Roosting dynamics of Eastern Bent-wing Bats *Miniopterus schreibersii oceanensis* in disused military sites in eastern Sydney

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ABSTRACT

Over-winter roosting sites for Eastern Bent-wing Bats *Miniopterus schreibersii oceanensis* occur in urban areas including parts of greater Sydney. Most of the known over-winter roost sites in Sydney are located in the northern and western suburbs (Hoye and Spence 2004). Only one roosting site was known to exist in eastern Sydney at La Perouse (Henry Head). In January 2004, a second roosting site was identified in the eastern Sydney, on the headland at Malabar. Both sites are close to the coast and are disused military tunnels and underground rooms that can be used by the bats. Routine monitoring surveys were set up to determine the significance of the Malabar site and whether bats from Henry Head also use the Malabar site. Searches were made for other bat roosting sites, and a third site, at Cape Banks, was later found. Apart from recording bat numbers during each survey, wind speeds at the entrance to the roosting sites and air temperatures inside the roosts were measured. It was concluded that all three sites were used by a single population of Bent-wing bats: Cape Banks rarely contained roosting bats, Henry Head was occupied more regularly whereas Malabar was occupied the most often. Cape Banks was the most wind- exposed site, Henry Head was partly exposed to the wind while Malabar was the least exposed site. Malabar also had the warmest roost temperatures. Bat numbers at each site were associated with prevailing weather conditions, with higher numbers of bats at Malabar during stormy conditions. Bent-wing bats arrive at the eastern Sydney sites in late February or early March and remain there throughout the winter. They depart in October and November, much later than has been reported for bats elsewhere in Sydney. In March 2005, two female bats were observed with young at Malabar, suggesting that the summer maternity roost may not be far from the eastern suburbs over-winter sites. Conservation measures are needed to protect the Malabar roost site from intruders and vandalism. Human disturbance of the roosting bats has been responsible for the bats periodically vacating the site.

Key words: Eastern Bent-wing Bat, *Miniopterus schreibersii oceanensis*, roosting behaviour, eastern Sydney, roost temperature and wind speed.

Introduction

Eastern Bent-wing bats *Miniopterus schreibersii oceanensis* are known to roost in a number of sites across Sydney. Hoye and Spence (2004) identified 39 roost locations and indicated where others were likely to occur. Few sites were identified in eastern Sydney. Historically, a large colony of Eastern Bent-wing bats was present in eastern Sydney in Elizabeth Bay House and extensive collections were made of these bats in the late 1880s, however, the Elizabeth Bay roost site is no longer used by Bent-wing bats. Over the last 20 years there have been several opportunistic recordings of Bent-wing bats in eastern Sydney and these have been in the area between Maroubra and La Perouse. Only one regularly-used roost site was identified in this area and that was at La Perouse (Henry Head; Hoye and Spence 2004).

Roosting sites for Bent-wing bats are more widespread in other parts of Sydney and they include St Michaels Cave at Avalon, Turramurra, Wahroonga, Pymble, Castle Hill, Prospect reservoir, Silverwater, Kingswood, Miller, Balls Head, North Sydney, Middle Head and Georges Head (Figure 1); the majority of these sites are in the northern or western parts of Sydney. Henry Head was the only identified roosting site in eastern Sydney. The movement of bats between roosting sites in Sydney is not well understood, but Henry Head appears to be the most isolated of all of the known roosting sites in Sydney. It is likely that other roosting sites remain undetected.

The Henry Head site consists of disused military tunnels and gun emplacements that were established in the early 1900s. Bent-wing bats roost in underground armament storage rooms and fly into and out of the site via the gun turret openings (A.White pers. obs.). Henry Head is now part of the Botany Bay National Park, but the park is fringed by dense residential areas and active industrial sites on the landward side. The flight path that the bats use to reach Henry Head is unknown, but considering the likely residential barrier to the west and north, it is most probable that the bats fly along the coastline to approach the site from the south. Bent-wing bats have been detected at Wooleware on the Kurnell Peninsula (Hoye and Spence 2004), so entry to the Henry Head site may involve a southern coastal flight path and a crossing of the Botany Bay heads.

In 2004, Bent-wing bats were found in other disused military tunnels at Malabar (A. White pers. data). The discovery of bats at Malabar triggered a monitoring study of the bats to try to determine the extent of the site usage,

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an estimate of the size of the bat colony, and whether this site was a significant roosting area that may require protection from human interference. In addition, the proximity of Malabar to Henry Head implied that there may be shared occupancy of these sites by the bats, so monitoring was extended to Henry Head and a search undertaken to try to find other nearby roosting sites.

Methods

Mapping potential bat roosts

Disused military sites containing underground facilities are present in three locations in eastern Sydney: Henry Head (La Perouse), Malabar and Cape Banks. Permission was sought from the New South Wales National Parks and Wildlife Service to enter these areas and conduct searches for potential roosting sites. Each site was explored on foot and the location of each room, chamber or tunnel was plotted onto a site map. Each potential roost site was then numbered and each site was surveyed routinely between 2004 and 2006.

Monitoring

Monitoring was carried out every two to three weeks from 10 January 2004 to 18 July 2006 at Malabar and Henry head, comprising 58 survey visits at each site. Monitoring was carried out from 27 May 2004 to 17 July 2006 at Cape Banks, comprising 49 surveys (Appendix Table A).

Routine monitoring of roost sites was carried out initially at Malabar and Henry Head, Cape Banks was included later in the study. Survey methods did not involve trapping or tagging bats. The sites were visited during daylight hours and bat counts were made using a red-light headlamp and binoculars. The room or chamber that contained the bats was not entered in order to minimise the disturbance of the bats as counts were only possible while the bats were roosting. Bats were counted from outside the room by looking through doorways, windows and access chutes. Occasionally, a room was entered if there were clusters of bats that could not be counted from a distance. If the room had to be entered, the surveyor remained pressed against the wall and moved slowly into a position where the bats could be counted. If the bats started to fly, the surveyor retreated from the room and allowed the bats to resettle before returning to complete the count.

Wind speed and air temperatures

Wind speed and air temperature were recorded at the three sites from May 2004 until the end of the project in July 2006. Wind speed was measured at the outside entrance to each site using a small anemometer on a stand. It was measured five times over a period of five minutes and an average wind speed was calculated. The air temperature inside the roosting site was measured using an electronic thermometer mounted on a stand in the room that contained the most bats. Roost temperatures

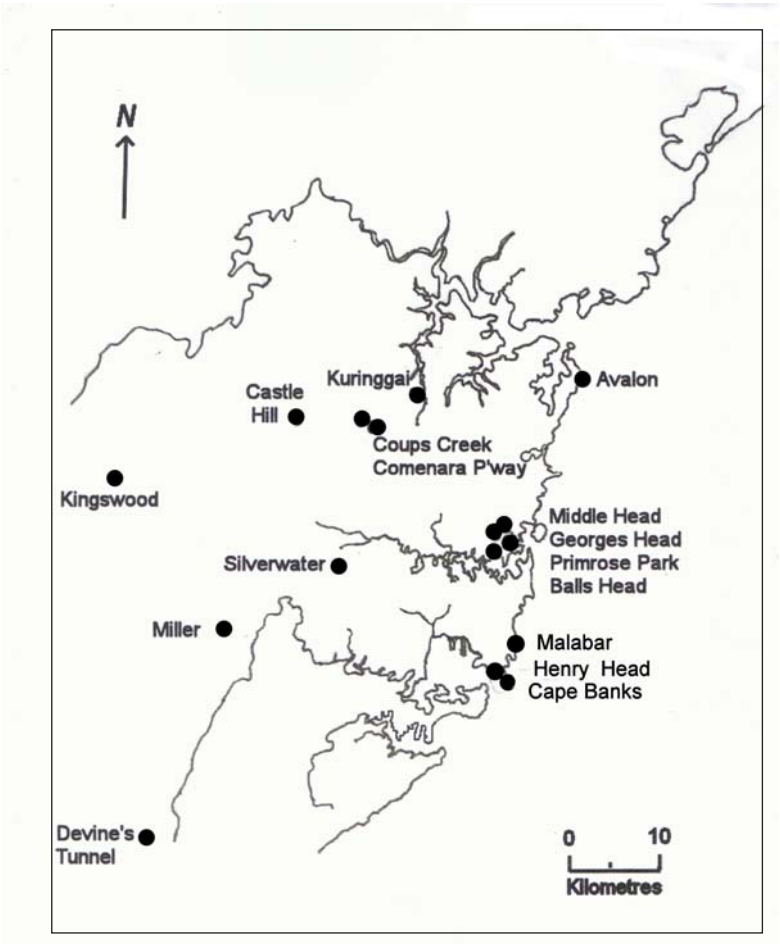

Figure: 1 Roosting sites for *Miniopterus schreibersii* in Sydney (after Hoye and Spence 2004).

were measures in room 13 at Malabar, room 2 at Henry Head and room 3 at Cape Banks.

Bat entry to roosting areas

In order to determine the means by which bats entered and exited the underground rooms at each site, the rooms were revisited at night several times over the period of the survey. Using a hand-held bat detector (Anabat, Titley Electronics, Ballina, NSW), each opening or potential flyway was scanned to try to detect bats passing through the opening. This was carried out 11 times at Malabar (where there were more potential entrances to the roosting areas), six times at Henry Head and twice at Cape Banks. To prevent disturbance to the bats' flight movements, the surveyor remained concealed near each suspected entrance/exit point while recording bat calls.

Effect of autumn gale

In March 2005, a forecasted autumn gale provided the opportunity to observe the response of the bats to extreme weather conditions. Bat monitoring was conducted before, during and after the gale had passed. The four months prior to the arrival of the gale had been unusually hot and dry and the gale was expected to bring gale force winds and heavy rain. More frequent (daily) surveys of the roosting sites at the three sites commenced on 21 March 2005 and ended on 31 March 2005. Apart from recording bat numbers, wind speeds and air temperatures were again recorded. In addition, the arrangement of bats in each roosting site was recorded as follows: the number of bats in each cluster and the number of bat clusters in the corners of the room as opposed to the open ceiling areas. Clusters were defined as a group of bats touching each other, a solitary bat was scored as an individual.

Results

Mapping potential roosting sites

The Malabar site consists of a long, bifurcated tunnel system leading to above-ground gun turrets. The tunnels leading to the turrets were lined with various sized rooms and smaller chambers. Twenty potential bat roosting sites were mapped and are presented in Figure 2.

Henry Head had a less extensive series of tunnels and rooms than Malabar: a single tunnel system linked the gun turret to a subterranean arsenal area. Eight potential bat roosting sites were mapped at Henry Head (Figure 3).

Cape Banks had two separate tunnel systems. The southern tunnel bifurcated to lead to two shell stacking

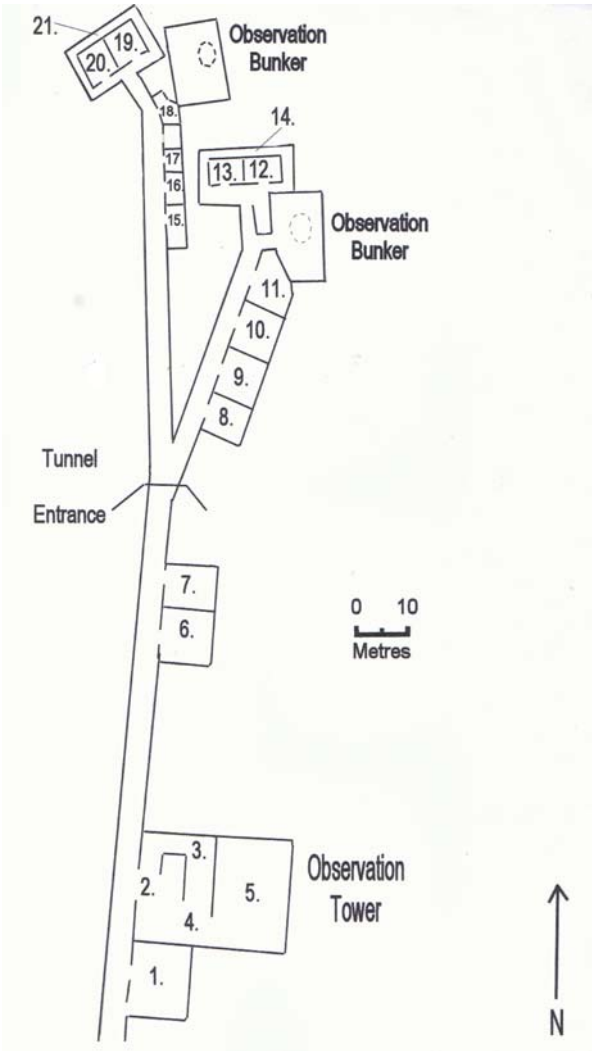

Figure 2: Room Plan Malabar

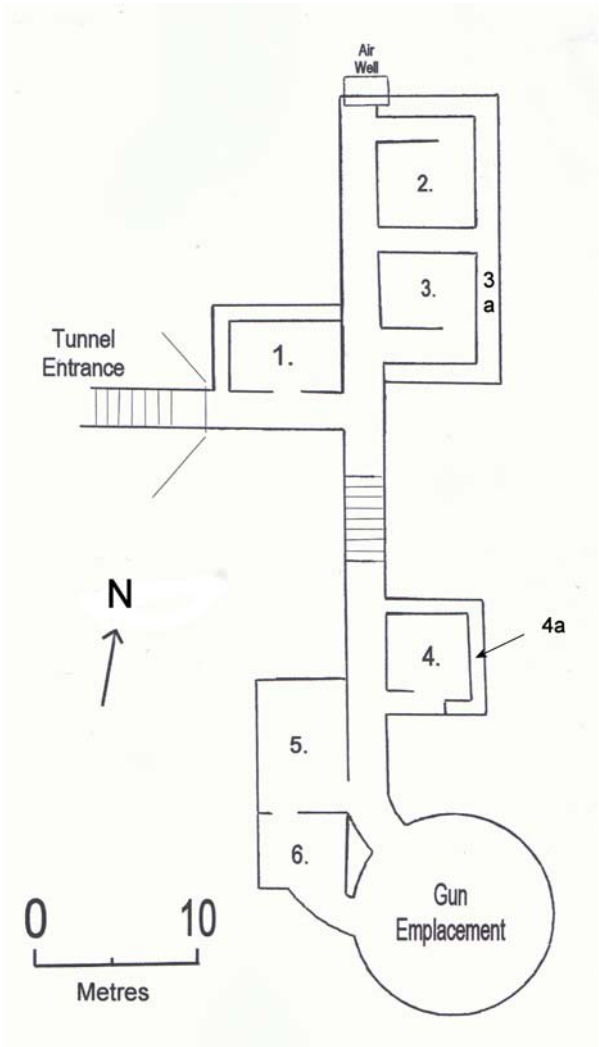

Figure 3: Room Plan Henry Head

rooms beneath the gun turrets. The eastern tunnel also divided into a main adit that led to the main armoury and shell hoisting area, and a second tunnel descended steeply into the ground and terminated in a very large ammunitions storage area (Figure 4). Despite the more complex nature of the Cape Banks site, only five potential bat sites were identified in the eastern tunnels and eight in the southern tunnels.

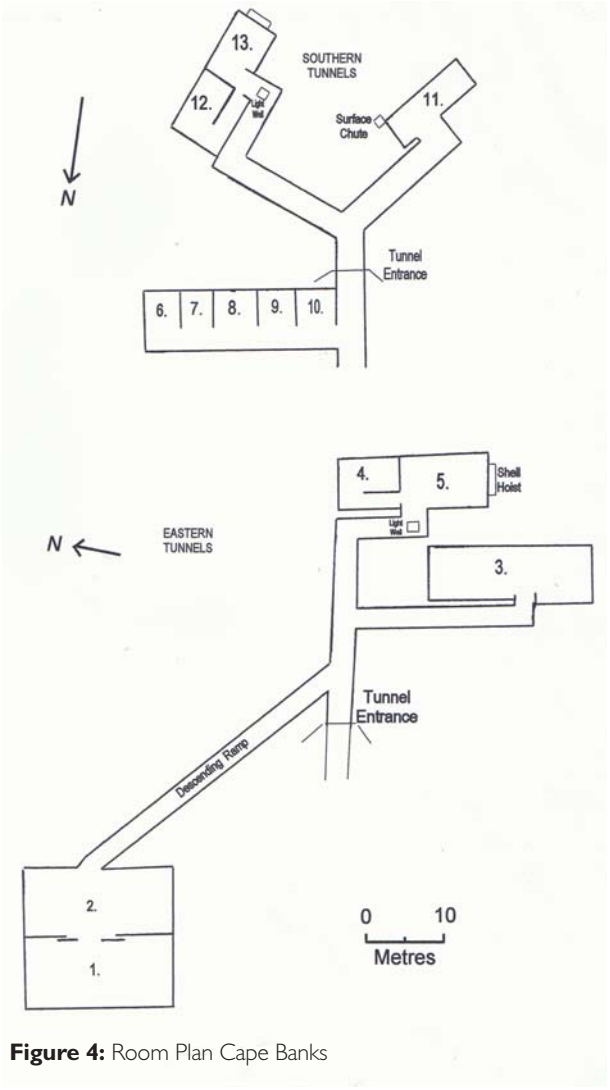

Figure 4: Room Plan Cape Banks

Monitoring results

Malabar

Bats were detected there in 37 of the 58 surveys (Appendix Table A). Bats were found to use 10 of the potential roosting sites. Most rooms were used occasionally while room 13 (Figure 2) was always used when bats were present at Malabar (Table 1).

The average number of bats detected when present at Malabar was 52.3, and more than 50 bats were detected on 27 occasions. The largest number of bats detected on a single occasion was 67. Bats were not detected at Malabar in November and December 2004, November and December 2005 and January and February 2006.

Henry Head

Fifty eight surveys were also carried out at Henry Head and bats were detected on 12 occasions (Appendix Table B). Bats were found to use four of the seven potential roosting sites but were mostly found in Room 2 (Figure 3) (Table 1).

When bats were present, the average number of bats detected at Henry Head was 22 (range 1 – 44 bats, n = 12 visits). Bats were often absent from Henry Head and were not detected in November and December 2004, between February and May 2005 or between November 2005 and February 2006.

Cape Banks

Bats were only detected at Cape Banks on one occasion (1st October 2004) (Table 1, Appendix Table C). On that occasion, two bats were found in room 3 (Figure 4), in the eastern tunnel system.

Statistical Analysis

A Spearman correlation was carried out between the number of bats at Henry Head and the number of bats at Malabar at any particular time; Cape Banks was excluded from the analysis because there so few records for that site. No correlation was found (r = 0.07, p = 0.64) because there were so many zeros scores in the data, but two components were evident in the distribution of the bats (Figure 5). When bats were present in high numbers at Malabar, very few were present at Henry Head; the reverse also applies.

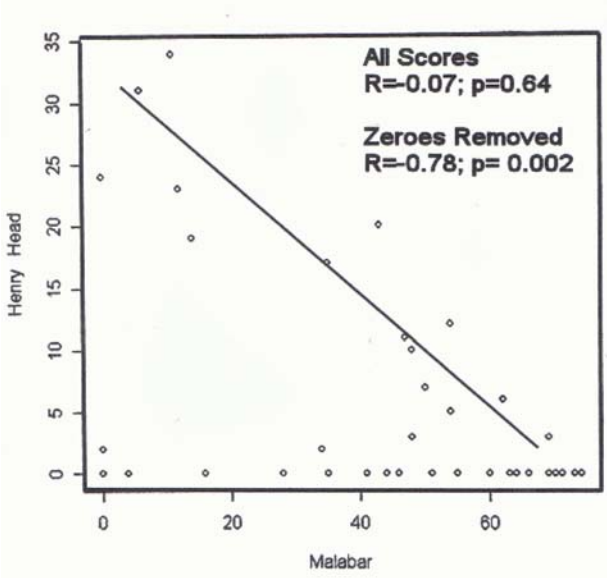

Figure 5: Correlation between Bat Numbers at Henry Head and Malabar

To allow for the effect of the zero scores, the data were divided into a zero score component and the remaining data modelled to a Poisson component (i.e. when the bat count was one or more). A multiple model inference approach (Burnham and Anderson 2003) was used to determine the best fit for the abundance of bats and the zero score component. All combinations of the three factors (wind speed, air temperature and the number of bats at Henry Head) were tested. The model with the best fit was the model that included all three factors (delta AIC to the next model>10).

Wind speed, air temperature

Average wind speed was greatest at Cape Banks, less at Henry Head and at its lowest strength at Malabar

Table 1. Monitoring Data for Roost Sites at Malabar, Henry head and Cape Banks.

Location	Total Number of bats recorded (n)	No. of Observations (n)	No. of times bat were present (n)	No. of bats (Mean and range)	Months when bats observed	Roost Air Temperature (Mean ± SD and Range °C)	Entrance Wind Speed (Mean ± SD and range km/hr)
Malabar All Sites	2017	58	37	34.8 0–84	Jan–Sept 04; Feb–Oct 05; Feb–July 06	14.3 ± 2.9 11°–23°	8.6 ± 6.2 0–32
Malabar Room 10	7	58	5	0.1 0–2	May–June 04; May 05; May–July 06		
Malabar Room 11	29	58	4	0.5 0–4	June 04; March 05; Oct 05; Feb–March 06		
Malabar Room 12	136	58	21	2.3 0–12	Jan–Sept 04; March–July 05; Oct 05; Feb–March 06		
Malabar Room 13	1634	58	37	28.2 0–62	Jan–Sept 04; Feb–October 05; Feb–July 06		
Malabar Room 14	105	58	14	1.8 0–7	Jan–Sept 04; March–Oct 05; March–July 06		
Malabar Room 17	2	58	5	0.03 0–1	May–July 06		
Malabar Room 18	7	58	3	0.1 0–2	Sept 04; May 06; July 06		
Malabar Room 19	49	58	12	0.8 0–5	June–July 04; March–July 05; Sept 05; Feb–July 06		
Malabar Room 20	46	58	11	0.8 0–6	March–Oct 05; March–July 06		
Malabar Room 21	2	58	3	0.03 0–1	March 05; July 06		
Henry Head All Sites	356	58	22	6.3 0–44	Jan 04; March–May 04; July–Oct 04; Jan–March 05; June–Sept 05; March–June 06	13.4° ± 2.9° 10°–21°	11.5 ± 8.8 0–38
Henry Head Room 2	250	58	22	4.3 0–28	Jan 04; April–May 04; July–Oct 04; Jan–March 05; June–Sept 05; March–May 06		
Henry Head Room 3	66	58	14	1.1 0–10	May 04; Aug–Oct 04; March 05; June–Sept 05; March–May 06		
Henry Head Room 3a	38	58	11	0.7 0–5	Jan 04; May 04; Aug, Oct 04; Jan, Mar 05; July, Sept 05; Apr–May 06		
Henry Head Room 5	2	58	1	0.03 0–2	May 05		
Cape Banks Room 3	2	49	1	0.04 0–2	Oct 04	13.2° ± 2.3° 9°–18°	15.6 ± 9.5 4–48

(Table 1). Air temperatures inside the roost sites were generally lowest at Cape Banks, slightly higher at Henry Head and highest at Malabar.

All combinations of the three factors (wind speed, air temperature and the number of bats at Henry Head) were then tested against the zero score component with all factors included in the Poisson component. The model with best fit included both wind speed and air temperature, the other two models had some support (Table 2).

From these data, the probability of bats being present at Malabar decreases as air temperature increases (P = 0.0016).

The number of bats at Malabar increases as wind speed increases (P = 0.0003), air temperature decreases (P < 0.0001) and the number of bats at Henry Head decreases (P < 0.0001).

The maximum roosting site air temperature when bats were present was 18°C at Malabar and 17°C at Henry Head; above these temperatures, bats were no longer found at either site. Bats were recorded at Malabar across the entire range of wind speeds experienced whereas bats were not recorded at Henry Head at wind speeds greater than 23 km/hr.

Autumn gale

The forecasted gale struck Sydney on the afternoon of 22 March 2005. Intense southerly winds and driving rain lashed coastal areas all that day and night, a total of 54 mm of rain fell at Malabar. The next day was overcast with blustery, windy conditions that persisted until late evening when the skies began to clear. A further 10 mm of rain fell on 23 March. The following two days were overcast and cool, with air temperatures dropping to 14 °C at night. The strong winds completely abated on 26 March although some drizzle showers were experienced. The next three days remained cloudy and mild with only light winds.

Table 3 below summarises the air temperature and wind speed data for the 11 day period of the observations, along with bat numbers. Bat numbers at Henry Head declined rapidly with the onset of the gale, while bat numbers rose by almost equivalent amounts at Malabar. Malabar was less wind-affected and more temperature-stable than Henry Head.

The clustering pattern of bats at Malabar also changed as the gale progressed. The number of bat clusters reduced as the group size per cluster increased. The number of clusters on the ceiling decreased as bats congregated more in the corners of the room (Table 4).

Discussion

Malabar–La Perouse Bent-wing Bat Roosting Dynamics

Correlation models developed from the bat abundance data at Malabar and Henry Head indicate that an inverse relationship exists between bat numbers at these two sites (Table 2). The bats arriving in the eastern suburbs of Sydney in late February each year roost at either Malabar or Henry Head, or both depending on the prevailing wind speed and air temperatures. Where the bats are coming from remains unknown and further studies are required to determine their source.

Table 2. Component Model For Bat Numbers, Wind Speed and Air Temperature

	Estimate	S.E.	Lower	Upper	*Z* value	Pr (>[z])
(intercept) x	4.572000	0.193300	4.193000	4.951000	23.650000	0.000000
windx	0.018300	0.005007	0.008481	0.028110	3.654000	0.00258
tempx	–0.052840	0.012060	–0.076480	0.029210	–4.382000	0.000012
HHx	–0.030390	0.003844	–0.037920	0.022850	–7.905000	0.000000
(intercept) z	11.570000	3.402000	18.240000	4.907000	–3.402000	0.000668
tempz	0.662100	0.196900	0.236100	1.008000	3.159000	0.001582

Table 3. Bat Numbers, Wind Speed and Air Temperature at Malabar and Henry Head during the Autumn Gale in 2005.

Date	Malabar Bats(n)	Air Temp °C	Wind Speed km/hr	Henry Head Bats(n)	Air Temp °C	Wind Speed km/hr
21.3.05	11	18	7	34	20	10
22.3.05	35	15	48	17	15	58
23.3.05	65	15	38	0	14	57
24.3.05	66	15	28	0	14	40
25.3.05	67	15	14	0	14	22
26.3.05	66	16	6	0	14	10
27.3.05	66	15	8	0	14	16
28.3.05	64	16	11	0	15	15
29.3.05	65	15	7	0	14	10
30.3.05	63	16	10	0	15	16
31.3.05	54	16	8	0	15	10

The arrival of bats in late February in eastern Sydney precedes the movement patterns of this species observed elsewhere in New South Wales. Dwyer (1963) reported that in north-eastern New South Wales female Bent-wing bats do not return to the over winter roosts until March. Similarly, Dwyer (1964, 1966a) reported that females depart the overwinter roosts in September to fly to maternity sites. The present study did not record the sex of the bats at Malabar or Henry Head and only recorded total bat numbers. Based on the number of bats being recorded at these two sites, there was no evidence of female bats leaving this early; the first signs of a drop in the bat numbers did not take place until mid-October in 2005 and early November in 2004. The sites were vacated during most of summer.

In south-eastern New South Wales, Bent-wing bats often hibernate for various intervals of up to 12 days (Hall 1982) when temperatures are low. Hibernating bats were observed at Malabar and Henry Head in July 2005, but this was the only instance of hibernation noted in the duration of the survey: at this time air temperatures inside the roosting areas dropped to 11ºC.

During autumn, winter and spring, the bats moved among the three survey sites (and possibly other undetected roost sites). During winter, bats were mostly found at Malabar but not Henry Head. As spring approached there was increased utilisation of the roosts at Henry Head (and on one occasion bats were found at Cape Banks). The majority of the bats continued to move between roosting sites according to prevailing weather conditions and external disturbances (see below). It is assumed that flights at this time were either for investigating new roost sites or for social interaction.

Bent-wing bats are strong-flying bats and typically forage at speed above the canopy of woodland and forests (Hoye and Hall 2008). Along the coastal strip between Malabar and La Perouse is a belt of coastal heath with occasional low, stunted trees. Moths are the major dietary prey item for Easter Bent-wing bats (Vestjens and Hall 1977). If Bent-wing bats are foraging in eastern Sydney, they must be flying in more sheltered areas or exploiting periods of reduced wind intensity to forage. In normal weather conditions, Bent-wing bats can fly 10 kilometres or more when foraging (Hoye and Hall 2008).

In the summer months, particularly January and February, the bats were not found at any of the three sites and it was presumed that female bats had moved to maternity sites. Hoye and Spence (2004) noted that, for the other bent-wing bat roosting sites around Sydney, the bats were often absent between September and March each year. This was interpreted to indicate that bats were dispersing to remote breeding sites where the females would give birth and rear the young to a stage where they could leave them and return to the roosting sites. Maternity sites close to Sydney have not been found although Wilson (2000, in Hoye and Spence 2004) has suggested that maternity roosts may occur within greater Sydney, rather than being hundreds of kilometres away.

At Malabar, bats were still present throughout November and December each year and it was not until the end of the year that all of the bats had departed. Similarly, the bats were returning in late February or the start of March. On one occasion, in March 2005, two female bats were observed with young at Malabar. No bats remained at Malabar or Henry Head over the summer months, so any female bats arriving at Malabar at the end of summer has either given birth late in the season, or they may have carried the young in flight. The inference from these observations is that the maternity site may be quite close to Malabar and so bats can afford to leave later in the year because the distance that they have to travel is not great, and that they re-appear early in March as they have not had to fly far to return to the roosting site.

Environmental factors

Wind speed outside the roosting sites and air temperature in the roosting sites were significant factors in determining roosting behaviour of Bent-wing bats at Henry Head and Malabar. Even strong flying bats, like Bent-wing bats, prefer to avoid flying in strong winds, so foraging flights are probably curtailed during windy weather (Dwyer 1966b). The three sites in eastern Sydney have different exposures to direct wind; Cape Banks was the most exposed roosting site, followed by Henry Head and Malabar was the least exposed. Henry Head, located on the western side of Botany Bay Heads and hence it is more protected against onshore winds, but it is still exposed to south-east winds. The Malabar site is not

Table 4. Bat Clusters at Malabar during Autumn Gale

Date	Bats (n)	Total No bats Clusters	Mean No bats per cluster	No clusters in corners	No clusters away from corners
21.3.05	11	7	1.6	2	5
22.3.05 #	35	5	7.0	4	1
23.3.05	65	6	10.8	6	0
24.3.05	66	6	11.0	6	0
25.3.05	67	6	11.2	6	0
26.3.05	66	7	9.4	6	1
27.3.05	66	10	6.6	5	5
28.3.05	64	11	5.8	5	6
29.3.05	65	10	6.5	5	5
30.3.05	63	14	4.5	4	10
31.3.05	54	15	3.6	4	11

date when gale reached Malabar.

located on coastal cliffs and is the least exposed of the three sites. The results of this study indicate that the pattern of bat utilisation of these sites is related to prevailing wind strength and the number of consecutive windy days. Further studies are necessary to confirm these results.

Bat behaviour in the roosting sites was also related to air temperature. Air temperatures inside the roost sites varied from 9°C to 23°C; Cape Banks had the lowest mean temperature while Malabar had the highest (Table 1). All three sites were most affected by southerly cold fronts with associated southerly winds (Bureau of Meteorology 2007). The arrival of southerly winds quickly dropped the outside air temperatures, and in sites where wind exposure can penetrate the tunnels, cold draughts reach the roost sites and air temperatures inside the roosts may also drop quickly. Roost sites at Cape Banks were the most vulnerable to wind movement and a sudden temperature drop whereas several roost sites at Malabar have restricted air movement and changes in air temperature are less pronounced.

Overall, Malabar offers the most favourable climatic conditions of the three sites but it has one apparent drawback however, the air temperature inside the roost may be too high at times. At Malabar, the air temperature may be too high on occasions when food resources are limited (e.g. during windy weather in spring or summer) and so bats may move to cooler roosting sites (e.g. Henry Head) where they can go into torpor easily and conserve their stored body fat. In other studied populations, Bent-wing bat regularly hibernate when food resources become scarce, or the bats cannot forage because of adverse weather conditions (Hall 1982).

Bats' response to extreme weather conditions

The autumn gale resulted in Bent-wing bats from being mainly based at Henry Head to being completely established at Malabar (Table 3). It is only 4 kilometres direct distance from Henry Head to Malabar (whereas it is only 900 metres from Henry Head to Cape Banks). Not all bats relocated to Malabar in the first 24 hours of the gale, some reached Malabar later when wind speeds were still in excess of 40 km/hr. The total number of bats that roosted at Malabar presumably included bats from Henry Head plus other bats whose origin is unknown. There are probably other sites in eastern Sydney where Bent-wing bats find temporary refuge during inclement weather.

When the gale subsided on 25 March, Bent-wing bats remained at Malabar for several more days before dispersing elsewhere (Table 3). No bats immediately returned to Henry Head.

Prior to the arrival of the gale, air temperature in the roosting area at Malabar was 18 °C and this fell by 3 °C within a day, while air temperature in the roosting areas at Henry Head fell from 20 °C to 15 °C in the same period (Table 4). Before the arrival of the gale, bats were scattered, or in groups of two or three, across the ceiling of each room (Figure 6). As the gale intensified, bats numbers increased at Malabar and the bats began to form larger clusters, particularly in corner of each room (Figure 7). Very few cluster remained in the open portion of the ceiling.

The number of clusters remained stable for several days as the gale abated (Table 4). It is unknown if the composition of these clusters changed during this period. No bats were observed moving about the ceiling of the roost during this period and some may have been in torpor. Short torpor episodes are commonly used to conserve body energy when the bats are unable to feed (Hall 1982). It is unlikely that bats attempted foraging flights during the first six days of the gale and no bats were seen flying in the roost site during this period.

Protection of roosting sites

The Malabar site is periodically subject to daytime disturbances by human visitors exploring the tunnels.

Figure 6: Small bat clusters prior to the advent of the gale

Figure 7: Large clusters of bats formed during the gale

The bats often take to the air when this happens and they will normally fly to other roosting sites in the tunnels rather than leave the tunnels. The only time that individuals were observed to exit during the day was when smoke from fires lit near the gun turrets invaded the tunnels.

The sites at Cape Banks and Henry Head are within the Botany Bay National Park and both have locked security gates at the tunnel entrances. Malabar is the only site that is open to public visitation. During the survey, people were found inside the tunnels; often they were unaware that there were resident bats. The tunnels were most frequently visited during school holidays when local youths would use the old buildings as meeting places. Occasionally, groups of more than 20 people were observed inside the tunnels, and during the spring and summer, gangs including the "Cave Clan" inhabit the rooms overnight. Apart from noise, movement and light at night, small fires were sometimes lit in the rooms for warmth or large bonfires were lit near the gun turrets. Bats at Malabar are regularly disturbed during the spring and summer by human visitors and it is not clear how much this disturbance regime contributes to the local dispersal movements of the bats. Repeated disturbances and arousal from hibernation causing loss of fat reserves is a known cause of mortality in bats (Hall 1982).

As a measure to help protect the bats, the main tunnel doors were closed and barricaded in December 2006 after all of the bats had left. People can still enter the site via the gun turrets, but this access is far less inviting to bushwalkers or casual passers-by. Locked, barred gates are required at the neck of each gun turret to prevent people from disturbing the bats and to reduce the vandalism of the military site. In 2005, a Facility Management Plan was prepared for the Commonwealth Government for Malabar headland and a strong recommendation in the report was that the headland be gazetted as national park (Coffey 2005). Should this happen, the protection of the bat roost sites should become a high priority. It is clear from this study that multiple secure roost sites are necessary in eastern Sydney to conserve the Eastern Bent-wing bat; this will allow the bat population to optimise its choice of roosts during particular weather conditions.

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Appendices

Table A. Site Occupancy Data for Malabar

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	No. Bats
10.1.04	0	0	0	0	0	0	0	0	0	0	0	11	24	2	0	0	0	0	0	0	0	37
20.2.04	0	0	0	0	0	0	0	0	0	0	0	8	33	5	0	0	0	0	0	0	0	46
19.3.04	0	0	0	0	0	0	0	0	0	0	0	3	39	2	0	0	0	0	0	0	0	44
4.4.04	0	0	0	0	0	0	0	0	0	0	0	5	40	3	0	0	0	0	0	0	0	48
1.5.04	0	0	0	0	0	0	0	0	0	1	0	4	44	6	0	0	0	0	0	0	0	55
27.5.04	0	0	0	0	0	0	0	0	0	0	0	2	10	0	0	0	0	0	0	0	0	12
10.6.04	0	0	0	0	0	0	0	0	0	1	1	3	36	5	0	0	0	0	3	0	0	49
6.704	0	0	0	0	0	0	0	0	0	0	0	1	30	2	0	0	0	0	1	0	0	34
4.8.04	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	4
11.8.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30.8.04	0	0	0	0	0	0	0	0	0	0	0	2	10	2	0	0	0	0	0	0	0	14
11.9.04	0	0	0	0	0	0	0	0	0	0	0	3	21	3	0	0	0	2	0	0	0	29
1.10.04	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	6
10.11.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.12.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28.12.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.1.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31.1.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.2.05	0	0	0	0	0	0	0	0	0	0	0	3	32	0	0	0	0	0	0	0	0	35
20.3.05	0	0	0	0	0	0	0	0	0	0	4	3	34	0	0	0	0	0	0	0	0	41
21.3.05	0	0	0	0	0	0	0	0	0	0	0	1	10	0	0	0	0	0	0	0	0	11
22.3.05	0	0	0	0	0	0	0	0	0	0	0	3	32	1	0	0	0	0	0	0	0	36
23.3.05	0	0	0	0	0	0	0	0	0	0	4	6	52	2	0	0	0	0	0	0	0	64
24.3.05	0	0	0	0	0	0	0	0	0	0	3	5	53	1	0	0	0	0	0	0	0	62
27.3.05	0	0	0	0	0	0	0	0	0	0	3	5	48	6	0	0	0	0	2	0	0	64
29.3.05	0	0	0	0	0	0	0	0	0	0	3	3	55	2	0	0	0	0	2	4	0	69
31.3.05	0	0	0	0	0	0	0	0	0	0	2	6	52	1	0	0	0	0	1	5	1	68
8.4.05	0	0	0	0	0	0	0	0	0	0	0	0	36	2	0	0	0	0	0	3	0	41
21.4.05	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0	0	2	5	0	42
1.5.05	0	0	0	0	0	0	0	0	0	0	0	3	50	4	0	0	0	0	1	1	0	59
16.5.05	0	0	0	0	0	0	0	0	0	1	0	2	33	3	0	0	0	0	1	0	0	40
27.6.05	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	0	28
25.7.05	0	0	0	0	0	0	0	0	0	0	0	4	62	7	0	0	0	0	4	3	0	84
8.8.05	0	0	0	0	0	0	0	0	0	0	0	5	45	3	0	0	0	0	0	5	0	58
17.8.05	0	0	0	0	0	0	0	0	0	0	0	0	32	1	0	0	0	0	0	5	0	38
3.9.05	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	23
21.9.05	0	0	0	0	0	0	0	0	0	0	0	0	36	4	0	0	0	0	4	0	0	44
3.10.05	0	0	0	0	0	0	0	0	0	0	1	6	58	1	0	0	0	0	0	0	0	66
13.10.05	0	0	0	0	0	0	0	0	0	0	0	4	62	0	0	0	0	0	0	1	0	67
26.10.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.11.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.12.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.12.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.1.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.2.06	0	0	0	0	0	0	0	0	0	0	0	12	9	0	0	0	0	0	0	0	0	21
5.3.06	0	0	0	0	0	0	0	0	0	0	0	4	39	2	0	0	0	0	2	0	0	47
13.3.06	0	0	0	0	0	0	0	0	0	0	0	0	27	5	0	0	0	0	4	2	0	38

Table A. (cont'd)Site Occupancy Data for Malabar

29.3.06	0	0	0	0	0	0	0	0	0	0	3	2	48	4	0	0	0	0	0	1	0	58
3.4.06	0	0	0	0	0	0	0	0	0	0	0	0	44	4	0	0	0	0	4	0	0	52
14.4.06	0	0	0	0	0	0	0	0	0	0	0	0	26	5	0	0	0	0	4	0	0	35
2.5.06	0	0	0	0	0	0	0	0	0	0	0	0	15	1	0	0	0	0	0	0	0	16
12.5.06	0	0	0	0	0	0	0	0	0	2	3	1	47	4	0	0	1	0	3	0	0	61
22.5.06	0	0	0	0	0	0	0	0	0	0	0	4	51	3	0	0	0	0	0	2	0	60
9.6.06	0	0	0	0	0	0	0	0	0	0	0	0	31	0	0	0	0	2	2	2	0	37
30.6.06	0	0	0	0	0	0	0	0	0	0	0	4	39	2	0	0	0	0	5	1	0	51
13.7.06	0	0	0	0	0	0	0	0	0	2	0	5	48	4	0	0	1	3	4	0	1	68
18.7.06	0	0	0	0	0	0	0	0	0	0	0	5	45	3	0	0	0	0	0	6	0	59
	0	0	0	0	0	0	0	0	0	7	29	136	1634	105	0	0	2	7	49	46	2	2017

Table B. Site Occupancy Data for Henry Head

Date	1	2	3	3a	4	4a	5	6	No. Bats
10.1.04	0	5	0	2	0	0	0	0	7
20.2.04	0	0	0	0	0	0	0	0	0
19.3.04	0	0	0	0	0	0	0	0	0
4.4.04	0	3	0	0	0	0	0	0	3
1.5.04	0	0	0	0	0	0	0	0	0
27.5.04	0	13	3	4	0	0	2	0	22
10.6.04	0	0	0	0	0	0	0	0	0
6.704	0	2	0	0	0	0	0	0	2
4.8.04	0	0	0	0	0	0	0	0	0
11.8.04	0	17	2	5	0	0	0	0	24
30.8.04	0	12	3	4	0	0	0	0	19
11.9.04	0	0	0	0	0	0	0	0	0
1.10.04	0	22	4	5	0	0	0	0	31
10.11.04	0	0	0	0	0	0	0	0	0
6.12.04	0	0	0	0	0	0	0	0	0
28.12.04	0	0	0	0	0	0	0	0	0
16.1.05	0	2	0	0	0	0	0	0	2
31.1.05	0	0	0	0	0	0	0	0	0
17.2.05	0	0	0	0	0	0	0	0	0
20.3.05	0	0	0	0	0	0	0	0	0
21.3.05	0	23	6	4	0	0	0	0	33
22.3.05	0	15	2	0	0	0	0	0	17
23.3.05	0	6	0	0	0	0	0	0	6
24.3.05	0	0	0	0	0	0	0	0	0
27.3.05	0	0	0	0	0	0	0	0	0
29.3.05	0	0	0	0	0	0	0	0	0
31.3.05	0	0	0	0	0	0	0	0	0
8.4.05	0	0	0	0	0	0	0	0	0
21.4.05	0	0	0	0	0	0	0	0	0
1.5.05	0	0	0	0	0	0	0	0	0
16.5.05	0	0	0	0	0	0	0	0	0
27.6.05	0	11	4	0	0	0	0	0	15
25.7.05	0	19	6	4	0	0	0	0	29
8.8.05	0	0	0	0	0	0	0	0	0
17.8.05	0	8	4	0	0	0	0	0	12
3.9.05	0	23	6	0	0	0	0	0	29
21.9.05	0	6	5	2	0	0	0	0	13

Table B. (cont'd)Site Occupancy Data for Henry Head

3.10.05	0	0	0	0	0	0	0	0	0
13.10.05	0	0	0	0	0	0	0	0	0
26.10.05	0	0	0	0	0	0	0	0	0
17.11.05	0	0	0	0	0	0	0	0	0
10.12.05	0	0	0	0	0	0	0	0	0
29.12.05	0	0	0	0	0	0	0	0	0
15.1.06	0	0	0	0	0	0	0	0	0
4.2.06	0	0	0	0	0	0	0	0	0
22.2.06	0	0	0	0	0	0	0	0	0
5.3.06	0	0	0	0	0	0	0	0	0
13.3.06	0	8	2	0	0	0	0	0	10
29.3.06	0	0	0	0	0	0	0	0	0
3.4.06	0	7	2	1	0	0	0	0	10
14.4.06	0	17	7	1	0	0	0	0	25
2.5.06	0	28	10	6	0	0	0	0	44
12.5.06	0	0	0	0	0	0	0	0	0
22.5.06	0	2	0	0	0	0	0	0	2
9.6.06	0	1	0	0	0	0	0	0	1
30.6.06	0	0	0	0	0	0	0	0	0
13.7.06	0	0	0	0	0	0	0	0	0
18.7.06	0	0	0	0	0	0	0	0	0
	0	250	66	38	0	0	2	0	356

Table C. Site Occupancy Data for Cape Banks

Date	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**No. Bats**
27.4.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27.5.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.6.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.704	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.8.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.8.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30.8.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.9.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.10.04	0	0	2	0	0	0	0	0	0	0	0	0	0	2
10.11.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.12.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28.12.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.1.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31.1.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.2.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.3.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21.3.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.3.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23.3.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.3.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27.3.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.3.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31.3.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.4.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21.4.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table C. (cont'd)Site Occupancy Data for Cape Banks

16.5.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27.6.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25.7.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.8.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.8.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.9.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21.9.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.10.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.10.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.11.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.12.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.12.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.1.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.3.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.3.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.4.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.4.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.5.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.6.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30.6.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.7.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	2	0	0	0	0	0	0	0	0	0	0	2