BOWEN ISLAND PENGUIN SURVEY

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Summary.

From 17–21 November 1998 a transect survey of Little Penguin *Eudyptula minor* breeding sites was done on Bowen Island, Jervis Bay, NSW. An estimate of about 2 450 breeding pairs was obtained. The colony was found to be restricted to the western side of the island, extending at most about 130 m inland from the shoreline.

Twenty-three landing sites were mapped, all on the western shore. Landing on the eastern side of the island is impossible because of high cliffs. On 22 November landing counts in the evening suggested that about 2 650 penguins arrived.

Comparisons are made with results of similar surveys on Montagu and Gabo Islands. The population on Bowen Island was found to be half that of the size of the colony on Montagu Island and both of these islands are considerably smaller than the estimated 18 250 breeding pairs of Gabo Island. The relative breeding densities were found to be comparable ranging between 1.5–2.3 nests sites per 100 m^2. Comparing the highest densities found on the three islands, Bowen had 8 nest sites per 100 m^2 while Montagu had 6 and Gabo had 15 per 100m^2. However, these high densities are exceptional (<1%) and the most common density on all three islands was 1 site per 100 m^2.

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INTRODUCTION

In south-eastern Australia the breeding season of Little Penguins *Eudyptula minor* may start as early as May and as late as October. Food availability is assumed to be a main factor in determining the onset and success of breeding (Stahel and Gales 1987). Although often established in burrows where the soil is sandy, Little Penguins appear to be content to nest almost anywhere as long as there is adequate shelter. On Montagu Island, in southern NSW, 85–87% of nests are found on the surface under dense vegetation of Spiny-headed Mat-rush or Kikuyu Grass (Heyligers and Fullagar 1995). On Gabo Island, in East Gippsland, Victoria, only 16% of nests were found on the surface (Fullagar *et al*. 1995).

As a rule, a clutch of two eggs is laid. Brooding takes about five weeks and chicks fledge at seven to nine weeks after hatching. If the season is favourable, double brooding occurs with a second clutch laid several weeks after the successful fledging of the first brood (Marchant and Higgins 1990).

Bowen Island is situated at the entrance to Jervis Bay, NSW, at Lat. 35° 07´ S: Long. 150° 46´ E. Its geography and ornithological history has been described by Lane (1976, 1979). He gives a rough estimate of 1 000 breeding pairs as the population of Little Penguins on the island following a 7 hr visit in mid April 1975. It must be admitted that any attempt to estimate penguin breeding numbers on such a short visit and at that particular time of the year is difficult. In late November 1982 near Penguin Beach (see fig 1) P. Ormay found 4 and 6 breeding pairs of Little Penguins in two 100 m^2 quadrats (Ormay unpubl. in Fortescue 1991). Fortescue (1991) also mentions that M. Lintermans estimated the population of penguins breeding in 1982 to be 1500 pairs based on four 100 m^2 quadrats.[1]

Fortescue (1991, 1995) conducted a detailed study of the breeding biology of the Little Penguin on Bowen Island between 1987 and 1990. As part of this study he determined the size of the breeding population and its distribution within various habitats. He estimated the breeding population to be about 7 000 pairs (Fortescue 1995). Fortesue (1991) also provides information on the geological and recent history of the island and describes the remarkable changes in vegetation from low grassland and heath in 1952 to predominantly woodland and scrub by 1984. Recently, Taws (1997) has mapped and described the vegetation of the island in greater detail based on aerial photography taken in 1993 expanding and updating the work of Ingwersen (1976).

In view of the contradictory figures for the size of the colony on Bowen Island we sought the co-operation of the Booderee National Park Authority and the Jervis Bay Penguin Study Group to conduct a survey following the procedures for assessing breeding population sizes of Little Penguins on Montagu Island and Gabo Island.

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[1]These data are not included in Lintermans (1988) as stated by Fortescue (1991) on page 8.

A survey was carried out on Bowen Island between 17 and 22 November 1998 using transects to locate nest sites. For the timing of this survey we relied on information in Fortescue (1991, 1995) and our own experience at Montagu Island. A further survey on Montagu Island was carried out between 18 and 30 November 1998 to provide a comparison with our survey on Bowen Island (Trezise *et al*. in prep.).

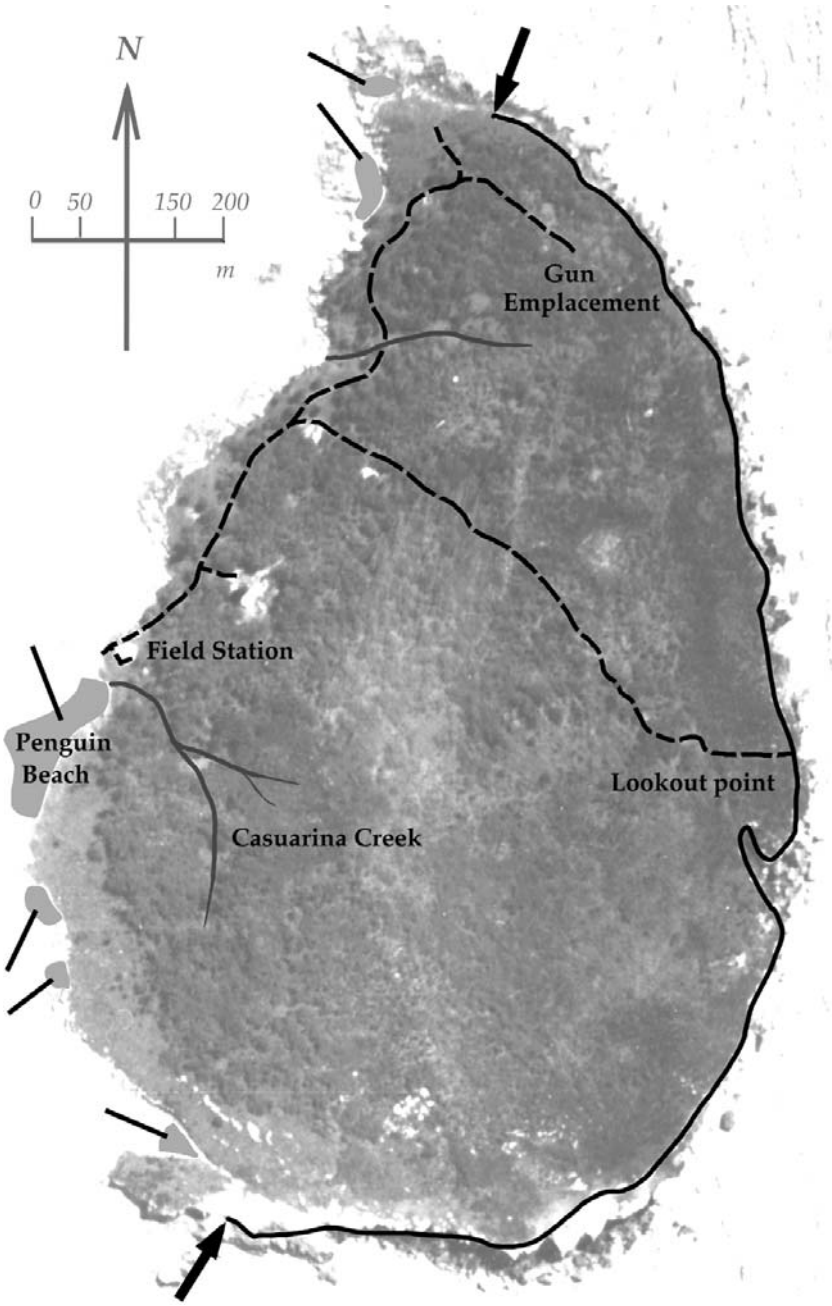

FIGURE 1. Some topographic features of Bowen Island.
The positions of two creeks (grey lines) and the remaining track systems (broken lines) are shown. The six markers along the western shoreline point to areas of sandy beach. The continuous line between the two arrows indicates steep cliffs up to 30 m high.

METHODS

The transect technique we used has been described by Fullagar & Heyligers (1992), Heyligers & Fullagar (1995) and Fullagar *et al.* (1995), but the following points, in particular, need to be noted. On Bowen Island we used 10 transects, running W–E at 100 m intervals, starting and finishing at the edge of the vegetation (Fig. 2). We used 50 m long survey tapes to lay out each transect section along which we determined nest site positions accurate to 1 m. The survey tape was laid by compass (78˚ or 258˚ magnetic) with correction as often as possible to ensure accuracy in following the predetermined position of each transect. Our experience was that the transects finished, even for the longest runs, reasonably close to the expected terminal positions on the east cliffs. In preparation for day to day use we had drawn all transects onto a plastic coated emlarged colour print of an aerial photograph (NSW 4110: Jervis Bay, 4-2-93, #27–28). Survey forms were prepared for recording information on penguin nest sites and other signs of penguin activity, on shearwater burrows, vegetation, topographic features and soil depth along each 50 m section (Appendix). These data sheets required careful completion in the field to avoid error. The search width was exactly 1 m either side of the graduated survey tape. We worked in two teams on different transects. All transects were worked from west to east and the survey took 4 days to complete.

Penguin nesting and resting sites were detected by thorough searching of vegetation and burrows. For the occupied nests, eggs, chicks and adults were counted. Age classes of chicks were determined according to the key of Stahel & Gales (1987). We assumed that the presence of one or two adults in a burrow was an active nest site. As there is also a slight possibility that we had found a non-breeding bird that had stayed ashore, we have used the term 'sites with adults only present' rather than 'nests'. 'Nest sites' includes both 'nests' and 'sites with adults only present'. Any burrow that was too deep to determine for certain the presence of nesting evidence was marked and later examined with a burrowscope. This ‘Burrow-Cam’ consisted of a vidicon tube with a Magnalite™ (AA penlight torch) fixed alongside. This assembly was strapped to a small ‘sledge’ and connected to a colour TV monitor run from a single 12v DC gelcell battery. The sledge was attached to a 2 m flexible hose which allowed control of the video camera in the burrow.

The western perimeter of the island was searched on 22 November for penguin landing sites (Fig. 2). A count of birds landing at dusk on 22 November was made at four of these sites. The whole of the eastern side of the island is cliff with no suitable points of access for penguins (Fig. 1).

RESULTS

Distribution of the penguin and shearwater colonies

The ten transects traversed 4 761 m of the island; 1171 m (25%) ran through the penguin colony. As it turned out, the penguin colony was limited to a strip about 130 m wide along the western side of the island but somewhat wider at the northern end (Fig. 2). Shearwater colonies were found in the northern and south-western parts of the island. Of the transects, 265 m (6%) ran through shearwater colonies and these areas were characterized by high burrow densities (34 shearwater burrows per 100 m^2). Penguin burrows occurred within most of these colonies (Table 1).

TABLE 1 Distribution of penguin and shearwater colonies in relation to vegetation types.

Vegetation types *	A	B	C	D	E	F	*Totals*
Penguin sites							
nest sites in burrows	18	2		11	9		*40*
nest sites on surface	8			1			*9*
unoccupied surface sites	3			2			*5*
Empty burrows							
transects with penguin nests only	2	1		5			*8*
transects with penguin and shearwater nests	16		23	149		1	*189*
estimated number of extra penguin burrows	1			6			*7*
estimated number of shearwater burrows	15		23†	143		1†	*182*
Totals for penguin sites	*32*	*3*		*25*	*9*		*69*

* **A** *Banksia integrifolia* woodland, ground cover of *Lomandra* with or without bracken
B *Casuarina glauca* forest, ground cover of *Lomandra* and scattered bracken
C *Leptospermum laevigatum* scrub, open *Lomandra* ground cover
D *Lomandra* vegetation with or without bracken (*Pteridium esculentum*)
E kikuyu vegetation with or without *Lomandra* or *Lomandra* and bracken
F *Sporobolus virginicus* grassland

† These figures have not been used for calculating the likely proportion of penguin burrows as no active penguin sites were found in these vegetation types.

Table 1 shows the distribution of the shearwater and penguin colonies in relation to the vegetation. From this table it is apparent that most shearwater burrows occur in vegetation dominated by *Lomandra*, while penguin sites are as likely to be found in *Banksia* woodland as in *Lomandra* or kikuyu vegetation. No burrows were found in large areas of dense vegetation covering much of the central and eastern parts of the island (Figs. 2 & 3). These areas carry scrub, heath, sedgeland or woodlands of various types with a thick undergrowth and often a lot of windfall. Throughout these areas sandy soils were present and in many places would be suitable for burrowing.

Size of the penguin colony

Sixty-nine penguin sites were found along the transects (Table 1; Fig 3). Of 49 nest sites nine (18%) were on the surface rather than in burrows. We have assumed that the five sites occupied by adult birds only (Table 2) indicated that these birds were about to start a second clutch and were not merely birds resting ashore. We make this assumption because there were 14 other nests with eggs, most of which were being incubated (Table 2).

TABLE 2 Penguin nest site statistics.

One adult present, no eggs or chicks	3
Two adults present, no eggs or chicks	2
Egg(s) present with or without an adult	14
Chick(s) present with or without an adult	30
Total of occupied sites	*49 [9*]*
Estimated number of unoccupied burrows**	15
Unoccupied surface sites	5
Total of penguin sites	*69*

* Number of sites on the surface.
** See text below for explanation.

Within shearwater colonies the distinction between penguin burrows and those of the shearwaters was often not possible, as at this time of year the shearwaters are absent from their burrows during the day. We have arrived at the number of unoccupied penguin burrows by taking the numbers of unoccupied burrows on transects outside shearwater colonies and applying a proportional multiplier to calculate a likely figure for the total for all transects. This worked out to be 15. These sites in addition to the five unoccupied surface sites indicate that 29% of penguin sites were unoccupied (Tables 1 & 2).

In calculating the area occupied by the penguin colony we have assumed that the western boundary of the colony coincided with the limit of the vegetation along the shore, while for the eastern limit we determined a cut-off point along the transects in the following way. We calculated the average distance between nests sites on each transect and added a distance equal to this figure beyond the eastern-most observed nest site on that transect. We then connected these points to define the inland boundary of the colony (Fig. 2). The area thus outlined comprises 120 000 m^2. The areas inside the colony searched along the transects total 2 342 m^2. Hence, at the time of the survey there were about 3 450 penguin sites on the island, of which about 2 450 were occupied. This means that the penguin breeding population was in the order of 4 900 (SE = ± 98) birds.This equates to a average density for the colony of 2.1 breeding sites per 100 m^2.

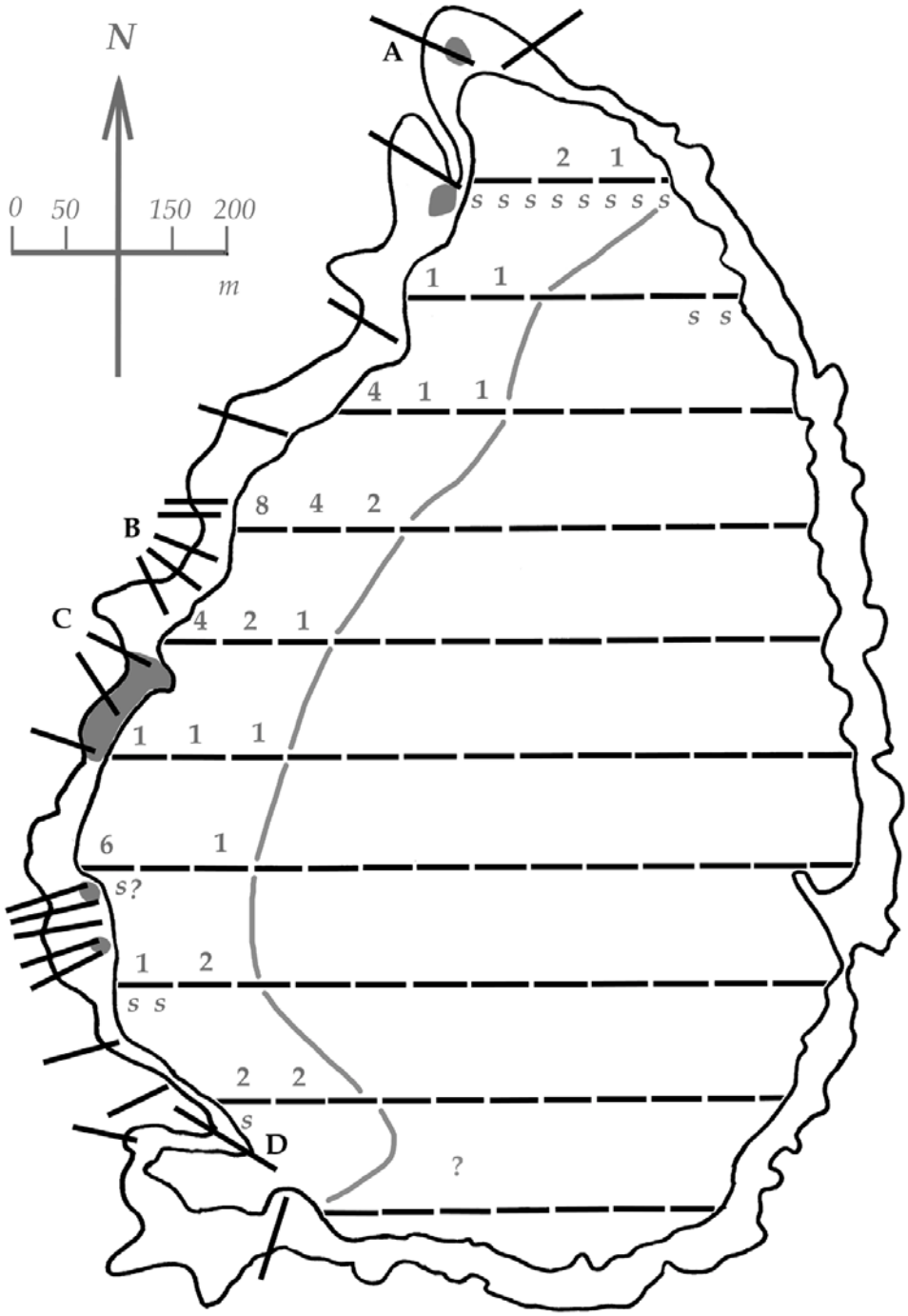

FIGURE 2. Transects, number of penguin nest sites found per 50 m of transect and position of landing sites on Bowen Island in November 1998. Pale line delimits eastern extent of penguin colony. *S* = shearwaters present. *?* indicates area at southern end where penguins probably occur in low numbers. Lines on western shore indicate approximate positions of 23 penguin landing sites and A–D are the landing sites counted.

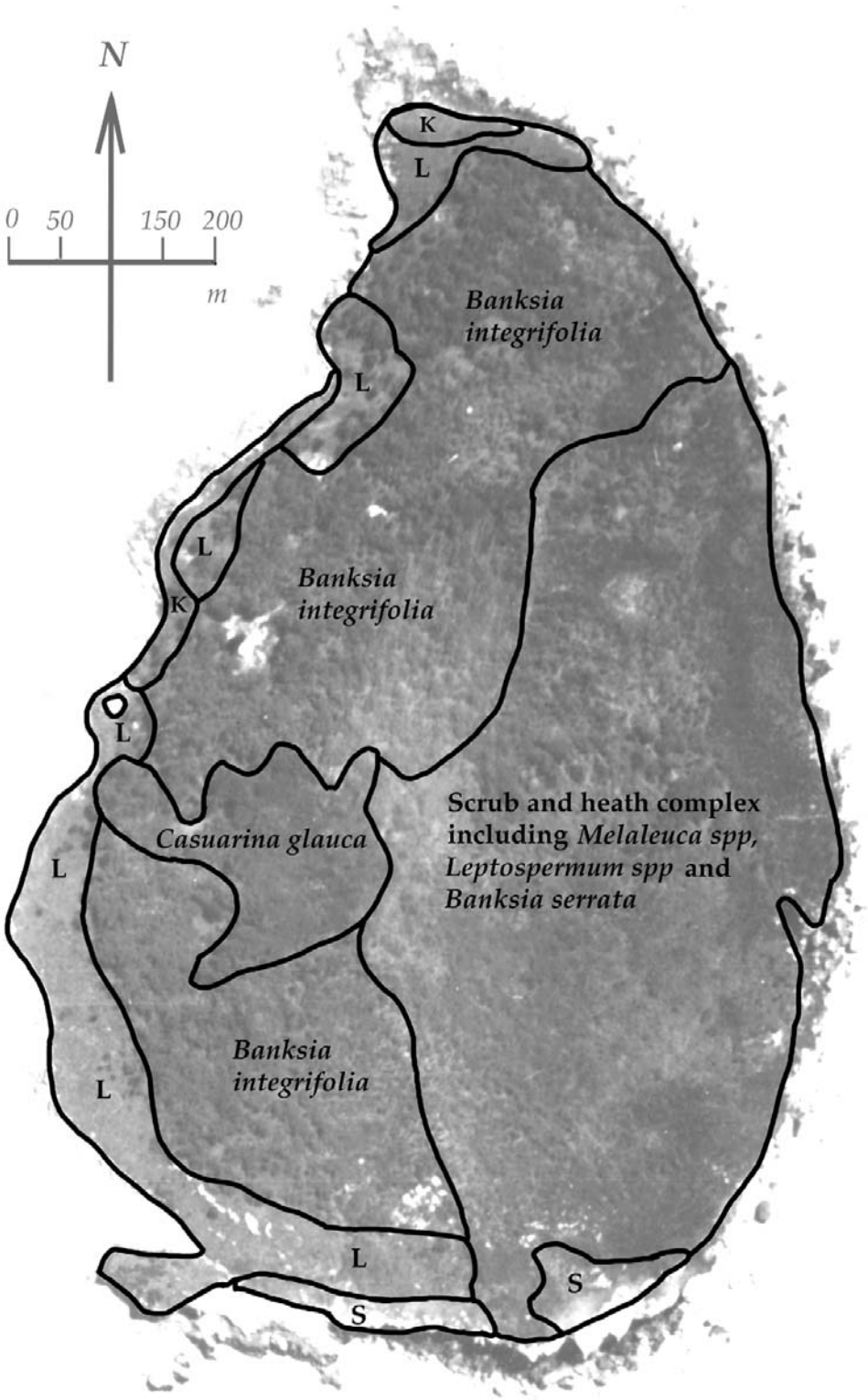

FIGURE 3. Broad classification of vegetation on Bowen Island adapted from information in Taws (1997).
K: *Pennisetum clandestinum* ; L: *Lomandra longifolia*; S: *Sporobolus virginicus.*

Composition of clutches

Tables 3 and 4 list the details of the nest contents. It is noteworthy that several age classes of chicks were not represented in our sample. Of particular interest is the absence of two to three week old chicks (class d). Given that there were five nests with chicks less than a week old (class b), this suggests that the older age classes represent the 'tail' of the first brood. Although no old chicks (class g) were present in our sample, birds of this age were seen on the surface during the night of the landing counts.

The assumption of a second brood is the simplest explanation for the relatively large number of nests with eggs and the presence of two to seven day old chicks (class b) at this time of the breeding season. Given the rather small size of our sample it comes as no surprise that no one day old chicks (class a) were seen.

TABLE 3 Penguin nests with eggs.

	number of nests	**number of eggs**
One egg, no adult present	1	1
One egg, one adult present	1	1
Two eggs, no adult present	1	2
Two eggs, one adult present	11	22
Totals	*14*	*26*

Landing sites

A reconnaissance mapping of landing sites was made on 22 November (see Fig. 3). Usually it is possible to assess the intensity of use by various signs of activity such as footprints and 'whitewashing' along the pathways between the points of landing and the colony, but on this occasion this was not possible because of unfamiliarity with the situation on Bowen Island. It would be best to survey landing sites after a period of dry weather and on a falling tide in the morning. At least 23 landing sites were identified. In the evening, counts were made at four landing sites (Table 5). At Penguin Beach (site C) twice as many penguins were coming ashore as at sites A and B.

Assuming that the four sites counted on 22 November were a representative sample, an estimated 2 650 penguins landed that evening.

TABLE 4 Penguin nests with chicks.
( ) indicate number of nests in which also an adult was present.

Age class*	one chick	two chicks	*total chicks*
a. head floppy	0	0	*0*
b. eyes not fully open	2 (1)	3 (3)	*8*
c. new down incomplete	0	1 (1)	*2*
d. feet dark grey	0	0	*0*
e. egg tooth still present	1	3 (2)	*7*
f. down still complete	4**	16	*36*
g. adult plumage present	0	0	*0*
Totals	*7*	*23*	*53*

* Age classification of chicks follows Stahel & Gales (1987, pp 73-74):

a. head floppy: the chick is not yet able to support its head (day-old);
b. eyes not fully open: the chick is between two and seven days old;
c. new down incomplete: the second down cover has not yet fully replaced the first, i. e. the chick is not yet 14 days old;
d. feet dark grey, i.e. their top has not yet turned white and the bottom black: the chick is less than 21 days old;
e. egg tooth still present; the egg tooth has only disappeared completely when the chick is 28 days old;
f. second down cover still complete, i.e. no adult plumage visible yet: the chick is not yet 56 days old;
g. adult plumage present, down may still cover head and neck: the chick is older than 56 days; when all down is gone, feathers on flippers are blue and shiny.

** Two of these nests also contained an unhatched egg.

TABLE 5 Number of penguins coming ashore at four sites, Bowen Island; 22 November 1998.

Sites	A	B	C	D	*Totals*
Time					
19:30–19:45 hrs	0	-	-	-	*(0)*
19:45–20:00 hrs	0	0	0	0	*0*
20:00–20:15 hrs	0	9	8	15	*32*
20:15–20:30 hrs	50	39	116	71	*276*
20:30–20:45 hrs	21	28	25	7	*81*
20:45–21:00 hrs	10	6	24	7	*47*
21:00–21:15 hrs	-	4	8	2	*(14)*
21:15–21:30 hrs	-	2	-	5	*(7)*
21:30–21:45 hrs	-	-	-	2	*(2)*
21:45–22:00 hrs	-	-	-	2	*(2)*
Totals	*81*	*88*	*181*	*111*	*461*

DISCUSSION

Timing of survey

Given that with only one survey we aim to get the best possible estimate of the size of the breeding population for a season, we try to choose that stage in the breeding cycle that most chicks of the first brood are within a couple of weeks of fledging. In practice this means that the earliest of clutches are likely to have fledged, but also that a certain number of birds that produce a second brood will be tallied. As not all early breeders will lay a second clutch, the size of the breeding population deduced from the results of the survey is a minimum estimate for that season.

Fortescue (1995) surveyed sample plots along transects on Bowen Island 'during the peak of the 1987 breeding season, in December.' His monitoring of permanently marked burrows revealed that the number of chicks peaked in November averaged over the 1988-1990 breeding seasons and that this coincides with a peak in the numbers of birds coming ashore in the first hour after sunset at Penguin Beach. This information, in addition to our experience with timing the surveys on Montagu and Gabo Islands, was the reason for our decision to do the Bowen Island survey in the second half of November. An additional consideration was that in the last decade, and especially in the last few years, the breeding season has collapsed due to food shortages manifesting themselves during December. In view of this possibility recurring in 1998, it would not have been prudent to do a survey any later.

Size of the breeding population in 1998 compared with previous estimates

Appart from early claims of thousands of Little Penguins breeding on Bowen Island (Hindwood 1948) an estimate was given by Lane (1976) after a one day field trip in April 1975. Although Lane reported ample evidence of regular breeding in good numbers he admitted that his estimate of 1000 breeding pairs might be far from accurate as some potential locations were not searched. According to informartion in Fortescue (1991) M. Lintermans estimated the breeding population to be 1 500 pairs based on four 100m^2 quadrats investigated in June and November 1982.

Fortescue (1995) states the size of the Little Penguin colony of Bowen Island to be *c.* 7 000 breeding pairs. This is a conservative estimate, as in the Abstract of the same paper he mentions that 'a comparative study of breeding success [during 1987-1990] found most breeding occurred in tussock scrubland [*Lomandra*] (6 104 breeding pairs in 4.4 ha) compared to [*Banksia*] woodland (2 318 breeding pairs in 2.7 ha).' The total of breeding pairs in these two habitats alone already amount to about 8 500 pairs, and to this figure should be added birds breeding in Kikuyu Grass vegetation and in *Casuarina glauca* forest. We can only assume that Fortescue carried out his research in a favourable period for the colony, and that his estimate of 7 000 pairs is based on an inferred long-term average, taking into account the results of earlier assessments.

The distribution of nesting sites

Fortescue (1991, p 88) states that 'the maximum straight line distance recorded from point of access to burrow on Bowen Island was 216 m, although 95% of burrows examined fell within 100 m of mean high tide, and 80% fell within 60 m'. This statement appears to conflict with information given on a map delineating the penguin colony into five sections (Fortescue 1991, Fig. 3.1, p. 77). We can only assume his map does not show the true boundaries of the penguin colony at the time of the 1987-90 study, but that the actual boundary was in a position not very different from that established by our survey. He showed that there was no consistent statistical relationship between mean burrow densities and distance from water. Inspection of our survey results (Fig. 2) might not support this conclusion.

Landing sites

Fortescue (1991, p. 93) found 'thirty penguin access tracks visible on the..... aerial photograph'. He 'observed over 300 birds per night using each of four major tracks, one of which had as many as 900 birds landing during the peak of the season.'

We identified 23 landing sites in a preliminary survey but may have overlooked some because recent rainfall and high tides would have reduced the signs of activity used for detection. It is also possible that different interpretations of landing sites will occur. We record sites branching into several tracks as a single landing, while others might count them as separate sites.

Our site C where 181 birds came ashore (Table 5) is the same as Fortescue's Penguin Beach. At this site he recorded a mean daily count in November of 310 birds landing in the first hour after sunset (Fortescue 1991; Fig. 2.1, p. 31).

The Bowen Island penguin colony compared with the colonies on Montagu and Gabo Islands

THE SIZE OF THE BREEDING POPULATIONS

We estimated the breeding population of penguins on Bowen Island in November 1998 to be 2 450 ± SE 49 pairs. In November 1992 a breeding population of 4 250 pairs was estimated to be present on Montagu Island (Fullagar & Heyligers 1992; Heyligers & Fullagar 1995) and a repeat survey in November 1994 gave a larger estimate of 6 358 pairs (Heyligers & Fullagar 1995). In 1998 an estimate of 4 007± SE 127 breeding pairs was made for the population on Montagu Island using a revised statistical method (Trezise *et al*. in prep.). Applying this method to the data from the two previous Montagu surveys the following revised estimates were obtained; for 1992: 4 546± SE 194 and for 1994: 6 976 ± SE 220 pairs. On Gabo Island in November 1994 the estimated breeding population was 18 244 ± SE 131 pairs (Fullagar *et al*. 1995).

The calculation, if justified, that 2 650 penguins were landing at night is consistent with our population estimate of 2 450 pairs in that surveys on Montagu and Gabo islands have shown that numbers landing at this time in the season are generally slightly higher than the estimated numbers of breeding pairs present (Fullagar & Heyligers 1992; Heyligers & Fullagar 1995 and Fullagar *et al*. 1995).

The colony on Bowen Island occupied an area of 12.0 ha while the area considered suitable for breeding colonies on Montagu Island was 58.8 ha and on Gabo Island 126.5 ha. These figures would indicate nesting densities of 2.1 pairs per 100 m^2 on Bowen Island, 0.7 (1992), 1.1 (1994) and 0.6 (1998) pairs per 100 m^2 on Montagu Island and 1.2 pairs per 100 m^2 on Gabo Island. However, Bowen Island is 48 ha in total area and a density of breeding penguins calculated from the total length of transects would give a figure of 0.5 pairs per 100 m^2.

To determine average breeding densities in colonies on Montagu and Gabo islands we have always regarded the colony area equivalent to the total vegetated area of the island. Clearly, on Bowen Island the colony is discrete and we used only 25% of the area of the island for density calculations. For a more realistic comparison it might be sensible to exclude unused areas on Montagu and Gabo islands. To do this we have taken the proportion of 50 m sections without breeding sites on each island as an indication of the proportion not used for breeding.

Table 6 and Fig 4 shows the frequency distribution of breeding densities on Bowen, Montagu and Gabo Islands based on the 50 m sections of the transects. The numbers for Gabo Island were extracted from Fig. 2 in Fullagar *et al*. 1995, but for Montagu Island we used the draft calculations for Fig. 2 in Heyligers & Fullagar 1995 and data from the 1998 survey (Trezise *et al*. in prep.).

TABLE 6 Frequency distributions of breeding site densities on Bowen, Montagu and Gabo Islands.

	Number of nest sites per 50 m of transect.									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**15**
Island and year										
Bowen 1998	74	11	6	0	3	0	1	0	1	0
Montagu 1992	75	37	9	7	1	1	0	0	0	0
Montagu 1994	63	39	18	9	6	1	1	0	0	0
Montagu 1998	103	59	13	4	1	0	0	0	0	0
Gabo 1994	133	55	29	8	16	4	4	6	0	1

As expected 75% of transect sections on Bowen Island did not have any penguin breeding sites. Using this reasoning, we find that 58% (1992); 46% (1994) and 57% (1998) of Montagu Island and 52% of Gabo Island was not used for breeding.

If we now correct data from the surveys on Montagu Island and Gabo Island to allow for the proportion of these islands not used for breeding we can derive the following average breeding densities: Montagu Island had 1.5 nest sites per 100 m^2 in 1992 and in 1994 but 1.3 nest sites per 100 m^2 in 1998; Gabo island had 2.3 nest sites per 100 m^2. These figures are comparable to the 2.1 nest sites per 100 m^2 found on Bowen Island in 1998.

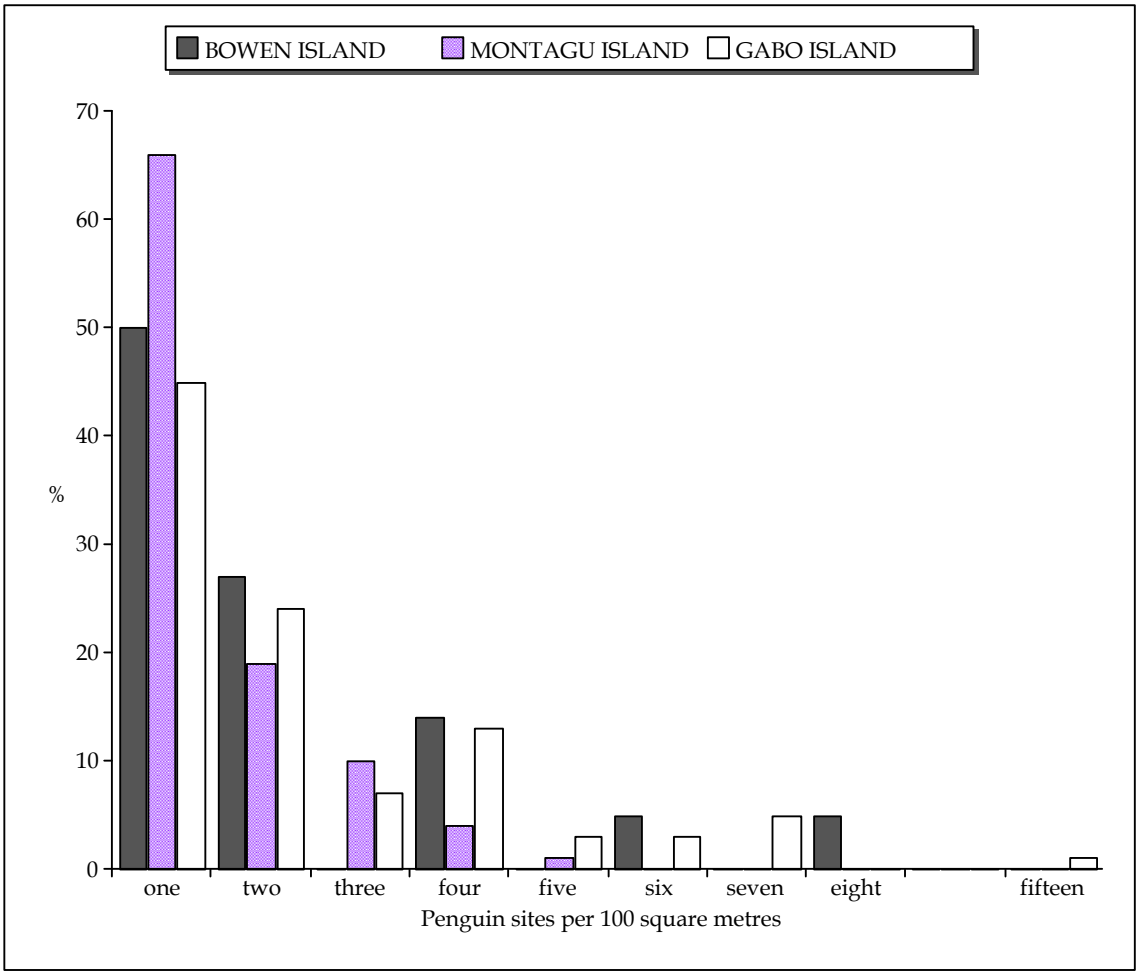

Figure 4. Frequency distributions for densities of penguin breeding sites on Bowen, Montagu and Gabo Islands.

DISTRIBUTION OF NEST AND LANDING SITES

The topography of Bowen Island restricts the landing sites for penguins to the western shoreline (Figs 1 & 2). It is therefore not surprising to find that the colony is concentrated along the western side of the island and that few occupied borrows are found more than 100 m inland. However, there could be other factors restricting penetration to points further inland and of these the density of the ground cover from tree fall and thick vegetation may be the most important. As already described by Fortescue (1991) penguins do penetrate inland where possible, for example, up Casuarina Creek.

With respect to access from the sea, Bowen Island differs from Montagu Island and Gabo Island where birds can land from all directions. However, on these islands nesting sites are by no means evenly distributed. Accessibility is enhanced by a network of cleared tracks opening up parts of the interior of both islands .

On Bowen Island the main track leads from the hut near the main beach to the northern end of the island. It has two side tracks, one running to an old gun emplacement and another crossing the island to the eastern shore lookout (Fig 1). On the latter track there was some indication that it was used by penguins to reach further inland than was possible elsewhere.

CONCLUSIONS

1. About 2 450 pairs of Little Penguins were breeding on Bowen Island in November 1998.

2. The extent and pattern of distribution of the penguin breeding colony on Bowen Island in 1998 confirmed the findings from a study in 1987–90 (Fortescue 1991; 1995).

3. Transects provided a suitable means for assessing colony size of breeding penguins and the distribution of nest sites.

4. Systematic evening counts at landing sites may be a simple alternative method of assessing numbers of penguins breeding on the island.

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APPENDIX Survey form

BOWEN ISLAND PENGUIN SURVEY - NOVEMBER 1998

Transect N°: Sheet N°: Date:

Searchers: N: S: Recorder: Others:

Distance from start of transect: m.

Little Penguins N: burrow length, eggs, chicks, adults	Little Penguins S: burrow length, eggs, chicks, adults	Vegetation: appearance, height, tree cover, shrub cover, ground cover	Dominant or common species: Baukia integrifolia; Cassinia glauca; Rainforest species; Baukia serrata; Allocasuar. distyla; Melaleuca capitata; Leptosp. laevigatum; Baukia ericifolia; Baeckea imbricata; Other shrubs; Bracken; Other ferns; Lomandra longif.; Other sedges/rushes; Kikuyu; Other grasses	Soil: Condition; Penetrability	Slope: Angle; Up or down?	Shearwater burrows: N; S	Notes
							Penetrability
							Penetrability

000 Empty nest camp:camp site

Chick age:
a Head not supported (day 1)
b Eyes not fully open (-day 7)
c Down cover incomplete (-day 14)
d Feet dark grey (-day 21)
e Egg tooth present (-day 28)
f Down cover general (-day 56)
g Absent or head/neck only (57 + days)

Appearance: Forest, Woodland, Scrub or shrubland, Heath, fern Brake, Grassland, Rush- or sedgeland.

Cover: dense, medium dense, Open, scattered.

Species abundance: dominant, codominant, numerous, present

Soil: **condition**: dry, moist or damp, wet or swampy, rock.
penetrability: to be measured (in cm) every 25 m.

Slope: **angle**: negligible, gentle, moderate, steep, very steep.

Shearwater burrows
b : bird(s) present
e : empty

HOW TO USE THE SURVEY FORM.

Transects run West to East, are 100 m apart, and start at the edge of the vegetation. Each survey form provides room for recording 50 m of transect. The distance from the starting point of each 50 m section to the starting point of the transect has to be recorded in the heading to enable double-checking with the sheet number. **Search width** is exactly 1 m at either side of the tape laid out to define the transect. If in doubt whether a burrow is inside or outside the 1 m strip, check with a tape or make-shift measure. If more than half of the entrance is within the boundary, the burrow is counted; if more than half falls outside, the burrow is ignored (if we do not stick to this rule, than the results become statistically unreliable).

For every metre of transect burrow details are to be recorded individually and separately for each side. The columns for recording penguin and shearwater data are at opposite sides of the form to make recording in the wrong columns less likely. Details on the recording of penguin burrows are given in the next paragraph. Numbers for **shearwater burrows** are to be annotated with 'b': bird(s) present, or 'e': empty. No length measurements are required for shearwater burrows. Ownership of empty burrows has to be determined by differences in the size of the entrance, smell, foot-prints, faeces or other signs.

Little Penguin data. Penguin sites are either '**nest**' or '**camp**' sites, the latter being sites where (non-breeding?) penguins rest (it would not be possible to distinguish reliably between sites if the bottom of a burrow cannot be properly inspected. This should be indicated under 'Notes'). Measure or estimate **burrow length** in tenths of metres. If there are surface sites, burrow length would, of course, be zero. Record number of **eggs, chicks** and **adults**, indicating chick age after the chick number, e.g. 0,2c,1. If more information on estimating chick age is required, see photocopy of pp. 72-74 from Stahel and Gales (1987). Additional data can be entered in the column' Notes', e.g. the status of an empty nest, or whether an observation was made with the burrowscope. Also, details about the burrow or sheltering vegetation can be given here.

Vegetation. It is the aim of the sections on structure and floristics to give a general impression of the vegetation crossed by the transects, not to provide metre to metre accurate detail. Hence, the notations may have to refer to a swath wider than 2 m, especially in woody vegetation. Draw a line across the vegetation columns where the vegetation changes noticeably and assess the new situation. It is not the intention that individual trees, shrubs or tussocks are recorded. If a burrow is found, say, at the base of a *Lomandra longifolia* tussock, this can be recorded under 'Notes'.

Appearance is meant to convey what the vegetation looks like. Terms are given at the bottom of the form. Most of these have been taken from Nicki Taws' (1997) report to Environment Australia 'Vegetation Survey and Mapping of Jervis Bay Territory'. **Forest** is a vegetation dominated by trees, often with some shrubs in the understorey and a ground layer of ferns, *Lomandra* or other herbaceous plants. **Woodland** has an open overstorey of trees, while the understorey is dominated by shrubs or herbaceous plants. **Scrub** is a vegetation dominated by tall shrubs, i.e. woody plants with multiple stems reaching heights of 3 or 4 m. **Shrubland** is the 'woodland version' of scrub. **Heath** is a vegetation dominated by smaller shrubs, often with small, hard leaves. In the other three vegetation types the herbaceous groundlayer is the one that is dominant. In **fern brakes** ferns are the dominant element, in **grassland** grasses, and in **rush-** or **sedgeland** other, grass-like plants form the dominant component.

Height is recorded for the dominant storey of the vegetation and is estimated to about 0.1 m if lower than 2 m, or to 0.5 or 1 m if taller. Give a range if the height is variable. **Foliage cover** is assessed for each storey separately and recorded in the next three columns using **d, m, o** or **s** according to the density scale given at the bottom.

Example. A filled out vegetation section for a stand of *Banksia integrifolia* forest with some shrubs and a groundcover of bracken could look like: forest

5-7 m s d

The **dominant** or **common species** are to be indicated according to the species abundance scale. For instance, in the example used above both *Banksia* and bracken get a 'd' and the occasional shrub is ignored. If *Lomandra* happens to occur among the bracken, it would get a 'p'.

Soil. Condition refers to the drainage status, not to the effect of recent rainfall. Hence, 'dry' refers to well-drained soil, 'wet' to situations of impeded drainage. **Penetrability** is measured (in cm) by pushing one of the fibreglass transect markers into the sand as far as it will go. This is to be done at least every 25 m; the boxes in the column 'Soil' are there as a reminder.

Slope. Record the slope angle of the transect according to the scale given at the bottom of the form. Although this scale consists of 'common sense' categories, the boundary between 'steep' and 'very steep' is meant to be about 30° to 35°, the slip angle of loose sand. The slope is either 'up' or 'down' coming from the westerly starting point of the transect.

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