Marine Ecosystems

Monitoring of the Australian sea lion population at Seal Bay: 2020/21

Simon D Goldsworthy, Melanie Stonnill and Roger Kirkwood

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December 2021

Report to the Department for Environment and Water

Government of South Australia
Department of Primary Industries and Regions

Government of South Australia
Department for Environment and Water

SARDI
South Australian Research and Development Institute

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

This report provides an update on the status and trends in abundance of the Australian sea lion (ASL) population at Seal Bay and Seal Slide, Kangaroo Island, following the 2020/21 breeding season. The 2020/21 ASL breeding season commenced at Seal Bay on 20 October 2020 with the final birth recorded on 19 October 2021, a period of almost 12 months. The median pupping date was 9 February 2021 (sd = 65 days), with 90% of births occurring over 7 months (215 days), between 24 October 2020 and 27 May 2021. The current breeding season interval is 17.9 months, but the timing of breeding has shifted back by about one month over the last 16 years.

Pup production for the 2020/21 breeding season, based on the cumulative number of births, was estimated to be 242. Trend estimates for twelve breeding seasons between 2004 and 2020/21 indicate pup production at Seal Bay is declining by 0.9% per year (or -1.3% per breeding season), the same rate of decline as the maximum live pup counts over the last 35 years. There are some positive signs that may indicate the trajectory of the Seal Bay population is changing. Pup production over the last five breeding seasons has been relatively stable (range 232 to 242) and has shown an increase over the last two breeding seasons. Breeding season pup mortality in 2020/21 was 28.9%, in line with the average for summer/autumn breeding seasons since 2008/09 (32.8%, sd = 5.4).

A total of 179 pups were microchipped during the 2020/21 breeding season. Microchip scanning efforts directed towards breeding females resulted in 96% of all females that pupped in the 2020/21 breeding season at Seal Bay being scanned, of which 84% (195) were microchipped (and hence known age). The most notable feature for the 2020/21 breeding season was the highest recruitment of 4.5 and 6 year-old females on record. The higher pup production in the last two breeding seasons, coupled with record recruitment, may translate into further increases in pup production in the coming breeding seasons.

The current capacity to predict future population trajectories or evaluate different management strategies to recover ASL populations is limited and would benefit from more regular demographic analyses that should be built into the Seal Bay monitoring program. Ideally this would be undertaken every few years.

ASL pup production at Seal Slide was estimated to be 11 for the 2020/21 breeding season and falls within the 8 to 15 (mean 11) range reported over the last 12 breeding season, with no significant trends in abundance.

Keywords: Australian sea lion, Seal Bay, population monitoring.

1. INTRODUCTION

1.1. Background

Seals are one of the premier tourism attractions on Kangaroo Island (KI) and they underpin a regional multimillion dollar tourism industry, the centrepiece of which is the Australian sea lion (ASL, *Neophoca cinerea*) population in the Seal Bay Conservation Park. Information on the status and trends in abundance of the Seal Bay ASL population is essential for ensuring that ongoing tourism activities and developments are undertaken sustainably and in a way that does not impact natural population processes (Department of Sustainability Environment Water Population and Communities 2013). The information is also needed to provide long-term economic security to the regional tourism industry that is directly or indirectly dependent on Seal Bay (Department of Environment and Water (DEW), Commercial Tour Operators, regional tourism businesses).

ASL populations off South Australia (SA) are estimated to have declined by almost 70% over the last 40 years, with the species recently (December 2020) being uplisted from Vulnerable to Endangered under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Some of this decline has been attributed to sustained bycatch in demersal gillnet fisheries off SA that have been operating since the 1960s (Goldsworthy *et al.* 2021). Following a major study undertaken in the late 2000s into the impacts of bycatch mortality on ASL populations (Goldsworthy *et al.* 2010b), the Australian Fisheries Management Authority (AFMA), which manages the gillnet sector of the Gillnet Hook and Trap Fishery (GHAT), introduced a range of management measures to mitigate bycatch of ASL, including spatial closures around all breeding sites (Australian Fisheries Management Authority 2015). Since these measures were introduced (between 2010 and 2012) bycatch of ASL in the fishery has reduced significantly.

ASL are unique among pinnipeds in having a non-annual breeding cycle (~18 month between successive breeding seasons) in which breeding can occur at any time of the year. Breeding seasons last 4 to 9+ months and occur asynchronously across the species range (i.e., neighbouring colonies can breed at different times). A result of the near 18-month period between breeding is that at Seal Bay the seasons for breeding currently swap between predominantly summer/autumn and winter/spring. The 2020/21 season at Seal Bay was a summer/autumn breeding season.

Asynchronous breeding across the range of ASLs is thought to be maintained by extreme philopatry and population sub-structuring that effectively makes most breeding sites subpopulations (Campbell *et al.* 2008, Lowther *et al.* 2012). The non-annual and asynchronous

breeding habit of ASL makes systematic monitoring of their status and trends in abundance extremely challenging (Goldsworthy *et al.* 2021). Seal Bay forms a critical monitoring site for the species and is the only location where the population vital rates (survival and reproductive rates) are being monitored (Goldsworthy *et al.* 2019, 2020). Such data are essential to assess how anthropogenic mortality from key threats such as fishery bycatch as well as natural environmental variability impact the species population dynamics and their recovery potential. Maintenance of this program is identified as a key priority to the conservation of ASL, and to informing the effectiveness of the ASL recovery plan (Department of Sustainability Environment Water Population and Communities 2013).

The corner stone of population monitoring at Seal Bay is a microchipping program that commenced in 2002/03. The program seeks to microchip all pups surviving to >2-months of age in each breeding season, so that over time most seals from each cohort in the population will be of known age. This will allow fine scale scrutiny of critical population parameters (e.g. survival, recruitment, reproductive histories and rates) that are difficult to obtain, and rarely available for wild populations.

1.2. Objectives

This report provides details on the ASL monitoring program at Seal Bay, Kangaroo Island, for the 2020/21 breeding season, including estimates of pup production and their trends at Seal Bay and Seal Slide (Cape Gantheaume Wilderness Protection Area). Updates on the maintenance of the Seal Bay microchipping program and the age-structure of breeding sea lions at Seal Bay are also provided.

2. METHODS

2.1 Field sites

Seal Bay is part of the Seal Bay Conservation Park situated on the south coast of Kangaroo Island, centred on 35.996°S, 137.327°E. The ASL colony comprises four main areas (Figure 1) that are referred to as Pup Cove (2 km west of the visitor centre), the Western Prohibited Area (WPA), Main Beach (MB), including the sand dunes and swales inland from MB and the scrub behind the swales (referred to as the Road Reserve), and the Eastern Prohibited Area (EPA). Limestone promontories separate the WPA and the EPA from MB. Most pups are born in the WPA and at the western end of MB, with smaller numbers in Pup Cove, inland from the WPA and MB, in the dunes behind the eastern end of MB, and in the EPA (Goldsworthy *et al.* 2007). The WPA and EPA were declared in 1972 under the *National Parks and Wildlife Act 1972* (SA Government Gazette, December 7, 1972, pp. 2543-2544) for the "purposes of conserving the native animals on that portion of the Seal Bay Conservation Park described". The ASL colony known as the Seal Slide (36.028°S, 137.539°E) is located in the Cape Gantheaume Wilderness Protection Area, on the south-east coast of Kangaroo Island. The colony can be accessed by 4WD vehicle.

2.2 Pup production and population growth estimates

At Seal Bay, two methods were used to estimate pup abundance: direct counts of live and dead pups, and the cumulative count of new births and deaths throughout the colony based on repeat (usually twice-weekly) surveys (Goldsworthy *et al.* 2008, 2011). The latter is the main method of estimating pup production and we refer to it as the estimate based on the cumulative number of births. It can also be determined from the number of microchipped pups plus cumulative dead (not microchipped) pups at the end of the breeding season.

Previously, mark-recapture methods using the Petersen estimate were also used to estimate pup production, using pups that had been clip-marked during the microchipping process (McIntosh *et al.* 2012). However, it is apparent that clip-marks applied to pups in their brown lanugo may not be readily detectable once moulted. The loss of marks violates the assumptions of the Petersen estimate (Caughley 1977), and has likely led to over-estimates of pup abundance in some breeding seasons. Therefore, the Petersen estimate is no longer used to estimate pup abundance at Seal Bay.

The mortality of pups was calculated as the number of cumulative dead pups at the end of the breeding season, divided by the overall estimate of pup production, expressed as a percentage. The median date of birth and the period over which 90% of births occurred were

determined using a modified probit analysis of cumulative pup production data (Caughley 1977).

The standard ground count methodology was used to survey the Seal Slide. This included counting the number of live pups present in different pelage categories, as the pelage categories provide a proxy for pup age: black mate-guarded (pups whose mother is mate-guarded by an adult male indicate a pup aged 0-10 days), black (post-mate-guarded pups, 1-4 weeks), brown (pups approximately 4 - 16 weeks), moulting (pups, ~16-20 weeks) and moulted (pups, >20 weeks) (Goldsworthy *et al.* 2021). Dead pups are typically marked within surveys to avoid double counting.

2.3 Microchipping and demography program

Pups older than 2-months and un-attended by an adult female were captured by hand, weighed in a canvas bag using a spring balance to the nearest 0.1 kg, and then sexed and measured (standard length - nose to tail to the nearest ± 0.5 cm). Each pup was externally marked by clipping the fur across the rump (Figure 2) and a Passive Integrated Transponder tag (PIT tag: TIRIS™ RFID 23 mm) was implanted subcutaneously using a sterile single-use needle. PIT tags (microchips) were inserted in the clipped area, parallel to the spine and close to the tail to minimise the effect of gravitation causing tag movement.

During the breeding season and between breeding seasons, hand-held scanning of animals (using Allflex RS420 EID ‘boom’ readers) was undertaken regularly throughout the colony. To successfully identify seals with a microchip, the Radio Frequency Identification (RFID) reader was held near the animal within 10 cm from the insertion site (rump) (Figure 2). Mother-pup pairs were also targeted throughout the breeding season to assess the tagged status of the pups and identify if the mother had been microchipped. In addition to monitoring during the breeding season, all available sea lions are scanned over 3 days at approximately two-month intervals (or once every two -weeks) to monitor individual survival. All scanning data were entered in real time into a purposely developed data management app (Seal Bay ASL Monitoring V3 and SB BS Records V2) developed using the Fulcrum software (https://web.fulcrumapp.com) and operated on a handheld device.


Seal Bay Conservation Park - Site Map
Legend
Beach
Buildings
Cliff Face
Coastal Rock
Dunes
Native Vegetation
Roads and Walkways
Seal Bay
Conservation Park
Pup
Cove
WPA
Boundary
Main Beach
EPA
Boundary
EPA 1
EPA 2
Southern Ocean
Government of South Australia
Department for Environment and Heritage

3. RESULTS

3.1. Seal Bay

3.1.1 Distribution of births

A total of 57 twice-weekly pup surveys were undertaken between 20 October 2020 and 3 June 2021. New pup births or deaths were recorded on a subsequent six occasions until 19 October 2021, giving a total 63 surveys for the breeding season (Table 1, Figure 3). The breeding season commenced on 20 Oct 2020 with the last new pup birth recorded a year later, 19 October 2021. Based on these observations, the duration of the breeding season was 12 months. A probit analysis of the cumulative number of births estimated a median pupping date of 9 February 2021 (sd = 65 days), with 90% of births occurring over 215 days (7.1 months), between 24 October 2020 and 27 May 2021 (Table 2).

Variation in the chronology of breeding across the last 13 breeding seasons is presented in Figures 4 and 5. The mean breeding interval (period between successive median pupping dates) for twelve consecutive breeding seasons since the 2002/03 breeding season was 545 days (range 541 - 553, sd = 5.4) or 17.9 months (range 17.8 - 18.2, sd = 0.2) (from data in Table 1, Figure 4a). The timing of breeding appears to be shifting back by about 2.1 days per breeding season since 2003, for both summer/autumn and winter/spring breeding seasons (Figure 4b). This represents a shift of about one month over the last 16 years (Figure 3).

Table 1. Summary of surveys of Australian sea lion pups at Seal Bay during the 2020/21 breeding season indicating new births and dead pups, cumulative births and deaths, and direct counts of brown pups (BP), moulted pups (MP) and total live pups.

Survey	Date	Survey	New	New	Cummulative				Counts	
No.		day	Births	Dead	Born	Dead	Alive	BP	MP	Total live
1	20-Oct-20	0	2	0	2	0	2	2	0	2
2	26-Oct-20	6	1	1	3	1	2	1	0	1
3	02-Nov-20	13	1	1	4	2	2	2	0	2
4	05-Nov-20	16	2	1	6	3	3	4	0	4
5	09-Nov-20	20	0	0	6	3	3	3	0	3
6	12-Nov-20	23	1	0	7	3	4	1	0	1
7	14-Nov-20	25	3	0	10	3	7	6	0	6
8	16-Nov-20	27	2	1	12	4	8	8	0	8
9	23-Nov-20	34	3	0	15	4	11	9	0	9
10	26-Nov-20	37	4	0	19	4	15	10	0	10
11	01-Dec-20	42	5	3	24	7	17	13	0	13
12	03-Dec-20	44	2	0	26	7	19	14	0	14
13	07-Dec-20	48	9	0	35	7	28	19	0	19
14	10-Dec-20	51	4	0	39	7	32	21	0	21
15	14-Dec-20	55	6	2	45	9	36	26	0	26
16	17-Dec-20	58	7	1	52	10	42	34	0	34
17	22-Dec-20	63	3	2	55	12	43	25	0	25
18	24-Dec-20	65	2	0	57	12	45	32	0	32
19	28-Dec-20	69	4	0	61	12	49	32	0	32
20	31-Dec-20	72	6	1	67	13	54	38	0	38
21	04-Jan-21	76	9	0	76	13	63	48	0	48
22	08-Jan-21	80	15	2	91	15	76	53	0	53
23	11-Jan-21	83	6	3	97	18	79	50	0	50
24	14-Jan-21	86	5	2	102	20	82	53	0	53
25	18-Jan-21	90	5	2	107	22	85	59	0	59
26	22-Jan-21	94	11	1	118	23	95	79	0	79
27	26-Jan-21	98	6	4	124	27	97	65	0	65
28	29-Jan-21	101	14	2	138	29	109	67	0	67
29	01-Feb-21	104	1	0	139	29	110	76	0	76
30	04-Feb-21	107	0	1	139	30	109	57	0	57
31	08-Feb-21	111	7	2	146	32	114	57	0	57
32	11-Feb-21	114	3	0	149	32	117	59	0	59
33	15-Feb-21	118	7	3	156	35	121	79	0	79
34	19-Feb-21	122	10	4	166	39	127	91	0	91
35	22-Feb-21	125	5	5	171	44	127	80	6	86
36	25-Feb-21	128	6	1	177	45	132	85	0	85
37	02-Mar-21	133	6	2	183	47	136	89	0	89
38	06-Mar-21	137	3	3	186	50	136	95	0	95
39	11-Mar-21	142	5	3	191	53	138	73	0	73
40	15-Mar-21	146	2	3	193	56	137	84	0	84
41	18-Mar-21	149	5	0	198	56	142	100	0	100
42	23-Mar-21	154	8	1	206	57	149	95	0	95
43	25-Mar-21	156	0	1	206	58	148	83	0	83
44	29-Mar-21	160	3	1	209	59	150	83	0	83
45	02-Apr-21	164	4	0	213	59	154	72	0	72
46	06-Apr-21	168	1	0	214	59	155	79	0	79
47	10-Apr-21	172	2	0	216	59	157	75	0	75
48	15-Apr-21	177	5	1	221	60	161	67	0	67
49	22-Apr-21	184	1	1	222	61	161	90	0	90
50	27-Apr-21	189	1	1	223	62	161	97	0	97
51	01-May-21	193	1	0	224	62	162	92	0	92
52	05-May-21	197	3	1	227	63	164	110	0	110
53	11-May-21	203	0	1	227	64	163	90	0	90
54	17-May-21	209	0	1	227	65	162	107	8	115
55	17-May-21	209	0	0	227	65	162	105	8	113
56	31-May-21	223	5	1	232	66	166	77	13	90
57	03-Jun-21	226	0	0	232	66	166			
58	21-Jun-21	244	4	1	236	67	169			
59	22-Jul-21	275	1	2	237	69	168			
60	31-Jul-21	284	2	1	239	70	169			
61	05-Oct-21	350	1	0	240	70	170			
62	15-Oct-21	360	1	0	241	70	171			
63	19-Oct-21	364	1	0	242	70	172			

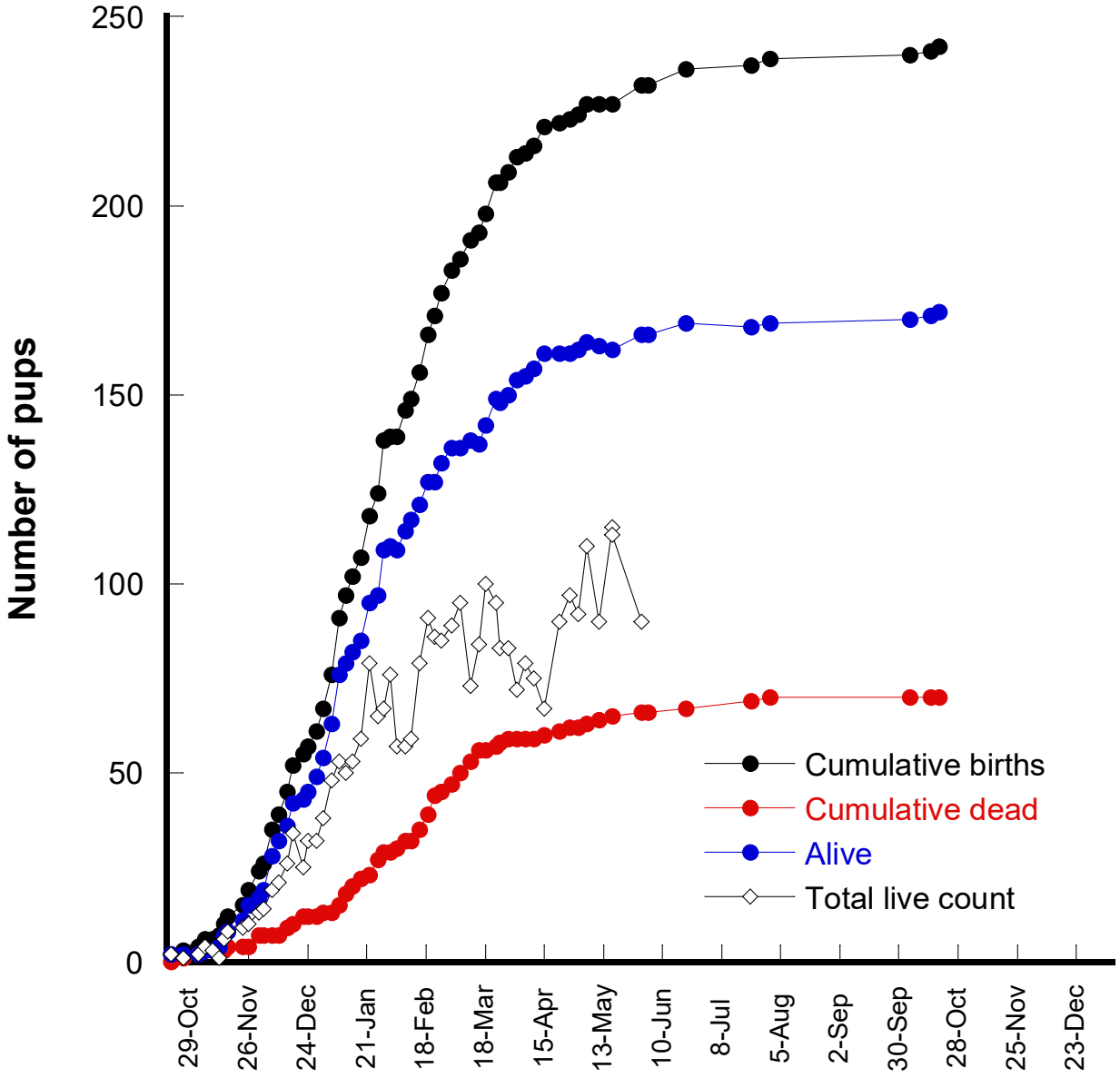
Number of pups
250
200
150
100
50
0
29-Oct
26-Nov
24-Dec
21-Jan
18-Feb
18-Mar
15-Apr
13-May
10-Jun
8-Jul
5-Aug
2-Sep
30-Sep
28-Oct
25-Nov
23-Dec
Cumulative births
Cumulative dead
Alive
Total live count

Table 2. Summary of the timing and duration of 13 consecutive breeding seasons of the Australian sea lion at Seal Bay, and pup abundance estimates including cumulative births and deaths; maximum live (and concurrent dead) pup count; total numbers of microchipped pups and minimum pup production (microchipped + cumulative pup deaths); and the overall estimate of pup production. Estimated mortality rate is also included. Comparative data for the 2002/03, 2004 and 2005/06 breeding seasons are from McIntosh et al. (2006) and McIntosh et al. (2012) unless otherwise indicated. Data for the remaining breeding seasons (BS) are from Goldsworthy et al. (2008, 2010a, 2011, 2013, 2014, 2015, 2017, 2019), and for the 2020/21 season, this report. Note: Overall, estimates of pup production for some earlier seasons may differ from previous reports because mark-recapture methods are no longer included as part of the estimation procedure.

	2002-03	2004	2005-06	2007	2008/09	2010	2011/12	2013	2014/15	2016	2017/18	2019	2020/21
Month breeding season commenced	Dec-02	Jun-04	Dec-05	May-07	Oct-08	May-10	Oct-11	Mar-13	Aug-14	May-16	Oct-17	Mar-19	Oct-20
Duration of breeding season (months)	9	7	6	7	7	9	8	12	12	8	10	12	12
Median pupping date	13-Mar-03	5-Sep-04	28-Feb-06	27-Aug-07	24-Feb-09	28-Aug-10	21-Feb-12	25-Aug-13	1-Mar-15	28-Aug-16	13-Feb-18	8-Aug-19	9-Feb-21
± s.d. (days)	42	39	36	36	41	46	48	47	53	53	50	34	65
90% births (5%- 95%)	May[1]	3 Jul -1 Nov	4 Jan-18 Apr	28 Jun- 26 Oct	18 Dec-3 May	Nov	5 Dec -9 May	Nov	3 Dec - 27 May	1 Jun - 24 Nov	26 Nov - 1 May	14 Jun - 2 Oct	May
90% births (days)	139	121	104	120	136	150	156	156	175	176	164	111	215
Maximum live pup count	122	148	125	154	122	119	84	99	103	163	110	138	115
At months since beginning of BS	6	7	6	6	7	6	6	4	12	6	6	6	7
Max live pup count + cumulative dead[2]	185	208	197	198	197	180	166	126	170	192	178	178	180
Cumulative births	-	200	207	245	268	259	249	259	239	240	231	228	242
Cumulative pup deaths total	73	70	75	51	88	66	104	54	67	43	75	46	70
Chipped										10	6	4	12
Unchipped										33	69	42	58
Mortality rate		25.7%		20.1%	32.8%	24.7%	41.8%	20.8%	28.0%	17.9%	32.3%	19.2%	28.9%
Total pups micro-chipped	148	202	144	203	161	201	118	161	153	201	163	197	179
Minimum pup production	221	272	219	254	249	267	222	215	220	234	232	239	237
Overall estimate of pup production	-	272	-	254	268	267	249	259	239	240	232	239	242

[1] Shaughnessy *et al*. (2006)

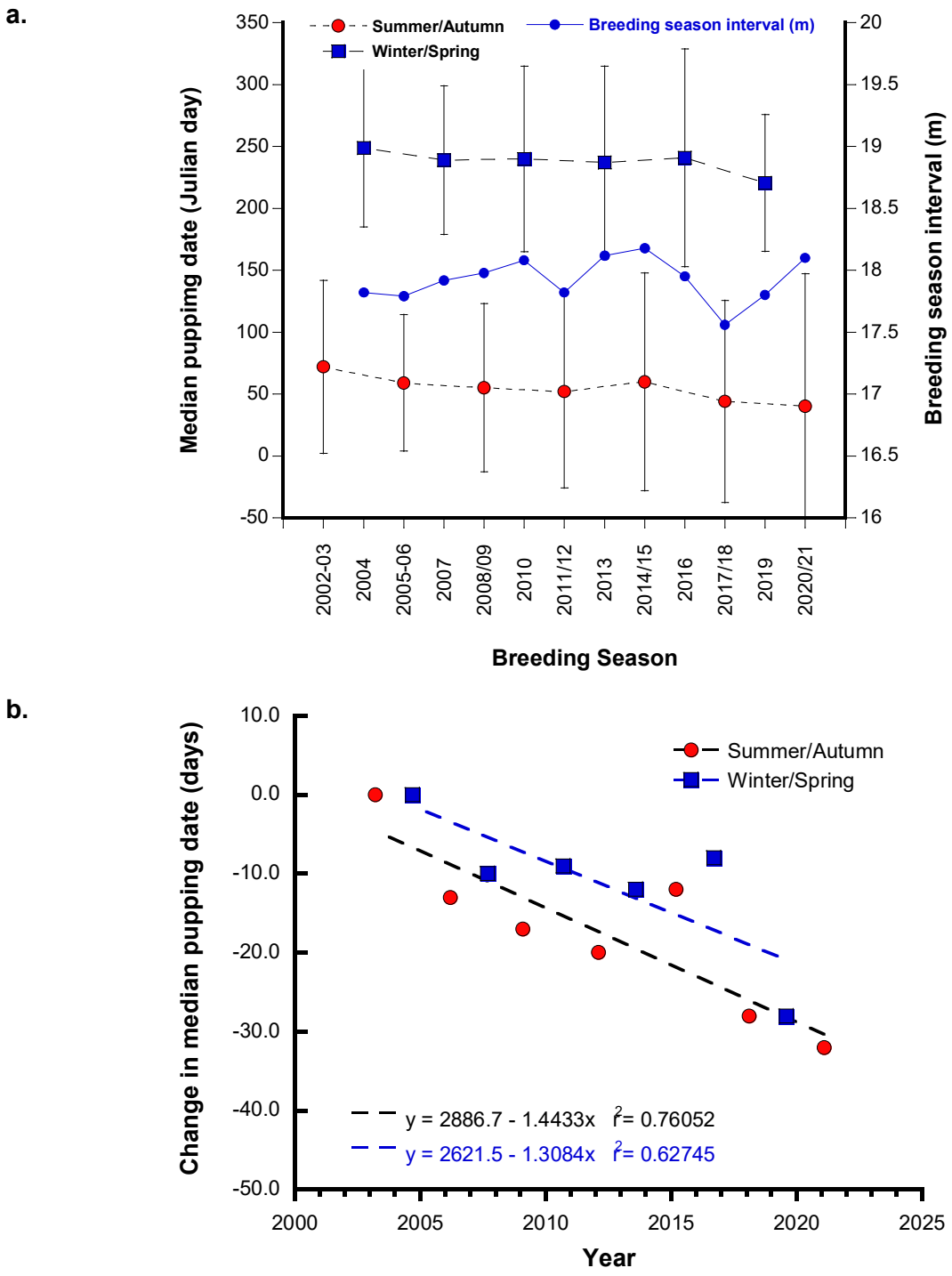

Figure 4. Variation in the breeding season phenology of Australian sea lions at Seal Bay across 13 consecutive breeding seasons (2002/03 to 2020/21). (a) Timing of breeding expressed as median pupping dates (Julian days, error bars represent the spread of 90% of births), including the breeding season interval (months); and (b) change in median pupping date (days) as a function of the first summer/autumn (2002/03) and winter/spring (2004) breeding seasons.

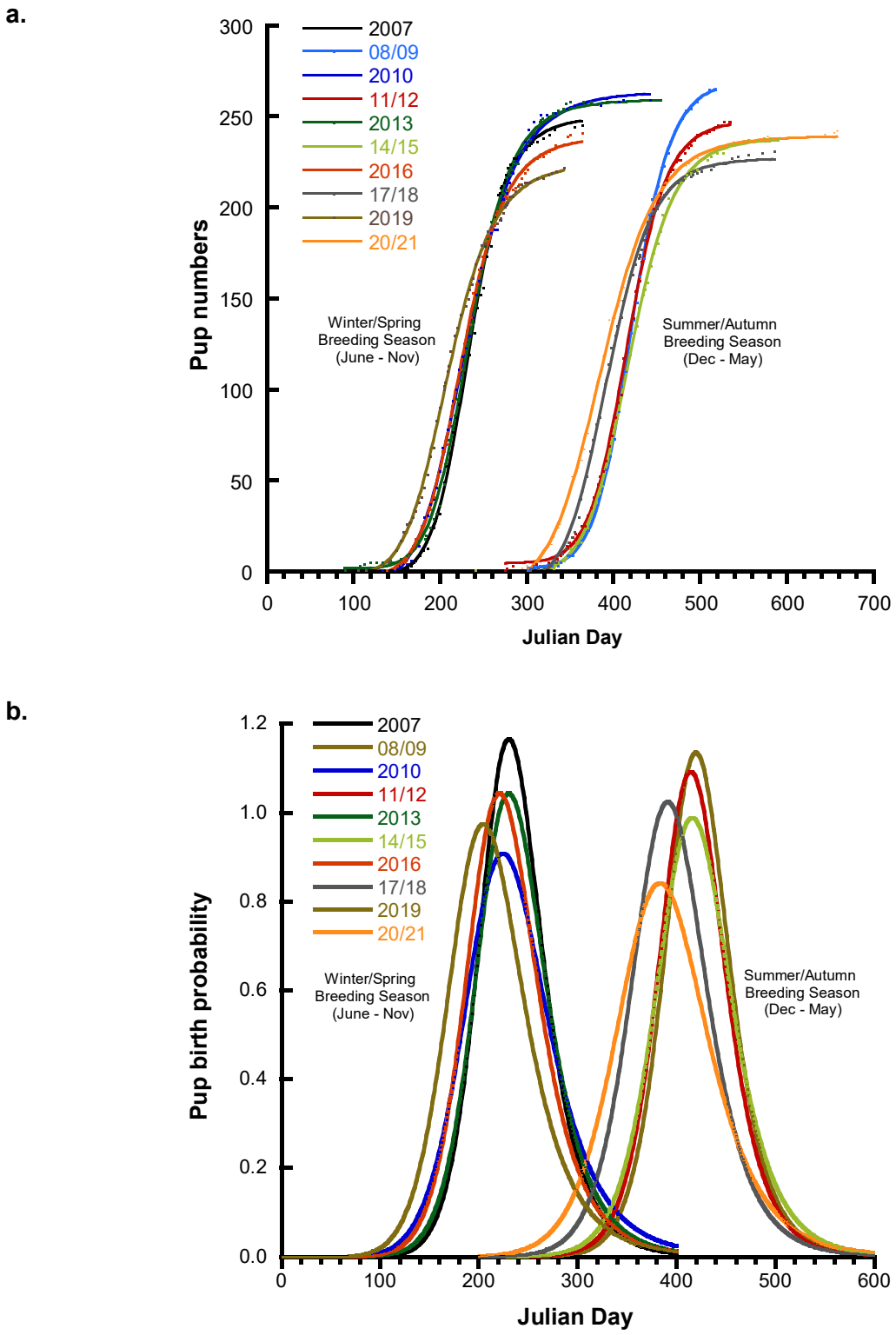

Figure 5. Distribution of cumulative births of Australian sea lion pups at Seal Bay (a) and their probability distributions (b) in each of the last ten breeding seasons, 2007 to 2020/21. Julian day begins at 1 on January 1st of each breeding season. The figure demonstrates different ways of visualising the timing and distribution pup births across the different winter/spring and summer/autumn breeding seasons.

3.1.2 Pup production

The pup production estimate based on the cumulative number of births recorded for the 2020/21 breeding season at Seal Bay was 242 (Table 1). This comprised 179 microchipped pups, 58 dead pups that had not been microchipped and five pups whose birth was recorded but they were not microchipped and their survival status was not known (Table 1, Figure 6).

Most pups were born in the Main Beach/Road Reserve areas west of the area accessed by the public (125 pups, 52%) and in the EPA (88 pups, 36%), with 23 pups (10%) reported for the WPA and 6 pups (2%) in Pup Cove (Figure 7). As Pup Cove could only be surveyed from vantage-points along an over-looking cliff-line (and this season was surveyed less frequently), the total births for this area may be an under-estimate. Trends in the distribution of observed births over the last eight breeding seasons indicates a progressive increase in the proportion of births in the Main Beach/Road Reserve areas, and a concomitant decrease in the proportion of births in the WPA and Pup Cove areas, suggesting an eastward shift in the distribution of births over time (Figure 7).

The maximum direct count of live pups was 115 on 17 May 2021, when the cumulative number of dead pups was 65. The cumulative number of pup deaths to the end of the breeding season was 70 (Table 1).

3.1.3 Trends in pup production

The trend in estimated pup production based on eleven estimates over the last 12 breeding seasons between 2004 and 2020/21 are presented in Figure 6. The decline in pup production over time (determined from linear regression of the natural logarithm of pup numbers against year) is significant, and estimated to be -0.9% per year, or -1.3% per breeding season ($r^2 = 0.61$, $P = 0.008$). There is the same rate of decline in maximum live pup count over the last 35 years (-0.9%/year or -1.3% per breeding season, respectively) ($r^2=0.24$, $P = 0.003$) (Figure 6).

Since the 2014/15 breeding season, pup production appears to have stabilised, and there has been no significant change in pup production over the last five breeding seasons ($r^2 = 0.15$, $P = 0.61$). The last two breeding seasons have shown an increase in pup production from the 2017/18 low of 232 pups. This is the first time we have recorded two consecutive seasons of increased pup production.

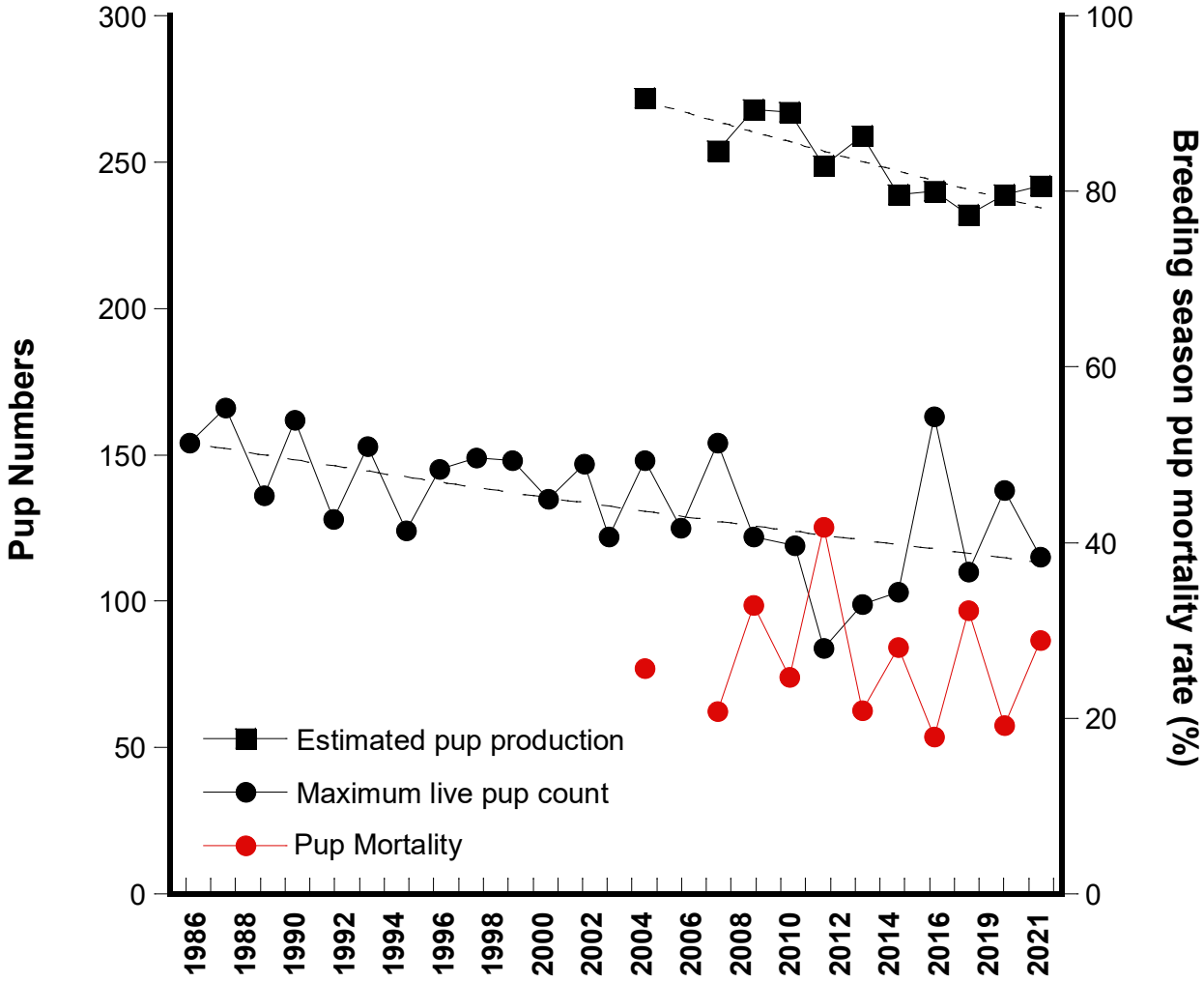

Figure 6. Trends in the abundance of Australian sea lion pups at Seal Bay based on maximum live pup counts for 25 breeding seasons between 1985 and 2020/21. Trends in estimated pup production and breeding season pup mortality rate are presented for eleven of the last twelve breeding seasons. Exponential regression curves are fitted to pup numbers.

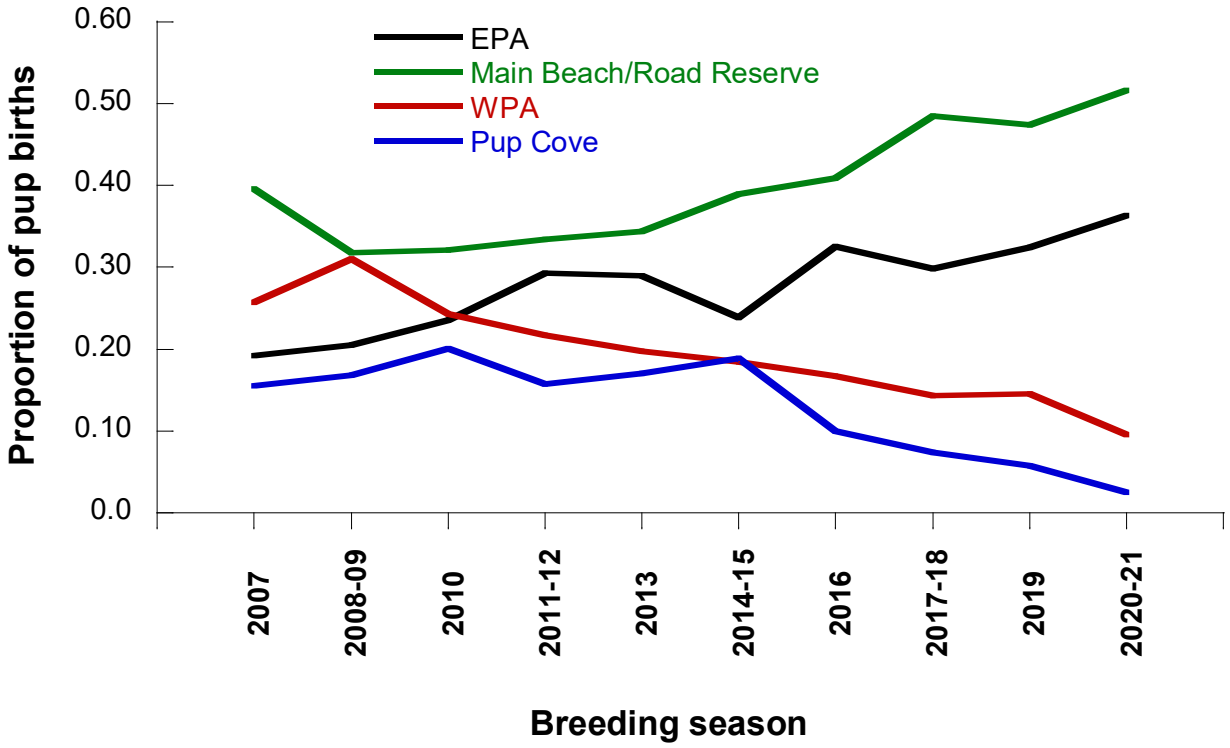

Figure 7. Geographic shifts in the distribution of Australian sea lion pup births at Seal Bay over ten consecutive breeding seasons between 2007 and 2020/21.

3.1.4 Breeding season pup mortality

Pup mortality for the 2020/21 breeding season at Seal Bay was 28.9% (i.e., 70 deaths from 242 births, Table 2, Figure 6). Breeding season pup mortality rate can be estimated for 11 of the last 13 breeding seasons and has averaged 26.9% (sd = 7.2; range 17.9 - 41.8%, Table 2, Figure 6).

Breeding season pup mortality is lower in winter/spring breeding seasons averaging 21.4% (sd = 3.1, n = 6), and is higher in summer/autumn breeding seasons averaging 32.8% (sd = 5.4, n = 5) (Table 2). There is no significant trend in breeding season pup mortality over time (Figure 6, r^2 = 0.003, P = 0.86), but there is a significant negative relationship between breeding season pup mortality rate and maximum live pup counts (Figure 8, r^2 = 0.49, P = 0.016).

Estimates of pup production and breeding season pup mortality rate have been important in determining that declines in live pup counts over the last 35 breeding seasons reflect real declines in pup production, and not just changes in pup mortality rate.

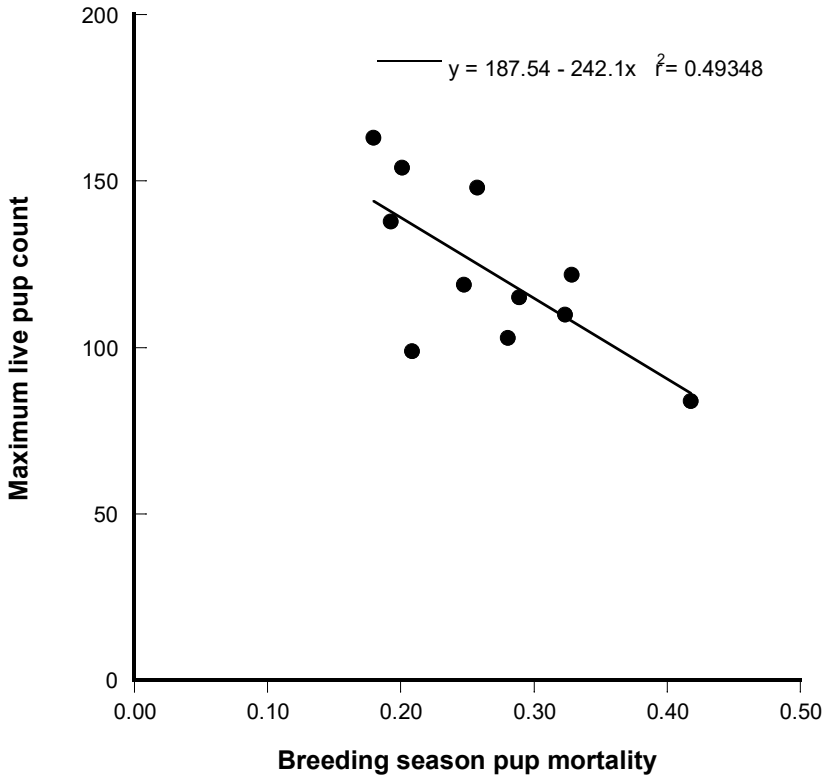

Figure 8. Relationship between the estimated breeding season pup mortality and maximum live pup count for ten breeding seasons between 2007 and 2019.

3.1.5 Population scanning and microchipping

Between February 2013 and September 2021, a total of 17,452 individual microchip resight scans were undertaken at Seal Bay (Figure 9a). The proportion of animals scanned that were microchipped has steadily increased from around 55% in 2013 to 89% in 2020 (Figure 9b). In 2021, the proportion of scanned animals that were microchipped has remained steady at ~90%. Given that microchipped animals in the Seal Bay ASL population are currently ≤19 years of age and maximum known age recorded for an ASL is 26 (McIntosh 2007), we should see this proportion plateauing over coming seasons.

A total of 179 pups were microchipped in the 2020/21 breeding season; 12 of these have subsequently been recorded as dead (Table 2).

3.1.6 Age distribution of breeding females and males

Since the 2011/12 breeding season, scanning of breeding females to monitor reproductive rates has been conducted more assiduously. This has involved attempts to scan as many females as possible during the peri-natal period (when females are mate-guarded) and later, to identify known-age females and to monitor age-specific and inter-breeding season variation in birth rates (births per female per breeding season).

There were 241 female sea lions known to give birth in the 2020/21 breeding season, one of which gave birth to twins (i.e. 242 births from 241 females). Of these, 232 (96%) were scanned, of which 195 (84%) were chipped and 37 (16%) un-chipped (Figure 9). There were 13 un-scanned females, that were unable to be scanned during the peri-natal period. Seven of these were within the main colony area while six were inaccessible (in Pup Cove). At least four of the seven females were scanned later in the main colony area with older pups and found to be microchipped (known as ‘Discovery scans’). The number of adult females microchipped in a breeding season has steadily increased since the 2011/12 breeding season (Figure 10).

The age distribution of the 195 microchipped breeding females that are known to have pupped during the 2020/21breeding season at Seal Bay is presented in Figure 11. The most notable feature for the 2020/21 breeding season was the strong recruitment of 6-year-old females and 4.5-year-old females (6 individuals) pupping for the first time. Trends in the recruitment index (mean number of microchipped females ≤ 6 years of age that pup within a breeding season) indicate strong recruitment in the last two breeding seasons, with the 2020/21 breeding season having the highest recruitment index recorded to date (Figure 12). Six-year-old females (31

individuals born in 2014/15) were the strongest breeding cohort across all age groups (20% of total). Other key age-classes that each had 25+ females were: 7.5 (2013 cohort); 10.5 (2010 cohort) and 13.5-year-olds (2007 cohort; Figure 11).

The age distributions of known-aged female ASL recorded in the last seven breeding seasons are presented in Figure 13 along with the pooled distributions for all seven breeding seasons. There is an apparent difference in the age distribution of breeding females in summer/autumn and winter/spring breeding seasons. In the three winter/spring breeding seasons (2013, 2016, 2019), the recruitment of ≤6-year-old females into the breeding population is pronounced, while it is diminished in three of the four summer/autumn breeding seasons (2011/12, 2014/15 and 2017/18), the exception is 2020/21 (Figure 13).

Whereas most females will start pupping at around six years of age, most males commence their mate-guarding from age 10 (Figure 11). A total of 105 individual males were recorded mate guarding during the 2020/21 breeding season. Curiously, one of the males that was observed to be mate-guarding in 2020/21 was just 4.5 years old.

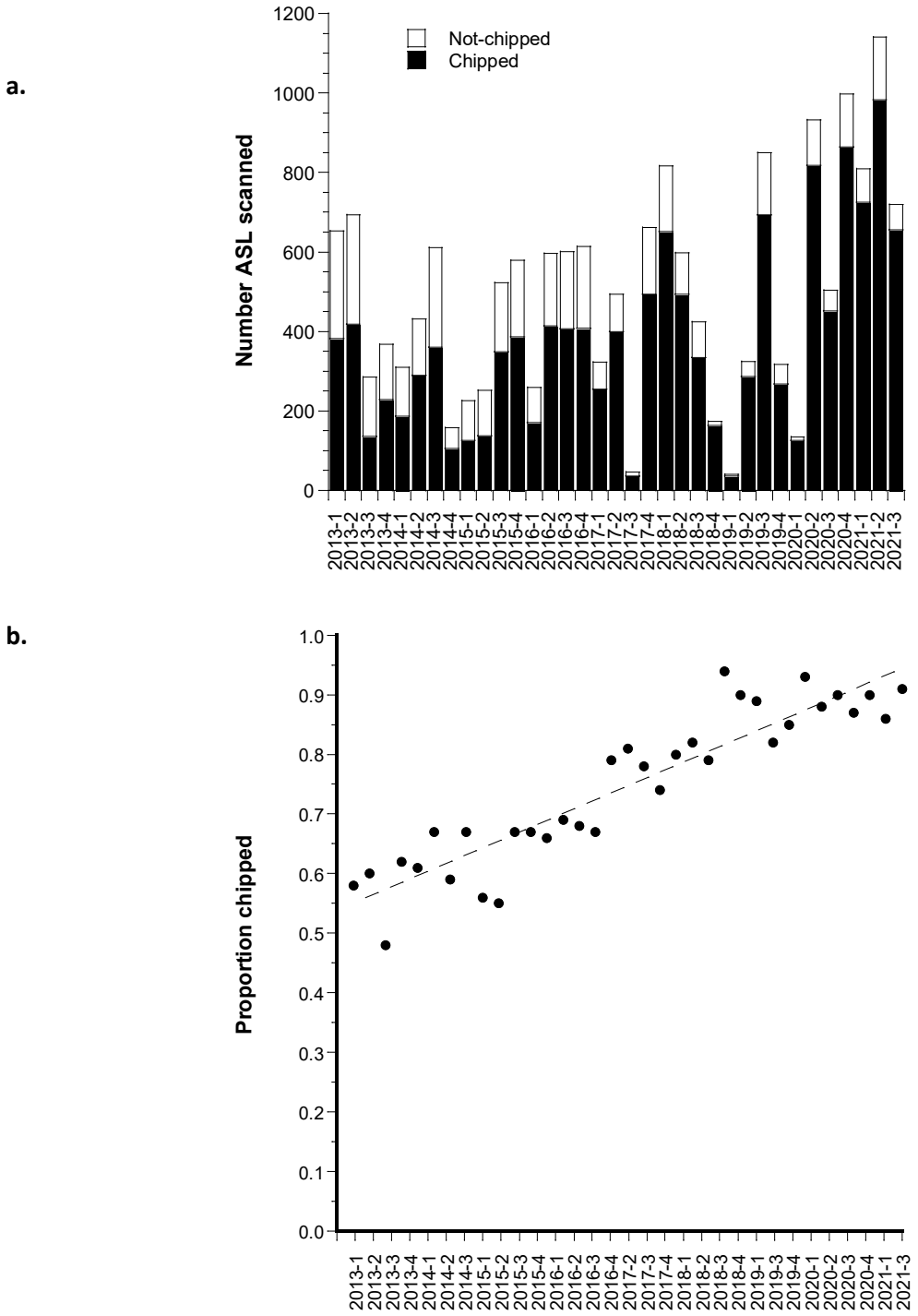

Figure 9. Microchip scanning effort of the Australian sea lion population at Seal Bay summarised into the quarterly (3 month) periods between 2013 and 2021 (a), indicating the total number scanned (chipped and not chipped). The proportion of scanned individuals that were microchipped is also presented (b).

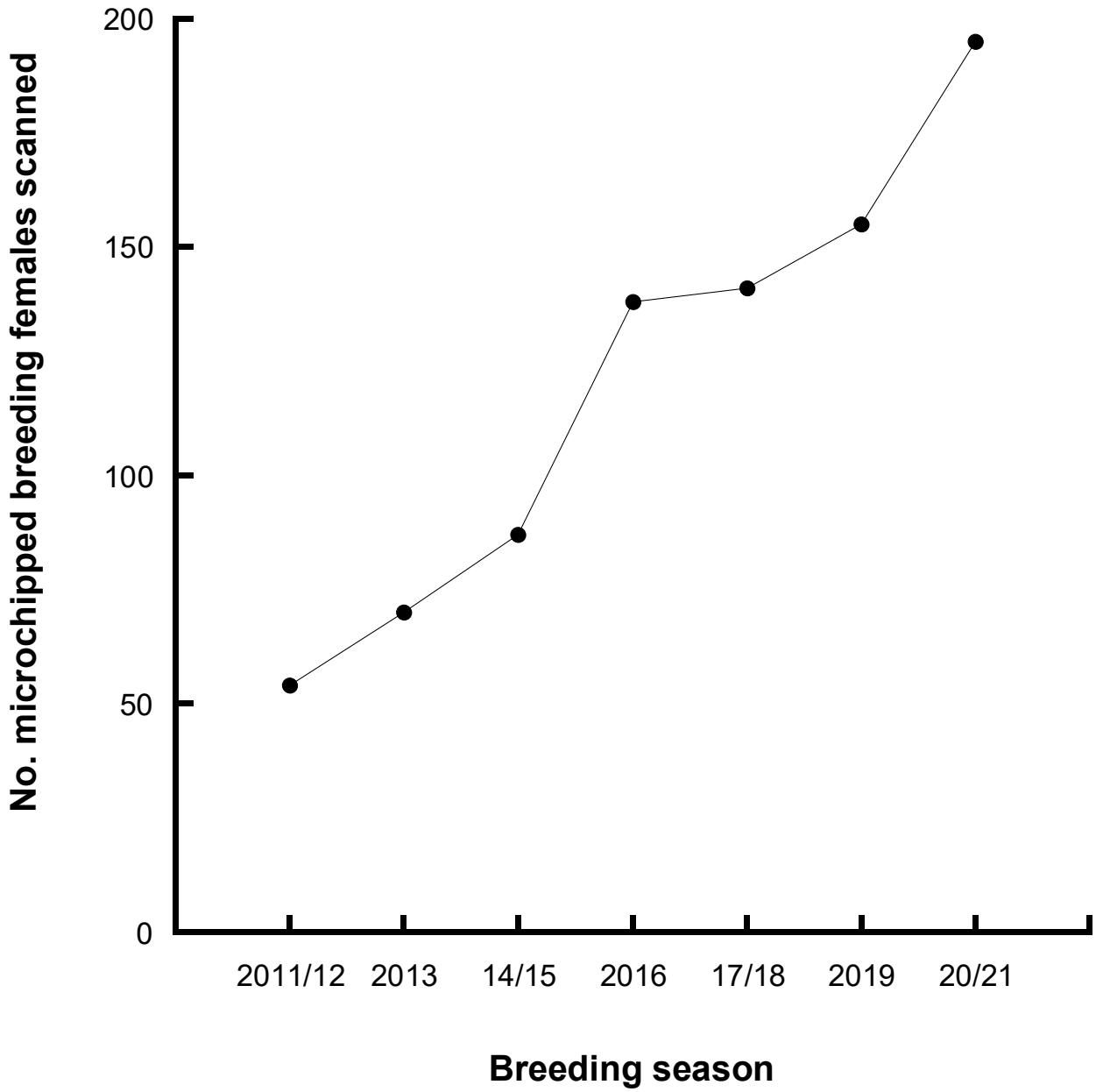

Figure 10. The number of microchipped, breeding female Australian sea lions scanned in each of seven breeding seasons (2011/12 to 2020/21) at Seal Bay.

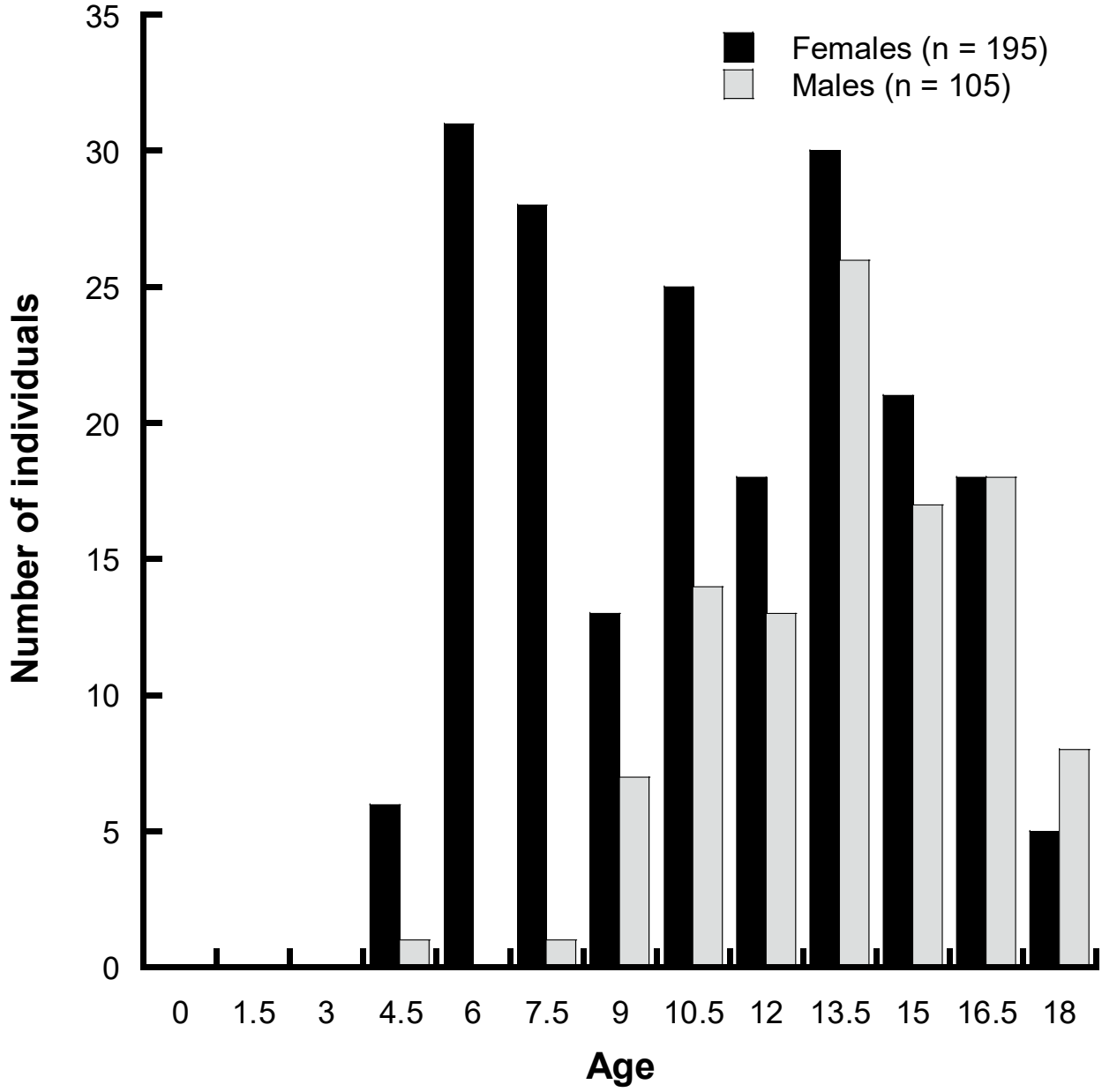

Figure 11. Age distribution of known-age Australian sea lion females (n = 194) that pupped at Seal Bay in the 2020/21 breeding season and known-age adult males (n = 102) observed to mate-guard females during the peri-natal period. Note that microchipping commenced in the 2002/03 breeding season, so the oldest known-aged seals were ≤19 years in 2020/21, and no data are available for animals >19 years of age.

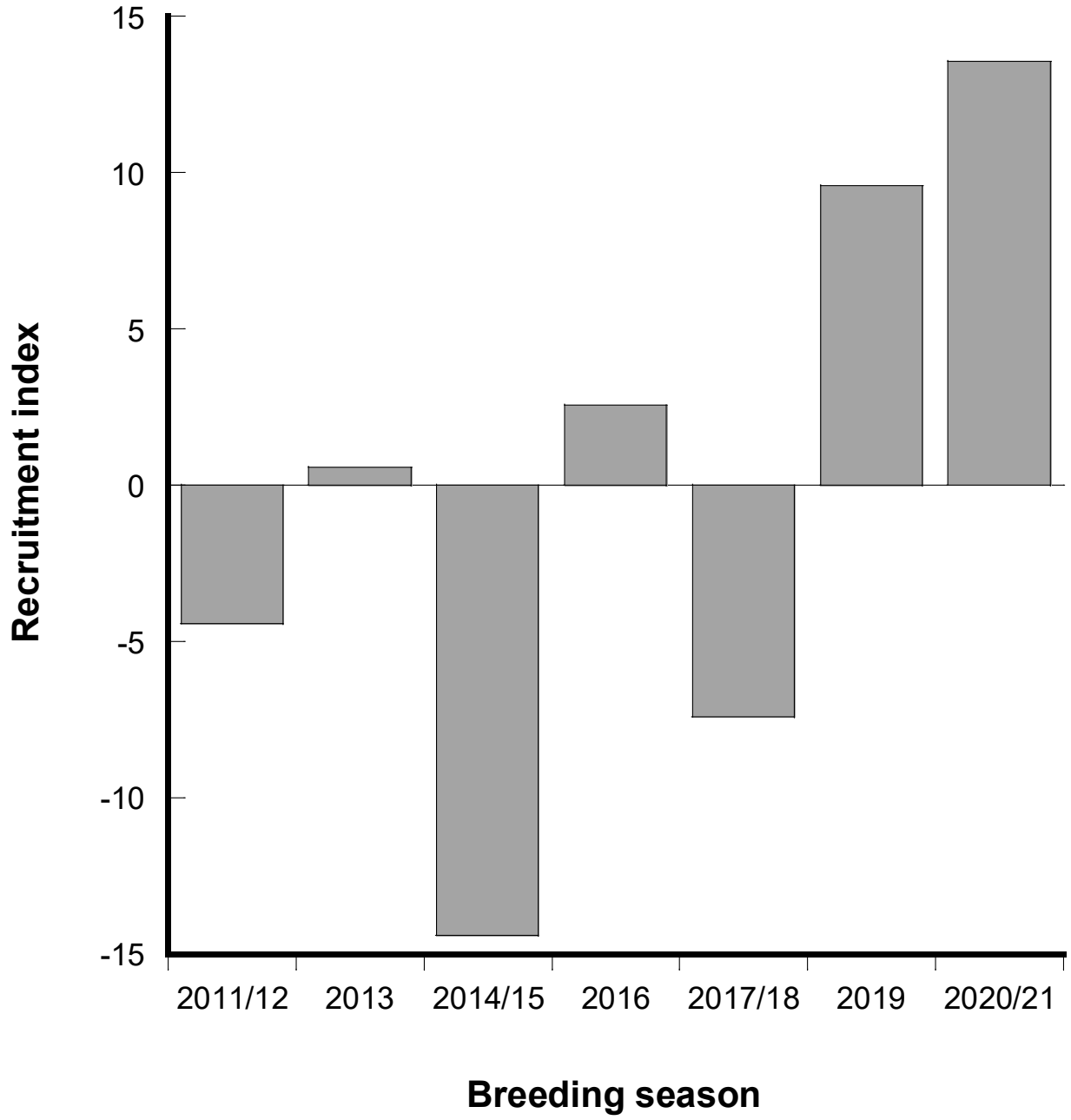

Figure 12. Change in the recruitment index (deviation from mean number of microchipped females ≤ 6 years of age that pup within a breeding season) of adult female Australian sea lions into the breeding population between the 2011/12 and 2020/21 breeding season at Seal Bay.

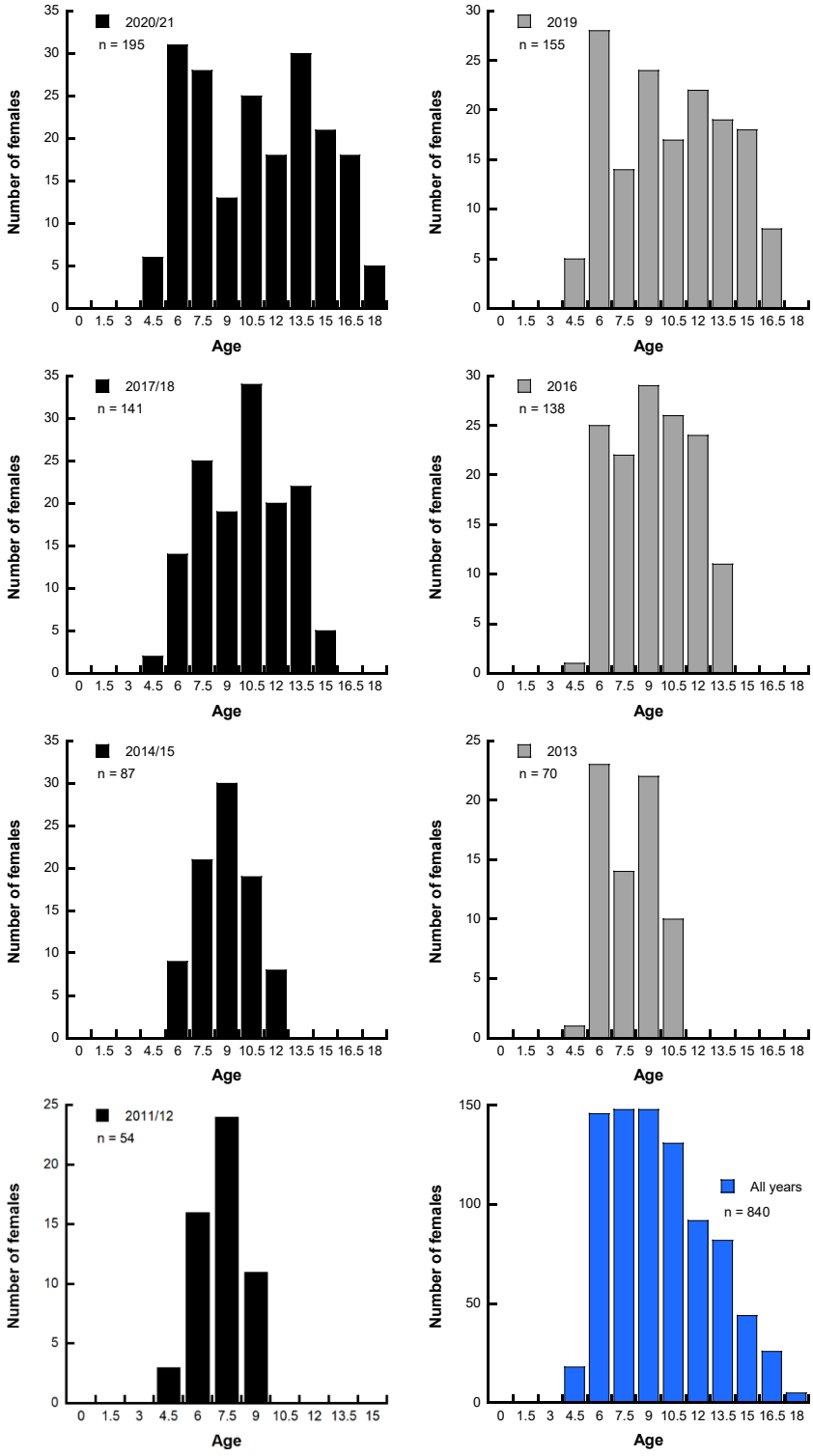

Figure 13. Age distribution of known-age Australian sea lion females that pupped at Seal Bay in the 2011/12, 2013, 2014/15, 2016, 2017/18, 2019 and 2020/21 breeding seasons. Seasons with black bars represent summer/autumn, while grey bars reflect winter/spring breeding seasons. The pooled age-distribution across these breeding seasons is also presented in the bottom right (blue bars). Note that microchipping commenced in the 2002/03 breeding season, so the oldest known-aged females were 18 years in 2020/21, and no data are available for females >18 years of age.

3.2. Seal Slide

Three ground count surveys of ASL pups were undertaken at Seal Slide during the 2020/21 breeding season. On 8 December 2020, a total of 4 pups were recorded (1 black mate-guard, 3 black), on 27 January 2021 8 pups were counted (1 black mate-guard, 1 black, 6 brown) and on 6 April 2021 at total of 11 pups were counted (1 black mate-guard, 9 brown, 1 moulting). Three pups were microchipped on 27 January 2020. The final survey was judged to have taken place at the end of the breeding season, giving a minimum pup production estimate for the 2020/21 breeding season of 11.

Comparable estimates of pup abundance at Seal Slide are now available for the last 12 breeding seasons, since 2002/03 (Figure 14). The change in pup production over time (determined from linear regression of the natural logarithm of pup numbers against year) has a weak, non-significant, positive trend ($r^2 = 0.06$, P = 0.80), of 0.92% per year, or 1.38% per breeding season (Figure 14). Pup numbers have ranged from 8 to 15 (mean 10.8).

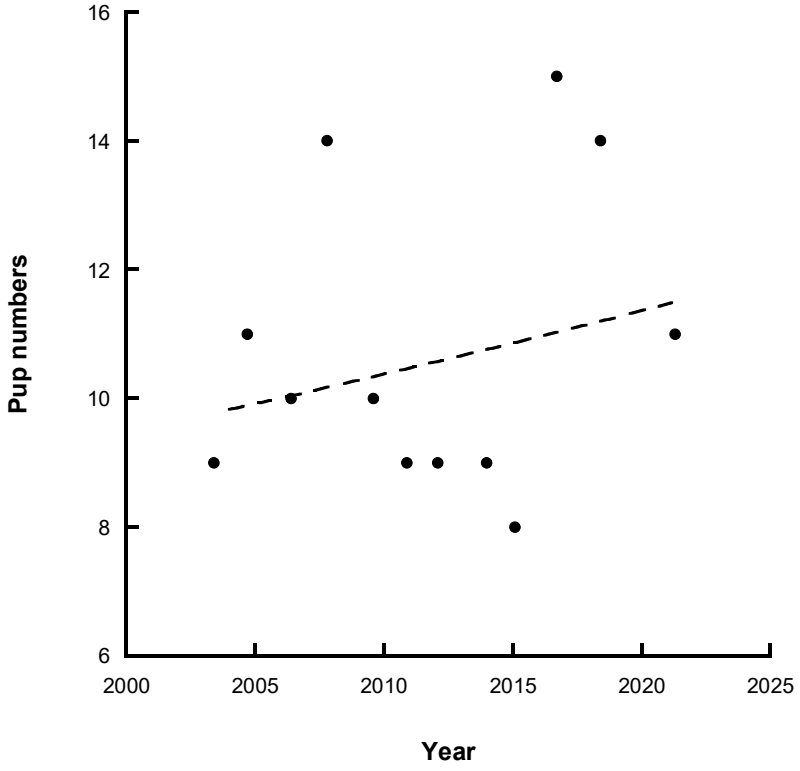

Figure 14. Trends in the estimated Australian sea lion pup production at Seal Slide (Kangaroo Island), over twelve consecutive breeding seasons (2002/03 to 2020/21). An exponential regression of the trend in pup numbers is indicated by the dashed line.

4. DISCUSSION

Monitoring of the ASL population at Seal Bay continues to provide critical information on the status of the population, its trends in abundance and life-history data on cohort and age-specific survival and reproductive success. Such information is not only essential to managing the species at Seal Bay and ensuring that ongoing tourism activities and developments are undertaken sustainably, it also provides important knowledge for conservation and management of the species as a whole, as the life-history data is not readily obtainable from other ASL populations.

Long-term trends in live pup counts at Seal Bay indicate the population underwent a sustained decline for at least 35 years. Goldsworthy *et al.* (2021) reported a ~34% decline over 42 years (3-generations), equating to an annual decline of ~1% per year based on changes in maximum live pup counts (plus cumulative dead pups). Trends in pup production provide a more accurate estimate of changes in population abundance and have been determined at Seal Bay since the 2002/03 breeding season. These data indicate that trends in pup production are consistent with these longer-term trends in live pup counts. The multi-decadal decline in the Seal Bay population has been lower than the SA average of 2.6%/year (based on 23 SA subpopulations), and the estimated 67% decline in total SA abundance over 3-generations (Goldsworthy *et al.* 2021).

There are some positive signs that may indicate the trajectory of the Seal Bay population is changing. Pup production over the last five breeding seasons has not changed significantly (range 232 to 242), and we have seen two successive breeding seasons of increased pup production (the first time this has been recorded). Furthermore, there has been a marked increase in the recruitment of ≤6-year-old females into the breeding population over the last two breeding seasons, which suggests that juvenile survival in recent cohorts has improved. Based on these results, plus the relatively high number of 4.5-year-old females (i.e., from the 2016 cohort) that pupped in 2020/21 and the low breeding season mortality for the 2016 breeding season, the 2022 breeding season could be expected to also show high recruitment of 6-year-old females. This should translate into another season of higher pup production.

Presently, the data are too limited to directly link the stabilisation (and potential increase) in pup production and recruitment to management changes to limit the bycatch mortality of ASL introduced in the gillnet sector of the Gillnet Hook and Trap fishery off SA between 2010 and 2012. However, the timing is consistent with when a recovery would be detectable, based on population modelling projections (Goldsworthy *et al.* 2020). Continued monitoring and evaluation of the demographic response of the ASL population at Seal Bay, and changes in pup abundance

at other breeding sites, will be critical to linking population recovery to the bycatch mitigation measures introduced by the Australian Fisheries Management Authority (Australian Fisheries Management Authority 2015). It will also provide an important basis to evaluate the extent to which any recovery observed in other SA subpopulations can be attributed to changes in bycatch mortality of ASL.

The ongoing demographic study that has been in place since 2003, continues to microchip entire pup cohorts (pups that survive each breeding season) and undertake regular scanning throughout the colony to resight individuals. Almost 90% of individual sea lions currently being scanned are chipped, suggesting less than 10% of the population achieve ages >19 years. A proportion of unchipped individuals will also be those missed as pups and some individuals that have entered from other colonies. However, assuming a maximum longevity of 26 years for females and 21.5 years for males (McIntosh 2007), within the next 5-6 years we should have the majority of individuals from all cohorts microchipped.

It is relevant to mention that other ASL conservation-based research is continuing at Seal Bay and one concurrent project that could have bearing on analysis of population parameters in the future is an Ivermectin inoculation trial to reduce hook-worm disease in pups. This is being conducted by researchers from the Faculty of Veterinary Science at the University of Sydney (led by Dr Rachael Gray). Hookworm is an important source of disease and mortality and can significantly reduce pup survival (Marcus *et al.* 2014, 2015). In the past two breeding seasons, about half of the pups born at Seal Bay have been inoculated with the drug Ivermectin to assess it efficacy in improving health outcomes and reducing mortality. While in the first breeding season (2019, winter/spring), there was no significant difference in the short-term survival of treated and control pups, in the second breeding season (2020/21, summer/autumn), the survival of treated pups was higher (R. Gray, personal communication). Monitoring of their survival through juvenile years to recruitment and subsequent reproductive success will continue.

The last time a full demographic analysis was undertaken of Seal Bay life-history data was following the 2017/18 breeding season (Goldsworthy *et al.* 2019). Several fundamental life-history parameters, or vital rates, are required to understand population dynamics, including pup production, survival, fecundity, and dispersal. Age specific survival rates are considered one of the best indicators of population change in pinnipeds (Pistorius *et al.* 1999). The population ecology and demography of ASL are poorly understood and will differ in many respects from all other ‘typical’ (annual and synchronous breeding) pinnipeds. As such the life history study of ASL

at Seal Bay provides essential information to aid conservation and management of this unique pinniped. Estimates of age-specific survival, recruitment and fecundity will be used to develop better demographic models for the species. Such information will improve population viability analyses (PVA) developed for the species and help to better understand the population dynamics of decline and recovery, how survival, recruitment and reproductive rates are impacted by season of breeding and changes in the marine environment, and the likely consequences of different conservation and management actions.

The current capacity to predict future population trajectories or evaluate different management strategies to recover ASL populations is limited. There is a need for more regular demographic analyses to be built into the Seal Bay monitoring program. Ideally this would be undertaken every few years.

Estimated pup production at Seal Slide over the last 12 breeding seasons (since 2002/03) has been variable with no consistent trend. Further monitoring of Seal Slide and the other two small ASL breeding sites on Kangaroo Island (Cape Bouguer and North Casuarina Island), should be continued. Because of their small size, these sites are more vulnerable to impacts and stochastic change (Goldsworthy *et al.* 2021).

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