

## Status and trends in abundance of New Zealand fur seal populations in South Australia



**Peter D Shaughnessy, Simon D Goldsworthy  
and Alice I Mackay**

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SARDI Aquatics Sciences  
PO Box 120 Henley Beach SA 5022

**June 2014**

Final Report to the Australian Marine Mammal Centre

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## EXECUTIVE SUMMARY

Two species of fur seal breed in South Australia (SA), the New Zealand (NZ) fur seal *Arctocephalus forsteri* and the Australian fur seal *A. pusillus doriferus*. For the NZ fur seal, most of the SA population breeds between Kangaroo Island and the southern tip of Eyre Peninsula. For the Australian fur seal, most of the SA population is on Kangaroo Island and the nearby Casuarina Islands.

Fur seal populations in southern Australia were heavily exploited by colonial sealers between 1801 and 1830, resulting in major reductions in range and abundance. Numbers remained at very low levels for almost 140 years, when they slowly began to build up and new colonies established across their former range. Recovery of populations of the two fur seal species has benefitted from protection of the breeding colonies by State and Commonwealth governments. The best quality and most continuous data set on the recovery of New Zealand fur seals in Australia comes from the long-term monitoring program in colonies on Kangaroo Island, particularly at Cape Gantheaume Wilderness Protection Area (WPA) where it has extended for 26 consecutive seasons.

Objectives of this project were to estimate pup abundance of the NZ fur seal at all SA colonies during the 2013-14 breeding season and to compare the estimate with that made in 1989-90, and to record the incidence of Australian fur seals in SA.

NZ fur seals were recorded from Baudin Rocks in the south-east of the State to Nuyts Reef in the north-west. There were 28 breeding sites which produced a total estimate of 20,426 pups. That estimate is 3.6 times greater than the previous estimate of 5,636 pups from a survey in the 1989-90 breeding season. The increase is attributed to the recovery of the fur seal population from overharvesting in the 19<sup>th</sup> century. The overall estimate of pup numbers for SA leads to an estimate of abundance of NZ fur seals in SA of 97,200.

The greatest number of NZ fur seal pups was on Kangaroo Island, with 49.6% of the overall estimate, followed by the Neptune Islands, with 38.6%. Two new breeding sites were discovered, Williams Island and a site 1 km east of Remarkable Rocks on the south coast of Kangaroo Island, as well as three new sub-colonies at North Hummock, Pearson and South Ward Islands.

## 1. INTRODUCTION

### 1.1. Background

Two species of fur seal breed in South Australia (SA), the New Zealand (NZ) fur seal *Arctocephalus forsteri* which is also known as the long-nosed fur seal, and the Australian fur seal *A. pusillus doriferus* (Goldsworthy 2008, Shaughnessy *et al.* 2010). For the NZ fur seal, most of the SA population is distributed between Kangaroo Island and the southern tip of Eyre Peninsula. For the Australian fur seal, most of the SA population is on Kangaroo Island and the nearby Casuarina Islands.

Fur seal populations in southern Australia were heavily exploited by colonial sealers between 1801 and 1830, resulting in major reductions in range and abundance (Kirkwood and Goldsworthy 2013). Numbers remained at very low levels for almost 140 years, when they slowly began to build up and new colonies were established across their former range.

The best quality and most continuous data set on the recovery of New Zealand fur seals in Australia comes from the long-term monitoring program in colonies on Kangaroo Island, particularly at Cape Gantheaume Wilderness Protection Area (WPA), where it has extended for 26 consecutive seasons. Recovery of populations of the two fur seal species has benefitted from protection of the breeding colonies by State and Commonwealth governments.

On Kangaroo Island, the main aggregations of NZ fur seals are in the Cape Gantheaume WPA, centered on Cape Gantheaume (36.07S, 137.46E) and at Cape du Couedic (36.06S, 136.71E), Off the Eyre peninsula the main aggregations are on South Neptune Island (35.33S, 136.11E), North Neptune Island (35.23S, 136.07E) and Liguanea Island (34.99S, 135.62E) (Figure 1). At each of these sites there are several breeding aggregations of fur seals. In addition, there are small colonies in other parts of the State.

The abundance of NZ fur seals in SA was first estimated in the summer of 1989-90 by Shaughnessy *et al.* (1994) using mark-recapture procedures in most large colonies and direct counting of pups in other colonies. More recent estimates of abundance have been provided by Goldsworthy *et al.* (2003) and Goldsworthy and Page (2007). In addition, previously unpublished estimates of pup abundance at the Neptune Islands and Liguanea Islands, from surveys conducted during the 2006-2008 breeding seasons (SARDI *unpublished data*), are provided in this report. Since the original survey was undertaken, the population size in SA has increased considerably, based on a long-term project that began in the 1988-89 summer (Shaughnessy 1989, Goldsworthy and Shaughnessy 2013) aimed at determining trends in abundance of NZ fur seals on Kangaroo Island.

The abundance estimates are directed at pups because they form the only age-class that is easily recognisable based on their small size and black natal coat (lanugo). Furthermore, they are all ashore together and don't leave the colony (or its vicinity) when disturbed. Although the relationship between the number of pups and the total population size is variable, depending on the status of the population, pup numbers form a useful index of population size (Berkson and DeMaster 1985).

## **1.2. Objectives**

The main objectives of this project were to estimate pup abundance of the NZ fur seal at all colonies in SA during the 2013-14 breeding season and estimate trends in abundance since the previous State-wide survey in 1989-90. This report provides estimates of abundance of pups at each location where they were found.

Two other objectives were (i) to weigh and sex samples of NZ fur seal pups at Cape Gantheaume and South Neptune Island to compare with pup weights at these colonies taken in previous years and (ii) record the incidence of Australian fur seals in SA.

## 2. METHODS

### Colonies and place names

A map of SA showing survey sites is provided in Figure 1. Aggregations of breeding fur seals are described as breeding 'colonies', 'aggregations' or 'sites'. Fur seal aggregations that included pups within 2 km of each other were referred to as a single colony, and the individual aggregations within a colony are referred to as sub-colonies. This is based on the terminology adopted by Shaughnessy *et al.* (1994), although they referred to aggregations within 2 km as 'breeding localities' (which are referred to here as a 'breeding colonies'). Locations where fur seals were seen ashore but there was no evidence of breeding are referred to as haul-out sites.

These definitions have greatest effect on two breeding colonies on Kangaroo Island, referred to as Cape Gantheaume and Cape du Couedic. The former includes the sub-colonies Cape Gantheaume (around the headland of that name), Little Weirs (100 m north-east of the eastern end of the Cape Gantheaume colony) and Berris Point (2km further north-east). The Cape Gantheaume and Berris Point sub-colonies were further divided into sectors to aid the estimation of pup production. Boundaries were based on recognisable landscape features which were marked with steel stakes and coloured ribbon; pup numbers were estimated separately for each sector. In addition, there were small aggregations of fur seals in caves 0.5 km west of the Cape Gantheaume headland and near the Little Weirs sub-colony which were included in the Cape Gantheaume breeding colony. At the north-east end of the Cape Gantheaume Wilderness Protection Area (WPA) is the Cape Linois colony; it was not included in the Cape Gantheaume breeding colony because it was beyond the 2 km limit (being 14 km north-east of the Berris Point sub-colony).

The Cape du Couedic breeding colony, which is within Flinders Chase National Park, comprises ten fur seal sub-colonies distributed over 6 km of coastline with up to 1.5 km between them. Sub-colonies occur at the base of steep limestone cliffs and are separated from each other by a headland impassable to researchers, by a rocky cove or by a beach. On the east side they are referred to as Knife and Steel Point, Weirs Cove North, Weirs Cove South, Ladders North, Ladders South and Admirals Arch (with the last extending around the Cape). On the west side they are referred to as Nautilus Rock, Nautilus North, Libke and Spooks. The Libke sub-colony was divided into sectors using recognisable features.

South of Cape du Couedic is North Casuarina Island, which is referred to as a separate colony following Shaughnessy *et al.* (1994). The island was divided into two sectors for surveying, one

on high ground on the south and west of the island, and in a deep gully, the other on a rock platform on the eastern side of the island and in a cave.

Large breeding colonies with several sub-colonies also occur on the Neptune Islands and at Liguanea Island. At South Neptunes, the 11 sub-colonies are disjunct and referred to as Eagle Bay, Swimming Pool, North-east, North-central Fiord, Fishing Point, Hut, South coast, West coast, Woodpile, Middle Island and Lighthouse Island. At North Neptune Island, the six sub-colonies are referred to as A to D, E and F, G, H, I and East Island. At Liguanea Island, the four sub-colonies are separated by three distinctive features: two chasms and a group of white rocks.

On the west coast of Eyre Peninsula, sub-colonies were recognized at Four Hummocks Islands (on South, Middle and North islands), on Pearson Island where there were two sub-colonies on the north island, and at Ward Islands, where there were sub-colonies on the main island and on nearby South Ward Island.

We refer to colonies and haul-out sites in SA from east to west. Most place names were taken from the description of islands in SA provided by Robinson *et al.* (1996) or from the South Australian State Gazetteer as displayed on the internet as 'PlaceNamesOnline' ([www.placenames.sa.gov.au](http://www.placenames.sa.gov.au)). Geographical positions were from the latter source or from Google Earth. The sub-colony and sector names in the large breeding colonies are unofficial.

## **Access**

Access to the vicinity of fur seal sites on Kangaroo Island was by vehicle. The SARDI research vessel *RV Ngerin* and an inflatable dinghy was used to access sites on the Neptune Islands and Liguanea Island. Island sites in southern Spencer Gulf and off the west coast of Eyre Peninsula were surveyed using a Robinson R44 helicopter.

## **Timing of the project**

The project was conducted primarily from January to March in 2014, beginning in late January on Kangaroo Island, continuing in early February on Neptune and Liguanea Islands, and then on islands off the west coast of Eyre Peninsula and in southern Spencer Gulf in mid-February and mid-March 2014.

Timing for the project was chosen to minimise interactions between fur seals and people, and began when NZ fur seal pups averaged 5 weeks of age, based on the median date for the pupping season at Cape Gantheaume and South Neptune Island being between 23 and 29

December (Goldsworthy and Shaughnessy 1994, Shaughnessy 1994, McKenzie 2006,). Territorial structure of the colonies had broken down when the project began and most adults moved away when confronted by people. This made it safer for workers to enter colonies and less stressful for animals than if work had begun earlier. When islands in southern Spencer Gulf and off the west coast of Eyre Peninsula were surveyed, pups were still recognisable.

## **Recognition of live Australian fur seals**

Features used to differentiate between NZ fur seals and Australian fur seals were described by Goldsworthy (1989) and Goldsworthy *et al.* (1997). Briefly, Australian fur seals are larger and paler than NZ fur seals, especially adult males which were the predominant age-class of Australian fur seals seen during the survey. In addition, vocalizations of Australian fur seals are deeper and simpler, and the animals often move over rocks using one fore-flipper after the other, whereas NZ fur seals generally move both fore-flippers together. New Zealand fur seal pups can be distinguished from Australian fur seal pups by their smaller size and sharper facial profile.

## **Estimating procedures**

Mark-resight estimation procedures were used in the large breeding colonies (50+ pups) and direct counting was used for smaller breeding colonies (<50 pups). Direct counting was also used at some large sites with difficult access and at sites where large numbers of pups had not been expected. Surveys were therefore of two types. First, those conducted at major breeding areas where a combination of mark-resight and counting methods were used to estimate pup abundance. These areas included Cape du Couedic and North Casuarina Island of south-western Kangaroo Island, the Cape Gantheaume Wilderness Protection Area of south-eastern Kangaroo Island, and North and South Neptune Islands, and Liguanea Island off the southern Eyre Peninsula. Second, pup abundance at minor breeding sites was estimated by counting methods only.

In this survey, pup numbers were not estimated at a small number of breeding colonies, because of difficult access (Ladders North and Ladders South sub-colonies at Cape du Couedic, at the base of high vertical cliffs) and at some small colonies at distant sites (Baudin Rocks in the South-east region and at some sites on the south coast of Kangaroo Island). Estimates from previous breeding seasons are used for these colonies.

## **Direct counting**

For most small colonies, pup numbers were counted by one or two people while walking through the colony. One person recorded pup numbers using a hand-held tally counter. During helicopter surveys of islands in southern Spencer Gulf and off the west coast of Eyre Peninsula, pups in some small colonies were counted from the air. Where pups were seen to be plentiful, the helicopter landed and a count was made while walking through the colony. These are all referred to as 'direct counts' to distinguish them from the mark-resight estimates.

## **Mark-resight estimation – marking**

NZ fur seal pups were marked by clipping the black natal hair (lanugo) on the top of their heads between the eyes and down toward the nose, with curved surgical scissors to reveal light grey underfur. This is a temporary mark, in that the natal hair is shed in April, when the adult-type pelage emerges. Australian fur seal pups on North Casuarina Island were marked by cutting a transverse swathe of black hair across the rump to reveal the lighter coloured underfur.

Pups were marked by a team of up to 12 people, with one person recording, and another marking dead pups (details below), while the team moved through each breeding colony together catching all pups that were readily available. The aim was to mark about 50 per cent of pups in each colony. To improve the accuracy of the mark-resight estimates, large colonies were divided into several sub-colonies or sectors, and the marking effort was distributed uniformly throughout each sub-colony or sector.

## **Mark-resight estimation – resighting**

Resights were conducted visually without handling the pups. Resighting sessions were conducted by single persons walking through each colony using a hand-held tally-counter in each hand, one to record marked pups and the other for unmarked (clear) pups. Data were recorded in a field notebook at the completion of each sector or sub-colony, and tally-counters reset to zero. At Cape du Couedic, two people worked together while they walked the length of each sub-colony. One person recorded data in a field notebook, and the other observed pups. The observer scanned pups' heads for signs of the clip mark and, for each pup sighted, informed the recorder

whether it was marked or clear. There were six to 12 resight sessions at each colony, at least half an hour apart. Resight sessions generally began a day or more after pups had been marked, but at Little Weirs Cove and Liguanea Island they were conducted on the same day because of logistical constraints. After each resighting session, pups that were awake were mobile and many that were under rocks and not visible were aroused by the disturbance. Consequently pups mixed well between each resight session.

By distributing marks and conducting recapture sessions uniformly throughout the entirety of each breeding colony, the sampling process at resighting should be random with respect to the marking process, which is an important assumption of mark-recapture estimation. The sampling was done without replacement; in other words, care was taken to avoid recording pups more than once in each recapture session, and all observed pups were scored as either marked or clear. The percentage of marked pups observed in a sector or a sub-colony was calculated using the number of pups marked there and the mark-recapture estimate of live pups.

## **Dead pups**

In each colony, dead pups were recorded when pups were marked (Tables 1 and 2) and covered with rocks or marked with spray paint to ensure they were not re-counted. In colonies where mark-resight estimates were made, dead pups were also counted at resighting sessions, and were recorded as being 'marked' or 'unmarked'. The proportion of dead pups in a colony was calculated from the number of dead pups divided by the sum of the estimates of live pups and dead pups, and expressed as a percentage.

## **Calculation of mark- resight estimates**

Pup numbers were estimated for each sector or each sub-colony at Cape Gantheaume and Cape du Couedic, and at North Casuarina, South Neptune, North Neptune and Liguanea Islands. Pup numbers (N) were calculated using a variation of the Petersen method (Seber 1982), with the formula



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

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

The variance of this estimate was calculated from

$$V = \frac{(M+1)(n+1)(M-m)(n-m)}{(m+1)^2(m+2)}.$$

There were several mark-resight estimates ( $N_j$ ) for each sector or sub-colony, one from each resight session, and they were combined by calculating the mean ( $N$ ) using formulae from White and Garrott (1990):

$$N = \sum_{j=1}^q N_j / q,$$

where  $q$  was the number of resight sessions. The variance of this estimate was calculated from

$$\text{Var } N = \frac{1}{q^2} \sum_{j=1}^q \text{Var } (N_j).$$

Following (Kuno 1977), its standard error (s. e.) was calculated from

$$[\text{Var } (N)]^{1/2}.$$

To calculate the estimate of pup numbers for the breeding colonies, the mark-resight estimates for each sector or sub-colony were summed. The variance of the combined estimate was calculated by summing the variance estimates for each sector or sub-colony; its standard error was then calculated by taking the square root of the variance. Direct counts made in any portion

of the colony were then added to the mark-resight estimate to give an overall estimate for the colony. The count of dead pups was added to the estimated number of live pups to give the overall estimate of pup numbers in each sector or sub-colony.

The 95% confidence limits of the estimates were calculated from

$$N \pm (1.96 * [\text{Var} (N)]^{1/2}).$$

## Trend analyses

The rate of change in pup numbers for colonies with a long time series (Cape Gantheaume, Cape du Couedic, Neptune Islands and Liguanea Island) was calculated using linear regression of the natural logarithm of the mean estimate of pup numbers against year. The exponential rate of increase ( $r$ ) is the slope of the regression line.

The rate of change in pup numbers for SA with only two estimates was calculated using the formula

$$\frac{N_{2014}}{N_{1990}} = e^{rt}$$

where  $N$  refers to the pup estimates in 2013-14 and 1989-90, respectively,  $r$  is the exponential rate of increase and  $t$  is the number of years (24) between the surveys. An exponential rate of increase has been demonstrated for New Zealand fur seals on Kangaroo Island (Shaughnessy *et al.* 1995).

The exponential rate of increase ( $r$ ) can also be expressed as a percentage increase using the formula

$$(e^r - 1) * 100.$$

## **Pup weighing**

On 27 January 2014, 110 pups were weighed and sexed at the Cape Gantheaume colony and on 7 February 2014, 35 pups were weighed and sexed at South Neptune Island. Pups were weighed to the nearest 0.25 kg using a spring balance (0 to 15 kg). Pups were supported during weighing using a rope around the chest and under one axilla. Mean weights of male and female pups were compared statistically using a two-tailed T-test with a 5% significance level.

### 3. RESULTS AND DISCUSSION

#### Distribution of NZ fur seals in SA

During the survey in the 2013-14 breeding season, NZ fur seals were recorded from Baudin Rocks in the south-east to Nuyts Reef in the north-west (Figure 1). Previously, small numbers of fur seals have been recorded further west, at the base of the Bunda Cliffs (Dennis and Shaughnessy 1996). The Bunda Cliffs were not included in this survey. Overall there were 28 breeding sites, distributed from Baudin Rocks to Fenelon Island in the north-west.

Fur seals, but no pups, were seen at the following sites, which are referred to as haul-out sites: Seal and Althorpe Islands, Southwest Rock, Peaked Rocks west, Albatross, Thistle and Sibsey Islands, Donnington Reef, Curta Rocks, The Brothers (Coffin Bay), Rocky North and West Waldegrave Islands, Point Labatt, Nicolas Baudin Island and Nuyts Reef. On Thistle Island, the fur seal haul-out site has moved from Horny Point (which is close to human habitation) to headlands near the southern end of the island. Small numbers of pups have been seen previously at three of these islands: at Althorpe Island (5 in 2006-07, L. Eindoer in Shaughnessy 2010), Nicolas Baudin Island (2 in June 2007, Shaughnessy and Goldsworthy 2007) and West Waldegrave Island (1 in February 2004, Shaughnessy *et al.* 2005). Fur seals have also been recorded at West Island in Encounter Bay and on the barrages at Goolwa (S. Iwao, pers. comm.), with the latest survey being in June 2013.

No fur seals were seen at the following islands during the surveys: Peaked Rocks east, Wedge Island, Dangerous Reef, Rabbit, Smith, Price, Avoid and Cap Islands and Veteran Isles (north), which are previously known NZ fur seal haul-outs (Shaughnessy and Goldsworthy in litt), nor at Black Rocks, Haystack, English, Spilsby, and Golden Islands.

#### Estimates of abundance

For the mark-resight estimates, 1,875 pups were marked at the Cape due Couedic and North Casuarina Island colonies (Table 1), 2,872 at colonies within the Cape Gantheaume WPA colonies on Kangaroo Island (Table 2), and 4,403 were marked on Neptune Islands and Liguanea Island (Table 3), making a total of 9,150 pups. Mark-resight estimates of pup abundance for breeding colonies at these sites and for sectors within the colonies in 2013-14 are presented in Tables 1 to 3, along with 95% confidence limits of the estimates, the proportion of pups marked

and percentage of dead pups seen. Details of surveys and their results conducted at the North Neptune, South Neptune and Liguanea Islands in 2005-06, 2006-07 and 2007-08 are presented in Tables 4-6.

On Kangaroo Island, at Cape du Couedic the estimate of pup abundance in the 2013-14 breeding season was 4,070 pups (including 27 counted at Admirals Arch); the percentage of marked pups was 45% and 3.9% of pups were dead. At North Casuarina Island the estimate of pup abundance was 245 pups; the percentage of pups marked was 52% and 7.8% of pups were dead (Table 1). Within the Cape Gantheaume WPA, the estimate of pup abundance was 5,333, the percentage of marked pups was 55% and 2.4% of pups were dead. That estimate includes 64 pups at the Cape Linois sub-colony, 1,344 pups in the Berris Point sub-colony, 134 in the Little Weirs sub-colony and 3,791 in the Cape Gantheaume sub-colony (Table 2).

At the North Neptune Islands, the estimate of pup abundance in the 2013-14 breeding season was 4,669, the percentage of marked pups was 48% and 5.0% of pups were dead (Table 3). At the South Neptune Island the estimated pup abundance was 3,210, where the percentage of marked pups was 43% and 6.5% of the pups were dead (Table 3). On Liguanea Island, the estimate of pup production was 1,832; the percentage of marked pups was 43% and 5.2% of the pups were dead (Table 3).

Pup numbers were estimated at smaller sites between Baudin Rocks in the east and Fenelon Island in the west, where between 1 and 182 pups were counted (Table 7). Overall, 28 breeding sites were recognised with the overall estimate of pup numbers for SA 20,426 (Tables 7 and 8). This leads to an estimate of abundance of NZ fur seals in SA of 97,200 animals using the multiplier 4.760 developed by Goldsworthy and Page (2007) based on a life table for the species.

The highest number of breeding sites was on Kangaroo Island (12, including North Casuarina Island), where the estimate of pup abundance was 10,133 pups, accounting for 49.6% of the overall pup abundance estimate for SA (Table 8). There was also a high number of breeding sites on the West Coast of Eyre Peninsula (10), but the pup production estimate for these sites was low with a total of 391 pups counted, amounting to 1.9% of the total pup abundance estimate for SA. Most of those were on Four Hummocks Islands (131 pups) and on Ward Islands (161 pups). For the Neptune Islands (two colonies), pup abundance was estimated at 7,879 pups (38.5% of the SA total) and for Liguanea Island (one colony) was 1,832 pups (9.0%). For these three island sites between Kangaroo Island and Eyre Peninsula, total estimated pup production was 9,711 pups, being 47.5% of the total for SA. In southern Spencer Gulf, there were two breeding sites;

direct counts there totalled 189 pups (0.9% of the State); most of these were on Williams Island (182 pups). The other region in SA was the South-east with a single small breeding site.

Two new breeding sites were discovered, at Williams Island (182 pups), and on the south coast of Kangaroo Island 1 km east of Remarkable Rocks (six pups). Three new sub-colonies were discovered, at North Hummock Island (68 pups), on Pearson Island at North Bay (24 pups), and at South Ward Island (also 24 pups). The fur seal sub-colony at North Hummock Island is likely to have established in recent years because the island has been visited on two previous occasions and fur seal pups were not seen: on 29 January 1990 when two adult males and six adult female fur seals were seen, and on 19 January 1996 (Shaughnessy *et al.* 1994, 2005).

## Trends in abundance

Increasing populations of NZ fur seals have been demonstrated at two breeding colonies on Kangaroo Island as part of a long-term monitoring project (Shaughnessy *et al.* 1995, Goldsworthy and Shaughnessy 2013), and since 1989 pup production on Kangaroo Island has increased exponentially both at Cape du Couedic and Cape Gantheaume (Figure 2). The most recent breeding seasons when both sites were surveyed were 2010-11 and 2013-14; in that interval pup abundance has increased by 19.1% at Cape du Couedic and 15.3% at Cape Gantheaume

Since 1992-93, pup production surveys have been undertaken during seven breeding seasons at the Neptune Islands (North and South), and five breeding seasons at Liguanea Island (reported in Shaughnessy (2005) and in Tables 4 – 6 of this report). Estimates of pup production for the 2013-14 breeding season are almost double those for the 1989-90 breeding season at the Neptune Islands and over three times at Liguanea Island (Figure 3). However, the trend in pup production at these islands no longer appears to be increasing exponentially. To date, peak pup production estimates for both Neptune Islands and Liguanea Island were obtained during the 2005-2006 breeding season. Pup production estimate for the 2013-14 breeding season at South Neptune Island was 17.3% lower than for the 2005-06 breeding season, while estimates for North Neptune Island were similar in the two breeding seasons (Figure 3). A decreasing trend in pup production is also apparent at Liguanea Island, with a 12.8% reduction in estimated pup numbers for the current season compared with the peak estimate in 2005-06 (Figure 3).

The estimate of pup production for NZ fur seal pups in SA from this survey (20,426) is 3.6 times greater than the previous estimate from a survey in the 1989-90 breeding season of 5,636 pups (Shaughnessy *et al.* 1994). It also exceeds the estimate of 11,119 pups in SA that can be

computed from the compilation by Goldsworthy *et al.* (2003) of available data between 1989 and 2001, and that of 17,622 pups by Goldsworthy and Page (2007). The increase from 1989-90 to 2013-14 has been at an average exponential rate of  $r = 0.054$ ; equivalent to 5.5% per annum. This rate of increase is likely conservative, as pup production estimates for the Neptune Islands and Liguanea in 1989 were obtained using a mixture of direct counts and mark-recapture, and therefore likely under-estimated the number of pups produced on those islands for that breeding season. For a subset of surveys for years when the major NZ fur seal colonies on Kangaroo Island and the Neptune and Liguanea Islands were surveyed between 1998-99 and 2013-14 (representing >90% of the SA pup production), pup production has increased at an average exponential rate of  $r = 0.051$ ; equivalent to 5.3% per annum (Figure 4). The overall exponential increase in NZ fur seal pups can be attributed to the recovery of the fur seal population from overharvesting in the 19<sup>th</sup> century.

## **Pup mortality**

Pup mortality from the six breeding colonies with mark-resight estimates was 4.43% (837 dead pups of 18,910). Among the breeding colonies, pup mortality varied from 2.47% at Cape Gantheaume sub-colony to 7.77% at North Casuarina Island (Tables 1 and 2). At the latter, part of the colony is on high ground with little shade and few rock pools (Sector A) and part is closer to the sea where NZ fur seal pups share space with Australian fur seal pups (Sector B). Both sectors had relatively high levels of pup mortality. Pup mortality in 2013-14 was higher at both North and South Neptune Islands and Liguanea Island than recorded previously (Table 3). On South Neptune Island pup mortality was 6.64%, three times the previous highest estimate, which was recorded in the 2007-08 breeding season (Table 6).

## Pup weights

At Cape Gantheaume, male NZ fur seal pups averaged 6.6 kg and females 6.0 kg, and at South Neptune Island, males averaged 6.1 kg and females 5.8 kg (Table 9). Male pups were significantly heavier than females at Cape Gantheaume ( $P = 0.006$ ); the weight difference was not significant at South Neptune Island ( $P = 0.42$ ), possibly because of the smaller sample size. For Cape Gantheaume, these mean weights were lighter than the long-term averages, by 0.94 kg for males and 0.80 kg for females. Pups of both sexes were heavier at Cape Gantheaume than at South Neptune Island, despite the latter being weighed 11 days later and pups increasing in weight by an average of 0.0675 and 0.057 kg per day for males and females, respectively, for their first 50 days at Cape Gantheaume (Goldsworthy 1992).

## Australian fur seals

At North Casuarina Island, the abundance of Australian fur seals was estimated by mark-resight procedures, as described above for NZ fur seals. On 29 January 2014, 35 pups were marked and one pup was found dead. Six resight sessions on the following day resulted in an estimate of 76 pups (including the dead one), with 95% confidence limits of 69.5 and 82.2. The percentage of pups marked was 47% and 1.32% of the pups were dead. Australian fur seal pups were recorded at three other localities: six on Baudin Rocks during March (R. Roach, pers. comm.), two on Williams Island on 14 March which were among 182 NZ fur seal pups and one pup at Cape Gantheaume in January. A single Australian fur seal pup was also sighted at Cape Gantheaume during the 2012-13 breeding season. In addition, a hybrid pup was tagged there in January 1995; genetic analysis indicated it resulted from mating of an Australian fur seal male and a NZ fur seal female (Shaughnessy *et al.* 2010).

In late January and early February 2014, Australian fur seal adults were seen but not counted on North Casuarina Island, at Cape Gantheaume and Admirals Arch, Cape du Couedic. They were also seen at North Island (six on 14 March), on Rocky South Island (47 on 13 March) and Greenly Island (11 on 13 March).

Previously, there have been sightings of Australian fur seals from a large part of the SA coast, from Baudin Rocks in the south-east, where 80 animals were ashore in May 2008, to Point Labatt on the west coast of Eyre Peninsula, where a single juvenile was sighted in January 1990 (summarised in Shaughnessy *et al.* 2010). Satellite tracking data have shown that adult males and adult females travel on the continental shelf of SA waters to the eastern part of the Great



Australian Bight (Kirkwood *et al.* 2006, Arnould and Kirkwood 2008). Hence our sightings of Australian fur seals on islands off the west coast of Eyre Peninsula are not unexpected.

## 4. CONCLUSION

Fur seal populations in southern Australia were heavily exploited by colonial sealers between 1801 and 1830, resulting in major reductions in range and abundance. Numbers remained at very low levels for almost 140 years, when they slowly began to build up and new colonies established across their former range. Recovery of populations of the two fur seal species has benefitted from protection of the breeding colonies by State and Commonwealth governments. The State-wide estimate of 20,426 pups for the 2013-14 breeding season survey is 3.6 times greater than the previous estimate of 5,636 pups from a survey in the 1989-90 breeding season.

NZ fur seal pup production continues to increase exponentially on Kangaroo Island, and the breeding distribution has also expanded with one new haul-out site with occasional pupping identified 1 km east of Remarkable Rocks on the south coast of Kangaroo Island. Expansion has also occurred at three other sites, with new sub-colonies discovered at North Hummock, Pearson and South Ward Islands. A previously unidentified breeding site was also discovered at Williams Island.

Pup production estimates for North Neptune Island were similar for the 2013-14 breeding season as the peak estimate to date, obtained in the 2005-06 breeding season. In contrast pup production estimates were 17.3% lower at South Neptune Island, and 12.8% lower at Liguanea Island, than the 2005-06 estimates. The stabilisation of pup production at North Neptune Island and reduction at South and Liguanea Island likely reflects the fact that all suitable breeding habitat on these islands is occupied, with some animals now breeding on sub-optimal habitat, and with no further suitable habitat for these colonies to expand into. High pup mortality rates at South Neptune in the 2013-14 breeding season (three times higher than previously recorded) may reflect this expansion into sub-optimal breeding habitat.

Understanding the distribution, population size and trends in abundance of marine protected species such as NZ fur seals, is primary information needed to assist conservation and management strategies. The overall increasing trend in NZ fur seal populations in SA is likely to continue over the coming decade.

There is growing concern about how increasing populations of fur seals will impact the future and sustainability and production of key fisheries and the broader marine ecosystem as a whole. As such, accurate information on the status and trends in abundance of the species is important for stakeholders, and essential to assist management agencies to make informed management decisions.

## REFERENCES

- Arnould, J. P. Y., and Kirkwood, R. (2008). Habitat selection in a benthic diver: the foraging areas of female Australian fur seals (*Arctocephalus pusillus doriferus*). *Aquatic Conservation* 17, S53-S67.
- Berkson, J. M., and DeMaster, D. P. (1985). Use of pup counts in indexing population changes in pinnipeds. *Canadian Journal of Fisheries and Aquatic Sciences* 42, 873–879.
- Dennis, T. E., and Shaughnessy, P. D. (1996). Status of the Australian sea lion, *Neophoca cinerea*, in the Great Australian Bight. *Wildlife Research* 23, 741-754.
- Goldsworthy, S. D. (1989). Maternal care and diet of New Zealand fur seals, *Arctocephalus forsteri*. Wildlife Conservation Fund, South Australia, Final Report, November 1989.
- Goldsworthy, S. D. (1992). Maternal care in three species of southern fur seal (*Arctocephalus* spp.). PhD thesis, Monash University, Melbourne.
- Goldsworthy, S. D. (2008). New Zealand fur seal *Arctocephalus forsteri* (Lesson, 1828). In 'The Mammals of Australia'. (Eds S. Van Dyck and R. Strahan) pp. 717-719. (Reed New Holland: Sydney).
- Goldsworthy, S. D., and Page, B. (2007). A risk-assessment approach to evaluating the significance of seal bycatch in two Australian fisheries. *Biological Conservation* 139, 269–285.
- Goldsworthy, S. D., and Shaughnessy, P. D. (1994). Breeding biology and haul-out pattern of the New Zealand fur seal, *Arctocephalus forsteri*, at Cape Gantheaume, South Australia. *Wildlife Research* 21, 365–376.
- Goldsworthy, S. D., and Shaughnessy, P.D. (2013). Abundance of New Zealand fur seal pups in the Cape Gantheaume Wilderness Protection Area, Kangaroo Island: 2011-12 breeding season. SARDI Publication No. F2013/000070-1. SARDI Research Report Series No. 735.
- Goldsworthy, S. D., Pemberton, D., and Warneke, R. M. (1997). Field identification of Australian and New Zealand fur seals, *Arctocephalus* spp., based in external characters. In 'Marine Mammal Research in the Southern Hemisphere'. (Eds M. Hindell and C. Kemper). pp. 63-71. (Surrey Beatty and Sons: Chipping Norton, Sydney).
- Goldsworthy, S. D., Bulman, C., He, X., Larcombe, J., and Littnan, C. (2003). Trophic interactions between marine mammals and Australian fisheries: an ecosystem approach. In 'Marine Mammals: Fisheries, Tourism and Management Issues'. (Eds N. Gales, M. Hindell and R. Kirkwood.) pp. 62–99. (CSIRO Publishing: Melbourne.)
- Kirkwood, R., and Goldsworthy S. (2013). 'Fur Seals and Sea Lions'. (CSIRO Publishing: Melbourne.)
- Kirkwood, R., Lynch, M., Gales, N., Dann, P., and Sumner, M. (2006). At sea movements and habitat use of adult male Australian fur seals (*Arctocephalus pusillus doriferus*). *Canadian Journal of Zoology* 84, 1781-1788.
- Kuno, E. (1977). A sequential estimation technique for capture-recapture censuses. *Research in Population Ecology* 18, 187–194.
- McKenzie, J. (2006). Population demographics of New Zealand fur seals (*Arctocephalus forsteri*). PhD thesis, La Trobe University, Bundoora, Vic.

Robinson, T., Canty, P., Mooney, T., and Rudduck, P. (1996). 'South Australia's Offshore Islands'. (Australian Heritage Commission: Canberra.)

Seber, G. A. F. (1982). 'The Estimation of Animal Abundance and Related Parameters.' (MacMillan: New York.)

Shaughnessy, P D (1989). Abundance of New Zealand fur seals *Arctocephalus forsteri* at Cape Gantheaume, Kangaroo Island and other colonies in South Australia. Final report to South Australian Wildlife Conservation Fund.

Shaughnessy, P. D. (1994). New Zealand fur seals *Arctocephalus forsteri* on Kangaroo Island, South Australia in 1993/1994: abundance at three colonies. Report to South Australian National Parks and Wildlife Service.

Shaughnessy, P. (1998). Seals in South Australia, 1997/98: abundance of New Zealand fur seal pups on Kangaroo Island. Report to South Australian National Parks and Wildlife, Department of Environment, Heritage and Aboriginal Affairs.

Shaughnessy, P. (2005). Population assessment of New Zealand fur seals and Australian sea lions at some colonies in South Australia, 2004-05. Report to Department for Environment and Heritage [South Australia].

Shaughnessy, P. (2006). Population assessment of fur seals and sea lions at some colonies in South Australia, 2005-06. Report to Department for Environment and Heritage, South Australia.

Shaughnessy, P. D. (2010). Abundance of New Zealand fur seal pups on Kangaroo Island in 2009-10 and of Australian sea lion pups at The Pages Islands in 2009. Report to Department for Environment and Heritage, South Australia.

Shaughnessy, P. D., and Goldsworthy, S. D. (2007). Population assessment of fur seals and sea lions at some colonies in South Australia, 2006-07. Final report to the Department for Environment and Heritage, South Australia and the South Australian Wildlife Conservation Fund. SARDI Aquatic Sciences Publication Number: F2007/000750-1. SARDI Research Report Series Number: 236.

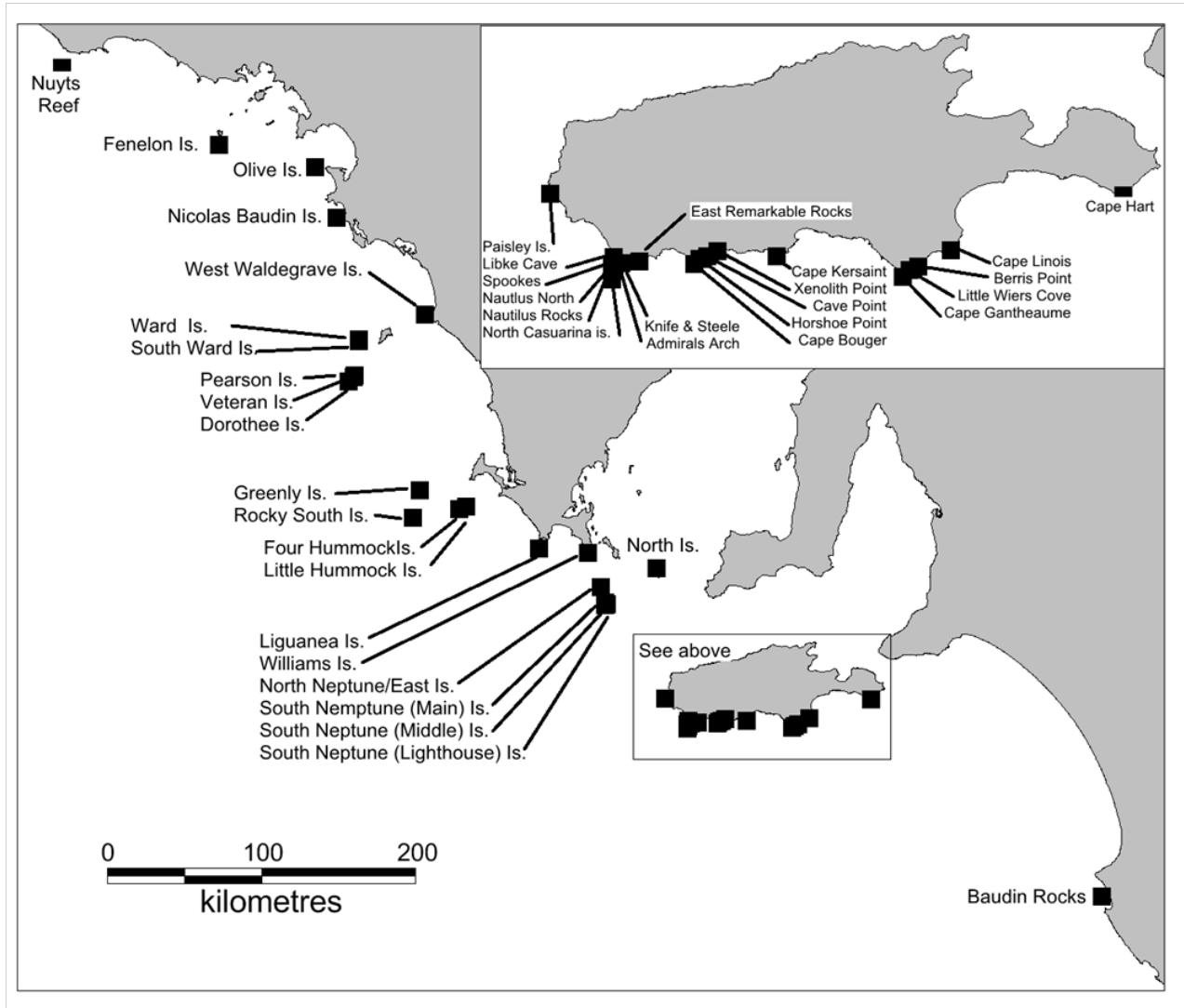
Shaughnessy, P. D., Gales, N. J., Dennis, T. E., and Goldsworthy, S. D. (1994). Distribution and abundance of New Zealand fur seals, *Arctocephalus forsteri*, in South Australia and Western Australia. *Wildlife Research* 21, 667-695.

Shaughnessy, P. D., Goldsworthy, S. D., and Libke, J. A. (1995). Changes in the abundance of New Zealand fur seals, *Arctocephalus forsteri*, on Kangaroo Island, South Australia. *Wildlife Research* 22, 201-215.

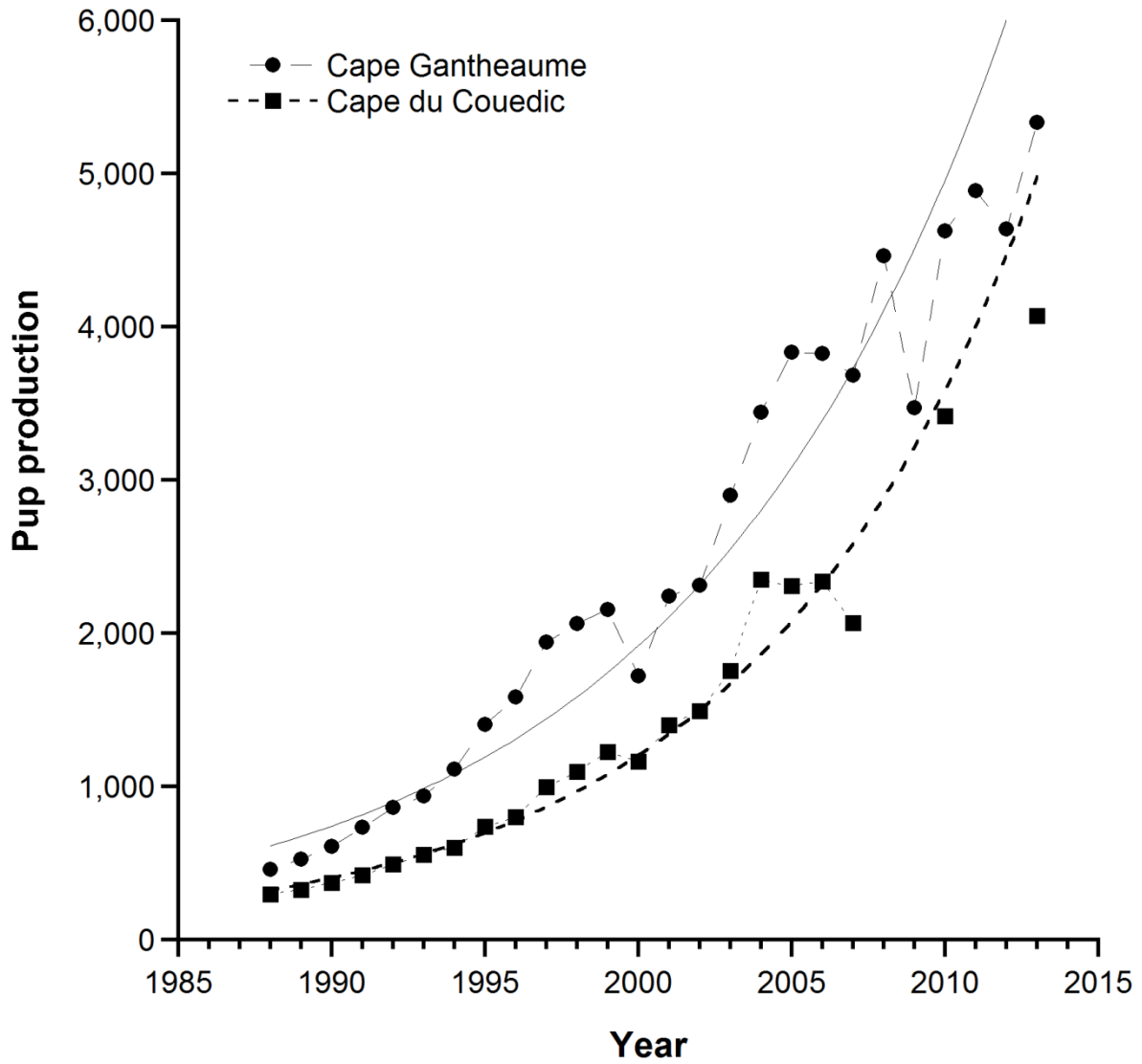
Shaughnessy, Stirling, I., and Dennis, T. E., (1996) Changes in the abundance of New Zealand fur seals, *Arctocephalus forsteri*, on the Neptune Islands, South Australia. *Wildlife Research* 23, 697-709.

Shaughnessy, P. D., Dennis, T. E., and Seager, P. G. (2005). Status of Australian sea lions, *Neophoca cinerea*, and New Zealand fur seals, *Arctocephalus forsteri*, on Eyre Peninsula and the far west coast of South Australia. *Wildlife Research* 32, 85-101.

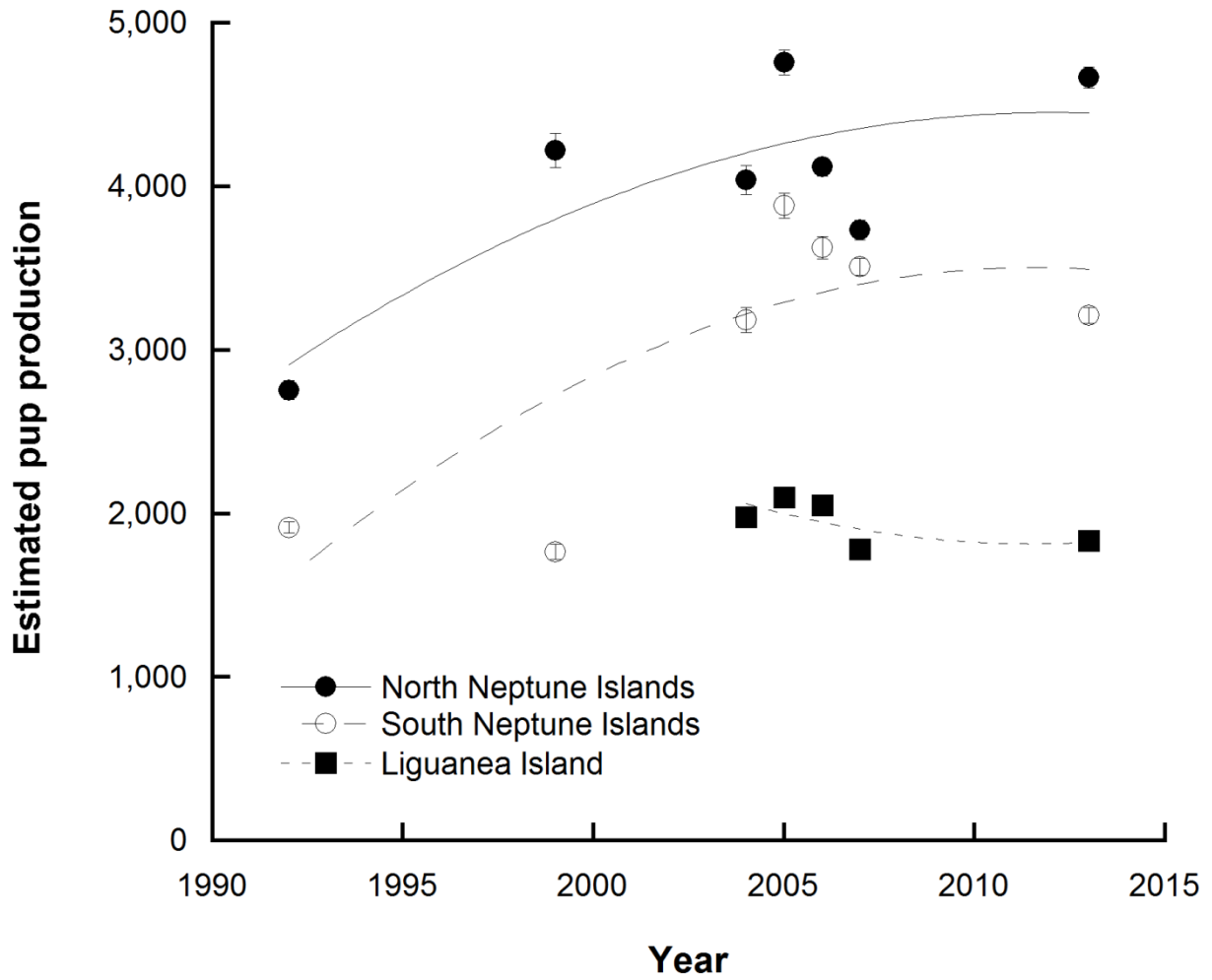
Shaughnessy, P. D., McKenzie, J., Lancaster, M. L., Goldsworthy, S. D., and Dennis, T. E. (2010). Australian fur seals establish haulout sites and a breeding colony in South Australia. *Australian Journal of Zoology* 58, 94-103.



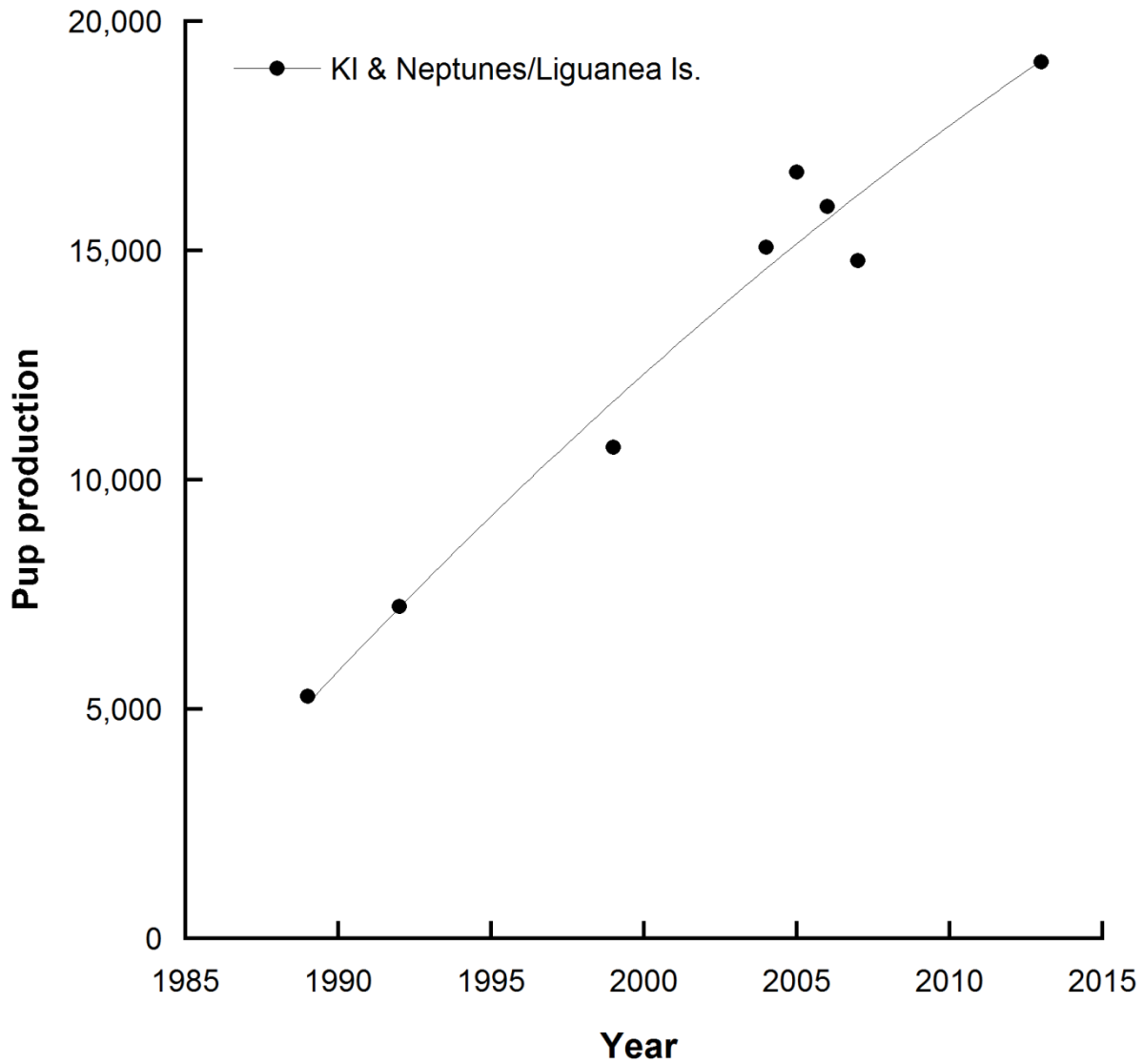
**Figure 1.** Map of New Zealand fur seal survey sites off South Australia included in this study.



**Figure 2.** Trends in pup production in the Cape Gantheaume Wilderness Protection Area and at Cape du Couedic (excluding North and South Ladders sub-colonies) New Zealand fur seal colonies 1988-89 to 2013-14, with exponential curves fitted to the data.



**Figure 3.** Trends in pup production at New Zealand fur seal colonies on North and South Neptune Islands (seven seasons) and Liguanea Island (five seasons) 1992-93 to 2013-14, with a 2<sup>nd</sup> order polynomial curve fitted to each time series.



**Figure 4.** Combined trends in pup production at major New Zealand fur seal breeding colonies in South Australia (Kangaroo Island, North and South Neptune Islands and Liguanea Islands) between 1989-90 and 2013-14, with a 2<sup>nd</sup> order polynomial curve fitted to time series. Only years where simultaneous surveys were undertaken on Kangaroo Island and the Neptune Island are presented. Surveys were not undertaken at Liguanea Island in 1992-93 or 1999-00; for these years pup production was estimated from the exponential rate of increase ( $r$ ) between two successive surveys. Data for the 1989-90 and 1992-93 surveys are from Shaughnessy *et al.* (1994) and Shaughnessy *et al.* (1996), data for the 2004-05 surveys are from Shaughnessy (2005).



**Table 1.** Estimates of abundance of New Zealand fur seal pups at colonies in western Kangaroo Island, in January to March 2014. Survey method: count = direct count; MR = mark-recapture estimate. \*Summation differs due to rounding areas.<sup>1</sup>From Shaughnessy (1998)

Site (survey method)	Date marked/counted	Date of resight	Live count	No. pups marked	No. pups dead	No. resight estimates	Overall Estimate	95% CL	% pups marked	% pups dead
<b>i) Cape Kersaint East</b> (count)	27 Jan 14		10		0		<b>10</b>			
<b>ii) Cape Kersaint West</b> (count)	19 Feb 14		28		0		<b>28</b>			
<b>iii) Cave Point</b> (count)	23-Jan-14		58				<b>58</b>			
<b>iv) Cape Bouguer</b> (count)	20-Mar-14		71				<b>71</b>			
<b>v) East Remarkable Rocks</b>	25-Feb-14		6				<b>6</b>			
<b>vi) Cape du Couedic</b>										
Knife and Steel (MR)	22-Jan-14	24-26 Jan 14		270	20	8	539	522-555	52	3.7
Weirs Cove North (MR)	22-Jan-14	24-26 Jan 14		148	15	8	324	312-335	48	4.6
Weirs Cove South (MR)	22-Jan-14	24-26 Jan 14		75	4	8	149	141-157	52	2.7
Nautilus Rock (MR)	20-Jan-14	24-26 Jan 14		97	12	7	255	235-275	40	4.7
Nautilus North (MR)	20-Jan-14	24-26 Jan 14		289	26	7	700	672-729	43	3.7
Libke Cave (MR)	21-Jan-14	24-26 Jan 14		19	3	<b>6</b>	64	53-76	31	4.7
Libke South (MR)	21-Jan-14	24-26 Jan 14		157	11	6	368	349-386	44	3.0
Libke North (MR)	21-Jan-14	24-26 Jan 14		188	24	6	487	462-511	41	4.9
Spooks (MR)	21-Jan-14	24-26 Jan 14		515	43	6	1158	1120-1196	46	3.7
Admirals Arch (count)	22-Jan-14		27				27			
Ladders North (MR) <sup>1</sup>	26 Jan-98	28 Jan-2 Feb 98			3	7	257	238-276	60	1.2
Ladders South (count) <sup>1</sup>	26 Jan-98		21				21			
<b>Subtotal Cape du Couedic</b>				<b>1758</b>	<b>158</b>		<b>4348*</b>	<b>4281-4415</b>	<b>45</b>	<b>3.9</b>
<b>vii) North Casuarina</b>										
Sector A (MR)	28-Jan-14	29-Jan-14		103	13	7	220	209-230	50	5.9
Sector B (MR)	28-Jan-14	29-Jan-14		14	6	6	25	23-26	74	24.0
<b>Subtotal North Casuarina</b>				<b>117</b>	<b>19</b>		<b>245</b>	<b>234-255</b>	<b>52</b>	<b>7.8</b>
<b>Viii) Paisley Island</b> (count)	29-Jan-14		22				<b>22</b>			
<b>Total</b>			<b>222</b>	<b>1875</b>	<b>177</b>		<b>4788</b>	<b>4718-4853</b>		<b>3.9</b>

**Table 2.** Estimates of abundance of New Zealand fur seal pups at colonies in Cape Gantheaume Wilderness Protection Area, Kangaroo Island, in January 2014. Survey method: count = direct count; MR = mark-recapture estimate.

Site (survey method)	Date marked/counted	Date of resight	Live count	No. pups marked	No. pups dead	No. resight estimates	Overall Estimate	95% CL	% pups marked	% pups dead
<b>i) Cape Linois (count)</b>	27-Jan-14		64		0		<b>64</b>			
<b>ii) Berris Point</b>										
North (MR)	23-Jan-14	25-Jan-14		376	13	12	663	649-678	58	2.0
Middle (MR)	23-Jan-14	25-Jan-14		215	17	12	361	353-369	62	4.7
South (MR)	23-Jan-14	25-Jan-14		189	12	12	319	311-328	62	3.8
<b>Subtotal Berris Point</b>				<b>780</b>	<b>42</b>		<b>1344</b>	<b>1325-1362</b>	<b>60</b>	<b>3.1</b>
<b>iii) Little Weirs Cove</b>										
Little Weirs East (count)	26-Jan-14		3				3			
Little Weirs East (MR)	26-Jan-14	26-Jan-14		65	5	6	129	119-139	52	3.9
Little Weirs West (count)	26-Jan-14		2				2			
<b>Subtotal Little Weirs</b>				<b>65</b>	<b>5</b>		<b>134</b>	<b>124-144</b>		
<b>iv) Cape Gantheaume</b>										
West of Beach (count)	26-Jan-14		36				36			
Cave (count)	26-Jan-14		15				15			
Sector Beach (MR)	23-Jan-14	25-Jan-14		465	21	12	882	866-898	54	2.4
Sector A, B (MR)	24-Jan-14	26-Jan-14		63	7	12	118	112-123	57	6.0
Sector C, D, E (MR)	24-Jan-14	26-Jan-14		219	15	12	387	377-398	59	3.9
Sector F, G, H (MR)	24-Jan-14	26-Jan-14		195	8	12	410	394-427	49	2.0
Sector I, J (MR)	24-Jan-14	26-Jan-14		454	7	12	877	858-897	52	0.8
Sector K, L (MR)	24-Jan-14	26-Jan-14		631	24	12	1066	1047-1085	61	2.3
<b>Subtotal Cape Gantheaume</b>				<b>2027</b>	<b>82</b>		<b>3791</b>	<b>3754-3829</b>	<b>55</b>	<b>2.2</b>
<b>Total</b>			<b>120</b>	<b>2872</b>	<b>129</b>		<b>5333</b>	<b>5290-5376</b>		<b>2.4</b>

**Table 3.** Estimates of abundance of New Zealand fur seal pups at breeding colonies on the Neptune Islands and Liguanea Island in February 2014. \*Summation differs due to rounding areas.

Site	Date marked/counted	Date resight	Live count	No. pups marked	No. pups dead	No. resight estimates	Overall Estimate	95% CL	% pups marked	% pups dead
<b>i) North Neptune Islands</b>										
Sectors A-D	3-Feb-14	6-Feb-14		1527	161	10	3042	2994-3091	53	5.3
Sectors E-F	3-Feb-14	6-Feb-14		403	50	10	941	914-968	45	5.3
Sector G	3-Feb-14	6-Feb-14		118	13	10	265	248-282	47	4.9
Sector H	3-Feb-14	6-Feb-14		44	5	10	115	103-128	40	4.3
Sector I	6-Feb-14		12		0	10	12			0.0
East Island	6-Feb-14	6-Feb-14		130	6	6	293	270-317	45	2.0
<b>Subtotal</b>			<b>12</b>	<b>2222</b>	<b>235</b>		<b>4669*</b>	<b>4605-4733</b>	<b>50</b>	<b>5.0</b>
<b>ii) South Neptune Islands</b>										
Eagle Bay	7-Feb-14	8-Feb-14		72	25	9	181	167-196	46	13.8
Swimming Pool	7-Feb-14	8-Feb-14		84	15	9	159	151-168	58	9.4
North-East	7-Feb-14	8-Feb-14		57	6	9	111	103-119	54	5.4
North-Central/Fiord	7-Feb-14	8-Feb-14		85	16	9	191	179-202	49	8.4
Fishing Point	7-Feb-14	8-Feb-14		231	29	9	479	459-499	51	6.1
Hut	7-Feb-14	8-Feb-14		224	29	9	401	388-415	60	7.2
South Coast	7-Feb-14	8-Feb-14		39	4	9	134	116-152	30	3.0
West Coast	7-Feb-14	8-Feb-14		478	61	9	1160	1131-1188	44	5.3
Woodpile	7-Feb-14	8-Feb-14		37	8	9	81	76-87	51	9.9
Middle Island	7-Feb-14	7-Feb-14		84	10	9	161	152-169	56	6.2
Lighthouse Island	7-Feb-14		147		5		152			
<b>Subtotal</b>			<b>147</b>	<b>1391</b>	<b>208</b>		<b>3210</b>	<b>3162-3258</b>	<b>49</b>	<b>6.6</b>
<b>iii) Liguanea Island</b>										
South - 2nd chasm	5-Feb-14	5-Feb-14		218	35	8	458	439-476	52	7.6
1st - 2nd chasm	5-Feb-14	5-Feb-14		120	9	8	199	191-208	63	4.5
2nd chasm - White rocks	5-Feb-14	5-Feb-14		164	17	8	355	341-369	49	4.8
White rocks - North	5-Feb-14	5-Feb-14		288	32	8	682	657-707	44	4.7
Outside MR area	5-Feb-14		135		3		138			
<b>Subtotal</b>			<b>135</b>	<b>790</b>	<b>96</b>		<b>1832</b>	<b>1797-1867</b>	<b>49</b>	<b>5.2</b>
<b>Total</b>			<b>294</b>	<b>4403</b>	<b>539</b>		<b>9711</b>	<b>9624-9798</b>	<b>45</b>	<b>5.6</b>

**Table 4.** Estimates of abundance of New Zealand fur seal pups (mark-resight estimates and direct counts) at breeding colonies on the Neptune Islands and Liguanea Island in January-February 2006.

Site	Date marked or counted	Date ofresight	Live count	No. pups marked	No. pups dead	No. resight estimates	Overall Estimate	95% CL	% pups marked	% pups dead
<b>i) North Neptune Islands</b>										
Sectors A-D	29-Jan-06	30-Jan-06		1394	44	8	3031	2979-3084	46	1.5
Sectors E-F	29-Jan-06	30-Jan-06		446	14	8	1043	1008-1078	43	1.3
Sector G	29-Jan-06	30-Jan-06		132	11	8	392	358-426	34	2.8
Sector H	29-Jan-06	30-Jan-06		35	2	8	96	84-107	36	2.1
East Island	29-Jan-06	30-Jan-06		84	4	4	198	180-216	42	2.0
<b>Subtotal</b>				<b>2091</b>	<b>75</b>		<b>4760</b>	<b>4685-4835</b>	<b>44</b>	<b>1.6</b>
<b>ii) South Neptune Islands</b>										
Eagle Bay/Swimming Pool	31-Jan-06	1-Feb-06		240	9	6	492	468-517	49	1.8
North-East	31-Jan-06	1-Feb-06		53	0	6	83	75-91	64	0.0
North-Central/Fiord	31-Jan-06	1-Feb-06		96	6	6	263	240-287	37	2.3
Fishing Point	31-Jan-06	1-Feb-06		267	8	6	570	492-528	47	1.4
Hut	31-Jan-06	1-Feb-06		319	11	6	726	702-750	44	1.5
South Coast	31-Jan-06	1-Feb-06		32	4	6	121	93-149	26	3.3
West Coast	31-Jan-06	1-Feb-06		508	23	6	1395	1349-1442	36	1.6
Woodpile	31-Jan-06	1-Feb-06		36	2	6	79	69-89	46	2.5
Middle Island	31-Jan-06		93				93			
Lighthouse Island	31-Jan-06		58				58			
<b>Subtotal</b>			<b>151</b>	<b>1551</b>	<b>63</b>		<b>3883</b>	<b>3807-3955</b>	<b>40</b>	<b>1.6</b>
<b>iii) Liguanea Island</b>										
South - 2nd chasm	27-Feb-06	28-Feb-06		219	14	6	479	457-500	46	2.9
1st - 2nd chasm	27-Feb-06	28-Feb-06		115	2	6	231	218-243	50	0.9
2nd chasm - White rocks	27-Feb-06	28-Feb-06		249	8	6	470	452-487	53	1.7
White rocks - North	27-Feb-06	28-Feb-06		441	3	6	871	846-897	51	0.3
Outside MR area	27-Feb-06		47		2		49		0	
<b>Subtotal</b>			<b>47</b>	<b>1024</b>	<b>29</b>		<b>2100</b>	<b>2062-2141</b>	<b>49</b>	<b>1.4</b>
<b>Total</b>			<b>198</b>	<b>4666</b>	<b>167</b>		<b>10743</b>	<b>10629-10845</b>	<b>43</b>	<b>1.6</b>

**Table 5.** Estimates of abundance of New Zealand fur seal pups (mark-resight estimates and direct counts) pups at breeding colonies on the Neptune Islands and Liguanea Island, January-February 2007.

Site	Date marked or counted	Date of resight	Live count	No. pups marked	No. pups dead	No. resight estimates	Overall Estimate	95% CL	% pups marked	% pups dead
<b>i) North Neptune Islands</b>										
Sectors A-D	31-Jan-07	3-Feb-07		1312	41	7	2626	2574-2679	50	1.6
Sectors E-F	31-Jan-07	3-Feb-07		427	8	7	907	874-941	47	0.9
Sectors G	31-Jan-07	3-Feb-07		121	5	7	308	278-337	39	1.6
Sectors H	31-Jan-07	3-Feb-07		25	0	7	72	60-84	35	0.0
Sector I	31-Jan-07		7		0		7			
East Island	31-Jan-07	3-Feb-07		110	3	7	200	190-209	55	1.5
<b>Subtotal</b>			<b>7</b>	<b>1995</b>	<b>57</b>		<b>4120</b>	<b>4063-4204</b>	<b>48</b>	<b>1.4</b>
<b>ii) South Neptune Islands</b>										
Eagle Bay/Swimming Pool	1-Feb-07	4-Feb-07		263	0	6	449	428-470		0.0
North-East	1-Feb-07	4-Feb-07		54	1	6	105	95-113	59	1.0
North-Central/Fiord	1-Feb-07	4-Feb-07		78	2	6	185	171-200	51	1.1
Fishing Point	1-Feb-07	4-Feb-07		305	5	6	515	492-528	42	1.0
Hut	1-Feb-07	4-Feb-07		375	7	6	691	661-721	59	1.0
South Coast	1-Feb-07	4-Feb-07		52	1	6	185	148-223	54	0.5
West Coast	1-Feb-07	4-Feb-07		718	4	6	1254	1220-1288	28	0.3
Woodpile	1-Feb-07	4-Feb-07		37	4	6	87	77-98	57	4.6
Middle Island	4-Feb-07		112				112		43	
Lighthouse Island	4-Feb-07		44				44			
<b>Subtotal</b>			<b>156</b>	<b>1882</b>	<b>24</b>		<b>3627</b>	<b>3560-3695</b>	<b>52</b>	<b>0.7</b>
<b>iii) Liguanea Island</b>										
South - 2nd chasm	30-Jan 07	2-Feb-07		262	15	8	494	471-517	53	3.0
1st - 2nd chasm	30-Jan 07	2-Feb-07		122	5	8	210	198-221	58	2.4
2nd chasm - White rocks	30-Jan 07	2-Feb-07		230	10	8	380	367-392	61	2.6
White rocks - North	30-Jan 07	2-Feb-07		446	22	8	877	850-903	51	2.5
Outside MR area	30-Jan 07		90		0		90			
<b>Subtotal</b>			<b>90</b>	<b>1060</b>	<b>52</b>		<b>2051</b>	<b>2012-2090</b>	<b>52</b>	<b>2.5</b>
<b>Total</b>			<b>253</b>	<b>4937</b>	<b>133</b>		<b>9798</b>	<b>9693-9904</b>	<b>50</b>	<b>1.4</b>

**Table 6.** Estimates of abundance of New Zealand fur seal pups (mark-resight estimates and direct counts) pups at breeding colonies on the Neptune Islands and Liguanea Island in February 2008.

Site	Date marked or counted	Date of resight	Live count	No. pups marked	No. pups dead	No. resight estimates	Overall Estimate	95% CL	% pups marked	% pups dead
<b>i) North Neptune Islands</b>										
Sectors A-D	1-Feb08	3-Feb-08		1287	70	9	2421	2381-2462	53	2.9
Sectors E-F	1-Feb08	3-Feb-08		413	22	8	828	795-860	50	2.7
Sectors G	1-Feb08	3-Feb-08		90	6	9	255	225-286	35	2.4
Sector H	1-Feb08	3-Feb-08		30	4	9	56	52-61	54	7.1
Sector I	1-Feb08		9		1		10			
East Island	1-Feb08	3-Feb-08		96	11	7	164	155-173	59	6.7
<b>Subtotal</b>			<b>9</b>	<b>1916</b>	<b>114</b>		<b>3734</b>	<b>3673-3795</b>	<b>51</b>	<b>3.1</b>
<b>ii) South Neptune Islands</b>										
Eagle Bay/Swimming Pool	4-Feb-08	5-Feb-08		222	6	9	385	370-400		1.6
North-East	4-Feb-08	5-Feb-08		51	4	9	108	100-117	58	3.7
North-Central/Fiord	4-Feb-08	5-Feb-08		70	1	9	206	187-225	47	0.5
Fishing Point	4-Feb-08	5-Feb-08		266	16	9	529	508-550	34	3.0
Hut	4-Feb-08	5-Feb-08		346	26	9	672	655-670	50	3.9
South Coast	4-Feb-08	5-Feb-08		56	6	9	161	143-178	51	3.7
West Coast	4-Feb-08	5-Feb-08		541	16	9	1171	1141-1200	35	1.4
Woodpile	4-Feb-08	5-Feb-08		34	3	9	93	81-106	46	3.2
Middle Island	5-Feb-08		124				124		37	
Lighthouse Island	5-Feb-08		61				61			
<b>Subtotal</b>			<b>185</b>	<b>1586</b>	<b>78</b>		<b>3510</b>	<b>3458-3562</b>	<b>45</b>	<b>2.2</b>
<b>iii) Liguanea Island</b>										
South - 2nd chasm	2-Feb-08	6-Feb-08		233	19	9	409	396-421	57	4.6
1st - 2nd chasm	2-Feb-08	6-Feb-08		115	11	9	183	176-190	63	6.0
2nd chasm - White rocks	2-Feb-08	6-Feb-08		215	7	9	372	361-383	58	1.9
White rocks - North	2-Feb-08	6-Feb-08		295	27	9	699	678-720	42	3.9
Outside MR area	6-Feb-08		115		3		118			
<b>Subtotal</b>			<b>115</b>	<b>858</b>	<b>67</b>		<b>1781</b>	<b>1753-1808</b>	<b>48</b>	<b>3.8</b>
<b>Total</b>			<b>309</b>	<b>4360</b>	<b>259</b>		<b>9025</b>	<b>8939-9109</b>	<b>48</b>	<b>2.9</b>

**Table 7.** Estimates of abundance of New Zealand fur seal pups at colonies, primarily in 2013-14 with some estimates from earlier breeding seasons. 'MR' indicates the estimate was made using mark-resight procedures, 'CL' indicates 95% confidence limits for the mark-resight estimates. Detailed estimates for the mark-resight estimates are provided in Tables 1-3. Data for Ladders North, Ladders South, Horseshoe Bay points and Xenolith Point are from Shaughnessy (1998, 2006, and 2007).

Breeding site	No. of pups in colonies	95% CL	Method	Date
Baudin Rocks	2		Count	May-08
Cape Hart	8		Count	18-Mar-14
Cape Linois	64		Count	27-Jan-14
Berris Point	1344	1325-1362	MR	Jan-14
Little Weirs	134	124-144	MR & Count	Jan-14
Cape Gantheaume	3791	3754-3829	MR & Count	Jan-14
Cape Kersaint East	10		Count	27 Jan, 19 Feb
Cape Kersaint West	28		Count	27 Jan, 19 Feb
Xenolith Point	1		Count	2006-07
Cave Point	58		Count	23-Jan-14
Horseshoe Bay points	3		Count	2005-06
Cape Bouguer	71		Count	20-Mar-14
East of Remarkable Rocks	6		Count	25-Feb-14
Cape du Couedic	4348	4281-4415	MR & Count	Jan-14, Jan 98
North Casuarina Is.	245	234 – 255	MR	Jan-14
Paisley Is.	22		Count	29-Jan-14
North Islet	7		Count	14-Mar-14
Williams Island	182		Count	14-Mar-14
South Neptune Islands colony	3210	3162-3258	MR & Count	Feb-14
North Neptune Islands colony	4669	4605-4733	MR & Count	Feb-14
Liguanea Is.	1832	1797 - 1867	MR & Count	Feb-14
Rocky (South) Is.	19		Count	13-Mar-14
Little Hummock Is.	27		Count	13-Mar-14
Four Hummocks (South) Is.	16		Count	13-Mar-14
Four Hummocks (Middle) Is.	47		Count	13-Mar-14
Four Hummocks (North) Is.	68		Count	13-Mar-14
Greenly Is.	13		Count	13-Mar-14
Dorothee Is.	2		Count	12-Feb-14
Veteran Isles (South)	1		Count	11-Feb-14
Pearson Is (North, north bay)	24		Count	11-Feb-14
Pearson Is (North, east coast)	15		Count	11-Feb-14
Ward Is.	127		Count	11-Feb-14
South Ward Is.	24		Count	11-Feb-14
Olive Is.	5		Count	11-Feb-14
Fenelon Is.	3		Count	19-Mar-14
<b>Total pups for SA</b>	<b>20,426</b>	<b>20,307 – 20,544</b>		

**Table 8.** Distribution of New Zealand fur seal breeding aggregations in regions of South Australia in the 2013-14 breeding season.

<b>Region</b>	<b>Breeding sites</b>	<b>Pup abundance</b>	<b>Per cent abundance</b>
South-east	1	2	0.01
Kangaroo Island and North Casuarina	12	10,133	49.6
Neptune and Liguanea Islands	3	9,711	47.5
Lower Southern Spencer Gulf	2	189	0.92
West Coast of Eyre Peninsula	10	391	1.91
<b>Totals</b>	<b>28</b>	<b>20,426</b>	



**Table 9.** Mass (kg) and standard deviation of New Zealand fur seal pups at two colonies following the 2013-14 breeding season. Long-term data for the Cape Gantheaume sub-colony from 1989-89 are also included (means for each sex, and maxima and minima of the annual means for each sex).

<b>Cape Gantheaume</b>	<b>27 January 2014</b>		<b>Long-term data</b>	
	<b>Male</b>	<b>Female</b>	<b>Male</b>	<b>Female</b>
Mean	6.60	5.96	7.54	6.76
Standard deviation	1.27	1.14		
Sample size	56	54		
Maximum	10.75	9.2	8.60	7.48
Minimum	4.4	4.25	6.39	5.78

<b>South Neptune Island</b>	<b>7 February 2014</b>	
	<b>Male</b>	<b>Female</b>
Mean	6.13	5.82
Standard deviation	1.18	1.12
Sample size	15	20
Maximum	8.9	7.7
Minimum	4.4	3.7