Status of the Steamers Head (NSW) Australian and New Zealand fur seal haul-out site and influence of environmental factors and stochastic disturbance on seal behaviour

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ABSTRACT

The most northern Australian haul-out site for the fur seal *Arctocephalus pusillus doriferus* is at Steamers Head, New South Wales (NSW). This study represents the first quantitative status report on the composition and abundance of seals at the Steamers Head haul-out and can be used as a baseline for future long term monitoring. Seasonal trends, environmental effects and disturbances on haul-out numbers were investigated for seals at this site. The haul-out site was occupied by both Australian *A. pusillus doriferus,* and New Zealand *A. forsteri*, fur seals, with *A. pusillus doriferus* the far more abundant species. For both species, adult males, sub-adults and juveniles were present, but sub-adults represented the most numerous age group. Observed numbers of hauled-out seals increased from occasional individuals during May, peaked at 135 in September, and declined during October. The seasonal occupation of the site suggests that those animals present are non-breeding. Daily haul-out numbers varied considerably. Two large declines in numbers coincided with stochastic disturbance from a landslide at the site and unusually intense naval bombardment at a nearby weapons range. No diurnal or tidal effects on haul-out behaviour were observed, though more *A. pusillus doriferus* hauled-out in strong winds and warm air temperatures. At the site, which is sheltered, shaded, steep and has a southerly aspect, environmental effects have different influences on the fur seals' haul-out behaviour compared to more exposed sites. Thus generalisations regarding haul-out behaviour of seal species in response to environmental conditions need to be viewed with caution.

Key words: *Arctocephalus pusillus doriferus, A. forsteri,* landslide, naval bombing, environmental factors, disturbance, haul-out, Jervis Bay.

Introduction

Populations of the Australian, *Arctocephalus pusillus doriferus,* and New Zealand, *A. forsteri,* fur seals are widely distributed throughout the southern waters of Australia. The Australian range of *A. pusillus doriferus* includes the North Casuarina Islets at Kangaroo Island in South Australia, east to Steamers Head on the New South Wales (NSW) south coast, and south to Maatsuyker Island on southern tip of Tasmania (Brothers and Pemberton 1990; Shaughnessy 1999). *A. forsteri* is distributed from the Rottnest Island near Perth and along the south coast of Western Australia to Maatsuyker Island in Tasmania and Montague Island in NSW. Seals are also found across the Tasman to New Zealand and south on the sub-antarctic islands (Shaughnessy *et al.* 1994). Occasionally, individual *A. forsteri* are sighted as far north as Queensland and New Caledonia (Shaughnessy 1999).

A. pusillus doriferus only breeds in Australian waters at 11 known sites, 10 of which are located on islands within the Bass Strait (Shaughnessy 1999), and one recently discovered colony near Kangaroo Island (P. Shaughnessy pers. comm.). The peak breeding and pupping season occurs from late October to late December (Pearse 1978; Pemberton and Kirkwood 1994). *A. forsteri* breeds both in New Zealand and at 32-36 locations in Australia waters, from Western Australia to Macquarie Island from mid December to early January (Goldsworthy and Shaughnessy 1994; Goldsworthy *et al.* 1997; Shaughnessy 1999; Shaughnessy *et al.* 2005). As female NZ fur seals come ashore at breeding colonies, the number of hauled-out bachelor males decreases while the number of territorial males increases; territorial male numbers ashore start to decline with females as the season ends (Goldsworthy and Shaughnessy 1994). At least some of these males move from the breeding to non-breeding haul-out sites. Non-breeding, seasonal, haul-outs usually consist of adult males, sub-adults, and juveniles, and possibly sub-adult females, which are similar in appearance to juvenile males (Shaughnessy *et al.* 2001). Of the 17 locations for Australian fur seals identified by Kirkwood *et al.* (2005), 10 were considered non-breeding haul-out sites, though 35 non-breeding haul-outs were identified in Tasmania alone by Pemberton and Kirkwood (1994), and there are numerous other haul-outs in Victoria and NSW

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(Kirkwood pers comm.). Shaughnessy *et al.* (1994) identified that 54 of the 88 sites recorded for NZ fur seals in South and Western Australia during the 1989-90 breeding season lacked pups and could be considered haul-outs for non-breeding fur seals. It should be noted that since these early 1990s estimates, other non-breeding haul-outs and some additional breeding sites may have established.

In 2005, the population of *A. pusillus doriferus* was estimated as 92,000 seals, up from the 47,000-60,000 estimates in 1992, but still below the 200,000 seals thought to compose the population pre-European colonisation (Kirkwood *et al.* 1992; 2005). In 1989/1990, the number of *A. forsteri* was estimated to be 135,000 (Wickens and York 1997), with approximately 35,000 of these animals in Australian waters (Shaughnessy *et al.* 1994), however no approximation of this population's original size has been attempted. The number of NZ fur seals modeled more recently by Goldsworthy *et al.* (2003) is 31, 285 females (all age classes) and 26,158 males (all age classes); 57,443 in total. The historical northern limit of *A. pusillus doriferus* was Seal Rocks in northern New South Wales (Warneke 1982), while *A. forsteri* once occurred in the Furneaux Group of eastern Bass Strait until they were eliminated in the 19th century by sealers. By 1825 all easily accessible colonies of both species had either been reduced to very low numbers or completely eliminated by commercial exploitation (Warneke 1982).

Seals gradually received total protection throughout all of Australia's southern states by 1889 (Shaughnessy 1999). However, in response to political pressure from professional fishermen, sealing was permitted in Victoria in 1948-49 with approximately 700 *A. pusillus doriferus* being landed in Melbourne (McNally and Lynch 1954; D.D. Lynch pers. comm.). Beside this one season, there have been no legal culls of seals in Australia for at least 75 years (Shaughnessy *et al.* 1988a, b; 1999) though Pemberton *et al.* (2005) lists one-off harvests at some colonies (750 seals from Judgment Rocks and West Moncoeur in 1921, 77 at Seal Rocks in 1928–1929, 691 at Seal Rocks and Lady Julia Percy in 1948–1949 and 232 at Seal Rocks in 1970–1971). While both species have increased in number, the recovery of *A. pusillus doriferus* has been slower than that of *A. forsteri* for reasons that are as yet unknown but speculated to involve lethal interactions with fishers/fishing gear and nutrient poor environments (Pemberton and Kirkwood 1994; Kirkwood *et al.* 2005).

A. pusillus doriferus and *A. forsteri* have recently established a haul-out site at Steamers Head near Jervis Bay on the NSW south coast. Seals move from the NSW state waters of the Jervis Bay Marine Park to the commonwealth territory of the Booderee National Park when they haul out onto Steamers Head. Fur seals were first noticed at Steamers Head in 1989 and by 1993 had reached approximately 30 seals in number which rapidly increased to an estimated 100 animals by 1997 (M. Fortescue pers. comm.). Although this is the most northern haul-out for *A. pusillus doriferus* no quantitative assessments of the population are available. The site is now popular with various eco-tourism ventures; for instance it is the 11th most visited dive site of the 78 known sites in Jervis Bay (Lynch *et al.* 2004). As an important wildlife asset of the Jervis Bay Marine Park (JBMP), protection of the haul-out site was considered important by management and baseline data to monitor the site was required. To develop a monitoring procedure an assessment of environmental factors that affect haul-out patterns by both species and at various scales of temporal variation was also required. We therefore collected both environmental and seal count data detailing monthly, daily and diurnal patterns in abundance and population structure for fur seals at Steamers Head in 1999. Our seasonal approach to sampling also allowed for the investigation of stochastic disturbance on seal haul-out behaviour.

Materials and Methods

Site description

Our study site at Steamers Head (35°11'S, 150°44'E) was approximately 6 km south of Jervis Bay on the NSW South Coast and was only accessible by boat (Fig. 1). The site was situated at the base of a large cliff in a small sheltered bay with a southerly aspect. The seals hauled-out onto three rock platforms and into an adjacent cave. The largest rocky outcrop, hereafter called the main platform, is approximately 70 m in diameter and adjoins the entrance of the cave. To the east of the cave are two smaller platforms, the 2nd and 3rd platforms (Fig. 1).

Sampling protocol

We chose index counts rather than an estimate of the entire population size as animals inside the cave could not be counted due to inaccessibility and the risk of disturbing the animals, while the number of animals in the water was also difficult to estimate. Hence the total number of seals at Steamers Head was likely to be higher than the maximum numbers presented here as animals inside the cave and in the water were not counted. From the stern of our 6.0 m research vessel counts of seals were made through 7x50 Offshore binoculars (Tasco - USA). To minimise observer bias, data used in this study were solely collected by AB. Using distinguishing characteristics described in Table 1, counts of seals were categorized by species (Australian and New Zealand) and age group (adult, sub-adult and juvenile).

Counts were all undertaken at a distance of 75 m from the haul-out, a distance we continually measured with our laser range finder (Bushnell Lytespeed 400), as we deduced that at this distance we did not disturb the seals' haul-out behaviour (see Burleigh *et al.* 2008). Monthly counts of seals were conducted between January and October 1999. More counts were made during the peak haul-out period to determine diurnal behaviour, with one count per month at 1200 h between January and May 1999 and in October 1999. We aimed to make five counts per day for five days each month between June and September 1999, though in many cases sampling opportunity was lost due to inclement weather (106 planned with 59 counts completed). When we conducted multiple counts, we sampled throughout the day at 0900, 1030, 1200, 1330, and 1500 h to determine if time of day influenced haul-out number.

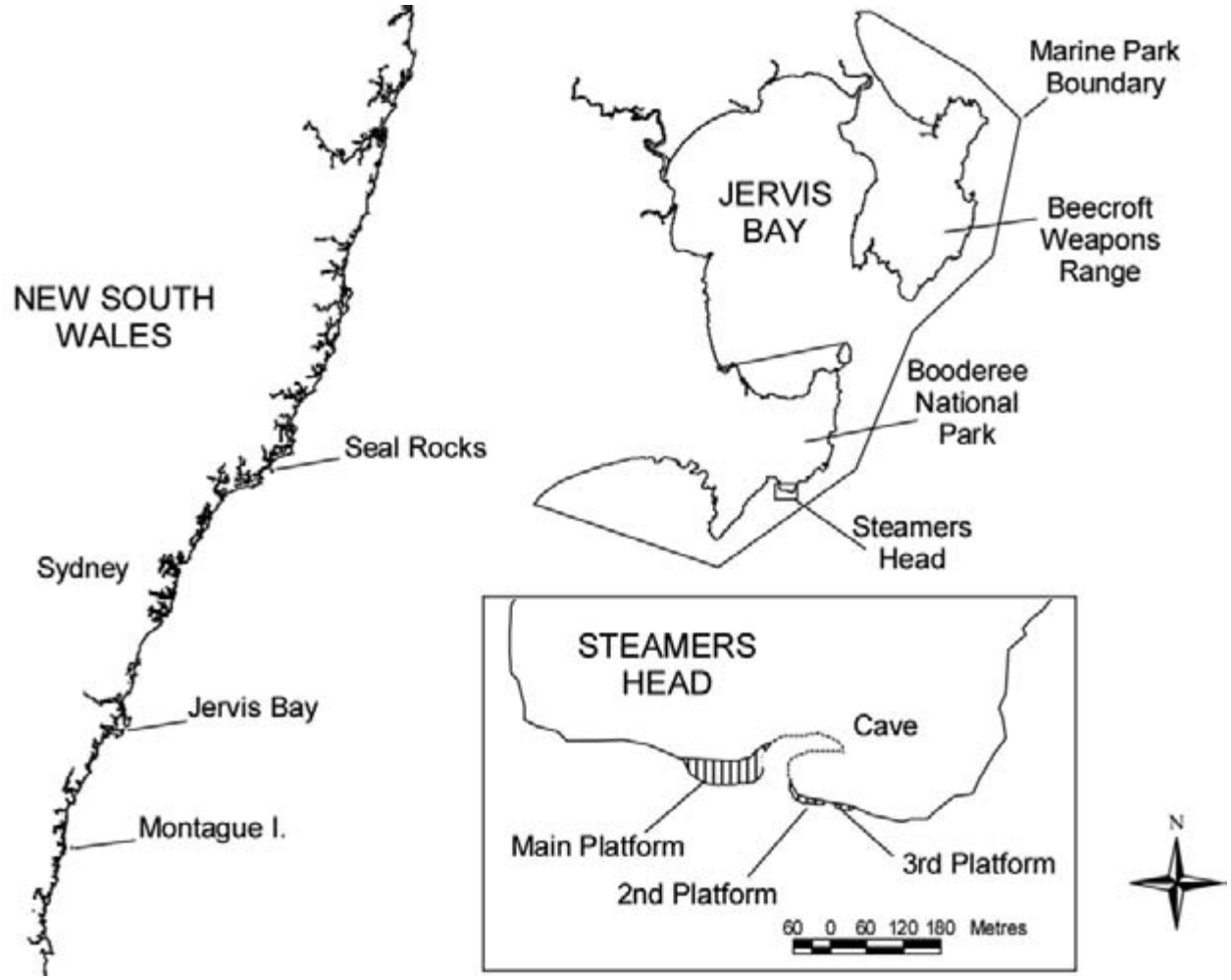

Figure 1. The Steamers Head fur seal haul-out.

On each sampling day we measured air and water temperatures at the site. We also used Australian Bureau of Meteorology records from their Point Perpendicular weather station located next to the Beecroft Weapons Range (Fig. 1) for cloud cover, wind speed and swell size at 0900, 1200 and 1500 h. Although available, swell and wind direction were not analysed as the swell was always from the south during counts and little data were collected when moderate to strong southerly winds blew because the site became inaccessible. Tides were categorised from local tables into low rising, high rising, high falling, and low falling.

Analysis

To identify diurnal variation in haul-out patterns, we used a one-way analysis of variance to compare counts with time of day during the peak haul-out season. Due to weather constraints it was not always possible to conduct all five counts. For the nine days when counts throughout most of the day were undertaken, the numbers of counts conducted for each time are shown in parentheses: 0900 h (9); 1030 h (8); 1200 h (9); 1330 h (8); and 1500 h (7).

The seasonal pattern of abundance for each species was described over the year from both the maximum counts for each month and the mean number of seals observed hauled out at the site. The population structure of *A. pusillus doriferus*, i.e. juveniles, sub-adults and adults (Table 1), was also plotted as means with standard errors for each sampled month. Due to the low number

Table 1. Summary of seal species and age classes (Irvine *et al.* 1997; Goldsworthy and Shaughnessy 1994)

Species	Age Group	Description
Australian fur seal *Arctocephalus pusillus doriferus*	Juvenile	1 to 4 years. 1.0 to 1.7 m long. 30-110 kg. Pale chest and brown belly with lighter fur extending to jaw ventrally and behind the ears.
	Sub-adult	4 to 8 years. 1.5 to 2 m long. 110-200 kg. Developing heavy shoulders and coarse mane. Uniform grey pelage.
	Adult Males	8 to 19 years. 2 to 2.2 m long. 218-360 kg. Coarse mane and heavy shoulders. Often scarred.
New Zealand fur seal *Arctocephalus forsteri*	Juvenile	Pale muzzle, white vibrissae, rusty coloured pelage, smaller than sub-adults.
	Sub-adult	Pointed snout, smaller than adult males.
	Adult Males	Well developed chests, manes and shoulders.

of observations of *A. forsteri* we only analysed the population dynamics and response of *A. pusillus doriferus* to time of day and environmental variables. Data were log-transformed to achieve normality and then multiple regression analysis was conducted to identify relationships between environmental variables and the number of seals hauled-out.

Two stochastic disturbances were associated with sharp declines in seal numbers. On 20 July, approximately 75 m by 25 m of the cliff-face, directly above the haul-out site, fell onto the seals. Many large rocks struck the main platform and at least one sub-adult Australian fur seal was killed. Due to the effects of the tidal cycles on the rubble, we deduced that the landslide occurred between 0500 h and 0900 h, before our first count of the day. The second disturbance was an unusually intense naval ship to shore bombardment of the Beecroft Weapons Range, 12 km to the North, on 9 September by the soon-to-be decommissioned Vietnam era destroyer, HMAS Perth.

Counts made on the day of the landslide or bombing were not included in the analysis of environmental effects on haul-out behaviour as these events were correlated with large decreases in seal numbers on the platforms.

Results

Behaviour in response to time and tide

There was no difference between the number of fur seals hauled out and the time of day (ANOVA: $F_{(4,36)}=0.134$, $P=0.969$) or tidal cycle (ANOVA: $F_{(3,44)}=0.266$, $P=0.850$). As time and tide did not correlate with seal haul-out behaviour, multiple counts on a day and the associated environmental factors were taken as not being serially correlated and were thus pooled as individual replicates for the seasonal variation and regression analysis.

Seasonal variation in seal haul-out numbers

Combined numbers of hauled out seals peaked in September at 135, with *A. pusillus doriferus* much more abundant than *A. fosteri* (Figure 2). For both species, adult males and sub-adult and juvenile males and females were observed, however, no adult females were observed. Sub-adults were the most common age class for both species, followed by juveniles and then adult males (Figure 3). Numbers of juvenile and adults peaked later in the year compared to the sub-adults of each species.

A. forsteri was restricted to the steepest and most seaward part of the main platform. Only *A. pusillus doriferus* was found on the second and third platform and then only in small numbers. Peak occupation of the second platform occurred in September with 11 seals, while only solitary *A. pusillus doriferus* was observed to occupy the third platform, and then only during September.

When daily counts were plotted, rather than monthly estimates, the number of seals hauled out varied considerably (Figure 4). Two of the major drops in numbers coincided with observed disturbances: (**a**) a rock fall and (**b**) a ship to shore naval bombardment.

Environmental Variables

There was a significant positive relationship between wind speed and the number of seals hauled out (Table 2) with more seals hauled out in strong winds (Figure 5a). There was also a significant positive relationship between air

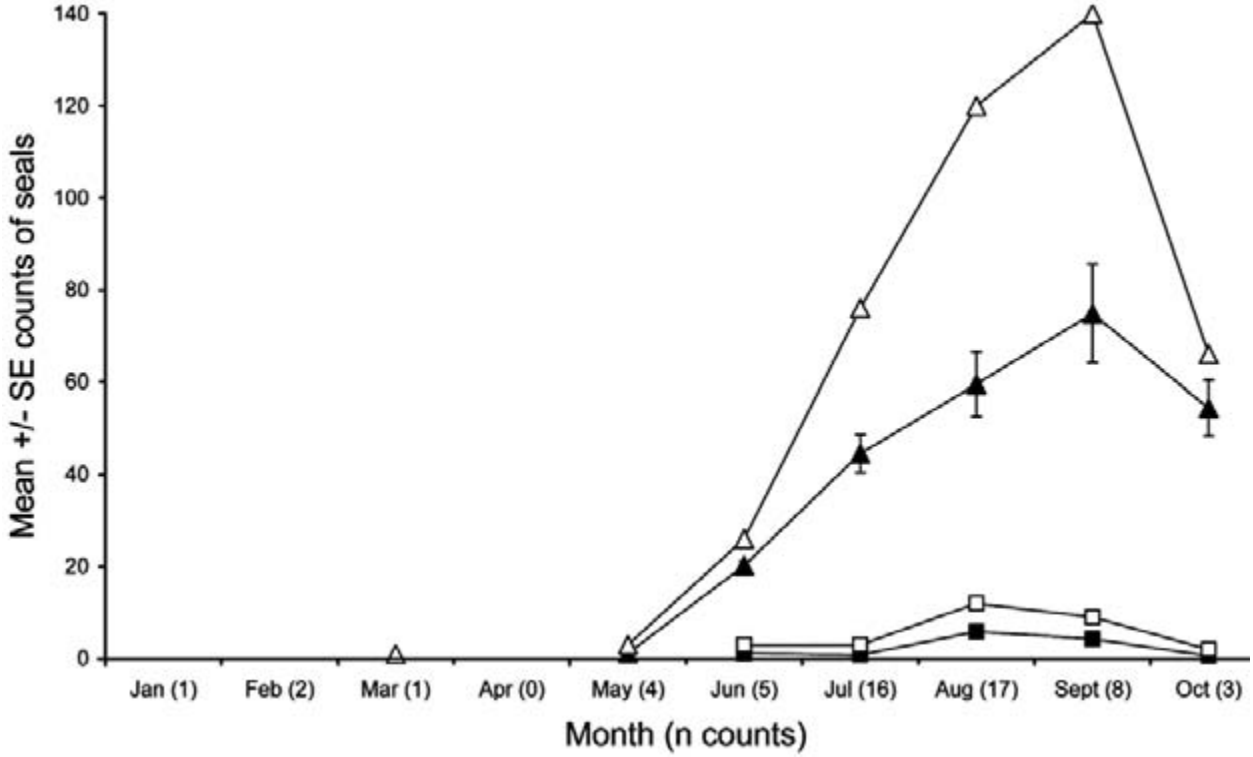

Figure 2. Seasonal change in monthly maximum numbers (open symbols) as well as mean (closed symbols) with SE for Australian (triangles) and New Zealand (squares) fur seals at the Steamers Head haul-out site, New South Wales, bracketed numbers are the number of counts undertaken for each month.

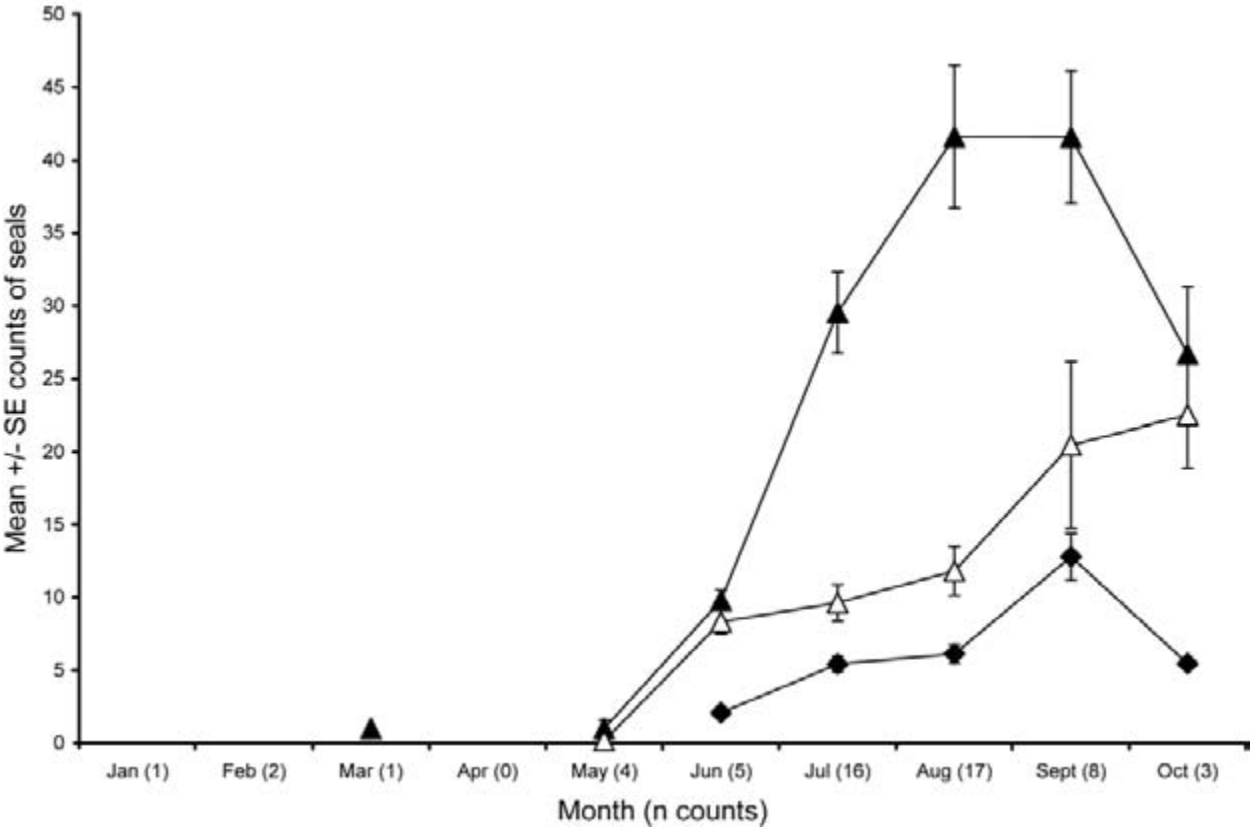

Figure 3. Mean (± SE) seasonal change in number of Australian fur seal in three age classes: sub-adults (▲), juveniles (△), adults (◆) at the Steamers Head haul-out site, New South Wales bracketed numbers are the number of counts undertaken for each month.

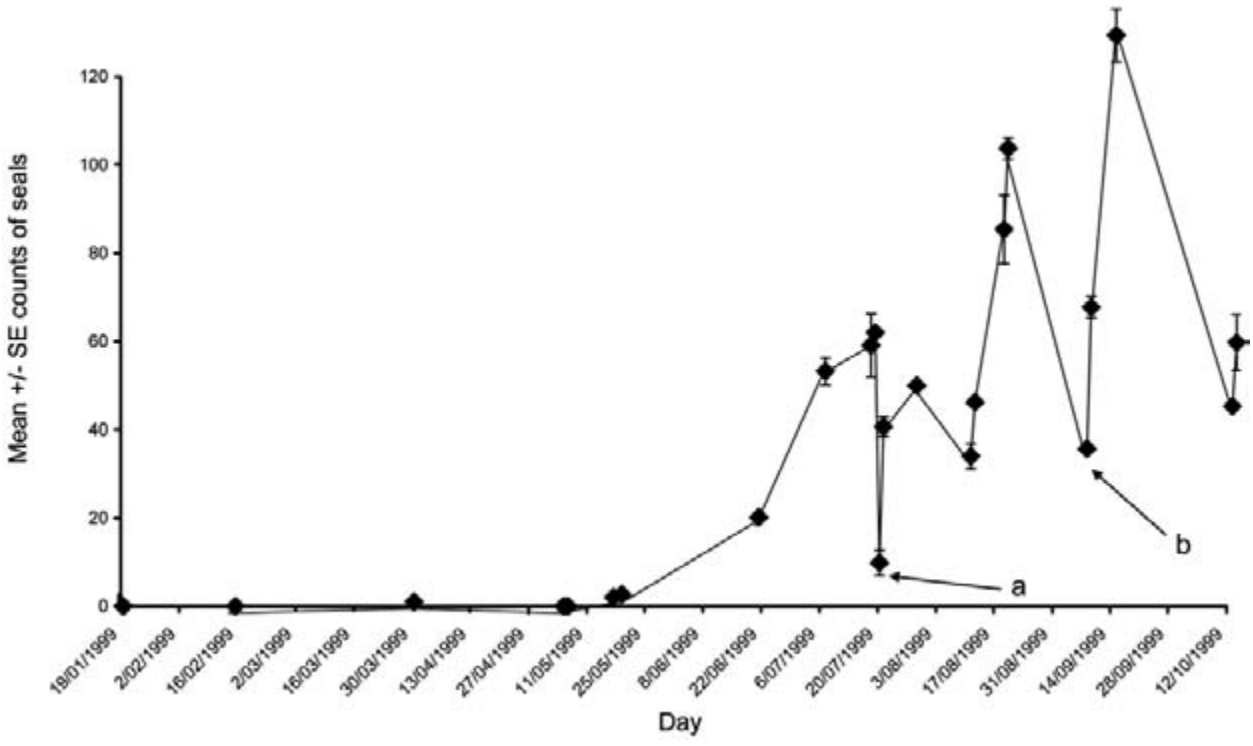

Figure 4. Mean (± SE) daily change in number of fur seals, (a) indicates a landslide onto the haul-out site, (b) indicates a major ship-to-shore bombardment 15 kilometres north of the Steamers Head haul-out site, New South Wales.

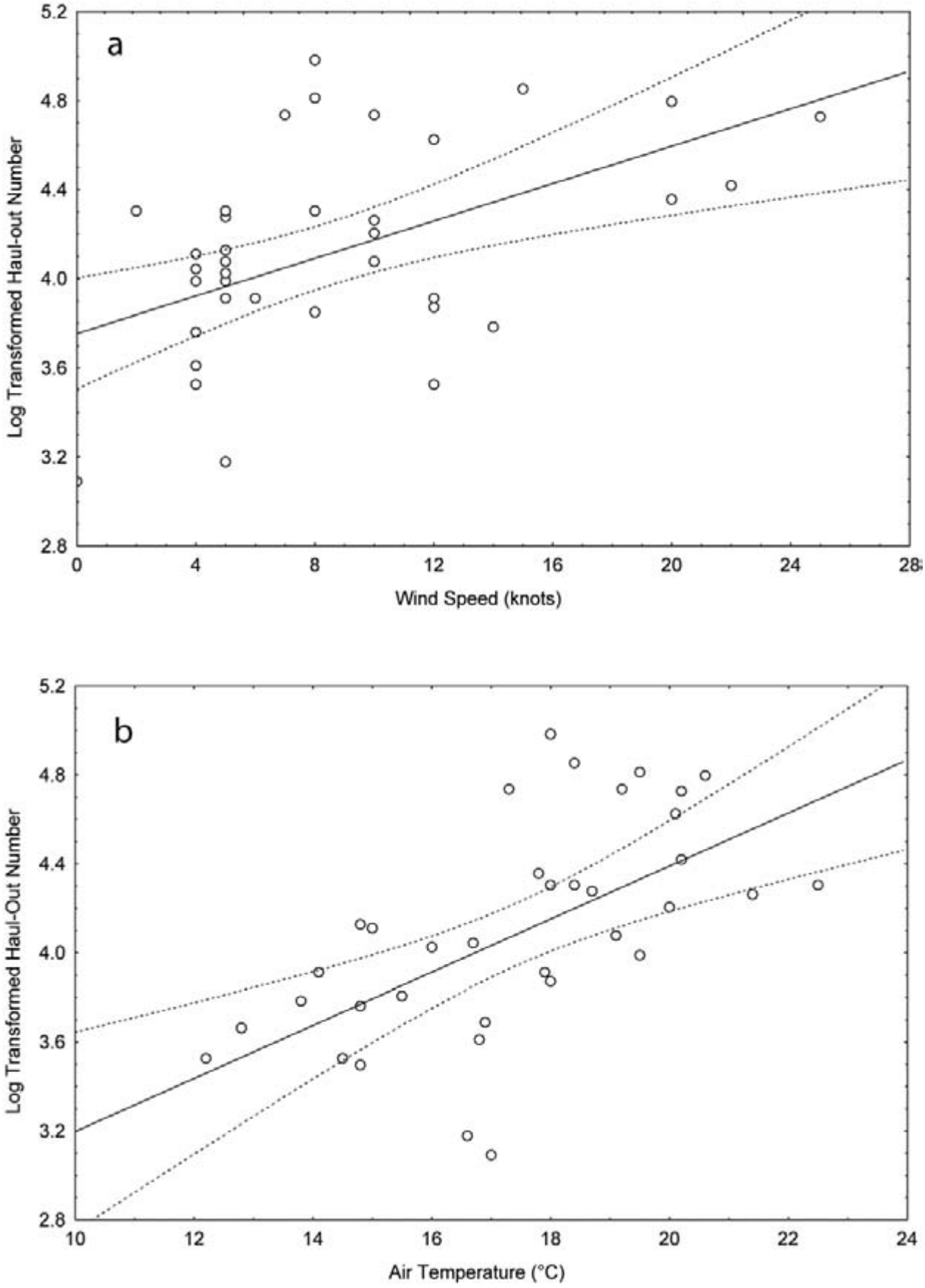

Figure 5. Relationships between (a) wind speed and (b) air temperature correlated with seal haul-out number (log) at the Steamers Head haul-out site, New South Wales; dashed lines represent 95% confidence limits.

temperature and the number of seals hauled out (Table 2), with more seals hauled out during higher temperatures (Figure 5b). Cloud cover, swell size, and water temperature were not significantly correlated with the number of seals hauled-out (Table 2).

Table 2. Multiple regression analysis on the effects of environmental variables on log-transformed seal haul-out numbers (June - October 1999).

Environmental Variable	R-value	*P*
Cloud Cover	0.067	0.724
Wind Speed	0.515	0.001*
Air Temperature	0.581	0.0001*
Water Temperature	0.030	0.890
Swell Size	0.265	0.150

* Statistically significant relationship

Discussion

Seasonal Variation

Steamers Head is the most northern, consistent, haul-out site for fur seals on the Australia East Coast and for *A. pusillus doriferus* in general. This haul-out may represent the most northern re-establishment of fur seals to their historical range. Our study represents the first quantitative status report on the composition and abundance of seals at the Steamers Head haul-out and can be used as a baseline for future long term monitoring. In 1999 the haul-out was predominantly occupied by *A. pusillus doriferus,* with a minority of *A. forsteri*. Sub-adult seals of both species were the most abundant age group, followed by juveniles, then adult males. For both species, occurrence of adult males and juveniles showed a similar seasonal pattern, with peaks in September; however, numbers of sub-adult seals peaked earlier, in August. The decline in numbers at site in October corresponds with the rise in fur seal numbers at breeding colonies in the Bass Strait (Warneke 1975), supporting the hypothesis that this is a non-breeding, seasonal haul-out site. The site also does not have the typical physical attributes of a breeding colony as the access is too steep and there are no shoals to break up waves and provide training pools for pups (Bradshaw *et al.* 1999). Pups would also have difficulty returning from the land to the sea due to the steep aspect of the site (P. Shaughnessy pers. comm.). There was also an absence of pups during the inspections of January, February and March when pups might have been seen and recognized in black lanugo. The Steamers Head haul-out therefore follows similar trends in seasonal occupation and composition to what is found at Montague Island, which is the closest other NSW seal haul-out site (Irvine *et al.* 1997).

At the Steamers Head site, fur seals occupied three rock platforms and a cave with the majority of observable seals on the main platform (Figure 1). During periods when numbers were at a peak the main platform contained up to 128 seals. *A. forsteri* occupied the steepest sections of the main platform, which were not used by *A. pusillus doriferus*. Species of fur seals differ in their terrestrial habitat preferences, with *A. pusillus doriferus* preferring open rocky platforms or pebble beaches, whereas *A. forsteri* prefers areas of jumbled boulders or irregular rocky sites (Brothers and Pemberton 1990; Goldsworthy *et al.* 1997) and this habitat preference by each species was also observed at Steamers Head.

Haul-out Behaviour

In other seal species, haul-out behaviour is influenced by a variety of environmental characteristics. For instance, the haul-out behaviour of the Weddell *Leptonychotes weddelli* and harbour *Phoca vitulina* seals is influenced by time of day (Pauli and Terhune 1987; Lake *et al.* 1997). However, for the Weddell seal, haul-out behaviour may relate more to air temperature, wind speed and thermoregulation rather than to daylight, with seals preferring to haul-out on the site in light winds which is believed to minimise the effects of wind chill. At Steamers Head, *A. pusillus doriferus* hauled-out in stronger winds. During calm days, the wind may not have circulated around the seals sufficiently to allow them to adequately thermoregulate. At higher wind speeds, the seals may be able to better adjust their temperature by altering their body position. Though it must be stressed that unlike Pauli and Terhune (1987) and Lake *et al.* (1997) study on Weddell and harbour seals, we only worked during daylight hours and Australian and New Zealand fur seal haul-out behaviour may vary at night.

Unlike the Steamers Head haul-out, at Montague Island, which is only 126 km further south, the number of hauled out seals decreased as the day progressed. This may again be related to air temperature, as less seals hauled-out in the hottest parts of the day (Irvine *et al.* 1997). Solar radiation is one of the biggest contributors to heat stress in seals (Gentry 1973), and it is thought that the un-shaded black rocks of the Montague haul-out required the seals to re-enter the water throughout the day in order to thermoregulate (Irvine *et al.* 1997). In contrast, numbers of seals hauled out at Steamers Head was positively correlated with increased air temperature. However, the seasonal scale of our analysis may have confounded the temperature effect because, generally, air temperatures rose from June to September. However, further evidence that there was not a strong solar environmental effect on numbers at Steamers Head was shown by the lack of any relationship between cloud cover and the haul-out pattern. The unusual haul-out behaviour of the Steamers Head seal in response to common environment variables may be due to the colonies southerly aspect and location at the bottom of a steep cliff, which resulted in the area being shaded for most of the day.

Swell size did not significantly affect the number of seals hauled-out at Steamers Head, which was contrary to findings at Cape Bridgewater where *A. pusillus doriferus* hauled-out in great numbers in calm and moderate seas (Stamation *et al.* 1997). This however may be a response to the steep aspect of the Steamers Head site, which differs markedly from Cape Bridgewater, and allows seals to move higher on the platform in large swells. The topography of the site may also explain why tidal patterns did not significantly affect haul-out numbers at Steamers Head.

Like other environmental variables, water temperature did not affect haul-out numbers of *A. pusillus doriferus* at Steamers Head, but the water temperature remained relatively stable at 19°C ± 1°C between June and September. Variability in

water temperature regimes due to unpredictable deep ocean up-wellings in the region (CSIRO 1994) may have an effect on haul-out behaviour, but this will only become apparent through long-term monitoring.

Though other authors have described species-specific haul-out behaviour, for instance for the harbour and monk *Monachus monachus* seals, with maximum numbers hauled out during low tide.

Our results suggest (Pauli and Terhune 1987; González *et al.* 1997) environmental affects may have variable influences on seal haul-out behaviour at both a site and species level. At the Steamers Head site, which is sheltered, shaded, and with a steep southerly aspect, environmental effects have different influences on the haul-out behaviour of fur seals compared to their behaviour at more exposed sites. Thus, generalisation along species lines in regards to environmental conditions may need to be viewed with caution.

There was, however, little ambiguity in the effects of a landslide at the site on numbers of hauled out seals. The maximum count of seals on the day prior to the landslide was 75. Interestingly, the seals were more flighty than usual on this day, being disturbed at a greater distance than normal (100 m), when 30 seals abandoned the site. On the day of the landslide, six seals were hauled-out at the site at 0900 h. By 1030 h, the number had risen to 17 and on the following day had reached 46. During this time the seals did not haul-out onto the exposed section of the main platform, where the main impact occurred, with the exception of one adult *A. pusillus doriferus*. Instead seals occupied the part of the main platform near the cave entrance, which was under the cover of the cliff overhang. Seal numbers did not return to pre-landslide levels until mid-August.

Human originated disturbances may also have had an impact on the number of seals hauled-out at the site. In particular, the bombing practice by the navy of the nearby Beecroft Weapons Range coincided with decreased numbers of seals hauled-out at the site. While ship-to-shore bombardment is common to this area, the intensity of the bombing event that occurred during our study was somewhat unusual for several reasons. First it was the extinguishing of all ordnance by the soon to be de-commissioned destroyer HMAS Perth, which is safer practice than unloading unused shells (T.P. Lynch pers. obs.). Second this obsolete class of destroyer had twice the firepower of any other ship in the Royal Australian Navy (2 x 127mm guns). Other disturbances, such as tour boats (Shaughnessy *et al.* 1999), (four different vessels were observed at Steamers Head site during the study), may affect the haul-out behaviour of seals and thus influence census results. A parallel paper, Burleigh *et al.* (2008), reports human disturbance to seals at the haul-out site by our research vessel approaches at different distances.

The unpredicted response of *A. pusillus doriferus* to environmental cues and the dramatic declines in seals hauled-out due to stochastic disturbances lead us to conclude that one-off yearly censuses of seal haul-out sites can be easily biased. In particular due to stochastic disturbance, which are probably not uncommon at other sites, we suggest that any monitoring program at seal haul-out sites will require sampling over a range of days to account for short-term and unpredictable temporal variation. Although at Steamers Head the best time of year to census appears to be during September, counts on either side of this month should also be conducted to determine if yearly variation occurs in seasonal haul-out numbers.

While Steamers Head is currently the most northern haul-out site, we suggest that if new sites emerge then site-specific, rather than species-specific, sampling protocols should be developed. Though it may be tempting to try and impose species-specific models of behaviour that allow for large scale comparisons and synthesis, the influence of the site appears to be the key factor in regulating the numbers of seals hauled out at Steamers Head.

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