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Comparisons of harp trap and bat detector efficiency for surveying bats in an urban landscape.

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Running head: Efficiency of harp traps and bat detectors in an urban landscape.

Abstract

Bat assemblages in urban landscapes must be surveyed in a cost effective and efficient manner so that adequate information can be obtained in order to make informed conservation management decisions. The efficiency of harp traps and bat detectors for surveying bat assemblages within an urban landscape was compared with respect to number and composition of species. Sampling was carried out in Brisbane, Australia and a total of 27 sites within three habitat types (remnant bushland, parkland, and low density residential) were sampled twice each. Twelve species and the genus *Nyctophilus* were identified from 3628 calls recorded by the bat detectors and four species and the genus *Vespadelus* were identified from the 17 individuals captured by the harp traps. All species captured by harp trap were also detected by bat detector, with the exception of *Nyctophilus bifax*. Species in the genus *Nyctophilus* cannot be distinguished from one another using bat detectors. Bat detectors recorded significantly more species per site than were captured by harp traps, both overall and within each of the three habitat types. Bat detectors were the most effective method

for surveying the bat assemblage in this urban landscape, as they detected more species at a wide variety of sites.

Introduction

Urbanisation destroys, degrades, and fragments large tracts of natural habitat, which many species are unable to survive (Forman and Godron 1986; Niemelä 1999). Consequently, the conservation of biodiversity in urban areas has become increasingly important (Savard *et al.* 2000; McKinney 2002). Insectivorous bats are a specious group and several studies have revealed that urbanisation has a large negative impact on bat diversity (Stebbings 1995; Guest *et al.* 2002; Mickleburgh *et al.* 2002). However, the ecology of bats in urban landscapes is poorly understood. Further information regarding the diversity of bats and the factors influencing their distribution and activity in urban areas is needed as a basis for conservation management (Niemelä 1999; Savard *et al.* 2000; Jaberg and Guisan 2001). In order to obtain such information it is important to survey urban bat communities adequately in a cost effective and efficient manner (Savard *et al.* 2000; Jaberg and Guisan 2001).

A number of different methods are commonly used to survey bats in flight, such as mist nets, harp traps and ultrasonic bat detectors (Churchill 1998; de Oliveira 1998). Mist nets and harp traps are set across ‘flyways’ in well vegetated areas, over small water bodies, and at roost entrances to capture bats. Flyways are passages bats may fly along, such as overgrown trails, streams and between trees or rock faces (Churchill 1998). Bat detectors detect and record the echolocation calls produced by bats as they fly past a microphone, which are later viewed and analysed in order to identify species.

The efficiency of different bat survey techniques have been compared (Tidemann and Woodside 1978; Francis 1989; Schulz and de Oliveira 1995; Mills *et al.* 1996; Kuenzi and Morrison 1998; Murray *et al.* 1999; O'Farrell and Gannon 1999; Duffy *et al.* 2000; Johnson *et al.* 2002; Milne *et al.* 2004). Harp traps appear to be more efficient for surveying bats than mist nets, capturing higher numbers of species and individuals (Tidemann and Woodside 1978; Francis 1989). Comparisons between bat detectors and mist nets or harp traps gave mixed results (Schulz and de Oliveira 1995; Mills *et al.* 1996; Kuenzi and Morrison 1998; Murray *et al.* 1999; O'Farrell and Gannon 1999;

Duffy *et al.* 2000). For example, Murray *et al*. (1999) and O'Farrell and Gannon (1999) recorded significantly more species per site using detectors than either harp traps or mist nets for a variety of habitats in studies by both while Kuenzi and Morrison (1998) found no differences in the efficiency of bat detectors and mist nets. Differences in efficiency may be affected by habitat type. In well vegetated habitats such as bushland remnants, vegetation in the range of the detector can reduce the likelihood of a call being detected while mist nets and harp traps tend to capture more bats in the dense vegetation where flyways are more distinct than open habitats (Duffy *et al.* 2000).

Due to the inherent biases associated with each sampling technique, a number of studies found that using a variety of techniques to survey bat fauna was more effective than using any single technique (Schulz and de Oliveira 1995; Mills *et al.* 1996; Kalko 1998; Kuenzi and Morrison 1998; Murray *et al.* 1999; O'Farrell and Gannon 1999; Duffy *et al.* 2000; Ochoa G *et al.* 2000). For example, Schulz and de Oliveira (1995) used a combination of harp traps, trip lines, bat detectors and roost location techniques in order to survey the bat fauna of Kroombit Tops in central Queensland. In this study, nine species were captured using harp traps which were not recorded by the bat detectors and a further three species were sampled by locating roost sites which were not recorded using any other survey methods (Schulz and de Oliveira 1995). The biases associated with mist nets, harp traps and bat detectors relate to differences in their ability to sample a given species due to interspecies differences in echolocation calls and flight behaviour. Echolocation calls of low intensity attenuate rapidly in the atmosphere, especially at frequencies above 100 kHz (Griffin 1971; Lawrence and Simmons 1982; Neuweiler 1989). Bats which emit low intensity echolocation calls can be difficult to detect from afar using detectors (de Oliveira 1998; Parsons *et al.* 2000) and may be under represented in samples. In contrast, species which emit high frequency echolocation (>50 kHz) calls are more difficult to capture than species which emit low frequency calls (10-30 kHz) (Francis 1989; Neuweiler 1989). Bats with high frequency echolocation calls are able to resolve fine targets against background clutter (Neuweiler 1989), and may detect and evade nets or traps easily (Francis 1989; Berry *et al.* 2004). Capture methods may also under-represent high flying species, which regularly fly well above the height of the nets or traps (Churchill 1998; O'Farrell and Gannon 1999; Duffy *et al.* 2000).

Most studies comparing the efficiency of different survey techniques were conducted in forested landscapes; to our knowledge none have assessed the efficiency of these techniques in urban environments. Urban landscapes differ greatly from other landscapes in being dominated by residential housing, commercial buildings, roads, and paved surfaces (Niemelä 1999). Thus they are more open and exposed landscapes with fewer potential flyways and sites suited to the capture of bats. In addition, most land is privately owned and obtaining permission for access can be difficult. Equipment may also be conspicuous and in populated areas this can increase the chances of interference, vandalism or theft. There may also be personal safety concerns. Therefore survey methods which may be efficient and cost effective in forested landscapes may not be so in urban landscapes.

Of the methods available, bat detectors and harp traps appear the most suitable for surveying bats in urban landscapes. While harp traps may be visually obvious when set out in the open, they will still capture bats if placed in flyways or other locations which may funnel bats toward the trap, such as under lone trees or small bridges (Churchill 1998; Duffy *et al.* 2000; Lumsden and Bennett 2005). Bat detectors have been used to survey bats in a wide variety of habitats and have a greater potential to sample open areas than capture methods (Fenton 1982; Murray *et al.* 1999; Ochoa *et al.* 2000; Hourigan *et al.* 2006; Lloyd *et al.* 2006). Both bat detectors and harp traps can be hidden and left unattended for short periods of time which reduces the chances of vandalism and theft, personal risk for the researcher, and allows multiple sites to be sampled simultaneously.

In this study we compare the efficiency of harp traps and bat detectors for surveying the bat fauna present within an urban landscape. In particular we determine: 1) whether these techniques yield comparable results in number of species and composition, both overall and within each of three different habitat types (remnant bushland, parkland, and low density residential); 2) whether using both techniques together results in a greater number of species being sampled than using one alone; and 3) which methods was most cost effective. We hypothesise that bat detectors will be more efficient and cost effective than harp traps in urban landscapes due to their open nature, but that overall, more species may be sampled using a combination of the two techniques than either alone. We also predict that bat detectors may record more species in open residential habitats rather than remnant bushland, whilst harp traps may be most efficient in well vegetated remnant bushland where flyways are more distinct than open parkland or residential areas. Species which emit low intensity echolocation calls are more likely to be sampled using harp traps than bat detectors, whereas species which emit high frequency echolocation calls may be less likely to be captured.

Materials and methods

Sampling was carried out in the city of Brisbane (27° 29'S, 153° 8'E), Queensland Australia. Nine sites were chosen in each habitat type (27 total); remnant bushland, parkland, and low density residential (Fig 1). Remnant bushland sites were areas of native forest greater than 500 ha in area, in which the understorey was present and canopy removal was less than 50% (Catterall and Kingston 1993). Parkland sites were large landscaped areas of mown grass with scattered trees and little to no understorey, greater than 50 ha in area. Low density residential sites were areas of low to moderate density housing (1 home/0.4 ha) including small parks, gardens and associated infrastructure. Low density residential sites were greater than 500 ha in area.

Insert Figure 1

All sites were located within a 30 km radius of the central business district, and were separated by a minimum of two kilometres to increase spatial independence. A transect 200 m in length and 20 m in width was plotted within each site. A sampling station was positioned at each end of this transect. One harp trap and one bat detector system were set approximately 10 m apart at the same station along the transect to ensure that one sampling method did not interfere with the capture/detection success of the other, and sampling occurred simultaneously. Each of the 27 sites was sampled on two non-consecutive occasions between December 2005 and March 2006. Two sites from different habitats were sampled on each occasion and the minimum time between the two sampling nights at a site was two days. Sampling did not occur when heavy rain was forecast.

We used standard (1.8 m x 2.35 m) two bank harp traps (Faunatech-Austbat, Mount Taylor, Australia). Traps were set up before sunset and checked 90 minutes before dawn. Captured bats were sexed, weighed, measured, identified and released before sunrise. The bat detector systems consisted of an Anabat II detector (Titley Electronics, Ballina, Australia) and either a Zero Crossing Analysis Interface Module (ZCAIM) connected to a laptop computer running Anabat6 software, powered by an 18 Volt battery; or a CF ZCAIM containing a 64 Mb memory card. Each system was set at ground level with the microphone positioned at approximately 45 degrees. The bat detectors were calibrated to achieve a uniform detection range and sensitivity using a Chirp Board (Nevada Bat Technology, Las Vegas, Nevada) following the methods outlined by Larson and Hayes (2000). Each system was set up before sunset to monitor and record bat calls automatically for the entire night. The Anabat system saves the recorded echolocation calls in files with text containing details of the recording location, along with the date and exact time at which the calls were made.

Species identification

The recorded echolocation calls were identified to species using the bat call analysis system Analook (version 4.9g). A call, or call sequence, can be defined as series of vocal pulses separated by pauses (de Oliveira 1998b). Each pulse is characterised by a maximum and minimum frequency, duration in milliseconds, and shape (O'Farrell *et al.* 1999). The following stepwise procedure was used to evaluate and identify species: 1) Anabat files were scanned rapidly and any without bat calls were discarded; 2) superfluous noise was removed. Such noise appears as random dots on the screen and is easily distinguished from bat calls; 3) call sequences were examined for differences in frequency and synchronisation of pulses to determine whether multiple bats were recorded simultaneously. When this occurred each sequence was analysed separately; 4) only call sequences with a minimum of three consecutive intact pulses were used to identify species. The characteristic frequency, end frequency, knee frequency, pulse duration and interval, and initial slope of calls were measured (as defined in Reinhold *et al.* 2001). Pulse shape and an alternation of pulse frequency were also used to assist in the identification of species from recorded calls; and 5) these measurements were used in conjunction with an identification key and existing call library for the south-east Queensland region (Reinhold *et al.* 2001) to determine the species. A subset of Anabat files were also examined by two independent consultants experienced in bat call analysis, for accuracy of call identifications. Nomenclature follows Duncan *et al.* (1999), with the exception of species in the genus *Mormopterus*. The taxonomy of the genus *Mormopterus* (Molossidae) is poorly resolved in Australia and one of the species which occurs within south-east Queensland has not been formally named (Duncan *et al.* 1999). Therefore this species was referred to as *Mormopterus* species 2, after Adams *et al.* (1988).

A list of the species sampled by the bat detector and harp trap was tabulated, as were the number of sites each species was sampled by the bat detector exclusively, the harp trap exclusively, and by both methods. The mean number of species recorded by each method was also determined for each of the three habitats. Two-tailed Wilcoxon matched pairs signed rank tests were used to test whether there was a significant difference in the number of species recorded by the two methods overall and within each habitat type. A Wilcoxon matched pairs rank sign test converts the values to ranks and compares the median of two matched samples (Fowler *et al.* 1998). A Kruskal-Wallis ANOVA was used to examine whether the number of species detected by either method differed significantly between the three habitat types. Statistical tests were conducted using SPSS for Windows (version 13.0).

Mean number of call sequences recorded by the Anabats per hour of sampling effort and mean number of individuals captured by the harp traps per hour of sampling effort were calculated in order to determine the relative success of each technique. In doing so we assumed that each bat captured or sequence recorded was a different individual. The cost effectiveness of each technique was also assessed by dividing the total number of call sequences and total number of individuals captured by the total cost of each technique. The total cost included the equipment plus associated materials required to set up and operate each technique for the duration of the sampling period. The mean time required to set up, position and take down one bat detector system and harp trap per sampling event was also determined for each technique.

Results

Twelve species and the genus *Nyctophilus* were identified using the bat detectors. Of the 3628 call sequences recorded by the detectors, 45% were of poor quality and unsuitable for identification while a further 8% could not be confidently identified to species. Four species and the genus *Vespadelus* were identified from the 17 individuals captured by the harp traps. With the exception of *Nyctophilus bifax*, all species captured using the harp traps were also detected by the bat detectors (Table 1).

Both *Nyctophilus gouldi* and *N. bifax* are thought to occur within the Brisbane area (Churchill 1998). However calls of species in the genus *Nyctophilus* cannot be distinguished from one another using bat detectors, as their call characteristics overlap substantially (Reinhold *et al.* 2001). Therefore these calls were grouped as *Nyctophilus* spp. The calls of *Scotorepens greyii* and *Scotorepens sp.* are also indistinguishable from one another and these species were grouped as *Scotorepens* spp. (Reinhold *et al.* 2001). Similarly, *Vespadelus troughtoni* and *Vespadelus pumilus* are also thought to occur within the Brisbane area (Churchill 1998). *Vespadelus pumilus* was recorded at six sites using the bat detector (Table 1), and seven individuals of this genus (all females) were captured at a single site using the harp trap. As penis morphology is used to distinguish between species within the genus *Vespadelus* (Parnaby 1992; Churchill 1998), it is uncertain which species we captured and therefore the individuals were recorded as *Vespadelus* spp. (Table 1).

Insert Table 1

Bat detectors were clearly more effective at sampling all 12 species and the genus *Nyctophilus* across the 27 sites than harp traps (Table 1). Bat detectors sampled significantly more species than were sampled by the harp traps (Wilcoxon, $Z = -4.471$, $n = 27$, $P<0.001$). The number of species detected was also significantly higher for bat detectors compared to harp traps in each of the three habitat types (Fig 2; remnant bushland Wilcoxon $Z = -2.552$, $n = 9$, $P<0.05$; parkland $Z = -2.673$, $n = 9$, $P<0.05$; low density residential $Z = -2.680$, $n = 9$, $P<0.05$). However, there was little difference in the number of species sampled by the bat detectors (Kruskal-Wallis $\chi^2 = 0.699$, df = 2, $P>0.05$) or harp traps (Kruskal-Wallis $\chi^2 = 0.009$, df = 2, $P>0.05$) between habitat types (Fig 2).

Insert Figure 2

Overall bat detectors recorded seven calls per hour of sampling effort (Table 2) and bats were recorded by the detectors in 89% of sampling events. In contrast, overall trap success was 0.04 captures per hour of sampling effort (Table 2), with just 7% of trapping events resulting in captures. Although we assumed that each bat captured or sequence recorded was a different individual, it is likely that multiple sequences were recorded from the same individual if it remained within the detection range of the bat detector or flew past repeatedly. This is likely to have inflated the number of calls recorded per hour. However, it is also likely that some individuals were also captured on multiple occasions as a single low density residential site accounted for the majority of harp trap captures (15 individuals from three species and the genus *Vespadelus*). At this site a harp trap was placed just within the entrance of a large concrete box culvert beneath the road. Vegetation flanked both sides of the entrance and continued away from the culvert along either side of an overgrown, dry creek bed. Bats were later discovered roosting in drainage holes in the ceiling.

The harp trap was cheapest of the two techniques but the least cost effective at $75.88/capture in this study (Table 2). In addition, the mean time required to set up, position and take down a harp trap was one hour per sampling event. This was double the amount of time required by the Anabat system in the field (Table 2). However, an additional mean time of three hours and 20 minutes per sampling event was required to identify the recorded echolocation calls to species (mean three minutes per sequence).

Insert Table 2

Discussion

The distribution of 25 insectivorous bat species fall within the South-east Queensland region, of which Brisbane is a part. However to the best of our knowledge, there have been no published surveys or studies of the bat fauna occurring within the urban mosaic of Brisbane prior to this study. This study is the first large scale systematic survey of the bat fauna to be completed in Brisbane. We recognise that not all 25 species are likely to occur within urban areas of the South-east Queensland region;

and that both techniques are likely to have missed species that evaded capture or detection, or flew outside the area sampled by each technique. However, our goal here was not to obtain a complete inventory of species, but to compare the efficiency and cost effectiveness of two techniques. To determine whether they yielded similar results in the number and composition of species they sampled, and whether using both would result in more species being sampled overall.

Urban bat detector and harp trap efficiency

Of the two methods compared in this investigation, the most effective for surveying the bat fauna in an urban landscape was with the bat detector. Significantly more species were sampled using bat detectors than with harp traps, and using both of these techniques concurrently did not result in a greater number of species being recorded per habitat than would have been obtained using the bat detector alone. Similarly, O'Farrell and Gannon (1999) found that significantly more species were recorded using detectors than harp traps across a range of habitats and elevations in the south-western United States of America. Of the 20 species detected in their study, 14 were documented more frequently by bat detector rather than by capture, and capture techniques did not record any additional species that were not detected acoustically.

These results contrast to those of several other Australian studies (Schulz and de Oliveira 1995; Mills *et al.* 1996; Duffy *et al.* 2000) and our predictions. These studies found that harp traps and bat detectors were complementary in detecting the suite of species present, so that both methods together detected more species than either used alone. While bat detectors did not sample a greater number of species than the harp traps in any study overall, detectors did produce more species records per site within the drier, more open and fragmented forests of the Box-Ironbark region in Victoria (Duffy *et al.* 2000). However, all these studies were conducted in forested landscapes. Harp traps may have been less successful within the urban landscape of the present study compared with forested landscapes due the relatively sparser vegetation with fewer potential flyways in which to place the traps. Yet harp traps have been successfully used to capture bats flying around isolated trees in rural landscapes (Lumsden and Bennett 2005). The presence of a greater number of additional structures in an urban landscape, such as streetlights, may also spread bat activity over wider area making bats more difficult to target and catch in flight regardless of habitat type.

Bat detectors may have been more efficient in our study because a higher proportion of calls may have been identifiable, since we used a laptop computer or CF ZCAIM in conjunction with the Anabat, rather than tape recorders which were used by Schulz and de Oliveira (1995), and Duffy *et al.* (2000). Although Schulz and de Oliveira (1995) do not report the percentage of their calls which were identifiable, Duffy *et al.* (2000) report that only 35%, 10% and 12% of calls could be confidently identified to species level in the Box-Ironbark, North-east and Gippsland regions respectively. This is low compared with the 47% of calls which were identifiable in the present study. Sequences saved using digital rather than analogue recording techniques result in higher quality recordings, increasing the number of call sequences that can be used for identification (O'Farrell *et al.* 1999). Johnson *et al.* (2002) and Milne *et al.* (2004) both compared the quality and quantity of calls recorded to tapes versus laptops and showed that significantly more calls of better quality were recorded using laptops; enabling more species to be identified. O’Farrell and Gannon (1999) also used laptops to record calls detected by bat detectors, in their comparison of acoustic versus capture techniques. The high quality and quantity of calls recorded in our study may also the reason bat detectors were as efficient in well vegetated remnant bushland areas, as more open residential and parkland habitats.

Differences in species detected

As calls of the species in the genus *Nyctophilus* cannot be distinguished from one another using the Anabat detectors and the low intensity echolocation calls they emit may not be readily detected (de Oliveira 1998a), the harp trap may be a useful tool for resolving which of these species may be present in a survey area. However, since the harp traps in this study captured only one individual of this species at a single site, very little could be said about the distribution, activity or the frequency at which *N. bifax* occurs within the urban landscape. In addition, bat detectors may record *Nyctophilus* spp. despite the associated biases, as species of this genus typically fly within two to five meters of the ground (Brigham *et al.* 1997). It is also significant that reliable identifications of some species are not always possible even with captured bats. When species identification is based on sex dependant information, such as species in the genus *Vespadelus*, the individuals of one sex will invariably be grouped at the genus level.

Only species which emitted relatively high frequency (>50 kHz) calls were captured by the harp traps, which was contrary to our prediction. The characteristic frequency of calls emitted by *Chalinolobus morio* and *Miniopterus australis* range between 47 and 55 kHz and 57 to 66 kHz respectively, while the linear sweep of calls emitted by *Myotis macropus* and *Nyctophilus bifax* start at 70 to 80 kHz and drop to 35 to 40 kHz (Jones and Corben 1993; de Oliveira 1998b; Reinhold *et al.* 2001). Calls of *Vespadelus* spp. could be either 48 to 55 kHz (*Vespadelus troughtoni*) or 50 to 57 kHz (*Vespadelus pumilus*). Although these species use calls which may allow them to resolve finer targets and detect harp traps, they also fly below the canopy whilst foraging which may have made them easier to catch (Lumsden and Bennett 1995; Churchill 1998). However, as the majority of captures were inadvertently made at a roost entrance, it is more likely that we simply captured species that were roosting in the culvert rather than foraging along the creek. Harp trap efficiency may be increased in urban landscapes by specifically targeting structures such as culverts with high ceilings.

Logistical considerations

The use of bat detectors was clearly the most efficient and cost effective sampling method for surveying the bat fauna in our urban landscape. However, a considerable amount of time was required to identify the recorded echolocation calls to species. While the time this takes is dependant on experience and may be faster for experts in analysing and identifying bat calls to species, additional costs may also be associated with hiring such an expert to identify the calls, if none of the researchers have the experience to do so. Despite this, bat detectors are quick to set up in the field, can be automated to run for the entire night without the presence of an observer, are unobtrusive and sample a wide variety of habitats. This allows multiple sites to be sampled simultaneously over a wider area. Although the time it takes to set up either bat detectors or harp traps will vary with experience, the extra people required and the need for sites to be of a particular nature means that only a small number of sites within close proximity can be sampled and managed effectively at one time when using harp traps. This is especially so in urban areas where vandalism and theft are more likely to occur as the traps are more obvious and cannot be hidden from view as well as the bat detectors. Of course both bat detectors and harp traps require appropriate training in order to be useful in the outset. Sampling success and cost effectiveness may vary for studies in other regions, and to some extent the level of experience in using either technique. For example, researchers with more experience may find better locations at a site in which to place traps which may result in more individuals being captured than would otherwise be the case for those who are inexperienced.

These limitations, in conjunction with our findings. suggest that harp trapping would be less suitable or effective for sampling bats in urban landscapes. While acoustic methods have a number of biases and constraints which must be taken into consideration, bat detectors alone were sufficient to sample the bat assemblage. However, harp traps have other advantages, including allowing the collection of demographic information such as the ratio of sex or age classes and patterns of movement, which cannot be obtained using bat detectors. Therefore the specific research question being examined will also determine the choice of technique(s) to be used. In the present study where the primary goal was to compare the species diversity and composition of habitats in the urban mosaic, the use of bat detectors alone was clearly the most cost effective and efficient method.

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