AUSTRALIAN SPELEOLOGICAL FEDERATION
PROCEEDINGS 10TH BIENNIAL CONFERENCE

ROOST SELECTION OF THE EASTERN HORSESHOE BAT *RHINOLOPHUS MEGAPHYLLUS*

L.S. Hall*, R.A. Young+, and A.P. Spate'

ABSTRACT

The distribution of the Eastern Horseshoe bat, *Rhinolophus megaphyllus* is described and the known maternity caves for this species are recorded. Temperature and humidity readings from a large number of caves and mines show that this species of bat has a definite preference for roosting in areas exhibiting high temperatures and humidities. These caves, cave chambers or mines are usually of small dimensions, often containing rock-falls or dirt-fill.

The importance of temperature, humidity and size of the roosting site is discussed in relation to the bat's distribution, both on a local and extended scale.

Recognition of roost selection is essential in the conservation and management of this species.

I. INTRODUCTION

In recent years there has been concern expressed over the world wide decline in the numbers of bats, especially cave-dwelling species (Stebbings, 1971; Mohr, 1972; Editorial comments in U.S.A. Bat Research News). In Australia, a definite decline in the numbers of several cave-dwelling bat species has been reported by Hall and Dunsmore (1974).

The decline is largely due to the destruction of roosting sites, specimen collecting and disturbance by bat workers, speleologists and tourists, (Stebbings, 1966; R.L. Martin and A Brosett, pers. comm.).

The availability of roosting sites with a favourable microclimate is an important factor affecting the distribution and survival of insectivorous bats. Published data on the microclimate of diurnal roosts used by Australian bats has been mainly restricted to caves used as maternity sites by *Miniopterus schreibersii* (Dwyer and Hamilton-Smith, 1965; Dwyer and Harris, 1972).

The purpose of this paper is to describe the physical structure and microclimate of roosting sites selected by the Eastern Horseshoe bat, *Rhinolophus megaphyllus*, in eastern Australia.

II. DISTRIBUTION

Rhinolophus megaphyllus occurs in New Guinea and in eastern Australia from Cape

* CSIRO Division of Wildlife Research, P.O. Box 84, LYNEHAM. A.C.T. 2602.
+ Darling Downs Institute of Advanced Education, P.O. Box 128, TOOWOOMBA. QLD. 4350.
' 1 Hoskins St., HALL. A.C.T. 2618.

York Peninsula to Victoria (Hamilton-Smith, 1966; Ride, 1970). Figure 1 shows the distribution of *R. megaphyllus* in Australia. Most records are from the eastern slopes of the Great Dividing Range, but the species is also found on the western slopes. Purchase (1962) recorded *R. megaphyllus* at Mandurama, N.S.W. (Cleifden), and Dwyer (1966) observed the species at 15 localities on the inland North-western Slopes of N.S.W.

The record of Krefft (1866) of "frequently observing the species flying over Gunbower Creek" in north western Victoria (Fig. 1) would have to be regarded as extremely doubtful. Krefft did not collect any specimens and more recently, Ryan (1964) claimed that *R. megaphyllus* does not extend into Western Victoria. The two collecting localities recorded by Hamilton-Smith (1966), are considered to be extralimital and further observations are required to confirm the existence of *R. megaphyllus* in these areas (Fig. 1).

The type locality for the species is Cave Flat, N.S.W., (Ryan, 1964), which is now submerged by the waters of Burrinjuck Dam.

III. ROOST SELECTION

In addition to roosting in caves, *R. megaphyllus* also occurs in mines, hydro-electric tunnels, bomb shelters and culverts (Tate, 1952; George and Wakefield, 1961; Purchase, 1962; Dwyer, 1966; and information derived from registers of the Queensland Museum, Australian Museum and CSIRO Division of Wildlife Research). There are several records of individuals roosting in buildings (Tate, 1952; Harrison, 1962), but there are no records of colonies occupying buildings.

It appears however, that *R. megaphyllus* favours a roost site of small dimensions, often being found in small caves with dirt-fill or rock-fall chambers (Dwyer, 1966). Dwyer records the species as being present in only half of the possible cave and mine sites in north-eastern N.S.W. Most of the unoccupied sites were colder and on the higher slopes of the coastal escarpment and the Nandewar Range, west of the Great Dividing Range.

IV. PHYSICAL STRUCTURE AND MICROCLIMATE OF ROOST SITES SELECTED BY *R. MEGAPHYLLUS*

(A) Queensland

In the Toowoomba area of south-eastern Queensland, non-maternity colonies have been located in two abandoned mines (Anjuramba and Black Duck Creek mines) and in a cave located in Ravensbourne National Park. A single individual was found in a small rock fissure near a cave in the Bunya Mountains, periodically used by *Miniopterus schreibersii* but *R. megaphyllus* has never been observed in the cave. On June 10, 1972 the temperature and relative humidity in the cave was 12.2°C and 88% respectively. *R. megaphyllus* has never been recorded in caves and mines located on the Darling Downs, West of the Great Dividing Range.

The location of maternity sites in Queensland are generally unknown, however Dwyer (1970) suggested that a small, highly humid chamber in Larynx Labyrinth Cave in the Mt. Etna area may serve as a maternity site for *R.megaphyllus*.

The Anjuramba colony is located in an abandoned molybdenite mine, 59 km north, north-east of Toowoomba. The mine consists of a single tunnel, approximately 45 m long with access to the last 8.8 m partially blocked by a dirt fall.

Localities mentioned in text:

1. Mt. Etna
2. Bunya Mts.
3. Big Hill Mine
4. Anjuramba Mine
5. Ravensbourne Nat. Park
6. Black Duck Creek Mine
7. Riverton
8. Willi Willi
9. Cleifden
10. Talwong Mine
11. Cave Flat
12. Wee Jasper
13. Mount Fairy
14. North Durras
15. Cooleman Plains
16. Yarrangobilly
17. Cleatmore
18. Marble Arch
19. Wyanbene
20. Bendethera
21. Mooresford Cave
22. Anticline Cave
23. Dickson's Cave
24. Club Terrace Mine
25. Nargun's Cave

○ Extralimital collecting locality.

◉ Gunbower Creek.

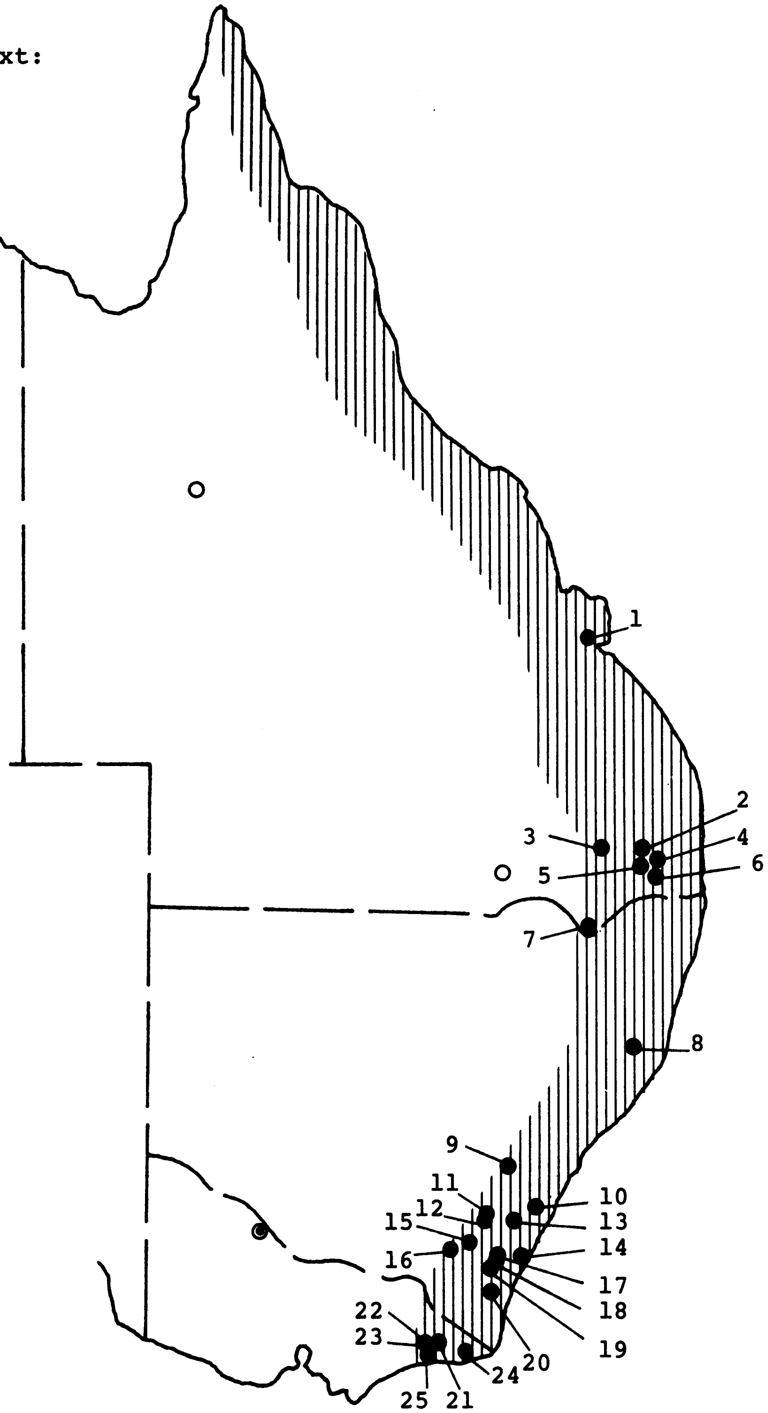

Figure 1. Distribution of the bat *R. megaphyllus* in Australia.

The temperature and relative humidity of the mine were taken on 14 occasions between 1970-72. Fluctuations in temperature and humidity towards the mine entrance were noticed, but the deep internal microclimate remained very constant. (Table 1). The greatest maximum-minimum temperature difference recorded at the end of the tunnel over a 28 month period was 2.2°C. The maximum temperature recorded was 22.2°C with a minimum of 20.0°C. Relative humidity varies from 85.5% to 95.5% in the deeper recesses of the mine.

The Ravensbourne colony occurs in a relatively small cave, located 30 km north-east of Toowoomba. There are several entrances to the cave, the largest of which is approximately 45 cm in diameter. Most of the other openings are too small to allow human entry. In most areas of the cave the ceiling height is between 15 cm and 100 cm. There is one small chamber with a domed ceiling, located about 15 m from the largest entrance.

Environmental conditions within the Ravensbourne Cave were only measured on one occasion (March, 1972). The temperature and relative humidity in the chamber was 22.0°C and 95.5% respectively. (Table 2).

The Black Duck Creek Mine is situated in a diatomaceous earth deposit, 40 km south-east of Toowoomba. The mine consists of a relatively short passage with two lateral excavations (chambers) and a terminal chamber. The terminal chamber is partially blocked by a rock-fall.

Miniopterus schreibersii and *M. australis* also use the mine as a roosting site, but only under conditions of extreme disturbance was *R. megaphyllus* observed roosting near *Miniopterus*. Dwyer (1966) also noted the segregation of adult *R. megaphyllus* from *Miniopterus* in northern N.S.W.

Temperatures recorded in the Black Duck Creek Mine chamber occupied by *R. megaphyllus* are given in Table 2. During a dry winter period in 1974, the relative humidity in the chamber occupied by *R. megaphyllus* was 95.5%, compared with 32% near the mine entrance.

There is very little information on the microclimate of roosting sites selected by *R. megaphyllus* in northern Queensland. In the Mt. Etna area this species occupies caves varying greatly in structure and microclimate, but most larger colonies occur in relatively enclosed chambers with a high relative humidity (Dwyer, 1970; R. Ladynski, pers. comm.).

(B) New South Wales

R. megaphyllus has been recorded from a large number of caves, mines and tunnels in N.S.W. Although the temperature and relative humidity throughout these roosts is generally quite high, the sites where *R. megaphyllus* has been found roosting is always the warmest and most humid part of the cave or mine. (Table 2). A comparison of the microclimate in roosts regularly used by *R. megaphyllus* with the microclimate of caves and mines never or infrequently used is also given in Table 2. In most instances the temperature in caves and mines not used as roosting sites is considerably lower than the temperature in regularly used roosting sites.

Data on the range of temperature and relative humidity measured over a two year period in several maternity and non-maternity roosts of *R. megaphyllus* is given in Table 1. The temperature and relative humidity in maternity chambers is substantially higher than in the unoccupied areas of the same roost. Temperatures recorded in non-maternity roosts are lower than those recorded in maternity chambers, however the relative humidity in the occupied areas of non-maternity roosts is very high.

Almost all of the caves and mines where *R. megaphyllus* is found are of small dimensions, an exception being Bendethera Main Cave. Generally the areas in caves occupied by roosting *R. megaphyllus* are small chambers with rock or dirt-fill. These small chambers are frequently close to the cave entrance or near the ground surface. In these chambers the humidity is extremely high and areas surrounding roost sites are often covered with a film of water. In Bendethera Main Cave *R. megaphyllus* roosts in small avens at the far end of the cave.

The sea cave at North Durras has the maternity site located in a small rock-fall chamber close to the surface of the ground. (Fig. 2a). In 1972, the entrance to this chamber was enlarged and some slumping of the rock-fall occurred. This resulted in an air flow which decreased the temperature in the chamber and since then no *R. megaphyllus* have been observed in the cave.

The maternity site in Humidicrib Cave, Wee Jasper occurs in a small, high level chamber which is close to the ground surface (Fig. 2b). Geothermal activity in the immediate vicinity of the cave might account for the high temperatures recorded in the maternity chamber.

At Bendethera, Cleatmore and Marble Arch large numbers of *M. schreibersii* are found in the same caves as *R. megaphyllus* in the winter months. In Wyabene, Humidicrib and Durras Caves and in Talwong mine, *M. schreibersii* occurs in small numbers at infrequent intervals.

(C) Victoria

In Victoria a number of caves in the Buchan area and a mine near Club Terrace are known as roosting sites for *R. megaphyllus*. These sites are also occupied by *Miniopterus schreibersii* and small numbers of *Myotis adversus* also occur in several of the caves.

Maternity colonies of *R. megaphyllus* occur at Anticline, Mooresford and Nargun's Caves.

Anticline Cave is a relatively large cave consisting of two main chambers, separated by a narrow passage. Lactating females and juveniles roost in high-level avens just inside the main entrance. However, on several occasions clusters of juveniles have been observed in the deeper, more inaccessible areas of the cave. Temperatures and relative humidities recorded during December, 1974 in several areas of Anticline Cave are given in Table 2.

Mooresford Cave is located on the Snowy River, east of Buchan. The maternity colony of *R. megaphyllus* occurs in a small, collapsed chamber approximately 8 m from the cave entrance. This chamber is a cul-de-sac located close to the ground surface under a cliff which has a north-westerly aspect. Temperatures 5 m below the roosting site of *R. megaphyllus* are 2-4°C higher than in other parts of the cave. *M. schreibersii* has been observed roosting in these other areas.

The third maternity site for the East Gippsland population of *R. megaphyllus* occurs in Nargun's Cave. The cave consists of a long (300 m) passageway with a single main chamber (Fig.2c). An intermittent stream flows along the passage-way and sinks under the floor of the main chamber. Two maternity colonies of *R. megaphyllus* occur in small, high-level avens, whereas the year round roosting sites are closer to the chamber floor. One maternity site is in one of several high-level avens in the main chamber. The second maternity site occurs in high level avens located in a small side passage, approximately 14 m from the upstream entrance to the cave. Temperatures and relative humidities recorded in Nargun's Cave are given in Table 2.

Nargun's Cave also serves as a maternity site for up to 60,000 *Miniopterus schreibersii* (Dwyer and Hamilton-Smith, 1965). This species selects four separate maternity areas; one in the main chamber and the other three in the upstream areas (Dwyer and Hamilton-Smith, 1965; Spate, unpublished).

V. DISCUSSION

The selection of a diurnal roosting site with a favourable microclimate is an important factor in the total ecology of small insectivorous bats. A suitable microclimate assists in maintaining a favourable metabolic and water balance during periods of inactivity and also promotes the growth of juveniles. Verschuren (1957) considered that the microclimatic conditions are of greater importance in a roosting site than the total nature of the environment where the roost is situated. Ransome (1968), on the other hand, considered that the population size of *Rhinolophus ferrum-equinum* in various caves, is not simply a function of microclimate, but can be determined by such factors as food supply and feeding conditions near roosts.

Although individual *Rhinolophus megaphyllus* may select relatively exposed roosting sites, such as shallow caves or overhangs (Dwyer, 1966), most larger aggregations are found in relatively closed subterranean roosts. Within these roosts *R. megaphyllus* appears to select high-level avens or high level chambers partially blocked by dirt and/or rock-falls as roosting sites (e.g. Humidicrib, Nargun's and Mooresford Caves). These sites frequently exhibit higher temperatures and humidities when compared with other parts of the caves or caves in the same general area.

Several intrinsic and extrinsic thermal processes can account for the high temperatures recorded in roosts occupied by *R. megaphyllus*. They are: 1. metabolic heat produced by large numbers of bats. 2. the oxidation of guano and naturally occurring sulphides. 3. geothermal activity in the immediate vicinity of roosting sites. 4. solar insolation. Heat produced by these processes would be readily trapped by high-level avens and enclosed chambers in mines and caves with little or no air circulation.

The role of metabolic heat in increasing cave temperatures within maternity roosts of *Miniopterus schreibersii* has been well documented by Dwyer and Hamilton-Smith (1965) and by Dwyer and Harris (1972). A number of these roosts (Nargun's, Mooresford, Willi Willi and Riverton caves), also serve as maternity sites for *R. megaphyllus*. The metabolic heat produced by large numbers of *Miniopterus* would be readily retained by the high-level roosting sites occupied by *R. megaphyllus*.

There appears to be very little information available on the importance of guano decomposition and sulphide oxidation in heating cave and mine atmospheres. The oxidation of iron pyrites (iron sulphide) yields 4.3 cal/ccO_2 absorbed compared with 2.1 cal/ccO_2 for that of coal (Peele, 1966). The oxidation of sulphides might account for the relatively high temperatures recorded in Talwong Mine.

Geothermal activity in the immediate vicinity of Humidicrib Cave, Wee Jasper coupled with guano decomposition could possibly account for the high temperatures recorded in the maternity chamber of *R. megaphyllus*.

The possibility of solar insolation as a heat source can only be considered when cave chambers are very close to a ground surface that is relatively free of soil and vegetation or in the case where the aspect and structure of cave entrances (e.g. Nargun's Cave) facilitates the heating of air moving into the cave. Chambers in limestone caves would have to be very close to the surface in order to be heated externally due to the relatively low thermal conductance of limestone and soil. Limestone and dry soil have thermal conductances of approximately 6×10^{-3} and less than 0.5×10^{-3} cal/cm sec °C respectively (Clark, 1966).

The sea cave at North Durras could possibly be heated from an external source because the maternity chamber is very close to the surface which is exposed to the west and consists of loose aggregations of sandstone-conglomerate rocks.

R. megaphyllus is very prone to desiccation in conditions of high temperature and low relative humidity. It has been noted that the wing membranes of this species often become dried-out when the animal is removed from the humid conditions of its roost.

The high humidity requirement of *R. megaphyllus* probably prevents this species from regularly using buildings as a roosting site. A nursery colony of *Chalinolobus morio* occupying the attic of a building in the Bunya Mountains (Qld.) regularly experiences temperatures of 40°C and humidities as low as 30% during the summer months (Young, unpublished).

Present data suggests that *R. megaphyllus* does not make extensive journeys between roosts and that males are more sedentary than females (Dwyer, 1966; Young and Spate, unpublished). From the data available on roost site selection, movement patterns, and reproductive biology it appears that the numbers and the geographical distribution of *R. megaphyllus* is controlled to some degree by the availability of warm and humid maternity sites in close proximity to other roosting sites with a constant, high relative humidity. This predeliction for warm caves with high humidities possibly explains why this species of bat has never been recorded from caves at Cooleman or Yarrangobilly, N.S.W. Hamilton-Smith (1966) suggested that the greater distance between caves west of the Great Dividing Range might be a factor limiting the distribution of *R. megaphyllus*.

Due to the special roost site requirements of *R. megaphyllus* every effort should be made to minimize disturbances (by humans) within roosts, particularly during winter months and during maternity season (Nov. to Feb.). The preservation of roosting sites and their environs is also essential for the continued survival of this species.

References

CLARK, S.P. Jr., 1966 Handbook of Physical Constants. Geological Soc. of America. N.Y.
DWYER, P.D., 1966 Observations on the Eastern Horse-shoe Bat in North-Eastern New South Wales. *Helictite* 4(4), 73-82.
DWYER, P.D., 1970 "Mammals", in Mount Etna Caves. Ed. J. Sprent. *Univ. Qld. Speleol. Soc. Pub.* 44-64.
DWYER, P.D. and E. HAMILTON-SMITH, 1965 Breeding caves and maternity colonies of the Bent-Winged Bat in South-Eastern Australia. *Helictite* 4(1), 3-21.
DWYER, P.D. and J.A. HARRIS, 1973 Behavioural acclimatization to temperature by pregnant *Miniopterus* (Chiroptera). *Physiol. Zool.* 45(1), 14-21
GEORGE, G. and N.A. WAKEFIELD, 1961 Victorian cave bats. *Vict. Nat.* 77, 229-302.
HALL, L.S. and J.D. DUNSMORE, 1974 A survey of Cave Dwelling bats. *Aust. Speleol. Fed. Newsletter* 64, 9-10.

HAMILTON-SMITH, E., 1966 The geographical distribution of Australian cave-dwelling Chiroptera. *Inter. J. Speleol.* II. 91-104 + plates.
HARRISON, J.L., 1962 Mammals of Innisfail. I. Species and distribution. *Aust. J. Zool.* 10, 45-83.
KREFFT, G., 1866 On the vertebrated animals of the Lower Murray and Darling, their habits, economy and geographical distribution. *Trans. Phil. Soc. N.S.W.* (1862-5) : 1-33.
MOHR, C.E., 1972 The status of threatened species of Cave-dwelling bats. *Bull. Nat. Speleol. Soc.* 34 : 33-37.
PEELE, R., 1966 Mining Engineers Handbook. 3rd Ed. Vol. 1. Wiley Handbook Series.
PURCHASE, D., 1962 A second report on bat-banding in Australia. CSIRO Aust. Wildl. Res. Tech. Pap. 2, 16 pp.
RANSOME, R.D., 1968 The distribution of the Greater Horse-Shoe Bat, *Rhinolophus ferrum-equinum* during hibernation, in relation to environmental factors. *J. Zool. Lond.* 54, 77-112.
RIDE, W.D.L., 1970 A guide to the native mammals of Australia. Oxford University Press, Melbourne.
RYAN, R.M., 1964 The type locality of the Australian horseshoe bat, *Rhinolophus megaphyllus*. *Aust. J. Sci.* 27, 259-60.
STEBBINGS, R.E., 1966 Bats under stress. *Studies in Speleology* 2, 103-108.
TATE, G.H.H., 1952 Results of the Archbold Expeditions. No. 66. Mammals of the Cape York Peninsula, with notes on the occurrence of rain forest in Queensland. *Bull. Am. Mus. Nat. Hist.* 98(7), 567-616.
VERSCHUREN, J., 1957 Exploration du Parc National de la Garamba. 7 Cheiropterès, Brussels.

TABLE 1.

Temperature and humidity ranges recorded in two maternity caves and three non-maternity sites of *R. megaphyllus*. Figures represent the range of measurements during the time period indicated for each locality.

	Maternity Caves			
	Maternity Site		Unoccupied Areas	
Locality	Temp. °C	Humidity (%)	Temp. °C	Humidity (%)
Humidicrib, Wee Jasper (N.S.W.) 1970-72	23-33	100	14-24	62-100
Sea cave, Durras (N.S.W.) 1970-72	17-31	64-100	13-20	45-78
	Non-maternity Roosts			
	Occupied Areas		Unoccupied Areas	
Anjuramba Mine (Qld.) 1970-72	20-22.2	85-95.5	17-20	76-95*
Thermocline Cave, Marble Arch (N.S.W.) 1971-73	12.2-15.0	88.5-100	8.9-13.5	72-76

* *R. megaphyllus* occasionally present.

TABLE 2.

Spot temperature and relative humidity records from a number of caves and mines in eastern Australia.

Locality	Date	Unoccupied Areas Temp. °C	Unoccupied Areas Humidity(%)	Roosting areas Temp. °C	Roosting areas Humidity(%)
Sites regularly used by *R. megaphyllus*					
Black Duck Cr. Mine (Qld.)	18.7.74	-	-	18.3	95.5
	20.9.70	-	-	18.0	-
	12.11.70	-	-	19.0	-
Ravensbourne Cave (Qld.)	18.3.72	-	-	22.0	95.5
Bendethera Cave (N.S.W)	27.11.74	15.0	86	20.2	100
Marble Arch (N.S.W.)	23.6.72	10.5	64	15.5	95 plus
	18.10.74	13.5	82	17.5	100
Cleatmore (N.S.W.)	12.5.73	11.0	80	15.2	95 plus
	15.12.73+	13.0	90	19.5	100
Wyanbene (N.S.W.)	18.10.65	15.0	-	21.0	-
Talwong Mine (N.S.W.)	12.3.72	-	-	23.0	-
Nargun's Cave, Nowa Nowa (Vic.)	7.12.74	14.0-15.5	91	15.5-17.0	84-93
Anticline Cave, Buchan (Vic.)	8.12.74*	15.5-16.0	85-94	17.0-17.5	95
Mooresford Cave (Vic.)	8.12.74*	13.4	94	16.1	89.5
Sites never or infrequently used by *R. megaphyllus*					
Bunya Mts. Cave (Qld.)	10.6.72	12.2	88		
Big Hill Mine, Pratten (Qld.)	30.7.74	17.8	78		
Mt. Fairy Cave (N.S.W.)	30.7.73	10.0	86.5		
	15.12.70	12.2	94.5		
Punchbowl Cave, Wee Jasper (N.S.W.)	28.6.65	12.8	83-87		
	13.9.65	11.6	94-96		
Dickson's Cave, Buchan (Vic.)	8.12.74	12.8	94.5		

+ *Miniopterus schreibersii* also present
* Roost unoccupied.

Figure 2. Details of three caves contining maternity sites of the bat *R. megaphyllus*.