

# Marine Environment & Ecology



## Australian sea lion population monitoring at Seal Bay and the Seal Slide, Kangaroo Island: 2010 breeding season



Photo: R McIntosh

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SARDI Publication No. F2011/000216-1  
SARDI Research Report Series No. 556

SARDI Aquatic Sciences  
PO Box 120 Henley Beach SA 5022

June 2011

Report to the Department of Environment and Natural Resources



Government  
of South Australia



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**Simon D Goldsworthy<sup>1</sup>, Brad Page<sup>1</sup>, Clarence Kennedy<sup>2</sup>,  
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This publication may be cited as:

Goldsworthy, S.D., Page, B., Kennedy, C., Welz K., Shaughnessy, P.D (2011). Australian sea lion population monitoring at Seal Bay and the Seal Slide, Kangaroo Island: 2010 breeding season. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000216-1. SARDI Research Report Series No. 556. 36pp.

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Printed in Adelaide: June 2011

SARDI Publication No. F2011/000216-1

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Date: 30 June 2011

Distribution: Department of Environment and Natural Resources, SAASC Library, University of Adelaide Library, Parliamentary Library, State Library and National Library

Circulation: Public Domain

## TABLE OF CONTENTS

TABLE OF CONTENTS .....	1
1 EXECUTIVE SUMMARY .....	2
2 INTRODUCTION .....	4
3 METHODS.....	6
Field sites .....	6
Pup production estimates.....	7
Seal Bay – micro-chipping and demography program .....	7
4 RESULTS AND DISCUSSION.....	8
Seal Bay – breeding chronology surveys for cumulative births and deaths, and mark-recapture .....	8
Seal Bay - trends in pup abundance and pup production .....	9
Seal Bay - pup mortality .....	10
Seal Bay – micro-chipping and demography program .....	10
Seal Slide - pup abundance .....	11
5 ACKNOWLEDGMENTS.....	22
6 REFERENCES .....	23
7 APPENDIX .....	25

## 1 EXECUTIVE SUMMARY

Seals are one of the premier tourism attractions on Kangaroo Island and they underpin a regional multimillion dollar tourism industry, the centrepiece of which is the Australian sea lion population at the Seal Bay Conservation Park. The aims of this project were to assess pup production and mortality of Australian sea lions by direct counting and mark-recapture methods at the Seal Bay and Seal Slide colonies on Kangaroo Island during the 2010 breeding season (May 2010 to February 2011), and maintain the micro-chipping and monitoring program at Seal Bay to assess annual and cohort changes in survival and recruitment in the population.

Pup production for the 2010 breeding season at Seal Bay was estimated to be 269 (range 267-276), based upon a range of methods including twice-weekly surveys of new pup births and deaths, the total number of tagged (micro-chipped) pups, mark-recapture methods using the Petersen estimate and direct counts of pups in Pup Cove. This estimate is similar to those from the previous two breeding seasons (2007: 255; 2008-09: 268), with between season variability being lower than for three earlier surveys (2002-03, 2004, 2005-06). Part of this reduced variability may be attributed to continued improvements to survey methodologies between seasons, especially since 2008-09 when access to the Eastern Prohibited Area was available for the entire breeding season.

Based upon 25 years (1985 to 2010) of data of maximum counts of live pups, pup abundance is still declining significantly in the colony. However, the time series for pup production estimates (last six seasons) is too short to provide confidence in these rates of decline.

At the Seal Slide Australian sea lion colony, five surveys were undertaken to estimate pup production using the capture, mark and count method. The estimate of pup production for the 2010 breeding season was 10. Based on pup production estimates for the last six breeding seasons at the Seal Slide, there has been no significant change in pup production.

At Seal Bay in the 2010 breeding season, 201 pups were micro-chipped (75 % of pup births), comprising 108 males and 91 females (2 animals not sexed). Re-sights of micro-chipped sea lions using hand-held and automated flat-bed scanners were continued throughout the breeding season. Of 107 breeding females scanned up until March 2011, 32 (30%) were micro-chipped; most were tagged as pups in the 2002-03 and 2004 breeding seasons and were 6-7 years old during this study. Greater efforts to scan breeding females will be made in

subsequent seasons, so that age- and season-specific reproductive rates can be calculated. These data will be used to improve demographic models to better understand the causes of decline at Seal Bay, and the consequences of anthropogenic impacts such as fishery bycatch. These will be important in the ongoing management of the Seal Bay population, because such measures provide an assessment of longer-term demographic vulnerability and a means to forecast population trajectories.

## 2 INTRODUCTION

The Australian sea lion (ASL) population at Seal Bay is an iconic tourism attraction for Kangaroo Island and South Australia, and underpins a regional tourism economy. The species was listed as a threatened species under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* in February 2005. In South Australia, it was listed in February 2008 as Vulnerable under the *National Parks and Wildlife Act 1972*. In October 2008, the International Union for the Conservation of Nature (IUCN) upgraded its listing of the Australian sea lion to endangered.

A recent report on the status of the ASL population at Seal Bay indicates that the decline detected by Shaughnessy et al. (2006) over 13 breeding seasons (1985 - 2002/03) has continued over 17 breeding seasons (1985 to 2008-09) (Goldsworthy et al. 2010a). Although there is some corroboration of this decline based on results from a demographic model of the Seal Bay population (McIntosh 2007), estimates of total pup production achieved through improved survey methodology over the last five breeding seasons show no significant trend in abundance (Goldsworthy et al. 2010a). Because improvements to survey methodology have only occurred in recent seasons, the time-series of pup production estimates and the demographic factors upon which the population model was developed are limited. As such, there is a high degree of uncertainty in the current status and trends in abundance of the Seal Bay ASL population, and in the expected trajectory of the population into the near future. This provides significant challenges for State and Commonwealth threatened species managers, managers of the Seal Bay Conservation Park, and presents sustainability issues for the Kangaroo Island regional tourism industry.

Bycatch of ASL in the Commonwealth managed shark demersal gillnet fishery (gillnet sector of the gillnet hook and trap fishery – GHAT) has been identified as a major cause for declines in ASL populations in South Australia, and represents the single most significant threat to the sustainability of the Seal Bay population (Goldsworthy et al. 2010b). Gill-net fishery closures were introduced around all ASL colonies in South Australia by the Australian Fisheries Management Authority in July 2010 (AFMA 2010). The closure introduced around Seal Bay extends 10 nm (18.5 km), and was estimated to reduce female bycatch mortality in that subpopulation by about 22.8% (Goldsworthy & Lowther 2010). Even with this reduction, current levels of expected bycatch mortality are estimated to be unsustainable in the long-term (Goldsworthy & Lowther 2010; Goldsworthy et al. 2010b). On 1 May 2011, AFMA extended

many of these ASL colony closures, including additional closures south of Kangaroo Island (the 'Kangaroo Island gillnet strip'), that now extend at least 28km from Seal Bay. AFMA have also introduced ASL bycatch trigger limits in areas open to the fishery, which would result in regional temporary closures if unacceptable levels of bycatch mortality were reported (AFMA 2010). The effectiveness of such management measures in reducing ASL bycatch has been questioned (Goldsworthy & Lowther 2010). Close monitoring of the Seal Bay ASL population provides a critical assessment of the effectiveness of fishery closures and other management measures.

The first commercial tours at Seal Bay began in 1955. In 1967, two prohibited areas were declared, at the eastern and western ends of the site, which were intended to protect the main breeding sites from human disturbance. The remainder of the Seal Bay beach was dedicated as a Fauna Conservation Reserve under the Crown Lands Act. By 1969, six commercial tourist operators operated at Seal Bay and additional tourists visited the Seal Bay beach. From 1970-1972 the number of tourists visiting Seal Bay increased from ~20,000 to 30,000 per year. The Park was proclaimed under the *National Parks and Wildlife Act* in 1972 to protect the ASL population and the natural habitat, and the two prohibited areas remained within the park. The Management Plan for Seal Bay was developed by the National Parks and Wildlife Division of the Department for the Environment in 1977 and the objectives of the Plan included: 1) the protection and maintenance of the ASL colony, and 2) the improvement of public access to the colony. The Plan noted that tourist numbers had increased steadily, without apparent affect on the colony, and that tourist numbers would continue to increase with the expansion of tourism on the island.

Since 1987, entry to the ASL colony at Seal Bay has been limited to boardwalks and/or guided tours. These tours were implemented to reduce disturbance to the ASL colony, because tourist numbers had continued to increase as had been forecast. On guided tours, people walk along the beach amongst ASL that are resting between foraging trips. Tourist numbers at Seal Bay have remained relatively stable over the last 10 years; with between 100,000–111,000 visiting the site each year (DENR unpublished data). It is not known what level of disturbance or visitation is sustainable at Seal Bay, or if current and proposed changes to management strategies for tourist interactions are impacting on the ASL population (Page et al. 2011). Monitoring of the Seal Bay ASL population is essential to ensure that management strategies for tourist interactions are not negatively affecting the population, and that the future for sustainable ecotourism is secure.

In 2010, DENR funded a joint DENR/SARDI project to maintain essential monitoring of the Seal Bay ASL population over two breeding seasons (2010 and 2011-12), following recommendations detailed by Goldsworthy et al. (2008; 2007a).

The aim of this project was to:

maintain monitoring of ASL pup production during the next two breeding seasons at Seal Bay and the Seal Slide (2010 and 2011-12),

maintain monitoring population vital rates during the next two breeding seasons at Seal Bay (2010 and 2011-12), and

provide detailed reports subsequent to the next two breeding seasons, and develop a proposal for ongoing monitoring needs of Seal Bay ASL population in the final 2012 report.

This report provides details of the project following the 2010 breeding season.

### **3 METHODS**

#### ***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 EPA from MB. Most pups are born in the WPA and at the western end of MB, with smaller numbers of pups born 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.* 2007b). 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 Cape Gantheaume Conservation Park, on the south-east coast of Kangaroo Island. The colony can be accessed by 4WD vehicle and was visited on five occasions during the 2010 breeding season (28 June, 25 September, 11 October, 10 December, 21 December).

***Pup production estimates***

At Seal Bay, three methods were used to estimate pup production during the 2010 breeding season: direct counts of live and dead pups; the cumulative survey of new births and deaths throughout the colony; and mark-recapture methods using the Petersen estimate (see Goldsworthy et al. 2008). The overall estimate of pup production was taken as the largest of the three estimates. The mortality rate 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. The methodology to survey the Seal Slide followed that described by Goldsworthy et al. (2007b) for small colonies and is referred to as the cumulative mark and count (CMC) method.

***Seal Bay – micro-chipping and demography program***

Pups older than two-months of age 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; sexed and measured (standard length - nose to tail to the nearest  $\pm 0.5$  cm). Each pup was externally marked by clipping the fur of the rump and a Passive Integrated Transponder tag (PIT tag: TIRIS™ RFID 23mm) was subcutaneously implanted using a sterile single-use needle. PIT tags (micro-chips) were inserted in the clipped area, parallel to the spine and close to the tail to minimise gravitation.

Throughout the breeding season and beyond, hand-held scanning of animals was undertaken regularly throughout the colony. To successfully identify seals with a micro-chip, the RFID reader was held near the animal at a distance of up to 10 cm from the insertion site. Mother-pup pairs were also targeted throughout the breeding season to assess the tagged status of the pups as well as to identify if the mother had been chipped.

In addition to hand-held scanning, four automated recording stations comprising RFID flat-bed aerials were located in the colony along major pathways used by ASL between the beach and dune areas. Each had its own data-logger and was powered by a solar panel. Regular maintenance (clearing of sand, checking of cables), and monthly downloading of the scanners was performed.

## 4 RESULTS AND DISCUSSION

### ***Seal Bay – breeding chronology surveys for cumulative births and deaths, and mark-recapture***

Results of the surveys for births and death undertaken during the 2010 breeding season at Seal Bay are presented in Table 1 and Figure 2. Details of all the survey results for each area within the Seal Bay colony are given in Appendix 1. The breeding season commenced on 13 May 2010 (first pup birth) and the last pup was born on 15 Feb 2011. The duration of the breeding season was 9.1 months. Based on probit analyses, the median pupping date was 28 August 2010 (sd = 46 days), with 90% of births occurring over 150 days (4.9 months), between 14 June and 11 November 2010 (Table 2).

Variation in the chronology of breeding across the last six breeding seasons is presented in Figure 3. The mean breeding interval (period between successive median pupping dates) between the five consecutive breeding seasons was 545 days (range 541-550, sd = 3.7) or 17.9 months (range 17.8-18.1, sd = 0.1) (from data in Table 2, Figure 4). Over this period, the breeding interval has increased significantly by about 2.2 days per season (linear model:  $F_{1,3} = 25.930$ ,  $P = 0.015$ ,  $r^2 = 0.896$ ) (Figure 4). Correspondingly, there was a declining trend for the interval between the beginning of the breeding season (5% of births) ( $F_{1,3} = 2.651$ ,  $P = 0.202$ ,  $r^2 = 0.470$ ; non-significant) and an increasing trend for the interval between the end of the breeding season (95% of births) ( $F_{1,4} = 11.610$ ,  $P = 0.0422$ ,  $r^2 = 0.795$ ; significant); although there was no overall trend in the duration of breeding seasons (90% of births) ( $F_{1,4} = 5.915$ ,  $P = 0.0932$ ,  $r^2 = 0.664$ )(Figure 3).

The cumulative number of births recorded for the 2010 breeding season at Seal Bay was 259 (Table 1, Figure 2). Most pups were born in the Main Beach area west of the area accessed by the public (83, 32.0%) and the WPA (63 pups, 24.3%), with 61 (23.6%) pups reported for the EPA and 52 pups (20.1%) for Pup Cove (see Appendix 1). As Pup Cove could only be surveyed from along the cliff-line at various vantage points, the number of cumulative births for this area may be an under-estimate.

Details of 13 mark-recapture estimates are provided in Table 1. Only surveys where marked pups (M) were estimated to account for at least 25% of the estimated live pups (N) present, and where variance estimates were less than 1000 were used. Estimates of *AdjN* (which includes cumulative dead pups, plus remaining new births that occurred after a particular

survey) ranged between 240 and 286 (Table 1, Figure 2), with the mean (total) estimate of pup production ( $\tilde{N}$ ) being 269 with 95% CL 261-276 (Tables 1 and 2). This is 10 more than estimated from the cumulative survey of new births (259), but only two more than the estimate of minimum pup production, 267 (total microchipped [201] plus cumulative dead pups [66]) (Table 2).

Given that some births may have been missed using the cumulative surveys of new births (particularly in Pup Cove), the final estimate of pup production for the 2010 season at Seal Bay was 269 (range 267-276), with the lower bounds set at the minimum pup production estimate and the upper bounds set as the +95% CL of the Petersen estimate (Table 1 and 2).

### ***Seal Bay - trends in pup abundance and pup production***

The surveys undertaken during the 2010 season at Seal Bay represent the sixth consecutive breeding season where cumulative pup births and mark-recapture procedures have been used to provide estimates of pup production (Table 2). Trends in direct counts of live pup counts between 1985 and 2010 (18 breeding seasons), and the overall estimate of pup production (based on cumulative pup births or mark-recapture) and mortality rates of pups between 2002-03 and 2010, are presented in Figure 5.

As detected by Shaughnessy et al. (2006), an examination of the trends in maximum live pup counts between 1985 and 2010 identified an apparent oscillation in pup numbers between high and low seasons, and a declining trend (Figure 5). Trend analysis of the maximum live pup counts for 18 breeding seasons between 1985 and 2010, demonstrates an annual decrease of -0.67% per year ( $F_{1,16} = 6.455$ ,  $P = 0.022$ ,  $r^2 = 0.288$ ), or -0.97% per breeding season ( $F_{1,16} = 6.378$ ,  $P = 0.022$ ,  $r^2 = 0.285$ ), which amounts to a decrease of 15.3% over 18 seasons (~25 years).

Examination of estimates of pup production based on cumulative pup births and mark-recaptures over the last six breeding seasons, supports the same oscillation in pup numbers between high and low pup production seasons observed from maximum counts of live pups, with 2002-03 and 2005-06 being the low years and 2004 and 2007 being the high years (Figure 5). However, there has been a marked reduction in the variance between pup production estimates over the last three breeding seasons (Figure 5). Part of this may be attributed to improvements in survey methodologies, following improvements to cumulative pup birth surveys mid-way through the 2007 breeding season, when access to the Eastern

Prohibited Area (EPA) was approved for pup surveys. Analysis of pup production estimates for six pupping seasons between 2002-03 and 2010 showed no significant trend in pup production by year ( $F_{1,4} = 0.654$ ,  $P = 0.464$ ,  $r^2 = 0.140$ ) or by breeding season ( $F_{1,4} = 0.651$ ,  $P = 0.465$ ,  $r^2 = 0.140$ ) (Figure 5).

Based upon an additional five breeding seasons of maximum counts of live pups after those reported by Shaughnessy et al. (2006), pup abundance is still declining significantly. Unfortunately the time series for pup production estimates based on cumulative pup births or on mark-recapture estimates, only covers the last six seasons, and is too short to provide confidence in the rates of decline based on maximum live counts for 18 breeding seasons.

### ***Seal Bay - pup mortality***

Based on a pup production estimate of 269 pups for the 2010 breeding season at Seal Bay, and a total of 66 cumulative pup deaths, the mortality rate for the breeding season was estimated to be 24.5% (Table 2). The average over the last six breeding seasons is 28% (sd = 5.8). The mortality rate over the last six breeding seasons has varied between about 20% and 35%, and it has continued to oscillate between the low and high end of that range in consecutive seasons, with 2010 being a low mortality season (Figure 5).

### ***Seal Bay – micro-chipping and demography program***

In the 2010 breeding season, 269 pups were estimated to have been born at Seal Bay. Approximately 25% (66, Table 1) of these died during or shortly after the breeding season. Of the estimated 203 pups that survived, 201 (108 male, 91 female, 2 sex not noted) or 99% were micro-chipped, representing 75% of all pup births for the 2010-11 season.

During the 2010 season we introduced more systematic surveys of breeding females in order to monitor reproductive rates. This involved attempts to scan as many females with as possible during the peri-natal or later periods in order to identify known-age females and to monitor age-specific and seasonal variation in fecundity. Of the 259 cumulative births recorded, 207 occurred in areas where scanning was achievable (all areas with the exception of Pup Cove). Of these, 107 (52%) were scanned, 32 (30%) of which had a micro-chip. For 31 of these female the breeding season of birth could be determined: 10 (32%) were born in the 2002-03 season (5 breeding seasons earlier, ~7 yrs old) and 21 (67%) were born in the 2004 breeding season (4 breeding seasons earlier, ~6 yrs old). No younger or older micro-chipped females were observed to breed during the 2010-11 breeding season, but some additional females nursing pups may be scanned before the next breeding season commences.

Between 1991 and 2001-02, only about 50 pups were micro-chipped each season (Goldsworthy et al. 2007a). The 2002-03 and 2004 breeding seasons coincided with the first seasons when a greater micro-chipping effort was introduced by McIntosh (2007), and when Destron microchips (12mm, lower read-range) were replaced with TIRIS microchips (23mm, higher read-range) (Table 2). Effort will be increased in future seasons to scan as many breeding females as possible.

Regular efforts to re-sight other individual microchipped sea lions continued throughout the season, using hand-held scanners and flat-bed aerials. Total numbers scanned were not available at the time of preparing this report. Much of the automated scanning equipment at Seal Bay is aging and operating inefficiently due to more frequent breakdowns and maintenance need. We aim to upgrade as much of the equipment as we can between now and the next breeding season which should commence towards the end of the year (2011).

### ***Seal Slide - pup abundance***

A total of seven pups were marked over five surveys of the colony in the 2010 breeding season. Details on the number of unmarked, marked and dead pups sighted on each survey are presented in Table 3. The minimum number of marked, dead and unmarked pups in the population, based on the re-sight and marking history is also presented. Based on these data, the minimum estimate of pups born in the subpopulation was 10, based on the survey undertaken on 10 December (Table 3). No mark-recapture estimates were undertaken, so there are no confidence limits around these estimates.

Although records of pups born at the Seal Slide date back to 1975 (Dennis 2005), the quality of some surveys relative to the timing of breeding is uncertain, and as such there is the potential that many of the pups recorded there previously may represent those dispersed from Seal Bay. To this end, Shaughnessy et al. (2009) restricted counts of pups to those observed within four months of the beginning of the breeding season at Seal Bay. Although accounting for dispersed pups from Seal Bay, this adjustment may result in an underestimate of actual pup production as it will omit pups born during the last third of the breeding season. Surveys undertaken in the 2002-03 and 2004 breeding seasons differed from earlier ones in that they included monthly surveys where only pups <1 month old (and therefore assumed to have been born at the Seal Slide) were counted on each survey by experienced observers. The cumulative number of pups <1 month old observed on each survey was used to estimate the number of pups born in those seasons. For those two seasons, results (9 and 11 pups) were therefore more accurate and reliable, and previous estimates were lower.

Estimates of pup abundance with a high level of confidence at the Seal Slide are now available for the last six breeding seasons since 2002-03 (Figure 6). The first two are from Shaughnessy et al. (2009): 9 pups in 2002-03 and 11 pups in 2004. The next three resulted from use of the CMC method: 10 pups, range 10-11 based upon the Peterson estimate in 2005-06; 16 pups, range 15-18 based upon the Peterson estimate in 2007; and 12 pups in 2008-09 (2010a; 2008; Goldsworthy et al. 2007b), and 10 pups this season. There was no significant trend between pup abundance and year ( $F_{1,4} = 0.440$ ,  $P = 0.543$ ,  $r^2 = 0.099$ ), or breeding season ( $F_{1,4} = 0.473$ ,  $P = 0.529$ ,  $r^2 = 0.106$ ) (Figure 6).

**Table 1.** Summary of surveys undertaken for new births and for dead pups, cumulative births and deaths, and direct counts of brown (BP), moulted (MP) and total live Australian sea lion pups at Seal Bay during the 2010-11 breeding season. Details of Petersen mark-recapture estimate are also given, where *M* is the number of marked pups at risk of being sampled during recapture surveys, *n* is the number of pups examined in the recapture sample, and *m* is the number of marked pups in the recapture sample. *N* is total estimate of live and cumulative dead pups and counts in Pup Cove on the day of each survey (see appendix 1), *Adj N* includes the remaining new births in the population that occurred after a particular survey; SE is the standard error. The overall mean of the *Adj N* estimates ( $\bar{N}$ ) and its 95% CL are also presented.

No.	Date	New		Cumulative			Counts			Petersen M-R estimates				<i>Adj N</i>	SE
		Births	Dead	Born	Dead	Alive	BP	MP	Total live	M	n	m	<i>N</i>		
1	13-May	1	0	1	0	1	1	0	1						
2	27-May	0	0	1	0	1	1	0	1						
3	2-Jun	2	0	3	0	2	2	0	2						
4	10-Jun	1	1	4	1	4	4	0	4						
5	16-Jun	2	1	6	2	5	5	0	5						
6	24-Jun	8	1	14	3	12	12	0	12						
7	1-Jul	16	1	30	4	21	22	0	22						
8	5-Jul	1	3	31	7	21	23	0	23						
9	8-Jul	6	3	37	10	24	26	0	26						
10	12-Jul	3	4	40	14	18	20	0	20						
11	15-Jul	6	2	46	16	24	25	0	25						
12	19-Jul	9	2	55	18	24	25	0	25						
13	22-Jul	13	2	68	20	33	40	0	40						
14	27-Jul	10	0	78	20	34	41	0	41						
15	30-Jul	6	2	84	22	38	45	0	45						
16	3-Aug	10	1	94	23	45	54	0	54						
17	6-Aug	6	4	100	27	37	45	0	45						
18	10-Aug	11	1	111	28	48	58	0	58						
19	14-Aug	7	1	118	29	49	58	0	58						
20	18-Aug	5	3	123	32	56	67	0	67						
21	22-Aug	7	2	130	34	60	68	0	68						
22	26-Aug	10	3	140	37	64	75	0	75						
23	30-Aug	12	3	152	40	69	78	0	78						
24	2-Sep	8	0	160	40	71	86	0	86						
25	4-Sep	7	1	167	41	66	76	0	76						
26	8-Sep	13	3	180	44	84	94	0	94						
27	12-Sep	3	3	183	47	72	82	0	82						
28	16-Sep	3	1	186	48	81	95	0	95						
29	20-Sep	2	2	188	50	81	94	0	94						
30	23-Sep	0	2	188	52	86	103	0	103						
31	27-Sep	5	1	193	53	80	94	0	94						
32	30-Sep	12	1	205	54	94	108	0	108	35	94	24	204	258	13
33	4-Oct	3	0	208	54	73	84	0	84	48	73	25	203	254	15
34	7-Oct	6	0	214	54	61	76	0	76	48	61	23	195	240	14
35	11-Oct	5	0	219	54	73	90	0	90						
36	14-Oct	6	1	225	55	70	87	0	87	70	70	29	239	273	17
37	18-Oct	3	1	228	56	76	89	0	89	70	76	33	229	260	15
38	21-Oct	3	1	231	57	82	97	0	97	70	82	31	255	283	19
39	25-Oct	5	0	236	57	91	103	0	103	70	91	35	249	272	16
40	29-Oct	7	0	243	57	80	92	0	92						
41	4-Nov	4	1	247	58	82	96	0	96						
42	12-Nov	4	3	251	61	105	118	0	118	92	105	47	278	286	15
43	19-Nov	0	0	251	61	119	128	0	128	92	119	53	276	284	13
44	29-Nov	1	0	252	61	89	81	11	92	134	89	61	259	266	10
45	12-Dec	2	1	254	62	117	117	6	123	154	117	90	268	273	6
46	21-Dec	2	1	256	63	114	112	4	116	154	114	88	264	267	7
47	20-Jan	0	0	256	63	76	46	30	76						
48	10-Feb	2	1	258	64										
49	15-Feb	1	2	259	66	88	50	38	88						
50	18-Mar	0	0	259	66	125	25	100	125						
													$\bar{N}$	269	3.9
													$\pm 95\% \text{ CL (261-276)}$		

**Table 2.** Summary of the timing and spread of six consecutive breeding seasons of the Australian sea lion at Seal Bay, and pup abundance estimates including cumulative births and deaths; maximum live pup count; total numbers of micro-chipped pups and minimum pup production (micro-chipped + cumulative pup deaths); adjusted mark-recapture Petersen estimates ( $\hat{N}$ ); 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 (2006) and McIntosh (2007b), unless otherwise indicated. Data for the 2007 and 2008-09 breeding seasons are from Goldsworthy et al. (2010a; 2008); data from the 2010 season are from this report.

	2002-03	2004	2005-06	2007	2008-09	2010
Month breeding season commenced	Dec-02	Jun-04	Dec-05	May-07	Oct-08	May-10
Duration of breeding season (months)	9	7	6	7	7	9
Median pupping date	13-Mar-03	5-Sep-04	28-Feb-06	27-Aug-07	24-Feb-09	28-Aug-10
± s.d. (days)	42	39	36	36	41	46
90% births (5%- 95%)	2 Jan—21 May <sup>1</sup>	3 Jul -1 Nov	4 Jan-18 Apr	28 Jun-26 Oct	18 Dec-3 May	14 June-11 Nov
90% births (days)	139 <sup>1</sup>	121	104	120	136	150
Cumulative births	-	200	207	245	268	259
Cumulative pup deaths	73	70	75	51	88	66
Maximum live pup count	122	148	125	145	122	128
At months since beginning of BS	6	7	6	6	7	6
Max live pup count + cumulative dead <sup>2</sup>	185	208	197	198	197	189
Total live pups microchipped	148	202	144	203	161	201
Minimum pup production <sup>3</sup>	221	272	219	254	249	267
$\hat{N}$	227	288	203	255 <sup>4</sup>	267 <sup>4</sup>	269
( 95% CL)	(216-239)	(273-302)	(199-207)	(245-266)	(259-275)	(261-276)
No. recapture estimates	3	2	3	11	7	13
Overall estimate of pup production	227	288	219	255 <sup>4</sup>	268 <sup>4</sup>	269
Confidence limit (min est. to +95% CL)	(221-239)	(273-302)		(254-266)	(268-275)	(267-276)
Mortality rate	32.2%	24.3%	34.2%	20.0%	32.8%	24.5%

<sup>1</sup>Shaughnessy et al. (2006)

<sup>2</sup>at time of maximum live count

<sup>3</sup>total microchipped + cumulative dead

<sup>4</sup>estimates have been slightly modified from previous reports (Goldsworthy et al. 2010a; Goldsworthy et al. 2008), to rectify errors in the number of marked pups (M) available for re-sighting during some surveys.

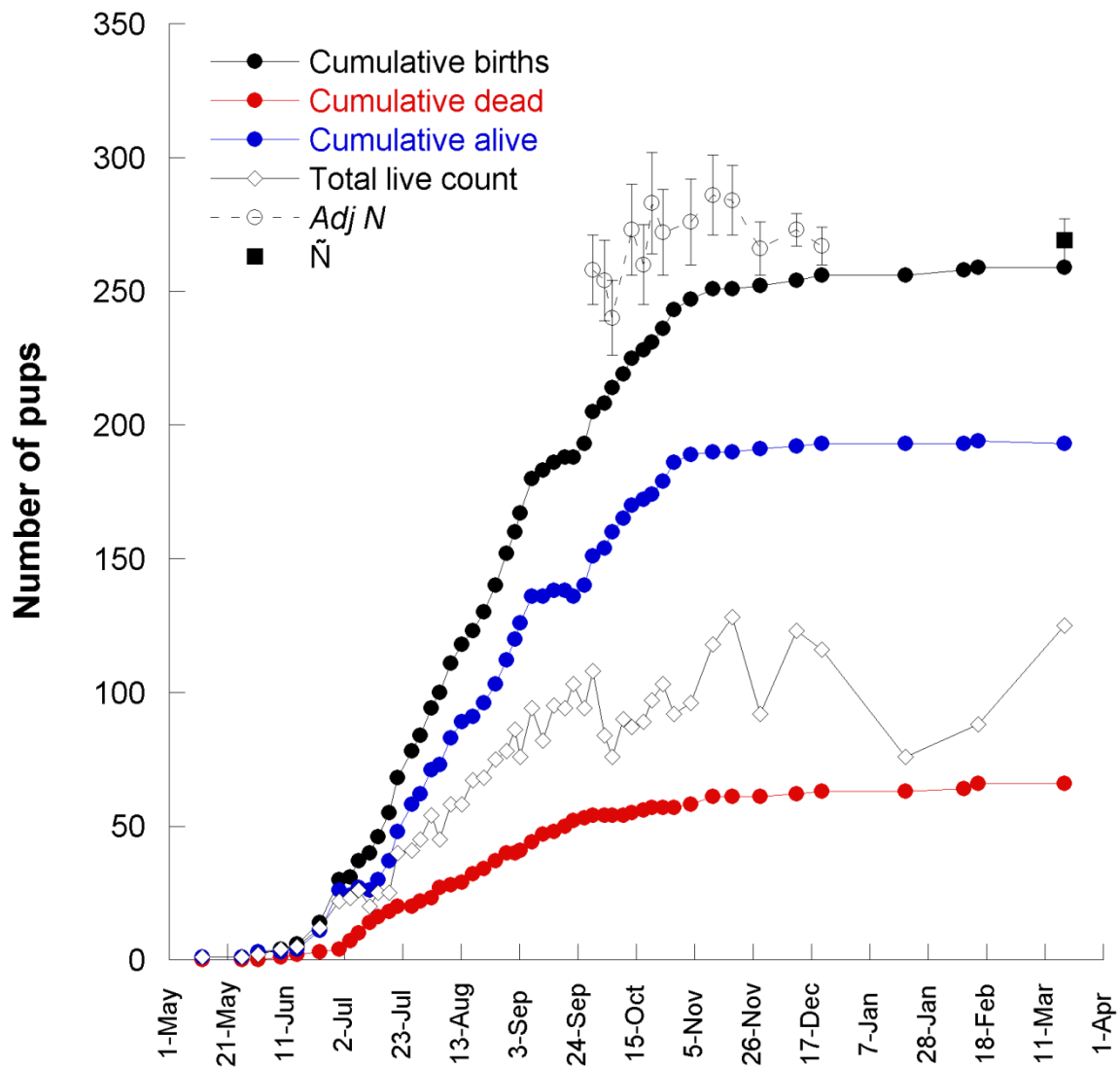
**Table 3.** Details of pup surveys undertaken at the Australian sea lion colony at the Seal Slide (Kangaroo Island) between June and December 2010. The number of clear (unmarked), marked, dead and total pups seen on each survey is indicated, in addition to the number of new marks applied. The number of marked pups available to be re-sighted at each survey is presented, along with the cumulative number of dead pups recorded. The maximum number of pups at each visit is estimated by summing the number of pups marked, maximum number of unmarked pups and cumulative number of dead pups.

Date	Clear count	Marked count	Dead clear	Dead marked	Total live count	Total live & dead count	New marked	Cum. marked	Min Alive	Cum. dead clear	Min Total
28-Jun	0	0	0	0	0	0	0	0	0	0	0
25-Sep	5	0	1	0	5	6	4	4	5	1	6
11-Oct	1	2	0	1	3	4	1	5	5	1	6
10-Dec	4	3	0	0	7	7	2	7	9	1	10
21-Dec	0	4	0	0	4	4	0	7	7	1	8*

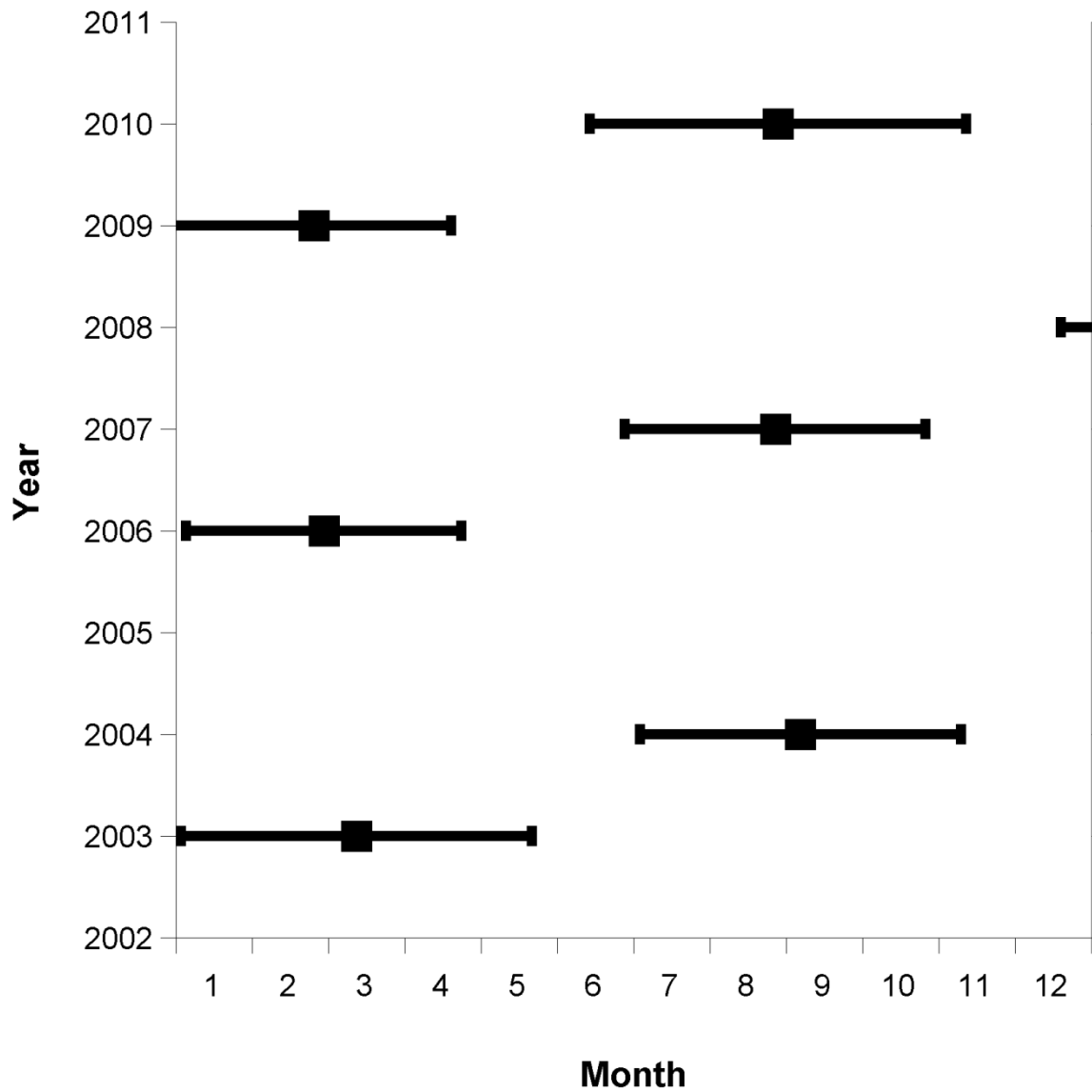
\*2 additional clipped pups from Seal Bay seen.



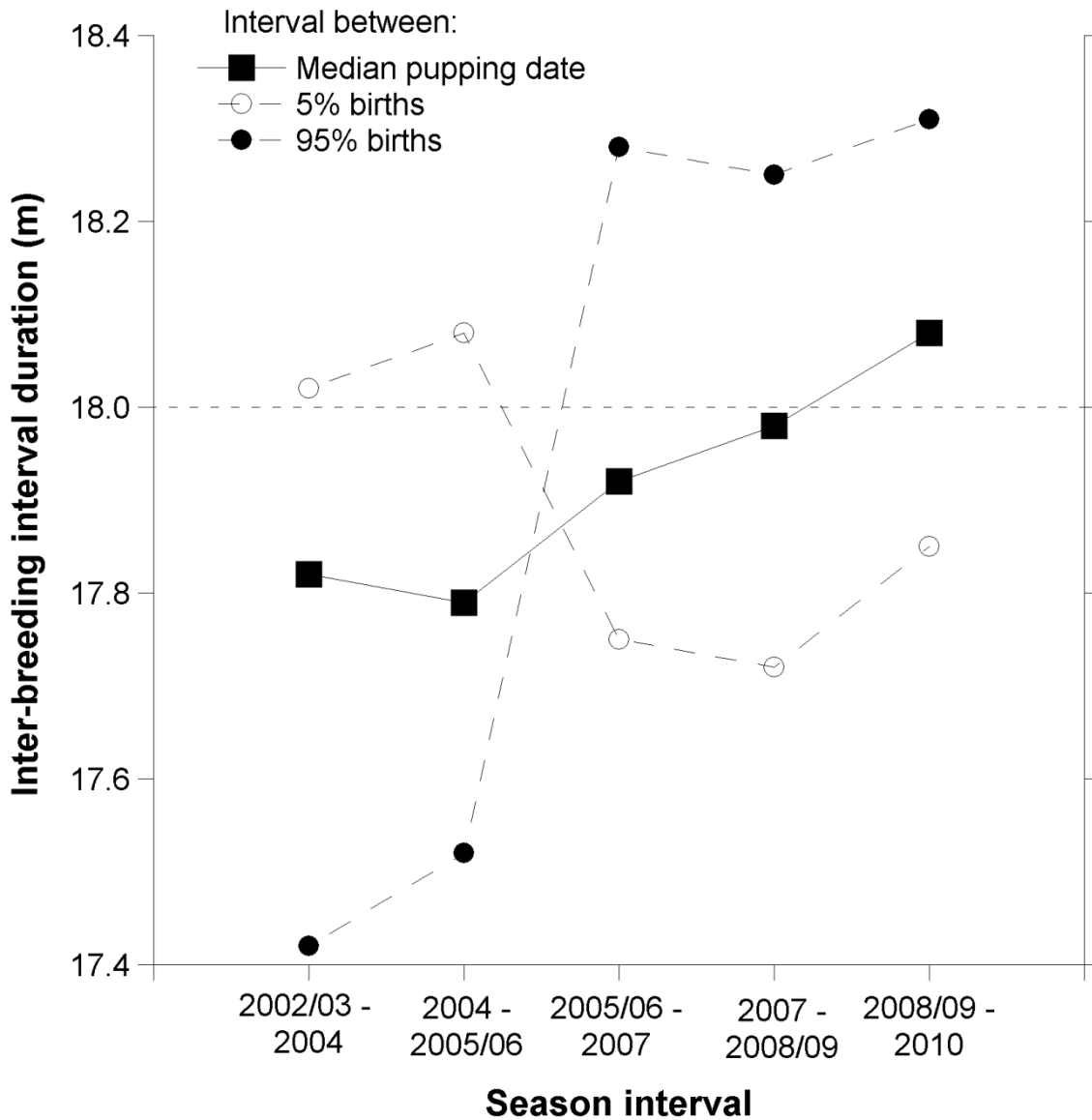
**Figure 1.** Map of Seal Bay breeding colony, Kangaroo Island, extended to Bay 2 (EPA 2) of the Eastern Prohibited Area (EPA). Western Prohibited Area (WPA), Main Beach and EPA comprise the main areas of the site.



**Figure 2.** Changes in the number of cumulative pup births, cumulative deaths, minimum number of pups alive (cumulative alive), and number of live pups counted during twice weekly surveys of Australian sea lion pups at Seal Bay between 13 May 2010 and 18 March 2011. Values of *Adj N* ( $\pm$  SE) based on mark-recapture estimates and the overall estimate of pup production  $\hat{N}$  ( $\pm$ 95% CL) are also given.

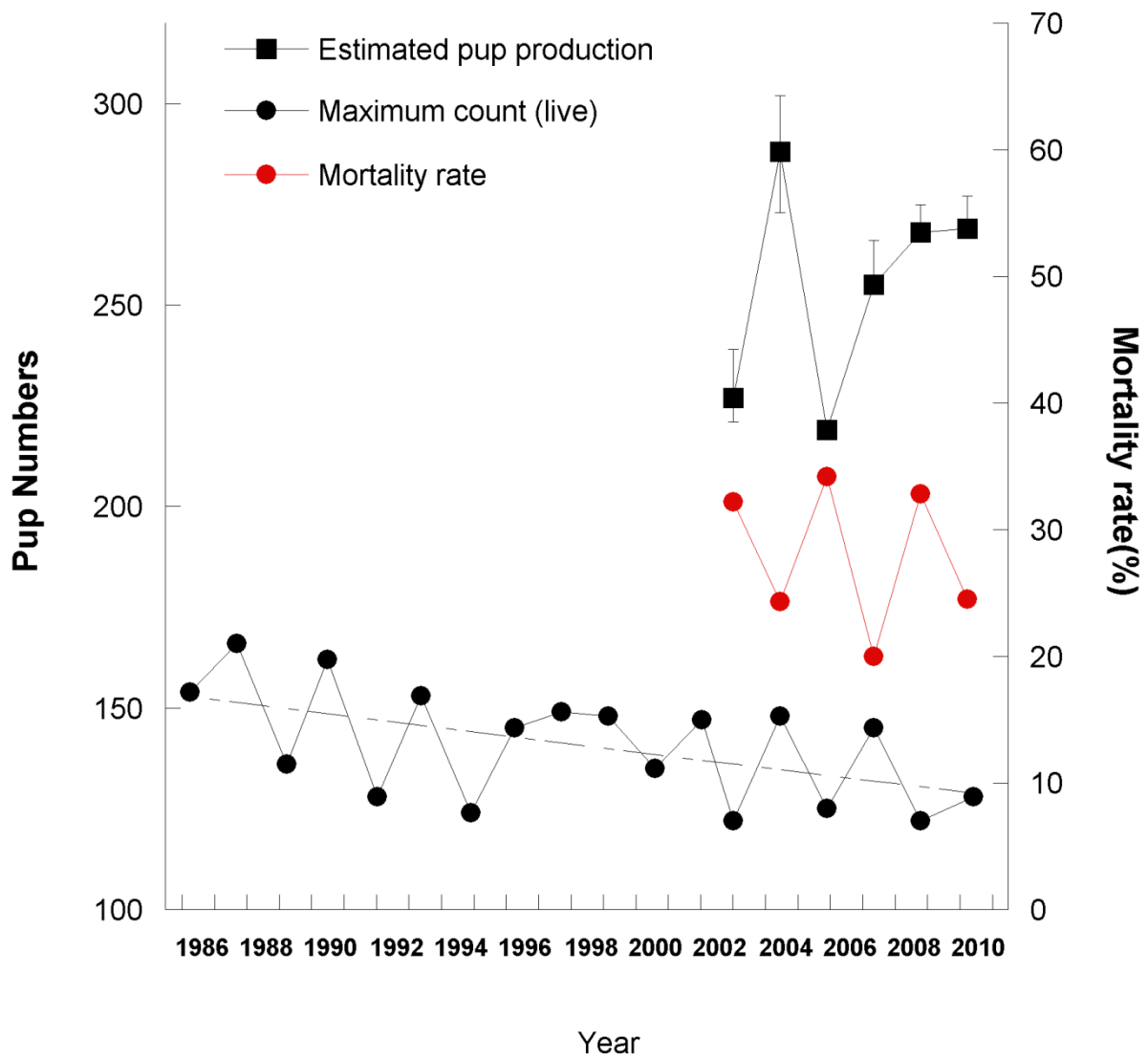


**Figure 3.** Variation in the breeding season chronology of Australian sea lions at Seal Bay, across six consecutive breeding seasons. Median puping dates are indicated by squares and error bars represent the spread of 90% of births (5-95%) based on probit analyses of cumulative pup births.

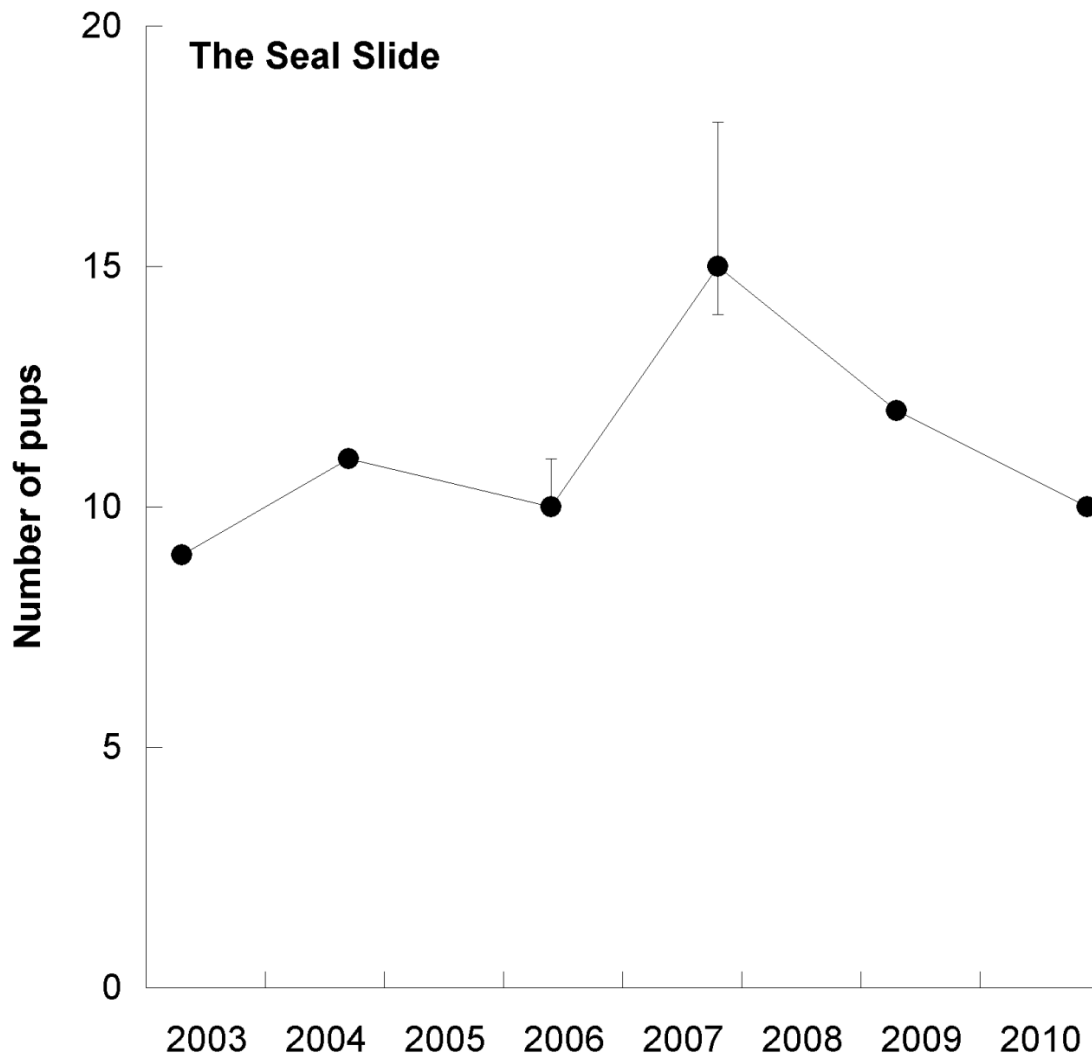


Fig

**Figure 4.** Variation in Australian sea lion inter-breeding interval between six consecutive breeding seasons at Seal Bay. The duration between successive median pupping dates, and between the dates when 5% and 95% of births have occurred is indicated. The horizontal dashed line indicates a breeding interval of 18 months. Results are based on based on probit analyses of cumulative pup births.



**Figure 5.** Trends in the abundance of Australian sea lion pups at Seal Bay based on maximum live pup counts for 18 breeding seasons between 1985 and 2010. Trends in the overall estimate of pup production and pup mortality rate are presented for the last 6 breeding seasons.



**Figure 6.** Trends in the estimated Australian sea lion pup production at the Seal Slide (Kangaroo Island), over six consecutive breeding seasons (2002-03 and 2010-11). Upper (95%) and lower (absolute minimum) confidence limits are available for the 2005-06 and 2007 breeding seasons.

## **5 acknowledgments**

The work was conducted under an animal ethics permit from SA Department of Environment and Natural Resources and the PIRSA Animal Ethics Committee. We thank Kate Lloyd and Peter Canty (SA Department of Environment and Natural Resources) for provision of SA DENR Permits. We thank Bill Haddrill for providing both staff and financial support to this program, and to Janet Simpson (Seal Bay Site Manager) and other DENR staff at Seal Bay for support of this program. We thank DENR for its commitment to fund the Australian sea lion monitoring program at Seal Bay, and Simon Bryars for project management support.

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## 7 APPENDIX

**Appendix 1.** Results from 48 pup surveys of the Australian sea lion population at Seal Bay, Kangaroo Island undertaken between 13 May 2010 and 15 February 2011. Observers include Clarence Kennedy, Janet Simpson and Kate Venable. BP = Brown Pup, MP = moulted pup, New = new live pup, Chipped = micro-chipped pup, Dead = new dead pup.

Survey No.	Observer(s)	Date	Accumulated count			Total for day of survey					
			Cumulative Dead	Cumulative Born	Cumulative Alive	Total live count	BP	MP	New	Chipped	New
1	Clarence	13-May-10	0	1	1	1	1	0	1	0	0
2	Janet	27-May-10	0	1	1	1	1	0	0	0	0
3	Janet	02-Jun-10	0	3	3	2	2	0	2	0	0
4	Janet	10-Jun-10	1	4	3	4	4	0	1	0	1
5	Clarence/Emma	16-Jun-10	2	6	4	5	5	0	2	0	1
6	Clarence	24-Jun-10	3	14	11	12	12	0	8	0	1
7	Clarence	01-Jul-10	4	30	26	22	22	0	16	0	1
8	Janet	05-Jul-10	7	31	24	23	23	0	1	0	3
9	Janet	08-Jul-10	10	37	27	26	26	0	6	0	3
10	Janet	12-Jul-10	14	40	26	20	20	0	3	0	4
11	Janet	15-Jul-10	16	46	30	25	25	0	6	0	2
12	Janet	19-Jul-10	18	55	37	25	25	0	9	0	2
13	Clarence	22-Jul-10	20	68	48	40	40	0	13	0	2
14	Clarence	27-Jul-10	20	78	58	41	41	0	10	0	0
15	Clarence	30-Jul-10	22	84	62	45	45	0	6	0	2
16	Clarence	03-Aug-10	23	94	71	54	54	0	10	0	1
17	Clarence	06-Aug-10	27	100	73	45	45	0	6	0	4
18	Clarence	10-Aug-10	28	111	83	58	58	0	11	0	1
19	Clarence	14-Aug-10	29	118	89	58	58	0	7	0	1
20	Clarence	18-Aug-10	32	123	91	67	67	0	5	0	3
21	Clarence	22-Aug-10	34	130	96	68	68	0	7	0	2
22	Clarence	26-Aug-10	37	140	103	75	75	0	10	0	3
23	Clarence	30-Aug-10	40	152	112	78	78	0	12	0	3
24	Clarence	02-Sep-10	40	160	120	86	86	0	8	0	0
25	Clarence	04-Sep-10	41	159	118	76	76	0	7	0	1
26	Clarence	08-Sep-10	44	172	128	94	94	0	13	0	3
27	Kate	12-Sep-10	47	175	128	82	82	0	3	0	3
28	Kate	16-Sep-10	48	178	130	95	95	0	3	0	1
29	Kate	20-Sep-10	50	180	130	94	94	0	2	0	2
30	Kate	23-Sep-10	52	180	128	103	103	0	0	0	2
31	Kate	27-Sep-10	53	185	132	94	94	0	5	4	1
32	Clarence/Kate	30-Sep-10	54	197	143	108	108	0	12	24	1
33	Clarence	04-Oct-10	54	200	146	84	84	0	3	25	0
34	Clarence	07-Oct-10	54	206	152	76	76	0	6	23	0
35	Clarence	11-Oct-10	54	211	157	90	90	0	5	25	0
36	Clarence	14-Oct-10	55	217	162	87	87	0	6	29	1
37	Clarence	18-Oct-10	56	220	164	89	89	0	3	33	1
38	Clarence	21-Oct-10	57	223	166	97	97	0	3	31	1
39	Clarence	25-Oct-10	57	228	171	103	103	0	5	35	0
40	Clarence	29-Oct-10	57	235	178	92	92	0	7	40	0
41	Clarence	04-Nov-10	58	239	181	96	96	0	4	39	1
42	Clarence	12-Nov-10	61	243	182	118	118	0	4	47	3
43	Clarence	19-Nov-10	61	243	182	128	128	0	0	59	0
44	Clarence/Alan	29-Nov-10	61	244	183	92	81	11	1	64	0
45	Clarence	12-Dec-10	62	246	184	123	117	6	2	90	1
46	Clarence	21-Dec-10	63	248	185	116	112	4	2	88	1
47	Clarence	10-Feb-11	64	250	186	-	0	0	2	0	1
48	Clarence	15-Feb-11	66	251	185	-	0	0	1	0	2

## Appendix 1. cont.

Survey No.	Road Reserve RRE					Road Reserve RRC					RRW				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3															
4															
5															
6															
7											1		1		
8											1				
9											2		1		
10															
11											1		1		
12											1				
13											1				
14											1				
15											1				
16											1				
17											2		1		
18											2				
19						1					1				
20											3				
21											3				
22											5		1		
23											6		1		
24											9				
25						2					3				
26						2					5				
27											8				1
28											9				
29											10				
30											9				
31											10			3	
32						7			3		5		2	1	
33											5			1	
34											3			3	
35															
36											4			2	
37											3			1	
38						1			1		2			1	
39															
40															
41															
42															
43															
44						1			1						
45															
46															
47															
48															
			SUM	0				SUM	0				SUM	8	

## Appendix 1. cont.

Survey No.	WPA SHELF					WPA Shelf Beach					WPA Grotto				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14	2		2												
15	2														
16	2														
17	2														
18	2										1		1		
19	4		2								1				
20	4														
21	4										1				
22	2										2		1		
23	1					2					1				
24	2					1					2				
25	2										1				
26	2										1				
27	1					2									
28	4		1												
29	1					1									
30	2					1									
31	3		1	1											
32	5		1	1							1				
33	5					1					2			1	
34	4		1	1		1									
35	3														
36	5														
37	2					1									
38	2			1							1		1		
39	2			1		2			1		1				
40	4			2		1			1						
41	4				1	1									
42	2					1					2			1	
43	1					1					3			1	
44						8			7						
45	5	1		4		3			3		8			6	
46	3			2		4			4		2			1	
47										1					
48															
			SUM	8				SUM	0				SUM	3	

## Appendix 1. cont.

Survey No.	WPA Grotto Beach					Grotto WU					Arch				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21						1		1							
22	0		0												
23															
24															
25															
26															
27											1		1		
28															
29															
30															
31															
32															
33															
34						1									
35						2		1							
36						2		1			1				
37						2		1			3			1	
38						1		1			2			1	
39															
40	2			2		1					3			2	
41											4			3	
42	7			4							2		1	1	
43	7			2							1				
44	4			4											
45	5			4		1		1			7			5	
46															
47															
48															
			SUM	0				SUM	1				SUM	2	

## Appendix 1. cont.

Survey No.	WPA Pup Rock					Pup Rock WU					Sandy Beach				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15												1			
16												1			
17															
18															
19															
20												1			
21												1			
22							1		1						
23							1					1			
24							1					1			
25							1								
26	2		2				1								
27	2		1				1		1			4			
28	2						1					1			
29							1					3			
30	1						2					3			1
31							1					5	1		
32	2			1			2			1		1			
33	3			1			1					3		1	
34	4			2											
35							4		2						
36	3											1			
37	2			1								2		1	
38	3			1								1			
39	5			3											
40	3			1								1		1	
41	1											1			
42	2			1								2		1	
43	3			2			1								
44	5			3								0	0		
45	3			3			1		1			3		2	
46	3			2											
47													2		
48															1
		SUM	3				SUM	2				SUM	3		

## Appendix 1. cont.

Survey No.	WPA Saber					Saber WU					Pebble Beach				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14											1				
15	1		1		1						1				
16	3		3								1				
17	3										1				1
18	4		1								1				
19	2										1				
20	2										1				
21	3		1								1				
22	2				1						1				
23	2										2		1		
24	3		1								1				
25	3		1		1						2		1		
26	3		1								3		2		
27	2										8				
28	2										9				
29	2		1								7				
30	1										9				1
31	1										7				
32	2			1							3		1	1	
33	2										3		1		
34	5		1	1							2				
35	2			1							4		1	1	
36	2		1								1				
37	2														
38											7			1	1
39	1			1							7		2	4	
40	2			1							0				
41	1										2				
42	1										5				
43	1										1				
44	2		1	1											
45											1			1	
46	3		1	2											
47															
48															1
		SUM	14				SUM	0				SUM	9		

## Appendix 1. cont.

Survey No.	WPA Pebble Beach WU					Danger Point					Danger Point Cove				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3															
4															
5															
6	1		1												
7	1		1		1										
8	1				1										
9	1														
10	1					1		1							
11	1					1									
12	1		1												
13	3		2												
14	2														
15	2														
16	2														
17	1				1										
18	1														
19	2														
20	3		1												
21	3										1		1		
22	4		1								1				
23	4		1								1		1		
24	3										1				
25	1														
26	5		2			2		1							
27						4					0				
28						2					1				
29						6									
30						3									
31						4									
32	7			3							2		1	1	
33	6			3											
34	6			3											
35	2			2							2			1	
36	5			1		2					4			4	
37	5		1	1							2			2	
38											7			4	
39						1					2			2	
40	4			2		5			1						
41	3		1	1		1		1			3			2	
42											4			2	
43						1					7			5	
44											10			8	
45											4			4	
46						1			1						
47															
48															
			SUM	12				SUM	3				SUM	3	

## Appendix 1. cont.

Survey No.	WPA Danger Cove WU					West Cove					West Cove WU							
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead			
1																		
2																		
3																		
4											1		1					
5											2		1		1			
6											1							
7											2		1					
8						1		1			1							
9						1					1							
10						2		1			1							
11						4					1		1					
12											4							
13											3							
14											5		1					
15						1		1			4		1					
16						1					3							
17						2		1			3							
18						2					1							
19						2					3							
20						1					4							
21											4							
22											5		1		1			
23						2					5							
24						2		1			4							
25						2					6							
26											5							
27						3		1		2	3							
28						0				0	9							
29																		
30																		
31																		
32											1							
33						1					2			1				
34																		
35						1												
36																		
37																		
38																		
39																		
40																		
41																		
42						2			1		1				1			
43						1			1									
44																		
45						1			1									
46																		
47																		
48																		
						SUM		0			SUM		6			SUM		7

## Appendix 1. cont.

Survey No.	WE					Dunes West					MBW				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3		1	1												
4		1													
5		1													
6		1													
7		3	2			3		3							
8		3				1				1					
9		5	3							2					
10		3								3					
11		6	3												
12		3	2			2		2							
13		5			1	5		3							
14		4	1			6		1							
15		5	1			4				1					
16		6	1			7		1							
17		4				4				1					
18		4	1			10		5							
19		2	1		1	11		1							
20		5			1	10				1					
21		6				9		1		1					
22		3				14		3		2					
23		4	2			13		1		1					
24		4	1			12		1							
25		8				10									
26		6			1	10		1							
27		5			1										
28		1				6		1			1		1		
29		3		0	1	8					5				
30		1				9					4				
31		1				12		1			3		1		1
32		4		1		17		2	4						
33		4		1		10			5						
34		2		1		16		1	5		1			1	
35		4		1		13			4		7			3	
36		4	1	2		14			8		4			2	
37		3	1	1		16			10	1	2			1	
38		2				17			7		2				
39		5		1		13			6		8			3	
40		5	2	1		13			7						
41		6		2		14			8		3			3	
42		3	1	1		5			1		18			6	
43		6		4		16			11		2			2	
44		6		5		5			3		4	1		4	
45		3		3		3			2		8	1		6	
46						10			9		10			8	
47															
48			1												
		SUM	25				SUM	28				SUM	2		

## Appendix 1. cont.

Survey No.	Dunes Centre					MBC					ED				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3															
4															
5	1		1		1										
6															
7											1		1		
8															
9															1
10															
11															
12															
13	1		1												
14															
15	1														
16	1														
17	1														
18										1					
19															
20	1														
21	1										1		1		
22											2		1		
23	2										2		1		1
24															
25	4										2				
26	2										1				
27	2														
28	6										2				
29	6														
30	10										3				
31	8										3				
32	3			2							1				
33	3			1		2				1					
34						1				1					
35	4			3		1					1				
36															
37	5			2		1				1	2				
38	2					3				2	2				1
39	1					3									
40	4			2							4				3
41	5			3		3				2	1				1
42	8			5		3				1	3				3
43	8			6		2				1	10				5
44	1			1		5	5			4	8				9
45						5				4	4	4			3
46	5			4		9	1			7	2				2
47															
48															
		SUM	2				SUM	0				SUM	4		

## Appendix 1. cont.

Survey No.	EMB					EPA Bay 1					EPA Bay 2				
	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1						1		1							
2						1									
3															
4						1									
5								1							
6						8		6		1					
7						10		6							
8						13				1					
9						13									
10						7				1	1				
11						11		2		1					
12						14		3		1					
13						12		2		1	1		1		
14						12		2			1				
15						15		3			1				
16						16		2		1					
17						15		2		1	1		1		
18						16		1			2		1		
19						17		3			2				
20						19		2		1	3		1		
21						18					2				
22						18		2			2				
23						20		2		1	1				
24						21		2			2				
25	1					17					4				
26						31		1			2				
27						21					2				1
28						30					4				
29						25				1	3				
30						26					2				
31						21					1		1		
32	2					24		1	5		5				
33	3			2		12			6		5		1	1	
34	2					10		1	5		3				
35	3			1		16			5		4		1		
36	1					13			8		4			1	
37	1					19			10		3				
38	3			3		20		1	7		4		1		
39	8			3		29		2	10		3				
40	6			4		17		2	6		5				4
41	2			2		15			6		10				5
42	7			3	1	25		1	15		2				
43	2					41			17		4			2	
44	3			3		14		1	10		2			1	
45	21	2	1	17		20	2	1	16	1	5			4	
46	19			15		31	2	1	24	1	8	1		7	
47															
48															
			SUM	1				SUM	53				SUM	8	

