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Australian sea lion abundance in the Bunda Cliffs region, GAB Marine Park



Alice Mackay, Peter D Shaughnessy and Simon D Goldsworthy

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



Government of South Australia
Department of Environment,
Water and Natural Resources



Government
of South Australia
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EXECUTIVE SUMMARY

Ten Australian sea lion (ASL; *Neophoca cinerea*) breeding sites and 14 haul-out sites have been reported in the Bunda Cliffs region of the Great Australian Bight (GAB) in South Australia. Sites are spread over approximately 170 km of coastline. Sporadic surveys to count ASL at these sites have been undertaken between 1994 and 2013.

The major threat to the ASL population in the Bunda Cliffs region is from bycatch in the demersal gillnet shark fishery managed by the Australian Fisheries Management Authority (AFMA). Foraging grounds of ASL from these colonies extend many kilometres south of the Great Australian Bight Marine Park (GABMP), and overlap with the shark fishing grounds. Management actions have been introduced by AFMA since 2010 to mitigate the interaction. Monitoring the response of ASL populations to these measures is seen as a critical performance measure by the GABMP Steering Committee, the Australian Sea Lion Recovery Plan and AFMA.

The aims of this study were to conduct a survey of ASL in the Bunda Cliffs region in the 2012/13 pupping season and provide advice to the GABMP Steering Committee on the status and trends in abundance of this Australian sea lion population. All available data collected from cliff-top surveys of ASL breeding and haul-out sites at the Bunda Cliffs region were also collated and analysed.

Survey effort varied greatly both within and between years. An estimate of timing of breeding seasons in the Bunda Cliffs region based on the percentage of brown to moulted pups sighted during surveys and on estimates from some previously published surveys is provided.

A linear regression model of the maximum pup counts recorded at breeding sites adjusted by survey effort indicates a significant decline in mean maximum number of pups counted per site between the 1993/94 and 2012/13 pupping seasons. Similarly, total numbers of ASL counted (adults, juveniles, unclassified and pups) adjusted for survey effort, showed a significant decline over this period. Two breeding sites (B3 and B8) had sufficient survey effort between 1993/94 and 2012/13 to allow analysis of trends in pup numbers, which indicated that pup numbers had declined but did not show a statistically significant trend. The declines are consistent with previous assessments of unsustainable levels of ASL bycatch in the demersal gillnet shark fishery in the region. Monitoring of the Bunda Cliffs ASL population should be maintained to confirm these trends and assess if fishery closures introduced into the region are adequate to mitigate bycatch impacts.

When future surveys are scheduled, the observed asynchrony in the timing of breeding among breeding sites in the Bunda Cliffs region should be noted, and monitoring at sites B3 and B8 maintained to extend their time series, as survey effort to date has been greatest at these two sites.

1. INTRODUCTION

1.1. Background

The Australian sea lion (*Neophoca cinerea*) (ASL) is listed as Vulnerable under the threatened species category of the Commonwealth *Environment Protection and Biodiversity Act 1999* (EPBC Act), as Vulnerable under the South Australian *National Parks and Wildlife Act (1972)* and as Endangered by the International Union for the Conservation of Nature (IUCN) Redlist. Eighty-five per cent of the ASL population breeds within South Australian (SA) State waters.

Ten ASL breeding sites (B1, B1.1, and B2–B9) and 14 haul-out sites (H1–H14) have been reported in the Bunda Cliffs region of the Great Australian Bight (GAB) in South Australia (Dennis and Shaughnessy 1996, Dennis 2001). Sites are spread over approximately 170 km of coastline (Fig.1), and sporadic surveys to count ASL at these sites have been undertaken between 1994 and 2011. Each of these sites is considered to have an individual ASL colony.

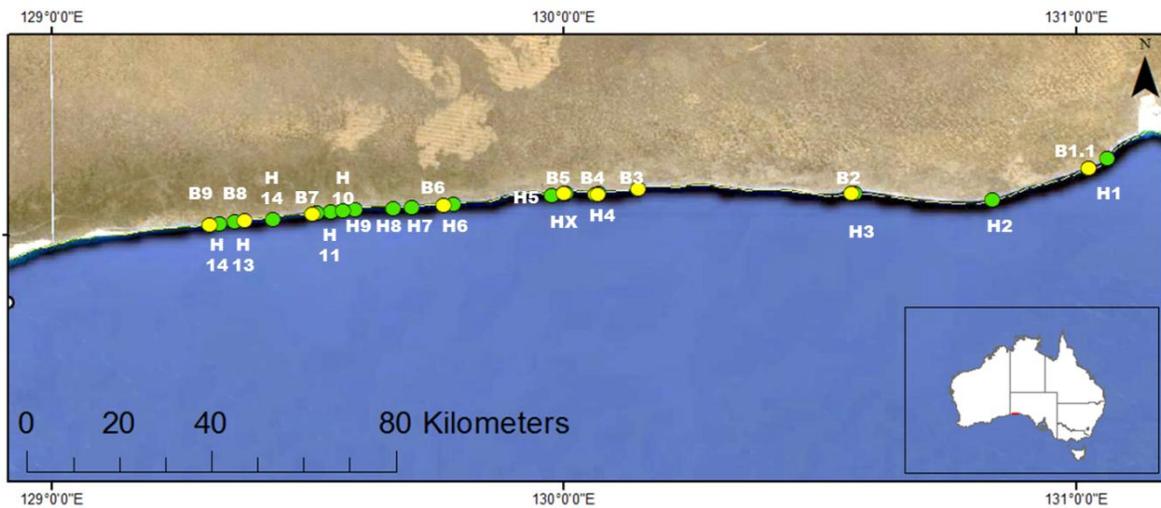


Figure 1. Location of Australian sea lion breeding (yellow) and haul-out colonies (green) in the Bunda Cliffs Region, South Australia.

Surveys of the sites are difficult because colonies are located at the base of ~90 m high cliffs, and observations are restricted to vantage points from cliff edges or slight promontories above them (Dennis and Shaughnessy 1996).

The current major threat to the ASL population in the Bunda Cliffs region is from bycatch in the Australian Government-managed demersal gillnet shark fishery of the Southern and Eastern Scalefish and Shark Fishery (SESSF) (Goldsworthy *et al.* 2010a, Hamer *et al.* 2011, SEWPaC 2013). ASL colonies in the Bunda Cliffs region have foraging grounds that extend many kilometres south of the GAB Marine Park (GABMP), and these overlap with the shark fishing grounds resulting in bycatch mortalities that have likely been unsustainable for most Bunda Cliffs breeding colonies (Goldsworthy *et al.* 2010a, Hamer *et al.* 2011). The Marine Mammal Protection Zone within the GABMP is closed to commercial fishing and non-commercial fishing activities between the 1st of May to the 31st of October each year during the southern right whale (*Eubalaena glacialis*) breeding and calving season. Spatial closures in the shark fishery to include all GAB Marine Park waters, and bycatch trigger limits, have been introduced by the Australian Fisheries Management Authority (AFMA) in a series of management actions since 2010 (AFMA 2013) to mitigate ASL bycatch in the fishery. Monitoring the response of ASL populations to these mitigation measures is seen as a critical performance measure by the Great Australian Bight Marine Park (GABMP) Steering Committee, Australian Sea Lion Recovery Plan and AFMA.

1.2. Objectives

The aims of this study were to provide advice to the GABMP Steering Committee on the status and trends in abundance of the ASL at the Bunda Cliffs by:

1. Reviewing and analysing existing data sets to assess the status and trends in abundance of the ASL population in the Bunda Cliffs region;
2. Reviewing the monitoring methods for the Bunda Cliffs ASL population and developing an appropriate protocol for on-going monitoring; and
3. Undertaking a survey of ASL pup abundance at the Bunda Cliffs breeding sites for the 2012/13 breeding season.

2. METHODS

2.1. Analysis of existing data sets

All available data collected from cliff-top surveys of ASL breeding and haul-out sites at the Bunda Cliffs region were collated. Table 1 lists the sources of survey data arranged by pupping season covering the period 1994 to 2013. The primary sources of data were Dennis and Shaughnessy (1996), Dennis (2001, 2008) and records of the GABMP management authority of National Parks and Wildlife SA (NPWSA). No survey data were available for five years during this 18-year period.

Table 1. Summary of Australian sea lion survey times and data sources for the Bunda Cliffs, Great Australian Bight Marine Park. The collectors of unpublished data are indicated where known.

<i>Pupping season</i>	<i>Source</i>
1993/94	A Zepf/NPWSA records
1993/94	Dennis & Shaughnessy (1996)
1995	A Zepf/NPWSA records
1995	Dennis & Shaughnessy (1996)
1996/97	T Dennis, R Belcher, S Clarke and B Robins/NPWSA data
2001	R Belcher/GABMP data
2001	S Clark/GABMP Management Authority
2001	S Clarke/AWNRM data
2001	T Dennis, R Belcher, S Clarke and B Robins/NPWSA data
2002/03	S Clark/GABMP Management Authority
2003	S Clark/GABMP Management Authority/ C Zwick/NPWSA data
2004	S Clark/GABMP Management Authority
2005	S Clark/GABMP Management Authority
2006/07	GABMP Management Authority
2008	Dennis (2008)
2009/10	B Dalzell/S Kumar/GABMP Management Authority
2010	S Kumar, A Lowther/GABMP Management Authority
2011	No surveys
2012/13	S Goldsworthy, P Shaughnessy, D Holman, A Mackay, S Kumar, A Lowther

2.2. Survey methodology

2012/13 pupping season

Three cliff top surveys of breeding and haul-out sites at the Bunda Cliffs region were conducted during the 2012/13 pupping season (6–7 November 2012, 14–16 January 2013 and 5–7 March

2013). Geographic locations of breeding and haul-out sites were stored in a hand-held GPS. The survey team drove to the vicinity of each geo-referenced site and then walked to the cliff-top to conduct counts using binoculars. Where possible, counts were made from at least two points along the cliff edge to obtain as complete a view of the site as possible. The number and age/sex class of all animals were recorded.

Assigning age and sex class – all survey data since 1994

During surveys, each observed sea lion was assigned to one of the following age and/or sex categories: adult male, sub-adult male, adult female, juvenile, unclassified, moulted pup, brown pup, dead pup. These categories were based on definitions in Gales *et al.* (1994). However, not all categories were used on all surveys. For example, on some surveys non-pup animals were simply categorised as “unclassified”, and initial surveys did not include the category “juvenile”. Sea lion pups were classified according to their pelage colour. Moulted pups, which have a similar pelage colour to adult females, are estimated to be >20 weeks of age, with those in lanugo (“black pups”) or undergoing moult (“brown pups”) estimated to be 0–20 weeks of age (McKenzie *et al.* 2005). For some surveys the number of black pups, as a subset of the brown pups category, was also recorded. Black pups are estimated to be <4 weeks of age.

Estimate of timing of pupping seasons

Australian sea lions breed every 17 to 18 months although the interval between breeding seasons can range from 16–20 months, and 90% of pups tend to be born within the first five months of the pupping season (Shaughnessy *et al.* 2006, Goldsworthy *et al.* 2008). The length of the pupping season appears to be related to colony size; extending to eight or nine months for larger colonies compared to only five months for smaller colonies (Shaughnessy *et al.* 2011). In order to obtain maximum counts of pups, the optimal time to survey ASL breeding colonies is within the 3rd or 4th month of the breeding season. However, predicting the timing of the commencement of the pupping season is difficult as, along with variation in the length of breeding cycles, the timing of breeding is also asynchronous between colonies. Asynchrony in the pupping season between ASL breeding sites at the Bunda Cliffs has previously been reported (Dennis 2001).

To estimate the timing of pupping seasons at the Bunda Cliff ASL colonies, an assessment of all survey data collected since 1994 was conducted. Where the available data allowed, the proportion of brown to moulted pups recorded during a survey at an individual site was determined. As pups moult when approximately four months old, the presence of only brown

pups is indicative of the survey coinciding with the first four months of breeding, whereas the presence of moulted pups suggests that the peak of breeding has passed. A higher proportion of moulted pups is indicative that the breeding season is almost over or has ended.

The timing of pupping seasons at Bunda Cliff ASL colonies presented in this report are best estimates based on the available data and the breeding cycle interval and pupping season length observed in other ASL colonies. However, two factors will affect the precision of these estimates; asynchrony of timing of pupping between sites at the Bunda Cliffs (Dennis 2001), and possible variations in breeding cycle interval and pupping season length over time. Such variations have been observed from a long-term study of an ASL colony on Kangaroo Island, SA (McIntosh *et al.* 2012). In order to obtain a greater understanding of both the breeding cycle interval and pupping season length of Bunda Cliff ASL colonies, multiple surveys of all sites across predicted future pupping seasons will be required.

Estimating trends in pup production

Survey effort at individual breeding colonies varied greatly, both within and between pupping seasons. In order to estimate trends in pup production, data were restricted to the maximum pup count per site per season. To assess overall trends, these maximum counts per pupping season were combined for all sites along the Bunda Cliffs. In order to account for differences in survey effort (i.e. not all sites being surveyed), this total count was divided by the number of sites surveyed during a season. Where available, data were analysed at an individual breeding site level. Of the 10 extant breeding sites, the highest survey effort within pupping seasons has been at B3, B7 and B8. Modelling was restricted to sites B3 and B8 because maximum pup counts at B7 during pupping seasons have only ranged from 0 to 3 and therefore were not suitable to model.

3. RESULTS

3.1. 2012/13 pupping season

Eight of the ten existing breeding sites were surveyed on 6–7 November 2012 (Table 2). B1, a cave accessible only from the sea, has not been surveyed since 1995. Dennis (2001) did not survey the cave, although noted it still existed. However sometime after this survey the cave at B1 collapsed and is no longer viable ASL habitat. Brown pups were present at two of the sites (B5 and B8), with no moulted pups recorded, indicating that this survey occurred at or near the start of the breeding season. Two dead pups were recorded at B9. No animals were observed at B6 and no adult females were observed at four sites. The adult female at B2 was observed to be heavily pregnant.

All nine breeding sites and eleven of fourteen haul-out sites were surveyed on 14–16 of January (Table 2). An additional site (nominally a haul-out site) were surveyed based on its inclusion in the GPS locations provided (HX). No ASL were seen at this site. Eight and three brown pups were counted at B3 and B5, respectively. The eight pups counted at B3 were all in lanugo, and one adult female was being mate-guarded, so it is likely that another pup was present at the site, but out of view from the cliff top. In contrast, the three pups counted at B5 were estimated to be 6–8 weeks of age. A single dead pup was counted at both B7 and B8.

All nine breeding sites and thirteen of the fourteen haul-out sites were surveyed on 5–7 March, 2013. Nominal haul-out site HX was also surveyed. Results of this survey are presented in Table 2. Brown pups were recorded at B3, B5 and B6 (two, five and two, respectively). Two moulted pups were recorded at B3 and seven moulted pups at B8. No new dead pups were recorded. One of the brown pups recorded at B3 and four of the five pups recorded at B5 were in lanugo, whilst both brown pups recorded at B6 were estimated to be 1–2 months in age.

Table 2. Results of cliff top surveys of Australian sea lion breeding sites at the Bunda cliffs in November 2012, January 2013 and March 2013.

Site	Adult Male	SAM	Adult Female	Unclassed	Juvenile	Brown pup	Moulted pup	Dead pup	Total count	Total pup
6-7 November 2012										
B2	2	1	1	0	0	0	0	0	4	0
B3	4	1	0	1	0	0	0	0	6	0
B4	1	0	0	0	0	0	0	0	1	0
B5	2	0	3	0	0	3	0	0	8	3
B6	0	0	0	0	0	0	0	0	0	0
B7	0	0	0	0	0	0	0	0	0	0
B7.1	1	0	1	0	0	0	0	0	2	0
B8	3	1	3	3	0	1	0	0	11	1
B9	0	0	3	0	0	0	0	2	5	2
14-16 January 2013										
B1.1	0	0	0	0	0	0	0	0	0	0
B2	0	1	0	0	0	0	0	0	1	0
B3	4	2	9	0	0	8	0	0	23	8
B4	0	0	1	0	0	0	0	0	1	0
B5	1	0	1	0	0	3	0	0	5	3
B6	0	1	0	0	0	0	0	0	1	0
B7	0	0	0	0	1	0	0	1	2	1
B8	0	0	2	0	1	0	0	1	4	1
B9	1	0	0	0	0	0	0	0	1	0
H1	0	0	0	0	0	0	0	0	0	0
H4	0	0	0	0	0	0	0	0	0	0
H5	0	0	0	0	0	0	0	0	0	0
H6	0	0	0	0	0	0	0	0	0	0
H7	0	0	0	0	0	0	0	0	0	0
H8	0	0	0	0	1	0	0	0	1	0
H9	0	0	0	0	0	0	0	0	0	0
H10	0	0	0	0	0	0	0	0	0	0
H12	0	0	0	0	0	0	0	0	0	0
H13	0	0	1	0	0	0	0	0	1	0
H14	0	0	1	0	2	0	0	0	3	0
HX	0	0	0	0	0	0	0	0	0	0
5-7 March 2013										
B1.1	0	0	3	0	1	0	0	0	4	0
B2	3	0	3	0	0	0	0	0	6	0
B3	2	1	4	0	0	2	2	0	11	4
B4	0	0	1	0	0	0	0	0	1	0
B5	2	2	13	0	2	5	0	0	24	5
B6	0	0	1	0	1	2	0	0	4	2
B7	0	1	1	0	0	0	0	0	2	0
B8	2	0	6	0	5	0	7	0	20	7
B9	1	0	4	0	2	0	0	0	7	0
H1	0	0	0	0	0	0	0	0	0	0
H2	0	0	0	0	0	0	0	0	0	0
H3	0	0	2	0	0	0	0	0	2	0
H4	0	0	1	0	0	0	0	0	1	0
H5	1	0	1	0	0	0	0	0	2	0
H6	0	0	1	0	0	0	0	0	1	0
H7	0	0	0	0	1	0	0	0	1	0
H8	0	0	2	0	0	0	0	0	2	0
HX9	0	0	0	0	0	0	0	0	0	0
H10	0	0	1	0	0	0	0	0	1	0
H12	0	0	0	0	2	0	0	0	2	0
H13	0	0	0	0	0	0	0	0	0	0
H14	0	0	7	0	3	0	0	0	10	0
HX	0	0	1	0	0	0	0	0	1	0

3.2. Analysis of existing survey data sets - changes in breeding and haul-out sites

Since 1994, two additional breeding sites B1.1 (Dennis 2001) and B7.1 (Dennis 2008) have been identified. Breeding site B1.1 is described in Dennis (2001) as consisting of a cave, overhang and platform. Dennis (2001) reported that the number of pups he counted at this site in 2001 was likely a minimum estimate as, given the behaviour of adult females there, it was likely that more pups were present, but it was not possible to see all areas of the site due to the overhang and cave. Site B7.1 was first reported in 2008; we have been unable to find additional information about this site.

The GPS location of a further haul-out site (HX) was provided, in a hand-held GPS device to SARDI by DEWNR, and was surveyed twice in 2013. The provenance of this site is unknown. While no ASL were seen at HX on either survey, signs of recent use were observed, based on the presence of tracks in the sand. There are no records of surveys at H11 since 1995, which was described in Dennis and Shaughnessy (1996) as “cliff undercut at base”. In 1994, 13 ASL were seen in the water at H11, while none were sighted there in 1995. We consider that H11 no longer exists as a haul-out site and it requires no further monitoring.

3.3. Estimate of timing of pupping seasons

Accurately estimating the timing of pupping seasons at the Bunda Cliffs region from 1994 to 2013 is confounded by the variability in survey effort and timing of surveys both between sites and years, and asynchrony in the timing of pupping between sites across the Bunda Cliffs. Figure 2 provides an estimate of timing of breeding seasons in the Bunda Cliffs region based on the percentage of brown to moulted pups sighted during surveys and estimates from some previous published surveys (Dennis and Shaughnessy 1996, Dennis 2001, 2005, 2008, Shaughnessy *et al.* 2011). For these estimates the pupping season length is estimated to be between 6–7 months to allow for asynchrony in the timing of pupping between breeding sites, as smaller ASL colonies have been found to have shorter pupping seasons (~ five months) than larger ones (Shaughnessy *et al.* 2011).

Figure 2. Estimated temporal variation in the timing of breeding of Australian sea lion colonies in the Bunda Cliffs region (1994 to 2013). Shaded areas indicate breeding seasons, with dark and light grey cells representing alternate seasons. Numbers indicate the number of individual breeding sites surveyed in that month.

Year	Jan	Feb	March	April	May	June	July	August	Sep	Oct	Nov	Dec
1994			1					9				
1995					1	2	1	9				
1996												
1997												
1998												
1999												
2000												
2001							9	3	5			
2002												
2003							3			3		
2004							4			3		
2005							4	2	2			
2006			8	8				5				2
2007				7								
2008									9			
2009										3	9	9
2010		10	1	8	8							
2011												
2012											9	
2013	10		10									

Fourteen ASL pupping seasons are estimated to have occurred at the Bunda Cliffs region since 1994. Cliff-top surveys of breeding sites were conducted during eight of these pupping seasons; however survey effort varied from one or two sites being surveyed once within a pupping season, to multiple surveys of all sites on several occasions during some pupping seasons. 38% of all months surveyed fell outside estimated pupping seasons.

Figure 3. The total number of Australian sea lion pups (brown, moulted, dead) counted at all breeding sites along the Bunda Cliffs during months when cliff-top surveys occurred. Zero values represent surveys where no pup was seen. Data are not effort adjusted.

Year	Jan	Feb	March	April	May	June	July	August	Sep	Oct	Nov	Dec			
1994	5			37											
1995					4	5	3	77							
1996															
1997															
1998															
1999															
2000															
2001			39					2	4						
2002															
2003								0	2						
2004							10	0							
2005								5	6	6					
2006	6		9									1	0		
2007	24														
2008						25									
2009											0	0	1		
2010	7		0	16	9										
2011															
2012										6					
2013	13		18												

A number of surveys conducted outside the estimated pupping season recorded pups. In August 1994, 85% of pups counted were moulted. The two and four pups counted in August and September 2001, respectively, were brown pups. Fifty per cent of the pups counted in July 2004 and all pups recorded in May 2010 were moulted. In addition, several surveys recorded brown pups outside estimated pupping seasons. Two brown pups were also recorded in October 2003 (NPWSA unpublished data) and 1 brown pup was recorded in each of April and August 2006 (GABMP unpublished data).

The highest total pup count within a breeding season was recorded in 1995 (n=75 pups), of which 17% were counted at breeding site B1. This site accounted for 30% of the 37 pups counted during the August 1994 survey.

No brown pups or moulted pups were observed at any of the haul-out sites on surveys during the 2012/13 pupping season. Moulted pups were recorded at haul-out sites in 1994 (n=49) and 1995 (n=13) (Dennis and Shaughnessy 1996), and brown pups have been recorded at haul-out sites in three subsequent years. Two brown pups were recorded at H1 in 2001 (Dennis 2001), and single brown pups were recorded at H5 and H6 in 2006, and at H12 in 2010 (GABMP data).

3.4. Survey effort

Survey effort has varied greatly both within and between pupping seasons. Tables 3 and 4 present the annual survey effort at each of the ASL breeding and haul-out sites at the Bunda Cliffs region between 1994 and 2013. The percentage of breeding sites surveyed per pupping season ranged from 0–100%, with 100% of all sites being surveyed in only 3 of the 14 pupping seasons, and with no sites surveyed during five pupping seasons. Survey effort at individual *existing* breeding sites across pupping seasons ranged from 33–64%. Survey coverage of the 14 haul-out sites was lower, with no sites surveyed during 6 of 14 pupping seasons. Survey effort at individual haul-out sites across pupping seasons ranged from 14–57%.

Table 3. Survey effort by pupping season at each of the Bunda Cliffs breeding sites. Black shading indicates those years when a site had not been identified or when a site was no longer surveyed. Grey shading indicates years when a survey took place, and values indicate the number of times an individual site was surveyed during the predicted pupping season, or within four months of the end of the predicted pupping season. The right hand column indicates the percentage of sites surveyed in a particular year. The bottom row indicates the survey effort at individual sites.

Pupping season	B1	B1_1	B2	B3	B4	B5	B6	B7	B7.1	B8	B9	
1993/94	1		1	2	1	1	1	1		1	1	100%
1995	1		1	4	1	1	2	1		1	1	100%
1996/97												0%
1998												0%
1999/00												0%
2001		3	1	2		2	3	1		1	2	89%
2002/03												0%
2004				2			1	1		1	2	56%
2005			2	5	4	3	3	4		4	3	89%
2006/07				1		1				1	1	44%
2008			1	1		1	1	1	1	1	1	80%
2009/10		3	6	5	5	6	5	6		4	5	90%
2011												0%
2012/13		2	3	3	3	3	3	3	1	3	3	100%
	100%	33%	50%	64%	36%	57%	57%	57%	50%	64%	64%	

Table 4. Survey effort by pupping season at each of the Bunda Cliffs haul-out sites. Grey shading indicates years when a survey took place, and values indicate the number of times an individual site was surveyed during the predicted pupping season, or within four months of the end of the predicted pupping season. Figures in parentheses indicate the number of times a site was surveyed 6 months or later than the predicted end of the previous pupping season. The right hand column indicates the percentage of sites surveyed in a particular year. The bottom row indicates the survey effort at individual sites.

Year	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	
1993/94	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100%
1995	1	1	1	1	1	1	1	1	1	1	1	3	1	1	100%
1996/97															0%
1998															0%
1999/00															0%
2001	2				1	1	1	1		1		2	1	2	64%
2002/03															0%
2004															0%
2005					2 (1)	2 (1)	2	2 (1)		2 (1)		3 (1)	3	3	57%
2006/07					2	1						1		1	29%
2008	1	1		1	1	1	1	1	1			1	1	1	79%
2009/10	2	1	3	3	3	3	3	3	3	3		3	4	4	86%
2011															0%
2012/13	2	1	1	2	2	2	2	2	2	2		2	2	2	86%
	43%	36%	29%	36%	57%	57%	50%	50%	36%	43%	14%	57%	50%	57%	

3.5 Estimating trends – individual breeding sites

Only two breeding sites (B3 and B8) were surveyed with sufficient effort, and had enough non-zero counts, between 1993/94 and 2012/13 to allow analysis of trends in pup numbers at the individual breeding site level. Figure 4a and 4b present the maximum pup counts recorded at sites B3 and B8, respectively, between the 1993/94 and 2012/13 pupping seasons.

Results from a linear regression model fitted to the maximum counts of pups recorded at B3 and B8 did not show a statistically significant trend (B3: $F_{1,6}=1.202$, $p=0.315$, $r^2=0.03$. B8: $F_{1,4}=0.7075$, $p=0.44$, $r^2=0.15$).

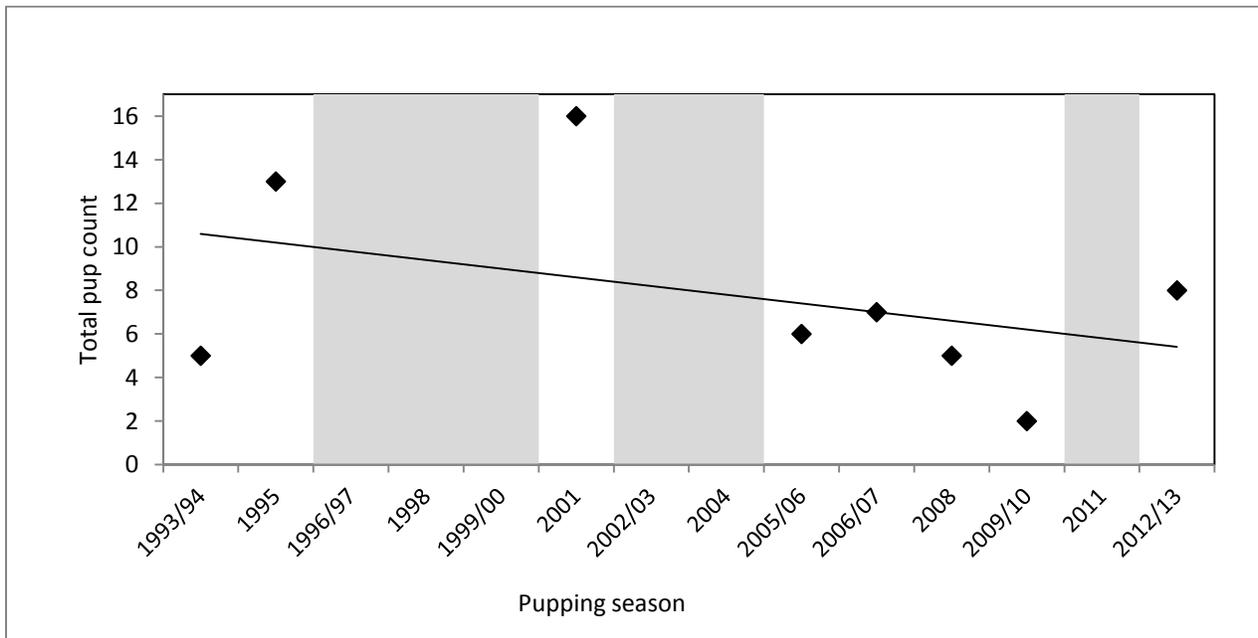


Figure 4a. Maximum Australian sea lion pup counts recorded at site B3 in the Bunda Cliffs during eight pupping seasons between 1993/94 and 2012/13. Shaded grey areas indicated pupping seasons when no surveys were conducted.

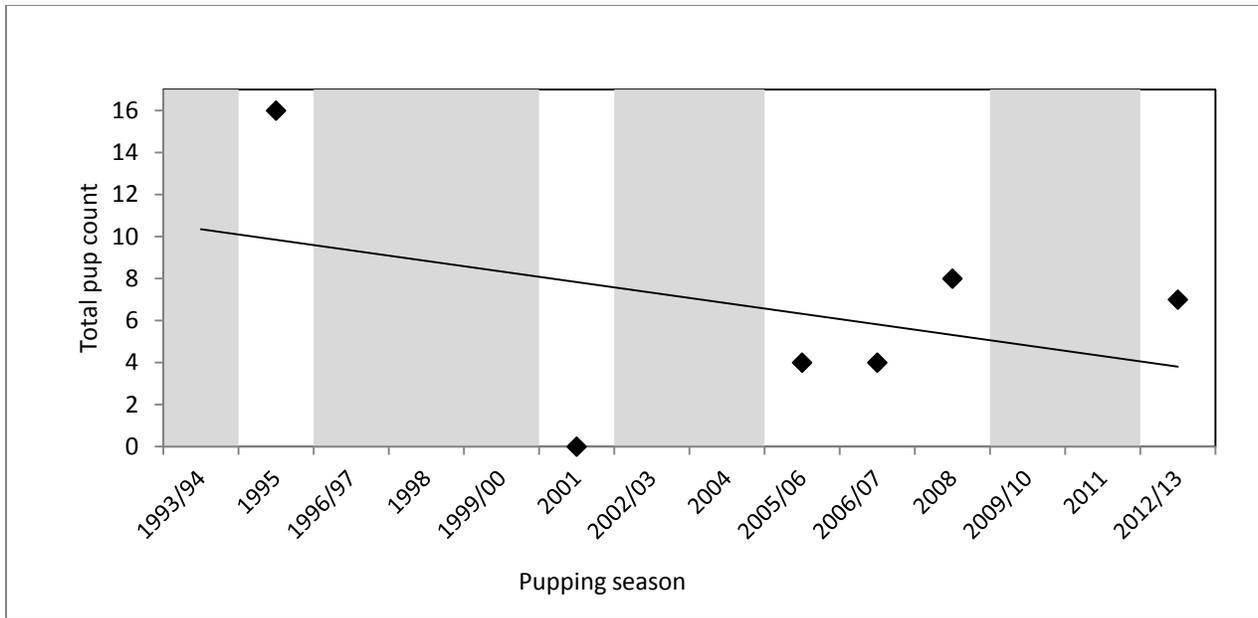


Figure 4b. Maximum Australian sea lion pup counts recorded at site B8 in the Bunda Cliffs during eight pupping seasons between 1993/94 and 2012/13. Shaded grey areas indicated pupping seasons when no surveys were conducted.

A significant relationship between cumulative pup counts and alternate winter and summer pupping seasons has been identified in ASL colonies at Seal Bay (McIntosh *et al.* 2012), and Dangerous Reef (Goldsworthy *et al.* 2010b), however this pattern has not been observed in all colonies (Shaughnessy *et al.* 2013). As over two thirds of the counts modelled were collected during winter months it was not possible to determine whether there is an effect of alternating pupping seasons on pup numbers at Bunda Cliff colonies.

3.6 Estimating trends – all breeding sites combined

As survey effort at individual breeding sites varied greatly both within and between pupping seasons, a means of accounting for effort is required before estimating trends from data combined for all surveyed sites. The relative contribution of each site to the total number of pups counted across all sites during pupping seasons was investigated as a means of weighting counts for individual sites by the relative proportion of total pups counted from all breeding sites. There was no consistent pattern in the relative contribution of sites (B1 to B9 inclusive) to total pup numbers between the 1993/94 and the 1995 pupping seasons when all nine sites were surveyed (Figure 5), nor were these patterns consistent across the four pupping seasons (Figure 6). The lack of consistent pattern in the relative contribution of

individual breeding sites to total pup numbers means that it is not possible to weight counts based on site importance. Therefore, a simpler method was used to account for survey effort when combining pup counts from all surveyed sites. While this approach is not ideal, given the limited data, it is the best method to account for variation in the number of sites surveyed during breeding seasons in order to investigate trends when data from all surveyed sites is combined.

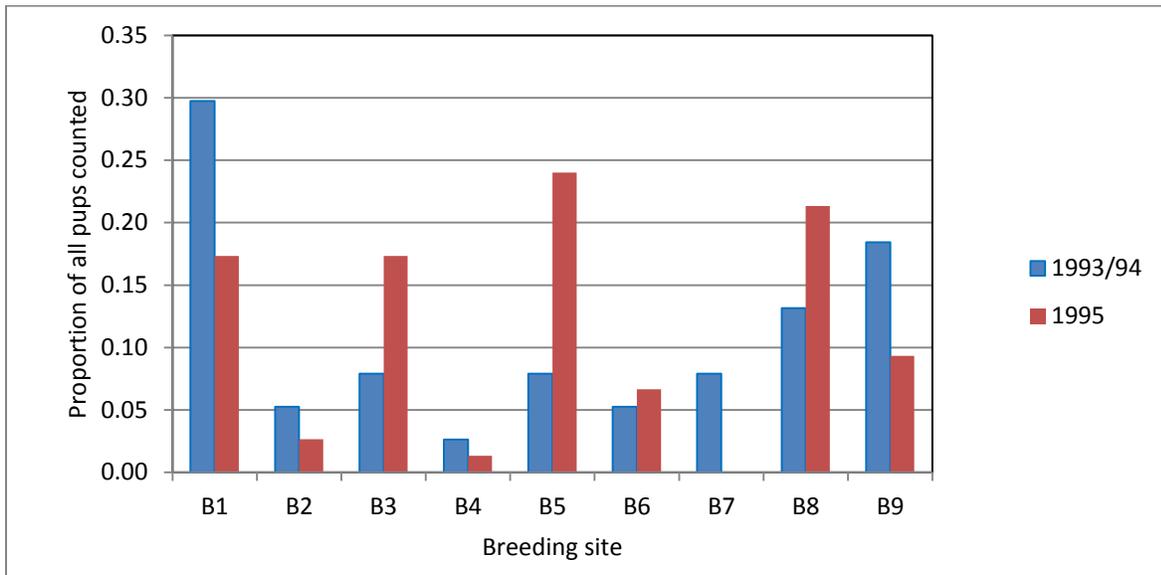


Figure 5. Proportion of total pup counts recorded at individual breeding sites during the 1993/94 and 1995 pupping seasons when nine sites (B1 to B9) were surveyed.

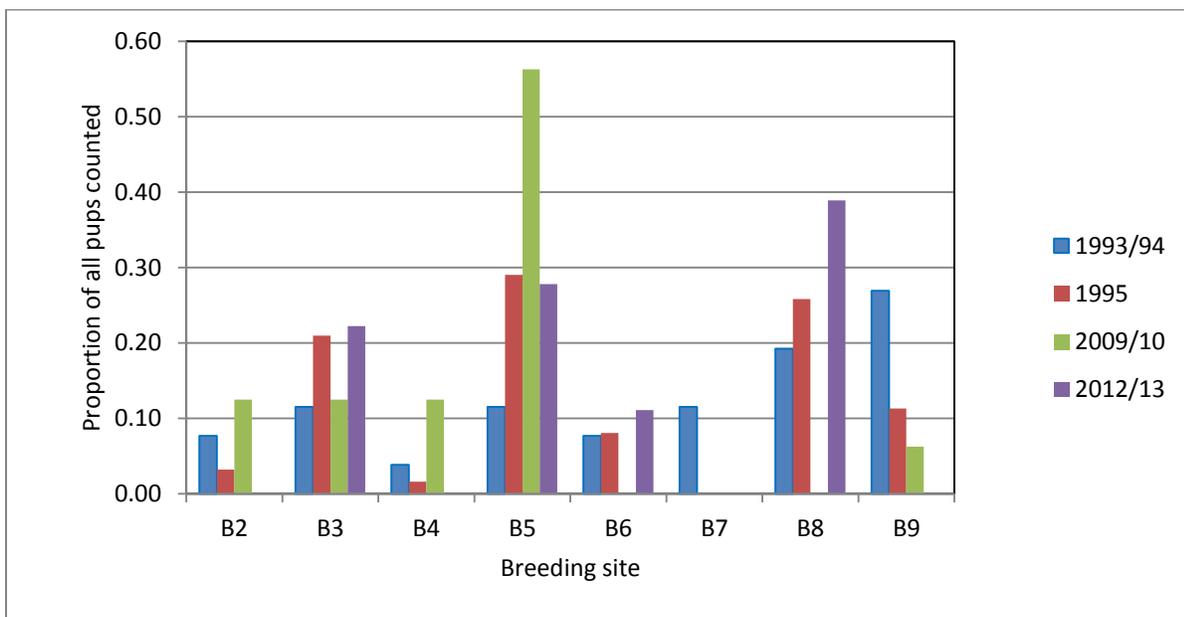


Figure 6. Proportion of total pup counts that were recorded at individual breeding sites over four pupping seasons when eight sites (B2 to B9) were surveyed.

Figure 7 shows the mean maximum pup count recorded at breeding sites during, or just after pupping seasons, adjusted by survey effort (i.e., the maximum pup count divided by the number of breeding sites surveyed to obtain that maximum count). Only data collected during the estimated pupping season, or within four months of the end of the season, were included for this analysis, as this is the extent of time for which pups can be reliably identified as having been born in that season. Results from a linear regression model indicate a significant decline, of 39%, in mean maximum number of pups counted per site between the 1993/94 and the 2012/13 pupping season ($F_{1,6}=18.46$, $p<0.001$, $r^2=0.71$). As site B1 accounted for 30% and 17% of all pups counted in the 1993/94 and 1995 pupping seasons, respectively, but has ceased to exist since, the effect of removing B1 from the dataset was investigated. The decline in mean maximum number of pups remained significant when B1 was removed ($F_{1,6}=23.04$, $p<0.001$, $r^2=0.76$), although the predicted decline was lower (36%).

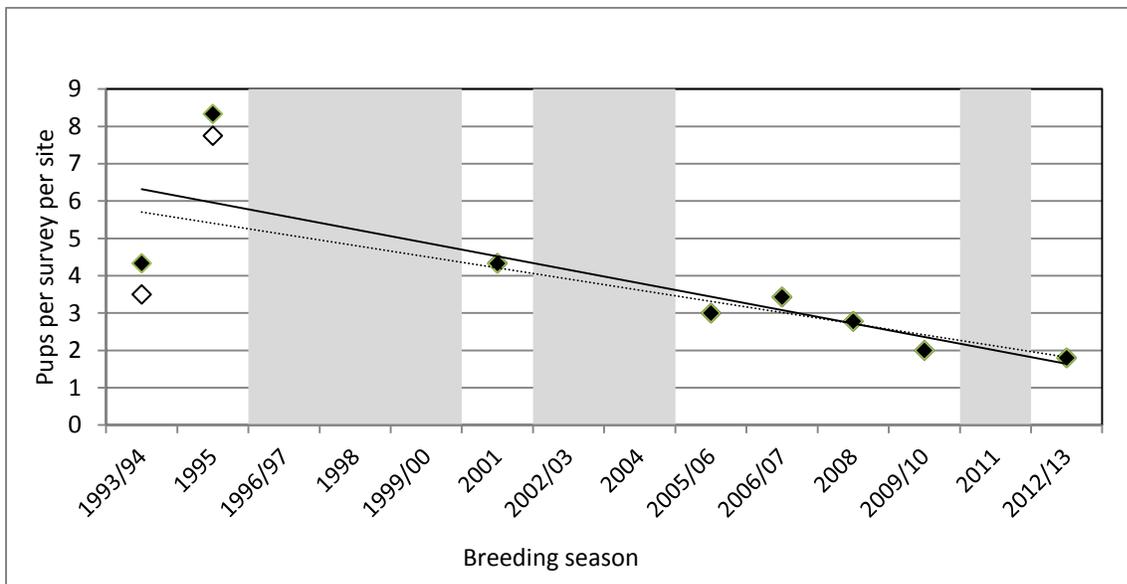


Figure 7. The mean maximum number of Australian sea lion pups counted per breeding site, per breeding season in surveys conducted along the Bunda Cliffs over eight pupping seasons between 1993/94 and 2012/13. White diamonds for 1993/94 and 1995 and dashed line indicate mean maximum counts and trends respectively, when data from B1 are removed. Shaded grey areas indicate pupping seasons when no surveys were conducted.

The sum of the maximum number of ASL counted (adults, juveniles, unclassified and pups), adjusted for survey effort, also showed a significant decline ($F_{1,6}=53.98$, $p<0.001$, $r^2=0.88$) (Figure 8). This significant decline remained even when data collected from B1 in 1993/94 and

1995 (which accounted for 26% and 18% of the total ASL count during those pupping seasons respectively) were excluded.

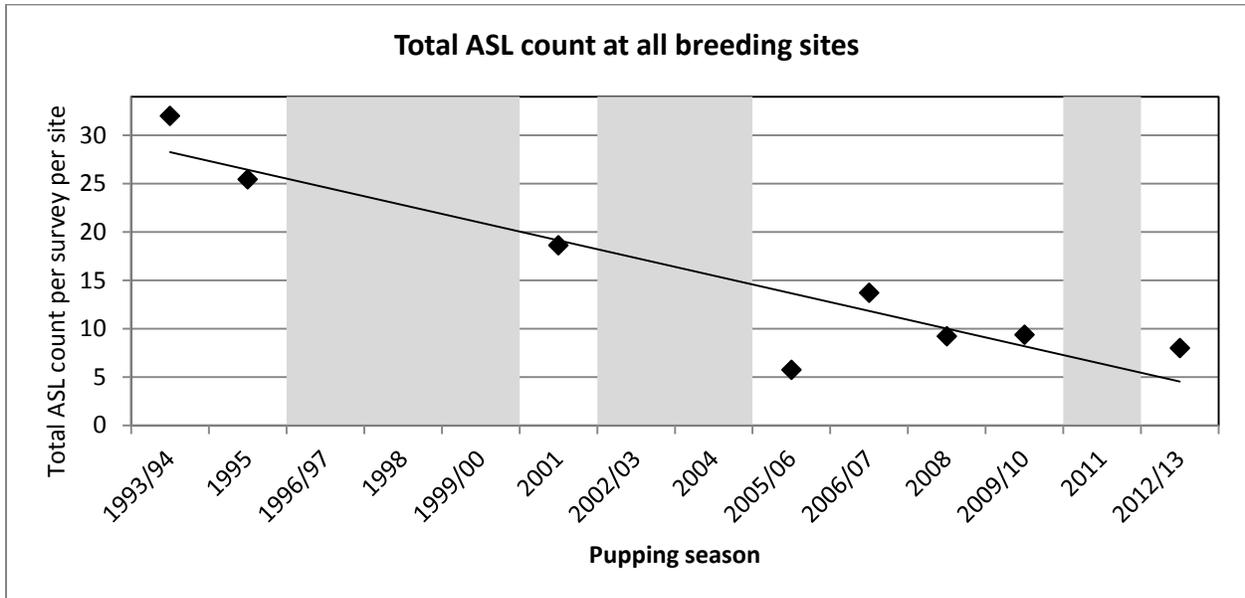


Figure 8. The mean maximum total number of Australian sea lions counted (all age/sex classes) per breeding sites, per breeding season in surveys conducted along the Bunda Cliffs (GABMP) over eight pupping seasons between 1993/94 and 2012/13. Shaded grey areas indicate pupping seasons when no surveys were conducted.

4. DISCUSSION

Since 1993/94, the number and timing of surveys relative to the timing of the pupping season have varied greatly. No surveys were conducted during five of the 14 pupping seasons, while surveys of all breeding sites within the same month have only occurred during five pupping seasons. Survey effort at individual breeding sites has also varied, both within and between pupping seasons. Dennis (2001) noted asynchrony in the timing of breeding among different breeding sites in the Bunda Cliffs region. Although it was not possible with the available data to make a quantitative assessment of the relative timing of breeding among breeding sites, a qualitative assessment supports Dennis' observation, with breeding commencing earlier at western sites. All pups recorded at B8 during the March 2013 survey were already moulted, while at site B5, approximately 60 km east of B8, 80% (n=4) of the pups recorded were still in lanugo. Unless the timing of surveys can be scheduled to coincide with the appropriate time of the pupping season at individual sites, counts will be underestimates.

Observer effort may also bias the number of ASL counted during surveys. The number of ASL counted at a site may be affected by the amount of time an observer spends surveying the site (additional animals may move into view over time), and how many cliff-top vantage points along the site are used. The total number of ASL at breeding and haul-out sites counted from cliff top surveys should be viewed as minimum numbers as it is likely that some animals may not have been visible to a cliff-top observer. For example, a within-colony ground survey at H12 in 1994 doubled the number of sea lions counted at this site on the same day from a cliff top survey (Dennis and Shaughnessy 1996). During the March 2013 survey, seven moulted pups were recorded at B8, although no pups (brown or moulted) were recorded at this site during the January 2013 survey. It is likely that these pups would have been at B8 in January, but were not visible from the cliff top.

There appears to have been inconsistencies in the latitude and longitude positions assigned to some sites between years. Geographic locations of sites surveyed during the 2012/13 pupping season were provided by the GABMP, which did not include locations for H9 or H11. An assessment of GPS locations used by the GABMP in 2008 found that the recorded location of

H5 surveyed then was more than 4 km east of the GPS position for this site used in the 2012/13 survey.

Analyses of historical and current survey data suggests there has been an overall decline in both pup numbers and the total number of Australian sea lions in the Bunda Cliffs between the 1993/94 and 2012/13 pupping seasons. This is likely the result of bycatch in the demersal gillnet shark fishery of the SESSF, and is consistent with previous assessments based on the distribution of fishing effort, ASL foraging distributions and estimated bycatch levels that have indicated that ASL bycatch in the region is unsustainable (Goldsworthy and Page 2007, Goldsworthy *et al.* 2010a, Hamer *et al.* 2011). For two breeding sites which have had the highest survey effort within pupping seasons, declines were not statistically significant. More dedicated survey efforts are required to confirm these trends.

5. RECOMMENDATIONS FOR FUTURE SURVEYS

- Future surveys should note the observed asynchrony in the timing of pupping among breeding sites in the Bunda Cliffs region.
- The distinction between breeding sites and haul-out sites for aggregations of ASL on the Bunda cliffs should be disbanded and all sites should be renamed sequentially by their longitude which will make locating and monitoring them simpler.
- Omit H11 from the survey protocol as this site has not been surveyed since 1995.
- Future surveys should ensure that, as a minimum, sites B3 and B8 are included to extend their time series.
- Future surveys should include all sites to avoid the possibility that some animals might move between sites and not be surveyed.
- Adequate time (at least two days on the Bunda Cliffs) should be allowed for each survey to ensure that all sites are visited.

Each site should be surveyed for a minimum of 30 minutes from a number of cliff-top vantage points to allow for additional animals moving into view over time.

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