from the single survey contributed single resights of individuals that were sighted many times throughout the season. Therefore, the observer bias introduced by including aerial survey images is obsolete.

In collaboration with Murdoch University, Unmanned Aerial Vehicles (UAVs) were used during 2016–2021 (excluding 2020) to photograph SRWs at HOB and these images contributed to the assessment of residency. Methods for data collection using UAVs is outlined in Christiansen *et al.*, (2018).

Data Analysis

Residency

Intra-seasonal residency of females with calves and unaccompanied adults were assessed using photo-ID resights collected between June and September, 2014–2021 and compared with earlier published data for 1992–1994, collected between June and October (Burnell and Bryden, 1997). Short field season (< six weeks) were completed in 2020 and 2022 and consequently these years are not included in residency analysis. Residency was assessed for individuals that were sighted at least twice and the date of first and last sighting was considered the period of residence. The assessment of residency was limited by the survey duration and therefore residency is considered a minimum duration that SRWs occupy the site. Females with calves who arrived at HOB after 1 September were excluded from residency estimates because this is after the peak abundance period and maximum date of calving, so it was assumed those females were transiting through the site and not selecting calving habitat.

It is recognised that the introduction of UAV technology in 2016 increased the effort for collecting resight data. The challenge in collecting the resight data for all individuals also increased with time given that whale abundance at the site increased from around 20 females with calves in the early 1990s to over 100 females with calves in the 2010s and 2020's. Observer bias was not assessed or tested statistically although the close proximity to the base of the cliff observation points and the whale's slow movements will greatly reduce the chance of missed sightings. A one-way analysis of variance (ANOVA) was performed in XLSTAT 2023.1.3 to compare the effect of years on mean residency.

Site fidelity

Site fidelity was assessed for the calving female population using 29 years (1991–2019) of inter-annual resights using photo-ID data. An individual was considered to display a degree of fidelity to HOB if it was sighted at least twice at the site in different years, either with or without a calf. The calving site fidelity of females with a calf was assessed based on the number of sightings of a female with a calf in different years.

The site fidelity of SRWs seen only once at HOB and not sighted elsewhere was deemed indeterminable (Burnell, 2001). This study assessed only sighting histories recorded at HOB and does not consider other sightings of the same individuals in other areas in Australia. Therefore, an individual that displayed site fidelity to HOB may also display fidelity to another area. For example, an individual may have been sighted with a calf in two different years at HOB but also been sighted during the WAM aerial surveys with a calf on three occasions in Esperance, WA. This study attempts to assess only site fidelity to HOB. Burnell (2001) assessed the site fidelity of individuals to HOB relative to other areas by including sighting histories of individuals from the south-west and the south-east of Australia. The Australasian right whale photo-ID dataset is currently being curated to include all major Australian datasets, however, given that the HOB regional dataset is curated and consolidated to 2019, this data was used in this study.

Natal site fidelity

Calves identified in their year of birth at HOB that were later sighted with a calf of their own were considered to show natal site fidelity. The mean number of calves for each individual with natal site fidelity was assessed. The probability of sighting the calves at HOB prior and post maturity was assessed by plotting the total number of calves identified against the number of calves resighted prior to the mean age of first parturition of nine years (Charlton *et al.*, 2019a).

Date of calving

The date of calving was estimated using data from seven seasons from 2014–2021 when data was collected between mid-June and the end of September and resight information on pregnant females was available. A female was determined pregnant if she was sighted as an unaccompanied adult and later that season sighted with a calf. The mean date of calving was estimated using the average between the last day an individual was sighted as a pregnant female (or unaccompanied adult) and the first date sighted with a calf. There is a bias considering that the exact date of calving is unknown. By selecting the mean date between sightings, the adult without a calf (underestimate) and with a calf (overestimate) is used to counteract the bias. No observer bias was applied to account for the likelihood that calves were sighted after their date of birth. This data builds on the assessment of date of calving completed by Burnell and Bryden (1997) using data from 1993–1994.

RESULTS

Residency

Photo-identification success

Survey effort varied among years (1991-2022), however during 1994-1996 and 2014-2021 (excluding 2020 due to COVID 19 restrictions) extended field seasons were undertaken at HOB and allowed for the assessment of seasonal residency. During 1994-1996 surveys were completed between 108 and 114 days, and during 2014-2021 surveys were completed between 91 and 102 days. The photo-ID effort varied among years with the introduction of UAVs in 2016 to compliment the cliff based photography. The mean number of photo-ID sightings recorded per year between 2014 and 2022 for female and calf pairs was 660 (range 239–1328, SD 355.4) and for unaccompanied adults was 135 (range 47–212, SD 55.2). Inter-annual variation in maximum abundance of SRWs at HOB and in number of individuals photo-ID'd in the study site was also observed between 2014 and 2022 (Table 1).

Table 1. Southern right whale study periods at Head of Bight, South Australia, 1992–1994 (Burnell and Bryden, 1997) and 2014–2022, mean residency periods for calving females and unaccompanied adults, maximum daily counts per year and photo identification success, and mean number of resights. *Short field season (<six weeks) completed in 2020 and 2022 do not apply for residency analysis.

		Mean days within aggregation area and range		**Maximum daily count, (number of individual's photo identified) and photo ID success (%)**		**Mean resights per individual (range)**	
Year	Start-Finish dates and study period (days)	Calving females	Unaccompanied adults	Calving females	Unaccompanied adults	Calving females	Unaccompanied adults
1992	25 Jun - 10 Oct: 108	72	18	18 (17) 94%	7 (18) 257%	NA	NA
1993	18 Jun - 13 Oct: 118	75	20	26 (26) 100%	21 (41) 195%	NA	NA
1994	19 Jun – 12 Oct: 116	66	21	23 (24) 104%	24 (74) 308%	NA	NA
Mean 1992-1994	**114 days**	**70.9 (2-118)**	**20.4 (2-93)**	**22 (67) 100%**	**17 (133) 256%**	NA	NA
2014	19 Jun - 28 Sept: 102	29 (2-73)	15 (2-52)	60 (87) 145%	17 (47) 276%	3 (1-10)	2 (1-6)
2015	18 Jun - 25 Sept: 100	53 (2-92)	14 (2-47)	28 (36) 129%	27 (78) 289%	6 (1-17)	2 (1-5)
2016	16 Jun - 25 Sept: 102	60 (2-99)	16 (2-51)	81 (92) 114%	29 (105) 362%	6 (1-22)	2 (1-8)
2017	16 Jun - 25 Sept: 102	44 (2-92)	9 (2-37)	74 (97) 131%	27 (96) 356%	8 (1-24)	2 (1-6)
2018	16 Jun - 25 Sept: 102	59 (2-94)	18 (2-58)	67 (97) 145%	23 (93) 404%	8 (1-26)	2 (1-13)
2019	16 Jun - 25 Sept: 102	53 (2-84)	10 (2-32)	53 (68) 128%	25 (68) 272%	11 (1-32)	2 (1-8)
2020	NA*	NA*	NA*	51 (58) 114%	20 (43) 220%	5 (1-13)	2 (1-6)
2021	27 Jun - 25 Sep: 91	50 (1-92)	16 (1-41)	61 (89) 146%	17 (58) 341%	11 (1-30)	2 (1-8)
2022	NA*	NA*	NA*	49 (75) 153%	10 (20) 200%	6 (1-17)	2 (1-5)
Mean 2014–2022	**100 days**	**51 (1-99)**	**14 (1-58)**	**58 (78) 134%**	**22 (68) 302%**	**8 (1-32)**	**2 (1-13)**

Photo-ID success was high and exceeded 100% when the number of individuals photo-ID'd was compared to the maximum daily count of the year, for female and calf pairs and unaccompanied adults. The total number of unique females accompanied by a calf photo-ID'd between 2014 and 2022 (n = 699), exceeded the maximum daily counts (n = 524), by a third (Table 1), indicating substantial movement of individuals into and out of the site during the survey period. For unaccompanied adults the total number of individuals photo-ID'd between 2014 and 2022 (n = 608), exceeded the maximum daily counts (n = 195) by over three times (Table 1), supporting the transient nature of unaccompanied adults across coastal aggregation areas during wintering months.

Residency periods

Residency periods were available for 473 females with calves and 185 unaccompanied adults that were sighted at least twice in a season (2014–2021). The mean number of photo-ID resights of individual whales between 2014 and 2022 was 8.3 (SD = 6.3, range = 1–32) for female and calf pairs and 1.8 (SD = 1.4, range = 1–13) for unaccompanied adults. The number of resights of individuals per year varied across years (Table 1).

Mean residency for female and calf pairs at HOB between 2014 and 2021 was 51.1 days (SD =21.2, range = 2–99 days) and for unaccompanied adults was 13.9 days (SD = 14.0, range = 2–58 days) (Table 1). There was inter-annual variation in the mean residency period recorded for females with a calf, with the lowest mean residency of 23 days recorded in 2014 compared with 60 days in 2016 (Table 1). The mean residency of unaccompanied adults was consistent across years and ranged from 13 days in 2014 to 18 days in 2015 and 2018 (Table 1).

Survey effort increased from 2016, with the additional use of UAVs sightings data contributed from Murdoch University. Increase in effort was calculated in 2016 with an additional 777 sightings of females with a calf and 55 sightings of unaccompanied adults contributed from UAVs. Additional sightings resulted in a mean residency of 61 days (SD = 21, range = 2–99 days) for female and calf pairs and 15 days (SD = 12, range = 2–52 days) for unaccompanied adults. When using the UAV and cliff based sightings, the mean residency is significantly greater (p-value = < 0.001, SD = 22.43) for female and calf pairs and not significantly different for unaccompanied adults (p-value = 0.65, SD = 12.7), compared to using the cliff based sightings alone. The contribution of UAV sightings resulted in a 12 day increase in the mean residency for female and calf pairs and 1.4 day increase for unaccompanied adults. Whilst he whales do move around and can be photographed throughout the season from the cliff top vantage points, the use of UAVs enabled access to whales while they were occupying the shallow waters of the bay in the east of the study site, that were inaccessible from the cliff top vantage points. Based on significant difference in mean residency of female and calf pairs when using UAV and cliff based sightings, years with additional UAV data are considered a more accurate estimation of residency.

The mean residency for female and calf pairs at HOB between 2016 and 2021 (years with UAV and cliff based sightings) was 53.2 days (SD =20.3, range = 2–99 days) and for unaccompanied adults was 13.8 days (SD = 14.0, range = 2–58 days) (Table 1). A one-way ANOVA was performed to compare the effect of year on mean residency. The inter-annual variation was significant for female and calf pairs ($F(4, 390) = 9.049$, $p = <0.001$), a Tukey's HSD Test for multiple comparisons reveal significant difference in mean residency for 2016 compared with 2017 (p-value = <0.001), 2016 with 2021 (p-value = 0.01), 2018 with 2017 (p-value = <0.001) and 2018 with 2021 (p-value = 0.042). The inter-annual variation was also significant for unaccompanied adults ($F(4, 134) = 2.59$, $p = 0.04$), a Fisher (LSD) Test reveal significant difference when comparing mean residency periods for 2018 with 2017 (p-value = <0.009) and 2018 with 2019 (p-value = 0.022). There was no significant difference between other years.

Site fidelity

Site fidelity was assessed for calving females (n = 524) with sighting histories available from at least two sightings in different years between 1991 and 2019. Sighting history was available for individuals that were matched to individuals previously sighted at HOB in the long-term photo-ID catalogue. Site fidelity was displayed for 58.4% of reproductive females (234 of the 524) between 1991 and 2019. Calving site fidelity was displayed for 44.7% (306 of the 524) of the total reproductive females observed, or 76.5% of the females that showed fidelity to the site (n = 234). The mean number of calves recorded for all reproductive females was 3 (SD = 1.96). For females that displayed site fidelity, the mean number of calves observed at HOB was 3.6 (SD=1.97). The number of calves recorded at HOB for calving females that displayed calving site fidelity to the area ranged from 2–11 calves, with two being the most frequently recorded number of calves for each individual (n = 97 individual) after a single calf (n = 218) (Table 2, Figure 2).

Table 2: Number of calving events for reproductive females at Head of Bight, South Australia, 1992–2019.

No. calves	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	11
# (n. 524)	218	97	47	31	21	15	7	4	3	0	2
%	41.6	18.5	9.0	5.9	4.0	2.9	1.3	0.8	0.6	0.0	0.4

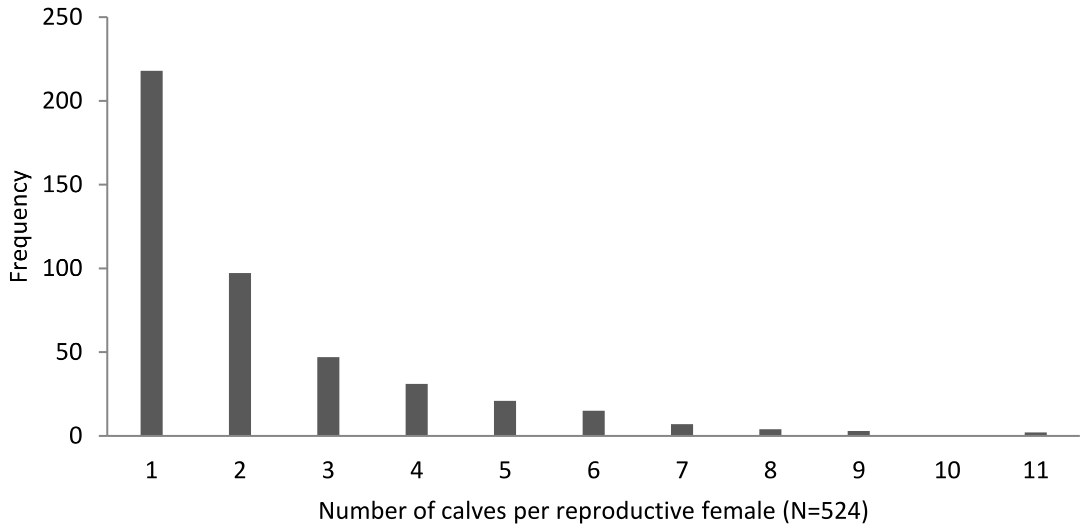

Figure 2: Frequency distribution of number of calves produced at Head of Bight by known reproductive females (n= 524).

Australian wintering grounds are important for reproductive females and unaccompanied adults. Reproductive females also migrate to Australian wintering aggregation grounds outside of calving years. A third of reproductive females were observed in non-calving years at HOB (30.1% N=160). Reproductive females were observed outside of calving years (including a calf, yearling, sub-adult or adult) on average 1.7 times (SD=1.2, range 1-8) at HOB.

Site fidelity for unaccompanied adults (non-reproductive females) was observed for 21% (n=206/977) and on average, unaccompanied adults were resighted at HOB 1.47 times (SD = 1.13, range 1-13).

Natal site fidelity

Natal site fidelity was displayed for 24 of the 75 calves that were resighted at HOB after their year of birth. The number of calves recorded for individuals that displayed natal site fidelity ranged from one to six, with a mean of 2.5 calves (SD = 1.6). Individuals that displayed natal site fidelity were also sighted returning to the site as juveniles. For example, of calves that displayed natal site fidelity, 33% returned to HOB as a yearling and 50% returned to HOB as a sub-adult in their first six years after birth.

Date of calving

The date of calving was estimated for 63 individuals between 2014 and 2021 (excluding 2020), that were sighted as an unaccompanied adult (pregnant) and later sighted in the same season with a calf (

Table 3). The minimum number of days between sighting as pregnant and then with a calf was one day, providing evidence that at least some SRWs must calve within the HOB study area. The mean date of calving was 24 July (SD = 14.7). The last sighting of a pregnant female occurred on 8 August. At the start of this study (1991-1995) mean date of calving was 26 July (Burnell and Bryden, 1997).

Table 3: Mean date of calving for female southern right whales at Head of Bight, South Australia (N = 63), using the average date between the last sighting of female unaccompanied (UA) and the first date of sighting with a calf (Cow Calf = CC). For each year the mean date last sighted as UA, mean date first sighted as CC and the range was calculated.

Year	N	Mean date last sighted UA and range	Mean date first sighted as CC and range
2014	1	25 Jun	20 Jul
2015	7	3 Jul (25 Jun – 19 Jul)	7 Aug (1 Jul – 27 Aug)
2016	11	4 Jul (19 Jun – 30 Jul)	20 Jul (1 Jul – 22 Aug)
2017	**7**	21 Jul (12 Jul – 25 Jul)	12 Aug (31 Jul – 25 Aug)
2018	16	9 Jul (23 Jun – 8 Aug)	25 Jul (26 Jun – 28 Aug)
2019	13	15 Jul (2 Jul – 2 Aug)	1 Aug (14 Jul – 21 Aug)
2021	8	12 Jul (26 Jun – 26 Jul)	3 Aug (9 Jul – 29 Aug)
	Mean 2014–2021	10 Jul (19 Jun – 8 Aug)	30 Jul (26 Jun – 29 Aug)

DISCUSSION

This study assessed residency, site fidelity, natal site fidelity, and date of calving at the major wintering reproductive and calving area for the Australian population of SRWs at HOB, SA. The study utilised a 32-year photo-identification mark-recapture data set from 1991 to 2022, obtained from annual shore-based count and photo-identification studies. The results of the study showed that calving females spent up to four months residing in the wintering aggregation area, while unaccompanied adults were more transient, with much shorter residency periods. The mean within-year residency of females with calves reduced across decades, and site fidelity was displayed for over half of the reproductive females, consistent with previous findings for this population. The study also found that calving site fidelity was displayed for less than half (41%) of all reproductive females, and females returned to the study site to calve up to 11 times.

It was hypothesized that residency and site fidelity of calving females and unaccompanied adults from the open population at HOB has declined in recent years when compared to records from 1991–1995 (Burnell and Bryden, 1997). The hypothesis was supported by the results of this study, which showed that the mean residency for unaccompanied adults decreased from 20.4 days during 1992–1994 to 13.8 days during 2016–2021. Similarly, the mean within-year residency of females with calves reduced from 70.9 days during 1992–1994 to 53.2 days during 2016–2021. Photo-ID success was high from 2014–2016 with a greater number of female and calf pairs and unaccompanied adults photo ID'd at HOB than the maximum daily counts, indicating within season movement of whales into and out of the study area. Results suggest that on average females reside for longer periods at HOB when there are fewer whales at the site. In years of high abundance at HOB, spatial pressures as the available habitat fills up, or conspecific attraction may enhance movement out of the area and subsequently reduce the mean residency. It is reported that calving females have a 'packing density' with a comfortable distance separating nearby whales (Charlton *et al.*, 2019a). Residency periods for small reproductive areas for SRWs at Fowlers Bay and Encounter Bay, SA to the east of HOB have been reported. Fowlers Bay, a recently recolonised reproductive area for SRWs approximately 170 km east of HOB, showed mean occupancy of 23 days for female and calf pairs and 2 days for unaccompanied adults from 2014–2016 (Charlton *et al.*, 2019b). Estimated residency for SRWs at Encounter Bay was 47 days for female and calf pairs and 12 days for unaccompanied adults from 2013–2022 (Kemper *et al.*, 2022; Gilmore 2022). Local climate drivers may also be impacting residency periods and further assessments on drivers of changes to threatened species population dynamics in biologically important areas in Australia should be investigated.

Site fidelity of SRW calving females to HOB is consistent across the survey years. A total of 58.4% of the breeding population identified between 1991 and 2019 (n = 524) were sighted more than once and displayed a degree of site fidelity. The study found that the mean number of calves recorded per individual was three during 1991-2019, highlighting that the HOB aggregation is an open population, and inter-seasonal movement across the core use area in Australia is likely. The mean inter-calving interval reported for this population is 3.9 years (+/- 95% CI 3.8, 4.1) (Charlton *et al.*, 2023) The number of new individuals sighted at HOB increased annually at an exponential rate and the proportion of the western population of SRWs (in the Australian context) that HOB represents has declined with time (Charlton *et al.*, 2019a). Fidelity shown to HOB by calving females does not imply exclusive use of the area by the individual whale. It is known that females display choice in breeding site selection and that movement and shifts in selected calving habitat occur for SRWs (Carroll *et al.*, 2014; Charlton, 2017; Watson *et al.*, 2021).

Australian wintering grounds are important for calving and non-calving individuals. Charlton *et al.*, (2019a) reported population class structure of 80% female and calf pairs and 20% unaccompanied adults. Coastal aggregation areas are important for nursing young, mating, socialising and resting. A third of reproductive females were observed in non-calving years at HOB (30.1% N=160). Non-calving females were resighted at HOB up to 13 times demonstrating the importance of the site for behaviours other than calving and nursing. It is possible that the energetic cost of remaining in foraging grounds during winter months exceeds the energetic cost of migration and that conspecific attraction for mating and socialising drive migration of non-calving whales. Recent movement data available from telemetry studies suggests (*unpublished*) that southern right whales off Australia are highly transient and that foraging grounds are broadly distributed, some much closer to wintering breeding aggregations than previously thought. The low mean number of sightings of unaccompanied adults (1.47, SD=1.13, range 1-13) and the short mean residency periods (20 days) supports that unaccompanied adults are transient and that there is a high degree of movement across the Australian core use area, intra-seasonally.

Within and between season movements of SRWs on the southern Australian coastline are documented (Burnell, 2001; Pirzl *et al.,* 2009; Carroll *et al.*, 2011; Charlton, 2017). Shifts in selected calving habitat were recorded for females that had previously displayed breeding fidelity to HOB and then re-selected calving habitat to adjacent habitat at Fowlers Bay, SA. Charlton, (2017) reported that shifts in calving habitat from HOB to Fowlers Bay in years of high abundance at HOB were driven by spatial pressures and the HOB site having possibly reached a finite carrying capacity. Habitat dispersal of SRWs from primary aggregation areas into alternative habitat with population growth was also recorded for right whale populations in Argentina and Brazil (Rowntree *et al.*, 2001; Danilewicz *et al.*, 2016; Seyboth *et al.,* 2016), South Africa (Barendse and Best, 2014) and NZ (Carroll *et al.*, 2011; 2014).

The HOB dataset provided evidence of natal site fidelity, with 23 known aged animals photographed in the year of their birth. The probability of calves being resighted at HOB was greater six years after birth, supporting the theory that calves may disperse to other areas and return to their site of birth once they reach sexual maturity. Age of first parturition for the Australian population of SRWs is a minimum of six years and a mean of 9.3 years (Charlton *et al.,* 2022). Of the calves that displayed natal site fidelity (n = 23), 60% returned to the site within the first six years since birth and 43% were sighted at HOB as a yearling. Results suggest that the return of juveniles to their site of birth, particularly as a yearling, may increase the likelihood of natal site fidelity. The assessment of natal site fidelity is limited by the ability to photograph calves once their callosity patterns have developed at around three months of age. This study provides the only data for known aged individuals spanning four decades in Australia.

The timing for calving for females that arrived pregnant at the site was consistent across three decades at HOB, with the mean date of calving being 24 July. The mean date of calving recorded in this study of 24 July is comparable to the estimated date of calving of 26 July reported previously for this population during 1991-1995 (Burnell, 2001). These findings are important for informing future research requirement for species management. For example, results validate the timing for the long term annual aerial surveys conducted in late August to early September, and the study period for population studies at HOB mid-July-late August, which aim to cover the peak abundance period (Charlton *et al.,* 2019b) and capture all female and calf pairs for national abundance and recovery assessments.

The calving season varies for different populations of SRWs in the Southern Hemisphere. For example, in South Africa, SRWs can be sighted all year round but females with calves are sighted between June and December, and peak numbers recorded in September (Best and Scott, 1993). In Península Valdés, Argentina, the calving season is between May and December, with the maximum number of whales reached from August to September (Crespo *et al.,* 2017; Rowntree *et al.,* 2001; Payne, 1986). The reasons for the different time of the calving season is unknown but could be related to the distances travelled to feeding grounds i.e., SRWs in Australia may travel further to southern feeding grounds and therefore the breeding season is shorter than Argentina and South Africa that are at lower latitudes. therefore, shorter distances to their feeding grounds. Triggers for arrival and departure to wintering aggregation areas may also include weather and climate factors such as local storm events, air and water temperature influencing thermoregulation (Burnell and Bryden, 1997) and poor body condition (Christiansen et al., 2020).

The findings of this study have important implications for the management of endangered SRWs in Australia. As the population recovers from whaling and abundance increases, habitat dispersal has occurred, and increased inter and intra-seasonal movement into and out of primary reproductive areas. This study highlights the importance of wintering aggregation areas and coastal connective habitat for reproduction and behaviours critical to survival, including calving and nursing young. This study improves the understanding of residency site fidelity and date of calving of SRWs within a coastal wintering aggregation area in Australia. It highlights the importance of calving aggregation areas and the need to understand more about the movement and connectivity of SRWs in Australian waters. With an increasing population and increased dispersal of SRWs to wintering aggregation areas it is important to understand site occupancy to direct future management planning, especiall for their habitat.

In conclusion, the present study provides important insights into the residency, site fidelity, natal site fidelity, and date of calving of SRWs at the HOB in SA. The reduction in residency and site fidelity could be attributed to the increase in population size contributing to habitat dispersal of SRWs along the Australian coast, and drivers likely include conspecific attraction and spatial density pressures. Ongoing research into population demographics, coastal movement and connectivity are a national priority. Increased legislative protection across the Australia marine park network in the coastal waters of Australia is needed for the management and recovery of the endangered southern right whale in Australia. The study's findings have important implications for the management of SRWs in Australia, and national assessments of coastal movement and connectivity are needed to inform improved legislation and policy for the protection of the species. The study highlights the importance of wintering aggregation areas and coastal connective habitat for the survival of this population of SRWs.

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SUPPLEMENTARY MATERIAL

Table 1. Mean date of calving for female southern right whales at Head of Bight, South Australia (N = 63), using the average date between the last sighting of female unaccompanied (UA) and the first date of sighting with a calf (Cow Calf = CC). Table includes HOB code for known individual, the year that the female was sighted as pregnant, the date of last sighting as a UA and date of first sighting with a calf (CC).

Code	**Year**	**Date last sighted UA**	**Date first sighted CC**	**Estimated date of calving**
H9357	2014	25-Jun	20-Jul	7-Jul
H0807	2015	25-Jun	31-Jul	13-Jul
H1507	2015	2-Jul	7-Aug	20-Jul
H1509	2015	1-Jul	15-Aug	23-Jul
H1510	2015	9-Jul	16-Aug	28-Jul
H1511	2015	19-Jul	17-Aug	2-Aug
H0451	2015	2-Jul	27-Aug	30-Jul
H1501	2015	27-Jun	1-Jul	29-Jun
H1608	2016	25-Jun	1-Jul	28-Jun
H0150	2016	25-Jun	3-Jul	29-Jun
H1611	2016	25-Jun	2-Jul	28-Jun
H1613	2016	2-Jul	19-Jul	10-Jul
H9401	2016	19-Jul	20-Jul	19-Jul
H0945	2016	29-Jun	14-Jul	6-Jul
H0703	2016	29-Jun	6-Jul	2-Jul
H1622	2016	8-Jul	3-Aug	21-Jul
H1625	2016	19-Jun	3-Aug	11-Jul
H1628	2016	18-Jul	4-Aug	26-Jul
H1638	2016	30-Jul	22-Aug	10-Aug
H0953	2017	22-Jul	31-Jul	26-Jul
H1717	2017	21-Jul	15-Aug	2-Aug
H0424	2017	23-Jul	11-Aug	1-Aug
H1438	2017	25-Jul	13-Aug	3-Aug
H0607	2017	22-Jul	12-Aug	1-Aug
H9572	2017	22-Jul	12-Aug	1-Aug
H1723	2017	12-Jul	25-Aug	3-Aug
H1170	2018	24-Jul	3-Aug	29-Jul
H9375	2018	24-Jun	4-Jul	29-Jun
H1805	2018	12-Jul	18-Jul	15-Jul
H0910	2018	23-Jun	26-Jun	24-Jun

H1218	2018	16-Jul	18-Jul	17-Jul
H9116	2018	26-Jun	4-Jul	30-Jun
H1029	2018	25-Jun	8-Jul	1-Jul
H0758	2018	26-Jun	8-Jul	2-Jul
H1809	2018	26-Jun	21-Jul	8-Jul
H1208	2018	16-Jul	17-Aug	1-Aug
H1468	2018	4-Jul	12-Jul	8-Jul
H1317	2018	20-Jul	31-Jul	25-Jul
H1816	2018	10-Jul	28-Aug	3-Aug
H1437	2018	12-Jul	16-Aug	29-Jul
H9319	2018	25-Jul	19-Aug	6-Aug
H1830	2018	8-Aug	20-Aug	14-Aug
H9144	2019	3-Jul	14-Jul	8-Jul
H1115	2019	2-Jul	15-Jul	8-Jul
H0929	2019	3-Jul	16-Jul	9-Jul
H0807	2019	9-Jul	19-Jul	14-Jul
H1163	2019	16-Jul	3-Aug	25-Jul
H1909	2019	9-Jul	1-Aug	20-Jul
H1910	2019	24-Jul	3-Aug	29-Jul
H1911	2019	19-Jul	1-Aug	25-Jul
H0577	2019	16-Jul	12-Aug	29-Jul
H1502	2019	1-Aug	12-Aug	6-Aug
H1673	2019	31-Jul	13-Aug	6-Aug
H1913	2019	9-Jul	13-Aug	26-Jul
H9308	2019	2-Aug	21-Aug	11-Aug
H1611	2021	26-Jun	9-Jul	2-Jul
H9401	2021	18-Jul	25-Jul	21-Jul
H2108	2021	13-Jul	25-Jul	19-Jul
H1710	2021	3-Jul	28-Jul	15-Jul
H1013	2021	19-Jul	8-Aug	29-Jul
H2110	2021	19-Jul	16-Aug	2-Aug
H1161	2021	5-Jul	8-Aug	22-Jul
H2112	2021	26-Jul	29-Aug	12-Aug