AUSTRALIAN AND NEW ZEALAND FUR SEALS AT THE SKERRIES, VICTORIA: RECOVERY OF A BREEDING COLONY.

CHARLES L. LITTNAN AND ANTHONY T. MITCHELL


The population size of Australian fur seals *Arctocephalus pusillus doriferus* and New Zealand fur seals *A. forsteri* at The Skerries, Victoria was estimated in two consecutive breeding seasons, 1999-2000 and 2000-2001 using both mark-recapture procedures and aerial surveys. 675 and 746 *A. p. doriferus* pups and 37 and 47 *A. forsteri* pups were captured and marked in 1999-2000 and 2000-2001, respectively. Resights (1999-2000 N = 3; 2000-2001 N = 6) were conducted 2 - 3 days after marking and pup population estimates were calculated using a modified Lincoln-Petersen estimate. The arithmetic mean for *A. p. doriferus* pup abundance was 1,867 in the first season and 2,237 in the second. *A. forsteri* abundance was 75 and 78, respectively. The *A. p. doriferus* population is estimated to have increased an average of 19.7% (*r* = 0.18) between 1999 and 2000. The arithmetic mean from five counts of aerial photographs of total animals present at the colony was 1,758 in 1999-2000 and 2,965 in 2000-2001. Due to high variation between counts, aerial surveys proved to be an inconsistent and inaccurate method for estimating the population of fur seals at The Skerries.

Key words: *Arctocephalus pusillus doriferus*, *Arctocephalus forsteri*, Australian fur seal, New Zealand fur seal, population estimates, mark-recapture.

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THE unregulated hunting of Australian fur seals, *Arctocephalus pusillus doriferus*, and New Zealand fur seals, *Arctocephalus forsteri* in the late 18th and early 19th century resulted in substantial population reductions in both species and local extirpation in some areas (Warneke 1982; Ling 1999). Prior to commercial exploitation the annual pup production of *A. p. doriferus* was estimated to be up to 50,000 and the total population to be around 225,000 animals (Warneke 1982). Little is known of the *A. forsteri* population in south-eastern Australia prior to sealing but it is believed that the species may have been eliminated entirely from the waters of north-eastern Bass Strait (Warneke 1975; Warneke and Shaughnessy 1985).

The Game Act of 1890 in Victoria and the Tasmanian Fisheries Legislation of 1889 provided protection for fur seals in Bass Strait, although regulated seasonal harvests continued until after 1923 (Warneke 1982). Under protection, the number of fur seals in Australia has increased but monitoring the recovery of both fur seal populations has involved limited range-wide censuses focused primarily on the populations at a few of the larger colonies.

**Australian fur seals (A. p. doriferus)**

Warneke (1988) completed the most recent range-wide survey of *A. p. doriferus* colonies in 1986 using aerial photography. He concluded that a small increase in numbers had occurred between a survey done in 1965 and the 1986 estimate. More recent studies report that individual *A. p. doriferus* colonies are increasing between 2 - 6.2% per annum (Pemberton and Kirkwood 1994; Shaughnessy *et al.* 1995; Arnould and Littnan 2000; Shaughnessy *et al.* 2000).
The current population of *A. p. doriferus* is restricted to nine colonies within Bass Strait and estimated at 46,000 - 60,000 animals and a pup production of 10,000 - 14,000 (Warneke and Shaughnessy 1985; Pemberton and Kirkwood 1994). These estimates include recent census results for the larger colonies in Bass Strait but also outdated and possibly inaccurate estimates of the smaller colonies including The Skerries island group.

**New Zealand fur seals (*A. forsteri*)**

Gales *et al.* (2000) reported that the *A. forsteri* population in Western Australia was increasing an average of 9.8% per annum, with an estimated total population of about 7,100 animals. Most of the *A. forsteri* population is in central South Australian waters, where there were an estimated 27,500 animals in 1993 (Shaughnessy *et al.* 1994). A much smaller population of 100 seals has also been reported on Maatsuyker Island, in southern Tasmania (Brothers and Pemberton 1990).

Australian and New Zealand fur seal breeding populations were initially considered to be allopatric, *A. forsteri* found in Western and South Australia and *A. p. doriferus* in the southeast (Warneke 1982; Shaughnessy and Warneke 1987; Ling 1999) but non-breeding populations overlap in southern Tasmania (Goldsworthy *et al.* 1997). Arnould *et al.* (2000) reported the first contemporary accounts of breeding *A. forsteri* alongside *A. p. doriferus* colonies at two sites within Bass Strait, at Kanowna Island and The Skerries.

The current paper describes the first mark-recapture estimates for the populations of both *A. forsteri* and *A. p. doriferus* at The Skerries. The efficacy of mark-recapture, aerial, and direct count surveys at The Skerries are compared to determine the most accurate technique for monitoring and managing this colony in the future.

**METHODS**

The Skerries (37° 45’ S, 149° 31’ E) are located approximately 500 m off the mainland and are within the boundaries of Croajingalong National Park, Victoria. The Skerries are thought to be the eastern extent of the breeding range for fur seals in Australia. The colony consists of three, small low-granite islets with an area of about 5 ha (Fig. 1). The topography is principally uneven boulder areas with some regions of smooth, sloping rock and shell grit. Tide and runoff pools are found on the islands. Adult *A. p. doriferus* occur in all but the highest points of the islands and within the small areas inhabited by *A. forsteri*. Pups use most of the available habitat except the highest points near the centre of each island and tend to congregate at the pools using them for swimming and thermoregulation.

**Fig. 1.** Diagram of the three islets of the Skerries Victoria. Australian fur seals occur in most areas of the islands excluding those outlined by the dotted line and locations of New Zealand fur seals are highlighted in black.

**Mark-recapture**

Mark-recapture estimates were used to estimate the number of fur seal pups at The Skerries. This method was chosen because the many large boulders and few high vantage points here do not allow for direct counting, a method which has proven successful at other *A. p. doriferus* colonies (Shaughnessy *et al.* 1995; Arnould and Littnan 2000). Counts were confined to pups born in the year of the census for several reasons: 1) pups are small and readily identifiable because they retain their natal pelage until the first moult and 2) young pups (< 3 months) do not swim well or flee to sea when disturbed and are consequently less likely to leave the study site during surveys.

The breeding season is nearly synchronous for the two species. Females give birth between November and January and the peak pupping date for *A. p. doriferus* is around 1 December (Warneke and Shaughnessy 1985) and 21 December for *A. forsteri*
(Goldsworthy and Shaughnessy 1994). Thus, censuses were conducted between 10 - 18 January in 2000 and 2001, when groups of 4 - 11 field workers entered the study area and caught both Australian and New Zealand fur seal pups. The islands were accessed using a 3.9 m inflatable craft with a 25 hp outboard motor. The two species were identified using characteristics described by Goldsworthy et al. (1997). 675 and 746 A. p. doriferus pups and 37 and 47 A. forsteri pups were captured and marked in 1999-2000 and 2000-2001, respectively. Pups were marked by clipping a small amount of black guard hair on the head revealing lighter fur underneath. A single mark was used to identify A. p. doriferus and two parallel horizontal bars for A. forsteri. Capture effort was spread evenly across the island to ensure that all parts of the population had been marked.

Pups were resighted over a 2 - 3 day period after allowing between 1 - 2 days for mixing of marked and unmarked individuals. A single, simultaneous survey of marked and unmarked pups on all three of the islands constituted one recapture session. Teams of two (one counter and one recorder) surveyed each island simultaneously by counting from high vantage points when possible to minimise disturbance, or by walking among pups when necessary. During resights, data for A. p. doriferus and A. forsteri were kept separate. The number of recapture sessions was influenced by the weather and sea conditions that determined when it was safe to land on or return from the islands.

In January 2000, pups were marked with a unique identifier per island. This information was used to determine whether pups moved between islands when disturbed, a behaviour that can bias mark-recapture estimates. Only 8 marked pups (1.3%) were resighted on islands other than their natal one; therefore, the probability of counting the same individual on more than one island was low so island-specific marks were not used in 2001.

For each recapture session, the number of pups \(N\) and its variance was estimated using a modified Lincoln-Peterson estimate:

\[ N = \frac{(n_1+1) (n_2+1)}{(m_2+1)} - 1 \]

where \(n_1\) is the number of animals marked from the population, \(n_2\) is the number of animals recounted, and \(m_2\) is the number of those animals recounted which were marked.

Two methods were used to estimate overall abundance for both years for the two populations. The first was an arithmetic mean of the estimates from each recapture session. The 95% confidence intervals for the arithmetic means were calculated using the formula:

\[ N_i = \overline{t} \pm \left( t \times V^{0.5} \right) \]

for \(i = \) the 1999–2000 or 2000–2001 breeding season, \(V\) was the estimate of variance between counts, and \(t\) was the 5% limit of Student's t distribution with 2 degrees of freedom for \(N_{01}\) and 5 degrees of freedom for \(N_{00}\) (Shaughnessy et al. 2000). For the second technique for estimating abundance we used NOREMARK software (White 1996) and assumed a joint hypergeometric maximum-likelihood distribution (Shaughnessy et al. 2000).

The exponential rate of increase of pup numbers between the seasons was calculated using the formula:

\[ N_{01} = N_{00} \times e^T \]

Where \(N_{01}\) and \(N_{00}\) are the two population estimates \(T\) years apart (Caughley 1980). The exponential increase was converted to a per cent increase by:

\[ \text{Rate} (\%) = (e^T-1) \times 100 \]

**Aerial Survey**

One aerial survey was done in each year (7 Feb. 2000 and 13 Feb. 2001) using a 185 Skywagon fixed-wing aeroplane. The flights were timed to coincide with high tide so that crevices between boulders that can obscure pups were submerged, and 1 - 2 hours before or after the sun reached its apex to minimise shadows and reflection of light off the rocks. Photographs were taken through a rear floor port with a hand-held 35 mm camera (24 – 85 mm lens; 200 ASA colour transparency film and 400 ASA black and white print film). All flight passes traversed the long axis of The Skerries (i.e., N-S, S-N). In 2000, aerial photographs were taken during seven different flight passes at altitudes ranging from 150 - 300 m. In 2001, 14 flight passes were made at lower altitudes of 100 – 150 m. During the surveys the seals showed no adverse reactions to the plane and remained on the islands.

Images from a single pass over the islands were projected onto a screen consisting of 35, 20 x 20 cm squares and counted by 5 observers to estimate total number of animals on the island. All participants in the counting were experienced with fur seals and had worked on The Skerries. The arithmetic mean described above was used to calculate the abundance of seals at The Skerries.

**RESULTS**

**Mark-recapture**

For the 1999-2000 pupping season, a total of 675 A. p. doriferus pups and 37 A. forsteri pups were marked. Three recounts were conducted and the recapture sample sizes ranged from 733 – 992 (mean = 855) A. p. doriferus and 27 – 38 (mean = 34) A. forsteri (Table 1). During the resight sessions a mean
of 33% of A. p. doriferus and 60% of A. forsteri pups observed had been marked. The estimate of A. p. doriferus pup numbers for the entire colony using the arithmetic mean was 1,867 (95% confidence interval from 1,756 – 1,978). The same estimate for A. forsteri pups was 75 (67 – 83) (Table 2). The hypergeometric means were 1,868 (1,802 – 1,941) for A. p. doriferus and 76 (68 – 89) for A. forsteri.

For the 2000-2001 pupping season, a total of 746 A. p. doriferus and 47 A. forsteri pups were marked. Recapture sample sizes ranged from 614 – 893 (mean = 780) and 27 – 42 (mean = 36), respectively. Thirty-six per cent of A. p. doriferus pups and 48% of A. forsteri pups counted in the recapture surveys had been marked. The arithmetic means for pup estimates were 2,237 (2,171 – 2,303) A. p. doriferus pups and 78 (72 – 84) A. forsteri pups. The hypergeometric mean and 95% confidence intervals were 2,239 (2,169 – 2,314) and 77 (72 – 83), respectively. There was a significant increase in the number of A. p. doriferus pups (Z = 50.5, p < .001) but not A. forsteri between the two breeding seasons in this study (Table 2).

Assuming total population size to total number of pups ratios from 3.5 – 4.5 : 1 (Harwood and Prime 1978; Harwood and Croxall 1988; Wickens and Shelton 1992; Pemberton and Kirkwood 1994), the mean A. p. doriferus pup number at The Skerries in the 2000-2001 breeding season of 2,237 was used to estimate a total colony size of between 7,830 – 10,067. The estimate of 78 A. forsteri pups was used to estimate a total colony size of 273 – 351 in 2001.

Aerial survey

All age- and sex-classes were included in counting animals on the transparencies of the islands. Both seasons showed a high variation among observers for the total number of animals counted. Counts ranged from 1,347 – 2,178 (mean = 1,758) for the 1999-2000 season and 2,000 – 3,817 (2,965) for 2000-2001 (Table 3). Duration of count sessions ranged from 2.6 – 3.1 hours (mean = 2.8) each.

<table>
<thead>
<tr>
<th>Pupping season</th>
<th>Re-sight session</th>
<th>Total counted</th>
<th>Marked re-sights</th>
<th>Petersen mean</th>
<th>95% confidence interval (±)</th>
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<tr>
<td>1999-00</td>
<td>1</td>
<td>992</td>
<td>363</td>
<td>1,843</td>
<td>1,619 - 2,068 (449)</td>
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<tr>
<td></td>
<td>2</td>
<td>733</td>
<td>276</td>
<td>1,793</td>
<td>1,512 - 2,073 (561)</td>
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<td></td>
<td>3</td>
<td>840</td>
<td>288</td>
<td>1,966</td>
<td>1,661 - 2,270 (609)</td>
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<td>2000-01</td>
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<td>765</td>
<td>280</td>
<td>2,030</td>
<td>1,834 - 2,226 (392)</td>
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<tr>
<td></td>
<td>2</td>
<td>779</td>
<td>264</td>
<td>2,192</td>
<td>1,966 - 2,418 (452)</td>
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<tr>
<td></td>
<td>3</td>
<td>614</td>
<td>194</td>
<td>2,348</td>
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<tr>
<td></td>
<td>4</td>
<td>812</td>
<td>254</td>
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<td></td>
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<td>893</td>
<td>292</td>
<td>2,273</td>
<td>2,054 - 2,491 (437)</td>
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<tr>
<td></td>
<td>6</td>
<td>813</td>
<td>274</td>
<td>2,204</td>
<td>1,983 - 2,426 (443)</td>
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<table>
<thead>
<tr>
<th>Method of calculation</th>
<th>Pupping season 1999-00</th>
<th>2000-01</th>
<th>Comparison</th>
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<tr>
<td>A. p. doriferus</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Arithmetic mean</td>
<td>1,867</td>
<td>2,237</td>
<td>Z = 50.5**</td>
</tr>
<tr>
<td>Hypergeometric mean</td>
<td>1,868</td>
<td>2,239</td>
<td>Z = 44.0**</td>
</tr>
<tr>
<td>A. forsteri</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arithmetic mean</td>
<td>75</td>
<td>78</td>
<td>n.s.</td>
</tr>
<tr>
<td>Hypergeometric mean</td>
<td>76</td>
<td>77</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Table 2. Estimates based on mark-recapture of the total abundance of A. p. doriferus and A. forsteri pups at The Skerries, Vic. for the 1999-2000 and 2000-2001 pupping seasons. ** p < 0.001
Population increase

The mean estimated number of *A. p. doriferus* pups on The Skerries increased from 1,867 in the 1999-2000 breeding season to 2,237 in the 2000-2001 breeding season. This represents a 19.7% (18.8 and 20.7% 95% CI) increase, or an exponential rate of increase of \( r = 0.18 \). This estimate of increase, though, must be taken with caution as other colonies within Bass Strait have shown large inter-annual fluctuations in pup mortality attributed to storm activity (Pemberton and Kirkwood 1994; Arnould and Littnan 2000). Intermittent estimates between 1944 and 1974 showed a relatively small, stable population of about 400 - 800 animals in total (Table 4). The most recent census prior to this study was an aerial survey done in 1986 by Warneke (1988) where he estimated 50 - 77 pups on The Skerries. Warneke’s (1988) estimates may have missed pups and/or been made during a particularly bad year for pup survival, nonetheless, the increase in pup production is still substantial.

This population growth has been accompanied by a spread of animals to all three islets over recent years. Observations made during the 1976-1977 breeding season indicate the seal colony covered only a small section of the outer island (Barton 1980). Warneke’s (1988) photos showed that there were no animals on the inner island and that pups were only seen on the outer island. Several local fishers also report, that until recent years, few animals were ever found on the inner island. However, during the 2000-2001 estimates there were at least 250 pups on the inner island and 851 in the middle island. Though this study presents evidence of rapid growth of The Skerries fur seal population, it is unlikely that the estimated total population of 7,000 - 10,000 animals is actually resident at the islands. It is more likely that juveniles and sub-adults leave the islands and spend time at one or more haulout locations. This is supported by the appearance of several permanent rafting and haulout points along the coast near The Skerries *pers. obs.*) and animals may move to other larger haulouts such as Montague Island, NSW.

This rapid population growth and increase in rafts and haulouts along the coast indicate that The Skerries are in the recolonisation phase of recovery (Roux 1987). Roux describes this phase as a period of: 1) high population densities on the original colony causing a rapid recolonisation of nearby islands and coastline by young animals; and 2) rapid population increase which may be as high as 15 - 17% per year. The duration of the recolonisation phase would be dependent on the available space for breeding and pup rearing. Due to the small size of The Skerries, it is possible that the rapid population growth will slow as the maximum density is reached and the colony moves into the establishment phase (Roux 1987).

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1</td>
<td>1,586</td>
<td>2,351</td>
<td>a</td>
</tr>
<tr>
<td>2</td>
<td>2,065</td>
<td>3,384</td>
<td>a</td>
</tr>
<tr>
<td>3</td>
<td>2,178</td>
<td>3,817</td>
<td>a</td>
</tr>
<tr>
<td>4</td>
<td>1,347</td>
<td>2,000</td>
<td>a</td>
</tr>
<tr>
<td>5</td>
<td>1,620</td>
<td>3,272</td>
<td>a</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>1,738.0</td>
<td>2,964.8</td>
<td>d</td>
</tr>
<tr>
<td>mean ± S.E.</td>
<td>± 156.1</td>
<td>± 339.4</td>
<td>d</td>
</tr>
</tbody>
</table>

Table 3. Aerial survey estimates of the total number of fur seals (*A. p. doriferus* and *A. forsteri*) at The Skerries, Vic, in each of five counting sessions.

**DISCUSSION**

Population increase

The mean estimated number of *A. p. doriferus* pups on The Skerries increased from 1,867 in the 1999-2000 breeding season to 2,237 in the 2000-2001 breeding season. This represents a 19.7% (18.8 and 20.7% 95% CI) increase, or an exponential rate of increase of \( r = 0.18 \). This estimate of increase, though, must be taken with caution as other colonies within Bass Strait have shown large inter-annual fluctuations in pup mortality attributed to storm activity (Pemberton and Kirkwood 1994; Arnould and Littnan 2000). Intermittent estimates between 1944 and 1974 showed a relatively small, stable population of about 400 - 800 animals in total (Table 4). The most recent census prior to this study was an aerial survey done in 1986 by Warneke (1988) where he estimated 50 - 77 pups on The Skerries. Warneke’s (1988) estimates may have missed pups and/or been made during a particularly bad year for pup survival, nonetheless, the increase in pup production is still substantial.

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<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated number</th>
<th>Source</th>
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<tbody>
<tr>
<td>1945-46</td>
<td>n/a 400 - 500</td>
<td>a</td>
</tr>
<tr>
<td>1946-47</td>
<td>n/a 300 - 400, max</td>
<td>a</td>
</tr>
<tr>
<td>1974-75</td>
<td>no estimate</td>
<td>a</td>
</tr>
<tr>
<td>1986-87</td>
<td>&gt; 50 724</td>
<td>b</td>
</tr>
<tr>
<td>1998-99</td>
<td>326 1,141 - 1,467</td>
<td>c</td>
</tr>
<tr>
<td>1999-00</td>
<td>1,867 6,535 - 8,402</td>
<td>d</td>
</tr>
<tr>
<td>2000-01</td>
<td>2,237 7,830 - 10,067</td>
<td>d</td>
</tr>
</tbody>
</table>

Table 4. Previous population estimates for The Skerries, Vic. a, Warneke (1982); b, Warneke (1986); c, Arnould and Littnan (2000); d, this study.

Estimates from other *A. p. doriferus* colonies in northern Bass Strait indicate those populations are stable or growing slowly (Arnould and Littnan 2000, Shaughnessy et al. 2000). The Kanowna Island colony has a population of between 5,600 and 7,200 animals and is growing at around 4% per year (J.P.Y. Arnould, pers. comm.). Shaughnessy et al. (2000) reported a larger and more rapidly increasing population (6.1% per year) at Seal Rocks. The population growth at The Skerries is greater than these and other colonies within Bass Strait. One factor responsible for this observation may be immigration from other colonies. The population at Seal Rocks has expanded into areas of the colony that may be unsuitable for raising pups (Shaughnessy et al 2000). Shaughnessy et al. (2000) also reported that in these areas pups were smaller and there was a lack of protection from storm surge and few pools for thermoregulation. Instead of breeding in these poor areas, animals may move to colonies, like The Skerries, with unoccupied areas more suitable areas for pup rearing.

The presence of *A. forsteri* on The Skerries was not reported until 2000 (Arnould et. al. 2000). However, the relatively small population size suggests that they had not colonised the islands until...
islands. Estimates for pup numbers for the 1998-1999 island. At other colonies, direct counts such as these and landed to count some sections of the middle Skerries from a small boat several metres off shore species.

monitor separate population trends of the two fur seal inaccuracies of this method, pup numbers were Littnan 2000). It is highly likely that due to the estimate of 1,141 - 1,467 animals (Arnould and Littnan 2000). However, on The Skerries this method have proven to be very successful (Arnould and rocks on the periphery of the colony could lead to inaccuracies. Pemberton and Kirkwood (1994) cautioned that differences in colony terrain may influence the accuracy of aerial counts and this is shown clearly by the high variation in estimates among observers during the recounts. Shaughnessy (1993) showed that aerial surveys were inferior to mark-recapture for assessing numbers of A. p. pusillus and Shaughnessy et al. (1994) commented that it was unsuccessful for estimating numbers of A. forsteri. All observers experienced difficulty distinguishing individuals in aggregations or on dark rocks. Finally, it is impossible to differentiate species through aerial photographs making it impossible to monitor separate population trends of the two fur seal species.

Arnould and Littnan (2000) counted pups at The Skerries from a small boat several metres off shore and landed to count some sections of the middle island. At other colonies, direct counts such as these have proven to be very successful (Arnould and Littnan 2000). However, on The Skerries this method proved ineffective and inaccurate as it missed pups hiding under boulders or resting in the interior of the islands. Estimates for pup numbers for the 1998-1999 breeding season were 326 with a total population estimate of 1,141 - 1,467 animals (Arnould and Littnan 2000). It is highly likely that due to the inaccuracies of this method, pup numbers were underestimated. Mark-recapture estimates, while causing a temporary disturbance within the colony, are the only way to estimate numbers of pups with an acceptable degree of precision. It is also the only method that will enable a monitoring program to differentiate the two seal species.

Comparison of methods

Results from the aerial surveys showed that aerial photography of The Skerries, while minimising disturbance to the colony, was an inaccurate method of estimating pup numbers and population size. Firstly, pups were difficult to count when they occurred in dense aggregations around pools and were missed entirely when obscured under rocks. Therefore, it was necessary to use the total number of animals for population estimates, which has the inherent bias that an unknown number of animals from different age- and sex-classes may be rafting in the water near shore or foraging out to sea. Secondly, the lack of contrast between seal and the dark wet rocks on the periphery of the colony could lead to miscounts. Pemberton and Kirkwood (1994) cautioned that differences in colony terrain may influence the accuracy of aerial counts and this is shown clearly by the high variation in estimates among observers during the recounts. Shaughnessy (1993) showed that aerial surveys were inferior to mark-recapture for assessing numbers of A. p. pusillus and Shaughnessy et al. (1994) commented that it was unsuccessful for estimating numbers of A. forsteri. All observers experienced difficulty distinguishing individuals in aggregations or on dark rocks. Finally, it is impossible to differentiate species through aerial photographs making it impossible to monitor separate population trends of the two fur seal species.

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