Factors in the design of an urban microbat flyway

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ABSTRACT

Bat surveys were conducted during 2006 and 2007 in the Willoughby Local Government Area (LGA) in the northern suburbs of Sydney to determine the occurrence and movement of microbats. Based on the frequency of bat detections and the direction of bat movements, two major and five minor bat flyways were identified in the study area. The two major flyways were north–south movement corridors that occurred on the eastern and western margins of the LGA; each major flyway had minor flyways branching from them. The two major flyways were separated from each other by the Pacific Highway rise that runs north–south through the centre of the study area. The rise acts as an effective flyway barrier as tree corridors are completely disrupted by an exposed, noisy, night-illuminated residential and commercial strip. Minor bat flyways approach the Pacific Highway rise from the east and west and are only separated by a relatively short distance. Extending these flyways to create an east–west passage across the study area would greatly extend the foraging range of bats on either side of it. In order to link the major flyways, the eastern and western minor flyways need to be extended by the creation of a continuous tree canopy through residential areas to the Pacific Highway rise. Controlled street planting and supported private plantings of trees along strategic routes, together with modified street lighting could achieve this result. The crossing of the Pacific Highway would require the construction of a lightweight "flyover bridge" that commenced and ended in the extended tree canopies. This would provide a wind and light shielded crossing point for bats attempting to fly east–west across the Willoughby LGA. The components of the "flyover bridge" are discussed along with other considerations in achieving an effective extended flyway through a densely populated residential area.

Key words: Bats, microbats, urban bat flyway, bat "fly-over", bat flyway barriers.

Introduction

Microbats may fly many kilometres each night in search of food or moving between roosting sites (O'Neill and Taylor 1989). Most microbats are small (3 to 8 grams body weight) and have high energy demands: a major factor that limits the distance that each bat can fly is food availability and their overall energy balance (Bullen and McKenzie 2002). The energy consumed in the search for food needs to be offset against the energy gained from prey. Bat flight pathways, therefore, cannot be overly arduous or difficult to traverse if the food returns are low or unreliable.

The route that a bat flies during commuting and foraging is affected by several factors, including the nature of the terrain, the likelihood of finding food, wing morphology and the degree of exposure to wind and nocturnal predators (Pavey *et al*. 2001). Many of the smaller microbats (such as Long-eared bats genus *Nyctophilus* and Horseshoe bats genus *Hipposideros*) fly beneath the tree canopy and utilise vegetative cover for shelter while still enabling them to forage for flying insects (Lumsden and Bennett 1996). Some microbats, such as Free-tailed bats genus *Tadarida*, can cross open spaces and are able to fly above the canopy and use their greater speed to avoid predators and overcome wind buffeting to some extent (Bullen and McKenzie 2002). For low-flying bats flyways are often determined by the presence of solid ground structures and flyways develop along tree lines and hedge lines, between buildings and along cliff lines. Open areas are problematic for many slow-flying bats as night predators are able to detect and swoop on bats from a greater distance (Pavey *et al*. 2001) and they also are more vulnerable to high winds.

Microbats that inhabit urban areas appear to face additional flight difficulties due to the high levels of night light, ambient noise and vehicle movement as well as reduced protection from wind and predators (Hill and Smith 1984). Regularly-used flight paths may be truncated by the removal of tree cover or the erection of street or commercial lighting. Main roads, in particular, form a brightly lit, noisy barrier with constant vehicle movement that is likely to deter many microbats from crossing. As cities develop, it is probable that bat flyways will become increasingly truncated and that bats are forced to travel in smaller and smaller areas in search of food.

Over the last 10 years, many urban councils in Australia have adopted biodiversity conservation strategies in response to the greater public demand for the retention of native flora and fauna in residential areas and the development of the state governmental biodiversity conservation policies (DEST 1996). These strategies are diverse and range from merely being a list of conservation aspirations to monitoring studies and habitat creation. In many cases, bats are mentioned as resident fauna but conservation actions directed at them are rarely contemplated. One council in Sydney, Willoughby City Council, has taken the proactive step of assessing the status of the local microbat population and determining the habitat areas and flyways used by these animals (White 2006). This present study expands on the earlier study and

Pp. 464–470 in *The Biology and Conservation of Australasian Bats*, edited by Bradley Law, Peggy Eby, Daniel Lunney and Lindy Lumsden. Royal Zoological Society of NSW, Mosman, NSW, Australia. 2011.

seeks to determine the distribution of bats across the study area, to gain an assessment of bat movements in this area, to identify flyway barriers, and to recommend specific managements actions, such as the removal or amelioration of flyway barriers and the creation of new flyways.

Methods

Detection of bats across the Willoughby LGA

The Willoughby LGA (study area) is about 950 ha and spans an area of Sydney between the Lane Cove River to the west and Middle Harbour to the east (Figure 1). The study area is highly urbanised and contains both medium and high density residential areas, but it also contains open parkland and about 90 ha of bushland in various stages of rehabilitation. Major bushland areas occur along the Lane Cove River valley to the west, and along the foreshore of Middle Harbour to the east. Brown and Bernhard (2010) have described Willoughby LGA from a biodiversity standpoint. To determine bat usage of the area, the study area was divided into 200 m x 200 m (i.e. 4 ha) grids and a convenient location near the centre of each grid square was chosen as a bat survey point. During the summer of 2005–2006, each grid was surveyed on four separate nights as part of a microbat survey (White 2006). During the survey, a hand-held bat detector (Anabat, Titley Electronics, Ballina, NSW) was used to record 20 minute sequences of calls of microbats onto a storage disc. All recordings were made within the first three hours after nightfall. The surveyor also recorded the direction that the bats were flying (when possible) and tried to determine whether the bats were foraging or commuting between sites; this was done by tracking the bats with a halogen headlamp and/or noting the number of feeding "buzzes" detected on the bat detector. Four species of microbats were detected during the survey, but species number was not used as a criterion in determining the relative importance of bat flyways. Flyway importance was based on the average number of bat calls detected at each site.

Each survey point was plotted on a grid map of the study area (Figure 1); sites where bats were detected were signified by the inclusion of the general direction of bat movements recorded at that site.

Assessment of bat movements

At each survey point where bats were detected, the field observations of the directions of bat flight were added to the location information. In this way, a map consisting of arrows depicting the direction of bat movement at each survey location was prepared (Figure 1). Where arrows from adjoining sites pointed in the same direction, a flyway was presumed to exist. A flyway was regarded to be a major flyway if 10 or more adjoining survey sites where bats were detected could be linked by a common direction of bat movement and the number of bat calls recorded at each site was greater than 50. A flyway was deemed to be a minor flyway if 4 to 9 adjoining sites were linked, there was a common direction of bat movement and the number of bat calls recorded at each site was less than 50.

Identification of major and minor flyway barriers

From the bat flight path map (Figure 2), barriers to bat movement were identified. These were identified at the terminal point of a flyway where bats reversed their direction of flight. Once the location of these barriers was determined, the sites were revisited during the day and night to better determine features of the sites that prevented bats from continuing in their initial flight

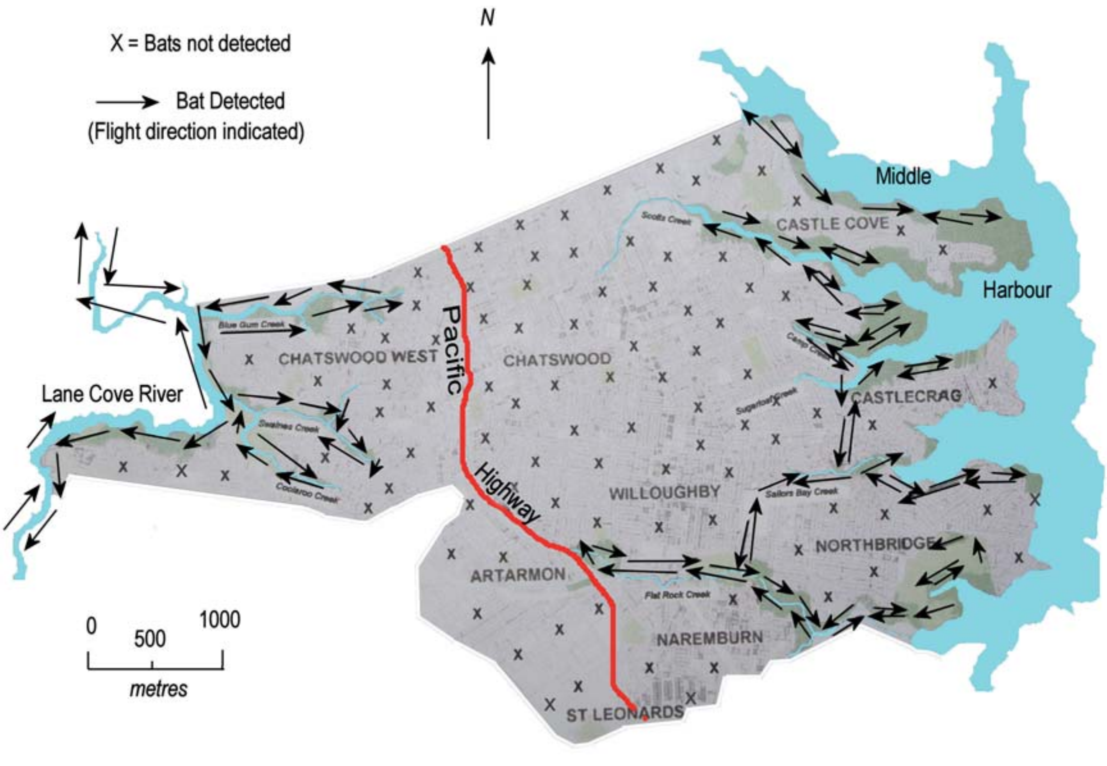

Figure 1 Bat survey sites, detections and directions of bat movements in the Willoughby LGA.

trajectory. The features that were assessed were the continuity of the tree canopy, the level of night lighting, the presence of major structural barriers or major roads, and the general levels of noise of vehicle and pedestrian movement in the area.

Enhancement of existing flyway corridors

In the areas where flyways terminated, a daylight assessment of the area was carried out to determine if an extended flyway route could be established. The area assessment involved determining possible routes for extended tree cover, routes that could bypass major structural barriers or roads, methods of minimising night lighting, and how far the flyway corridor could possibly be extended and where it would terminate.

Results

Survey Grid Locations

Bat surveys were carried out in 230 locations in the LGA; Figure 1 depicts the location of the survey sites in the study area. Microbats were detected in 56 of the sites; positive detections are indicated by an arrow showing the direction of bat movement; sites where bats were not detected are signified by a cross.

Bat species detected

Four bat species were detected during the survey; they were (in order of most commonly detected to least detected) Gould's Wattle Bat *Chalinolobus gouldii*, Little Forest Bat *Vespedalus vulturnus*, White-striped Freetail Bat *Tadarida australis*, Long-eared Bat *Nyctophilus* sp. and Mouse-eared Fishing Bat *Myotis macropus*. Three of these species are relatively low-flying bats while the White-striped Freetail bat will often travel above the tree canopy (Kitchener and Hudson 1982). It is likely that other high flying bat species will not have been detected during this survey as they will be out of range of the bat detector.

Determining Bat Flyways

By linking the locations where bats were detected, noting the direction of bat flight, it was possible to reconstruct corridors used by commuting microbats. Two major flyways (A and D), and five minor flyways, were identified in the study area (Table 1). The two major flyways were on opposite sides of the study area: flyway A followed the Lane Cove River valley along the western boundary of the Willoughby LGA while flyway D followed the foreshore of Middle Harbour. Over 400 bat calls were recorded at sites along flyway A whereas 188 bat calls were recorded at sites along flyway D.

All five minor flyways extended from the two major flyway corridors already identified. Flyways B and C were branched off flyway A. Flyway B traversed the Blue Gum Creek valley for approximately 1.2 kilometres and terminated at Blue Gum Park at Chatswood. Flyway C traversed the Swaines Creek valley for 1.4 kilometres and terminated at Campbell Park.

Flyways E, F and G branched off from the major flyway corridor D along Middle Harbour. Fewer calls were recorded at sites along flyways E (35 calls), F (22 calls) and G (37 calls) than for either B (49 calls) or C (37 calls). Flyway E followed the shoreline of Castle Cove and Crag Cove and extended up the Scotts Creek valley as far as Willis Park; flyway F extended from Sailors Bay westwards to Warners Park (some bats crossed the Eastern Valley Way to reach the Memorial Playing Fields at Northbridge); flyway G extended from Long Bay, along Tunks Park and Flat Rock Reserve to Artarmon Park.

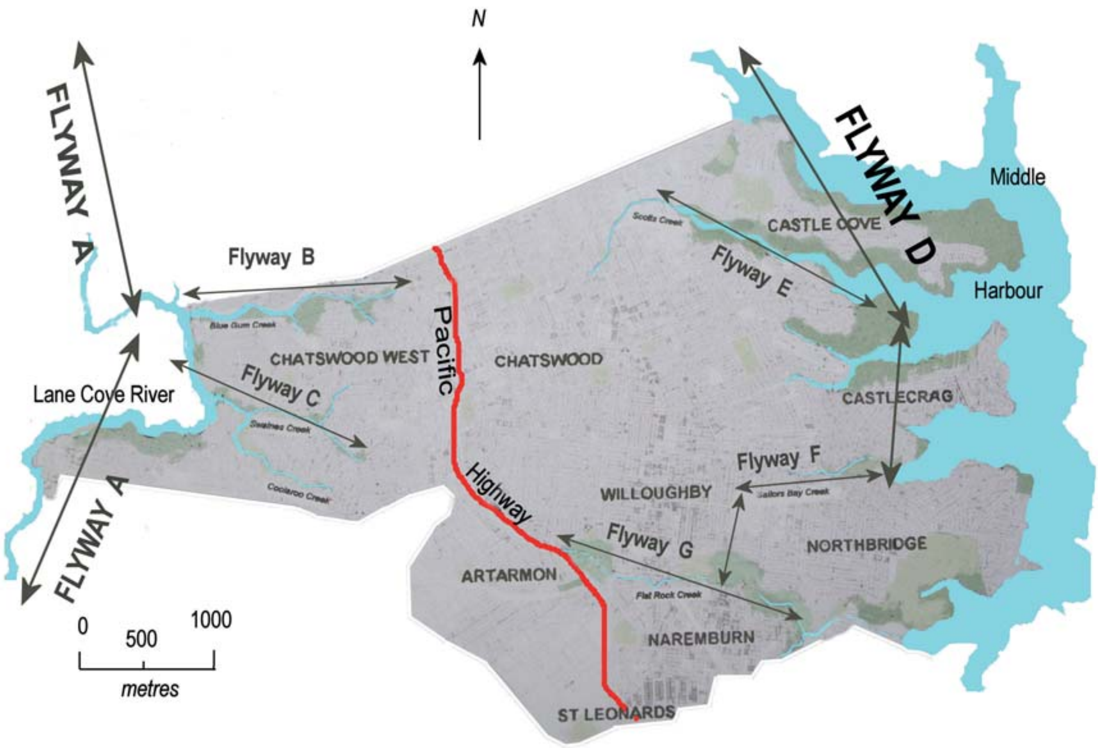

Figure 2 Inferred bat flyway corridors in the Willoughby LGA.

Flyway Corridor Barriers

Possible barriers at the end of identified flyways were identified and recorded in Table 2.

Two notable barriers were evident for microbats in the Willoughby LGA; the greatest barrier was the Pacific Highway which prevented east–west crossings by low-flying microbats. A lesser, but still substantial, residential barrier was present for southern dispersing bats at Northbridge. Some bats heading south from Warners Park at North Willoughby were able to fly across a major arterial road (Eastern Valley Way) in areas where there was high tree cover and escarpments that concealed part of the roadway. Once across Eastern Valley Way, the bats could travels within the tree cover that surrounds the War Memorial Playing Fields before flying on to Flat Rock Reserve. Flat Rock Reserve has large areas of high forest and uninterrupted bushland and appears to be a junction for bats to move eastwards towards Tunks Park and Northbridge Golf Course, or to fly west to Bicentennial Reserve and Artarmon Park.

Possible link for an east–west flyway corridor

One potential route to connect east and west flight corridors was identified. This link would unite flyways C and G. Flyway C extends eastward from the Lane Cove River Valley and terminates within 200 m of the Pacific Highway. Flyway G extends westward from Middle Harbour to Artarmon Park and is within 500 m of the Pacific Highway. To join the two flyways entails extending flyway C further eastwards along Ivy Street and Sharland Street to Moriarty Street and the highway. Flyway G needs to be extended westwards and northwards and this would be best achieved by utilising the railway corridor from Artarmon Park, past Artarmon Railway Station to Mowbray Road and Nelson Street. A bat flyover bridge spanning the Pacific Highway would be located near Moriarty Street on the western side and Nelson Street on the eastern side of the Highway.

Discussion

Mapping bat flyways

The need to determine bat flight movements and corridors has become a recent environmental requirement, particularly where major civil works are proposed. In Europe and North America, where forests and other natural habitat are already severely fragmented, the construction of new fauna barriers, such as motorways, has had to be countered by the development of effective amelioration measures to conserve local animals, including bats (e.g. Hudson 1993). The planning phase of these projects often entails intensive surveys for either targeted bat species (e.g. Greater Horseshoe Bat *Rhinilophus ferrumequimum;* Billington 2002) or all bat species (e.g. Somerset Highways 2005). Surveys are intended to determine the commonly used flight paths so that bat flight corridors can be identified, enhanced or relocated so that bat casualties can be minimised.

Willoughby bat flyways

Seven bat flyways were identified in the study area (Figure 2). Some were frequently used, others less so. The most heavily used was flyway A, along the Lane Cove River corridor. Bats entering the Willoughby LGA from the

Table 1. Major and Minor Bat Flyways Identified in the Study Are

Flyway	Type of Flyway Corridor	Corridor Location	Description of Corridor
A	Major	Lane Cove River Valley	River valley
B	Minor	Blue Gum Creek Valley	Urban creekline
C	Minor	Swaines Creek – Ferndale	Urban creekline
D	Major	Middle Harbour Foreshores	Harbour shoreline and river valleys
E	Minor	Castle Cove – Scotts Creek	Urban creekline
F	Minor	Warners Park – War Memorial Fields	Urban creekline and parkland
G	Minor	Tunks Park – Flat Rock Reserve – Artarmon Park	Urban creekline and parkland

Table 2. Identified Flyway Corridor Barriers

Flyway Corridor	Tree Canopy Cover	Night Lighting Levels	Major Road or Structural Barrier	Noise and Movement Levels
A	Continuous	Minor residential lighting.	No	Low
B	Canopy ends at Chatswood	Increasing residential and commercial lighting	Yes Pacific Highway	Low to high
C	Canopy ends at Lane Cove North	Increasing residential Lighting.	Yes Pacific Highway And Mowbray Road	Low to high.
D	Continuous as far as Sailors Bay	Minor residential lighting.	No	Low
E	Canopy ends at North Willoughby	Increasing residential and commercial lighting	Yes Eastern Valley Way	Low to high
F	Discontinuous canopy at Willoughby	Minor residential lighting.	No	Low
G	Canopy ends at Artarmon	Minor residential lighting.	Yes Northern Railway Easement and Pacific Highway	Low to high

north traversed flyway A and minor flyways before departing from the LGA by the same route. Flyway A extends northwards out of the Willoughby LGA into the Lane Cove National Park and is probably part of an even larger flyway that extends through the northern suburbs of Sydney.

In general, bat activity was greatest in the western regions of the study area because of the presence of the Lane Cove River valley and the relatively unconstrained nature of this flyway corridor. The number of bat detections on the eastern side of the study area was lower, and probably reflects the more difficult nature of the entry flyway (flyway D). Bats entering into the Middle Harbour sites can only do so from the north: microbats were detected from the Roseville Bridge, along Middle Harbour foreshore reserves as far as Middle Cove (Figure 2). It appears that some bats using flyway F fly over Eastern Valley Way and south to Flat Rock Reserve. Flat Rock Reserve appears to be a junction point for flyways F and G. From there, some bats appear able to cross Willoughby Road to reach Artarmon Park, where flyway G terminates (Figure 2).

Bats and roads

In Europe and North America, various trials (e.g. Gershor 2010) have been carried out to facilitate bat movements in areas associated with roads, however, nearly all of these projects involve roads in rural areas. Planners generally seek to confine bat movements away from areas where bats are likely to encounter vehicles. At some point, it is necessary for bats to cross roads and so "crossing points" were developed (Brinkman 2003). Crossing points can be above the road (a "fly-over") or below the road (a "fly-under").

For a crossing point to be effective, bats need to be directed to entry points at the crossing. Bats are prevented from crossing at other areas by the installation of tall, linear barriers such as lines of trees, buildings or barricade fences (Limpens *et al*. 2001). The entry points are darkened areas that are continuous with the tree canopy areas on either side of the road. Crossing points can be short (i.e. < 100 m long) or they may be more than one kilometre long (e.g. Combes Downs Mine Tunnel project: Nuttal 2006). Bat casualties on country roads are higher in areas where the tree line ends abruptly at a road crossing and low-flying bats make up the most common fatality in these areas (Lesinski 2007).

Crossing points are usually established in areas where bats already frequently traverse the landscape (Brinkman 2003). Controlled planting of trees connects the canopies of nearby woodlands with the entry and exits of the crossing points. "Fly-overs" usually consist of telegraph pole-supported netting suspended above the road. Various materials have been used to construct the "fly-over", the most successful were those that were relatively wind and light resistant (Limpens *et al*. 2001, Wray *et al.* 2006).

Overcoming flyway barriers at Willoughby

Bats at Willoughby are able to leave the Lane Cove flyway (flyway A) at several places, most notably at Mowbray Park, Chatswood Golf Course and Blue Gum Reserve. However, these three exits points are currently dead ends because of elevated residential development in the area and bats are forced to return back to flyway A in order to move further through the bushland areas in the study area (Figure 2). Bats on the eastern side of the Willoughby LGA can fly west as far as Artarmon Park and are separated from bats on the western flyway corridor C by less than a kilometre. The major obstacle preventing bats on the eastern side of the LGA from flying across to the Lane Cove River valley is the ridge along which the Pacific Highway was constructed. This ridge runs north–south and is very well lit at night, is denuded of tree cover, has constant traffic movements and is flanked in parts by high-rise buildings, especially in the Chatswood area.

High-rise development along the highway corridor is not continuous, and it appears possible to create a bat fly-over at one point on the highway, just north of the Mowbray Road intersection at Artarmon. In this area, there is little high rise development and minimal shop-front lighting. An east–west linking flyway could be created by:

- controlled tree planting leading up to the highway from the eastern and western sides,
- construction of a bat fly-over across the Pacific Highway, and
- restricting high-rise development along this short section of the highway.

An effective flyway corridor from the west could be achieved by utilising and enhancing the tree corridor already in place along Eddy Road, beside Chatswood High School. Suitable street tree planting at the top end of Eddy Road, as well as tree planting along Beresford, Pearl, Ivy and Moriarty Streets going uphill, and Goodchap Road going across the hill could extend the tree canopy at the end of flyway C all the way through to the Pacific Highway. At present, introduced deciduous trees dominate the higher margins of these streets. These trees would need to be replaced with evergreen native trees and flowering shrubs flanking both sides of the street. Native trees and shrubs could provide physical protection from light, wind and predators as well as a potential insect food sources. All of these factors help contribute to the tree canopy being able to also act as a flyway corridor. In addition, if residents living along the proposed flyway corridor may also be encouraged to plant tall native shrubs and trees, the corridor would become even more conducive for small bats. Willoughby City Council may be able to provide incentives for residents in these areas to become part of a collaborative campaign to develop bat-friendly spaces leading up to the highway.

On the eastern side of the highway, near Nelson Street, extended street plantings could create a flyway that utilises the railway corridor directly to Artarmon Station and Artarmon Park. The eastern side of the railway easements could be replanted and an uninterrupted canopy could be established as far as Mowbray Road. The canopy could also continue north of Mowbray Road and the hiatus would coincide with the overhead traffic bridge on Mowbray Road. Bats would have the option of flying under the traffic bridge or crossing over Mowbray Road.

The eastern flyway also needs enhancing between Warners Park and Flat Rock Reserve. At present, a restricted flyway extends west from Warners Park, across the Eastern Valley Way to the War Memorial Fields, which is flanked by tall trees that allow bats to travel southwards to Flat Rock Reserve. The small park between Windsor Street and Eastern Valley Way can be further developed to provide denser tree cover and a continuous tree canopy then can be maintained leading directly to War Memorial Fields. The tree canopy would need to be supported by tall shrub plantings to further reduce indirect night light. The tree canopy could then be extended south to Sailors Bay Road to Flat Rock Reserve to complete the flyway.

In time, bats would be able to traverse from east to west thus effectively increasing the foraging area for a range of insectivorous bats (see O'Neill and Taylor 1989).

The Pacific Highway crossing

To make an effective crossing of the Pacific Highway, three factors are important:

- the approaches to the crossing should be an extension of existing flyways on the eastern and western side of the highway (i.e. flyways C and F),
- the crossing needs to be at tree canopy height, and
- the crossing needs to be shielded from wind, noise and light (Dwyer 1965).

One location on the Pacific Highway, near Moriarty Street at Artarmon, appears suitable for the crossing. The buildings are only two stories high and there are no multi-storey buildings nearby. The crossing would need to be a suspended, flyover bridge that could be lightweight and relatively inconspicuous. To reduce the cost of the fly-over bridge, the main structural material could consist of suspended dense cloth (or synthetic material). The material would need to be strong enough to withstand strong wind, rain and UV light exposure. The flyover bridge would have two vertical walls and a floor but no roof. The crossing would need to be at least three metres wide and have side that extended vertically 2 to 3 metres above the floor. The structure could be suspended from supporting cables that span the highway at a height of about 5 metres. The cost of the structure could be met by the sale of advertising space on the outside of the fly-over bridge: if advertising is placed on the outer wall, associated night lighting would need to be directed downwards and not illuminate the interior of the bridge at night.

For the flyover bridge to become a reality, the immediate area on either side of the highway could not be rezoned for high-rise development. In addition, Council and residents would need to be supportive of the project and to understand how they can contribute to the conservation of the bats in their local area. Finally, government agencies, such as State Rail, need to be included in the project as bat flyways on railway land needs to be maintained in the long-term. Many stakeholders need to be involved in the development of the connecting tree corridors and fly-over bridge. The benefits of creating commuting habitats for bats needs to be fully explained to and understood by local residents and business people if the project is to succeed. The enhanced plantings and extended tree canopy will also provide additional habitat for other native species such as possums and birds.

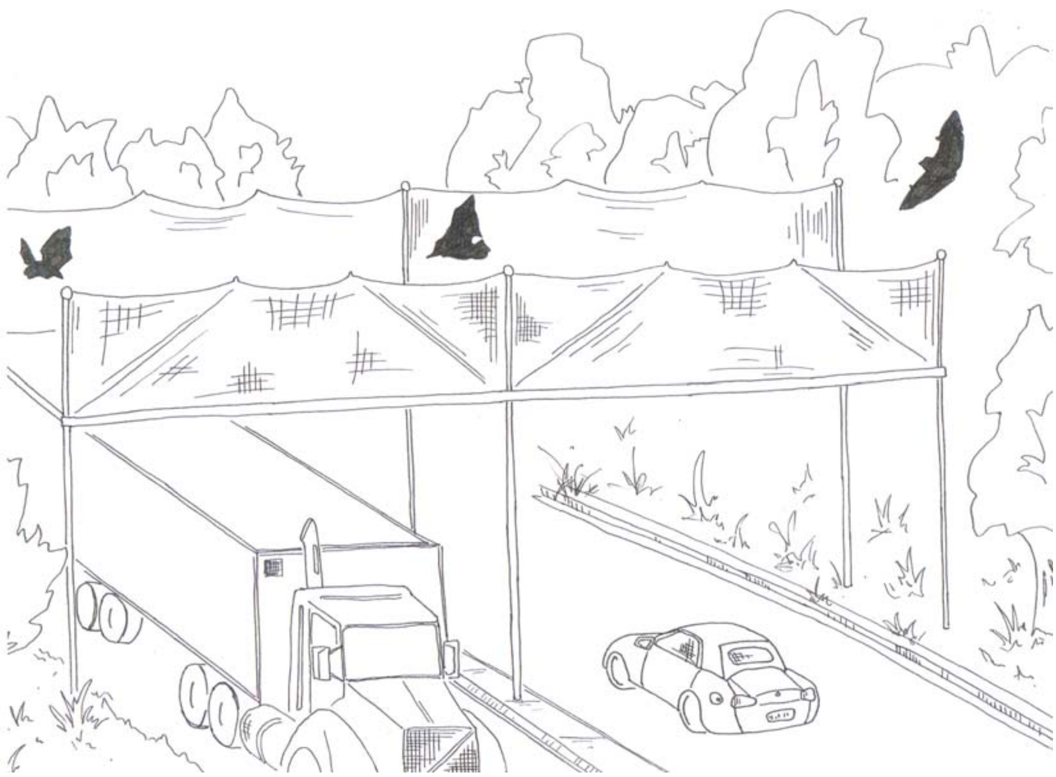

Figure 3 Artist's impression of the bat fly-over across the Pacific Highway at Artarmon.

Acknowledgements

This project came about because of the foresight of Willoughby Council officers and staff. In particular, I would like to thank Alfred Bernhard and Simon Brown for their strong support of the initial bat survey work. Thanks are also due to Ben White for preparing Figure 3.

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