The Large Bent-wing Bat *Miniopterus schreibersii* in Urban Environments: a survivor?

Glenn Hoye[1] and Julie Spence[2]

[1]Fly By Night Bat Surveys Pty Ltd, PO Box 271, Belmont, New South Wales 2280.

email: fbn@primus.com.au

[2]12 Kastelan Street, Blacktown, New South Wales 2148

ABSTRACT

The Large Bent-wing Bat *Miniopterus schreibersii* has often been perceived as a native species thriving in our rapidly expanding urban landscape. We used a number of historical and current data sets to assess whether this perception is supported by direct evidence. Investigation of museum records revealed that it was present within inner Sydney from at least 1892. Even at this time it was utilising human structures, including the cellar of Elizabeth Bay House. An examination of both historical and current use of diurnal roosts suggests that there has been a recent possible change in the structure of populations using the Sydney metropolitan area, Australia's largest urban landscape. All roosts examined since 1995 are occupied from March to September and are vacant over the summer months. This contrasts with the only roost prior to 1995 that has been studied in any detail. Banding records indicate that a disused railway tunnel at North Sydney was occupied during most months of the year until its abandonment by bats during the 1980s. It also was known to, at times, accommodate double the maximum number of bats recorded in any roost investigated since 1995. Investigation of injury rates in urban populations provides evidence that they are indeed under stress, suffering increasing rates of injury through the winter period, unlike populations in roosts away from urban influence.

Key words: *Miniopterus schreibersii*, urban bats, bat injuries, urban bat roosts.

Introduction

The Large Bent-wing Bat *Miniopterus schreibersii* is without doubt the most thoroughly studied Australian microchiropteran bat species. Investigations undertaken primarily during the 1960s concentrated on population structure, breeding behaviour, seasonal movement and a range of other facets (Dwyer 1963 to 1971). These studies provide an understanding of the general behaviour, reproductive and social requirements of this most regularly encountered cave-roosting bat. Despite these studies, major gaps in our knowledge of this bat exist. For example, it is not known whether populations are stable, in decline or increasing.

This bat is typically found in well-timbered areas where it forages above the tree canopy on small insects (Dwyer 1995). While its diet has not been intensively studied, moths appear to be an important prey item (Vestjens and Hall 1977). During winter, both males and females congregate in smaller colonies, which may occur in caves and human made structures such as old mines, stormwater channels and disused buildings. These roosts are usually cool, which enables individuals to enter hibernation to conserve energy stores at a time when food sources are low. Periods of torpor may last for at least 12 days (Hall 1982). Mating takes place in late autumn or early winter (Dwyer 1995). Females are fertilised at this time but implantation of the fertilised ovum does not take place until shortly before the females emerge from hibernation in August. The embryo then resumes normal development in early spring when food sources are more dependable. Females occupy the over-wintering roosts until September when they move to maternity roosts (Dwyer 1963). During these migrations, females have been recorded moving at least 70 kilometres overnight between roosts and may fly at speeds of 55 kilometres per hour (Dwyer 1965).

A distance of several hundred kilometres may be travelled between over-wintering sites and maternity roosts. In some cases, acclimatisation roosts may be used prior to the females moving to their maternity roosts. These roosts are believed to assist bats to adjust to the high humidity that is experienced in the maternity roost.

Three major maternity roosts are known in New South Wales, Willi Willi caves near Kempsey, Drum Cave at Bungonia near Goulburn and Church Cave at Wee Jasper (Hamilton Smith and Dwyer 1965). All three roosts occur in limestone karst systems and are located in domed caverns where the great number of bats elevate both temperature and humidity and in turn speed development of the young (Dwyer 1971). The number of adult bats may reach 50,000 individuals within these roosts. Births occur in early December with the young left at a creche while females emerge from the cave at dusk to feed. Maternity sites are often utilised year after year and generally comprise females from a particular watershed (Dwyer 1963a, 1969).

Several smaller maternity roosts have also recently been located within disused coal mines in the Hunter Valley and these appear to support breeding for a minor portion of the regional population (Hoye 2000). The breeding sites of the bulk of the Sydney population have not been identified. While sporadic movements of bats have been recorded between the Sydney populations and several of the known maternity roosts, these appear to be exceptions. It is likely that unknown maternity roosts exist within the vicinity of Sydney, but this has not been substantiated (Wilson 2000). During March, females return to mating roosts with the juvenile bats vacating the maternity roosts shortly afterwards.

Pp 138 - 147 in *Urban Wildlife: more than meets the eye,* edited by Daniel Lunney and Shelley Burgin 2004. Royal Zoological Society of New South Wales, Mosman, NSW.

The annual roost pattern of males differs slightly from that of females. Up to fifty percent of the male population is present at maternity roosts during the breeding season, with the remainder forming male colonies at roost sites used for other purposes at other times of the year. Following the birthing season, males join mating colonies or disperse to other roosts. At wintering roosts, where both females and males are present, there are normally similar numbers of both sexes. Juvenile bats disperse from the maternity roost to roosts consisting solely of juveniles. The juvenile bats occupy these roosts until they are one year of age, at which time they join adult roosts.

Dwyer (1966b) observed a range of predators, including carpet pythons, goshawks, Boobook Owls, feral cats, rats and foxes, consuming Large Bent-wing Bats near roosts. These predators, together with juvenile mortality, did not account for the level of mortality estimated to occur each year. Starvation during mid to late winter, when food is scarce, has been proposed as a dominant source of mortality (Dwyer loc cit). Mortality was thought to be highest in juveniles because they approach the winter with smaller fat reserves and are less efficient at selecting suitable wintering sites.

Superficially, this bat appears to be adjusting well to urbanisation. It was considered to be the most commonly encountered bat in the Sydney area by the first half of the twentieth century (Troughton 1973). It is regularly recorded during fauna surveys, albeit often in low numbers and only for part of the year, and it is known to forage around artificial lights and often utilises human structures for roosts. These observations are frequently used to support the assumption that the species is adaptable and coping well with the multitude of potential impacts present in urban environments (Parnaby 1996). To date, no evaluation has been undertaken to determine if there has been historical changes in use of urban areas by the Large Bent-wing Bat and if indeed urban populations are currently thriving or under threat.

The aim of this study was to assess if historical and current information on the occurrence of the Large Bent-wing Bat within the Sydney and Newcastle urban areas could provide evidence of change in the distribution, abundance or diurnal roost usage of this bat in major urban environments.

Methods

Historical Context

The collections of the Australian Museum and Macleay Museum were examined for specimens of the Large Bent-wing Bat from the Sydney area. Particulars, such as collection location and date, were recorded and the sex and reproductive condition of individuals assessed. Bat banding information from the Australian Bird and Bat Banding Scheme for the Sydney area was examined to obtain the location and date of banding as well as the number, sex, age and reproductive condition of bats banded. Information on previously used roosts was obtained from a variety of sources, including museum records, literature records, and correspondence with other researchers. Where possible, details of the maximum number of bats present, the months of occupation and year of use were also recorded.

Occurrence since 1995

General Distribution in the Sydney Area

Records of the Large Bent-wing Bat were compiled from a range of sources including the Wildlife Atlas of NSW National Parks and Wildlife Service, Australian Museum, Macleay Museum, literature records, unpublished reports, wildlife care group records and personal records. All records were categorised as either confident identifications or probable identifications. Confident identifications were those for which the identity of the bats were personally validated or those that were from reliable sources. Probable identifications were those for which the records were believed to be those of the Large Bent-wing Bat but there was some possibility of confusion with other species. This included some echolocation calls where there was possible confusion with those of the Large Forest Bat *Vespadelus darlingtoni*. Records containing a high likelihood of confusion with other bat species were removed from further comparisons.

Current use of Roosts

Roosts in current use were identified from a variety of sources including published papers, unpublished reports, and communication with other researchers. Previously unknown roosts were also located following reports of injured bats coming into the Wildlife Information and Rescue Service (WIRES), a native animal care group. Where possible, roosts were visited over a range of seasons to establish their use patterns. The number of bats present was estimated by either directly counting individuals or, where numbers were large, estimates were obtained from the spatial coverage of bats as described by Dwyer (1966). A sample of bats was captured using either a scoop net or harp trap to enable details, such as sex, reproductive condition, weight and forearm length to be recorded. Captured individuals were usually banded to allow their future identification, movements to other roosts and population estimates to be obtained. Roosts outside the direct impacts of urbanisation were also sampled to provide a comparison.

Injury Rates

To assess the health of urban populations, captured bats were examined for signs of injury, including tears or holes in the wing membranes or major bruising or contusions. While wing membranes were examined thoroughly for any signs of injury, obvious damage to other areas of the body was also recorded. The position and extent of any injury was recorded. Past injuries that had healed but were obvious from scarring were also recorded.

These examinations were undertaken at a range of urban roosts as well as at roosts away from the direct influence of urban impacts. The observations represent part of a larger investigation into injuries to bent-wing bats currently in preparation.

Results

Historical Context

Eighty two specimens of the Large Bent-wing Bat from the Sydney area were present within the museum collections (Table 1). Of these, most were from the cellars of Elizabeth Bay House. Bats were collected from the cellars on at least two and possibly three occasions. The first, and possibly the second collection, in the holdings of the Macleay Museum was undertaken between 1873 and 1892.

For five specimens, only the general locality of 'Sydney' is provided. It is uncertain whether these specimens originated from what is now inner Sydney or whether they were from outer areas, such as Penrith. Two series of specimens of bent-wings from a tunnel at prospect Reservoir are in the collection of the Australian Museum, one collected in 1925, the other in 1927.

General Distribution in the Sydney Area

The Large Bent-wing Bat was identified from 39 definite locations within Sydney and probable identifications were available for a further 50 sites. These records occur across the Sydney area and include a range of habitats including major reserves, residential areas and the CBD (Figure 1). While there was some clustering of records in particular areas, such as around Sydney harbour, it is uncertain whether this reflects habitat preferences of the Large Bent-wing Bat or sampling bias.

Table 1. Early records of the Large Bent-wing Bat from the Sydney area in the collections of the Australian and MacLeay Museums.

Specimen Number	Institution	Locality	Year of Collection	Number of Males	Number of Females	Total
MMUS525-532	MacLeay Museum	Elizabeth Bay House	1873-1892	6	4	10
MMUS616-629	MacLeay Museum	Elizabeth Bay House	1873-1892	2	12	14
MMUS552-554	MacLeay Museum	Sydney	1873-1892	1	2	3
P187	Australian Museum	Sydney	<1880	1	0	1
P189	Australian Museum	Sydney	<1880	0	1	1
M3677-3678	Australian Museum	Prospect Reservoir	1925	2	0	2
M8798-8813	Australian Museum	Prospect Reservoir	1927	7	9	16
M3987-4021	Australian Museum	Elizabeth Bay House	1927	12	23	35

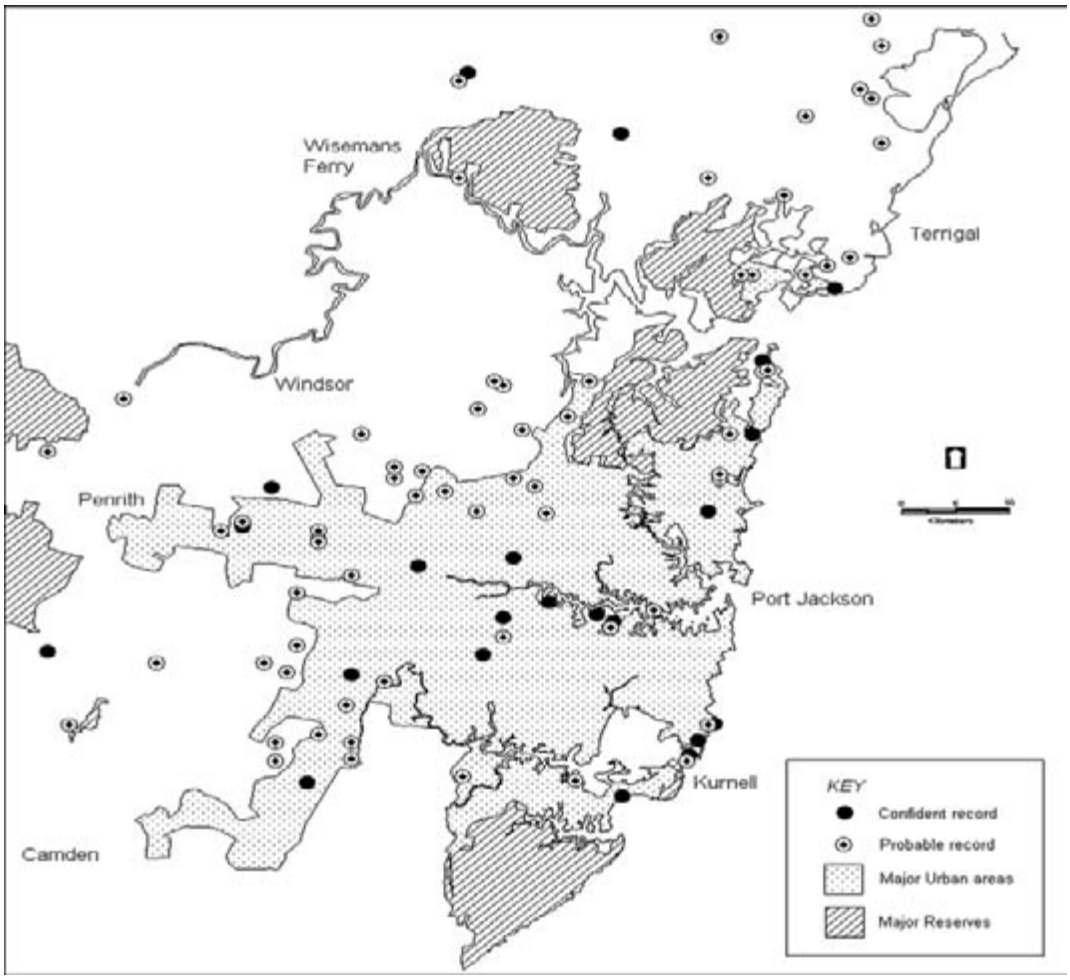

Figure 1. Large Bent-wing Bat records from the Sydney area.

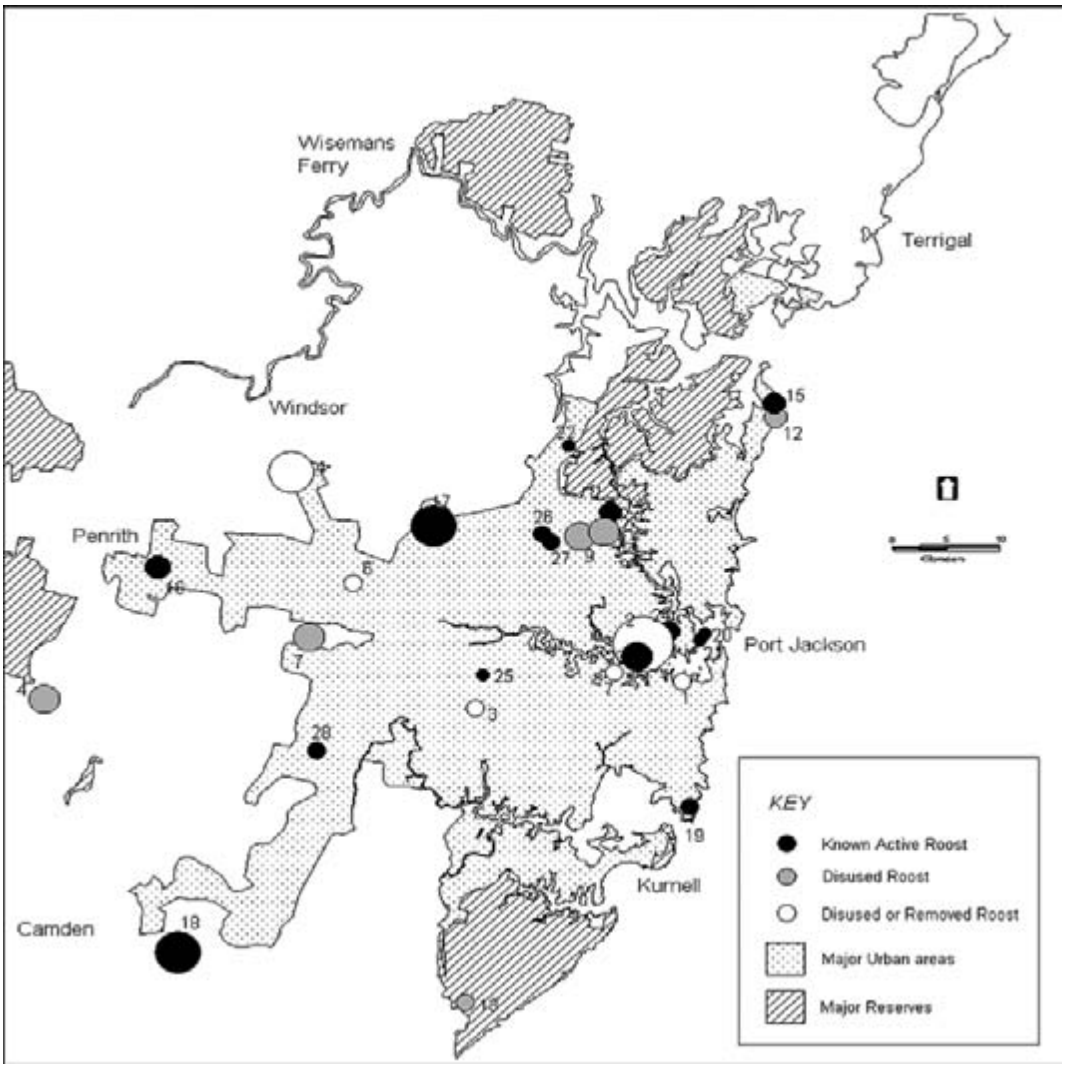

Figure 2. The location of past and current diurnal roosts of the Large Bent-wing Bat within the Sydney area (refer to Appendix 1 for roost details)

Past and Present Roosts

Twenty eight roosts, both historical and current, were identified from the Sydney area (Figure 2 and Appendix 1). Of these, the following six have been destroyed, had bats excluded or have appear to have been abandoned by the bats:

Elizabeth Bay House:

The earliest documented roost occurrence is the basement of Elizabeth Bay House that existed at least from 1892 to 1927. A series of 24 bats was collected by William MacLeay and George Masters between 1873 and 1894 from this basement. Australian Museum staff collected a further series of 35 specimens in July 1927. It is uncertain whether the basement was in continual or sporadic use between 1873 and 1927. The bats collected by the museum in 1927 may have been only a portion of the bats killed during a clean up of the basement to allow regular society ballroom dances following purchase of the house by new owners. An account to Harry Parnaby by a lady at Elizabeth Bay House in 1995 indicated that a wheel barrow or two of dead bats were taken out of the cellar (H. Parnaby, pers. comm.). Prior to the purchase, artists under the patronage of the owner, Arthur Allen, used the house as a studio.

An examination of the specimens in the Australian Museum revealed a high proportion of parous females. If we assume the sample taken by the museum staff was representative, this contrasts with the situation at almost all current known roosts where nulliparous females dominate (Appendix 1).

North Sydney Railway Tunnel

Large Bent-wing Bats were recorded roosting within a disused railway tunnel near North Sydney Railway Station between 1960 and 1983. Construction of the tunnel commenced in about 1932 for a possible rail link to the Manly/Warringah area. Banding of bent-wing bats by David Purchase and Barbara Dew (Australian Bird and Bat Banding Scheme) commenced in the tunnel in August 1960 and continued intermittently until June 1967. No subsequent banding was undertaken until six years later when Bill Price undertook banding in April 1973. A total of 1036 bats were banded in the tunnel from 1960 until 1973.

The regular monitoring of this roost during the 1960s and 1970s has provided a basis for comparison of roosts currently in use in the Sydney metropolitan area. An

Photo 1. Elizabeth Bay House is the earliest known artificial roost of the Large Bent-wing Bat in the Sydney area. It's use as a roost dates to at least 1894 and lasted until 1927.

Photo 2. The Coal Loader at Balls Head, North Sydney, provides a secure roost for several hundred Large Bent-wing Bats.

Photo 3. Domestic cats were recorded repeatedly preying on bats roosting within this stormwater drain at Blacktown. No bats have been recorded using this roost during recent years.

Photo 4. Up to 1000 Large Bent-wing Bats use this stormwater drain.

estimate of 2000 individuals was recorded during a visit to the tunnel on 28 August 1960. Bats were recorded within the tunnel during most months of the year.

Bats were observed in the tunnel during the early 1980s but appeared to have deserted the roost by the early 1990s (M. Archer and H. Parnaby pers. comm.). The tunnel was subjected to periodic disturbance during the early to late 1980s as evident from graffiti on the tunnel walls. High levels of human disturbance during this period may explain the cessation of use of this tunnel as a roost. By 1995, no evidence of bat usage was present.

Potts Hill Reservoir, Lidcombe

Elevated fecal coeliform counts at Potts Hill Reservoir, Lidcombe, led to the discovery of a colony of Large Bent-wing Bats roosting within a surge chamber leading into the main reservoir (Woodside and Hathaway 1997). Due to public health concerns, the bats were excluded from the chamber in May 1997 (Fly By Night 1997). Captured bats were individually banded and released the following day into a previously prepared alternate artificial roost at Prospect Reservoir. Subsequent inspections suggested that the individuals from Potts Hill were unable to successfully utilise the alternate roost at Prospect Reservoir.

Following their exclusion, banded individuals from Potts Hill were later recorded from a roost located in a stormwater drain at Castle Hill (June 1997), a disused coal mine near Greta in the Hunter Valley (November 1999) and the coal loader at Balls Head (May 2000). This suggested that at least a portion of the colony was able to assimilate into other roosts. The female recaptured at the coal loader had been found some months earlier on the wall of a building at Beacon Hill during the day. This is consistent with individuals excluded from Potts Hill Reservoir having some difficulty in assimilating into a secure roost.

Riverstone Meatworks

Indirect evidence suggests that a major roost of the Large Bent-wing Bat was present in disused buildings at Riverstone Meatworks. In June 1996 a number of bats were brought to WIRES after a youth had captured several buckets full of bats. Subsequent investigation of the site during 1998 revealed that the previously used structures had been demolished.

Balmain Power Station

A small colony of less than 12 individuals was recorded roosting in the basement of "A" station of the disused Balmain Power Station during the mid 1990s (AMBS 1995). The station had been closed in 1976. "A" station was demolished in the late 1990s during redevelopment of the site. The fate of bats roosting in the station prior to its demolition is unknown.

Blacktown

During the summer of 1991 a roost of Large Bent-wing Bats was discovered in a stormwater drain at Blacktown. The investigation was initiated after three injured bats (cat caught) were registered with WIRES by a nearby resident. An inspection of the drain revealed approximately 50 bats in cluster formation hanging from the ceiling.

Observations conducted prior to sunset at the drain opening revealed four domestic cats *Felis catus* positioning themselves around the opening, one on top of the pipe opening and the other three on the ground. Capture of the bats was not observed but the use of group hunting by the cats would appear likely. Irregular inspections of this roost during the following years revealed no evidence of its continued use.

Other Roosts

The fate of eight roosts is uncertain. The site of roosts in several stormwater drains were not located. Similarly, the exact location of a tunnel near Prospect Reservoir that appears to have contained reasonable bat numbers is unclear. It represents one of the earliest recorded artificial roosts of the Large Bent-wing Bat in the Sydney metropolitan area. An Australian Museum record exists from 1909 and other specimens were also collected from this locality in 1925. The exact location of the tunnel is unclear and it is unsure if it still exists and is used by bent-wing bats.

Records of bats within the past 30 years exist from four natural cave roosts on the outskirts of the Sydney area. The degree to which these roosts are currently used, and whether their function has changed, is also uncertain.

The remaining 13 roosts currently support colonies of a few individuals, with the exception of a stormwater drain at Castle Hill, which contains up to 1000 bats. Over half of these roosts are located within stormwater drains.

Injury Rates

Injury rates detected in both urban and non-urban bent-wing bat populations are shown in Figure 3. The number of individuals examined for injuries during each month for urban and non-urban sites are included. Rates in urban populations increased consistently through winter from negligible levels in March when bats first arrived at urban roosts until they reached rates of one in five bats with injuries during August immediately prior to the bats vacating the roosts. The values for March and August are based on small sample sizes and should be interpreted with caution. Sample sizes for the intervening months are reasonable and should reflect actual injury rates. It should be noted that these results are preliminary and further investigation is proposed to clarify the trends detected.

In contrast, injury rates at roosts away from direct urban influence were relatively consistent throughout the year, remaining below 8% with the exception of a peak in September when injury rates of over 15% were recorded. The timing of this peak coincides with the migration of bats from urban roosts to other sites, including maternity and bachelor roosts.

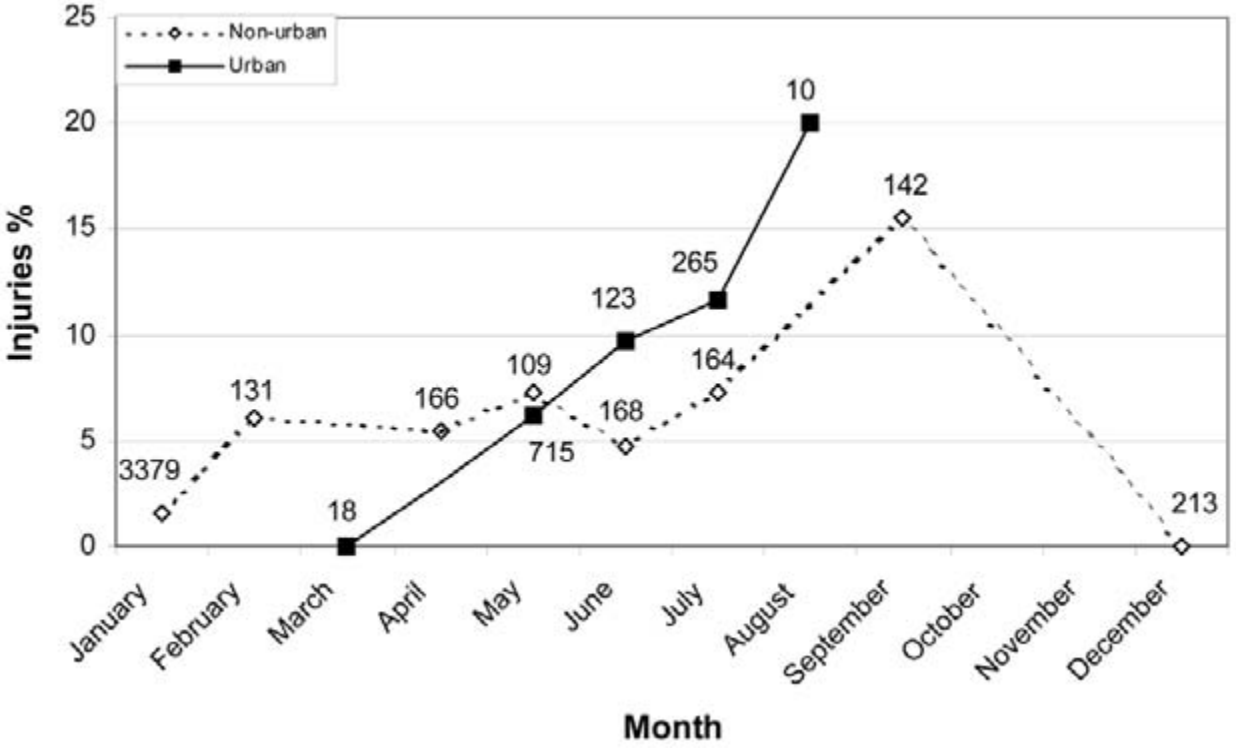

Figure 3. Injury rates at Large Bent-wing Bat roosts in urban and non-urban locations.

Discussion

The earliest recorded presence of the Large Bent-wing Bat from urbanised areas of New South Wales is from the cellars of Elizabeth Bay House, inner Sydney. While use of this roost had previously been documented from the mid 1920s, it was used for at least 35 years prior to this. A series of specimens from 1927, in the collection of the Australian Museum, contain a high number of mature females. In contrast, mature females are less common in almost all current roosts. The species was also recorded roosting in other human-made structures soon after the turn of the nineteenth century, including a tunnel at Prospect Reservoir.

The largest recorded roost within the Sydney area was located in a disused railway tunnel at North Sydney. Up to 2000 bats have been recorded within the tunnel from at least 1960 until its abandonment between 1983 and 1992. While banding was undertaken at other sites within the Sydney area during this period, no other roosts appear to have been sampled with the same intensity and over the breadth of seasons as was undertaken at North Sydney. Unfortunately, the information retained in banding records is limited. In particular, estimates of the number of bats present within the tunnel was not available for most visits. Despite these limitations, the repeated sampling of the tunnel has allowed a comparison to be made with roosts currently in use. The maximum number of bats recorded at North Sydney was greater than that recorded from the roosts present today with the possible exception of Riverstone Meatworks. Unsubstantiated observations suggest that Riverstone may have supported several thousand bats. Unfortunately the roost was demolished before its use was properly investigated.

The North Sydney railway tunnel was also exceptional in that bats had been recorded during most months of the year. This contrasts with roosts examined during recent years, all of which have contained bats only from early March until late August. Recent echolocation call survey at artificial lights at Sydney Olympic Park support this trend. Activity levels of this species were very low in summer but peaked in the winter sampling periods (Hoye in prep.).

Several reasons may account for changes in the seasonal use of roosts, including climate change and a loss of roosts with suitable microclimates. Since the 1970s, annual global temperatures have increased. This has included a string of record warm winters and summers. Such an increase in average ambient temperatures could lead to a later arrival and earlier exodus of Large Bent-wing Bats from near coastal locations. This should become more apparent with the predicted future rises in temperatures due to global warming leading to further decreases in the duration of the year for which bent-wing bats are present at urban sites. The contraction of the time that these bats are present at the Sydney and Newcastle roosts may also be explained by a loss of roosts with optimal microclimates that allows bent-wing bats to exist in low elevation coastal locations during the warmer months. This bat species is highly sensitive to subtle changes in both temperature and humidity and has been recorded changing roost positions to find microclimates optimal for their energetic requirements (Hall 1982). The section of North Sydney Railway Tunnel where bent-wing bats have been recorded roosting is more than 500 metres from the outside environment. This may have allowed considerable buffering from ambient temperatures and humidity. Many of the roosts now occupied are less extensive and appear to offer limited ranges in both temperature and humidity.

The one roost in recent years at which bats have been recorded, between October and February, occurs in an extensive tunnel system at higher elevations (Ecotone 1996). Bats were recorded roosting in Devine's Tunnel, on the outskirts of the Sydney basin during November (R.C. Williams Ecotone, pers. comm. 2000). It is not known whether the bats are consistently present in this roost over the summer months.

The reasons for the bats abandoning North Sydney railway tunnel are unclear, but human disturbance is a likely contributing factor. The tunnel had been visited regularly by people in the period in which the bats abandoned the roost, based on graffiti still present on the tunnel walls. The colony is also likely to have suffered considerable injury and mortality from the impact of trains as they travelled between the roost and the tunnel entrances. Presumedly, collisions with trains would have become more frequent as the use of the line increased from the 1960s when most of the banding was undertaken. Unfortunately, while the number of bats roosting within the tunnel was noted on a few occasions, no overall estimates of colony size are available from the time over which the bats were banded. Two thousand bats were noted in the tunnel on one inspection during August 1960. By comparison, a recent estimate of the population size of Large Bent-wing-bats in the vicinity of North Sydney indicate a population of less than 1000 individuals (Fly By Night 2000). This would suggest that there was a decrease in the population size of the Large Bent-wing Bat in the area since the 1960s.

At least part of this colony may have relocated to the nearby coal loader at Balls Head following the closure of the railway tunnel in 1990. Shortly after this time, bats were noted roosting within tunnels in the loader. The coal loader now provides a relatively secure roost for at least several hundred bats during the cooler months. Individuals appear to move frequently between the coal loader and a stormwater drain several kilometres away. The numbers utilising these structures are substantially less than maximum estimates of the colony formerly using the North Sydney railway tunnel. Also, bats have not been recorded using any of current known roosts during the summer months. A higher proportion of mature females was present in the coal loader compared with the stormwater drain at Primrose Park (Fly By Night 2000). This is consistent with the view of Dwyer (1966b) that juveniles are less adept than mature bats at finding suitable wintering roosts.

Unfortunately, the trend in the past twenty years has been one of loss of secure roosts for the Large Bent-wing Bat in the Sydney metropolitan area. Major roosts at North Sydney Railway Tunnel, Potts Hill Reservoir and Riverstone Meatworks have been destroyed or abandoned. Smaller colonies, such as the one in the disused Balmain Power Station, have also been evicted as these sites were demolished for redevelopment. Many of the known roosts

in the Sydney basin now occur in stormwater drains. Bats utilising these structures are vulnerable to a range of impacts including flooding, human disturbance, pollution and rat and cat predation. Floods have the potential to kill or injure large numbers of bent-wing bats. Apart from direct mortality from drowning and injury, bats abandoning drains during daylight hours are subject to attack by birds, such as ravens and currawongs. At one drain in the Blacktown area, domestic cat predation can be implicated in the demise of the colony.

While use of stormwater drains by bent-wing bats in the Sydney area is known from at least 1965, their use appears to be increasing. The species may once have been able to sustain the losses associated with a small proportion of the population roosting within these structures but this may not now be the case. A significant portion of the total population occurring within the Sydney Basin now appears to roost within stormwater drains and associated structures.

The changes described are based on limited historical information and, while highly suggestive of changes in bent-wing occurrence within the Sydney area, they are nevertheless arguable. We may never know with great certainty the population changes in this bat from the time of early settlement. The evidence that is more compelling is that Sydney populations of the Large Bent-wing Bat are currently under extreme pressure. An examination at the end of winter of injury rates of urban populations in Sydney and Newcastle revealed levels of four times that in non-urban sites. Levels at the non-urban sites were relatively constant throughout the year, with the exception of a peak during September coinciding with the time that the majority of bats have left urban areas and are en route to summer roosts. Movements of bats from urban sites in both Newcastle and Sydney to many of these non-urban roosts have been recorded through recapture of banded individuals (Hoye 2000).

Injury rates in urban bat populations increase throughout the winter from approximately 5% in March to 20% by the time the bats are preparing to depart at the end of winter (Hoye unpublished data). This indicates that these populations are already suffering high rates of injury and presumedly death. The causes of such injury and death have not been fully investigated but certainly include motor vehicle impact, human disturbance at roosts, cat predation and flooding of roosts. Other more novel causes include impact from tennis rackets and tennis balls at courts during the night where the bats are feeding on insects attracted to the lights. While many of these threats have been present at some level for at least 100 years, increasing urbanisation and a general increase in human population size of our urban centres has led to a dramatic increase in many of these impacts.

Populations of the Large bent-wing Bat in our larger urban centres of eastern New South Wales are clearly under considerable pressure. This is in stark contrast to the popularly-held belief that this bat is thriving in urban environments. The use of human structures as roosts and foraging around artificial light sources are often cited as evidence that this is an adaptable species that is not disadvantaged by increased urbanisation. If current impacts continue or increase, urban populations may act as sinks where mortality levels are greater than the recruitment levels.

What can be done to decrease pressures on urban bent-wing bat populations? The retention of existing secure roosts would be a start. The loss within recent years of several significant roosts has forced bats to roost within such structures as stormwater drains where threat levels are especially high. Priority should be given to retaining known secure roosts as well as those that are identified in the future. The augmentation of secure roosts may also be a feasible option, but is more problematical. Construction of artificial roosts for equivalent cave roosting bat species has been attempted in open cut mines (Tuttle and Taylor 1998). The success or otherwise of these structures has not been documented. If suitable roosts could be constructed, injury and mortality rates associated with bats roosting in less optimal situations may decrease. If sites are chosen carefully, injury from flooding, human disturbance and motor vehicle impact may be eliminated or substantially decreased.

A clearer understanding of the range and level of the various impacts on urban bent-wing bat populations is necessary in order to reduce injury and mortality rates. Identification of those factors that contribute to high injury levels may assist in formulating management options to conserve urban populations of the Large Bent-wing Bat.

Acknowledgements

Sandy Ingleby kindly provided details of specimens from Sydney held in the collection of the Australian Museum and allowed access to the collection. Stuart Norrington provided access to the Macleay Collection and readily assisted with my inquiries. Peter Wilson generously provided summaries of banding activities undertaken around the Sydney area during the 1960s all of which he had patiently collated. Harry Parnaby as always provided pertinent and useful suggestions as well as good company during discussions of the relevant issues. GH would particularly like to thank his supervisor Michael Mahony for his encouragement and support during a particularly trying year. The NSW Wildlife Information & Rescue Service Inc. reports on roost disturbances and or injured bats have led to the discovery of several roosts in the Sydney Metropolitan area.

References

Australian Museum Business Services (AMBS). 1995. *Fauna Impact Statement for proposed demolition of disused Balmain power Station - "A" station*. Report to Pacific Power. AMBS, 1 Stanley Lane, East Sydney 2010.

Dwyer, P.D. 1963a. The breeding biology of *Miniopterus schreibersii blepotis* (Temminck) (Chiroptera) in northeastern New South Wales. *Australian Journal of Zoology*. 11:219-240.

Dwyer, P.D. 1963b. Seasonal changes in pelage of *Miniopterus schreibersii blepotis* (Chiroptera) in northeastern New South Wales. *Australian Journal of Zoology.* 11:290-300.

Dwyer, P.D. 1964. Seasonal changes in activity and weight of *Miniopterus schreibersii blepotis* (Chiroptera) in northeastern New South Wales. *Australian Journal of Zoology.* 12:52-69.

Dwyer, P.D. 1965. Flight patterns of some eastern Australian bats. *Victorian Naturalist*. 82:36-41.

Dwyer, P.D. 1966a. The population pattern of *Miniopterus schreibersii* (Chiroptera) in northeastern New South Wales. *Australian Journal of Zoology.* 14:1073-1137.

Dwyer, P.D. 1966b. Mortality factors of the Bent-winged Bat . *Victorian Naturalist.* 83:31-36.

Dwyer, P.D. 1969. Population ranges of *Miniopterus schreibersii* (Chiroptera) in southeastern Australia. *Australian Journal of Zoology*. 17:665-686.

Dwyer, P.D. 1971. Temperature regulation and cave-dwelling in bats: an evolutionary perspective. *Mammalia* 35:424-455.

Dwyer, P.D. and Hamilton-Smith, E. 1965. Breeding caves and maternity colonies of the bent-wing bat in southeastern Australia. *Helictite* 4:8-21.

Dwyer, P.D. and Harris, J.A. 1972. Behavioural acclimitisation to temperature by pregnant *Miniopterus* (Chiroptera). *Physiological Zoology* 45:14-21.

Dwyer, P.D. 1995. Common Bentwing-bat *Miniopterus schreibersii*. Pp.494-95 in Strahan, R. ed. *The Mammals of Australia*. Reed Books, Chatswood..

Ecotone Ecological Consultants. 1996. Species Impact Assessment of Threatened Bat Species at Cataract Tunnel near Appin, NSW. Report prepared for Sydney Water. November 1996. Operations Services, Transwater, PO Box 365, Guilford, NSW, Australia 2161.

Fly By Night Bat Surveys. 1997. *The relocation and exclusion of a colony of Large Bent-wing Bats (Miniopterus schreibersii blepotis) from Potts Hill Reservoir near Lidcombe, New South Wales*. Report to Sydney Water. August 1997. Operations Services, Transwater, PO Box 365, Guilford, NSW, Australia 2161.

Fly By Night Bat Surveys. 2000. *Fauna and flora assessment – Waverton Peninsula*. Report to North Sydney Council. June 2000. North Sydney Council, PO Box 12, North Sydney, NSW Australia 2059.

Hall, L.S. 1982. The effect of cave microclimate on winter roosting behaviour in the bat, *Miniopterus schreibersii blepotis*. *Australian Journal of Ecology* 7:129-136.

Hoye, G.A. 2000. *The Discovery of Two New and Distinctive Maternity Roosts of the Large Bent-wing Bat in the Hunter Valley, NSW*. Spoken Presentation. *9th Australasian Bat Conference.* Tocal, New South Wales. April 2000.

Parnaby, H. 1996. The Common Name and Common Misconceptions about the Common Bentwing-bat. *The Australasian Bat Society Newsletter* 7:35-38.

Richards, G.C. 2000. Natural wing tears in Large Bentwing bats (*Miniopterus schreibersii*). *The Australasian Bat Society Newsletter* 15:48.

Tuttle, M.D. and Taylor, D.A.R. 1998. *Bats and Mines*. Resource Publication No. 3, Bat Conservation International.

Troughton, E. 1973. *Furred Mammals of Australia*. Abridged 9th Edition. Angus & Robertson. Sydney.

Vestjens, W.J.M. and Hall, L.S. 1977. Stomach contents of forty-two species of bats from the Australasian region. *Australian Wildlife Research.* 4:25-35.

Wilson, P.D. 2000a. *Old banding data for Miniopterus schreibersii: a potential goldmine*. *The Australasian Bat Society Newsletter* 15:24.

Wilson, P.D. 2000b. *Records for banding work by Barbara Dew (and a few others) extracted from notes transcribed from Microfiched Banding Schedules for Miniopterus schreibersii spanning from 1957 to 1984*. Unpublished material. August 2000.

Woodside, D.P. and Hathway, J.E. 1997. *Removal of bats from the Potts Hill Reservoir*. Report to Sydney Water from Zoological Parks Board of New South Wales. March 1997. Operations Services, Transwater, PO Box 365, Guilford, NSW, Australia 2161.

APPENDIX 1

Appendix 1: Historical and current roosts of *Miniopterus schreibersii* in the Sydney area.

KEY

Roost Type

B	Building
C	Cave
GE	Gun Emplacement
T	Tunnel
SD	Stormwater Drain

No	Roost	Roost Type	% Females	% Parous Females	Year Bats First Recorded	Year Bats Last Recorded	Current Status	Maximum Number Recorded
1	Elizabeth Bay House	B	59.3[1]	40.7[1]	1873-1892	1927	Removed	>35
2	North Sydney Railway Tunnel	T	61.0	?	1960	1983	Abandoned	2000
3	Potts Hill Reservoir	T	2.0	?	1996	1997	Bats excluded	50
4	Riverstone Meatworks	B	?	?	1996	1998	Removed	1000+
5	Balmain Power Station	B	?	?	1994	1998	Removed	12
6	Blacktown	SD	?	?	1991	1998	Abandoned	<50
7	Prospect Reservoir	T	60.0[1]	0[1]	1909	1927	Uncertain	>16
8	Warragamba Dam	T	?	?	?	1972	Uncertain	?
9	Turramurra	SD	57.1	?	?	?	Uncertain	?
10	Wahroonga	SD	?	?	?	?	Uncertain	?
11	St Ives	SD	?	?	?	?	Uncertain	?
12	Hole in the Wall Cave, Avalon	C	?	?	1967	1967	Uncertain	100
13	Royal National Park	C	12.5	?	1983	1983	Uncertain	<200
14	Kuringgai Wildflower Gardens	C	?	?	1999	1999	Uncertain	<200
15	St Michaels Cave, Avalon	C	?	?	?	1997	Current	200
16	Kingswood	SD	58.3	4.21	1994	2000	Current	300
17	Castle Hill	SD	54.3	0	1991	2000	Current	1000
18	Devine's Tunnel	T	?	?	?	2000	Current	1000
19	Henry Head	GE	17.6	17.6	1970	2000	Current	50
20	Middle Head	GE	?	?	?	2000	Current	10
21	George's Head	GE	?	?	?	2000	Current	10
22	Kuringgai Drain	SD	40.0	20.0	?	2000	Current	10
23	Coal Loader	T	43.7	14.2	1997	2000	Current	500
24	Primrose Park	SD	65.1	10.7	2000	2000	Current	200
25	Silverwater	SD	?	?	?	2000	Current	2
26	Coups Creek	SD	?	?	?	2000	Current	20
27	Comenarra Parkway	SD	68.7	56.3	1997	2000	Current	50
28	Miller	SD	?	?	1998	1998	Current	15

[1]Estimates from Australian Museum records