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Maintaining the monitoring of pup production at key Australian sea lion colonies in South Australia (2009/10)

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Simon D Goldsworthy, Brad Page and Peter D Shaughnessy

SARDI Publication No. F2010/000665-1
SARDI Research Report Series No. 491

SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

August 2010

Final report to the Australian Marine Mammal Centre

Government of South Australia

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This publication may be cited as:
Goldsworthy, S.D., Page, B. and Shaughnessy, P.D (2010). Maintaining the monitoring of pup production at key Australian sea lion colonies in South Australia (2009/10). South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000665-1. SARDI Research Report Series No. 491. 58pp.

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Printed in Adelaide: August 2010

SARDI Publication No. F2010/000665-1
SARDI Research Report Series No. 491

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Date:	26 August 2010
Distribution:	Australian Marine Mammal Centre, SAASC Library and University of Adelaide Library
Circulation:	Public Domain

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1 EXECUTIVE SUMMARY

This report details the monitoring of Australian sea lion pup production and abundance at a number of breeding colonies within South Australia between late 2008 and early 2010. The breeding season at Seal Bay commenced in October 2008 and finished in May 2009. Pup production at Seal Bay during the 2008/09 breeding season was estimated to be 268 (± 95% CL 268-269), 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. Based upon 17 years data of maximum counts of live pups from, pup abundance is still declining in the colony. Unfortunately the time series for pup production estimates (last five seasons) is too short to provide confidence in these rates of decline. Pup production for the 2008/09 breeding season at the Seal Slide was estimated at 12 using a capture, mark and count method. Based on pup production estimates for the last five breeding seasons (since 2002/03) at the Seal Slide, there has been no significant change in pup production.

Pup production at Olive Island during the 2008/09 breeding season was estimated to be 221 (± 95% CL 195-247), based on mark-recapture methods, but only two surveys were undertaken. It is likely that most if not all pups had been born by the time the first survey was undertaken (26 February 2008). A ground survey was undertaken at Jones Island on 28 February 2008 when ten live and one dead pup were counted, giving a minimum estimate of eleven pups born during the 2007/08 breeding season.

Pup production was estimated for the Dangerous Reef and English Island populations during the 2009/10 breeding season. A combination of mark-recapture methods, counts of live and dead pups (including cumulative mortality) and a method to estimate cumulative production between surveys were used to estimate pup production at Dangerous Reef. The breeding season at Dangerous Reef commenced in June or July 2009 and continued through to March 2010, a period of eight to nine months. Four surveys were made, roughly corresponding to the third, sixth, seventh and ninth month of the breeding season. Using the cumulative pup production estimation method, pup production was estimated to be 715 (95% CL 672-755) for the 2009/10 breeding season. Only one survey of English Island was possible this breeding season (5 December 2009) with a minimum estimate of 39 pups was determined, representing the highest number of pups reported for this colony. A survey was undertaken on the same day at Blyth Island and although a number of Australian sea lions

were counted, no pups or signs of breeding activity were observed, suggesting it is a haul-out site only.

Single ground surveys of pups were undertaken at Lounds, West, Purdie and Fenellon Islands in Nuyts Archipelago between 1 October and 28 November 2009. Most pups were moulted, indicated that the breeding season had ended 2-3 month earlier, and that the timing of the survey was too late to obtain meaningful estimates of pup production. Single ground surveys of pups were undertaken at North Rocky Island, Price and Albatross Island, and aerial surveys undertaken of Islands in the Four Hummock Islands Group (Whidbey Isles Conservation Park) off the southern Eyre Peninsula. Based on the number of female sea lions present at North Rocky Island, this breeding colony may be larger than previous surveys have indicated. The survey of pups at Albatross Island (69 in total post- breeding season), suggests this breeding colony may be much larger than suggested by the previous single ground survey undertaken in 1982 when 12 pups were counted.

2 INTRODUCTION

The Australian sea lion (*Neophoca cinerea*) is Australia's only endemic seal species and is also its least numerous. It is unique among pinnipeds because it is the only species that has a non-annual breeding cycle, which is temporally asynchronous across its range. It has the longest gestation period of any pinniped, as well as protracted breeding and lactation periods. The evolutionary determinants of this unusual reproductive strategy remain enigmatic. These factors, and the species' small population size (~14,700 individuals), which is distributed over numerous, small colonies, make the Australian sea lion vulnerable to extinction (Goldsworthy & Page 2007). Recent population genetic studies have indicated little or no interchange of females among breeding colonies, even those separated by short distances (Campbell et al. 2008). The important conservation implication is that each breeding colony is a closed population. As such, the Australian sea lion poses significant conservation and management challenges. The species is listed as vulnerable under the threatened species category of the Commonwealth *Environment Protection and Biodiversity 1999 Act* (EPBC Act), vulnerable under the South Australian *National Parks and Wildlife Act* (1972) and recently it was upgraded to endangered by the IUCN Redlist.

Original aims and work plan

The aims of this study were to: 1) Undertake end of season pup production surveys at Seal Bay, the Seal Slide, Olive and Jones Island to maintain long-term monitoring continuity; 2) Undertake pup production surveys at other key monitoring sites including Dangerous Reef, English Is, Lilliput Is and Blefuscu Is; and 3) Undertake single surveys at sites that have not been surveyed for long periods; including Albatross, Price/Golden, Four Hummocks, Rocky North Island (Southern Eyre Peninsula) and Lounds, Purdie, West, Fenelon Islands (Nuyts Archipelago). These surveys will establish the breeding status of islands, the timing of breeding schedules to facilitate future monitoring, and determine the number of pups present.

Revised aims and work plan

Delays in project funding notification impacted on parts of the original work plan. A revised work plan was provided to the Australian Marine Mammal Centre on 14 December 2009, and is summarised below:

a) Seal Bay and the Seal Slide – surveys undertaken.

b) Olive Island and Jones Island – two mark-recaptures surveys were undertaken at Olive Island in February and June 2009. Only one survey was possible at Jones Island in February 2009.

c) Blefuscu and Lilliput Island surveys – no surveys undertaken (note: Lilliput Island was visited in June 2009 and breeding was underway – weather constraints precluded the mark-recapture survey and attempts to get onto Blefuscu failed. Weather/sea conditions also prevented landing on both islands in August, and a visit to Lilliput Island in October indicated that breeding had finished, with very few pups remaining on the island. This suggests the breeding season occurred earlier than anticipated at both Lilliput and Blefuscu Islands.

d) Albatross, Four Hummocks, Price, Perforated, Rocky North Islands – ground surveys were undertaken in November 2009.

e) Lounds, Purdie, West and Fenelon Islands - single ground survey was undertaken in October 2009.

f) Dangerous Reef/English Island – mark-recapture surveys of Dangerous Reef were undertaken between October 2009 and March 2010. A single survey of English and Blyth Island was undertaken in March 2010.

3 METHODS

Seal Bay and Seal Slide

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 (Figure 1). The Australian sea lion colony comprises four main areas (Figure 2) 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 (McIntosh 2007). The WPA and EPA were declared in 1972 under the *National Parks and Wildlife Act, 1972* (SA Government Gazette, December 7, 1972, pp. 2543-2544) for the “purposes of conserving the native animals on that portion of the Seal Bay Conservation Park described”.

The Australian sea lion 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 (Figure 1).

The colony can be accessed by 4WD vehicle and was visited on three occasions during the 2008/09 breeding season (18 March, 15 May and 23 July).

At Seal Bay three methods were used to estimate pup production during the 2008/09 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 below). The methodology to survey the Seal Slide followed that described by Goldsworthy et al. (2007b) for small colonies, it is referred to as the cumulative mark and count (CMC) method.

Olive and Jones Island

Olive Island (32.719° S, 133.695° E, Figure 1) was accessed by charter vessel from the township of Streaky Bay, with three visits being made between 30 August and 9 November 2007. During each colony visit a sample of pups was tagged in the trailing edge of each fore-flipper with individually numbered plastic tags (Dalton® Size 1 Supertags). During each field trip, individual re-sight records were collected for marked individuals with the aid of binoculars. A record of dead pups was obtained and rocks were placed on top of carcases to avoid repeat counting. Records of the total number of tagged, untagged and newly recorded dead pups were noted on each field trip, and mark-recapture procedures undertaken to provide information on the numbers of pups present during each survey. The numbers of re-sights of individually marked pups on the days prior to recapture surveys were used as the number of 'marked' individuals in subsequent recapture events using the Petersen estimate procedure (see below).

Jones Island (33.185° S, 134.367° E, Figure 1) is situated at the entrance of Baird Bay on the west coast of the Eyre Peninsula, and was accessed by boat from the settlement at Baird Bay. The island was visited on one occasion during which a ground survey of pups was undertaken (28 February 2009).

Dangerous Reef

Dangerous Reef (34.870° S, 136.217° E) is 35 km south-east of Port Lincoln and forms part of the Sir Joseph Banks Group Conservation Park (Figure 1). It comprises Main Reef with nearby East Reef and West Reef. They cover about 12 ha (Robinson et al. 1996). Sea lion pups are born on Main Reef, and some move to West Reef several weeks after birth. Dangerous Reef was accessed by vessel from Port Lincoln four times, between 18 September 2009 and 13 March 2010. During each visit to the island, sea lion pup numbers were surveyed

by direct counting of live pups, surveying of dead pups and by mark-recapture. Each survey is defined as a session. Methodology for these approaches is detailed below.

Live and dead pup counts

The number of live pups was counted while slowly walking around the island, taking care not to disturb animals on the top of the island, to reduce the chance of double counting. After counting around the periphery of the island, the counters walked through its centre to count the pups.

Live pups were recorded in one of three categories: black pups (considered to be <4 weeks), brown pups (approximately 4-20 weeks) and moulted (>20 weeks age) (Shaughnessy et al. 2005). We recorded the number of pups that had died since the previous visit. To avoid double counting, dead pups were covered with rocks when they were counted. The number of dead pups was added to give the number of 'accumulated dead pups'. When that number was added to the number of live pups, it gave the best available estimate of pup production to that date.

Mark-recapture

Direct counting pups to estimate their abundance is known to underestimate total pup abundance, because pups that are hidden from view (sightability bias) or absent from the colony (availability bias) at the time of the survey are not included. The influence of these factors on estimates of pup numbers can be reduced to some degree by undertaking a mark-recapture procedure. Mark-recapture methods have been used to estimate pup production at fur seal colonies in Australia since 1988 (Shaughnessy et al. 1995, Shaughnessy & McKeown 2002, Kirkwood et al. 2005), but have only recently been applied to estimating pup production in the Australian sea lion population at Seal Bay, Dangerous Reef, Olive and North Page and South Page Islands (McIntosh et al. 2006, Shaughnessy et al. 2006, Goldsworthy et al. 2007b).

A mark-recapture procedure was used to estimate the number of live pups at Seal Bay, Dangerous Reef and Olive Island. At Seal Bay, pups were externally marked by clipping the fur of the rump and also by implanting Passive Integrated Transponder tags (PIT tags: TIRIS™ RFID 23mm) subcutaneously using sterile single-use needles. PIT tags (micro-chips) were inserted in the clipped area, parallel to the spine and close to the tail to minimise gravitation. At other sites, pups were tagged with individually numbered plastic tags (Dalton® Size 1 Supertags), applied to the trailing edge of each fore-flipper. During each field trip,

individual re-sight records were collected for marked individuals with the aid of binocular observations. As noted above, a record of dead pups was obtained by placing rocks on top of carcases to avoid repeat counting. Records of the total number of tagged, untagged and newly recorded dead pups were noted on each field trip (session).

Individual re-sights of tagged pups were usually undertaken over a minimum of three days prior to recapture surveys; they were used as the sample of 'marked' individuals in the population available for the recapture surveys on the last day. During recapture surveys, the individual identity of tagged pups was determined by reading tag numbers with binoculars. The number of untagged pups seen was also recorded, as was the number of recently dead pups that had not been marked. Pups sighted in future surveys (i.e., known to be alive) were included as being available for re-sighting in previous recapture sessions.

Mark-recapture estimates of pup numbers (N) were calculated using a variation of the Petersen method (formula attributed to D.G. Chapman by Seber 1982) with the formula

$$\hat{N} = \frac{(M+1)(n+1)}{(m+1)} - 1,$$

where *M* is the number of marked pups at risk of being sampled during recapture operations, *n* is the number of pups examined in the recapture sample, and *m* is the number of marked pups in the recapture sample.

The variance of this estimate is calculated as

$$\mathrm{var}(\hat{N}) = \frac{(M+1)(n+1)(M-m)(n-m)}{(m+1)^2(m+2)}.$$

Where several mark-recapture estimates ($\hat{N}_j$) are undertaken (one from each recapture session), they are combined by taking the mean (*N*) using formulae from White and Garrott (1990) (pp. 257 & 268):

$$N = \sum_{j=1}^{q} \frac{\hat{N}_j}{q}$$

where *q* is the number of estimates for the colony (i.e., the number of recapture sessions). The variance of this estimate is calculated as

$$\mathrm{var}(N) = \frac{1}{q^2}\sum_{j=1}^{q}\mathrm{var}(\hat{N}_j)$$

Following Kuno (1977) the square root of var(*N*) gives the standard error (*SE*) for the estimation, and the 95 % confidence limits calculated as

$$N \pm (1.96 * SE)$$

The Petersen estimates yields an accurate result as long as a number of conditions are met (Caughley 1977). These include: the probability of capturing an individual is the same for all individuals in the population; no animal is born or immigrates into the study area between marking and recapturing; marked and un-marked individuals die or leave the area at the same rate, and no marks are lost.

Cumulative pup production

The number of pup births that occurred between consecutive mark-recapture surveys $\hat{B}_{1-2}$ was estimated as

$$\hat{B}_{1-2} = \hat{N}_2 - \hat{N}_1\hat{\varphi}_{1-2},$$

Where $\hat{N}_1$ is the estimated total number of pups born from Petersen estimates plus cumulative dead pups up until Session 1, and $\hat{N}_2$ is the number of pups estimated in session 2. $\hat{N}_2 - \hat{N}_1$ is therefore the net pup production between sessions 1 and 2 (i.e. the number of births minus the number of deaths that have occurred between each session). $\hat{\varphi}_{1-2}$, is the apparent survival of pups between session 1 and 2 and is estimated as the proportion of the marked pups known to be alive in session 1 (M_1), that were known to be alive in session 2 (or M_2 / M_1). This approach was repeated to estimate the number of births that occurred between session 2 and 3, and sessions 3 and 4. Total cumulative pup production (*N*) was hence estimated as:

$$N = \hat{N}_1 + \hat{B}_{1-2} + \hat{B}_{2-3} + \hat{B}_{3-4},$$

Confidence limits (± 95% CL) for each between-session estimate were calculated using either the +95% CL or -95%CL estimates, rather than the mean estimate of $\hat{N}$.

Trends in abundance

The rate of change in pup numbers was calculated using linear regression of the natural logarithm of the mean estimate of pup numbers against year or breeding season (~1.5 years). The exponential rate of increase (r) is the slope of the regression line. An exponential rate of increase has been demonstrated for other seal species, for example the New Zealand fur seal on Kangaroo Island (Shaughnessy et al. 1995). It can be expressed as a percentage increase using the following formula $(e^r-1) * 100$.

English and Blyth Islands

English Island (34.638 S, 136.196 E) and Blyth Island (34.568 S, 136.292 E) form part of the Sir Joseph Banks Group Conservation Park in southern Spencer Gulf. Australian sea lions were surveyed on these islands on 5 December 2009 (Figure 1).

Nuyts Archipelago

Lounds, Purdie, West and Fenelon Islands in the Nuyts Archipelago were surveyed once between 28 October and 1 November 2009, when a helicopter became available for use. Ground counts of live and dead pup were undertaken, and pups were categorised according to the pelage stage (black, brown and moulted).

Lower Eyre Peninsula

Single ground surveys of Australian sea lions were undertaken on Rocky North, Price and Albatross Islands on 26 November 2009. Ground counts of live and dead pup were undertaken, and pups were categorised according to the pelage stage (black, brown and moulted). Islands of the Four Hummocks Group (North, Middle, between Middle and South, and South), including the small rock between the Four Hummocks and Perforated Island, were surveyed from the air during close approach fly-overs. Australian sea lions were counted and categorised either as juveniles, adult females or adult males, and a search was made for pups.

4 RESULTS AND DISCUSSION

Seal Bay and Seal Slide

Seal Bay - cumulative births and deaths surveys and mark-recapture

Results of the birth and death surveys undertaken during the 2008/09 breeding season at Seal Bay are presented in Table 1. Details of all the survey results for each area within the

colony are given in Appendix 1. The breeding season lasted 7.4 months, commencing in late October 2008 and ending in late May 2009. 90% of births occurred over 136 days (4.5 months), between 18 December 2008 and 3 May 2009 (Table 2). The median pupping date was 24 February 2009 (sd = 41 days) (Table 2). The mean interval in median pupping date between four consecutive breeding seasons was 543.8 days (range 541-547, sd = 2.8, n = 4) or 17.9 months, based on the median pupping dates in Table 2.

The cumulative number of births recorded for the 2008/09 breeding season at Seal Bay was 268 (Table 1, Figure 3). Most pups were born in the Main Beach area beyond the area accessed by the public (85, 31.7%) and the WPA (83 pups, 31.0%), with 55 pups reported for the EPA (20.5%) and 45 pups for Pup Cove (16.8%) (see Appendix 1). As Pup Cove could only be surveyed from along the cliff-line at various vantage points, the number of cumulative births there may be under-estimated.

Of the 268 births, 88 (32.8%) were reported dead by the end of the breeding season (Table 1). The highest live pup count was 122 on 11 May 2009 (Table 1, Figure 3).

Details of 19 mark-recapture Petersen estimates are provided in Table 1. For the *AdjN* values (estimates of total pup production), estimates ranged between 222 and 305 (Table 1, Figure 5). The estimate of pup production based on this approach was 259 with 95% CL 249-269 (Table 1 and 2). This is 9 fewer pups than estimated from the cumulative survey of new births, of 268.

Given that some births may have been missed (particularly in Pup Cove), the final estimate of pup production for the 2008/09 season at Seal Bay takes the lowest estimate as the cumulative number of births and the upper estimate as the upper 95% CL of the mark recapture estimate; hence it can be expressed as 268 (268-269).

Seal Bay - trends in pup abundance and pup production

The surveys undertaken during the 2008/09 season at Seal Bay represent the fifth consecutive breeding season when mark-recapture procedures have been used to provide Petersen estimates of pup production. Comparison of the timing of breeding, estimates of pup production, highest live pup counts and cumulative births and pup deaths between these four breeding seasons are given in Table 2. In addition, trends in live pup counts between 1985 and 2008/09 (17 breeding seasons), and Petersen estimates of pup production and mortality rates of pups between 2002/03 and 2008/09 are presented in Figure 4.

As detected by Shaughnessy et al. (2006), an examination of the trends in maximum live pup counts between 1985 and 2007 identified an apparent oscillation in pup numbers between high and low seasons, and a declining trend (Figure 4). Trend analyses in maximum live pup counts for the 17 pupping seasons between 1985 and 2008/09, demonstrate an annual decrease of -0.65% per year ($F_{1,16}$ = 4.70, P = 0.047, r^2 = 0.239, or -0.95% per breeding cycle ($F_{1,16}$ = 4.64, P = 0.048, r^2 = 0.236), which amounts to a decrease of -14.15% over the 17 year period.

Examination of estimates of pup production over the five consecutive breeding seasons based on mark-recapture and cumulative birth estimates 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 low pup production years and 2004 and 2007 being high pup production years. However, the pup production estimate for the 2008/09 season, which shows a slight increase compared to 2007 season (3.1%), is at odds with the maximum live pup count which shows a decline compared to 2007 season. Part of this may be attributed to improvements in survey methodologies between seasons. The Eastern Prohibited Area (EPA) was only accessible to regular surveys from mid-way through the 2007 breeding season. The 2008/09 breeding season therefore represents the first during which access to the EPA has been available for the entire breeding season.

Analyses of pup production estimates for five pupping seasons between 2002/03 and 2008/09 show no significant trend in pup production (year $F_{1,4}$= 0.333, P = 0.604; season $F_{1,4}$= 0.331, P = 0.605) (Figure 4). Given the variation in pup production estimates between years is high (mean 18.2%, range 3.1 – 26.9%), there are not enough seasons for which pup production estimates were made to provide a clear indication of trends at this stage.

Based upon four more seasons of maximum counts of live pups following those reported by Shaughnessy et al. (2006), pup abundance is still declining significantly. Unfortunately the time series for pup production estimates (last five seasons) is too short, and the variation in pup production between seasons is too high, to provide confidence in these rates of decline. Based upon a demographic model developed by McIntosh (2007) incorporating all the available data from tagged and micro-chipped seals in the Seal Bay population, the population is estimated to be declining at -4.5% per breeding season. However, demographic models are based on estimated fecundity, and incomplete estimates of adult survival that do not include senescence. Further analyses of survival data are currently underway, which should provide a further update on the status of the Seal Bay population.

Seal Bay - pup mortality

Based on a pup production estimate of 268 pups for the 2008/09 breeding season at Seal Bay, and a total of 88 cumulative pup deaths, the mortality rate for the breeding season was estimated to be 32.8% (Table 2). The average over the last five breeding seasons is 28.6% (sd = 6.4). The mortality rate in consecutive breeding seasons continues to oscillate between about 20% and 35%, with 2008/09 being a high season (Figure 4).

Seal Slide - pup abundance

A total of 7 pups were marked over three surveys of the colony in the 2008/09 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 present in the population, based on the re-sight and marking history is also presented. Based on these data, the minimum number of pups estimated to have been born in the subpopulation was 12, based on the survey undertaken on 7 May (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 go 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 in the past at the Seal Slide may represent dispersed pups 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 controlling for dispersed pups from Seal Bay, this adjustment is likely to result in an underestimate of actual pup production as it will omit any 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 age (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 that season. For those two seasons, results were therefore more accurate and reliable

Estimates of pup abundance at the Seal Slide with a high level of confidence are now available for the last five breeding seasons (Figure 5). 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 Peterson estimate in 2005/06; 16 pups, range 15-18 based upon Peterson estimate in 2007; and 12 pups in 2008/09 (Goldsworthy et

al. 2007b, Goldsworthy et al. 2008a). There is no significant trend in pup abundance based on these data (year $F_{1,4}$=2.223, P = 0.233; season $F_{1,4}$=3.238, P = 0.170) (Figure 5).

Olive and Jones Island

Olive Island

Ninety-eight pups were marked for the mark-recapture estimate procedure in February 2009. Only two mark-recapture sessions were undertaken, one on 26 February and the second on 1 June 2009. Petersen estimates of the number of live pups were greatest during the first session (mean 213, 95% CL 187-239), and lowest during the second session (mean 159, 95% CL 145-172, Table 4 and 5). The addition of eight cumulative dead pups to these values provided higher estimates of pup numbers, the greatest being 221 in February 2009 (95% CL 195-247, Table 4). By the time the second recapture session (undertaken about 3 month later), the breeding season was well and truly over, and the Petersen estimate was about 0.75 that of the previous survey (Table 4 and 5).

Based on tag re-sights between sessions 1 and 2, the apparent survival rate (φ) was about 0.79 (Table 4). Based on Petersen estimates of live pups plus cumulative dead pups, and using the cumulative pup production method, there was a net decline in pup numbers between session 1 and 2, suggesting that most/or all of the pup production occurred by 26 February, or that negative net-change in pup production between sessions was due to a greater number of pup dispersals than births.

Olive Island was recorded as a breeding colony in November 1977 when 52 pups were seen (Dennis 2005). Pups were also seen there in April 1979 (49 unclassed) (Ling & Walker 1979a) and in November 1990 (27 moulted and one dead) (Gales et al. 1994, Dennis 2005). Based on three ground counts undertaken between February and July 2003, 121 pups were estimated to have been born (117 pups were seen in July plus 4 dead in May 2003) (Shaughnessy et al. 2005). Ground counts undertaken in September 2004 and January 2005 estimated pup production of 131 pups (Shaughnessy 2005a). During the 2006 season, the highest ground count was 126 on 13 April with 24 dead recorded to that date (i.e. 150 in total). Combined Petersen and Cormack Jolly Seber estimates for the 2006 season determined that pup production was 206 (191-267), and for 2007 was 161 (151-172) (Goldsworthy et al. 2007b). The estimate for the most recent breeding season in 2008/09 using similar methods was 221 (195-247), similar to the 2006 survey. Based on the most accurate surveys undertaken at Olive Island over the last three breeding seasons, the pattern of alternate high and low pup production seasons, as observed at Seal Bay, may also be a feature of the Olive

Island colony. Given the limited time-series and high level of variation in estimated pup production between breeding seasons (22 –37%), more seasons data are required before trends in abundance can be assessed with some level of confidence.

Jones Island

Jones Island was surveyed on 28 February 2009. Ten live pups (1 black, 9 brown) and one dead pup were observed, giving a total of 11 pups. No further surveys were undertaken so it cannot be determined if further births occurred. As such the 2008/09 breeding season survey should be considered as a minimum estimate.

The first record of breeding at Jones Island was in August 1977 (2 pups) based on a ground survey, and the next survey when pups were seen was not until December 1990 (5 pups, Gales et al. 1994). More complete ground count data are available for the 1998/99 (9 pups), 2000 (6 pups), 2001/02 (12 pups), 2003 (7 pups) and 2004/05 (15 pups) breeding seasons (Shaughnessy et al. 2005). No data were obtained for the 2006 breeding season. The estimate of pup production for the 2007 season was 15 (Goldsworthy et al. 2008b).

Dangerous Reef

Pup counts

On the first visit to Dangerous Reef on 18 September 2009, 136 live pups were recorded, suggesting the breeding season had commenced 2-3 months earlier (in June or July) (Table 6). Newborn pups were sighted in the final surveys in March 2010, suggesting that the duration of the breeding season for 2009/10 was about 8-9 months. Counts of live and dead pups surveyed at Dangerous Reef during the 2009/10 pupping season are presented in Table 6. The largest estimate of pups, based on the maximum number of live pups counted (392) and cumulative dead pups (43), was 435 on 5 December 2009 (Table 6).

Mark-recapture estimates of pup numbers

Two hundred and thirty pups were marked for the mark-recapture estimate procedure (Table 6). The number of tagged pups available to be re-sighted varied considerably between surveys (from 52 to 168, Table 7). Petersen estimates of the number of live pups were greatest during the second session, in December 2009 (mean 445, 95% CL 422-468), and then progressively declined in the third (mean 417, 95% CL 383-444) and fourth recapture

sessions (mean 293, 95%CL 272-315, Table 7). The addition of cumulative dead pups to these values provided higher estimates of pup numbers, the greatest being 488 in December 2009 (95% CL 465-511, Table 6).

Comparisons of Petersen estimates with direct counts at Dangerous Reef have now been made over six breeding seasons (Table 8). Petersen estimates were between 1.19 and 1.38 times the direct count figures (95% confidence limits of comparisons ranged from 1.12 to 1.45). This indicates that estimates derived from mark-recapture procedures were similar to but larger than direct counts in the six pupping seasons. The discrepancy between the direct counts and the Petersen estimates on each occasion results from the difficulty of sighting all pups in the colony. Some pups may not be viewed during counting because they are away from the island, swimming in the shallows or obscured by rocks.

Cumulative pup production estimates

The cumulative pup production method assumes that the sum of the Petersen estimate and cumulative mortalities in the first session (158, 95% CL 149-167; 18 September 2009) are representative of all pups born to that date. Based on the pelage pattern of pups (Figure 6), this assumption is supported as most pups are likely to have been <3 months old, and as such would unlikely to be spending significant time at sea. Based on tag re-sights between sessions 1 and 2, 2 and 3, and 3 and 4, apparent survival rates (φ) were 0.75, 0.67 and 0.67, respectively (Table 6). Based on Petersen estimates of live pups plus cumulative dead pups, the numbers of births between these sessions was 370, 141 and 46, providing a cumulative pup production estimate for the 2009/10 breeding season of 715 (672-755, ±95%CL) (Table 6). This estimate is 38.4% greater than the largest Petersen estimate of live pups plus cumulative dead pups. The cumulative pup production method was also applied to the previous two breeding seasons at Dangerous Reef (2006/07; 2008) (Table 10). Cumulative pup production estimates range from 1.04 to 1.87 times Petersen estimate methods.

Assuming the 2009/10 breeding season at Dangerous Reef commenced about 3 months earlier than the first survey (i.e., on 18 June 2009), the estimated cumulative pup production curve is presented in Figure 7. A probit analysis of the sigmoidal function fitted to these data to determine the season of births (Caughley 1977) identified the median pupping date as 11 November 2009, with 90% of births occurring between 11 August 2009 and 11 January 2010 (184 days or 6.1 months).

Pup mortality

For the 2009/10 pupping season at Dangerous Reef, 43 dead pups were recorded by 5 December 2009 when the estimated number of births reached a maximum of 435, giving an incidence of pup mortality of 9.9% (Table 9).

For the last ten pupping seasons at Dangerous Reef (since 1996), the incidence of pup mortality has ranged from 9.9% to 44.6% (Table 9). It was higher for pupping seasons that occurred predominantly in winter (30.3% in 1996, 42.0% in 1999, 44.6% in 2002, 31.1% in 2005, and 43.0% in 2008, with un-weighted average 38.2%) and lower for pupping seasons that occurred predominantly in summer (15.3% in 1997/98, 22.9% in 2000/01, 18.6% in 2003/04, 13.9% in 2006/07 and 9.9% in 2009/10, with un-weighted average 16.1%). For this analysis, data for pupping seasons before 1996 have been omitted because dead pups were poorly surveyed. A one-way ANOVA comparing the mortality rate between summer and winter breeding seasons, indicated that mortality rate (proportion of dead pups) was significantly higher in winter breeding seasons than summer ($F_{1,8}$ =33.074, P<0.001, arcsine transformed data).

Based on cumulative pup production estimates, mortality rates to the last survey of the last three breeding seasons (2006/07, 2008, 2009/10) have been 10.6%, 42.7% and 9.6%, respectively (Table 10).

Trends in abundance at Dangerous Reef

Live and dead pup surveys

Estimates of pup numbers (live and dead) by direct counting are available for 14 seasons from 1975 to 2009/10, and range from 248 to 585 with an average of 402 (sd = 111) (Table 9, Figure 8).

Because dead pups were not counted in the 1994/95 season, the number of live pups in that season has been used to estimate the total number of births (Table 9, see Shaughnessy (2005c). Using the maximum live-pup counts and numbers of cumulative dead pups over these 14 breeding seasons (1975 to 2009/10) as an index of pup production, the number of pups born at Dangerous Reef has increased by r = 0.026 or 2.65% per breeding season (~ 1.5 years) or r= 0.017 or 1.76% per year. The trend is not significant ($F_{1,13}$ =10.604, P=0.069, R^2=0.469).

Estimated pup numbers from three pupping seasons are considerably smaller than the others: 262 pups in 1976/77, 260 in 1990 and 248 in 1997/98 (Figure 8). Each of these counts was made in the fourth month after pupping began, whereas maximum counts for all but one of the other seasons were made in the fifth month or later (Table 9). Counting that ended in the fourth month of a pupping season is likely to underestimate pup production considerably. Data for the 1994/95 season were incomplete, because there were no counts of dead pups and total births were adjusted for mortality based on the averages from the three preceding summer breeding seasons (Table 9). The most accurate pup count data have been collected since 1996. Analyses of the nine pupping seasons from 1996 (excluding 1997/98), indicate that pup counts have increased at r = 0.038 or 3.9% per breeding season, equivalent to r = 0.025 or 2.6% per year, which is greater than that obtained above over the full 14 seasons for which data are available. This is the best interpretation of these data and the increasing trend is significant ($F_{1,8}$ =7.486, P=0.029, R^2=0.517) (Figure 8).

Despite variable and often high rates of pup mortality between season, the maximum direct count of live pups (maximum pup count – cumulative dead pups at the maximum pup count), still showed a significant increase over 10 seasons from 1996 (r = 0.057, 5.9%) and years (r = 0.038, 3.9%) using data collected since 1996 ($F_{1,9}$ =5.61, P=0.045, R^2=0.427) (Figure 8).

Mark-recapture surveys

Petersen estimates for live pups plus the cumulative number of dead pups to the time of that survey, have been undertaken over seven breeding seasons between 1999 to 2009/10 (Table 8). Trend data for the seven seasons show an increase between seasons of r = 0.034 or 3.4% per season, which is equivalent to r = 0.022 or 2.3% increase per year (Figure 8). With the drop in pup numbers in the 2008 and 2009/10 breeding seasons, and with the limited time series of the mark-recapture data set, this trends is not significant ($F_{1,5}$ =0.936, P=0.388, R^2=0.436).

Cumulative pup production

Estimates of pup production based on the cumulative pup production method are only available for three consecutive breeding seasons (2006/07, 2008, 2009/10): 831, 541 and 715 (Table 10). Data from more breeding seasons are required before trends in abundance can be accurately assessed using this method.

English and Blyth Island

English Island was surveyed on one occasion, 5 December 2009. On this visit 37 live pups (11 black, 26 brown) and 2 dead pups were observed. This gives a total estimate of 39 pups for the 2009/10 season.

Australian sea lion pup abundance has now been surveyed at English Island over seven breeding seasons. Between 1998 and 2002, between 4 and 15 pups were recorded (Shaughnessy et al. 2005) and 18 pups were seen in February 1991 (Gales et al. 1994). In the 2005 breeding season pup production was estimated to be 27 (Goldsworthy et al. 2009d), and in 2008, a minimum of 23 pups were reported (Goldsworthy et al. 2009b). The estimate for the 2009/10 breeding season, based on a single survey, was 39 pups. Previous surveys have been confounded by the issue of pups dispersing to English Island from Dangerous Reef during the breeding season, as well as high variability in survey effort across breeding seasons. However, based on historical surveys the trend in pup abundance for this colony is positive.

A ground survey of Blyth Island on the same day English Island was surveyed identified that the island is an important haul-out location (18 adult males, 2 sub-adult males, 10 adult females and 38 juveniles). No pups were seen.

Nuyts Archipelago surveys

A helicopter survey of other Australian sea lion islands in the Nuyts Archipelago was undertaken on 7 April 2008. Ground surveys where pups were counted were undertaken at four breeding colonies (Lounds, West, Purdie and Fenelon islands). Details are presented in Table 11. Based on the pelage stage of pups (mostly moulted), the breeding season had probably ended within 2-3 months on most islands. As many pups are likely to have dispersed by this stage, these surveys likely represent an underestimate of the total pups born. Comparison with previous surveys are presented in Table 12. Information is sporadic, with the most comprehensive surveys undertaken in 1990 (Gales et al. 1994), 2005 (Goldsworthy et al. 2009d), and 2007/08 (Goldsworthy et al. 2009c). Breakwater Island and Gliddon Reefs were only confirmed as breeding colonies in 2005 by the presence of brown pups (Goldsworthy et al. 2009d), and as such do not appear in any previous surveys. Given that most surveys undertaken represent ground counts that are subject to biases and may not have been timed optimally relative to the breeding season, numbers of pups listed in Table 12 represent minimum numbers (with the exception of Lilliput and Blefuscu Island estimates 2007/08

season), and trends in abundances are not able to be assessed. Based on surveys undertaken in 2007/08, pup production for the entire Nuyts Archipelago is likely to exceed 400 pups (Goldsworthy et al. 2009c).

Lower Eyre Peninsula surveys

Ground surveys of North Rocky Island on 26 November 2009 indicated the presence of 17 fully moulted Australian sea lion pups, and a large number (49) of adult females (Table 13). All pups were judged to be older than 12 months, suggesting that the next breeding season would commence sometime between January and July 2010, and likely peak between July and December 2010. Eighteen adult males, three sub-adult males and 24 juveniles were also reported, giving a total of 111 Australian sea lions surveyed. The only other previous ground survey reported for North Rocky Island was on 14 January 1996, when 15 brown pups and one dead pup were sighted (Shaughnessy et al. 2005). The large number of females reported during the 2009 surveys may suggest that actual pup production is much greater than pup numbers on the two previous surveys suggest.

Aerial survey of the Four Hummocks groups on 26 November 2009 indicated 22 adult females, 9 adult/sub-adult males, 11 juveniles and 5 moulted pups. Two adult females, 3 adult/sub-adult males and 4 juveniles were also sighted on the small rocky island between Four Hummocks and Perforated Island. This is probably the same island referred to as Little Hummock by N. Gales, who reported 9 sea lions there on 29 January 1990 (Gales 1990).

A partial ground survey of Price Island on 26 November 2009 indicated the presence of a single moulted pup, and 24 other sea lions (Table 13). This survey did not correspond with the breeding season. A ground survey of Price Island in January 1996 reported 20 moulted pups, five brown pups and another 46 sea lions (Shaughnessy et al. 2005).

A ground survey of Albatross Island undertaken on 26 November 2009 reported 69 pups (63 brown, 3 moulted, 3 dead pups) and 126 other sea lions (Table 13). Most (51) of the brown pups were moulting, and the youngest pups were estimated to be 1-2 months old, suggesting that the breeding season had ended in late October 2009, with the peak of the breeding occurring from May to October. This suggests the next breeding season will occur between October 2010 and April 2011. The only other ground survey to have been undertaken on Albatross Island was on 24 November 1982, when 12 pups and another 58 sea lions were seen (Gales et al. 1994, Robinson et al. 1996). This recent survey indicated that the Albatross Island colony is much larger than the previously survey data suggest. Given that this survey

was undertaken shortly after the breeding season had ended, Albatross Island may produce over 100 pups if a substantial number of older pups had moved away from the colony.

Table 1. Summary of surveys undertaken for new births and for dead pups, cumulative births and deaths, and counts of brown (BP), moulted (MP) and total live Australian sea lion pups at Seal Bay during the 2008/09 breeding season. Details of Petersen mark-recapture estimates are also given, where *N* refers to total estimate of live and cumulative dead pups and counts in Pup Cove on the day of each survey, *Adj N* is the same as N but includes the remaining new births in the population that occurred after the particular survey. The mean *Adj N* and its 95% CL are presented.

	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	27-Oct	1	1	1	1	0	0	0	0						
2	30-Oct	1	1	2	2	0	0	0	0						
3	3-Nov	1	1	3	3	0	0	0	0						
4	10-Nov	0	0	3	3	0	0	0	0						
5	17-Nov	0	0	3	3	0	0	0	0						
6	24-Nov	0	0	3	3	0	0	0	0						
7	1-Dec	0	0	3	3	0	0	0	0						
8	4-Dec	2	1	5	4	1	0	0	0						
9	8-Dec	1	0	6	4	2	1	0	1						
10	12-Dec	3	1	9	5	4	2	0	2						
11	15-Dec	0	0	9	5	4	4	0	4						
12	18-Dec	0	0	9	5	4	3	0	3						
13	24-Dec	5	0	14	5	9	3	0	3						
14	28-Dec	3	1	17	6	11	6	0	6						
15	3-Jan	5	0	22	6	16	9	0	9						
16	5-Jan	1	0	23	6	17	11	0	11						
17	9-Jan	5	2	28	8	20	11	0	11						
18	12-Jan	4	0	32	8	24	13	0	13						
19	17-Jan	8	0	40	8	32	18	0	18						
20	25-Jan	16	1	56	9	47	26	0	26						
21	30-Jan	7	3	63	12	51	30	0	30						
22	4-Feb	10	5	73	17	56	31	0	31						
23	9-Feb	15	4	88	21	67	38	0	38						
24	12-Feb	14	2	102	23	79	47	0	47						
25	17-Feb	8	7	110	30	80	54	0	54						
26	20-Feb	14	3	124	33	91	55	0	55						
27	23-Feb	7	2	131	35	96	70	0	70						
28	26-Feb	7	1	138	36	102	75	0	75						
29	2-Mar	10	6	148	42	106	80	0	80						
30	5-Mar	14	1	162	43	119	77	0	77						
31	10-Mar	10	4	172	47	125	80	0	80						
32	12-Mar	10	1	182	48	134	90	0	90						
33	16-Mar	14	5	196	53	143	81	0	81	18	71	7	170	305	40.9
34	20-Mar	9	2	205	55	150	90	0	90	19	75	10	137	270	24.7
35	23-Mar	3	1	208	56	152	87	0	87	19	76	9	153	280	30.6
36	26-Mar	4	1	212	57	155	81	0	81						
37	30-Mar	10	2	222	59	163	83	0	83	19	70	7	177	295	43.2
38	2-Apr	1	2	223	61	162	91	0	91	19	77	13	110	230	14.3
39	7-Apr	7	1	230	62	168	88	0	88	19	81	9	163	270	32.8
40	10-Apr	6	0	236	62	174	87	0	87	24	79	15	124	226	16.3
41	15-Apr	6	3	242	65	177	105	0	105	24	94	15	147	249	19.7
42	20-Apr	4	4	246	69	177	95	0	95	24	81	13	145	250	22.8
43	24-Apr	3	2	249	71	178	99	0	99	24	88	17	123	224	13.4
44	27-Apr	4	2	253	73	180	83	0	83	24	75	14	126	222	17.9
45	4-May	1	1	254	74	180	88	0	88						
46	11-May	4	4	258	77	181	120	2	122						
47	18-May	4	3	262	80	182	83	4	87						
48	25-May	3	1	265	81	184	76	5	81						
49	1-Jun	0	3	265	84	181	83	0	83	89	78	38	181	273	15.4
50	9-Jun	3	2	268	86	182	80	1	81	117	76	51	174	265	10.2
51	15-Jun	0	0	268	86	182	76	3	79	123	76	60	156	245	6.5
52	23-Jun	0	0	268	86	182	63	10	73	123	70	54	159	248	7.6
53	30-Jun	0	0	268	86	182	61	9	70	123	68	56	149	237	6.0
54	7-Jul	0	2	268	88	180	60	4	64	123	62	41	185	275	13.3
55	17-Jul	0	0	268	88	180	94	13	107	132	104	73	188	279	7.9
56	4-Aug	0	1	268	88	180	65	16	81	149	76	61	185	278	7.9
													Mean Adj N	259	4.9
													(95% CL 249-269)		

Table 2. Summary of the timing and spread of five consecutive breeding seasons of the Australian sea lion at Seal Bay, and pup abundance estimates including: cumulative births and pup 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 (*Adj N*); and the overall estimate of pup production (which is taken as the maximum of the above estimates for each season). 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 (2007), unless otherwise indicated. Data for the 2007 breeding season are from Goldsworthy et al. (2008a); 2008/09 data are from this report.

	2002/03	**2004**	**2005/06**	**2007**	**2008/09**
Month breeding season commenced	Dec-02	Jun-04	Dec-05	May-07	Oct-08
Duration of breeding season (months)	9	7	6	7	7
Median pupping date	13-Mar-03	5-Sep-04	28-Feb-06	27-Aug-07	24-Feb-09
± s.d. (days)	42	39	36	36	41
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
90% births (days)	139[1]	121	104	120	136
Cumulative births	-	200	207	245	268
Cumulative pup deaths	73	70	75	51	88
Maximum live pup count	122	148	125	145	122
At months since beginning of BS	6	7	6	6	7
Max live pup count + cumulative dead[2]	185	208	197	198	197
Total live pups micro-chipped	148	202	144	203	161
Minimum pup production[3]	221	272	219	254	249
Adj N	227	288	203	260	259
(95% CL)	(216-239)	(273-302)	(199-207)	(249-272)	(249-269)
No. recapture estimates	3	2	3	21	19
Overall estimate of pup production	227	288	219	260	268
Confidence limit (min est. to 95% CL)	(221-239)	(273-302)		(254-272)	(268-269)
Mortality rate	32.2%	24.3%	34.2%	19.6%	32.8%

[1]Shaughnessy et al. (2006)

[2]at time of maximum live count

[3]total micro-chipped + cumulative dead

Table 3. Details of pup surveys undertaken at the Australian sea lion colony at the Seal Slide (Kangaroo Island) between March and July 2009. 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 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
18-Mar	3	0	1	0	3	4	3	3	3	1	4
7-May	8	0	0	0	8	8	0	3	11	1	12
15-May	5	1	0	0	6	6	3	6	8	1	9
23-July	3	6	0	0	9	9	1	7	9	1	10

Table 4. Summary of details of abundance estimates of Australian sea lion pups at Olive Island in the 2008/09 breeding season: counts, tagging, cumulative mortalities and various direct count and mark-recapture and cumulative pup production abundance estimates, during two visits (sessions), February and June 2009.

Session	**1**	**2**
Date	**26-Feb**	**1-Jun**
Cumulative marked	98	98
Maximum unmarked counted	28	40
Maximum count (live)	126	138
Cumulative dead (unmarked)	8	9
Cumulative dead (marked)	0	0
Total accumulative dead	8	9
Maximum count (live) + cumulative dead	134	147
Cumulative marked + dead (unmarked) + max unmarked	134	147
Petersen Estimate (live)	213	159
Petersen Estimate Lower – Upper CL	187-239	145-172
(No. recapture estimates)	6	6
Petersen Estimate (live) + cumulative dead	221	168
Lower – Upper CL	195-247	145-172
Apparent survival (φ) between sessions		0.786
Estimated pup production between sessions		-6
Lower – Upper CL		-1--13
Estimated cumulative pup production	221	215
Lower – Upper CL	195-247	196-234

Table 5. Details of Petersen mark-recapture procedures undertaken at Olive Island between February and June 2009. M = number of marked pups in the population, n = the total number of pups sampled and m = the number of marked pups in each recapture sample. N = the estimated pup population size, sd = standard deviation and V = variance. % = the percentage of marked pups in each sample, CV = the coefficient of variation. The lower and upper 95% confidence limits (CL) of each estimate, respectively.

Date	Recapture No.	Marked M	Examined n	M-R m	N	sd	V	%	CV	Nlo	Nup
Session 1											
26-Feb	1	98	47	20	225	32	1032	43%			
26-Feb	2	98	44	16	261	44	1966	36%			
26-Feb	3	98	49	21	224	31	959	43%			
26-Feb	4	98	28	16	168	23	543	57%			
26-Feb	5	98	35	18	187	26	671	51%			
26-Feb	6	98	36	16	214	34	1155	44%			
				Mean	**213**	**13**		**46%**	**6.2%**	**187**	**239**
Session 2											
1-Jun	1	77	66	27	186	21	448	41%			
1-Jun	2	77	47	23	155	18	337	49%			
1-Jun	3	77	70	30	178	18	339	43%			
1-Jun	4	77	71	36	151	12	155	51%			
1-Jun	5	77	63	36	134	10	106	57%			
1-Jun	6	77	49	25	149	16	267	51%			
				Mean	**159**	**7**		49%	**4.3%**	**145**	**172**

Table 6. Summary of details of abundance estimates of Australian sea lion pups at Dangerous Reef in the 2009/10 breeding season: counts, tagging, cumulative mortalities and various direct count and mark-recapture and cumulative pup production abundance estimates, during four visits (sessions) between September 2009 and March 2010.

Session	**1**	**2**	**3**	**4**
Date	**18-Sep**	**5-Dec**	**26-Jan**	**13-Mar**
Cumulative marked	52	181	230	230
Maximum unmarked counted	60	161	112	87
Maximum count (live)	136	392	324	212
Cumulative dead (unmarked)	19	40	50	56
Cumulative dead (marked)	0	3	3	13
Total cumulative dead	19	43	53	69
Maximum count (live) + cumulative dead	155	435	377	281
Cumulative marked + dead (unmarked) + max unmarked	131	382	392	373
Petersen Estimate (live)	139	445	417	293
Petersen Estimate Lower – Upper CL	130-148	422-468	383-444	272-315
(No. recapture estimates)	9	6	8	6
Petersen Estimate (live) + cumulative dead	158	488	470	362
Lower – Upper CL	149-167	465-511	436-497	341-384
Apparent survival (φ) between sessions		0.750	0.673	0.673
Estimated pup production between sessions		370	141	46
Lower – Upper CL		353-386	124-153	46-50
Estimated cumulative pup production	158	528	669	715
Lower – Upper CL	149-167	502-533	626-706	672-755

Table 7. Details of Petersen mark-recapture procedures undertaken at Dangerous Reef between September 2009 and March 2010. M = number of marked pups in the population, n = the total number of pups sampled and m = the number of marked pups in each recapture sample. N = the estimated pup population size, sd = standard deviation and V = variance. % = the percentage of marked pups in each sample, CV = the coefficient of variation. The lower and upper 95% confidence limits (CL) of each estimate, respectively.

Date	Recapture No.	Marked M	Examined n	M-R m	N	sd	V	%	CV	Nlo	Nup
Session 1											
18-Sep	1	52	76	32	123	10	97	42%			
18-Sep	2	52	88	32	142	12	143	36%			
18-Sep	3	52	41	21	100	11	124	51%			
18-Sep	4	52	92	32	148	13	160	35%			
18-Sep	5	52	87	29	154	15	223	33%			
18-Sep	6	52	77	21	187	25	645	27%			
18-Sep	7	52	98	45	113	4	20	46%			
18-Sep	8	52	88	33	138	11	122	38%			
18-Sep	9	52	91	32	147	12	155	35%			
				Mean	**139**	**5**		**38%**	**3.3%**	**130**	**148**
Session 2											
5-Dec	1	168	267	108	415	18	331	40%			
5-Dec	2	168	196	72	455	32	1005	37%			
5-Dec	3	168	185	65	475	36	1331	35%			
5-Dec	4	168	249	88	474	28	763	35%			
5-Dec	5	168	194	73	444	30	922	38%			
5-Dec	6	168	183	75	408	27	702	41%			
				Mean	**445**	**12**		38%	**2.7%**	**422**	**468**
Session 3											
26-Jan	1	162	170	63	435	33	1109	37%			
26-Jan	2	162	170	59	464	38	1451	35%			
26-Jan	3	162	151	61	399	30	930	40%			
26-Jan	4	162	183	71	416	28	808	39%			
26-Jan	5	162	128	50	411	37	1358	39%			
26-Jan	6	162	142	64	358	25	639	45%			
26-Jan	7	162	174	66	425	31	969	38%			
26-Jan	8	162	157	59	428	34	1184	38%			
				Mean	**417**	**11**		**39%**	**3.7%**	**383**	**444**
Session 4											
13-Mar	1	109	150	63	259	16	250	42%			
13-Mar	2	109	120	40	324	32	1041	33%			
13-Mar	3	109	126	51	268	21	424	40%			
13-Mar	4	109	124	38	352	37	1380	31%			
13-Mar	5	109	113	48	255	20	414	42%			
13-Mar	6	109	115	41	303	29	846	36%			
				Mean	**293**	**11**		37%	**3.8%**	**272**	**315**

Table 8. Summary of mark-recapture estimates of the abundance of Australian sea lion pups at Dangerous Reef over six breeding seasons, highlighting comparison between mark-recapture estimates and direct counts of live pups. For the 2006/07 season comparisons between methods can be made for two of the three mark-recapture estimates.

Date (breeding season)	Max. direct count (inc. dead)	Direct count of pups	Mark-recapture estimate of pups	Comparison[1]	95% confidence interval	No. month since pupping commenced to		Source
						Max count	Mark-recapture estimate	
July 1999 (1999)	383	240	285	1.19	1.12 - 1.25	4	4	(Shaughnessy & Dennis 1999)
Jan 2004 (2003/04)	499	333	423	1.27	1.21 - 1.31	5.5	5	(Shaughnessy 2004)
July 2005 (2005)	585	272	326	1.20	1.15 to 1.25	6	6	(Shaughnessy 2005a)
Nov 2006 (2006/07)	397	330	436	1.32	1.26 - 1.38	4	4	(Goldsworthy et al. 2007a)
Jan 2007 (2006/07)	575	495	629	1.27	1.12 - 1.42	6	6	(Goldsworthy et al. 2007a)
Aug 2008 (2008)	537	210	289	1.38	1.31 - 1.45	6-7	6-7	(Goldsworthy et al. 2009b)
Dec 2009 (2009/10)	435	392	488	1.24	1.19-1.30	6	6	This report

[1] Mark-recapture estimate divided by Direct count

Table 9. Estimated number of births of Australian sea lions at Dangerous Reef, South Australia for 14 pupping seasons between 1975 and 2009/10. Data are collated from Dennis (2005), Shaughnessy and Dennis (2001) and (2003), Shaughnessy (2004) and (2005b), Goldsworthy et al. (2007a), Goldsworthy et al. (2009b) and this report. The data for 1994/95 includes an adjustment to account for pup mortality because only live pups (295) were counted in that season, following Shaughnessy (2005).

Pupping season	Cumulative dead pups at max. pup count [a]	Max. pup count [b]	Pup mortality (%)	Month of max. live count since pupping began	Max. cumulative dead pup
1975	73	356	20.5	5	73
1976/77	26	262	9.9	4	26
1990	55	260	21.2	4	55
1994/95	-	354 [c]	not estimated	6.5	
1996	110	363	30.3	-	110
1997/98	38	248	15.3	4	43
1999	161	383 [d]	42.0	4	165
2000/01	90	393	22.9	7	90
2002	190	426 [e]	44.6	6	190
2003/04	93	499 [f]	18.6	5	100
2005	182	585 [g]	31.1	5	274
2006/07	80	575 [h]	13.9	6	88
2008	231	537	43.0	6-7	231
2009/10	43	435	9.9	6	69

[a] 'Cumulative dead pups' refers to the number of dead pups counted through to the maximum pup count.
[b] 'Max. pup count' refers to the maximum live pup count plus cumulative dead pups up until the date of the maximum live pup count.
[c] Adjusted for pup mortality using: "Maximum pup count" x 1.19954, where 0.19954 is the un-weighted average proportion of dead pups in three summer pupping seasons, 1997/98, 2000/01 and 2003/04.
[d] In addition, 23 newly-born pups were recorded on the last two visits; that number plus the previous estimate (of 383) leads to an estimate of pup numbers for the season of 406.
[e] In addition, 29 newly-born pups were recorded on the last visit; that number plus the previous estimate (of 426) leads to an estimate of pup numbers for the season of 453.
[f] In addition, 27 newly-born pups were recorded on the last visit; that number plus the previous estimate (of 499) leads to an estimate of pup numbers for the season of 526.
[g] In addition, 32 newly-born pups were recorded on the last three visits; that number plus the previous estimate (of 585) leads to an estimate of pup numbers for the season of 617.
[h] In addition, 4 newly-born pups were recorded on the last visit; that number plus the previous estimate (of 575) leads to pup count for the season of 579.

Table 10. Comparison of the estimated number of births of Australian sea lions at Dangerous Reef, South Australia for 3 breeding seasons between 2006/07 and 2009/10 based on Petersen estimates and cumulative pup production methods. Estimates of pup mortality for these breeding seasons based on cumulative pup production methods are also presented.

Breeding season	Method of estimating pup production				
	Petersen estimate plus cumulative dead (±CL)	Cumulative pup production (±CL)	Pup mortality based on cumulative pup production estimates	Comparison[1]	Source
2006/07	709 (636-783)	831 (751-912)	10.6%	1.17	(Goldsworthy et al. 2007a)
2008	520 (506-535)	541 (518-563)	42.7%	1.04	(Goldsworthy et al. 2009b)
2009/10	488 (465-511)	715 (672-755)	9.6%	1.87	This report

[1] Cumulative pup production divided by Petersen estimate plus cumulative dead

Table 11. Details of Australian sea lion pup surveys undertaken at Lounds, Purdie, West and Fenelon Islands in the Nuyts Archipelago between 28 October and 1 November 2009. Pelage stage of pups is also noted.

Island	Date	Black	Brown	Moulted	Total
Lounds Is	28-Oct-09	0	0	24	24
Purdie Is	29-Oct-09	0	12	55	67
West Is	31-Oct-09	0	9	23	32
Fenelon Is	1-Nov-09	0	3	8	11

Table 12. Numbers of Australian sea lion pups estimated at the eight breeding colonies within the Nuyts Archipelago from surveys undertaken between 1977 and 2009. Timing of the surveys and the data sources are given as footnotes. Unless otherwise indicated, all surveys represent single visit ground surveys; dashes indicate no survey was undertaken. Totals among colonies are only presented for the three most complete surveys.

Breeding colony	1977[1,2]	1982[2]	1990[3]	1992[4]	1995[5]	2002[6]	2004/05[7]	2007/08[8]	2009[9]
Lilliput Is.	-	-	46	-	-	-	67[A]	64[A,B]	
Blefuscu Is.	-	-	75	-	-	-	84[A]	99[A,B]	
Breakwater Is.	-	-	-	-	-	-	17[A]	15	
Gliddon Reef	-	-	-	-	-	-	7	7	
Lounds Is.	5	-	26	16	4	-	-	34	24
Purdie Is.	-	-	112	65	34	-	132	95	67
West Is.	-	-	14	-	18	-	56[A]	39	32
Fenelon Is.	-	8	21	-	9	19	10	40	11
Totals			294				373	393	393

[1]October 1977 (Ling & Walker 1979b, Dennis 2005)

[2]April 1992 (Robinson et al. 1996)

[3]September, November 1990 (Gales et al. 1994)

[4]February 1992 (Dennis 2005)

[5]August 1995 (Shaughnessy et al. 2005)

[6]September 2002 (Robinson et al. 2003)

[7]November 2004; January-July 2005 (Goldsworthy et al. 2009d)

[8]November 2007, January-April 2008 (Goldsworthy et al. 2009c)

[9]October/November 2009(This study)

[A]Multiple (2-4) ground surveys within one breeding season

[B]Estimates based on mark-recapture procedures.

Table 13. Details of Australian sea lion surveys undertaken at islands off the lower Eyre Peninsula on 26 November 2009. Surveys at North Rocky, Price and Albatross Islands were based on ground counts, all others were aerial surveys. Numbers of adult females (AF), adult males (AM), sub-adult males (SAM) and juvenile (JUV) sea lions are noted, as well as the pelage stage of pups.

					Pups			
Island	AF	AM	SAM	JUV	Brown	Moulted	Dead	Total
North Rocky Is	49	18	3	24		17		17
Four Hummocks Is (North)	10			6		3		3
Four Hummocks Is (Middle)	3	2						0
Four Hummocks Is (b/w Middle & South)	2			2		1		1
Four Hummocks Is (South)	7	5	2	3		1		1
Small rock b/w Hummocks and Perforated	2	2	1	4				0
Perforated Is	0	0	0	0				0
Price Is	7	4	1	12		1		1
Albatross Is	66	9	8	43	63	3	3	69

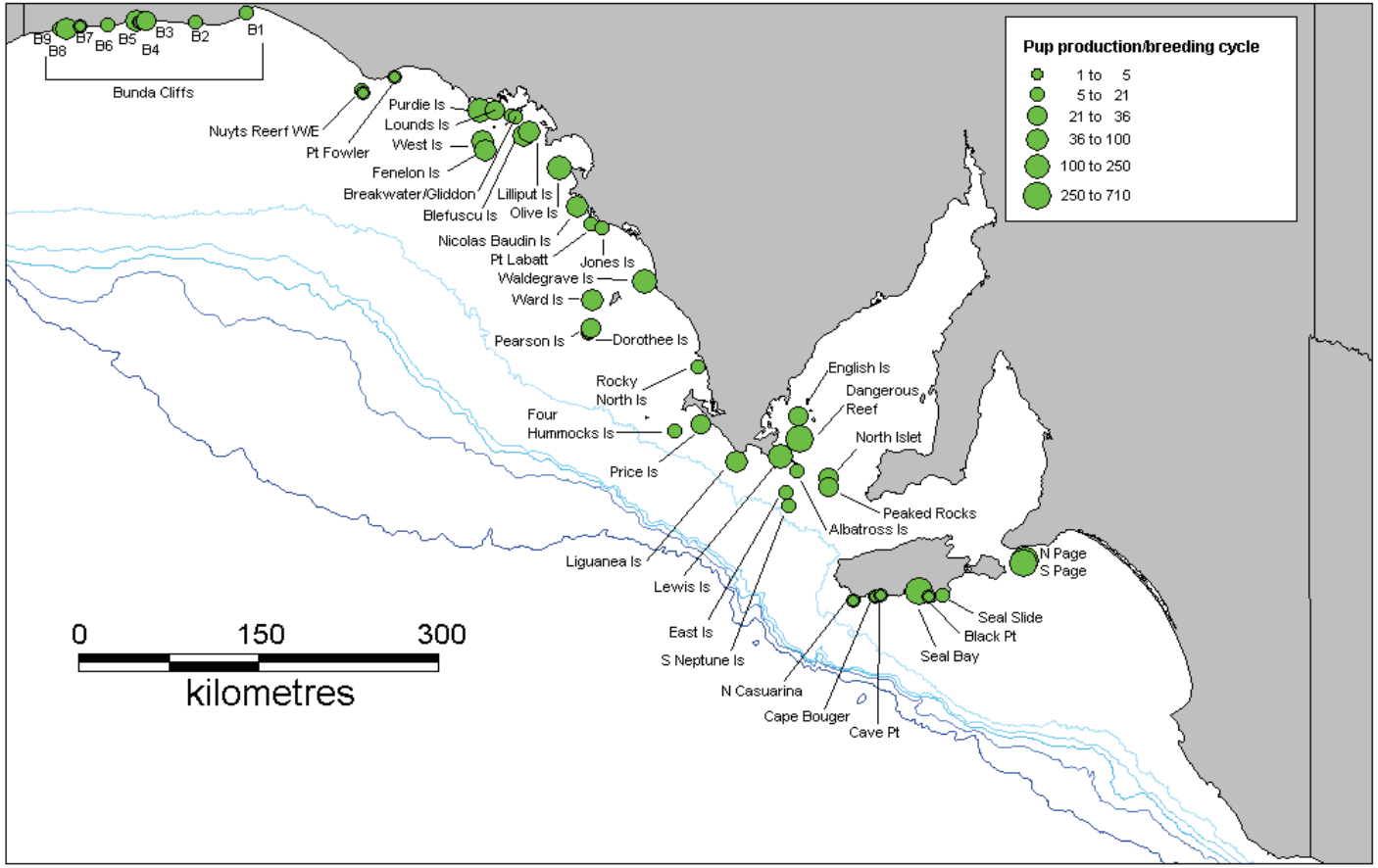

Figure 1. The location of Australian sea lion breeding sites (subpopulations) in SA and their relative pup production per breeding cycle. Data are sourced from Goldsworthy et al. (2009a). Bathymetry lines are indicated from light to dark blue (100, 200, 500, 1000, 2000m).

Figure 2. 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.

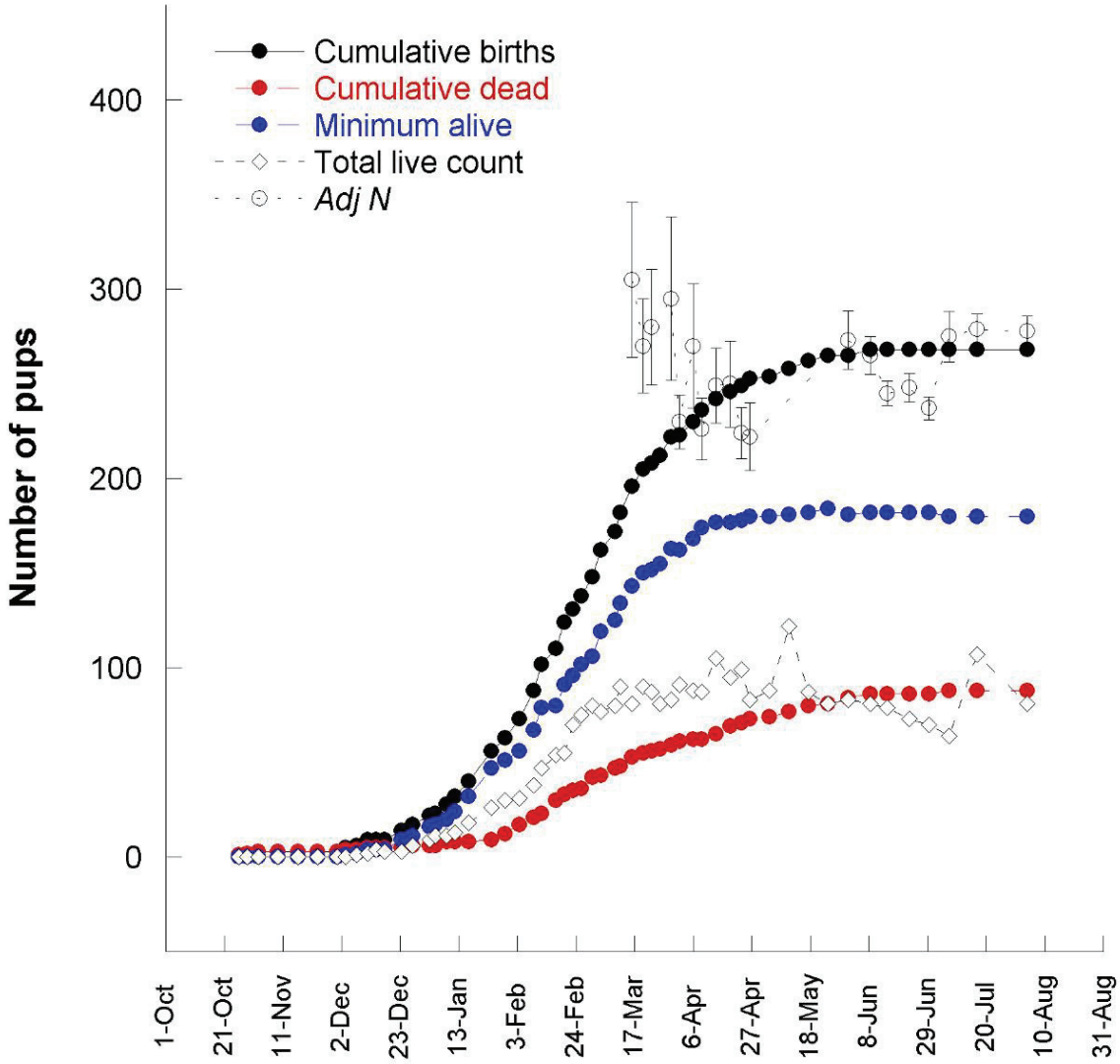

Figure 3. Changes in the number of cumulative pup births, cumulative deaths, minimum number of pups alive, and number of live pups counted during twice weekly surveys of Australian sea lion pups at Seal Bay between 1 October 2008 and 31 August 2009. Values of *Adj N* (± SE) are also given.

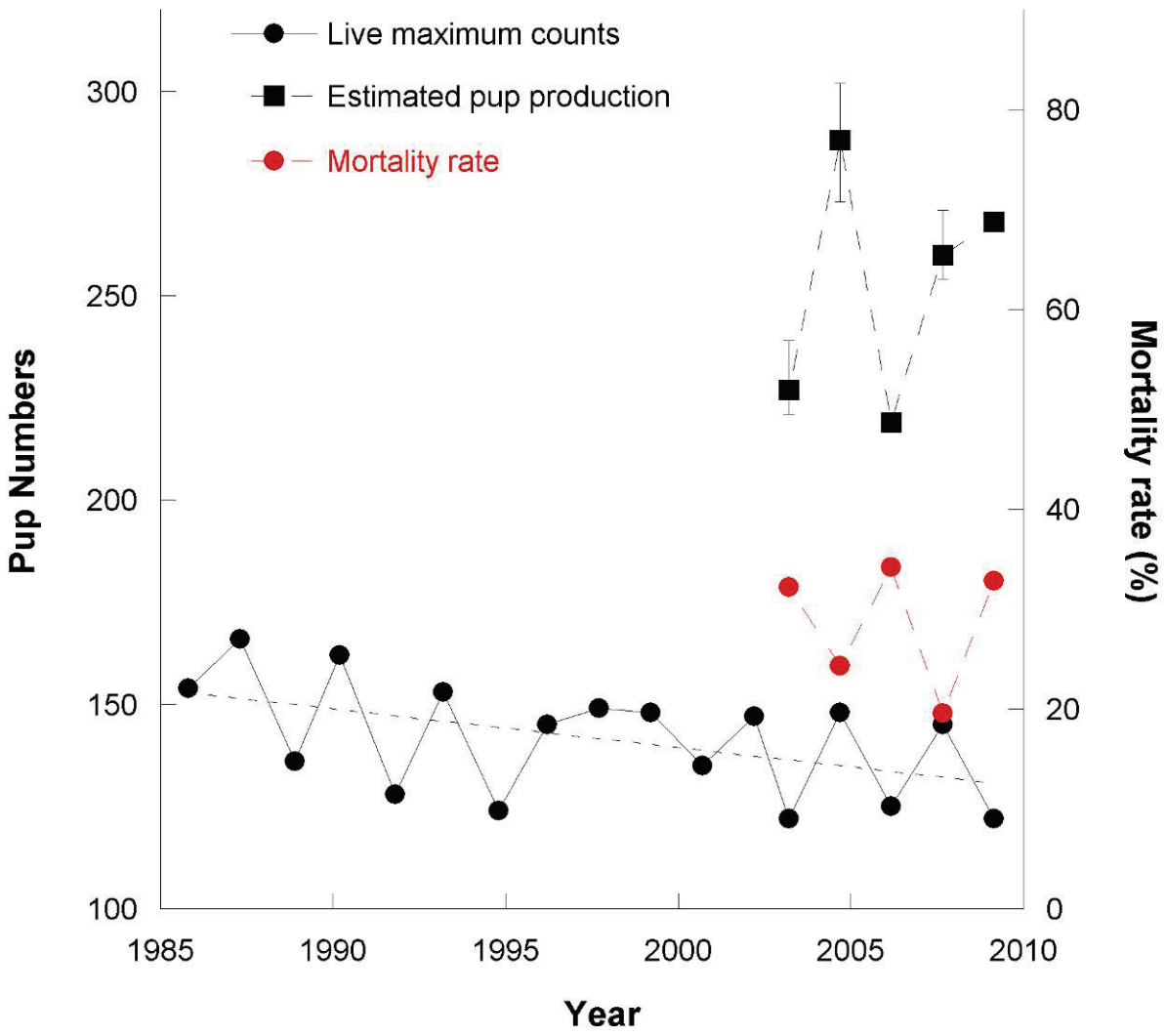

Figure 4. Trends in the abundance of Australian sea lion pups at Seal Bay based on maximum live pup counts, for 17 breeding season between 1985 and 2008/09. Trends in the overall estimate of pup production and pup mortality rate are presented for the last 5 breeding seasons.

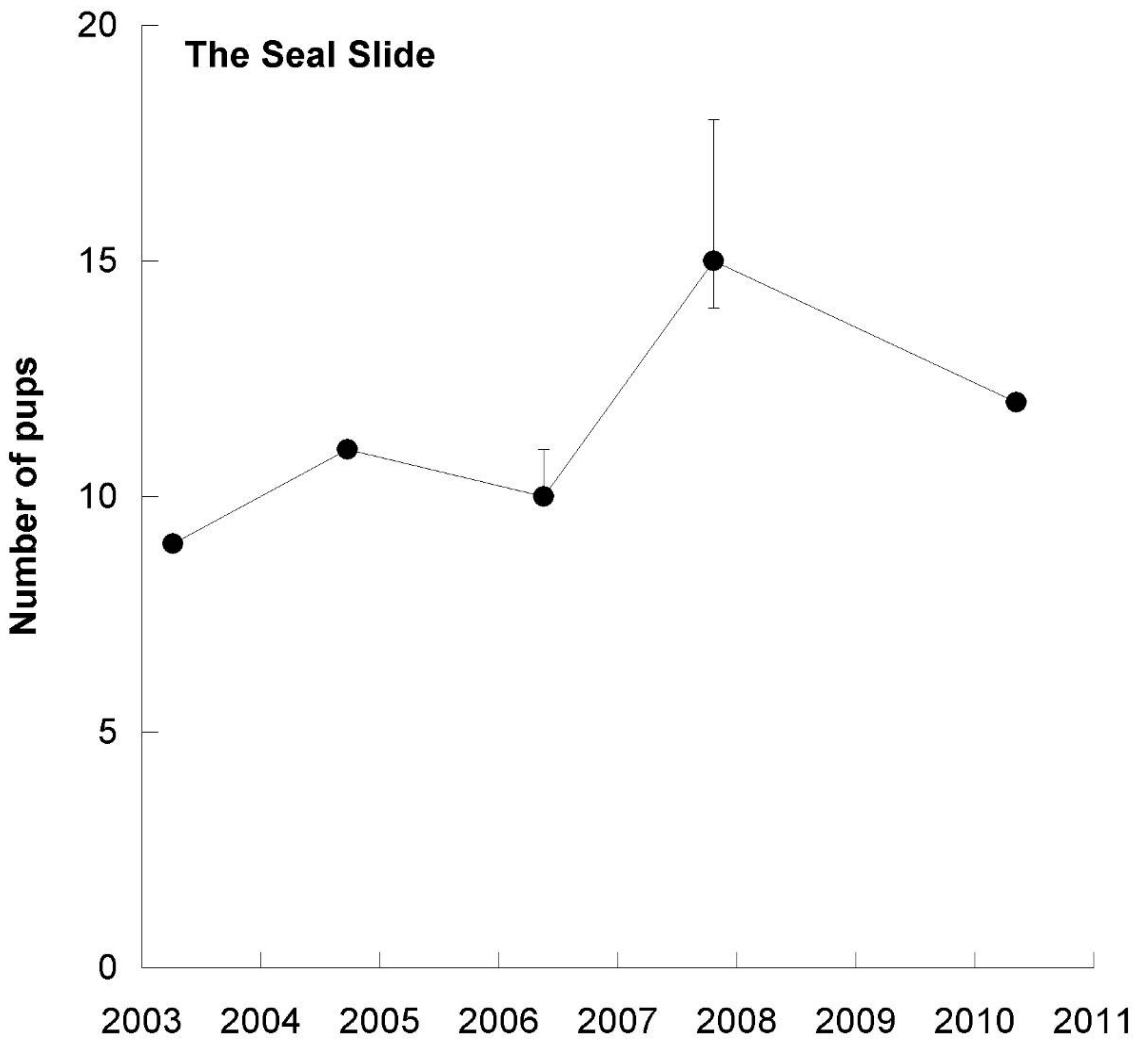

Figure 5. Trends in the abundance of Australian sea lion pups born at the Seal Slide (Kangaroo Island) over five consecutive breeding seasons between 2002/03 and 2009/10. Upper (95%) and lower (absolute minimum) confidence limits are available for the 2005/06 and 2007 breeding seasons.

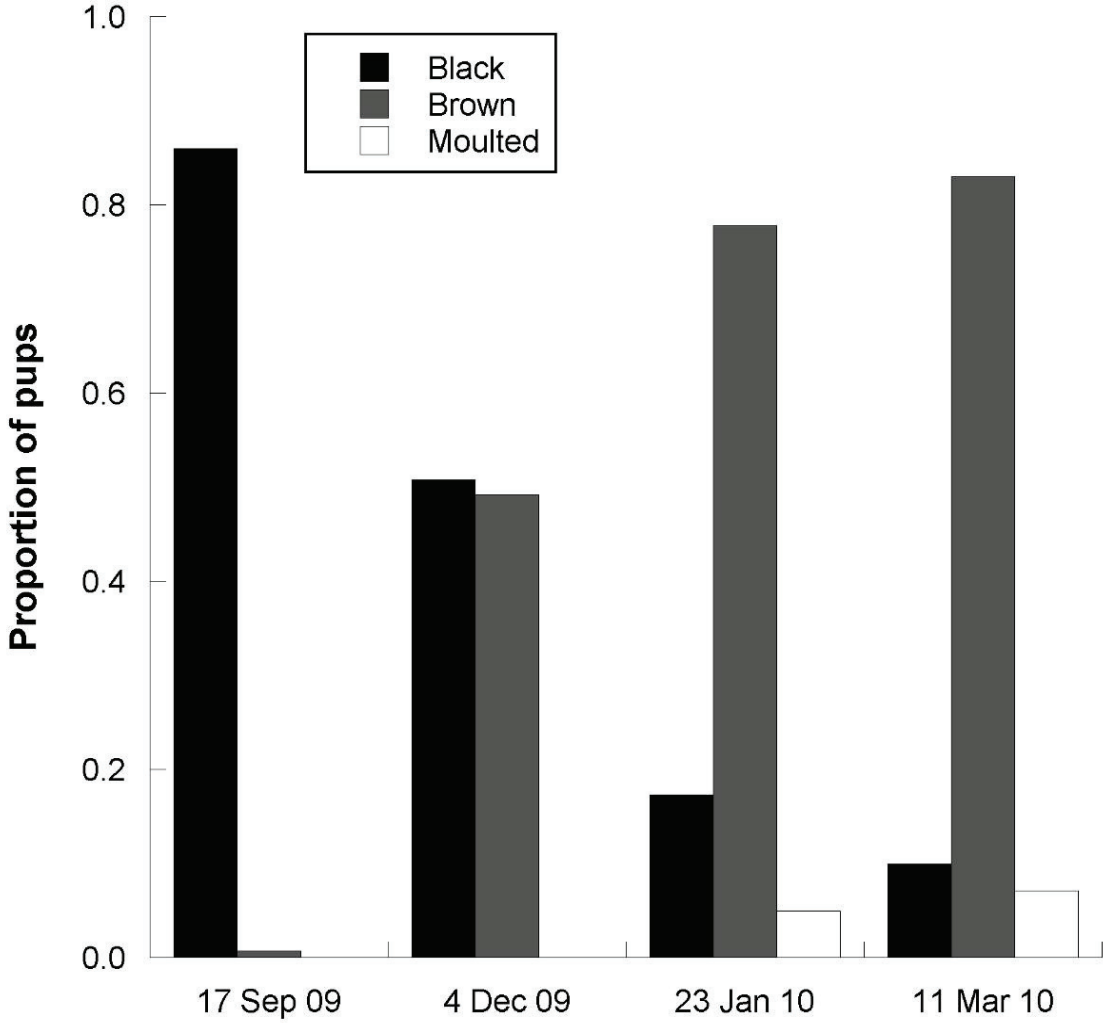

Figure 6. Proportions of Australian sea lion pups classified in three categories (black, brown and moulted) counted during four surveys at Dangerous Reef in the 2009/10 breeding season.

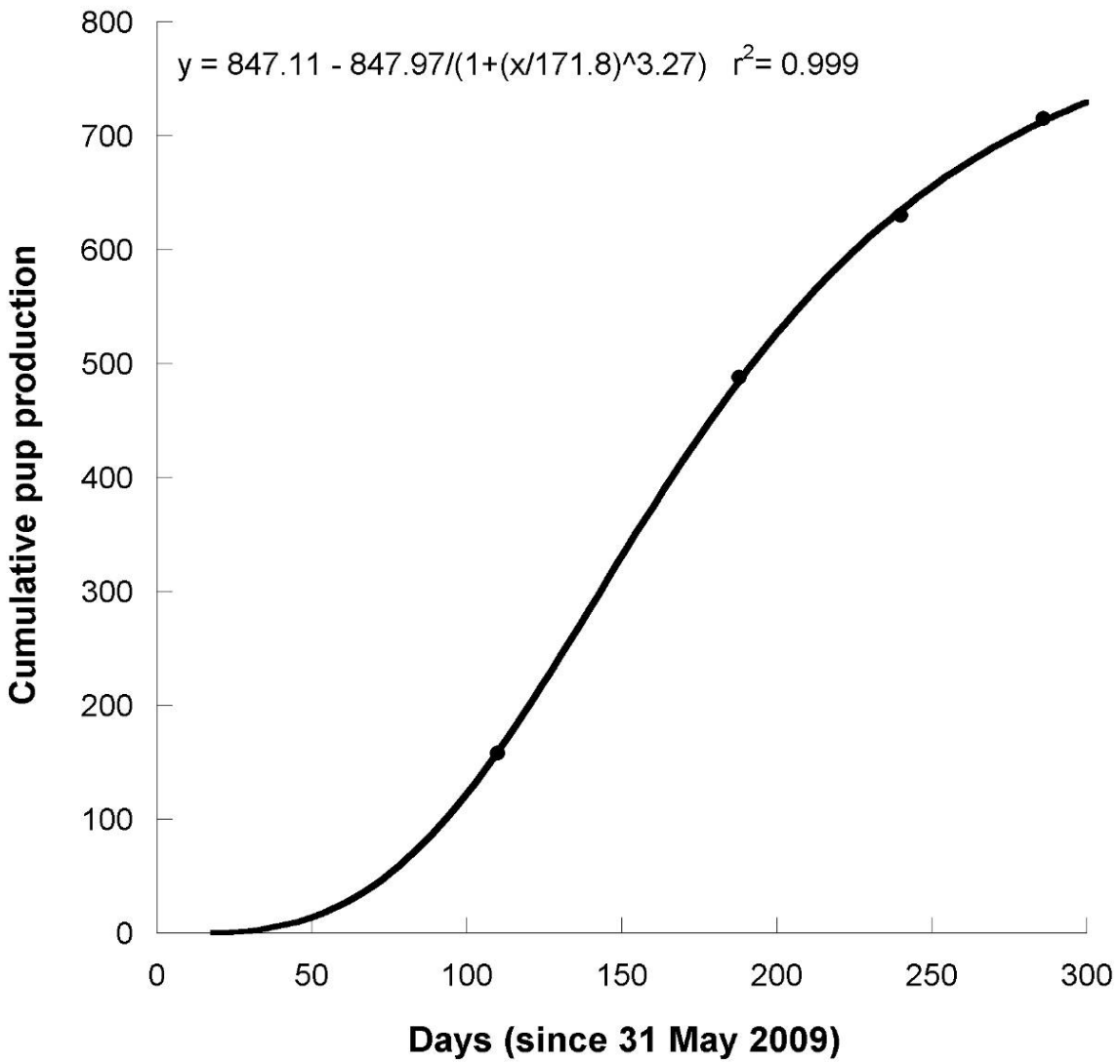

Figure 7. Estimated cumulative pup production of Australian sea lions during the 2009/10 breeding season based on estimates of pup production to 18 September 2009, and pup production between the next three surveys (5 December 2009, 26 January 2010 and 13 March 2010). The sigmoidal curve fitted to the data assumes that the breeding season commenced on 18 June 2009.

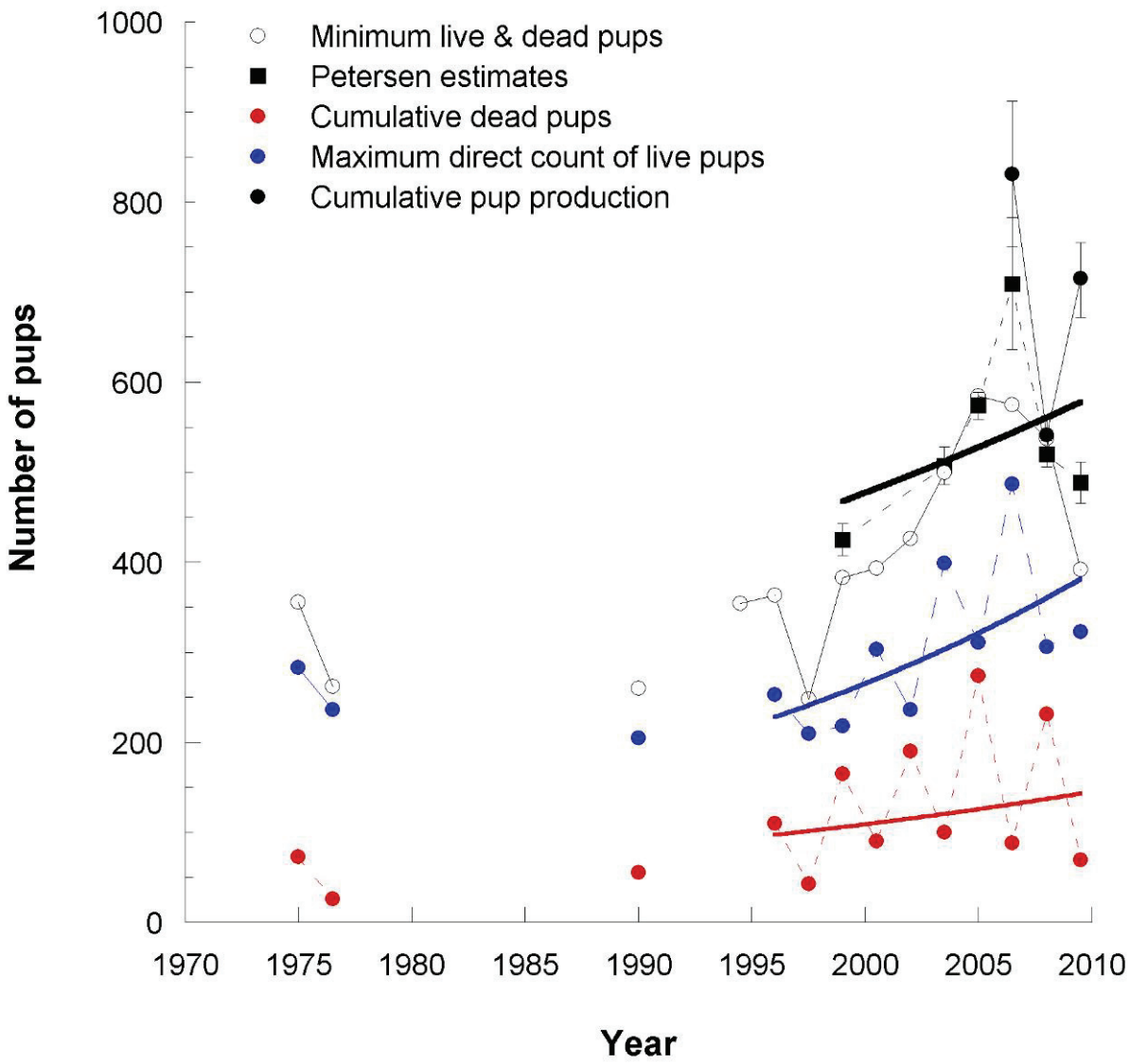

Figure 8. Trends in the abundance of Australian sea lion pups at Dangerous Reef, based upon cumulative pup production, Petersen estimates, minimum live and cumulative dead pup counts, maximum direct count of live pups, cumulative dead pups for 14 breeding season between 1975 and 2009/10. Error bars around estimates are ± 95% CL. Exponential curves are fitted to subsets of Petersen estimates, minimum live and cumulative dead pup counts.

5 ACKNOWLEDGMENTS

We thank the Australian Marine Mammal Centre for funding the project. Transport to Dangerous Reef and English Island was provided by Protec Marine Port Lincoln (Tony Jones and Adam Kemp). Transport to Olive Island was provided by Matt Guidera (Streaky Bay and Sceale Bay Blue Water Charters and Ocean Ecotours). We thank Alan Payne (Baird Bay Boat Charters) for assistance with surveys at Jones Island. We thank Clarence Kennedy, Janet Simpson, Rebecca McIntosh, Rachael Gray and Mike Terkildsen for assistance with Seal Bay and the Seal Slide surveys. We also thank Paul Rogers, Saras Kumar, Guido Parra, Andrew Lowther, Rachael Gray, Damien Higgins, Rob Harcourt, Ben Pitcher and Heidi Ahonen for field assistance at Dangerous Reef and Olive Island. The work was conducted under an animal ethics permit from SA Department of Environment Natural Resources, and the PIRSA Animal Ethics Committee. We thank Kate Lloyd and Peter Canty (SA Department for Environment and Natural Resources) for provision of SA DENR Permits. We thank David Currie and Mandee Theil for reviewing a draft of this report.

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7 APPENDIX

Appendix 1. Results from 56 pup surveys of the Australian sea lion population at Seal Bay, Kangaroo Island undertaken between 27 October 2008 and 4 August 2009. Observers include Clarence Kennedy and Janet Simpson. BP = Brown Pup, MP = moulted pup, New = new live pup, Chip = micro-chipped pup, Dead = new dead pup.

			Accumulated count			Total for day of survey					
Survey No.	Observer(s)	Date	Cumulative Dead	Cumulative Born	Alive	Total live count	BP	MP	New Births	Chipped Total	New Dead
1	Clarence	27/10/2008	1	1	0	1	0	0	1	0	1
2	Clarence	30/10/2008	2	2	0	2	0	0	1	0	1
3	Janet	3/11/2008	3	3	0	3	0	0	1	0	1
4	Janet	10/11/2008	3	3	0	3	0	0	0	0	0
5	Janet	17/11/2008	3	3	0	3	0	0	0	0	0
6	Clarence	24-Nov-08	3	3	0	3	0	0	0	0	0
7	Clarence	01-Dec-08	3	3	0	3	0	0	0	0	0
8	Clarence	04-Dec-08	4	5	1	4	0	0	2	0	1
9	Clarence	08-Dec-08	4	6	2	5	1	0	1	0	0
10	Clarence	12-Dec-08	5	9	4	7	2	0	3	0	1
11	Clarence	15-Dec-08	5	9	4	9	4	0	0	0	0
12	Clarence	18-Dec-08	5	9	4	8	3	0	0	0	0
13	Clarence	24-Dec-08	5	14	9	8	3	0	5	0	0
14	Clarence	28-Dec-08	6	17	11	12	6	0	3	0	1
15	Clarence	03-Jan-09	6	22	16	15	9	0	5	0	0
16	Clarence	05-Jan-09	6	23	17	17	11	0	1	0	0
17	Clarence	09-Jan-09	8	28	20	19	11	0	5	0	2
18	Clarence	12-Jan-09	8	32	24	21	13	0	4	0	0
19	Clarence	17-Jan-09	8	40	32	26	18	0	8	0	0
20	Clarence	25-Jan-09	9	56	47	35	26	0	16	0	1
21	Clarence	30-Jan-09	12	63	51	42	30	0	7	0	3
22	Clarence	04-Feb-09	17	73	56	48	31	0	10	0	5
23	Clarence	09-Feb-09	21	88	67	59	38	0	15	0	4
24	Clarence	12-Feb-09	23	102	79	70	47	0	14	0	2
25	Janet	17-Feb-09	30	110	80	84	54	0	8	0	7
26	Janet	20-Feb-09	33	124	91	88	55	0	14	0	3
27	Clarence	23-Feb-09	35	131	96	105	70	0	7	0	2
28	Clarence	26-Feb-09	36	138	102	111	75	0	7	0	1
29	Clarence	02-Mar-09	42	148	106	122	80	0	10	0	6
30	Clarence	05-Mar-09	43	162	119	120	77	0	14	0	1
31	Clarence	10-Mar-09	47	172	125	127	80	0	10	5	4
32	Clarence	12-Mar-09	48	182	134	138	90	0	10	8	1
33	Clarence	16-Mar-09	53	196	143	134	81	0	14	7	5
34	Clarence	20-Mar-09	55	205	150	145	90	0	9	10	2
35	Clarence	23-Mar-09	56	208	152	143	87	0	3	9	1
36	Clarence	26-Mar-09	57	212	155	138	81	0	4	5	1
37	Clarence	30-Mar-09	59	222	163	142	83	0	10	7	2
38	Clarence	02-Apr-09	61	223	162	152	91	0	1	13	2
39	Clarence	07-Apr-09	62	230	168	150	88	0	7	9	1
40	Clarence	10-Apr-09	62	236	174	149	87	0	6	15	0
41	Clarence	15-Apr-09	65	242	177	170	105	0	6	15	3
42	Clarence	20-Apr-09	69	246	177	164	95	0	4	13	4
43	Clarence	24-Apr-09	71	249	178	170	99	0	3	17	2
44	Clarence	27-Apr-09	73	253	180	156	83	0	4	14	2
45	Janet	04-May-09	74	254	180	162	88	0	1	10	1
46	Janet	11-May-09	77	258	181	199	120	2	4	14	4
47	Janet	18-May-09	80	262	182	167	83	4	4	18	3
48	Janet	25-May-09	81	265	184	162	76	5	3	12	1
49	Clarence	01-Jun-09	84	265	181	167	83	0	0	38	3
50	Clarence	09-Jun-09	86	268	182	167	80	1	3	51	2
51	Clarence	15-Jun-09	86	268	182	165	76	3	0	60	0
52	Clarence	23-Jun-09	86	268	182	159	63	10	0	54	0
53	Clarence	30-Jun-09	86	268	182	156	61	9	0	56	0
54	Clarence	07-Jul-09	88	268	180	152	60	4	0	41	2
55	Clarence	17-Jul-09	88	268	180	195	94	13	0	73	0
56	Clarence	04-Aug-09	88	268	180	169	65	16	0	61	1

Appendix 1. cont.

Survey	Mark recapture estimates					Road Reserve RRE					RRC				
No.	M	n	m	N	sd	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															
22															
23															
24															
25															
26															
27															
28															
29															
30															
31															
32															
33	18	71	7	170	41										
34	19	75	10	137	25										
35	19	76	9	153	31						3				
36											1			1	
37	19	70	7	177	43										
38	19	77	13	110	14						5			1	
39	19	81	9	163	33						5				
40	24	79	15	124	16						7			1	
41	24	94	15	147	20						7			2	
42	24	81	13	145	23										
43	24	88	17	123	13						9			2	
44	24	75	14	126	18						3			1	
45											4				
46						2					2			1	
47						4			1						
48						3									
49	89	78	38	181	15						3			2	
50	117	76	51	174	10						2			2	
51	123	76	60	156	6	2	1		2		5			2	
52	123	70	54	159	8						2			1	
53	123	68	56	149	6	1	1		2		1			1	
54	123	62	41	185	13						1			1	
55	132	104	73	188	8	7			7		1	1		2	
56	149	76	61	185	8	2			2						
							SUM	0				SUM	0		

Appendix 1. cont.

Survey	Road Reserve RRW				WPA SHELF					Shelf Beach				
No.	BP	MP	New	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									
16					1									
17					1									
18			1		1									
19	1				1		1							
20					2		1							
21					2									
22					3		1		1					
23				1	2							1		
24					2				1					
25					2		1							
26					1		2			1		1		
27					3					2				
28					3					1				
29					3					2		1		1
30					3					1				
31					5		2			1				
32					5			1		1				
33					7		1	1		1		1		
34					7		2	1						
35					7		1	1		1				
36	3				7					2				
37	5			2	10		3	2		2				
38					6			1	1	2				
39					6		1		1	3				
40					4		1			4		1	1	
41	5			2	5			1	1	4				
42	3			1	4					4			1	
43	5			1	4			1		3			1	
44	3			1	3									
45	3				1				1					
46	7			1	1					1			1	
47	3				1									
48										1		1		
49	1									1			1	
50	4			3										
51	10			8										
52	3	1		3						1			1	
53	7	1		7										
54	10	1		7						1			1	
55	13	1		10						1			1	
56	6	1		5										1
		SUM	1			SUM	18				SUM	6		

Appendix 1. cont.

Survey	WPA GROTTO					Grotto Beach					Grotto WU				
No.	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								1							
21						1									
22	1														
23										1					
24	1														
25															
26															
27															
28						1		1							
29						1									
30						1		1			1				
31	2														
32						2									
33															
34						1									
35						1									
36						1									
37						3		1	0		1				
38						4					1				
39	2					1		1			1				
40	1					1									
41	1										1				
42	3			1							1			1	
43	1										2			1	
44	2										1				
45	3										2				
46	4			1		2					1			1	
47	2			1		2			1		2		1		
48						1		1			3				
49	1			1		2			1		5			2	
50						1					2			1	
51											1			1	
52											2			2	
53						1			1		2			1	
54											2			1	
55						2			2		4			1	
56						1			1		2			1	
		SUM	0				SUM	6				SUM	1		

Appendix 1. cont.

Survey	WPA Arch					Pup Rock					Pup Rock WU				
No.	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													1		
19						1									
20											1				
21						1									
22						1									
23			1												
24															
25	1														
26	1														
27	1														
28	1														
29	1		1			1		1							
30	2		1			1		1							
31	1					1									
32						2			1		1		1		
33	2		1			1					1				
34	1					3		2			1		1		
35						2					1				
36						1					1				
37						2		1		1	1				
38	1					3			1		0				
39						3									
40						5			1						
41	1					1					1				
42	2					3		1		1					
43	1					3									
44						7									
45	1					1					1				
46	2					2			1		3				
47	1		1			2		1			2				
48	1					2					2				
49	1					3			1	1	1			1	
50	2			1	1						1			1	
51											2			2	
52															
53															
54															
55															
56	1			1							1			1	
		SUM	5				SUM	7				SUM	3		

Appendix 1. cont.

Survey	Sandy Beach					SABER					Saber WU				
No.	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								1							
20						1									
21						1		1							
22			1			1									
23						2		1							
24						2									
25			1		1	2		1							
26	2					1					1				
27	1		1			3		1							
28	1					3									
29	2					6		2							
30	2					5		1			1		1		
31						5			1						
32	2		1			5									
33	3					8		2	1						
34	6			1		4									
35	4					4			1						
36	5					3					1				
37	1					4									
38	3					1					1				
39	3		1			1					1				
40	1										1				
41	2										2				
42	1					3									
43						3			1						
44	1														
45															
46															
47					1						3				
48											3				
49															
50															
51															
52															
53															
54															
55	1	1		1		3			2						
56	1			1											
		SUM	5				SUM	10				SUM	1		

Appendix 1. cont.

Survey	WPA Pebble Beach					Pebble Beach WU					Danger Point				
No.	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1															
2															
3			1		1										
4															
5															
6															
7															
8			1		1										
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23			2												
24	3		1												
25	1				1			1							
26			1			1									
27	1				1	1									
28	3		1			2		1							
29	3					1				1					
30	2					1									
31	4		1			2		1		1					
32	4					1									
33	4		2		1	2									
34	1					4				1					
35	1					2									
36	1					3									
37	2		1			1					2		1		
38	1					1					4			3	
39						2					1				
40	3		1			1					5			3	
41	4				1										
42	2			1							3				
43	4														
44	4			2	1										
45	2										4				
46											3			1	
47											7			1	
48											6			1	
49						1			1		5			4	
50											1			1	
51											1			1	
52	2			1							1			1	
53						3			3		1			1	
54	1			1											
55	1			1											
56	3	1		4		1			1						
		SUM	12				SUM	3				SUM	1		

Appendix 1. cont.

Survey	WPA DPCove					Danger Cove WU					West Cove				
No.	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	0														
17															
18															
19															
20													2		
21											2				
22											1		1		1
23											2		1		1
24											2		1		
25	1										4				1
26	4		2			3					10		1		1
27											3		0		
28	1										2				
29	2										2				
30						1					1				
31						1									
32	2														
33	1		1			1					2			1	
34	3		1			1					3				
35	2					0					2				1
36	2										2				
37	1					2					1				
38	2										3			1	
39	1										5		1	1	
40											4			1	
41	3			2							5				
42	4			1	1										
43	3			1											
44	4			1											
45	2										7			3	
46	2										4				
47	3			1		5			1		1				
48	3		1			1									
49															
50															
51	2			1											
52															
53															
54															
55															
56											2			1	
		SUM	5				SUM	0				SUM	7		

Appendix 1. cont.

Survey	West Cove WU					WE					Dunes West				
No.	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead	BP	MP	New	Chip	Dead
1													1		1
2								1		1					
3															
4															
5															
6															
7															
8								1							
9						1									
10						1		2		1					
11						2									
12						2									
13						2		4							
14						4									
15						3		1							
16						3		1							
17						4		3							
18						6		1							
19						7		3					1		
20						10		3			1				
21						10		1		1	1				
22						13		2		1	1				
23			1			12		3		1	4		1		
24	1					16		4			3		1		
25						18		2		1	6				1
26	0					9					3		1		
27	5					14		1		1	8				
28	5					19		2			6		1		1
29	3					16				3	7				
30	5					10		2			8		1		1
31	6			2		13			1	2	5		1		
32	3			3		16		3	2		7		1	1	1
33	5		1	1		16		1	3		3				1
34	4					12			3		6				
35	3			2		14		1	2		7			1	
36	2			1		11			2		7		2	1	
37	3			1		6		1	1		6			1	
38	1					10			2		11			2	
39	3					14		2	4		8			2	
40	1			1		9			2		3				
41						6		1	1		7				
42	3					7					3		1		
43	5			3		7		1		1	5				
44	3			2		3		2			6		1	1	
45	2			1		1					3				
46											2				1
47	0										3			1	
48											5			1	
49						1					5			1	
50	1		1			8			3		3			1	
51	1					2					2	1		3	
52	2			1		1			1		3	1		2	
53	1					2			2		3	1		2	
54	2			1							4			3	1
55	2			1		1			1		5			1	
56											3	5		7	
		SUM	3				SUM	49				SUM	13		

Appendix 1. cont.

Survey	MBW					Dunes Centre					MBC				
No.	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													1		
19											1				
20	2		1					1							
21	1		1		1	1									
22	1									1					
23	2														
24	1										1				
25	1														
26	1					1		1							
27	1										0				
28	2														
29	2					1									
30	1					1									
31						2			1						1
32	1										1				
33											1				
34	1			1		1									
35						1									
36						2									
37															
38	1					1									
39	2			1											
40	1														
41	1					10			2						
42	4			1	1	4			1						
43	1					5			2						
44						7			2						
45						10			2		1				
46	1					17	1		1	1	3				1
47						5	1		2		3				
48						9	2		5						
49	1			1		6			2						
50						7			5						
51	1			1		8	1		6		2			2	
52	4	1		4		10			7		2	2		4	
53	1	1		1		9			9		1	1		2	
54	2					2			2	1	2	1		2	
55	2			2		2			2		6			5	
56						4			3						
		SUM	2				SUM	2				SUM	1		

Appendix 1. cont.

Survey	ED					EMB					EPA Bay 1				
No.	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													1		
11											1				
12											1				
13											1		1		
14											1		1		1
15								1			3		2		
16						1					4				
17						1					3		1		2
18											4				
19						1					4		1		
20						1					5		3		1
21											5		3		1
22											6		3		1
23											7		2		
24	1										9		5		1
25	2					1					10				
26						1					10		4		2
27	1					2					14		2		
28	5										13				
29	1		1			1		1			15				1
30	1		0			2		1			13		1		
31	2					5		1			12		2		
32	2					5					15				
33	1				1					2	12		3		
34	1			1		4			3	1	11		1		
35	3			1		1					15		1	1	
36	2										9		1		1
37	4				1						11		1		
38	2			1		1					11		1	1	1
39	2										10			1	
40	8		1	1		1					14		2	1	
41	6			1							17		3	3	1
42	2				1	5			1		16		1	3	
43	3					3			1		14		1	2	
44	7			1		2			1		10			1	
45	7			1		4					19		1	2	
46	11	1	1	4		8			1		28		1		1
47	9			5		1					17	2		3	2
48	11	2			1	1					15	1		4	
49	10			6	1	11			6		15			7	
50	22			18		3			2		10	1	1	8	1
51	14			12		6			5		8			6	
52	8	2		8		3			2		10	1		9	
53	13	1		11		1			1		7	2		6	
54	11	1		8		2			1		11			7	
55	13	5		12		3	1		3		12	1		8	
56	9	2		9		4	1		5		9	2		8	
		SUM	3				SUM	4				SUM	50		

Appendix 1. cont.

Survey	Bay 2					Bay 4					Bay 5				
No.	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															
22															
23															
24															
25															
26	1		1												
27															
28															
29	2		1												
30	2		1												
31	0														
32	1														
33	0														
34															
35	2														
36															
37	2														
38	1														
39	7														
40	5			3											
41	5			1											
42	4			1											
43	6			1							1		1		
44	9			1											
45	5			1											
46	11		1	1											
47	4	1		1											
48	3			1											
49	5			1	1										
50	8			5											
51	6			6											
52	6	2		7											
53	5	1		6											
54	7	1		6											
55	5	1		4							7	2		7	
56	3	1		3		0	0		0		8	3		8	
		SUM	4				SUM	0				SUM	0		

Appendix 1. cont.

Survey	Pup Cove					
No.	BP	MP	New	Chip	Dead	total PC
1						0
2						0
3						0
4						0
5						0
6						0
7						0
8						0
9			1			0
10	1					1
11	1					1
12						0
13						0
14	1		1			1
15	2		1			2
16	2					2
17	2		1			2
18	2					2
19	2		1			2
20	3		4			3
21	5		1			5
22	3		2			3
23	7		2			7
24	5		2			5
25	5		2		2	5
26	4					4
27	10		2			10
28	7		1			7
29	8		2			8
30	12		3			12
31	13		2			13
32	14		4			14
33	10		1			10
34	15		2			15
35	11					11
36	15		1			15
37	13		1			13
38	14					14
39	7		1			7
40	8					8
41	11		2			11
42	14		1			14
43	11				1	11
44	8		1			8
45	5					5
46	3		1			3
47	3		1			3
48	6					6
49	5					5
50	5		1			5
51	3			2		3
52	3					3
53	2					2
54	2			0		2
55	3					3
56	5					5
		SUM	45			