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Helictite

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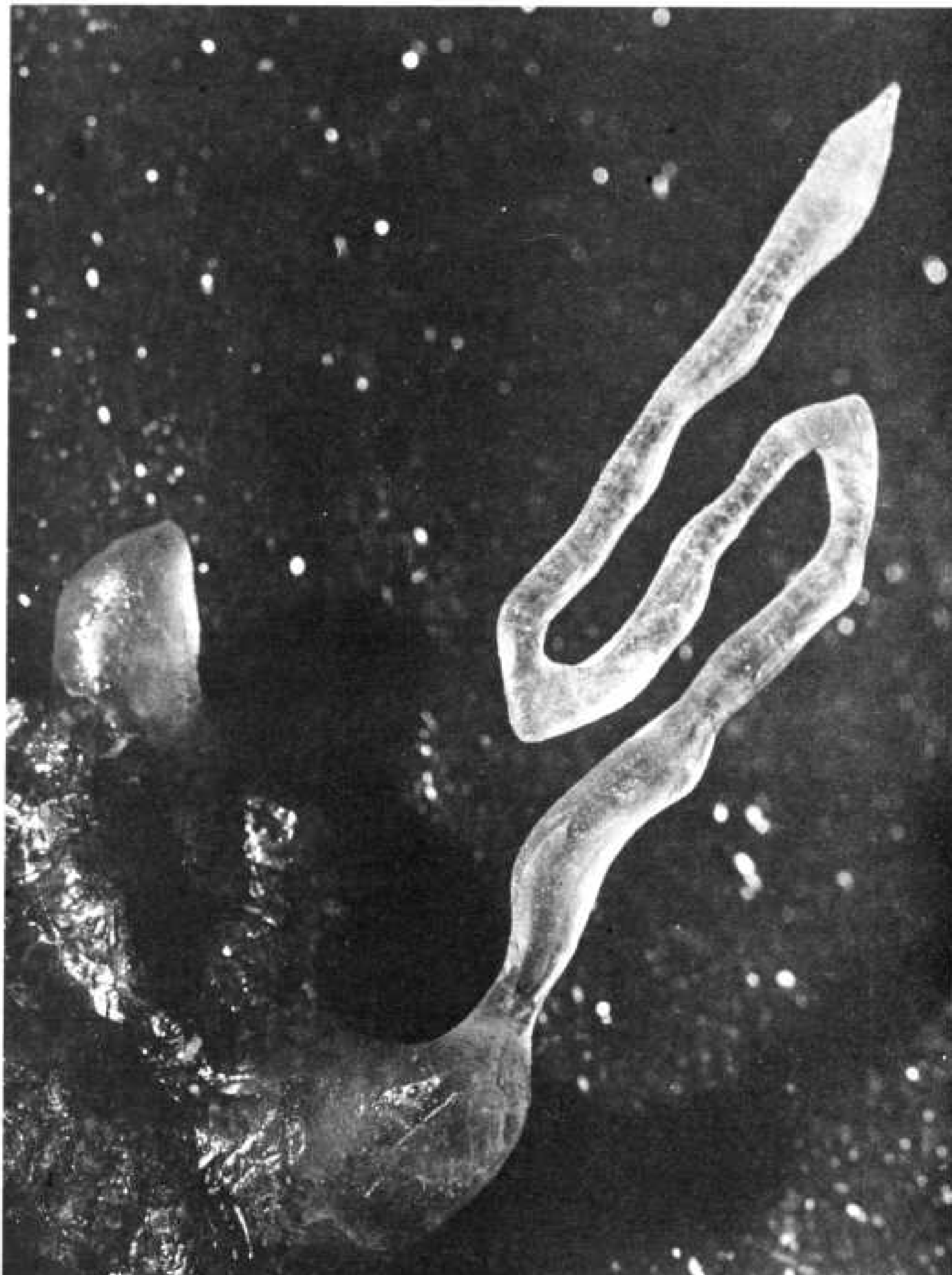

Helictite in Gem of the South formation, Temple of Baal, Jenolan, N.S.W.

Photo: A. HEALY

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" H E L I C T I T E "

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LUDWIG GLAUERT 1879-1963

One of Western Australia's best known naturalists died recently at the age of 84. Born in England, he arrived in Western Australia in 1908 and worked as a field geologist in the Geological Survey. In 1910, he transferred to the Western Australian Museum where he remained for 46 years. During that time he occupied positions as scientific assistant, keeper of ethnology and geology, Curator and finally Director.

His interest in palaeontology led him into many of the Western Australian caves, particularly those in the Margaret River area; but he also visited caves in the West Kimberleys and on the Nullarbor Plain. Between 1910 and 1948 he published many papers on fossilised vertebrate remains from these caves.

Glauert was awarded the Australian Natural History Medal in 1948, the Kelvin Medal for his contribution to science in 1954, the Carnegie Award in 1954, and received the M.B.E. in 1960. In 1953, he was made an Honorary Life Member of the Royal Society of Western Australia.

A B S T R A C T S

THE GEOLOGY OF YORKE PENINSULA. By A.R. Crawford. Bulletin No. 39, Department of Mines, Geological Survey of South Australia, 1965 : pp. 96, plus maps, text figures and 54 plates.

Comprehensive report based on two years field investigation and geological mapping of the Yorke Peninsula, South Australia. Contains much material on limestone and aeolianite in the area. All limestone areas are clearly shown on coloured maps and referred to in the text, although caves are not discussed. The report has much value to speleologists interested in the area. - E.A.L.

THE TAXONOMIC STATUS OF DASYURUS AFFINIS McCOY (1865)(DASYURIDAE) AND HYPSIPRYMNUS TRISULCATUS McCOY (1865)(MACROPODIDAE), TWO MARSUPIALS FROM A HOLOCENE CAVE DEPOSIT NEAR GISBORNE, VICTORIA. By J.A. Mahoney. Proc. Roy. Soc. Vict., 77, 1964 : 525 - 532.

Dasyurus affinis McCoy (1865) and *Hypsiprymnus trisulcatus* McCoy (1865) are recorded as junior synonyms of *Dasyurops maculatus* (Kerr 1792) and *Potorous tridactylus* (Kerr 1792), respectively. Some comments are made on the identity of a further three species, not specifically identified by McCoy, but included by him in his list of mammals from the Gisborne Bone Cave. Identification of these species is not effected. The year of issue of McCoy's list of mammals from the bone cave is stated by D.E. Thomas in a private communication, to be 1865. Available evidence supports the view that McCoy's fauna was modern. - A.M.R.

BREEDING CAVES AND MATERNITY COLONIES OF THE BENT-WINGED BAT IN SOUTH-EASTERN AUSTRALIA

By P.D. Dwyer*, M.Sc., and E. Hamilton-Smith**

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Summary

Eight breeding caves of Miniopterus schreibersi (Kuhl) are described from South Australia, Victoria, New South Wales and Southern Queensland, in terms of their structure, the location of nursery areas at which juveniles are deposited after birth, and their physical environments. Maternity colonies are found at these caves through spring, summer and early autumn. Established colonies range from about 15,000 to 200,000 bats at peak size. These individuals are predominantly adult females and their young. Adult males are conspicuous only at the single South Australian breeding cave. Births occur from approximately the beginning of December to mid-January at all colonies except that in South Australia, where a birth period is evident between mid-October and late November.

Artificial warming, as a consequence of bat activity, appears to be characteristic of these M. schreibersi breeding caves. It is suggested that this may have functional significance in facilitating adequate development of juveniles, and that the habit could be a reflection of the tropical ancestry of this species.

Introduction

The bent-winged bat, Miniopterus schreibersi (Kuhl), is the most abundant cave bat in south-eastern Australia (New South Wales, Victoria and South Australia). Here it is essentially coastal in distribution (Figure 1) and appears to be confined to areas that may be considered either humid or subhumid. Large colonies, sometimes numbering many thousands of individuals, have been recorded from a variety of natural caves and from man-made structures such as mines, adits, etc. (George and Wakefield, 1961; Purchase, 1962). Records of M. schreibersi in houses within this section of its range appear to be incidental, but Harrison (1962) notes it as a common house bat in the Innisfail area (lat. c 17°S).

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In north-eastern New South Wales, recruitment of young into the population occurs during the summer and involves large maternity colonies that are established in the spring and disband in autumn (Dwyer, 1963a). Each year the same few caves appear to function as sites for the maternity colonies.

The structure and physical environment of the eight known breeding caves are discussed, and their maternity colonies described in terms of size, sex/age composition, and the timing of reproductive events. For various reasons, the M. schreibersi breeding caves are visited infrequently. In consequence, the maternity colonies have been left relatively undisturbed.

Estimates of colony size are based on estimates of ceiling area occupied by clustered adults or juveniles, and on the ratio of lactating to non-lactating adults in samples taken randomly from the maternity colonies. The precision of such estimates is highly variable, and is not quantitatively assessable, but the general order of magnitude is considered satisfactory for comparative purposes.

Juveniles are aged on the basis of criteria, especially forearm length, suggested in Dwyer (1963a) and, where possible, yearlings and adults distinguished on pelage and reproductive criteria (Dwyer, 1963b).

BREEDING CAVES

Cave Structure and Nursery Areas

Plans of seven of the eight known breeding caves are given in Figures 2 and 3. Glen Lyon River Cave is not included. Ceiling areas where newborn juveniles have been deposited in numbers (i.e. nursery areas) are shown by crosses. Nursery areas are not marked in the Naracoorte Bat Cave. Willi Willi Bat Cave and Riverton Cave have been described previously (Dwyer, 1963a), but brief descriptions are included here.

(i) Riverton Cave (N.S.W./Q'ld Border).

This cave comprises a moderately large entrance chamber with an extensive south-western wing partially cut off, by walls and columns, from the rest of the cave. Running off the entrance chamber is a series of passages which join and provide access via low tunnels to a few small chambers. This entire extension is about 110 ft long. The roof of the south-western chamber is partially domed. A small, blind extension of this chamber served as the major nursery area in 1962-63 and 1963-64.

(ii) Glen Lyon River Cave (N.S.W./Q'ld Border).

This portion of the Glen Lyon cave system comprises a long, low stream passage about 4 - 5 ft high, that opens into a moderate-sized chamber about

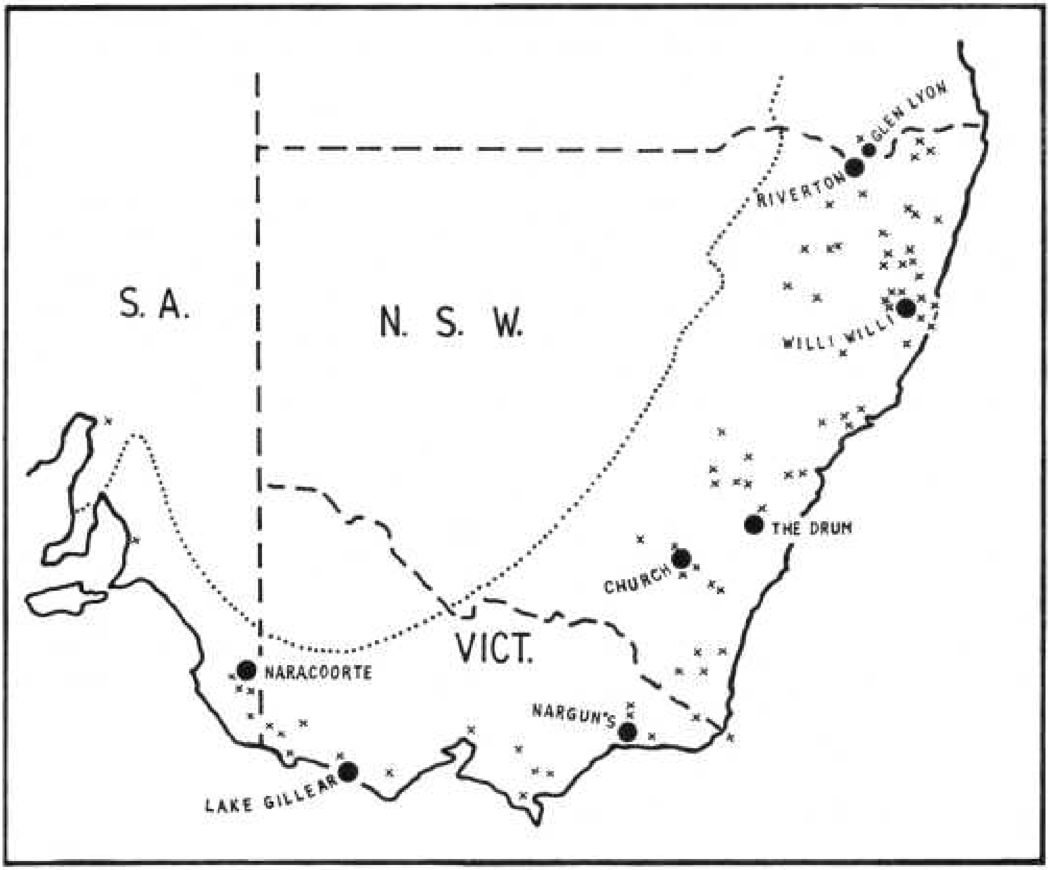


Figure 1. South-eastern Australia. Breeding caves of M. schreibersi are shown as spots, other distribution records are shown as crosses. The dotted line represents the western limit of the sub-humid zone (after Keast, 1959).

8 ft high. This chamber, which included the nursery area in December, 1963, is partially domed and opens directly to the surface at one end. The stream passage connects with the surface at three points.

(iii) Willi Willi Bat Cave (Kempsey, N.S.W.).

The Bat Cave is an inner chamber of an extensive system of the Willi Willi Cave Group. Access to this chamber is possible only through about 70 ft of narrow, and frequently low, stream passage that leads downwards from one wall of the main cave. This passage opens out to form the Bat Cave, a long and narrow chamber varying from 10 - 20 ft wide and about 120 ft long. Its height, in most portions, is less than 15 ft. Nursery areas have occurred in the upper section of this chamber in all three summer seasons that the cave has been visited - 1960-61, 1961-62 and 1962-63. Towards the end of the Bat Cave the roof becomes lower and the floor more broken, with a series of sinks and small lower-level extensions. Most of the chamber is in an advanced stage of decay with limestone blocks scattered over the floor.

(iv) The Drum (Bungonia, N.S.W.).

Access to this cave of the Bungonia system is via a wide, vertical shaft about 150 ft deep. From the bottom of the shaft a low, narrow passage leads downwards for about 100 ft to open out as a moderately large chamber. The height of this passage is less than 2 ft at several points. The first chamber leads to a further series of large chambers that have been followed to an estimated depth of 350 ft. In 1963-64, the nursery area was in a deep, irregular indentation of the roof, just beyond the first chamber.

(v) Church Cave (Wee Jasper, N.S.W.).

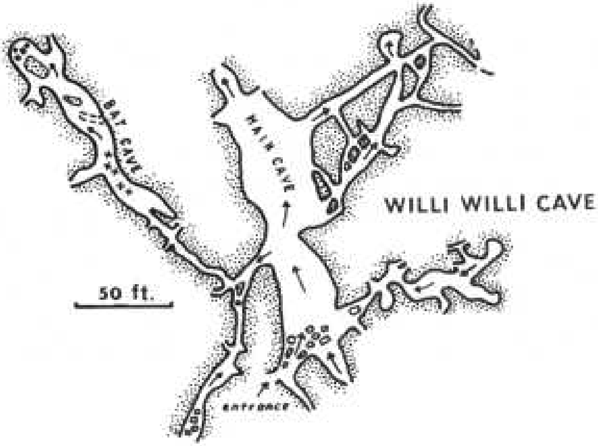
Entry to Church Cave is by a narrow cleft, about 30 ft long, that leads steeply downwards into the main chamber. At the back of it a narrow, vertical drop and a low tunnel provide access to the remainder of the system. In January, 1964, the nursery area was well beyond the tunnel at the end of a chamber about 50 ft long and 15 - 20 ft wide. The height of the breeding chamber is about 12 ft at the entrance and drops to below 6 ft in the nursery area. A long, low extension runs about 150 ft beyond the bat chamber and rises steeply to terminate as a small chamber.

(vi) Nargun's Cave (Nowa Nowa, Victoria).

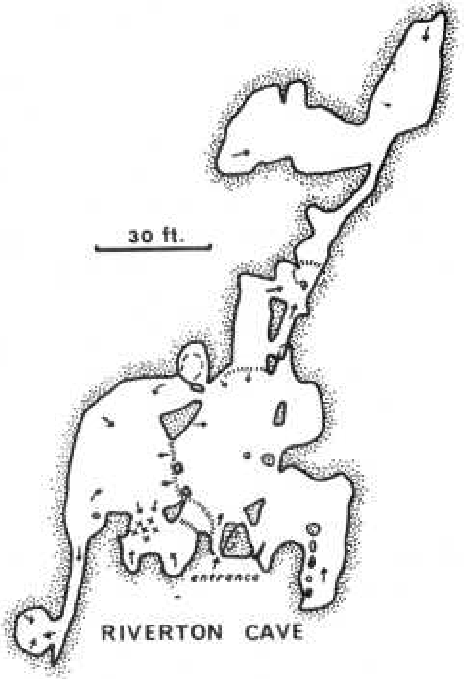
The cave occurs in extremely soft limestone of Tertiary age, and consists of a single long corridor about 3 - 4 ft wide and 20 - 30 ft high, with an opening at either end. The total length of the cave is 1,000 ft and the only large chamber is situated 750 ft from the upper entrance. This chamber is about 100 ft long, 30 ft wide, and with a maximum height of 60 - 70 ft. Its floor is higher than that of the remainder of the cave and comprises fallen blocks of limestone covered by a deep layer of guano.

Two nursery areas were present in January, 1964, and are marked on the map (Figure 3). The smaller area was in a shallow ceiling dome partly protected by a lip of the roof. The main nursery area (A - B) was inaccessible, being located in a chamber in the ceiling some 20 ft long by 10 ft wide and 10 ft above the general cave ceiling. The opening of this chamber to the cave corridor is only 4 ft by 10 ft, so that although part of the chamber is visible from the floor below, much is concealed from view. Inspection by means of a scaling pole in July, 1964, showed the whole inner surface of the high chamber to be deeply eroded. It is probable, therefore, that the entire ceiling is covered with bats during the maternity season.

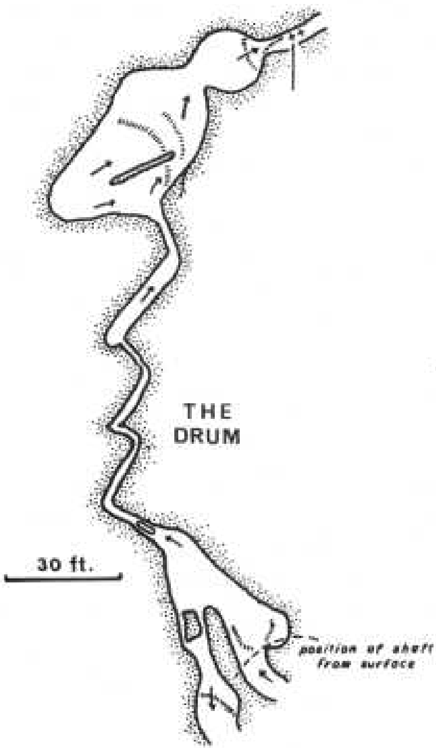
Figure 2 (opposite). Breeding Caves. Nursery areas shown by crosses. The Drum nursery area is shown by a line - top right.



BAT CAVE
MAIN CAVE
WILLI WILLI CAVE
50 ft.
entrance



30 ft.
entrance
RIVERTON CAVE



THE DRUM
30 ft.
position of shaft from surface

A
B
A
B
30 ft.
entrance
CHURCH CAVE

(vii) Lake Gillear Guano Cave (Warrnambool, Victoria).

The Lake Gillear Guano Cave is of massive proportions, but is relatively simple in structure. A large outer chamber, about 20 ft high and 60 ft wide, leads in from sea cliffs for about 160 ft to a ramp that slopes downwards for a similar distance to an inner chamber and thence to the two huge bell-like chambers that characterise the system. These chambers are 150 ft high and open at several apical points to the surface. A number of deep ceiling domes are a feature of these two chambers. At the base of the ramp there is a comparatively small side chamber that Gill (1948) refers to as Recess 2. Minor aggregations of very young *M. schreibersi* were observed in this recess in December, 1960, and late November, 1963 (J. Edge and F. Sheriff, personal communication).

(viii) Naracoorte Bat Cave (Naracoorte, South Australia).

This cave is also of relatively simple structure. A surface collapse gives entry to a tunnel about 30 ft high and 450 ft long. Several minor extensions and chambers occur, but the major chamber of the cave, at the end of the entry tunnel, is a huge domed room with a 90 ft high ceiling. The ceiling has a large number of depressions, from 4 ft to 8 ft in diameter, and as much as 8 ft deep. Two smaller chambers open off this room and appear to be of secondary importance, although often used by the bats.

During the maternity seasons from 1955-56 to 1963-64, virtually all bats were in the main chamber. Nursery areas apparently occurred in the high ceiling domes, for dead juveniles were found below several of these.

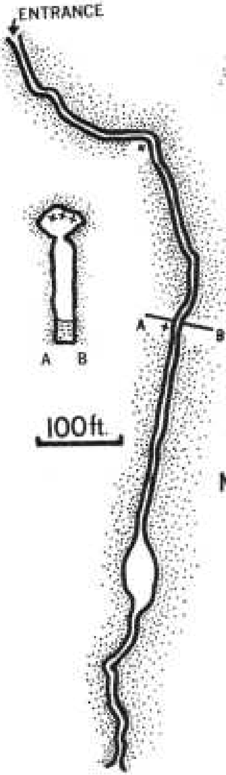
Physical Environment

(i) Guano Deposits.

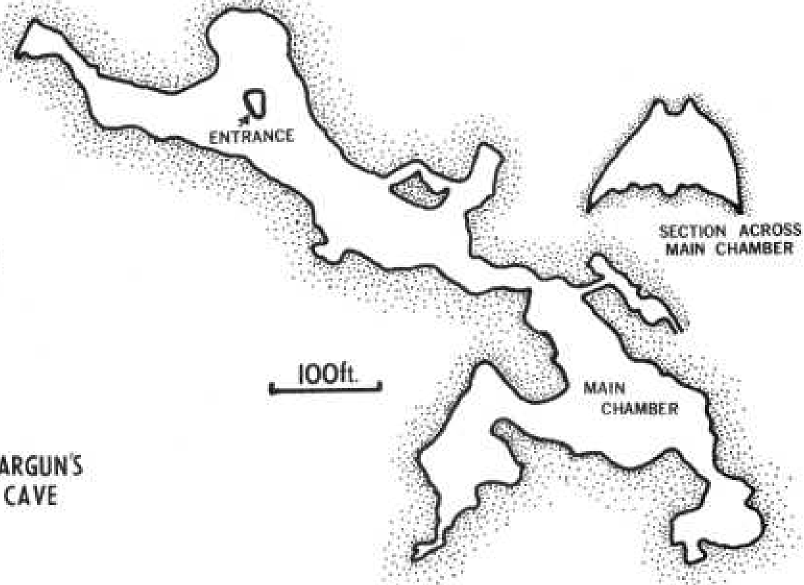
Guano deposits are extensive and deep in all breeding caves except Glen Lyon River Cave. Fresh guano deposits in these caves are generally very moist, and may be merely a liquid slush below clustered young (Dwyer, 1963a). In Glen Lyon River Cave, a permanent stream runs through the breeding chamber. The cave floods from time to time and consequently little guano remains. At Willi Willi, a small stream runs through the Bat Cave during periods of heavy rain washing small guano accumulations from the upper portions. However, large quantities of guano occur towards the end of the chamber. A similar, intermittent stream occurs in The Drum at Bungonia.

A stream running the length of Nargun's Cave is only a few inches deep, below the main entrance, but becomes nearly 5 ft deep beyond the large

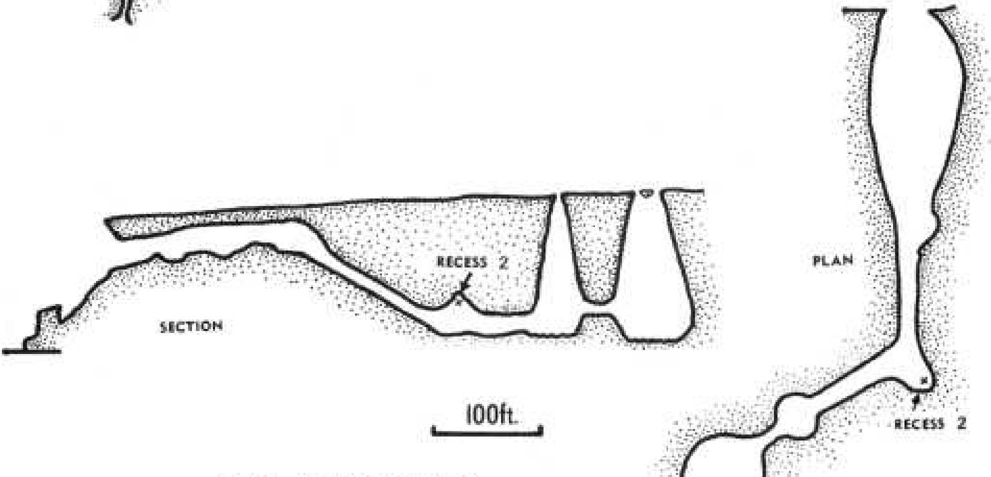
Figure 3 (opposite). Breeding Caves. Known nursery areas shown by crosses. Cross-sections for Nargun's Cave and Naracoorte Bat Cave are sketches only.



NARGUN'S CAVE



NARACOORTE BAT CAVE



LAKE GILLEAR GUANO

chamber. The surface 6 - 9 in. of this stream is a foul-smelling, viscous soup of rotting vegetation and freshly fallen guano. Rockfall and guano have raised the floor level of the chamber so that the stream temporarily vanishes from view. A huge bank of soft guano slopes steeply downwards from high on one wall of the chamber.

No streams or standing pools occur in the remaining breeding caves. The fresh guano in Lake Gillear Guano Cave dries fairly rapidly. Riverton is relatively dry also, except immediately below the nursery area.

(ii) Atmosphere.

High humidity and an intensely ammoniated atmosphere characterise all the breeding caves, except Lake Gillear Guano Cave, at least while the maternity colonies are present. At Willi Willi Bat Cave these characteristics persist throughout the year, but are less marked in winter. In summer they may be so intensely developed, particularly if the stream is not active, that breathing becomes difficult and vomiting may be induced. At Riverton the atmosphere of the cave is not unpleasant in winter. The absence of these conditions at Lake Gillear Guano Cave is apparently due to the continuous circulation of air permitted by the surface openings in the domes of the two large chambers.

In addition, "foul air" (i.e. air rich in carbon dioxide) is a characteristic feature of the Drum Cave and of Church Cave, and has frequently made impossible summer visits to inspect their bat populations (B. Dew and D. Purchase, personal communication). Foul air, however, is not necessarily due to the presence of bats in the caves for it is known in high concentrations from caves that do not support colonies of bats, e.g. the Gas Pipe, Wellington Caves, N.S.W. (Lane and Richards, 1963).

(iii) Temperatures.

At Willi Willi, temperatures have been recorded over two years by maximum/minimum thermometers placed in the main chamber, the passage to the Bat Cave, and in the Bat Cave itself. Temperatures in the main chamber have varied from about 15°C in winter to 18.3°C during January. In the passage and the Bat Cave, however, temperatures are conspicuously higher, ranging from 15.6 - 21.7°C in the passage, and from 18.3 - 27.8°C in the Bat Cave. Periods of low and high temperature match those of the main chamber. The lower portions of the Bat Cave, beyond the nursery areas, are always noticeably cooler than the upper portions near the entrance from the passage. Daily fluctuations of temperature occur in the passage and Bat Cave during the spring and summer and are apparently correlated with peak periods of bat activity.

In December, 1963, air temperature at Riverton, 2 ft below the clustered young, was 20.5°C, while the temperature recorded with the bulb of the thermometer touching the young was 30.5°C. In late March, 1963, air temperatures taken through the outer portions of the system ranged from 21.5 - 22.25°C, while in May, 1962, well after the bats had deserted the cave, temperature was about 17.25°C.

At Glen Lyon River Cave temperatures were taken on December 7, 1963, while the maternity colony was still present. These were 18.75°C about 3 ft below the roof of the breeding chamber, and 19.5°C and 21.5°C respectively 6 in. below two groups of clustered young. Temperatures within a nearby enclosed cave on the same date ranged from 15.75 - 16.25°C.

In February, 1963, temperature inside the entrance to The Drum, near the top of the shaft, was 13°C. No readings were taken in the breeding chambers, but the air was conspicuously warmer than in the outer portions of the system. On December 14, 1963, the temperature at the top of the shaft was 12.5°C, and a reading taken 20 ft below the clustered juveniles was 16.5°C.

Readings in the breeding chamber at Church Cave on January 18, 1964, were 23°C at the entrance to the chamber, 23.75°C 2½ ft below the juvenile masses, 27.5 - 30°C between 3 and 6 in. from the juveniles, and 39.25°C inside the mass.

On January 15, 1964, at Nargun's Cave, a reading of 16.1°C was taken about 15 ft below the first mass of juveniles in the passage, and a reading of 18.3°C at about half-height in the large chamber.

At Lake Gillear Guano Cave on January 12, 1964, air temperature was 15.25°C in the first large chamber and 15.5°C 2 ft below the ceiling of Recess 2.

Temperatures have been taken at Naracoorte Bat Cave on several occasions. In October, 1956, a reading of 25.6°C was obtained in the large breeding chamber. At this time a recording thermograph placed in the entrance passage, where the temperature during the day-time was approximately 20°C, registered an increase of about 1°C during the emergence flight. The October, 1956, reading was the highest obtained. Other readings in the breeding chamber ranged from 16.7°C in winter months to 21°C during December and January. It is probable that the high doming of the chamber means that higher temperatures occur near the ceiling. Temperatures taken in other caves of comparable size in the Naracoorte area have ranged from 11°C in winter months to 15.5°C in summer.

MATERNITY COLONIES

Birth Periods and Age Segregation of Juveniles

From data collected at Willi Willi Bat Cave and Riverton Cave in the summers of 1960-61 and 1961-62 it was concluded that the birth period extended from about December 5 to January 5 (Dwyer, 1963a). A single, exceptionally late birth was recorded from Willi Willi on about January 23, 1962.

Other birth dates have been estimated by aging juveniles, either according to forearm lengths or, for larger individuals, according to whether or not large numbers joined the evening flights (Dwyer, 1963a). Results for different maternity colonies are summarised in Table 1.

TABLE 1 : BIRTH PERIODS FOR MATERNITY COLONIES

Maternity Colony	Summer	Earliest Birth Date	Latest Birth Date
Riverton	1962-63	Dec. 4, 1962	–
Riverton	1963-64	Dec. 1, 1963	–
Glen Lyon	1963-64	Dec. 2, 1963	–
Willi Willi	1962-63	–	<Jan. 1, 1963
Bungonia	1962-63	Very early Dec. 1962	Very early Jan. 1963
Bungonia	1963-64	Very early Dec. 1963	–
Wee Jasper	1963-64	First week Dec. 1963	Jan. 19, 1964
Nowa Nowa	1963-64	First week Dec. 1963	Jan. 13, 1964
Naracoorte	1963-64	Mid-late Oct. 1963	c.Nov. 25, 1963

No juveniles were captured at Warrnambool in January, 1964, although many old and dried juvenile carcases had accumulated on the floor against walls. Four juveniles collected by Mr. J. Edge yielded the following data: two on December 30, 1960, had forearms of 19.2 mm (c. 5 days) and 44.6 mm (c. 13 days); one on December 8, 1962, had a forearm of 15 mm (1 day); and one on November 24, 1963, had a forearm of 15.3 mm (1 day). About 300 juveniles were present on the ceiling of Recess 2 in late November, 1963. Although extremes of birth dates cannot be assessed, this data does indicate a birth period from, at least, late November to late December.

A birth period of 1 - 1½ months is evident for all maternity colonies. This begins late in November, or very early December, except at Naracoorte. The longest periods (1½ months) are associated with the largest colonies, i.e. Wee Jasper and Nowa Nowa. The birth period at Naracoorte is strikingly different from that occurring elsewhere, the last young being born before births are initiated at other maternity colonies. Observations in 1962 and 1963 indicated that all Naracoorte juveniles had dispersed from the maternity colony by the end of February. At Wee Jasper and Nowa Nowa, however, the youngest individuals cannot fly from the cave until late March.

At Riverton, in February, 1962, the youngest juveniles in the cave were segregated from older individuals (Dwyer, 1963a). Similar segregation of different age groups of juveniles was very conspicuous at Church Cave in January, 1964. Virtually all the juveniles were present as a single continuous mass, but within this overall mass specific areas included individuals of approximately equivalent age. The youngest individuals were present at the edge of the cluster, or were in a small isolated cluster of about 75 individuals about two yards from the main mass. A tendency to deposit all young within a single cluster could lead to younger individuals occurring near the edge of the cluster. Segregation of this type could also reduce juvenile mortality for it would presumably decrease the chances of small individuals being knocked off the roof by larger and more active individuals. Similar segregation has not been observed at any other maternity colony. It does not appear to occur at Willi Willi, but cannot be discounted for any other colony.

Peak Size and Structure

Seasonal changes in the size and sex/age composition of the Willi Willi maternity colony have been discussed by Dwyer (1963a). Peak colony size occurs in late December and January and involves about 12,000 adult females, their young, and about 1,000 year-old bats, most of which are female. Adult males are conspicuous by their absence. Through the spring, year-old individuals are relatively numerous, but most have gone by late January.

Comparative estimates of peak colony size for all maternity colonies are given in Table 2 on the next page. The estimates for Willi Willi and Riverton are certainly the most reliable figures given. Those for Warrnambool and Naracoorte would be the least reliable. The tremendous size of these caves and the height at which most of the bats clustered rendered estimation of clustering areas difficult. Naracoorte is, however, by far the largest of the maternity colonies.

The Glen Lyon colony was only observed on December 7 - 8, 1963. Insufficient fresh guano was present at the cave to suggest that the maternity colony had been established since early spring (September-October). This cave had not functioned as a breeding cave in either 1961-62 or 1962-63. By February, 1964, no *M. schreibersi* were present in the cave. The maternity colony had proved unsuccessful. Several records of banded bats in December, 1963, indicated that the bats present at Glen Lyon River Cave were part of the population usually found at the Riverton Cave. Whether the attempted satellite maternity colony was due to an increase in overall population size beyond the capacity of Riverton Cave is not known. Dwyer's impression was that the combined colony size in December, 1963, was greater than the size of the Riverton colony alone in the two previous summers. Disturbance at Riverton Cave could be ruled out as a reason for transfer to Glen Lyon River Cave because apparently no-one had visited Riverton Cave since early spring.

TABLE 2 : PEAK SIZE OF MATERNITY COLONIES

Maternity Colony	Estimated Peak Size of Colony (Includes Juveniles)	Est. Month of Peak	Summers of Estimates
Riverton	15-20,000	Jan.	1961-62,62-63,63-64
Glen Lyon	c5,000	Dec.	1963-64
Willi Willi	25,000	Jan.	1960-61,61-62,62-63
Bungonia	15,000	Jan.	1962-63.63-64
Wee Jasper	60,000	Jan.	1963-64
Nowa Nowa	60,000	Jan.	1963-64
Warrnambool	10-20,000	Jan.	1963-64
Naracoorte	100-200,000	Nov.-Dec.	1963-64

At Riverton, year-old individuals were well represented in early December samples, with females predominant, but were not taken in a February sample of over 400. The sex and age composition for Bungonia, Wee Jasper and Nowa Nowa (Table 3, page 15) is apparently similar to that of Willi Willi and Riverton in that the vast majority of the non-juvenile bats are adult females, and adult males are characteristically absent. At Bungonia, most of the yearlings handled were male and relatively large numbers were still present at the colony even in March. Most of the yearlings taken at Wee Jasper and Nowa Nowa in January, 1964, were female. No sample was obtained at Warrnambool.

For Naracoorte, two small samples mist-netted during evening emergence are shown separately in Table 3. Some segregation of sexes into different clusters was established for this colony, and this, combined with the very large size of the colony, means that hand-netted samples may well be biased. However, combined figures for September-February samples are also shown. These data suggest that the Naracoorte colony is structurally different to all other maternity colonies. The approximate equivalence of sex ratio may mean that virtually all the bats in the area move to Naracoorte Bat Cave during spring and summer. This is supported by the apparent desertion of other caves throughout the south-east of South Australia.

Year-old males could not be separated from older males at Naracoorte for no differences in teste sizes was evident. However, the high ratio of yearling to adult females, in the single sample where these age classes were separated, might imply that population turnover is considerable for the Naracoorte population. Clearly this requires more information, for it

TABLE 3 : SEX AND AGE COMPOSITION OF MATERNITY COLONIES

(Juvenile Bats Excluded)

Maternity Colony	Sampling Dates	Sample Size	Percentages: Year-old Males	Percentages: Year-old Females	Percentages: Adult Females
Bungonia	Feb., Mar., Dec., 1963; Mar., 1964	637	8.7	4.8	86.5
Wee Jasper	Jan. 19, 1964	122	-	3.2	96.8
Nowa Nowa	Jan. 15, 1964	121	2.5	13.2	84.3

			Year-old and Adult Males	Year-old Females	Adult Females
Naracoorte (mist-netted samples)	Jan. 9, 1964	46	45.7	23.9	30.4
	Nov. 11, 1961	46	60.9	39.1	
Naracoorte (hand-netted samples)	Nov., 1961 Sept.,Nov., 1962 Feb., 1963	1234	50.3	49.7	

is also possible that on this occasion a large number of adult females had already left the cave. This could hold, since many juveniles were already on the wing and some were certainly joining the evening flight. Even if this were so, however, the Naracoorte colony still appears to include, proportionately, far more yearlings than occur at other maternity colonies at a corresponding time of the year, while the presence of many adult males at Naracoorte remains a unique characteristic.

OTHER BAT SPECIES

Species of bat, other than *M. schreibersi*, occur at all the recorded breeding caves except for Naracoorte Bat Cave and Lake Gillear Guano Cave.

The eastern horse-shoe bat, *Rhinolophus megaphyllus* Gray, is present casually at Glen Lyon River Cave. The Drum and Church Cave, and establishes maternity colonies of several hundred individuals at Riverton Cave, Willi Willi Bat Cave and Nargun's Cave.

A maternity colony of several thousand little bent-winged bats, Miniopterus australis Tomes, has been present at Willi Willi Bat Cave each summer from 1960-61 to 1963-64.

DISCUSSION

One of the principal characters of the subterranean region is the uniformity of the conditions found there. The structural characteristics of caves play a major role in determining internal meteorological conditions. Although relative humidity, air currents and temperature fluctuate to a limited extent, the cave environment is buffered from extreme variations. The larger and more enclosed a cave is, the greater the extent of buffering. Temperatures in the inner chambers of some large caves may hardly fluctuate from the local annual mean temperature for the sub-soil in which the cave is situated. On the other hand, caves with several entrances that readily permit circulation of air, may show conspicuous seasonal changes in temperature to match surface trends (Richards, 1962).

Temperatures in the extremely enclosed chambers of Willi Willi Bat Cave, The Drum and Church Cave should remain relatively constant throughout the year, and the expected temperatures should be near the local annual means. These are 18.8°C, 13.9°C and 14°C respectively. (See Table 4). Naracoorte Bat Cave is also very enclosed, but the extremely large entrance passage to the breeding chamber should permit some fluctuation. Annual mean temperature for Naracoorte is 13.9°C, and in summer a slight upward trend would be expected. Riverton Cave and Nargun's Cave are only moderately enclosed. Summer temperatures should therefore exceed the annual means (19.9°C and 13.9°C, respectively) but would probably not reach the respective summer averages of 26.5°C and 15.6°C. The expected Riverton temperatures given here are probably too high as the recording station used is some distance to the west. Perhaps a fairer indication of annual mean is given by the cave temperature of 17.25°C recorded in May, 1962. This could be slightly low. At Glen Lyon River Cave, expected temperatures would be somewhat lower than those of Riverton. Finally, the large main entrance to Lake Gillear Guano Cave, and the apical openings in the domed chambers of this cave, imply that air currents, and consequently temperature changes, must be considerable. In January, 1964, the draught from the apical openings was moderately strong. Thus summer temperatures here might rise well above the annual mean (13.6°C) and towards the summer average of 16.7°C.

A comparison of the actual temperatures recorded at breeding caves, particularly the summer temperatures, with the expected values derived above reveals some striking differences. This applies particularly for Willi Willi Bat Cave, Church Cave and Naracoorte Bat Cave. For these three caves, summer temperatures are above 20°C, and may reach almost 28°C, yet the expected temperatures do not exceed 18.8°C. In fact, at Naracoorte Bat Cave, the highest temperature (25.6°C) was recorded in October and is 12.3°C

TABLE 4

SEASONAL AND ANNUAL MEAN TEMPERATURES FOR STATIONS NEAR BREEDING CAVES

Readings, given in °C, are based on 20 year averages from the records of the Bureau of Meteorology (1956)

Breeding Cave	Station	Summer DFJ	Autumn MAM	Winter JJA	Spring SON	Annual Mean
Riverton and Glen Lyon River Cave	Goondiwindi	26.5	19.9	12.4	20.7	19.9
Willi Willi Bat Cave	West Kempsey	23.2	19.0	13.2	18.9	18.8
The Drum	Goulburn	20.1	14.0	7.3	13.9	13.9
Church Cave	Yass	21.1	14.1	7.1	13.6	14.0
Nargun's Cave	Orbost	15.6	14.4	9.5	13.6	13.9
Lake Gillear Guano Cave	Warrnambool	16.7	14.3	10.2	12.9	13.6
Naracoorte Bat Cave	Naracoorte	17.6	14.5	10.3	13.3	13.9

higher than the mean spring temperature. At The Drum and Nargun's Cave, recorded summer temperatures are some 4°C higher than expected, but are below 20°C. For the remaining three caves, actual summer temperatures observed approximate the expected values. However, autumn values for Riverton Cave are higher than expected, and the values at Glen Lyon River Cave are clearly above those for a nearby cave that was not occupied by large numbers of bats.

Dwyer (1963a and 1963c) suggested that high temperatures were the rule at maternity colonies of M. schreibersi and implied (Dwyer, 1964) that such temperatures would exceed 20°C. This rather enthusiastic generalisation is not fully supported by the data above. However, the important point is that summer temperatures at breeding caves (except Lake Gillear Guano Cave) generally exceed the expected values. This anomaly can only be explained if the activity of bats within the breeding caves is, in fact, raising air temperature.

The effect of bat activity on air temperature in the caves would vary according to the size of the maternity colony and cave structure. In relatively small chambers with moderately large or large maternity colonies (Willi Willi Bat Cave and Church Cave), heated air would dissipate slowly.

The rather low height of the chambers would mean that all the air, from floor to ceiling, would be warmed. This last point might be quite significant. Thus, although the extremely large maternity colony at Naracoorte Bat Cave warms the entire cave, the great height of the breeding chamber could produce a considerable ceiling to floor temperature gradient. Similarly, temperatures recorded at The Drum and Nargun's Cave may be several degrees lower than temperatures within the pockets where the bats cluster. The Drum is of considerable size and could not conceivably be warmed significantly by the relatively small maternity colony occurring there. An increase of 4°C over expected temperature, at a point 20 ft below the nursery area, indicates much higher temperatures in the nursery area. Similarly, at Nargun's Cave, very large numbers of bats were clustered in a ceiling chamber that would serve as an ideal trap for warm air.

If high air temperature has functional significance at maternity colonies, and is not merely an accidental consequence of colony size and cave structure, then the temperatures actually recorded at Lake Gillear Guano Cave are not relevant. At this cave the bats cluster in deep ceiling domes and the juveniles were apparently sometimes born in Recess 2. These sites would facilitate retention of warm air.

It is possible that metabolism of large numbers of bats, and particularly of large numbers of juveniles that remain clustered in the cave night and day for nearly three months, produces this increase in temperature. However, the structural characteristics of three of the breeding caves suggest strongly that high temperature does have functional significance. Thus at The Drum, Willi Willi Bat Cave and Church Cave, access to the breeding chamber is only possible via low and narrow passages or through very small openings. Similar structural features are not encountered at cave and mine colonies occupied by colonies other than maternity colonies. M. schreibersi typically avoids sites whose access necessitates intricate manoeuvring.

Thus, for all breeding caves, there is some evidence that either the entire cave, or the specific areas selected as nursery areas, are (or could be) conspicuously warmed by the heat produced during bat activity. In south-eastern Australia, cave temperatures in excess of 20°C only occur at maternity colonies of M. schreibersi, and here the temperatures must be a consequence of the activity of bats. Finally, the conditions of access to some breeding caves is strongly indicative of specific selection related to the needs of maternity colonies. Consequently, it is concluded that the high temperatures experienced at maternity colonies are essential to at least some phase of the series of events that occur there. At birth, juvenile M. schreibersi only weigh about 2.5 - 3.0 g (Dwyer, 1963a) and therefore they approach the minimum weight at which a homeotherm can regulate its body temperature (Lasiewski, 1963). It is likely that the function of high temperatures in breeding caves is to provide incubator-like conditions that facilitate adequate early growth of young. Where cave structure does not readily lend itself to retention of warmed air, behavioural traits could compensate. For example, if adult bats clustered with their young for longer periods at such caves, incubation during the early phases of juvenile growth would still be accomplished. There is, however, no evidence of this.

High temperatures resulting from bat activity are also characteristic of the breeding caves of the American free-tailed bat, Tadarida brasiliensis mexicana (Saussure) (Henshaw, 1960; Herreid, 1962; Davis, Herreid and Short, 1962). The maternity colonies of this species are measured in millions and may, in fact, reach as many as 20 million. Recorded temperatures at these caves range between 25 - 38°C and, therefore, approach the experimentally determined lethal limit for the species (Herreid, 1962). Davis, Herreid and Short (1962) have described the general characteristics of T. b. mexicana guano caves (= breeding caves) as follows: "They are large enough to allow millions of the animals to find hanging space on the walls and ceilings. Their large rooms have domed ceilings (minimum dimensions about 20 yards wide by 20 yards long and by 10 yards to top of dome). Access to the high-ceilinged rooms is afforded by large entrance passages (minimum dimensions about 30 ft wide by 15 ft high...)." This characteristic doming of the large breeding chambers would be readily amenable to heat retention when colony size is extremely large (c.f. Naracoorte Bat Cave). In the same paper, the authors suggest that "the dense clustering in the nursery areas may be useful in maintaining body heat and promoting growth. Perhaps the usefulness of the huge aggregations of adults built up in each guano bat cave during birth and rearing lies primarily in the maintenance of incubator temperatures through mass radiation of body heat. This radiation could be effective both through increased air temperatures in the cave and through conductive transfer from body surface to body surface...The general excess of bat body temperature over cave air temperatures suggested that body surface to body surface conduction of heat may be the main channel of heat transfer among bats in clusters."

It is clear for M. schreibersi, too, that the body temperature of clustered juveniles is higher than the general air temperature of the cave. The occurrence at Willi Willi of the first juvenile M. schreibersi within a cluster of juvenile R. megaphyllus (Dwyer, 1963a) certainly reflects the value of body surface contact. However, the artificial increase in cave temperature could conspicuously decrease the rate of body heat loss amongst clustered juveniles, particularly very young individuals, during the nocturnal absence of the adult bats. Similarly, since adult bats at maternity colonies do not appear to lower body temperature significantly during the day (Dwyer, 1964), energy economy could be achieved by this increase in cave temperature.

Both T. b. mexicana and M. schreibersi appear to be of tropical origin. T. b. mexicana does not invade the higher, colder latitudes of North America and, before winter, migrates from the northern portions of its range towards the tropics (Villa and Cockrum, 1962). M. schreibersi, however, is a non-migratory species that has evolved local wintering mechanisms (Dwyer, 1964). It is probable that the artificially raised temperatures encountered at breeding caves of these species reflect their tropical ancestry. Presumably the long-accustomed ancestral temperature environment of growing young could not be abandoned and, as the species expanded into subtropic and temperate latitudes, or were faced with contraction of more widespread tropical areas, they were forced to increase maternity colony size, or to select special breeding caves, or both.

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Miss Dew also supplied information on the Bungonia maternity colony. J. Coventry of the National Museum, Melbourne, assisted with information on Nargun's Cave.

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EDITOR'S NOTE

The authors of the above paper have been independently studying the biology of *M. schreibersi* for several years, Dwyer concentrating his activities in New South Wales, and Hamilton-Smith in South Australia and Victoria. The authors visited several of the breeding caves together in 1964. Dwyer, during the course of his studies, has visited all the known breeding caves at times when the maternity colonies were well-established. Since April, 1963, Dwyer has held a Reserve Bank of Australia 50th Anniversary Post-Graduate Scholarship. Work at Naracoorte by Hamilton-Smith has been assisted by a grant from the M.A. Ingram Trust towards the cost of equipment.

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A B S T R A C T S

TWO SPECIES OF THE EXTINCT GENUS STHENURUS OWEN (MARSUPIALIA, MACROPODIDAE) FROM SOUTH-EASTERN AUSTRALIA, INCLUDING STHENURUS GILLI sp. nov. By D. Merrilees. J. Roy. Soc. W. Aust., 48(1), 1965 : 22 - 32.

A new species of Sthenurus, S. gilli Merrilees, smaller than any so far known, is described from deposits near Strathdownie, Western Victoria. These deposits are of presumed Pleistocene age. A variant of S. gilli occurs in Haystall Cave, Naracoorte, South Australia, and the species may have ranged into Western Australia. A Sthenurus lower permanent premolar described and figured by Lundelius in 1963 from Madura Cave on the Nullarbor Plain, resembles S. gilli very closely.

A second (larger) species of Sthenurus, resembling S. occidentalis Glauert described from Mammoth Cave deposits in Western Australia, occurs in the Strathdownie deposit. The Haystall Cave deposit also contains a second species of Sthenurus resembling S. occidentalis. The taxonomic relationships of the larger Strathdownie species, the larger Haystall Cave species, S. occidentalis and S. oreas from the Darling Downs, Queensland, are to be considered by the author in a later paper. It is suggested that they could all represent geographical variants of a wide-ranging species which once included Western Australia in its range.

The Strathdownie deposit occurs in a limestone ridge extending from Casterton to Mt. Gambier. It is believed to have been subjected to cave formation during the latter part of the Pleistocene. The rich and varied marsupial remains were found in red "cave earths" revealed by quarrying.

The Haystall Cave specimens were recovered from a red to yellow sandy deposit at depths up to 2 ft 6 in. The specimens are probably approximately contemporaneous and of late Quaternary age. These specimens were presented to the South Australian Museum by the Cave Exploration Group (South Australia). - A.M.R.

FIRST NEW GUINEA RECORD OF THYLACINUS. By H.M. Van Deusen. J. Mammal., 44(2), 1963 : 279 - 280.

In April, 1960, during the course of an archaeological expedition to the Eastern Highlands of New Guinea, the left half of a mandible of Thylacinus (Tasmanian wolf) was excavated from the floor of a rock shelter at Kiowa, three miles from the Chuave Government Station, and approximately 5,000 ft above sea level. The rock shelter is at the entrance to an extensive series of limestone caves. The mandible was found between 9 - 10 ft below the surface in association with other bone material, pebble-tools and large and small flake implements. This remarkable discovery is the first evidence of the occurrence of Thylacinus on the island of New Guinea, although it is known to have ranged widely on the Australian continent in the Pleistocene. - A.M.R.

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