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Monitoring the status, trends in abundance and key demographic rates of the Australian sea lion population at Seal Bay – Kangaroo Island

Simon D Goldsworthy, Clarence Kennedy and Kym Lashmar

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SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

December 2014

Report to the Nature Foundation SA

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EXECUTIVE SUMMARY

This report provides information on the 2013 Australian sea lion breeding season, trends in abundance and the population ecology of the Seal Bay and Seal Slide populations on Kangaroo Island.

At Seal Bay the 2013 breeding season commenced with the first pup birth on 31 March 2013. The last pup birth at the end of the breeding season occurred on 16 December 2013, however, one late birth was recorded on 30 March 2014, 104 days (3.4 months) later. The duration of the breeding season was approximately 9 months (12 months including the pup born in March 2014). The median pupping date was 25 August 2013 (sd = 47 days), with 90% of births occurring over 156 days (5.1 months), between 8 June and 11 November 2013. Pup production for the 2013 breeding season at Seal Bay was estimated to be 268 (range 259-277), based principally on twice-weekly surveys of new pup births and deaths, and on Petersen mark-recapture estimates in most of the colony, as well as direct counts of pups in Pup Cove. This estimate is similar to those from the previous four breeding seasons (2010: 267-276; 2008-09: 268-275; 2007: 254-256; 2011-12: 249-256).

Trends in pup numbers are based on two sources: maximum counts of live pups seen in a breeding season (available for 20 consecutive breeding seasons); and pup production estimates based principally on twice-weekly surveys (available for eight breeding seasons). The trend in maximum counts of live pups over 20 consecutive breeding seasons between 1985 and 2013 shows a significant decline of 1.9% per breeding season, however, the shorter time-series of pup production estimates over eight consecutive breeding seasons (2002-03 to 2013), shows no significant change, and does not corroborate declines based on maximum live pup counts at this stage, The pup production estimates provide more precise data, but a longer time series is required for meaningful comparison with count data.

Pup mortality for the 2013 breeding season was estimated to be 20.1%. The average rate over the last eight breeding seasons is 28.8% (sd = 7.8); it has varied between about 20% and 41%, and oscillated between the low and high end of that range in consecutive seasons, with 2013 being a low mortality season.

A total of 161 pups were microchipped during the 2013 breeding season at Seal Bay. Of 140 adult females scanned during the peri-natal period, 60 (43%) had a microchip. An additional 14 females were scanned outside of the peri-natal period while nursing pups and were microchipped, giving a total of 74 microchipped females (70 of known age) for the 2013 breeding season. The youngest breeding females were ~4.5 years old (born in the 2008-09

breeding season), while the oldest identified were ~10 years old (born in the 2002-03 breeding season when the microchipping program commenced).

Pup production at the Seal Slide was estimated to be 10 for the 2013 breeding season using cumulative mark and count procedures. Estimates of pup abundance with a high level of confidence at the Seal Slide are now available for the last eight breeding seasons (since 2002-03), and range between 9 and 15 over this period. No trends are apparent at this stage.

Results from this study will provide important information on the population ecology of the species and assist their conservation and management.

1 INTRODUCTION

Kangaroo Island represents an important breeding location for otariid seals (fur seals and sea lions) in southern Australia, with all three species that breed in Australian coastal waters breeding here: Australian sea lion (ASL, *Neophoca cinerea*); New Zealand fur seal (NZFS, *Arctocephalus forsteri*); and Australian fur seal (*Arctocephalus pusillus dorifierus*) (Kirkwood and Goldsworthy 2013). Pinnipeds attract large numbers of tourists to Kangaroo Island each year, particularly to Seal Bay and Cape du Couedic. The ASL population at Seal Bay is an iconic tourism attraction for Kangaroo Island and South Australia, and underpins a regional tourism economy.

The Australian sea lion was listed as threatened 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 ASL to Endangered. A recent report on the status of the ASL population at Seal Bay indicates that the decline in maximum live pup counts detected by Shaughnessy *et al.* (2006) over 13 breeding seasons (1985 - 2002/03) has continued and extends to 20 breeding seasons (1985 to 2013) (Goldsworthy *et al.* 2014). Although there is some corroboration of this decline from a demographic model of the Seal Bay population (Goldsworthy *et al.* 2007a), estimates of total pup production achieved through improved survey methodology over the last seven breeding seasons show no significant trend in abundance (Goldsworthy *et al.* 2010, 2011, 2013, 2014) Because improvements to survey methodology have only occurred in recent seasons, the time-series of pup production estimates and demographic factors upon which the population model was developed are limited. As such, there is a high degree of uncertainty about the current status and trend in the abundance of the Seal Bay ASL population, and in the expected trajectory of the population in the near future.

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 and Lowther 2010). Gillnet 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 approximately 10 nm (18.5 km) offshore, and was estimated to reduce female bycatch mortality in that subpopulation by 22.8% (Goldsworthy and Lowther 2010). Even with this reduction, expected levels of bycatch mortality were estimated to be unsustainable in the long-term (Goldsworthy and Lowther 2010). On 1 May 2011, AFMA extended closures around many ASL colonies and introduced additional closures south of Kangaroo Island (the 'Kangaroo Island gillnet strip'), that now extend at least 28 km south of Seal Bay. AFMA has 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). Close monitoring of the Seal Bay ASL population provides a critical assessment of the effectiveness of fishery closures and other management measures introduced to mitigate ASL bycatch in the gillnet fishery.

The overall aim of this project is to monitor the status of the ASL population at the Seal Bay Conservation Park on Kangaroo Island. This population has been in decline for many. The project involves a monitoring program that will determine the response of the population to fisheries management actions that have been implemented to reduce sea lion bycatch. It will also inform future management decisions for the Seal Bay population, which forms an iconic SA ecotourism destination that underpins a regional multimillion dollar tourism industry. The specific objectives are to:

1. Monitor ASL pup production at Seal Bay and the Seal Slide breeding colonies on Kangaroo Island;
2. Monitor population survival and reproductive success during successive breeding seasons at Seal Bay;
3. Provide detailed reports on population dynamics and trends subsequent to each breeding season.

2 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 is comprised of 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 the Cape Gantheaume Wilderness Protection Area, on the south-east coast of Kangaroo Island. The colony was accessed by 4WD vehicle by the investigators regularly during the 2013 ASL breeding season.

Pup production and population growth estimates

At Seal Bay, three methods were used to estimate pup production during the 2013 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, 2011). As the first two methods provide minimum estimates, 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. 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).

To estimate the population growth rate at Seal Bay we considered three models fitted to the natural logarithm of maximum pup counts and pup production estimate in each breeding season. The models tested were: (1) simple linear regression model; (2) multiple linear regression model that included a factor (Period) to allow for the non-annual interval between breeding seasons of the Australian sea lion; and (3) generalised least squares (GLS) model to estimate and adjust for any auto-correlation in maximum pup counts/pup production between breeding seasons (Zuur *et al.* 2009) .

The model equation for (2) was:

$$\log(Pups) = \beta_0 + \beta_1 Season + \beta_2 Period;$$

where '*Pups'* was either the maximum live-pup count or the pup production estimate; '*Season'* was the breeding interval (set at 18 months); and '*Period'* was a factor that alternated between breeding seasons to account for the sesquiannual breeding cycle of the ASL (~18 months). For (1), the model equation was similar with the omission of the '*Period*' factor. The statistical significance of the candidate models was considered using Analysis of Deviance and by consideration of the 95% confidence intervals of model parameters. Models were fitted using the statistical package R, version 2.15.1 (R Core Team 2013).

Seal Bay - microchipping 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 ± 0.5 cm). Each pup was externally marked by clipping the fur across the rump and a Passive Integrated Transponder tag (PIT tag: TIRIS™ RFID 23mm) was subcutaneously implanted 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 gravitation.

During the breeding season and between breeding seasons, hand-held scanning of animals (using Aleis Model 9030 Reader; and Allflex RS320 EID 'boom' reader) 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 a distance of 10 cm from the insertion site (rump). 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 breeding season monitoring, scanning of all available sea lions was undertaken over 3 days every two months to monitor individual survival.

Seal Bay Demographic analysis

Capture-history matrices were constructed from the re-sight histories of individual seals over six cohorts up until the 2011-12 breeding season. Multiple re-sights within an ~18 month period extending from the beginning of one breeding season to the beginning of the following breeding season were treated as a single sighting. These capture matrices were used as input files for the capture–mark–recapture (CMR) program MARK (White and Burnham 1999) to estimate survival and capture probabilities after weaning. MARK provides survival (Φ) and recapture (p) estimates under the Cormack–Jolly–Seber (CJS) model (Cormack 1964, Jolly 1965, Seber 1965) and under several models that appear as special cases of the CJS model (Lebreton *et al.* 1992). Parametric goodness-of-fit (GOF) tests within MARK were used to test whether the CJS model assumptions were met (Burnham *et al.* 1987, Lebreton *et al.* 1992). This bootstrap procedure simulates encounter histories that exactly meet the CJS model assumptions. These simulated data were compared to the field data for compliance with the CJS model assumptions (White and Burnham 1999). To test the main hypothesis (e.g. effect of sex, age and cohort on survival) the c2 likelihood ratio test (LRT) statistics within MARK were used (White and Burnham 1999).

3 RESULTS AND DISCUSSION

Pup production and population growth

Results of the surveys for pup births and deaths undertaken during the 2013 breeding season at Seal Bay are presented in Table 1 and Figure 2. The breeding season commenced with the first pup birth on 31 March 2013. The last pup birth at the end of the breeding season occurred on 16 December 2013, however, one late birth was recorded on 30 March 2014, 104 days (3.4 months) later. The duration of the breeding season was approximately 9 months (12 months including the pup born in March 2014). Based on probit analyses of the cumulative number of births, the median pupping date was 25 August 2013 (sd = 47 days), with 90% of births occurring over 156 days (5.1 months), between 8 June and 11 November 2013 (Table 2).

Variation in the chronology of breeding across the last eight breeding seasons is presented in Figure 3. The mean breeding interval (period between successive median pupping dates) for the eight consecutive breeding seasons was 545 days (range 541-551, sd = 4.0) or 17.9 months (range 17.8-18.1, sd = 0.1) (from data in Table 2, Figure 3).

The cumulative number of births recorded for the 2013 breeding season at Seal Bay was 259 (Table 1, Figure 2). Most pups were born in the Main Beach (MB) area west of the area accessed by the public (89 pups, 34.4%) and in the EPA (75 pups, 29.0%), with 51 pups (19.7%) reported for the WPA and 44 pups (17.0%) for Pup Cove. 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.

The maximum direct count of live pups was 99 on 12 September 2013 when the cumulative number of dead pups was 27. The cumulative number of pup deaths to the end of the breeding season was 54 on 30 March 2014 when the last pup birth was recorded.

Details of mark-recapture Petersen estimates are provided in Table 1. As the most accurate mark-recapture surveys are obtained towards the end of the breeding season, we have only used surveys undertaken after 90% of the cumulative pup births were recorded. The mean adjusted estimate (*AdjN*), which includes cumulative dead pups plus the remaining new births that occurred after a particular survey, was 268 with 95% CL 258-277; (Table 1, Figure 2). This is 9 more than estimated from the cumulative survey of new births (259), and 54 more than the estimate of minimum pup production, which is 214 (total live pups microchipped [160] plus cumulative dead pups at the end of the breeding season [54]) (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 2013 season at Seal Bay was 268 (range 259-277), with the lower bound set at the minimum pup production estimate and the upper bound set as the +95% CL of the adjusted (*AdjN*) Petersen estimate (Tables 1 and 2).

Seal Bay - trends in maximum live-pup counts, pup production and mortality

Trends in live-pup counts 1985 to 2013

Trends in direct counts of live pups extend over 20 consecutive breeding seasons between 1985 and 2013 (Figure 4). A linear regression model fitted to the log of maximum live-pup counts shows a significant decline of 1.9% per breeding season ($F_{1,18} = 14.35$, $P = 0.001$, $r^2 = 0.44$). The multiple regression model also indicates a significant 2% decline per season with '*Period'* a significant factor, improving the model fit ($F_{2,17} = 14.35$, $P < 0.0002$, $r^2 = 0.63$). A generalised least squares (GLS) model to estimate and adjust for any auto-correlation detected the presence of auto-correlation in the data, with a lag of one breeding season. The model was fitted with an AR(1) structure and the correlation was estimated to be 0.3 but the lag was not statistically significant.

Trends in estimated pup production and mortality

Estimates of pup production (based on cumulative pup births or mark-recapture) and mortality rates of pups are available for eight consecutive breeding seasons between 2002-03 and 2013 (Figure 4). The linear regression model fitted to the log of estimated pup production showed no evidence of a trend ($F_{1,6} = 0.89$, $P = 0.38$, $r^2 = 0.13$). Including the '*Period'* term in a multiple regression model did not change this result ($F_{2,5} = 2.67$, $P = 0.16$, $r^2 = 0.52$). Pup production estimates for the eight consecutive breeding seasons since 2002-03 (Figure 4) indicate that the first four breeding seasons (2002–03 to 2007) show the same oscillation in pup numbers between high and low pup-production seasons as observed with the maximum live-pup counts, with 2002–03 and 2005–06 being low pup-production seasons and 2004 and

2007 being high pup-production seasons (Figure 4). However, the pattern is absent between the 2007 and 2010 breeding seasons, but is apparent between the 2010 and 2013 breeding seasons. After the 2005-06 breeding season, fluctuations in estimated pup production are much less marked; this is likely due to enhanced survey accuracy achieved mid-way through the 2007 breeding season, when access to the Eastern Prohibited Area (EPA) was approved for pup surveys.

Based on a pup production estimate of 268 pups for the 2013 breeding season at Seal Bay, and a total of 54 cumulative pup deaths at the end of the breeding season, the mortality rate for the breeding season is estimated to be 20.1% (Table 2, Figure 4). The average rate over the last eight breeding seasons is 28.8% (sd = 7.8); it has varied between about 20% and 41%, and oscillated between the low and high end of that range in consecutive seasons, with 2013 being a low mortality season (Figure 4) (Goldsworthy *et al.* 2011). Pup mortality in the low mortality breeding seasons has averaged 22.2% (sd = 2.5), while in the high mortality breeding seasons it averaged 35.4% (sd = 4.7) (from Table 2). There was no apparent trend in pup mortality between 2002-03 and 2013.

Seal Bay - microchipping and demographic program

Microchipping

In the 2013 breeding season, 268 pups were estimated to have been born at Seal Bay. Of these, at least 54 (20.1%) died before the end of the breeding season. Of the estimated 214 pups that survived, 161 (75%) were microchipped at the time this report was completed (Table 2), representing 60% of all pups estimated to have been born in the 2013 breeding season.

Birth rates

During the 2013 breeding season, attempts were made to scan as many females as possible during the peri-natal period or later in order to identify known-age females and monitor age-specific and seasonal variation in natality (birth rate). The scanning covered 140 adult females associated with the 259 pups recorded in the cumulative survey of new births (i.e. 54% of breeding females). Of these 140 adult females, 60 (43%) had a microchip. An additional 14 females were scanned outside of the peri-natal period while nursing pups and were microchipped, giving a total of 74 microchipped females, of which 70 were of known age. The youngest breeding females were ~4.5 years old (born in the 2008-09 breeding season), while the oldest known-age females were ~10 years old (born in the 2002-03 breeding season), although this also coincides with the beginning of the microchipping program, so it is likely that older breeding females were also present. Only one 4.5 year-old female (1.4% of the 70 known-age females) gave birth, compared to 23 (32.9%) 6 year-olds, 14 (20.0%) 7.5 year-olds, 22 (31.4%) 9 year-olds and 10 (14.3%) 10 year-olds (Figure 5).

Between 1991 and 2001-02, approximately 50 pups were microchipped each season (Goldsworthy *et al.* 2007a). A greater microchipping effort was introduced by McIntosh (2007) in the 2002-03 and 2004 breeding seasons, when Destron microchips (12 mm length, with lower read-range) were replaced with TIRIS microchips (23 mm length, with greater read-range). Effort will be increased in future seasons to scan as many breeding females as possible.

Population scanning

Between February 2013 and July 2014, 2,768 individual ASL were scanned at Seal Bay (Figure 6 and 7). Typically over the bi-monthly three-day scans around 250-350 animals would be scanned (Figure 6). Of the 2,768 individual scanning attempts, 1,656 (60%) had microchips that could be identified. These came from 560 individual sea lions that were scanned on average 2.8 times (range: 1-15, median = 2.0) over the ~17 month period (Figure 8).

Demography

Demographic analyses are available up to the 2011-12 breeding season at Seal Bay. Those detailed here follow that described in Goldsworthy *et al.* (2013). Survival (Φ) and recapture (ρ) estimates using the Cormack–Jolly–Seber (CJS) approach produced a range of models ranked from most to least supported (Table 3). There was no difference in survival related to sex (g) (X^2 = 0.039, p = 0.844, {Φ(.) ρ(.) & Φ(g) ρ (.)}) (where (.) = constant, (t) = time, (a) = age and (g) = gender/sex), enabling data from males and females to be pooled in subsequent analyses. There was also no effect of sex on recapture probability (X^2 = 0.123, p = 0.726, {Φ(.) ρ (.) & {Φ(.)ρ (g)}), but there was strong evidence (X^2 = 62.563, df=3, p<.0001) that recaptures varied with time (month scanned) {Φ (t) ρ (.) & Φ (t) ρ (t)} but not with age (delta AIC > 300 for all the age varying recapture models) (Table 3).

Survival varied significantly with age and cohort (Table 3, Figure 9). In general survival to age 1.5 years was low, but increases thereafter. Mean survival to age 1.5 years was 0.499 (±95% CL, 0.463 – 0.536), from 1.5 to 3 years was 0.804 (±95% CL, 0.740 – 0.856) and from 3 to 4.5 years was 0.916 (±95% CL, 0.850 – 0.954). The data for older seals are sparse and therefore difficult to model (Figure 9), consistent with studies on other species (Anderson *et al.* 2001, Burnham and Anderson 2001, 2002, 2004). There was evidence that cohort survival to 1.5 years (which approximates weaning age) varied across the six cohorts, although the evidence was not strong {Φ (age1-3) p (t) & Φ (age1-3 cohort) p (t)} X^2 = 11.453, df = 9, p= 0.246) (Figure 10).

Several fundamental life-history parameters, or vital rates, are required to understand population dynamics, including 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 the ASL are poorly understood, and likely to differ in many respects from all other pinnipeds, which have annual and synchronous breeding seasons. This project provides critical information for this unique pinniped and estimates of age-specific survival, recruitment and natality will be used to develop demographic models for the species. Understanding survival and recruitment are critical to managing the population at Seal Bay. Fishery interaction and population viability models will also be improved by the use of estimates based on demographic data rather than relying on assumptions from other species. The survival analysis will cover important life history events such as weaning and onset of reproductive maturity.

Seal Slide pup abundance

Three pups were marked over three surveys during the Seal Slide breeding season between July and December 2013. Details about 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 resight and marking history is also presented. Based on these data, the minimum estimate of pups born in the subpopulation was 10 (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 is uncertain. For example, there is the potential that some of the pups recorded at Seal Slide may have dispersed from Seal Bay. To counteract this possibility, Shaughnessy *et al.* (2009) restricted counts of pups to those observed within four months of the beginning of the breeding season at Seal Bay. While accounting for dispersal from Seal Bay, this adjustment may result in an under-estimate of pup production as it will omit pups born during the last third of the breeding season. In the 2002-03 and 2004 breeding seasons, only pups <1 month old (and therefore assumed to have been born at the Seal Slide) were counted by experienced observers and the cumulative number of pups <1 month old was used to estimate the number of pups born during those seasons resulting in more accurate, reliable and low (9 and 11) estimates of pup production.

Estimates of pup abundance at the Seal Slide with a higher degree of confidence are now available for the last eight breeding seasons since 2002-03 (Figure 11). The first two are from Shaughnessy *et al.* (2009): 9 pups in 2002-03 and 11 pups in 2004. The next six resulted from use of the CMC method: 10 pups, range 10-11 based upon the Peterson estimate in 2005-06; 15 pups, range 14-18 based upon the Peterson estimate in 2007; 12 pups in 2008-09 (Goldsworthy *et al.* 2007b, 2008, 2010), 10 pups in 2010, 13 pups in 2011-12, and 10 pups in 2013 (Figure 11). Analyses of trends in pups counts from eight breeding seasons since 2002-03 using linear and multiple regression models fitted to the log of pup counts identified no significant change in pup numbers with breeding season ($F_{1,6}$ = 0.35, P = 0.58, r^2 = 0.055), or with breeding season and period ($F_{2,5}$ = 0.16, P = 0.86, r^2 = 0.061).

4 CONCLUSION

This project aimed to provide information on the status, trends in abundance and health of the ASL population at Seal Bay and the Seal Slide. These sites represent the most well studied populations for this species, and as such, are of critical importance to informing both State and National Government conservation and management policy for this protected marine species. In addition, seals form an integral part of the Kangaroo Island ecotourism industry. In 2011/12, of the 193,975 visitors to Kangaroo Island 67% viewed ASL at Seal Bay and 79% went to see NZFS at Admirals Arch (South Australian Tourism Commission). Knowledge on the status and health of seal species is therefore relevant to ensure long-term sustainability of the ecotourism industry.

ASL pup production estimates were 268 pups for the Seal Bay Conservation Park and 10 pups for the Seal Slide and are similar to recent estimates of pup production and show no discernable trends in abundance.

Ongoing demographic analyses of age-structure, survival and fecundity of the Seal Bay population will provide important information on the population ecology of the species and evaluate changes since the implementation of management measures to mitigate bycatch in the demersal gillnet fishery.

Table 1. Summary of surveys undertaken for new births and 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 2013 breeding season. Shaded area highlights those surveys when Petersen estimates were calculated.

	Date	New	New	Cumulative			Counts			Petersen M-R estimates					
No.		Births	Dead	Births	Dead	Alive	BP	MP	Total live	M	n	m	*N*	*Adj N*	SE
1	31-Mar	1	1	1	1	0	0	0	0						
2	17-Apr	2	2	3	3	0	0	0	0						
3	23-Apr	1	1	4	4	0	0	0	0						
4	29-Apr	1	1	5	5	0	0	0	0						
5	07-May	0	0	5	5	0	0	0	0						
5	13-May	0	0	5	5	0	0	0	0						
6	21-May	0	0	5	5	0	0	0	0						
7	23-May	0	0	5	5	0	0	0	0						
8	26-May	0	0	5	5	0	0	0	0						
9	28-May	0	0	5	5	0	0	0	0						
10	04-Jun	2	0	7	5	2	2	0	2						
11	11-Jun	2	0	9	5	4	4	0	4						
12	13-Jun	1	0	10	5	5	1	0	1						
13	18-Jun	2	0	12	5	7	5	0	5						
14	25-Jun	5	1	17	6	11	13	0	13						
15	02-Jul	1	0	18	6	12	13	0	13						
16	03-Jul	2	1	20	7	13	3	0	3						
17	08-Jul	4	1	24	8	16	18	0	18						
18	11-Jul	5	1	29	9	20	21	0	21						
19	15-Jul	3	0	32	9	23	22	0	22						
20	18-Jul	4	0	36	9	27	26	0	26						
21	23-Jul	12	1	48	10	38	29	0	29						
22	25-Jul	11	3	59	13	46	31	0	31						
23	29-Jul	13	0	72	13	59	40	0	40						
24	01-Aug	8	0	80	13	67	46	0	46						
25	05-Aug	6	1	86	14	72	48	0	48						
26	08-Aug	9	0	95	14	81	43	0	43						
27	12-Aug	10	2	105	16	89	53	0	53						
28	15-Aug	6	2	111	18	93	55	0	55						
29	19-Aug	13	2	124	20	104	45	0	45						
30	20-Aug	2	2	126	22	104	58	0	58						
31	22-Aug	5	0	131	22	109	44	0	44						
32	26-Aug	5	0	136	22	114	47	0	47						
33	29-Aug	10	1	146	23	123	62	0	62						
34	02-Sep	10	2	156	25	131	64	0	64						
35	05-Sep	9	1	165	26	139	77	0	77						
36	09-Sep	14	1	179	27	152	81	0	81						
37	12-Sep	4	0	183	27	156	99	0	99						
38	16-Sep	9	0	192	27	165	71	0	71						
39	19-Sep	3	0	195	27	168	91	0	91						
40	23-Sep	4	1	199	28	171	86	0	86						
41	26-Sep	4	1	203	29	174	64	0	64						
42	30-Sep	5	1	208	30	178	84	0	84						
43	03-Oct	2	1	210	31	179	71	0	71						
44	08-Oct	8	2	218	33	185	73	0	73						
45	10-Oct	3	1	221	34	187	75	0	75						
46	14-Oct	3	0	224	34	190	95	0	95						
47	17-Oct	0	2	224	36	188	69	0	69	56	69	21	230	264	25
48	22-Oct	7	4	231	40	191	54	0	54	59	54	16	248	275	32
49	28-Oct	4	1	235	41	194	85	1	86	66	86	28	257	280	23
50	31-Oct	2	0	237	41	196	78	1	79	75	79	34	231	252	16
51	04-Nov	4	1	241	42	199	80	1	81	75	81	36	227	244	14
52	07-Nov	3	0	244	42	202	86	0	86	85	86	47	216	230	10
53	11-Nov	3	0	247	42	205	90	2	92	85	92	50	218	230	9
54	12-Nov	1	1	248	43	205									
55	14-Nov	1	0	249	43	206	80	1	81	85	81	43	224	234	11
56	21-Nov	1	0	250	43	207	85	1	86	85	86	44	231	240	12
57	26-Nov	2	3	252	46	206	78	0	78	89	78	40	242	249	14
58	02-Dec	1	3	253	49	204	62	3	65	89	65	28	278	284	23
59	08-Dec	1	1	254	50	204	81	5	86	89	86	31	320	325	27
60	11-Dec	3	1	257	51	206	59	0	59	110	59	34	267	269	17
61	16-Dec	1	0	258	51	207	85	7	92	110	92	45	302	303	18
62	31-Dec	0	0	258	51	207	46	7	53	110	53	26	301	302	26
63	09-Jan	0	0	258	51	207	68	17	85	110	85	44	292	293	17
64	28-Jan	0	1	258	52	206									
65	05-Feb	0	1	258	53	205									
66	13-Feb	0	1	258	54	204									
67	30-Mar	1	0	259	54	205									
				259	54	205							**AdjŇ =**	**268**	**4.9**
													±95% CL (258 – 277)		

Table 2. Summary of the timing and spread of seven 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 microchipped pups and minimum pup production (microchipped + cumulative pup deaths); adjusted mark-recapture Petersen estimates (Ň); 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 2007, 2008-09 and 2010 breeding seasons are from Goldsworthy *et al.* (2008, 2010, 2011); data from the 2011-12 season is from this report.

	2002-03	2004	2005-06	2007	2008-09	2010	2011-12	2013
Month breeding season commenced	Dec-02	Jun-04	Dec-05	May-07	Oct-08	May-10	Oct-11	Mar-13
Duration of breeding season (months)	9	7	6	7	7	9	8	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
± s.d. (days)	42	39	36	36	41	46	47	47
90% births (5%- 95%)	2 Jan—21 May[1]	3 Jul -1 Nov	4 Jan-18 Apr	28 Jun-26 Oct	18 Dec-3 May	14 June-11 Nov	5 Dec -9 May	8 June - 11 Nov
90% births (days)	139[1]	121	104	120	136	150	156	156
Cumulative births	-	200	207	245	268	259	249	259
Cumulative pup deaths	73	70	75	51	88	66	104	54
Maximum live pup count	122	148	125	145	122	128	84	99
At months since beginning of BS	6	7	6	6	7	6	6	4
Max live pup count + cumulative dead[2]	185	208	197	198	197	189	167	126
Total live pups microchipped	148	202	144	203	161	201	118	161
Minimum pup production[3]	221	272	219	254	249	267	222	215
Ň	227	288	203	255[4]	267[4]	269	251	268
(95% CL)	(216-239)	(273-302)	(199-207)	(245-266)	(259-275)	(261-276)	(246-256)	(258-277)
No. recapture estimates	3	2	3	11	7	13	17	16
Overall estimate of pup production	227	288	219	255[4]	268[4]	269	251	268
Confidence limit (min est. to +95% CL)	(221-239)	(273-302)		(254-266)	(268-275)	(267-276)	(249-256)	(259-277)
Mortality rate	32.2%	24.3%	34.2%	20.0%	32.8%	24.5%	41.4%	20.1%

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

[2]at time of maximum live count.

[3]total microchipped + cumulative dead at end of the breeding season.

[4]estimates have been slightly modified from previous reports (Goldsworthy *et al.* 2008, Goldsworthy *et al.* 2010), to rectify errors in the number of marked pups (M) available for resighting during some surveys.

Table 3. Demographic models for Australian sea lions at Seal Bay up the end of the 2011-12 breeding season. Overall model rankings – models in the shaded section are not well supported (from Goldsworthy *et al.* 2013).

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{ Φ (age1-3) ρ(t)}	3243.516	0	0.40994	1	8	100.9728
{ Φ (age1-5) ρ(t)}	3244.979	1.4628	0.19728	0.4812	10	98.3965
{ Φ (age1-4) ρ(t)}	3245.04	1.5237	0.19136	0.4668	9	100.478
{ Φ (age1 cohort age >1.) ρ (t)}	3246.411	2.8947	0.09642	0.2352	11	97.8057
{ Φ (age1-2 cohort age >2.) (t)}	3247.763	4.2472	0.04903	0.1196	15	91.0464
{ Φ (age1-2) ρ (t)}	3248.063	4.5468	0.04221	0.103	7	107.5361
{ Φ (age1-3 cohort) ρ (t)}	3250.305	6.7888	0.01376	0.0336	17	89.5195
{ Φ (t) ρ (t)}	3390.271	146.7547	0	0	9	245.709
{ Φ (.)ρ (t) }	3396.246	152.7298	0	0	6	257.7335
{ Φ (t) ρ (.)}	3446.784	203.2682	0	0	6	308.2719
{ Φ (.) (age 1-5)}	3543.59	300.0741	0	0	6	405.0778
{ Φ (.) (age 1-3)}	3558.334	314.818	0	0	4	423.8444
{ Φ (.) (age 1-4)	3559.993	316.4767	0	0	5	423.4928
{ Φ (.)ρ (.)}	3590.471	346.9548	0	0	2	459.9955

Table 4. Details of pup surveys undertaken at the Australian sea lion colony at the Seal Slide (Kangaroo Island) between July and December 2013. 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 resighted at each survey is presented, along with the cumulative number of dead pups recorded. The minimum number of pups at each visit is estimated by summing the count of clear pups and cumulative number of clear dead pups, plus the number of pups marked up to the previous survey.

Date	Live clear	Live marked	Dead clear	Dead marked	Live total	Live & dead Total	New marked	Cum. marked	Min Live	Cum. dead clear	Min Total
24 Jul 13	3	0	0	0	3	3	0	0	3	0	3
2 Sept 13	6	0	3	0	6	9	2	2	6	3	9
17Dec 13	5	1	0	0	6	6	1	3	7	3	10

Figure 1. Map of Seal Bay breeding colony of Australian sea lions , 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.

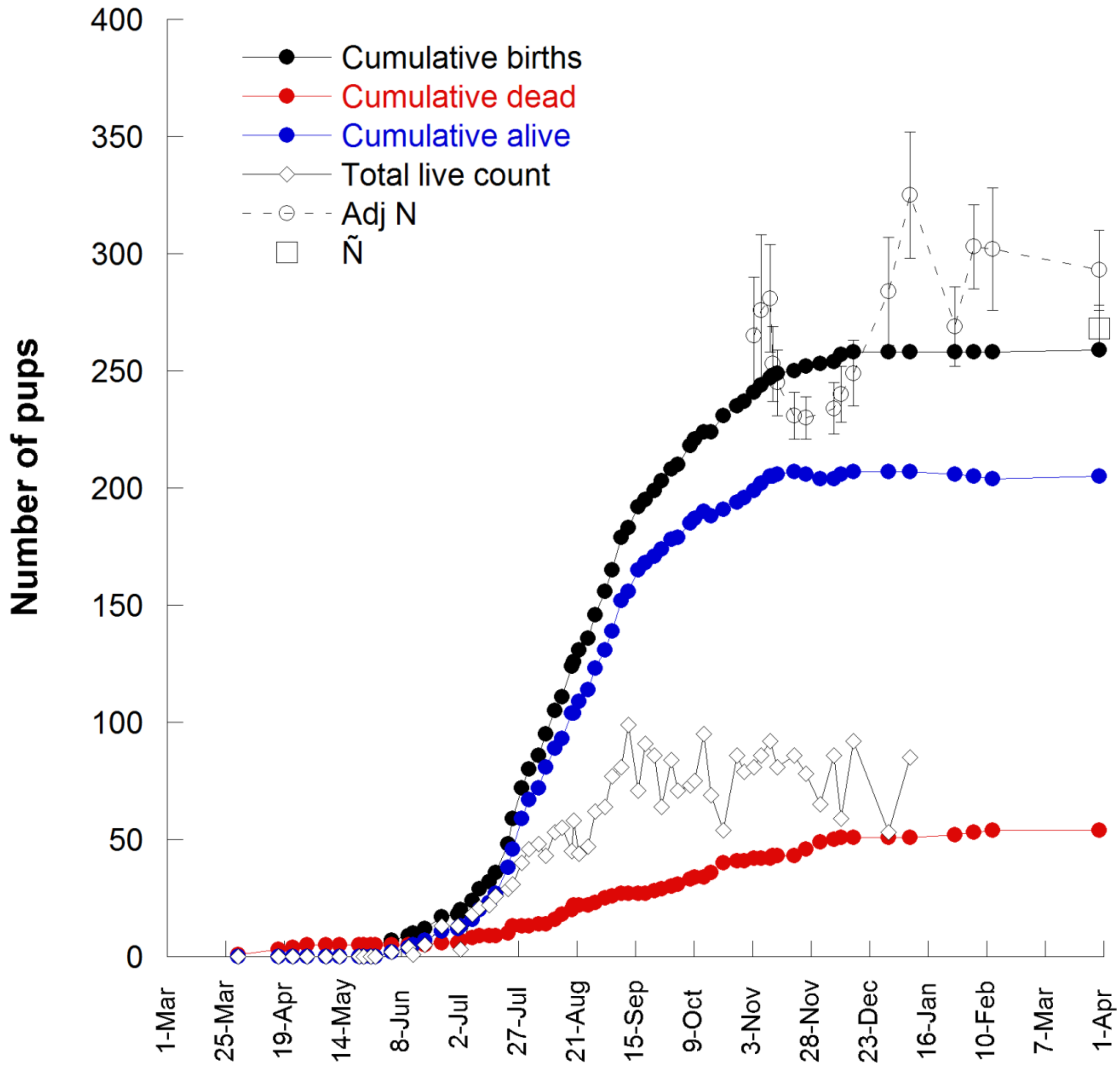

Figure 2. Changes in the number of cumulative pup births, cumulative pup deaths, minimum number of pups alive (cumulative alive), and number of live pups counted during surveys of Australian sea lion pups at Seal Bay conducted between 31 March 2013 and 30 March 2014**.**

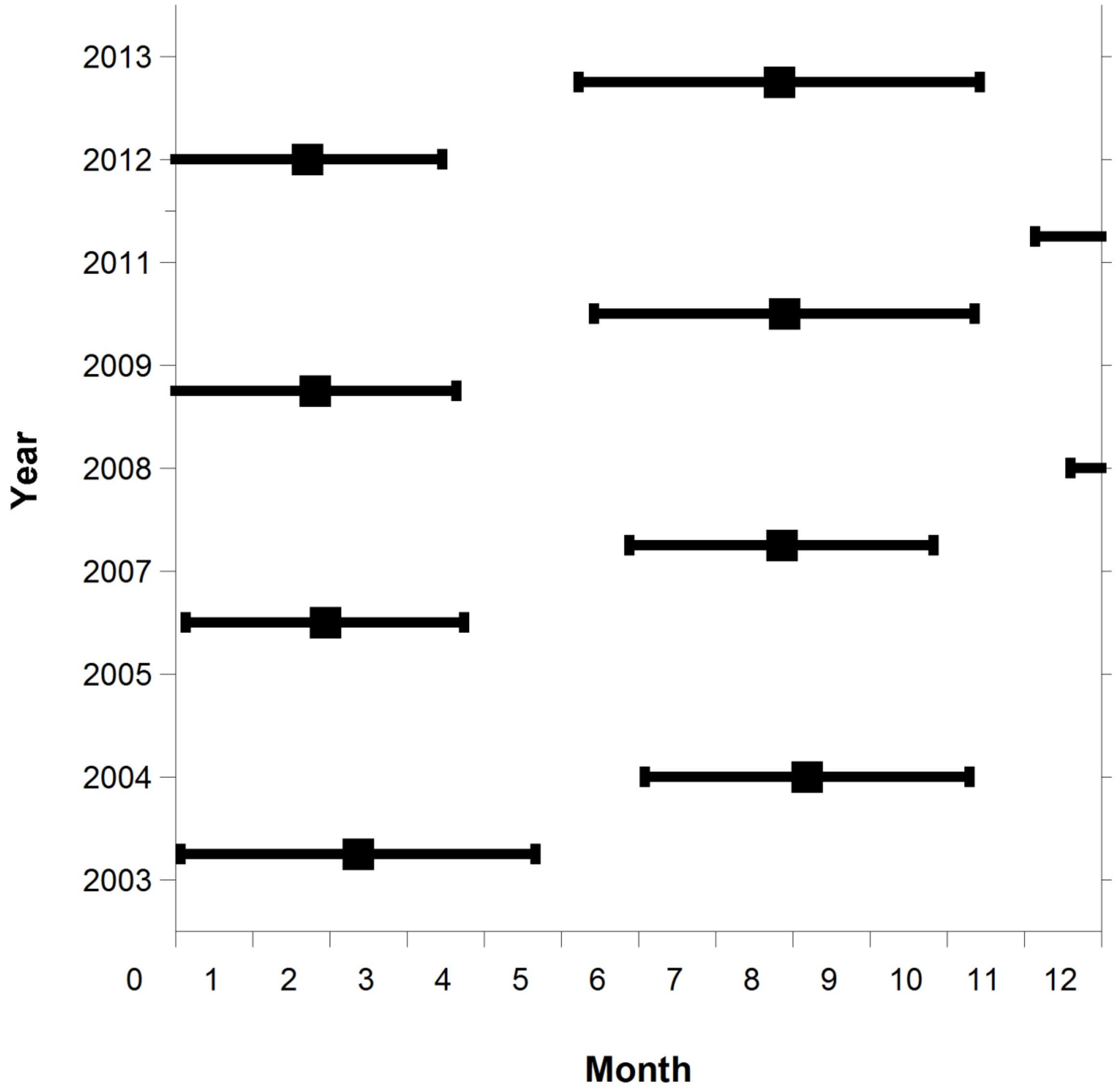

Figure 3. Variation in the breeding season chronology of Australian sea lions at Seal Bay, across eight consecutive breeding seasons. Median pupping dates are indicated by squares and error bars represent the spread of 90% of births (5-95%) based on probit analyses of cumulative pup births**.**

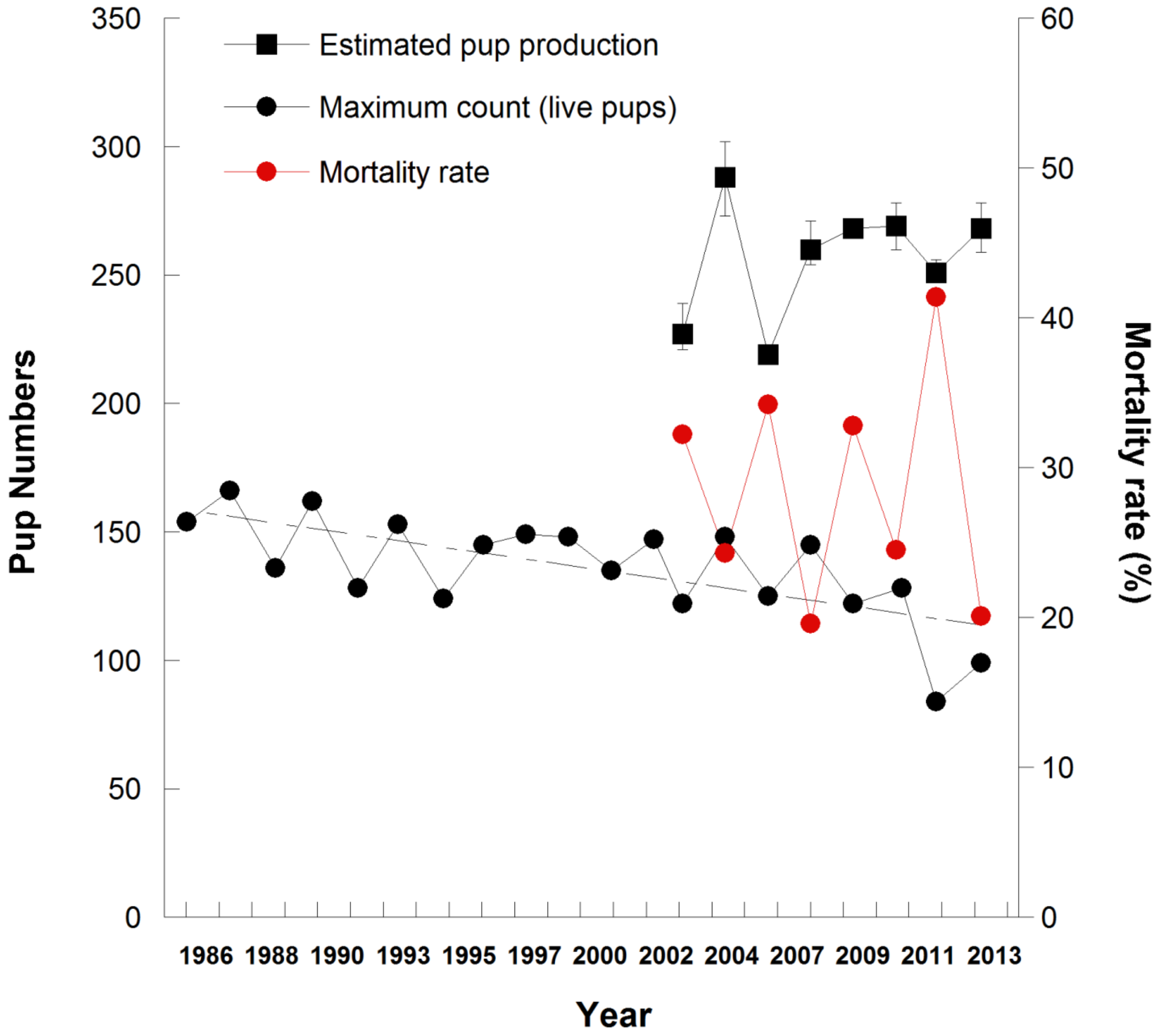

Figure 4. Trends in the abundance of Australian sea lion pups at Seal Bay based on maximum live pup counts for 20 breeding seasons between 1985 and 2013. Trends in the overall estimate of pup production and pup mortality rate are presented for the last 8 breeding seasons.

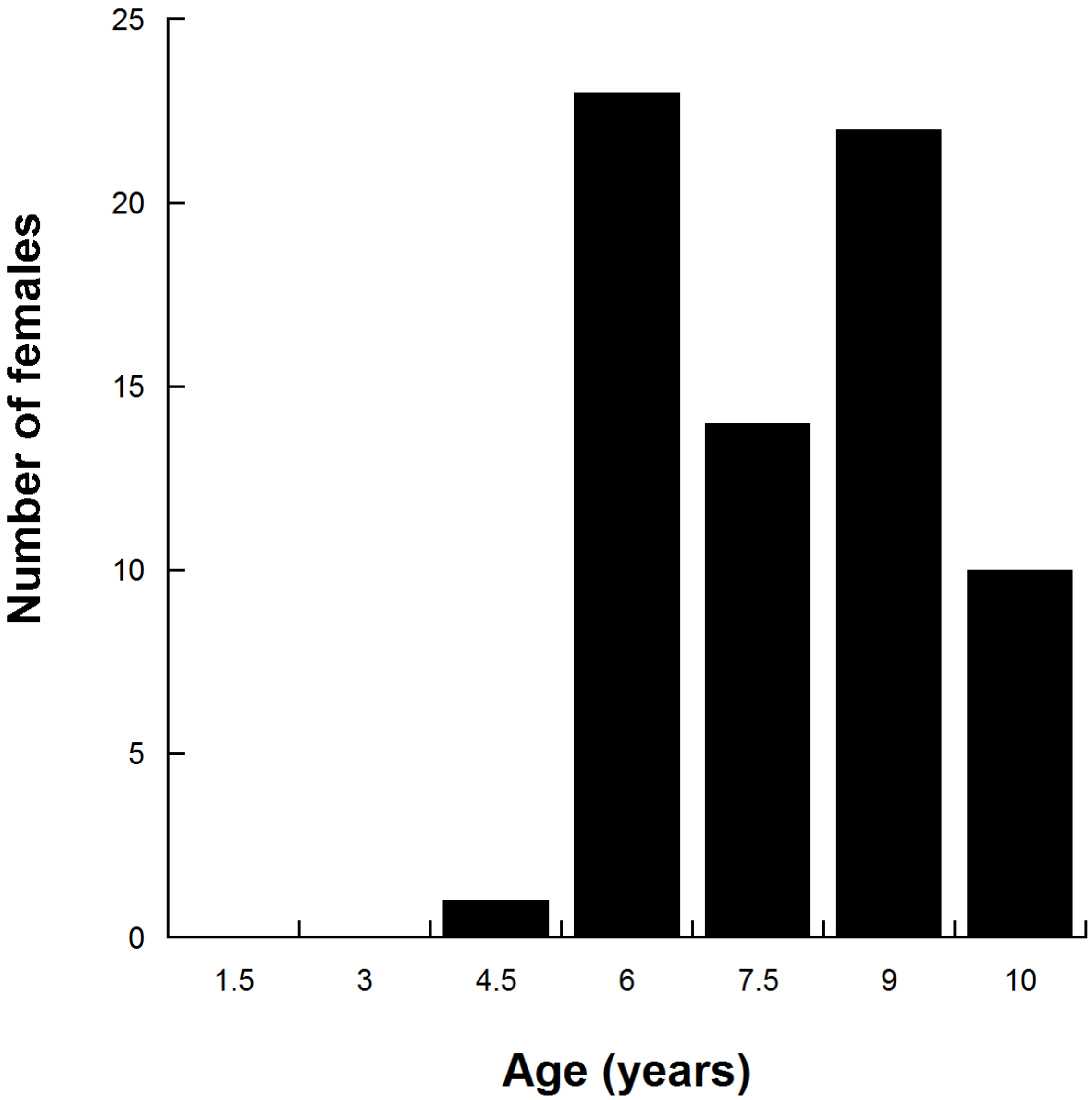

Figure 5. Age distribution of 70 known-age Australian sea lion females that pupped at Seal Bay in the 2013 breeding season. Note that microchipping only commenced ~10 years before the 2013 breeding season, and thus no data is available for females >10 years of age.

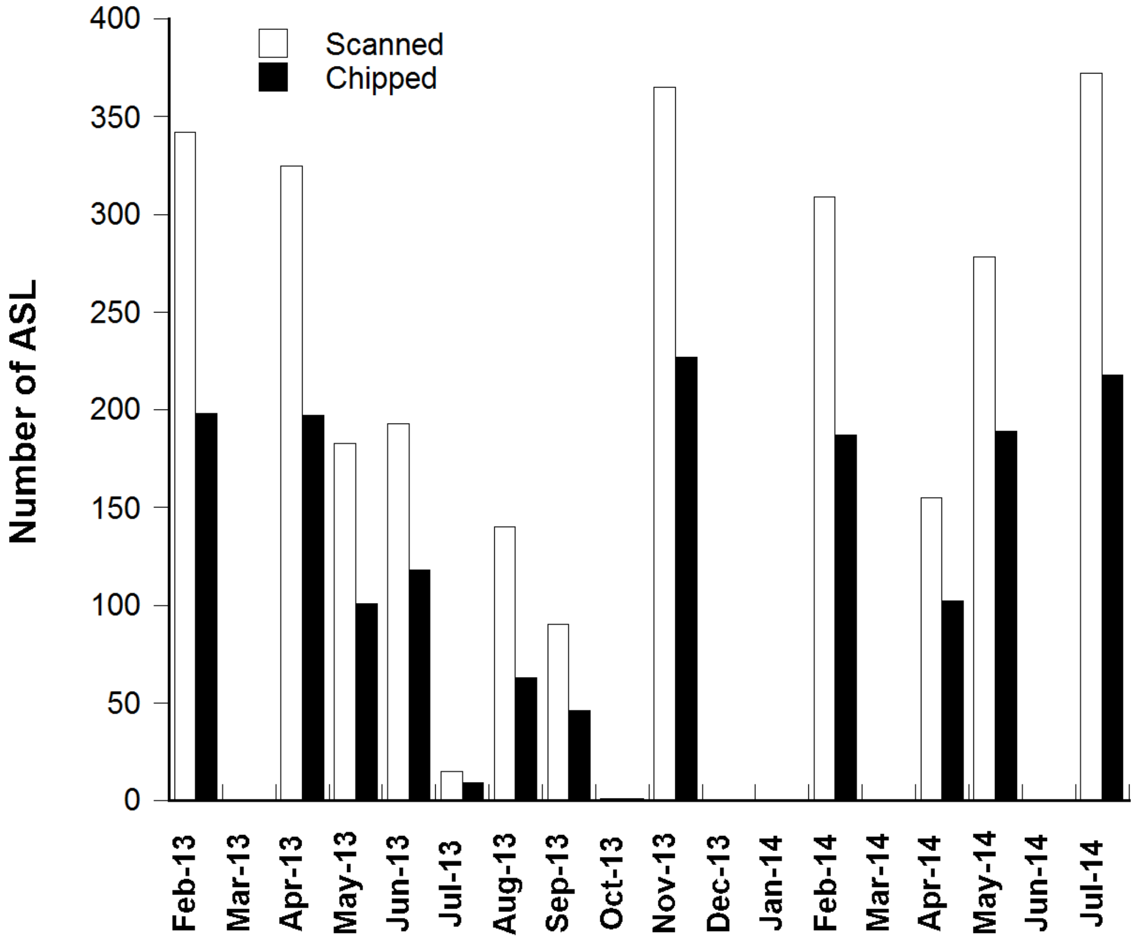

Figure 6. Histogram of Australian sea lion scanning effort at Seal Bay between February 2013 and July 2014. The total number of individual scans is indicated by the open bars (‘Scanned’), while the number of scans of microchipped animals is indicated by the closed bars (‘Chipped’).

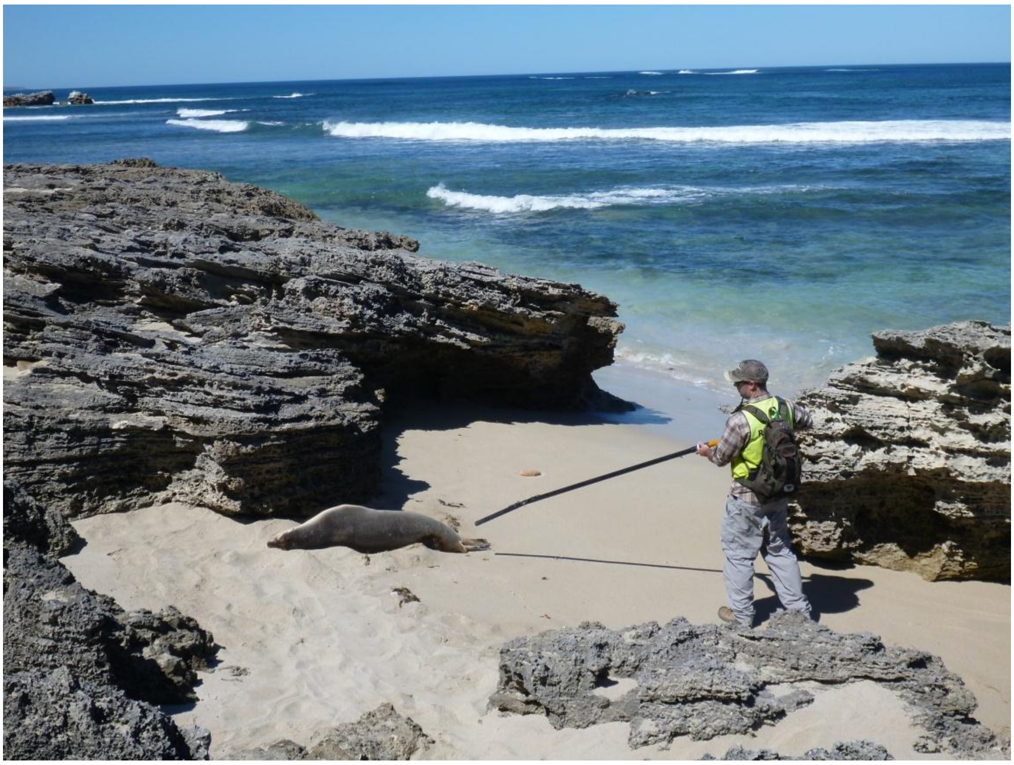

Figure 7. Typical scanning attempts of resting Australian sea lions at Sea Bay using an Allflex RS320 EID ‘boom’ reader (Photos: Kym Lashmar, DEWNR).

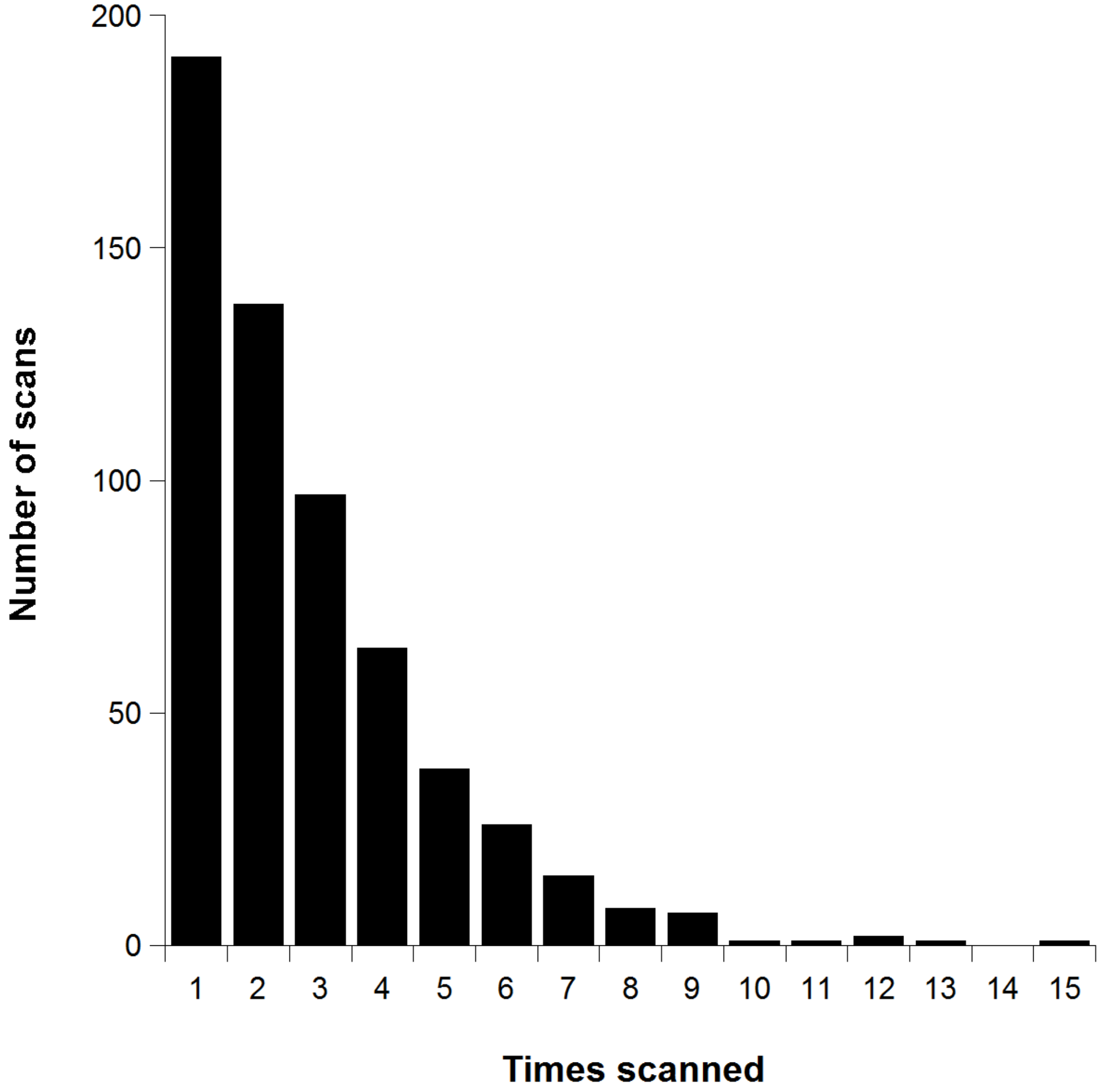

Figure 8. Frequency histogram of the number of times that individual microchipped Australian sea lions were scanned at Sea Bay between February 2013 and July 2014 (mean 2.8, median 2.0, range: 1-15).

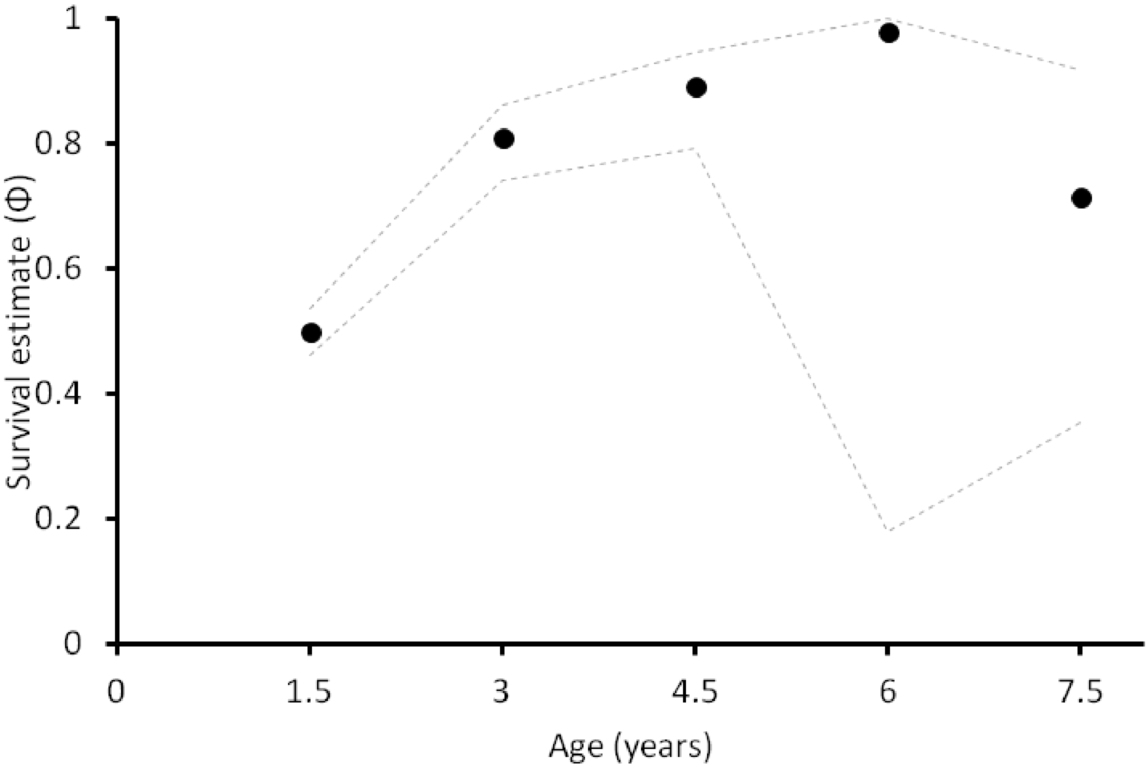

Figure 9. Age-specific survival estimates (filled circle) and the 95% confidence intervals for the estimates (dotted lines) for Australian sea lions at Seal Bay to age 7.5 years (includes data up to the end of the 2011-12 breeding season) (from Goldsworthy *et al.* 2013).

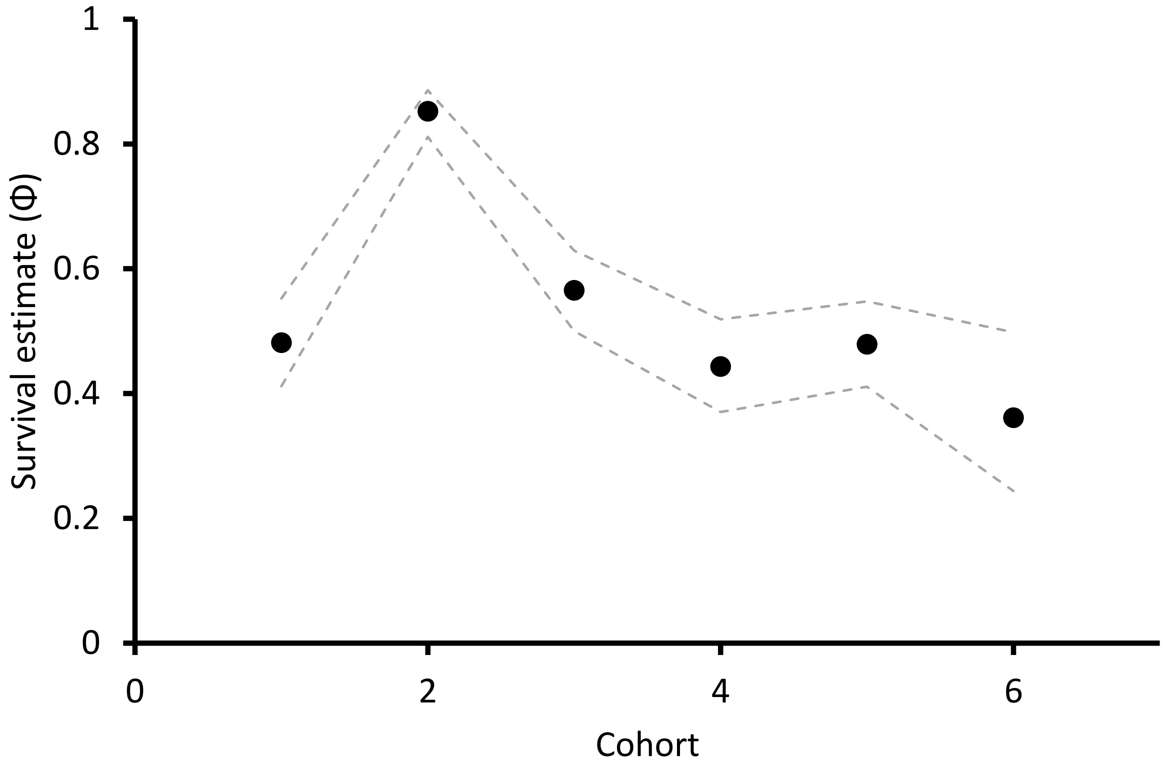

Figure 10. Survival estimates to age 1.5 (filled circles) and 95% confidence intervals (dashed lines) for six cohorts of Australian sea lions at Seal Bay years (includes data up to the end of the 2011-12 breeding season) (from Goldsworthy *et al.* 2013)..

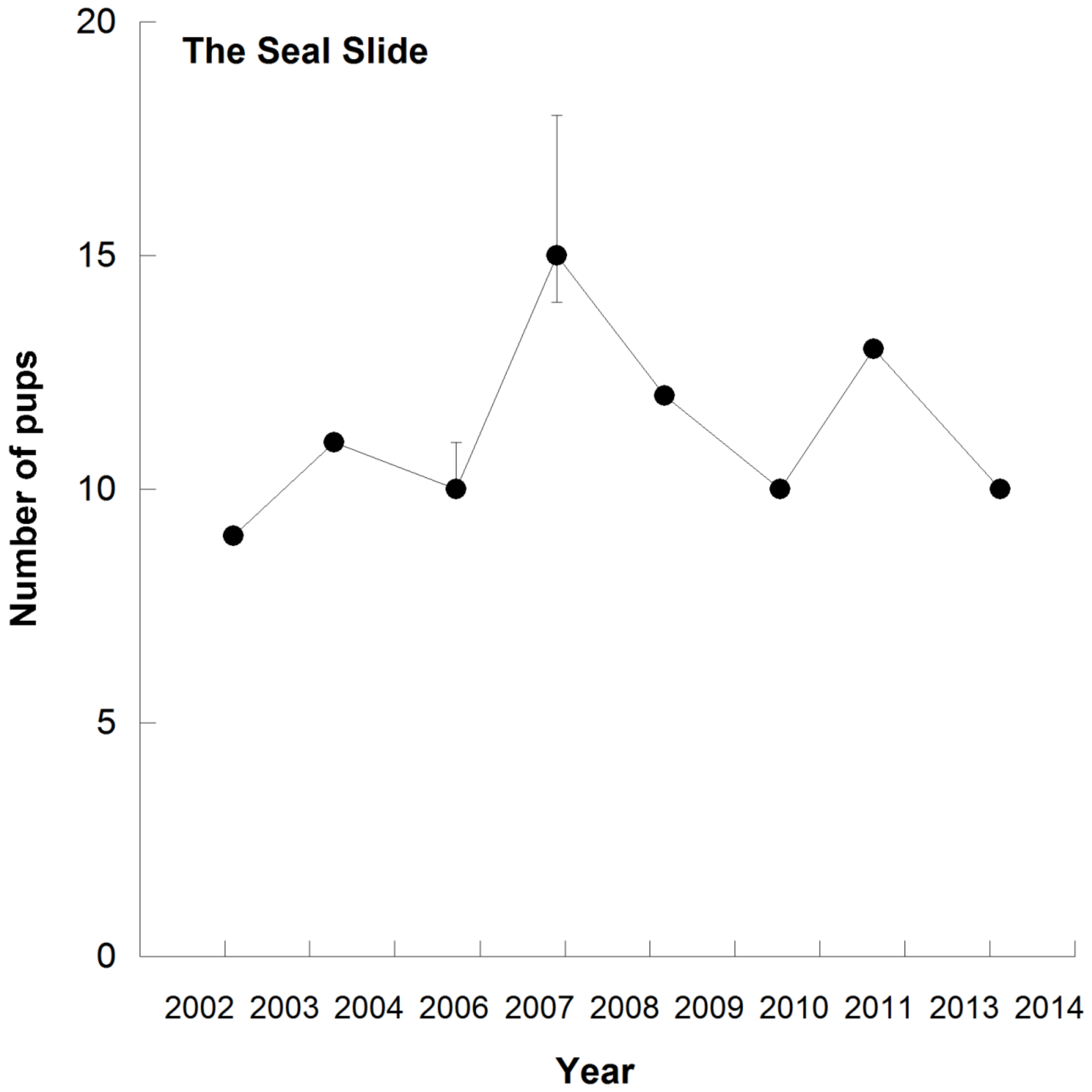

Figure 11. Trends in the estimated Australian sea lion pup production at the Seal Slide (Kangaroo Island), over eight consecutive breeding seasons (2002-03 and 2013). Upper (95%) and lower (absolute minimum) confidence limits are available for the 2005-06 and 2007 breeding seasons.

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