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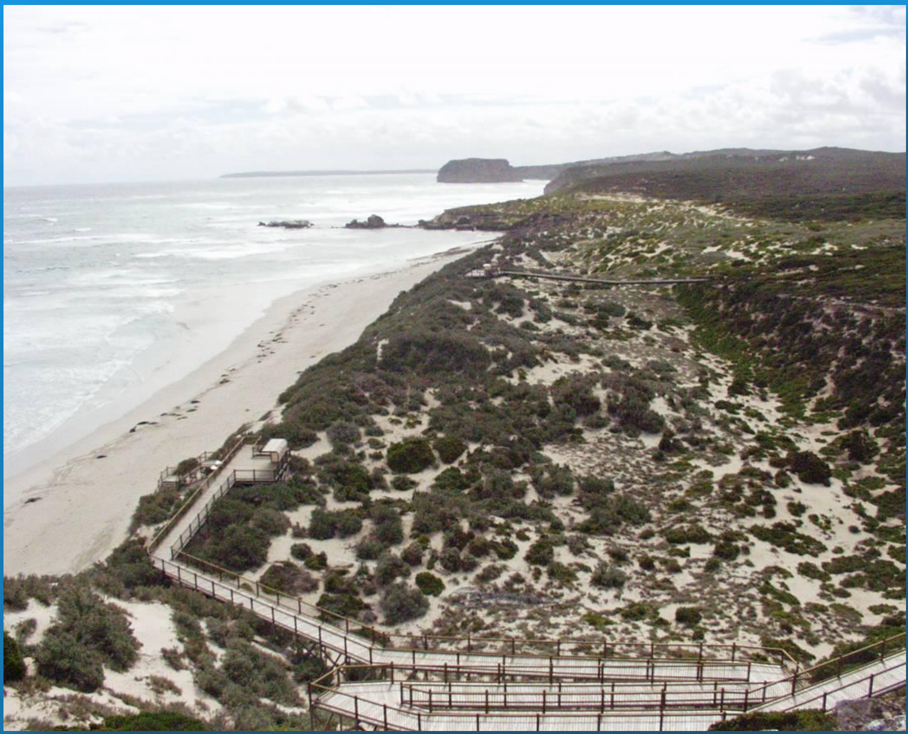
Australian sea lion population monitoring at Seal Bay and the Seal Slide, Kangaroo Island: 2011/12 breeding season



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Final Report to the Department of Environment, Water and Natural Resources

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1 EXECUTIVE SUMMARY

This report provides information on the 2011-12 Australian sea lion breeding season at Seal Bay and the Seal Slide, Kangaroo Island. At Seal Bay the breeding season commenced on 2 October 2011, with the final pup born on 20 June 2012 (duration ~8 months). The median pupping date was 21 February 2012 (sd = 47 days), with 90% of births occurring over 156 days (5.1 months), between 5 December and 9 May 2012. Pup production for the 2011-12 breeding season at Seal Bay was estimated to be 251 (range 249-256), based principally on twice-weekly surveys of new pup births and deaths and Petersen estimates, as well as direct counts of pups in Pup Cove. This estimate is similar to those from the previous three breeding seasons (2010: 267-276; 2008-09: 268-275; 2007: 254-256).

Trends in pup numbers come from two sources: maximum counts of live pups seen in a breeding season (available for 19 consecutive breeding seasons); and pup production estimates based principally on twice-weekly surveys (available for seven breeding seasons). The trend in maximum counts of live pups over 19 consecutive breeding seasons between 1985 and 2011-12 (26 years) shows a significant decline of 1.66% per breeding season, or a 34% decline over 26 years. However, the shorter time-series of pup production estimates over seven consecutive breeding seasons (2002-03 to 2011-12), shows no significant change, and cannot corroborate declines based on maximum live pup counts at this stage.

Pup mortality for the 2011-12 breeding season was estimated to be 41.4%, the highest mortality rate recorded at Seal Bay. Mortality rates over the last seven breeding seasons have varied between approximately 20% and 41%, and have oscillated between the low and high end of that range between consecutive breeding seasons, with 2011-12 being a high mortality season. Low mortality seasons average 22.9% (sd = 2.6), while high mortality seasons averaged 35.4% (sd = 4.3).

A total of 115 pups were microchipped during the 2011-12 breeding season at Seal Bay. Of 173 adult females scanned during the peri-natal period, 55 (32%) had a micro-chip, and 54 could be aged. The youngest breeding females were ~4.5 years old (born in the 2007 breeding season), while the oldest identified were ~9 years old (born in the 2003 breeding season when the microchipping program commenced.

Based on the scanning results between 2003 and 2012, survival and recapture estimates were calculated using Cormack–Jolly–Seber models. These indicated no difference in survival relative to sex, which also had no bearing on recapture probability. Recapture probabilities varied significantly with time, but not with age. Survival varied significantly with age and cohort. In general, survival was low to age 1.5 years and higher thereafter. Mean age-specific survival to age 1.5 years (approximate weaning age) 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). Given that the population ecology and demography of Australian sea lions is poorly understood, these demographic data provide critical information on sea lion life-history.

Pup production at the Seal Slide was estimated to be 13 for the 2011-12 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 seven breeding seasons (since 2002-03), and range between 9 and 16 over this period. No trends are apparent at this stage.

2 INTRODUCTION

The Australian sea lion (ASL, *Neophoca cinerea*) 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 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 17 breeding seasons (1985 to 2008-09) (Goldsworthy *et al.* 2010, McIntosh *et al.* 2012). Although there is some corroboration of this decline from a demographic model of the Seal Bay population (McIntosh 2007), estimates of total pup production achieved through improved survey methodology over the last six breeding seasons show no significant trend in abundance (Goldsworthy *et al.* 2010, 2011). 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 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). 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 approximately 10 nm (18.5 km) offshore, and was estimated to reduce female bycatch mortality in that subpopulation by about 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.

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 tourism businesses operated at Seal Bay and additional tourists visited the Seal Bay beach. From 1970-1972 the number of tourists visiting Seal Bay increased from about 20,000 to 30,000 per year. The Seal Bay Conservation 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 effect 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 beach tours. These tours were implemented to reduce disturbance to the ASL colony, because tourist numbers had continued to increase as 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 (DEWNR unpublished data). It is not known what level of disturbance or visitation is sustainable at Seal Bay, or if current or 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 required 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, the Department of Environment, Water and Natural Resources (DEWNR) funded a joint DEWNR/South Australian Research and Development Institute (SARDI) research project to maintain monitoring of the Seal Bay ASL population over two breeding seasons (2010 and 2011-12), following recommendations detailed by Goldsworthy *et al.* (2007a, 2008).

The aims of the project were to:

1) maintain monitoring of ASL pup production during the 2010 and 2011-12 breeding seasons at Seal Bay and the Seal Slide,
2) maintain monitoring population vital rates during the 2010 and 2011-12 breeding seasons at Seal Bay , and
3) provide detailed reports subsequent to these breeding seasons, and develop a proposal for ongoing monitoring needs of the Seal Bay ASL population in the final 2012 report.

A report on the 2010 breeding season at Seal Bay and Seal Slide was completed in 2011 (Goldsworthy *et al.* 2011); this current report provides results from the 2011-12 breeding season, and describes the future monitoring program proposed for seal populations on Kangaroo Island.

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 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 can be accessed by 4WD vehicle and was visited regularly during the 2011/12 breeding season.

Pup production and population growth estimates

At Seal Bay, three methods were used to estimate pup production during the 2011-12 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 in each breeding season. The models tested were: (1) a simple linear regression model; (2) a 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) a model using generalised least squares (GLS) 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 and environment R version 2.15.1

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 ± 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 (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 between breeding seasons, hand-held scanning of animals was undertaken regularly throughout the colony. To successfully identify seals with a micro-chip, the Radio Frequency Identification (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 the mother if it had been chipped.

Seal Bay Demographic analysis

Capture-history matrices were constructed from the re-sight histories of individual seals over six cohorts. Multiple re-sights within an ~18 month period extending from the beginning of one breeding season through 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 program MARK were used (White and Burnham 1999).

4 RESULTS AND DISCUSSION

Seal Bay - Pup production and population growth

Results of the surveys for pup births and deaths undertaken during the 2011-12 breeding season at Seal Bay are presented in Table 1 and Figure 2. The breeding season commenced with the first pup birth on 2 October 2011 and ended with the final pup birth on 20 June 2012. The duration of the breeding season was approximately 8 months. Based on probit analyses of the cumulative number of births, the median pupping date was 21 February 2012 (sd = 47 days), with 90% of births occurring over 156 days (5.1 months), between 5 December and 9 May 2012 (Table 2).

Variation in the chronology of breeding across the last seven breeding seasons is presented in Figure 3. The mean breeding interval (period between successive median pupping dates) for the five consecutive breeding seasons was 544 days (range 541-550, sd = 3.5) 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 2011-12 breeding season at Seal Bay was 249 (Table 1, Figure 2). Most pups were born in the Main Beach (MB) area west of the area accessed by the public (83 pups, 33.0%) and the EPA (73 pups, 29.3%), with 54 pups (21.7%) reported for the WPA and 39 pups (15.7%) 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 count of live pups was 84 on 16 April 2012 when the cumulative number of dead pups was 83. The cumulative number of pup deaths to the end of the breeding season was 104 on 20 June 2012 when the last new pup was recorded.

Details of 17 mark-recapture 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 95% 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 251 with 95% CL 246-256; (Table 1, Figure 2). This is 2 more than estimated from the cumulative survey of new births (249), and 30 more than the estimate of minimum pup production, which is 219 (total live pups microchipped [115] plus cumulative dead pups at the end of the breeding season [104]) (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 2011-12 season at Seal Bay was 251 (range 249-256), 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 2011-12

Trends in direct counts of live pups extend over 19 consecutive breeding seasons between 1985 and 2011-12 (26 years) (Figure 4).

The linear regression model fitted to the log of maximum live-pup counts shows a significant decline of 1.66% per breeding season ($F_{1,17}$ = 9.705, P = 0.006, r^2 = 0.326), equivalent to a 34% decline over 26 years. The multiple regression model also indicates a significant -1.66% decline per season with '*Period'* a significant factor, improving the model fit considerably ($F_{2,16}$ = 14.350, P < 0.0001, r^2 = 0.597). 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 seven consecutive breeding seasons between 2002-03 and 2011-12 (Figure 4). The linear regression model fitted to the log of estimated pup production showed no evidence of a trend ($F_{1,5}$ = 0.4926, P = 0.514, r^2 = 0.092). Including the '*Period'* term in a multiple regression model did not change this result ($F_{2,4}$ = 0.2346, P = 0.212, r^2 = 0.310). Pup production estimates for the seven 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 does not continue between the 2007 and 2011–12 breeding seasons, each of which is a high pup-production season. Part of this may be attributed to improvements in survey methodologies 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 251 pups for the 2011-12 breeding season at Seal Bay, and a total of 104 cumulative pup deaths at the end of the breeding season, the mortality rate for the breeding season is estimated to be 41.4%, the highest mortality rate recorded for any breeding season (Table 2, Figure 4). The average rate over the last seven breeding seasons is 30% (sd = 7.6); it has varied between about 20% and 41%, and oscillated between the low and high end of that range in consecutive seasons, with 2011-12 being a particularly high mortality season (Figure 4) (Goldsworthy *et al.* 2011). Pup mortality in the low mortality breeding seasons averaged 22.9% (sd = 2.6), while in the high mortality breeding seasons it averaged 35.2% (sd = 4.3) (from Table 2). There was no apparent trend in pup mortality between 2002 and 2011-12.

The best estimates of pup production and mortality commence in 2007; and hence cover just four breeding seasons. They are based on a consistent methodology of pup surveys with access to all parts of the Seal Bay breeding colony. As indicated above, the alternate pattern of high and low pup production apparent in the four breeding seasons up to and including 2007, and in the entire dataset of maximum live pup counts, is absent in the last four pup production estimates (Figure 4). The pattern of alternate high and low estimated pup mortality rates coincides with the alternate pattern in live pup counts that continues to the most recent breeding season (Figure 4). The absence of these fluctuations in the estimated pup production since 2007 suggests that the alternate pattern in live pup counts is largely due to alternate high and low pup mortality seasons which extend back to 1985 (Figure 4). The factors that have contributed to this apparent pattern in pup mortality are unknown, but the pattern raises the question about what is driving the observed decline in live pup counts between 1985 and 2011-12; is it reflecting a decline in pup production, or an increase in pup mortality over time, or both? A greater time series of pup production estimates is required before the relationship between pup production, pup mortality and trends in live pup counts can be resolved.

Seal Bay - micro-chipping and demography program

Microchipping

In the 2011-12 breeding season, 251 pups were estimated to have been born at Seal Bay. Of these, at least 106 (42.2%) died before the end of the breeding season. Of the estimated 147 pups that survived, 115 (80%) were microchipped at the time this report was completed (Table 2), representing 46% of all pups estimated to have been born in the 2011-12 breeding season.

Birth rates

During the 2011-12 breeding season, more systematic scanning of breeding females was introduced in order to monitor reproductive rates. This involved attempts 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 173 adult females associated with the 249 pups recorded in the cumulative survey of new births (i.e. 69% of breeding females). Of these 173 adult females, 55 (32%) had a micro-chip, and 54 could be aged. The youngest breeding females were ~4.5 years old (born in the 2007 breeding season), while the eldest known were ~9 years old (born in the 2003 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 three 4.5 year-old females (6% of the 54 known-age females) gave birth, compared to 16 (30%) 6 year-olds, 24 (44%) 7.5 year-olds and 11 (29%) 9 year-olds (Figure 5).

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

Demography

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 6). In general survival to age 1.5 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 6), 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 7).

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 understanding and managing the population at Seal Bay. Fishery interaction and population viability models will also be improved by the use of estimates based on real 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

A total of five pups were marked over five surveys of the colony in the 2011-12 breeding season at the Seal Slide. Details about the number of unmarked, marked and dead pups sighted on each survey are presented in Table 4. 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 13, based on the survey undertaken on 26 March 2012 (Table 4). 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 many 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 underestimate 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 lower (9 and 11) estimates of pup production.

Estimates of pup abundance at the Seal Slide with a high degree of confidence are now available for the last seven breeding seasons since 2002-03 (Figure 8). The first two are from Shaughnessy *et al.* (2009): 9 pups in 2002-03 and 11 pups in 2004. The next four 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 and 13 pups in 2011-12. The mean number of pups estimated at the Seal Slide over seven seasons is insufficient to provide robust estimates of trends in pup production at this site.

Ongoing monitoring

A monitoring program for ASL populations on Kangaroo Island has been funded for a further three years. The program will continue core monitoring of the ASL population at Seal Bay and the Seal Slide over the 2013 and 2014-15 breeding seasons. Given growing concerns over the potential impacts of expanding fur seal populations on the seafood industry and some sectors of the ecotourism industry, knowledge about the status and trends in abundance of New Zealand fur seal (NZFS, *Arctophoca forsteri*) populations is important to assist DEWNR in management decisions. The Cape Gantheaume Wilderness Protection Area forms an important monitoring site for NZFS because population expansion is not limited by space and suitable habitat, and it can be readily accessed by vehicle. Monitoring of NZFS pup production in the Cape Gantheaume Wilderness Protection Area will be conducted over three consecutive breeding seasons, with field work to be undertaken in January of 2013 to 2015.

The specific aims of the program are to:

1) maintain monitoring of ASL pup production during the 2013 and 2014/15 breeding seasons at Seal Bay and the Seal Slide, Kangaroo Island;
2) maintain monitoring of population, survival and reproductive success during the 2013 and 2014/15 breeding seasons at Seal Bay;
3) provide detailed reports on population dynamics and trends subsequent to the 2013 and 2014/15 breeding seasons;
4) maintain the annual monitoring of NZFS pup production in the Cape Gantheaume Conservation Park over three consecutive breeding seasons (2013, 2014 and 2015).

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 2011-12 breeding season. Shaded area highlights those surveys where Petersen estimates were calculated.

	Date	New	New	Cumulative			Counts			Petersen M-R estimates					
No.		Births	Dead	Born	Dead	Alive	BP	MP	Total live	M	n	m	*N*	*Adj N*	SE
1	02-Oct	1	1	1	1	0	0	0	0						
2	04-Oct	1	1	2	2	0	0	0	0						
3	11-Oct	1	1	3	3	0	0	0	0						
4	07-Nov	1	1	4	4	0	0	0	0						
5	21-Nov	1	1	5	5	0	0	0	0						
5	01-Dec	2	0	7	5	2	2	0	2						
6	05-Dec	2	1	9	6	3	4	0	4						
7	08-Dec	2	1	11	7	4	5	0	5						
8	12-Dec	3	3	14	10	4	4	0	4						
9	15-Dec	2	1	16	11	5	5	0	5						
10	19-Dec	3	1	19	12	7	6	0	6						
11	22-Dec	2	0	21	12	9	10	0	10						
12	26-Dec	0	0	21	12	9	8	0	8						
13	29-Dec	4	2	25	14	11	10	0	10						
14	02-Jan	0	1	25	15	10	9	0	9						
15	05-Jan	6	0	31	15	16	14	0	14						
16	09-Jan	4	1	35	16	19	15	0	15						
17	12-Jan	6	1	41	17	24	20	0	20						
18	17-Jan	7	4	48	21	27	22	0	22						
19	19-Jan	4	1	52	22	30	25	0	25						
20	23-Jan	3	3	55	25	30	24	0	24						
21	26-Jan	6	3	61	28	34	27	0	27						
22	30-Jan	8	3	69	31	39	27	0	27						
23	02-Feb	6	3	75	34	42	33	0	33						
24	06-Feb	10	1	85	35	51	40	0	40						
25	09-Feb	8	1	93	36	58	42	0	42						
26	13-Feb	4	2	97	38	60	43	0	43						
27	16-Feb	20	4	117	42	76	48	0	48						
28	20-Feb	9	1	126	43	84	54	0	54						
29	23-Feb	7	3	133	46	88	47	0	47						
30	27-Feb	6	2	139	48	92	54	0	54						
31	01-Mar	15	2	154	50	105	67	0	67						
32	05-Mar	6	4	160	54	107	55	0	55						
33	08-Mar	10	5	170	59	112	62	0	62						
34	12-Mar	12	3	182	62	121	62	0	62						
35	15-Mar	6	6	188	68	120	73	0	73						
36	19-Mar	7	2	195	70	125	61	0	61						
37	22-Mar	4	1	199	71	128	70	0	70						
38	26-Mar	4	4	203	75	128	62	0	62						
39	29-Mar	5	3	208	78	130	81	0	81						
40	02-Apr	5	1	213	79	134	82	0	82						
41	05-Apr	2	0	215	79	136	75	0	75						
42	09-Apr	5	1	220	80	140	79	0	79						
43	12-Apr	1	3	221	83	138	60	0	60						
44	16-Apr	4	0	225	83	142	84	0	84						
45	19-Apr	1	2	226	85	141	69	0	69						
46	22-Apr	0	0	226	85	141	69	0	69						
47	26-Apr	4	1	230	86	144	68	1	69						
48	30-Apr	3	1	233	87	147	65	0	65						
49	03-May	1	1	234	88	146	60	0	60						
50	07-May	3	1	237	89	148	59	0	59	68	55	33	219	231	9
51	10-May	3	2	240	91	149	47	1	48	71	43	22	246	255	16
52	14-May	0	2	240	93	147	49	3	52	73	50	27	246	255	13
53	17-May	1	1	241	94	147	49	2	51	74	46	30	227	235	9
54	21-May	0	0	241	94	147	50	2	52	79	48	34	226	234	7
55	24-May	1	2	242	96	146	35	1	36	82	35	17	283	290	24
56	29-May	1	2	243	98	145	43	2	45	88	41	28	249	255	11
57	31-May	1	1	244	99	145	74	3	77	89	74	51	252	257	6
58	04-Jun	1	2	245	101	144	49	0	49	90	49	36	248	252	8
59	07-Jun	0	2	245	103	142	47	2	49	90	46	39	235	239	5
60	11-Jun	2	1	247	104	143	63	3	66	93	62	46	256	258	6
61	14-Jun	0	0	247	104	143	56	2	58	93	56	44	250	252	6
62	17-Jun	0	0	247	104	143	51	5	56	93	53	40	256	258	7
63	20-Jun	2	0	249	104	143	58	2	60	93	56	38	270	270	9
64	2-Jul	0	2	249	106	143	48	2	50	93	49	39	254	254	6
65	5-Jul	0	0	249	106	143	45	3	48	98	46	41	248	248	4
66	12-Jul	0	0	249	106	143	59	4	63	105	60	55	253	253	3
				249	106	143							**AdjŇ =**	**251**	**2.4**
													±95% CL (246 – 256)		

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 micro-chipped pups and minimum pup production (micro-chipped + 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 (2007b), 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**
Month breeding season commenced	Dec-02	Jun-04	Dec-05	May-07	Oct-08	May-10	Oct-11
Duration of breeding season (months)	9	7	6	7	7	9	8
Median pupping date	13-Mar-03	5-Sep-04	28-Feb-06	27-Aug-07	24-Feb-09	28-Aug-10	21-Feb-12
± s.d. (days)	42	39	36	36	41	46	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
90% births (days)	139[1]	121	104	120	136	150	156
Cumulative births	-	200	207	245	268	259	249
Cumulative pup deaths	73	70	75	51	88	66	104
Maximum live pup count	122	148	125	145	122	128	84
At months since beginning of BS	6	7	6	6	7	6	6
Max live pup count + cumulative dead[2]	185	208	197	198	197	189	167
Total live pups microchipped	148	202	144	203	161	201	118
Minimum pup production[3]	221	272	219	254	249	267	222
Ň	227	288	203	255[4]	267[4]	269	251
(95% CL)	(216-239)	(273-302)	(199-207)	(245-266)	(259-275)	(261-276)	(246-256)
No. recapture estimates	3	2	3	11	7	13	17
Overall estimate of pup production	227	288	219	255[4]	268[4]	269	251
Confidence limit (min est. to +95% CL)	(221-239)	(273-302)		(254-266)	(268-275)	(267-276)	(249-256)
Mortality rate	32.2%	24.3%	34.2%	20.0%	32.8%	24.5%	41.4%

[1]Shaughnessy et al. (2006)

[2]at time of maximum live count

[3]total microchipped + cumulative dead

[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 re-sighting during some surveys.

Table 3. Demographic models for Australian sea lions at Seal Bay. Overall model rankings – models in the shaded section are not well supported

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 December 2011 and March 2012. 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 minimum 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
14-Dec-11	4	0	0	0	4	4	3	3	4	0	4
18-Jan-12	3	1	1	0	4	5	1	4	6	1	7
27-Jan-12	3	3	0	0	6	6	1	5	7	1	8
14-Feb-12	5	3	0	0	8	8	0	5	10	1	11
26-Mar-12	7	1	0	0	8	8	0	5	12	1	13

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.

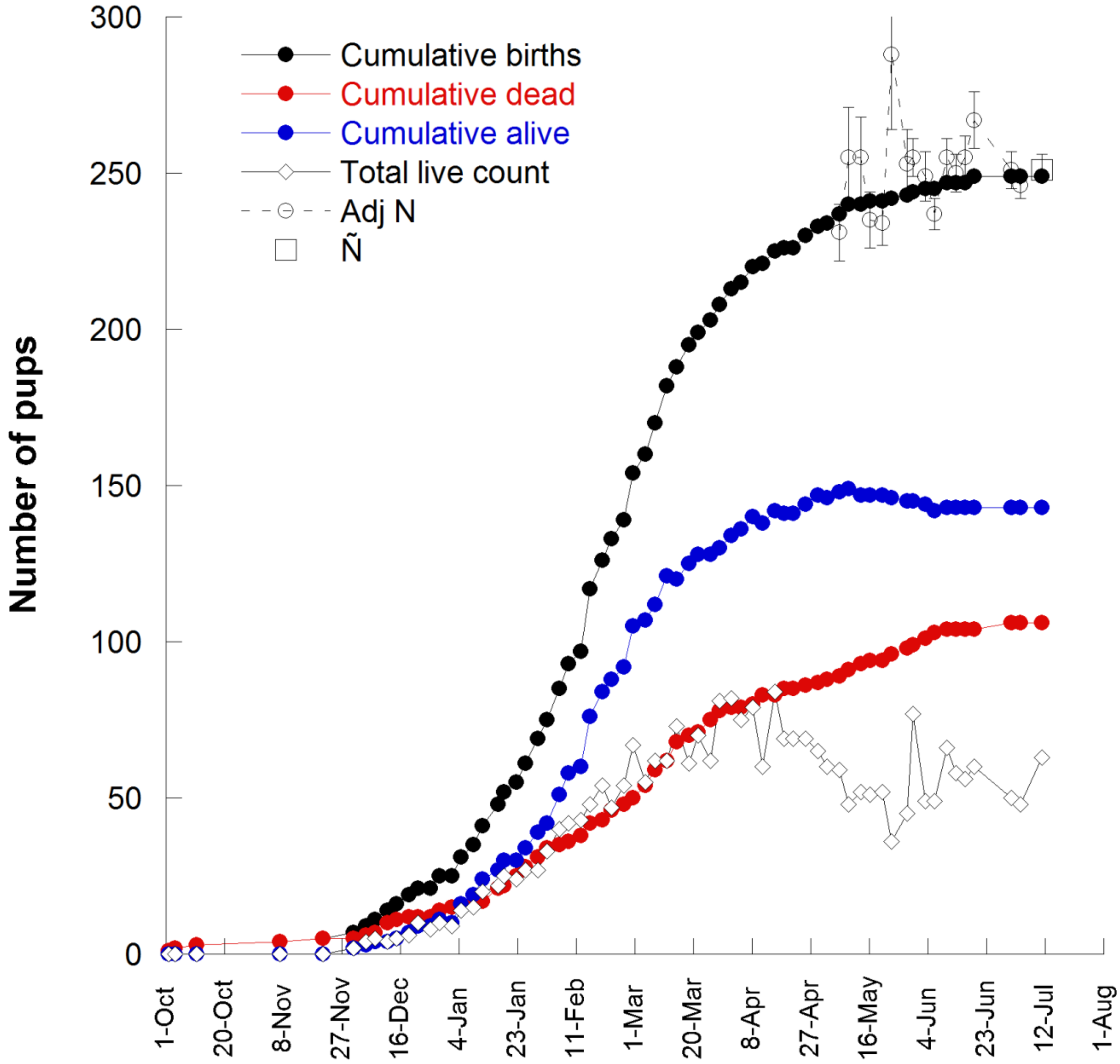

Figure 2. Changes in the number of cumulative pup births, cumulative pup deaths, minimum number of pups alive (cumulative alive), and number of live pups counted during twice weekly surveys of Australian sea lion pups at Seal Bay between 1 October 2011 and 1 July 2012.

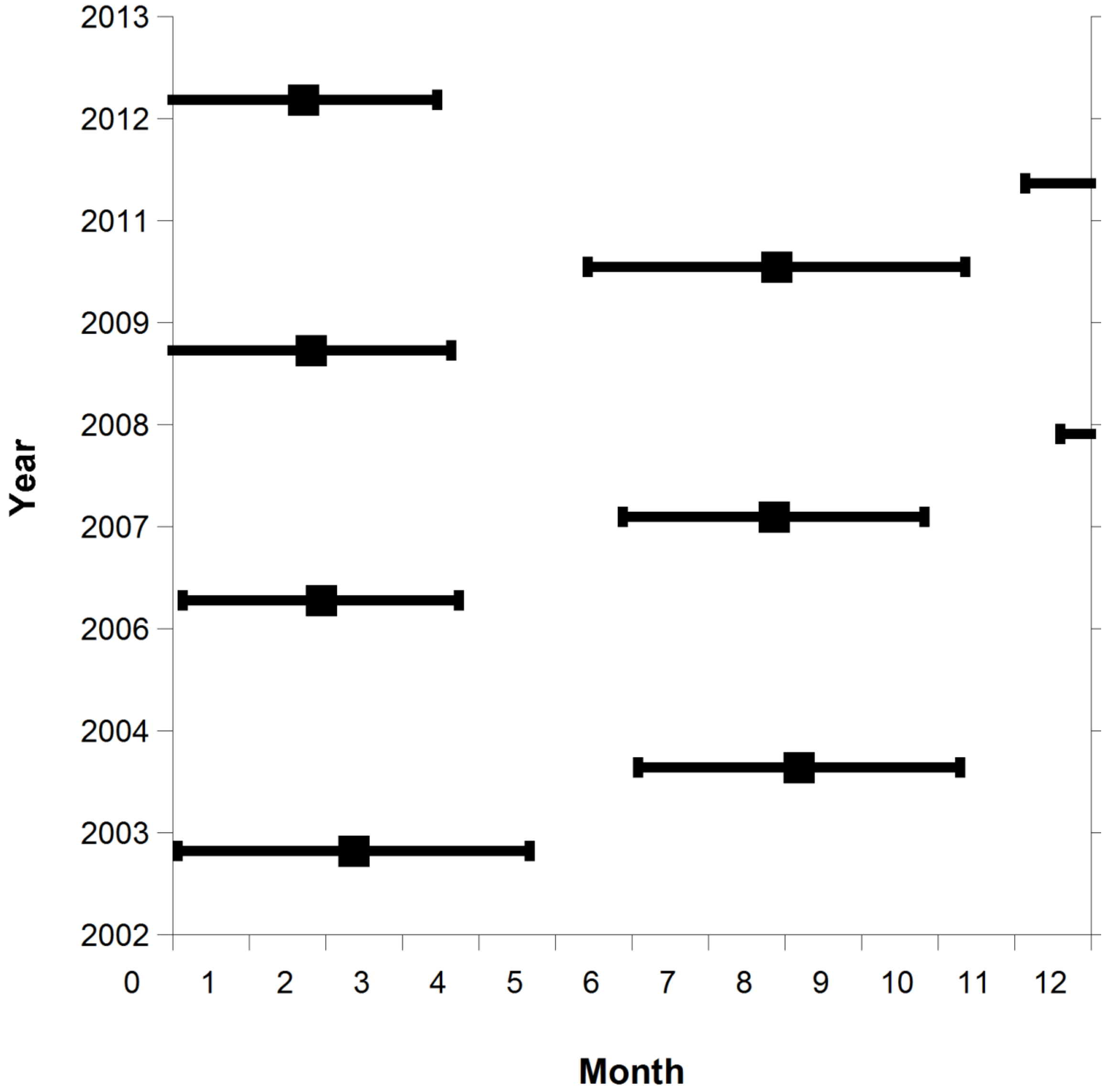

Figure 3. Variation in the breeding season chronology of Australian sea lions at Seal Bay, across seven consecutive breeding seasons. Median pupping dates are indicated by squares and error bars represent the spread of 90% of births (5-95%) based on probit analyses of cumulative pup births.

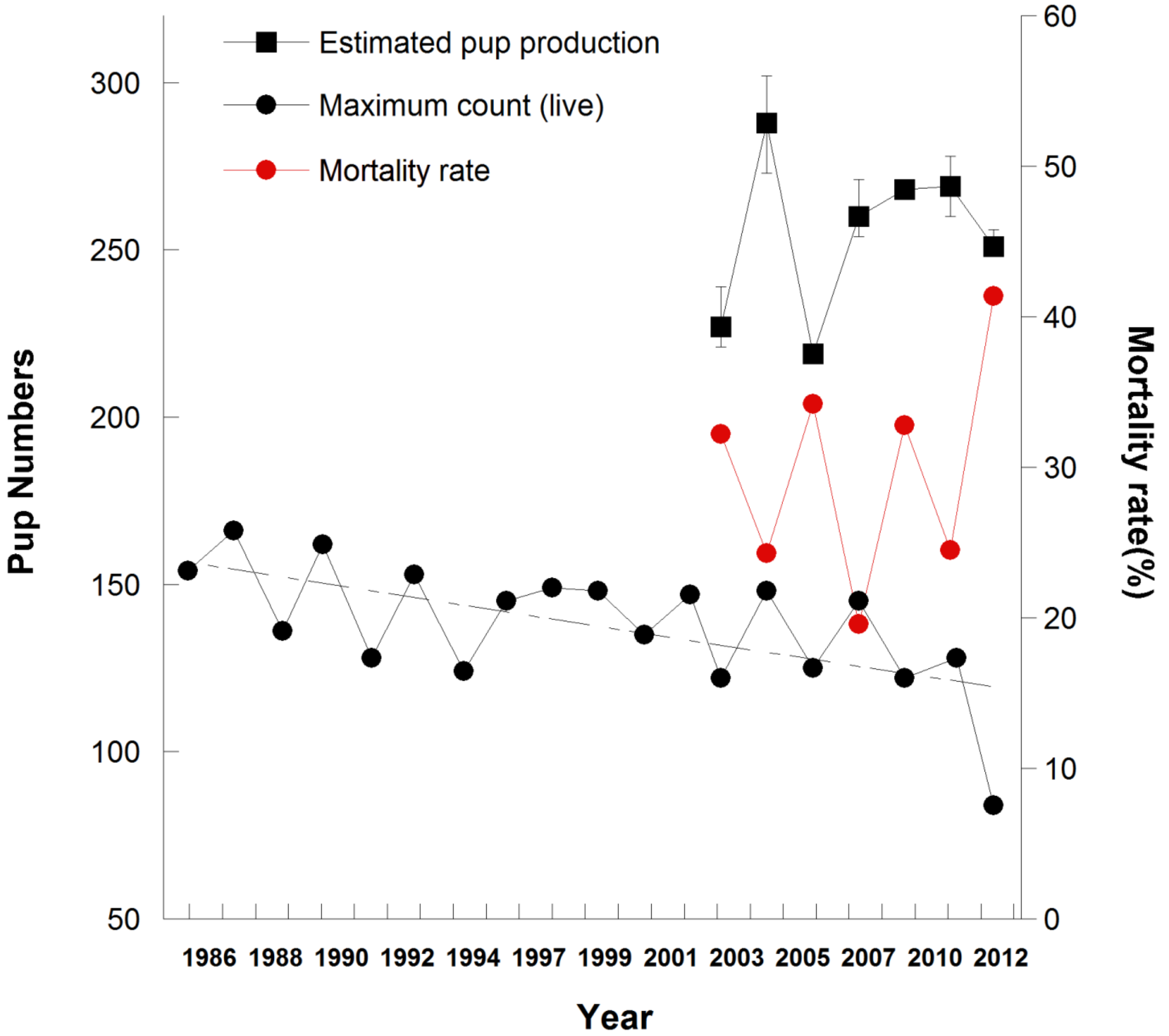

Figure 4. Trends in the abundance of Australian sea lion pups at Seal Bay based on maximum live pup counts for 19 breeding season between 1985 and 2011-12. Trends in the overall estimate of pup production and pup mortality rate are presented for the last 7 breeding seasons.

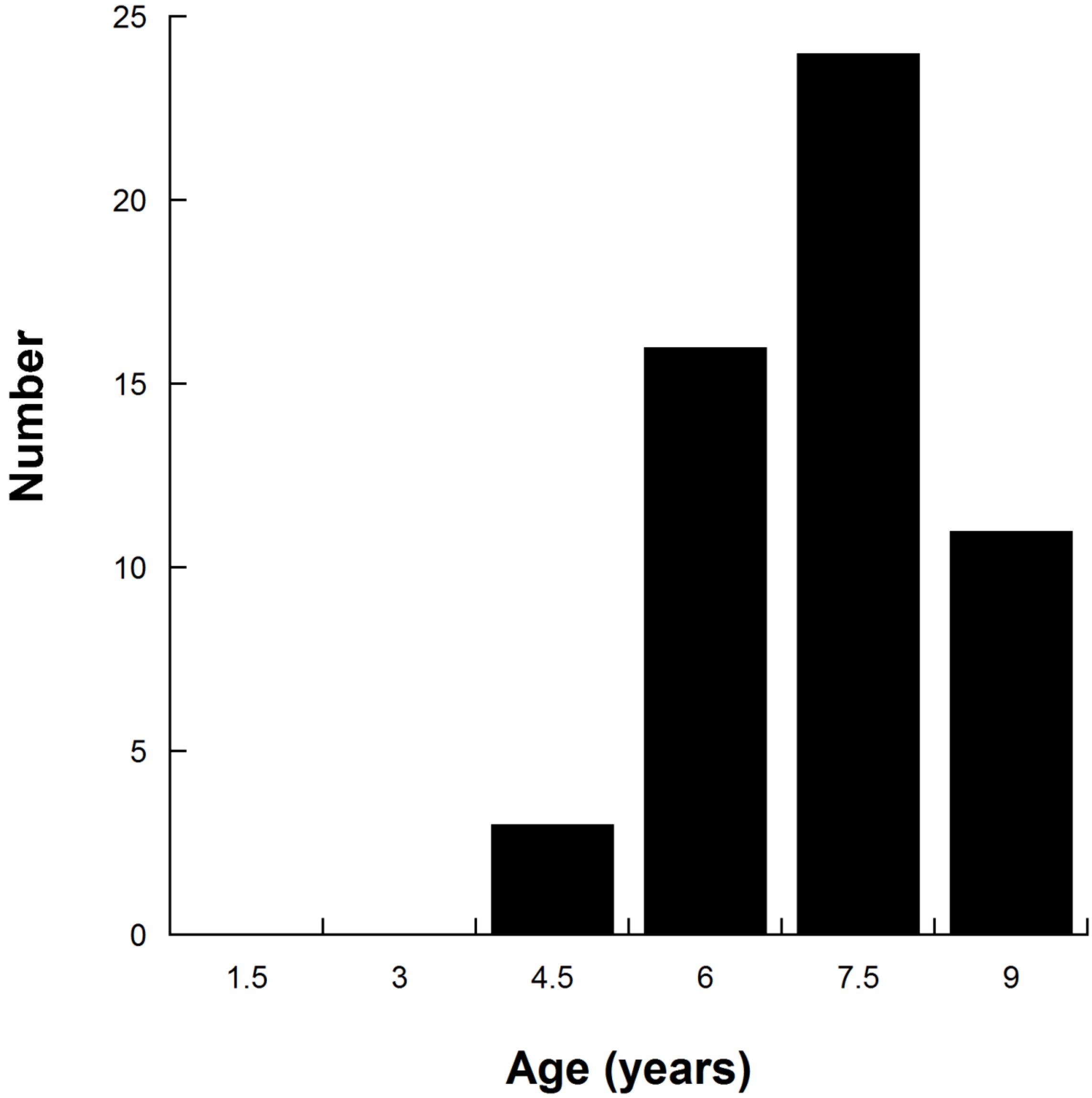

Figure 5. Age distribution of 54 known-age ASL females that pupped at Seal Bay in the 2011-12 breeding season. Note that microchipping only commenced 9 years before the 2011-12 breeding season, and thus no data is available for older individuals.

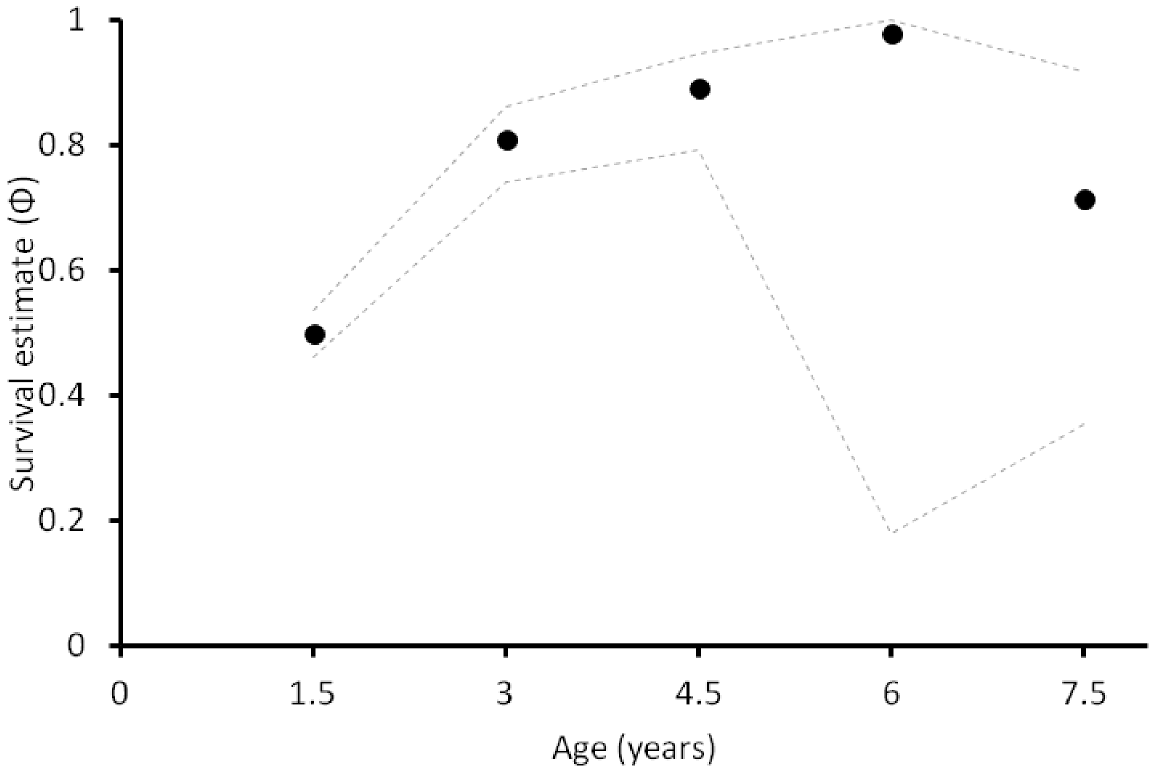

Figure 6. Age-specific survival estimates (filled circle) and the 95% confidence intervals for the estimates (dotted lines) for Australian sea lions at Seal Bay to age 7.5 years.

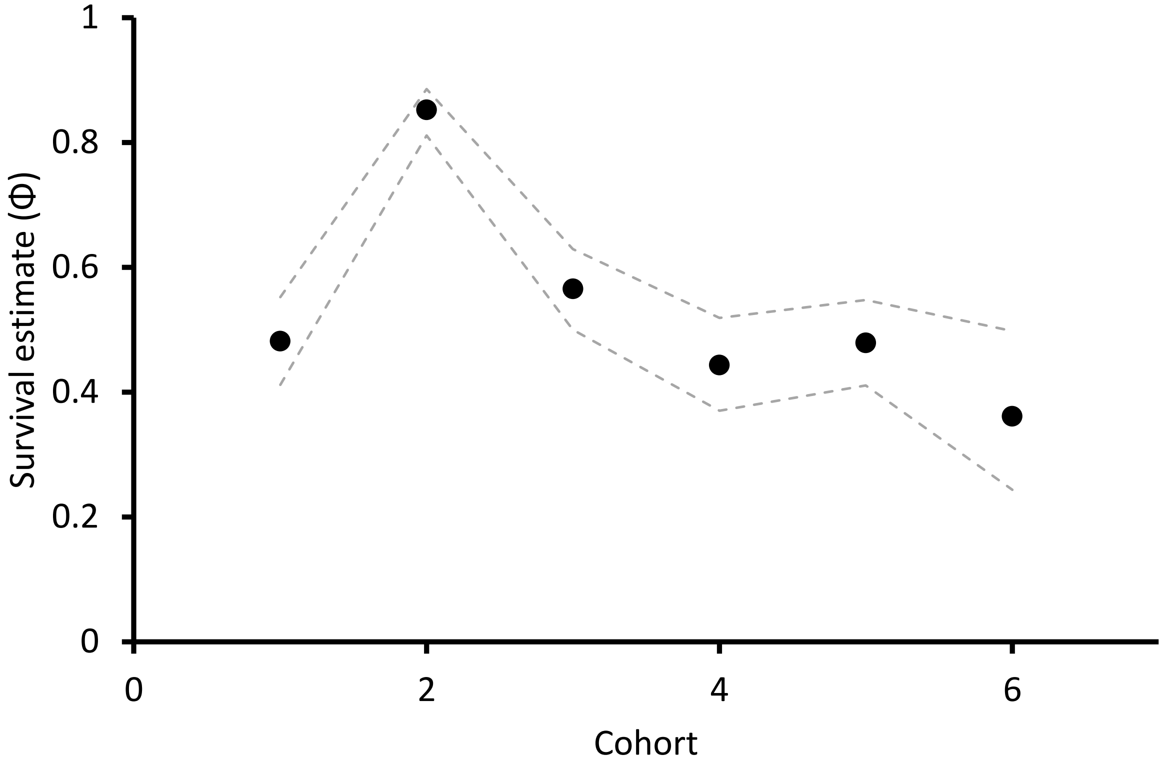

Figure 7. Survival estimates to age 1.5 (filled circles) and 95% confidence intervals (dashed lines) for six cohorts of Australian sea lions at Seal Bay.

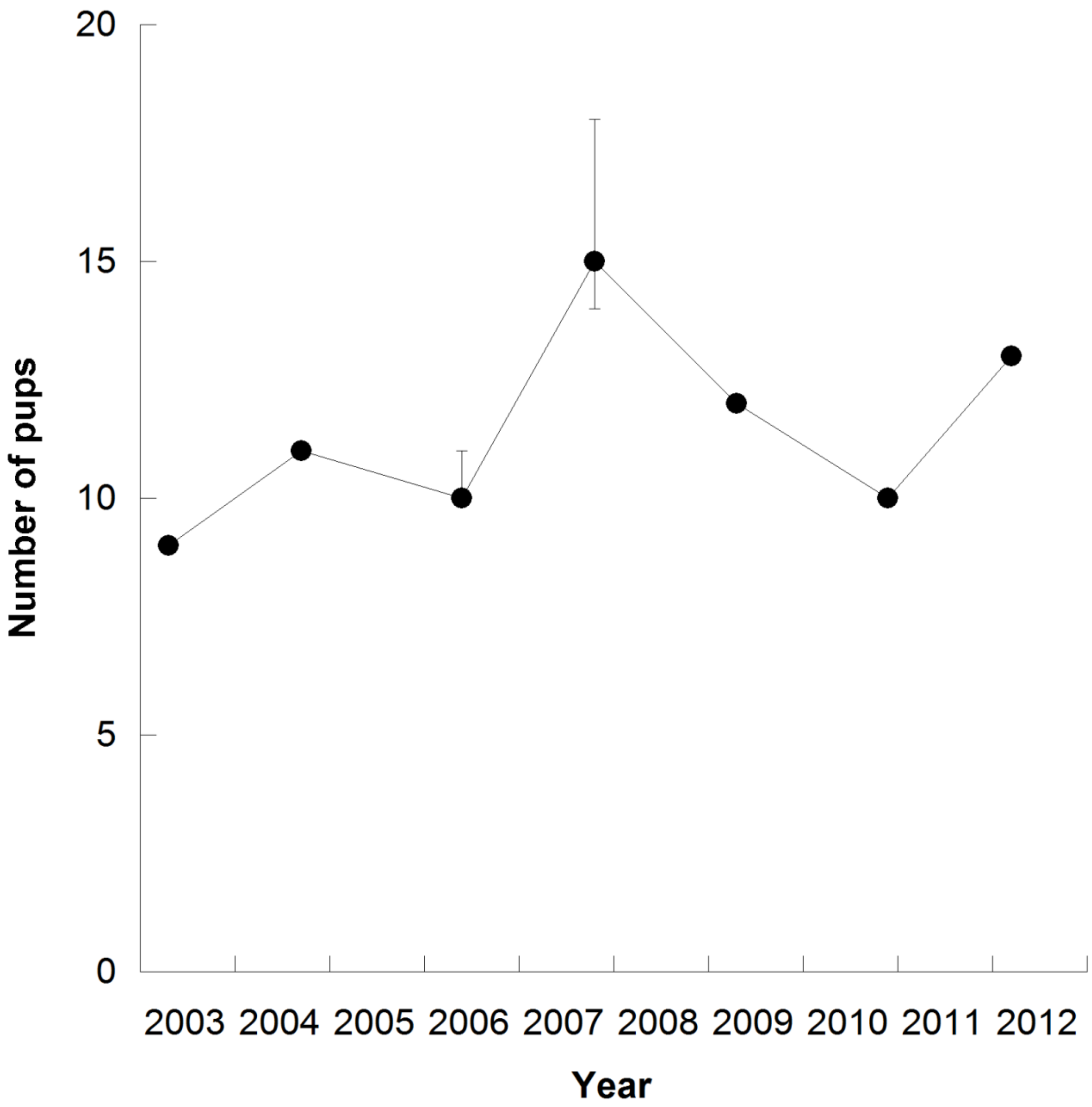

Figure 8. Trends in the estimated Australian sea lion pup production at the Seal Slide (Kangaroo Island), over seven consecutive breeding seasons (2002-03 and 2011-12). Upper (95%) and lower (absolute minimum) confidence limits are available for the 2005-06 and 2007 breeding seasons.

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