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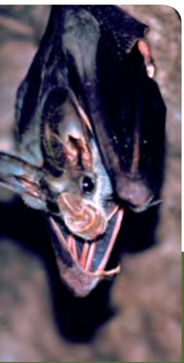


Survey guidelines for Australia’s threatened bats

Guidelines for detecting bats listed as threatened under the
Environment Protection and Biodiversity Conservation Act 1999

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HOW TO USE THESE GUIDELINES

The purpose of this document is to provide proponents and assessors with a guide to surveying Australia's threatened bats listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

These guidelines will help you to determine the likelihood of a species' presence or absence on your site. They have been prepared using a variety of expert sources, and should be read in conjunction with the Department of the Environment, Water, Heritage and the Art's *Significant impact guidelines 1.1 - Matters of national environmental significance.*

These guidelines are not mandatory. Proposals failing to meet these survey guidelines for reasons of efficiency, cost or validity will not necessarily default to a judgement that referral is required (that is, that a significant impact is likely), especially where the proponent issues an evidence-based rationale for an alternative survey approach. Alternatives to a dedicated survey may also be appropriate. For example, a desktop analysis of historic data may indicate that a significant impact is not likely. Similarly, a regional habitat analysis may be used to inform judgement of the likely importance of a site to the listed bats. Proponents should also consider the proposal's impact in the context of the species' national, regional, district and site importance to establish the most effective survey technique(s).

Failing to survey appropriately for threatened species that may be present at a site could result in the department applying the precautionary principle with regard to significant impact determinations. That is, if no supporting evidence (such as survey results) is presented to support the claim of species absence then the department may assume that the species is in fact present. The department will not accept claimed species absence without effective validation such as through these guidelines, other survey techniques (for example a state guideline or an accepted industry guideline), or relevant expertise. Where a claim of absence is made, proposals should provide a robust evaluation of species absence.

Biological surveys are usually an essential component of significant impact assessment, and should be conducted on the site of the proposed action prior to referral. Surveys assist in the evaluation of impact on matters of national environmental significance by establishing presence or the likelihood of presence/absence of a species. Before undertaking a survey, proponents may wish to contact the Department of the Environment, Water, Heritage and the Art's relevant assessment section to discuss their project and seek advice on appropriate survey effort and design.

Executing a survey to this model and identifying listed species presence does not in itself predict a significant impact. Species presence is one of many factors that increase the likelihood of significant impact. Proponents should use species presence as a consideration in establishing whether a significant impact is likely or certain. As part of the assessment process, sufficient information is usually required to determine if a species' presence at a site constitutes a 'population' or 'important population' as defined in the *Significant impact guidelines 1.1* publication. Information on whether the occurrence constitutes a 'population' or 'important population' will not necessarily be generated by surveys conducted using these guidelines.

These guidelines help determine presence or the probability of presence. They **do not** establish or assess species abundance, as the effort in terms of cost and time required for an abundance survey is much greater than that determining presence/absence. Effective abundance surveys would need to compare survey effort and techniques with further exploration of a proposal's context, including important population location(s), habitat importance, ecological function and species behaviour.

INTRODUCTION

Background

Ninety taxa (species or subspecies) of Australian bats (Chiroptera) were recognised in the *Action Plan for Australian Bats* (Duncan et al. 1999) and ten of these taxa are currently (June 2008) recognised as threatened nationally (Table 1). These are listed in categories that are considered matters of national environmental significance under the EPBC Act.

Table 1 Nationally threatened bat species listed under the EPBC Act as at June 2008.

Scientific name	Common name	Status under EPBC Act 1999
Miniopterus schreibersii bassanii	Southern bent-winged bat	Critically Endangered[5]
Pipistrellus murrayi	Christmas Island pipistrelle	Critically Endangered[4]
Saccolaimus saccolaimus nudicluniatus	Bare-rumped sheath-tailed bat	Critically Endangered[1]
Rhinolophus philippinensis (large form)	Greater large-eared horseshoe bat	Endangered[1]
Hipposideros semoni	Semon's leaf-nosed bat	Endangered[1]
Chalinolobus dwyeri	Large-eared pied bat	Vulnerable[1]
*Nyctophilus corbeni**	South-eastern long-eared bat	Vulnerable[1]
Pteropus conspicillatus	Spectacled flying fox	Vulnerable[3]
Pteropus poliocephalus	Grey-headed flying fox	Vulnerable[2]
Rhinonicteris aurantia (Pilbara form)	Pilbara leaf-nosed bat	Vulnerable[1]

Listings effective as of: [1] 4 April 2001; [2] 6 December 2001; [3] 14 May 2002; [4] 12 September 2006 and [5] 18 December 2007.

*Note that *Nyctophilus corbeni* is listed under the EPBC Act as *Nyctophilus timoriensis* (south-eastern form).

Some of these taxa are undergoing or may be subject to future taxonomic review. Regardless of their current or future taxonomic classification, the definition of a species under the EPBC Act includes subspecies and distinct populations that the federal environment minister has determined to be species for the purposes of the Act. Each 'species' has met the criteria required for listing in these categories, based on nominations assessed by the Threatened Species Scientific Committee and approved by the minister. Listings are subject to change, and should be checked for currency on the website of the Australian Government.

Australia's threatened bats are diverse in form, habit and relative abundance, and as such, the survey guidelines presented here have been written for each individually, rather than for categories of species with similar habit. State survey guidelines were considered in the review of available literature when developing this document.

The incomplete knowledge of the distribution of many of the threatened bat species is an important consideration. Distribution maps in the literature for these are based on the minimum convex polygon method, which involves joining the outer-most observations to form a distribution polygon. The resulting distribution maps may include those areas that lie between recorded localities, but which have not been surveyed, and extrapolations based on the distribution of suitable habitat for the species. For some species, this may result in an overestimate of both extent of occurrence and area of occupancy. Conversely, some key areas have been sampled inadequately for threatened bat species, and the currently accepted distribution may be greatly underestimated. More precise distribution maps are needed to serve as a basis for deciding whether a proposed project area falls within the distribution range of a threatened bat species, thus triggering the EPBC Act. Since many maps are likely to be inaccurate, and may change as new information becomes available, distribution maps for threatened bat species have not been included in these survey guidelines. The protected matters search tool can be used to assess the likelihood of a threatened species being found in a specific area (see also Step 1-Conducting surveys in six steps).

Scope of the survey guidelines

These survey guidelines provide guidance on what should be considered when planning and undertaking species presence surveys for threatened bats relevant to a referral to the federal environment minister under the EPBC Act. The individual taxa (species or subspecies) accounts provide a guide as to the survey methods and effort that are appropriate for assessment of whether those listed taxa occur at or near a specified site (‘study area’). Consequently, the guidelines focus on assessing the presence or likelihood of presence of taxa in a study area, and not on an assessment of the abundance of individuals.

The taxa accounts relate to the 10 bat taxa that are classified as threatened under the EPBC Act (see Table 1) as at June 2008. However, it is recognised that the EPBC Act threatened species list is dynamic and that survey guidelines are likely to be applied to some taxa not currently listed. Conversely, it is hoped that with ongoing conservation programs the populations of some taxa will recover and they can be removed from this list.

The survey guidelines are limited to recommending the effort with selected techniques to establish whether a target species is present, absent or in low abundance in a project area. A survey is interpreted as the first step in a process towards assessing the impact of a proposed project on any threatened bat species. The approaches in each species profile should be regarded as a minimum and should be included in any general fauna survey program that seeks to determine the presence of species of conservation significance. If threatened species are found to be present during the survey different techniques may be required to establish if the project area contains important habitat (roost sites, foraging sites, water sources and movement corridors) for those threatened species.

Determining if a survey should be conducted

As a guide, proposals that include areas within the broad distribution of a nationally threatened bat species, and any one of the following situations, could trigger the need for a targeted field survey:

- contains records of threatened bat species within or adjacent to the project area
- includes or is adjacent to known flying fox camps
- will affect vegetation containing potential food trees of flying foxes
- includes rocky outcrop containing caves

- includes historical or disused underground mine workings or other artificial structures likely to be used by threatened bat species
- is located in forest or woodland habitats and vegetation associations known to be used by threatened bat species, or
- contains water sources where high-flying species such as *Saccolaimus saccolaimus* may be encountered.

Making a predictive assessment of the relative value of an area for species of threatened bat should not be made in place of an actual survey. However, the likelihood of encountering these species can be assessed if some information is already known about the site from a reconnaissance or examination of aerial photography. This can help with planning the level of effort that might be required during a survey.

If habitat suitable for a threatened species occurs in the area, and an appropriate survey is not conducted to determine presence/absence, the department may follow the precautionary principle and assume that the species is in fact present.

Likelihood of presence: Low ↕ High	Location within the accepted range of a nationally threatened species and: • a bare field, with no features that could be used for roosting, foraging or dispersal such as overstorey, rocky outcrop or watercourses. • habitat containing some features of potential use for bats – trees with hollows, rocky outcrop, drainage features, but not connected to known occupied habitat or potentially suitable habitat. • isolated habitat with specific features that could be used by threatened bat species. • habitat adjacent or connected to potentially suitable habitat. • habitat adjacent or connected to habitat where a threatened species has previously been recorded.
Confirmed or unconfirmed records	Records based on: • echolocation call recordings • signs such as scats • capture and release after identification from measurements or diagnostic features, and • capture and specimen collection, lodgement in a museum, with or without skull measurements and DNA sequences.

PLANNING AND DESIGN OF SURVEYS

For any proposal, the timing of fieldwork is critical to the surveying and reporting process. Careful consideration of the necessary lead time is required as it may be necessary to undertake surveys at specific times of the year depending on the ecology of the species in the subject area. Surveys over multiple years may be required where a single year's data is not adequate to detect the species or to address the environmental factors. There may also be a timelag due to the availability of appropriate faunistic expertise. Proponents should make allowance for this lag when planning projects. Commissioning biodiversity surveys as early as practicable in the planning/site selection phase of a project will help avoid potential delays in approvals.

Effective surveys should always begin with thorough examination of the literature to identify the best times, locations and techniques for surveys. The profiles in this document provide a basis for effective surveys for bat species currently listed as threatened at a national level in Australia.

Conducting surveys in six steps

Step 1: Identify taxa that may occur in the study area

The first stage in the design and optimisation of surveys is to generate a list of threatened bats that could potentially occur in the study area. A four stage process is suggested below.

(i) Characterise the study area

The boundaries of the study area must be established clearly. A detailed map of the study area should then be constructed revealing the type, locations and condition of native vegetation and important habitat features for bats, such as caves, mines and forests. This process is not only critical to establishing which threatened species may occur in the area, but also in the selection of appropriate survey methods and effort. An appropriate map will aid almost every survey regardless of survey technique.

(ii) Establish the regional context

This stage requires an assessment of the habitat frequency and function. The regional context will help develop judgements of significance associated with the loss or disturbance of habitat. A useful test will involve the following questions:

- Are the habitats rare or common?
- Are the habitats likely to be critical to the species' persistence or ephemeral?
- How is the species likely use the site (for example, breeding, foraging etc)? Survey design may need to be adjusted to determine these aspects if necessary.

(iii) Identify those threatened bats that are known to, likely to or may occur in the region

This stage involves consulting a range of sources to determine which threatened bats could occur in the region surrounding and including the study area. There are a range of sources that should be consulted to create a list of taxa. These include:

- Department of Environment databases, including the protected matters search tool and species profiles and threats (SPRAT) database that allow you to enter the site of interest and generate predictive maps and information relating to threatened species distributions
- state, territory and local government databases and predictive models
- national and state threatened species recovery plans and teams
- reference books such as Australian bats (Churchill 2008)
- museum and other specimen collections
- unpublished environmental impact reports
- published literature, and
- local community groups and researchers.

(iv) Prepare a list of threatened taxa that *could* occur in the study area

This can be determined by comparing the habitat requirements of each threatened taxa known or likely to occur in the locality *(stage iii)* with the habitat types and features present within the study area *(stages i and ii)*.

The taxa identified in this process are referred to as 'target' taxa.

Step 2: Determine optimal timing for surveys of 'target' taxa

Detection of threatened species can be enhanced by sampling during the seasons and weather conditions when the species are most conspicuous. If it is not possible to survey for target taxa that have been previously recorded in the general location of the study area during the appropriate time of day or season, it should be assumed that these taxa do occur in the study area if suitable habitat exists (NSW DEC 2004).

Effort should be made to ensure that bat surveys will not cause a disturbance to bats when breeding. Seasonal considerations must be balanced between ensuring that:

- the time of year is suitable to maximise the probability of detection and
- the survey approach will not cause disruption to breeding individuals.

If surveys are to be conducted when females are heavily pregnant or with young attached, then the approach used should not include methods that could cause distress or the abandonment of young. Furthermore, disturbance to some species at particular times of the year might result in a greater risk of mortality. For example, disturbance causing exodus of a roost could have disastrous consequences during relatively dry periods for species such as *Rhinonicteris aurantia* if suitable alternative roosts are not within their nightly flight range.

Surveys should also be conducted during weather conditions when there is the greatest chance of encountering the species. Surveys should not be conducted on windy or cold or rainy nights. To account for seasonal movements or irregular occupation of roost sites, surveys for some species may need to be repeated at different times of the year.

The two species of megachiropteran bats are conspicuous, can form large colonies and are readily detected if present. However both individuals and populations are highly mobile, and they will move great distances in response to flowering and fruiting events, the timing and location of which can vary with both season and year. A survey conducted to determine the relative importance of a project area to these bat species could be entirely misleading if reliant solely upon detecting the presence of bats at one particular time of year. The survey guidelines recommended include diet plant surveys as a key survey technique.

Step 3: Determine optimal location of surveys

In some circumstances, the study area of interest will be small enough to allow a comprehensive search of the entire area within a reasonable period of time. The size of what is a searchable area will depend on the nature of the target taxa and the habitat and topography of the study area. If a comprehensive search is feasible, then sampling will not be required and the data collected will be representative of the entire area. In many cases the study area will be too large to permit a complete search within a reasonable time frame, and selective searches or sampling procedures will be required (Royle & Nichols 2003).

Many study sites will be comprised of a variety of distinct habitat types, especially if the area is extensive. Some of these habitats may be unsuitable for occupancy by the targeted taxa. An effective strategy to maximise the likelihood of detecting a particular taxon is to concentrate search effort within habitat that is favoured by the targeted taxon (Resources Inventory Committee 1998). This will require that the study area is divided up, or *stratified*, into regions of similar habitat types.

When stratifying a study area, the study area is usually partitioned first on biophysical attributes (for example, landform, geology, elevation, slope, soil type, aspect, water depth), followed by vegetation structure (for example, forest, woodland, shrubland, sedgelands). Strata can be pre-determined based on landscape features indicative of habitat which can be derived from topographic maps, aerial photographs that show habitat types, or existing vegetation maps. Preliminary assessment of the study area prior to commencing the surveys will be useful to check stratification units and further stratify the area if necessary (NSW DEC 2004). In other situations, such as the inundation of vast floodplains, there may be little alternative but to implement a form of stratified sampling based on accessibility of habitat during the course of the survey.

Focussing search effort on favoured habitat can be a valuable strategy to maximise the likelihood of detecting target taxa. However, this approach requires that the habitat preferences of target taxa are adequately known, which for many threatened species may not be the case. The fewer the number of habitat association records that have been reported for a taxon, the more likely that any apparent habitat preference will be an artifact of the small sample. Furthermore, subsequent surveys then tend to focus on these apparently preferred habitats, which can further distort the perception of habitat preference. Consequently, investigators should not exclude particular habitat strata from survey designs unless it is well established that these habitat types are consistently less favoured by the target taxa than other types within the study area.

Step 4: Establish sampling design and survey effort

The previous sections on survey timing and location highlight important strategies to help increase the chance of detection. However, replicated sampling will often be required either to reveal the target taxa/taxon or satisfy the argument that the taxon is absent or occurs at very low abundance within the study area. Information on species that occur at very low abundance may be important when considering the likelihood of a significant impact from the proposed actions. Sampling can be replicated in space (different locations at the same time) and time (same location at different times) or a combination of both (different locations at different times).

Spatial sampling

Replication in space will often be necessary to detect populations that are at low densities or clumped distribution. Even after stratification, sampling may still be required if the area of favoured habitat is large or if the habitat preferences of the target taxa are variable or poorly known. There are two basic spatial sampling designs:

- **Random sampling** - when all locations within the study area (or selected strata) have an equal chance of being sampled, and
- **Systematic sampling -** when units are spaced evenly throughout the study area (or selected strata).

Systematic sampling will generally be superior as it produces better coverage, is easier to implement and is less subject to site selection errors. It is also recommended that sampling units are placed to avoid boundaries of environmental stratification (for example, shorelines) and local disturbances such as roads, mines, quarries and eroded areas (Resources Inventory Committee 1998, NSW DEC 2004).

In general, sampling units should be positioned sufficiently far apart that individuals are unlikely to be detected from more than one sampling location, so that the samples are independent. The distance between sampling positions will usually depend on the territory or home range size of individuals in the target population and their detection distance. The inter-sample distance will also depend on the survey technique being employed. The number of sampling units within the study area (or strata) should be proportional to its size, a principle referred to as *area-proportionate sampling* (MacNally & Horrocks 2002). However, a linear increase in sample number with area will become impractical at very large study areas.

A formal sampling design, outlined above, is less critical in detection studies than abundance studies. A formal sampling design is still preferable for use in detection studies, especially if stratification is required (Resources Inventory Committee 1998a).

Temporal sampling

Temporal replication may be necessary to detect populations that fluctuate in abundance, occurrence or detectability with time, especially when these fluctuations are unpredictable. For example, some taxa are highly mobile, and may occupy regions within their range only for brief and unpredictable periods of the year. As a result, regular sampling during and throughout the time of year when the taxa are most likely to occur at the study area is desirable. Some locations may be occupied by target taxa in some years but not others, depending on environmental conditions.

Sampling over many years will rarely be feasible. In some cases, previous records can provide information on the use of such sites by particular taxa. If threatened taxa have been recorded in the general location of the study area when conditions were appropriate, it would be expected that these species will return again, unless the habitat has been irreparably changed. Where previous data are few or absent, assessment of the habitat will be vital and could provide the only indication of whether the site is likely to support these species when conditions are suitable in the future.

Temporal sampling may also be required when the study area is small. In this situation, the individuals of some taxa will have territories or home ranges that include, but are not restricted to, the study area. As a result, at any one time, some of these individuals will be absent from the study area and go undetected (Mac Nally & Horrocks 2002). Regular sampling over time is recommended as it will increase the probability that these individuals will be detected on at least one occasion. Off-study area sampling is another means to address this problem, whereby sampling is conducted in suitable habitat in the area surrounding the study area. This procedure effectively increases the study area, allowing greater spatial sampling, and enhances the probability of detecting individuals with home ranges larger than the core study area. In practice, this will be a useful strategy because temporal replication is often more costly to implement than spatial replication, as additional travel may be required to and from the study area.

Step 5: Select appropriate personnel to conduct surveys

The single most essential component of any survey is competent observers (Resources Inventory Committee 1998). It is an expectation of assessors under the EPBC Act that surveys be conducted by appropriately experienced observers who have excellent identification skills and a good knowledge of bat ecology, at least in relation to the taxa or group being targeted. Observers should have recognised relevant skills or experience. Observers should also have access to appropriate equipment (that is, traps and electronic echolocation call detectors). The need for excellent field identification skills of observers cannot be overstated.

Survey leaders should assess all contributors and, where necessary, provide training and guidance to maximise the effectiveness of all observers (for example, Saffer 2002). Some indication of the previous experience of observers with the target taxa, and the identification challenges inherent in surveying for these taxa should also be provided to help assess the competency of observers and reliability of observations.

The personnel engaged to conduct surveys for threatened bat species should have demonstrated experience working with bats, and preferably experience with the species to be targeted in a particular assessment. The reasons for this include:

- **Reliability of identifications:** it is crucial that the threatened species targeted be identified clearly.
- **On-site identification:** for bat detector studies, it is desirable to be able to identify bats in the field, rather than have calls identified by a specialist after the field work has been completed.
- **Adequate trapping experience:** for general bat surveys, many observers rely solely on the use of echolocation recording as a survey method, however these survey guidelines recommend the use of capture techniques in addition to echolocation recordings. Experience is required for handling and measuring bats, but especially for removing bats from mist nets without causing harm and distress to the animals.

- **Occupational health and safety:** suitable experience and in some cases formal training for working in caves and mines ('confined spaces') is important when surveying for some species, which will minimise risk to field personnel (reviewed in Armstrong and Higgs 2002, Mitchell-Jones 2004, Bat Conservation Trust 2007). It may also allow for greater survey effort following the granting of access to certain areas to individuals with appropriate experience and training. Vaccinations are also an important occupational health and safety consideration. The Australian Immunisation Handbook (9^{th} edition) recommends Lyssavirus and rabies vaccinations for anyone working with bats.
- **Experience with equipment placement:** although the purpose of the survey guidelines is to provide clear guidelines for surveys, each field situation is different, and therefore on-site decisions need to be made in terms of placement of traps, and where and how to look for roosts and signs of bats.

Personnel engaged to conduct surveys on nationally threatened bats must be familiar with the particular species, experienced with the methods described in this document, and/or demonstrate adequate training from an expert prior to conducting the survey.

In addition, there are other parties who should be contacted where appropriate prior to field surveys. These could include state government agencies or departments, the Australasian Bat Society, other researchers or workers familiar with or that have published on the species with the potential to occur in the project area, and local land managers. Some of these may maintain databases of known occurrence, and mention of some of these is provided in the individual species accounts to follow.

Step 6: Document survey methods and results

Survey methods and level of search effort vary widely between studies. For this reason it is essential that survey reports include detailed information on the methods used and the level of search effort adopted. This should include who was involved, what work was carried out, where the work was carried out, when the survey was conducted and how the survey was conducted. The survey report should follow the standard aims, methods, results, and discussion format common to all scientific research.

Without this information it is difficult to interpret the survey results, and impossible to replicate the study for comparative purposes (Resources Inventory Committee 1998). It is useful to record the GPS location of all sampling units and provide maps of the study area. Detailed descriptions of the habitat should also be recorded. Information on the condition of the habitat at the time of the survey should also be included, as this may be useful in later analysis (for example, determining whether species presence/absence is due to temporary factors such as drought). Documenting the habitat occupied by target taxa during the survey process, and a site description, will add value to the survey at minimal extra expense (NSW DEC 2004). Documentation of observers and their skills is also important. Presentation of all bat taxa recorded is essential as it can provide a measure of survey effort and effectiveness.

It is important that reports contain suitable information to demonstrate the survey was sufficient to draw the conclusions. Documenting the survey effort will be particularly important for species that might be present at very low abundance in the project area. Findings should be supported wherever possible by information such as:

- site photos showing equipment placement and habitat structure
- cave entrance photos
- photos of scat or other trace material
- summary tables with measurements and diagnostic observations from captures and
- photos of bats if no vouchers can be taken.

Tabulated GPS coordinates of sites and equipment placement will allow precise determinations of occurrence within a project area.

Maps should be included that show the location of planned infrastructure over the top of aerial photographs (ideal) or other geographical layers that represent the habitats present in the area. Indicating the location of equipment placement such as passive recording stations and trapping equipment, as well as caves/mines and GPS tracks of the transect path taken during active acoustic monitoring or searches for suitable roost caves will allow comprehension of survey effort.

Reports should also carry some justification of the survey design, whether it be opportunistic, systematic or focused on certain likely habitats. This would include information on the habitat types present and the survey effort given to each. The design should also distinguish between known or potential foraging, roosting and commuting habitats. For species that might be present at very low abundance, it is important to describe the likelihood of presence based on habitat descriptions made as part of the survey. Explanations on the timing of the survey, suitability of the weather, and tabulated duration of transects and recordings should also be given.

Survey data should also be made available to state and territory environment departments to be included in fauna databases where appropriate.

The identification of bat species from recorded echolocation calls is a specialist task, requiring a good understanding of bat ecology and a thorough knowledge of the scientific literature. A justification based on supporting information needs to be provided to allow confidence in identifications. The Australasian Bat Society, Inc. (ABS) recently produced a document detailing a set of minimum requirements for a transparent and sufficiently comprehensive consultative report of identifications made from acoustic recordings. These are given in Appendix A, and have been adopted for these survey guidelines. A justification for the recommendations is given within the ABS document. Its purpose is to ensure that sufficient detail is presented so that species identifications can be verified by an independent specialist. The reporting requirements will allow the discovery of consistent misidentification of a species and highlight whether reanalysis is warranted.

REVIEW OF SURVEY METHODS

Although bats fly and are active by night, they can be surveyed using well-established techniques and equipment (Kunz and Kurta 1988; Barlow 1999; Vonhof 2002; Finnemore and Richardson 2004; Bat Conservation Trust 2007). With few exceptions, Australian insectivorous (or microbat) species can be captured by standard trapping techniques and/or detected using echolocation call detectors (Helman and Churchill 1986; Churchill 1998, 2008; de Oliveira 1998). Megabat species can be surveyed using mistnets and traps (Tidemann and Loughland 1993), but typically the larger species are surveyed visually (for example, Hall 2000; Shilton et al. 2008). Approval may be needed under the EPBC Act and local or state/territory government regulations before undertaking trapping of listed threatened bat species.

Surveys targeting threatened bat species will often require a more concerted effort than those surveys that aim to compile an inventory of the bat assemblage occurring in an area. Although standard techniques are combined to form the basic approach to surveying threatened bat species, the application and adaptation of those techniques to certain species and habitats, together with the use of novel approaches, may require skill and knowledge that comes only from field experience with a particular species.

Bat survey techniques

The single most important guiding principle for surveys on nationally threatened species of bat is that non-invasive methods should be used in preference to those that would disturb roosts or cause distress to the bats. Efforts to detect a particular species should not be detrimental to it, and some surveys will be a compromise between detection and minimising disturbance. Only those survey techniques described for a particular threatened species in the specific profiles should be used.

Capture methods used in the survey guidelines

Harp traps

Harp traps usually consist of a 1.8 m square frame made of aluminium (or steel or wood) mounted on adjustable legs. Monofilament fishing line (breaking strain of 3 kg) is strung vertically in the frame in two banks, with the lines c. 2.5 cm apart and the banks separated by c. 10 cm, and with the lines of each bank offset. Below the bottom of the frame is a canvas catch bag lined with plastic. There are many harp trap designs, some with triple or quadruple banks instead of the usual two, and a range of frame sizes for uses such as vegetation corridors (large) or mine adit entrances (can be relatively small). A giant harp trap made using boat masts and wire has been designed for the capture of flying-foxes (Tidemann and Loughland 1993).

Traps are placed in vegetation corridors, over water tanks, and at cave or mine entrances. Bats fly into the fishing lines and slide down into the catch bag from which they cannot escape. Good descriptions of how to place harp traps are given in Churchill (1998, 2008) and Vonhof (2002).

Harp traps have the advantage of not requiring constant monitoring, and are usually left set for the full night.

Harp traps have proven to be very successful in catching bats, including species such as *Kerivoula papuensis* that cannot be captured using mistnets (Schulz 1999). Harp traps are particularly efficient in dense vegetation such as wet sclerophyll and rainforest (Kingston et al. 2003), but are useful in most habitat types (Francis 1989).

Harp traps have been used successfully to trap all of the nationally threatened bat microbat species except *Saccolaimus saccolaimus.*

Mistnets

Mistnets are made from 50 or 75 denier nylon or terylene with a mesh size of 30–50 cm and come in a range of lengths, depth and bench number. The most commonly used net size is 12 m long and 3 m deep with 4 benches. 'Ultra thin' 0.08 mm nylon monofilament mistnets are also available. These are preferred over traditional 2 ply polyester nets for microbats due to their low echolocation reflectance.

While the use of mistnets is less efficient for the capture of some bat species, they are the ideal method for trapping bats over isolated water bodies (dams, tanks, watercourses) in the arid and semi-arid zone, or other open habitats (Churchill 1998, 2008; Vonhof 2002). They can also be used near stands of vegetation in open areas or across flyways in dense vegetation, although the use of harp traps may be more efficient in the latter (Tidemann and Woodside 1978). Mist nets should not be used to capture bats at the entrance of caves or mines unless there is prior knowledge of the number of bats normally resident within.

Finnemore and Richardson (2004) describe other ways that mistnets can be used, and also give a good description of how to remove bats from nets. A novel tunnel trap configuration using mistnets can be found in Sedlock (2001).

Mistnets are generally set for 3–4 hours after sunset and must be monitored constantly. Many Australian bat workers rely on the combination of harp traps and bat detectors because of the extra effort required for mist-netting.

Other capture methods

The following capture methods have also been used in bat surveys, and are included here for reference. These methods are not endorsed by the department for the surveying of threatened bat species.

Trip lines

Trip lines are monofilament fishing lines stretched 3–10 cm above the water in dams, tanks or remnant creek pools. Bats flying in to drink strike the line and fall into the water, and then swim to the side where they can be picked up easily (Churchill 1998, 2008). Concern about the stress caused to bats using this technique prompted discussion within the Australasian Bat Society but no specific recommendations have been made. Since surveys for threatened bats must minimise disturbance, this technique might be considered only after less invasive methods have been attempted and demonstrated to be ineffective.

Shooting

Sampling bats using shotguns is still used occasionally in Australia as a survey method. Although shooting has not been included as a preferred technique in these guidelines, it may have a role in establishing reference calls for species that are seldom captured. A recent example of the utility of shooting is that of the rare Arnhem sheath-tailed bat *Taphozous kapalgensis,* which was recorded with an Anabat detector just prior to being shot (Milne et al. 2003). A more complete understanding of the distribution and conservation status of this species was then determined by a retrospective analysis of echolocation calls recorded in previous surveys in the top end of the Northern Territory. Apart from having the necessary firearm permits, the relevant animal ethics and landholder permissions should be sought.

Hand netting

The use of a hand net in roosts can be an efficient and acceptable method of capture for some species (for example, Barlow 1999). It is particularly effective for the capture of clusters of torpid individuals and is more common in cooler parts of the world. In some cases when cave entrance apertures are too large to screen with mistnets or traps, the capture of bats on ceilings or in avens (vertical shafts) with nets on long telescopic poles, might offer the only chance of success. Bats in long-term hibernation should not be captured in this way because if bats are awakened early it can cause premature depletion of energy reserves and leads to significantly increased mortality. Hand-netting is also discouraged in roosts where bats are not torpid, because most species of bat will abandon a roost after being pursued within it. Attempts to capture bats in flight with a hand net should never be undertaken because the wings can be easily damaged.

Other novel methods

A novel method uses an acoustic lure to attract nearby individuals within ‘range’ of mist nets or harp traps. These electronic devices are custom-built and programmable ultrasound synthesisers that simulate bat vocalisations, and while they are apparently very effective (Hill and Greenaway 2005), they have not been used to much extent in Australia. Some causal experiments have suggested that the electronic feeding buzzes emitted by the Bat Chirp Board (a bat call synthesiser) can attract bats, but these have not been employed routinely on surveys.

Some species of bat can be recognised when spotlighted from their fur colour or other features such as wing shape, and flight characteristics. A high degree of observer experience is required in order to be confident of accurate identifications. For surveys on nationally threatened bats, spotlighting should be used in conjunction with other methods, such as echolocation recordings, that allow presentation of unambiguous data that will support identification.

Echolocation call detection

Arguably the most significant change to bat surveys has been the increasing use of electronic detectors to record the ultrasonic echolocation calls of bats. Detectors offer several major advantages over trapping or other means of detection: they are non-invasive, can add significantly to the number of species detected at a particular site, allow detection of species not readily captured, and in many cases, do not need to be attended constantly (O’Farrell et al. 1999a; Hayes 2000). Vonhof (2002) gives a useful description of the different types of detectors, how they work, their strengths and limitations and the general approach to call analysis. There has also been some debate about the efficacy of different types of detectors (Fenton 2000; Corben and Fellers 2001; Parsons et al. 2000). In the time since these publications, developments and the cost of data storage have greatly improved, and there is now a considerable range of options for call detection and processing, data storage, and software for analysis and measurement.

The expectation that each bat species has a unique echolocation call has yet to be demonstrated, but it is argued that since bats use echolocation in a functional way (to capture insect prey and navigate around obstacles) species occupying the same niche might have identical calls (O'Farrell et al. 1999b; Barclay 1999). In reality, some species in an assemblage can be discriminated relatively easily, but the remainder produce calls that are not distinguished reliably from at least one other species – at least with current methods.

In Australia, the Anabat system (Titley Electronics) is the most widely used system. Anabat detectors are especially well suited for unattended detector surveys, with several options available for storing recorded calls (Corben and O'Farrell 2002). Until recently, calls detected by Anabat detectors were recorded to cassette tape, either directly or via a voice activated delay switch. The major limitations of using tape storage are the relatively low quality of recordings, and issues associated with frequency calibration following variations in tape speed from recording and playback. The system is also able to record calls directly to a laptop computer, but more recent models record to a Compact Flash card. This is particularly convenient because a card less than one gigabyte in capacity can hold many nights of recorded calls, and recordings are made easily over the entire night.

There is now a large body of experience using the Anabat system in Australia but call identification continues to be a complicated and vexed issue (Reardon 2003). Identification of calls recorded anonymously from bats in flight requires prior knowledge of the calls of all bat species in the area of interest. A reference library of calls for each region, constructed by capturing bats, identifying them and releasing and recording their calls, forms the foundation of call analysis. To build a complete reference library of calls for several species in a region typically requires the capture and recording of hundreds of bats (Kutt 1993; Duffy et al. 2000; Reinhold et al. 2001; Milne 2002; Pennay et al. 2004).

The ability to distinguish between calls of each species depends upon how different the calls are, the detector used to record calls and the call analysis approach. Most Australian bat workers use the Anabat system, which represents signals in a time-frequency domain after a Zero Crossings Analysis (ZCA). The resulting graphical representation of calls illustrates pulse structure and most numerical parameters in a way that is simple to comprehend following visual inspection, and much identification work is made from a brief examination of these. Three identification keys based on the Anabat – ZCA approach have now been published (Reinhold et al. 2001, Milne 2002; Pennay et al. 2004), and these show that most bat species in a region can be identified by their calls. However, several pairs or groups of species cannot yet be distinguished reliably using the Anabat system. Recent work by Law and colleagues (2002) has shown that there can be significant intraspecific variation in calls over short geographic range, which further complicates the process and reduces confidence in some identifications.

An alternative use of the Anabat detector has been shown to be able to discriminate species not possible previously using ZCA and measurements derived from the resulting time – frequency domain. This included calls of long-eared bat *(Nyctophilus)* species, and *Taphozous* and *Mormopterus* in Western Australia (Bullen and McKenzie 2002; McKenzie and Bullen 2003). The approach involves recording the frequency-divided signal without ZCA directly to MiniDisc, and then relies on two main variables measured manually from power spectra. It has not gained widespread acceptance and independent assessments have not been published. Importantly, two equivalent variables can be measured in AnalookW software that is part of the Anabat system.

The combination of other detector systems (such as those manufactured by Binary Acoustic Technology, Magenta Electronics Pettersson Elektronik AB, Skye Instruments, Stag Electronics and Ultra Sound Advice) and different analytical approaches (some still in development or just becoming available) may prove to be more powerful for distinguishing between species with closely related calls. To be effective, they must also be convenient to use in the field, and allow analysis to be undertaken in realistic timeframes. There are now several systems that allow semi or fully automated analysis of data, but these still have limitations and rely on comprehensive reference information.

One advantage of the Anabat system is that it can incorporate GPS information into each bat call recording. The units (SD1 or CF-ZCAIM) can connect to a GPS via a serial cable, or a GPS can be used in combination with a PDA (either a Compact Flash or bluetooth GPS). Anabat software has several functions that help manage the GPS data collected, which is useful if the unit is used to collect data while on a moving transect. The collection of georeferenced data should be considered important on surveys (discussed later in these guidelines) and other bat detectors can be used in combination with a hand held GPS.

Whichever detector or call analysis system is used, it is essential that there is a high degree of confidence in the call identifications made using that detector or system. The lack of rigour in call identifications has been a cause for concern in Australia and overseas (O'Farrell et al. 1999a, Reardon 2003). Most detectors (non-heterodyne) and software available commercially are suitable if they are employed with an understanding of their inherent limitations, and if sufficient data are presented for an independent verification of identifications. The way in which the detector is employed on a survey can significantly affect the quality of the dataset. Rather than relying solely on passive (stationary) monitoring stations, approaches that combine detection with active (real-time) monitoring of the instruments during transects, trapping and other activities will yield the best results.

Roost searches

The detection of individuals out foraging away from their daytime refuge might not provide sufficient information for a sound assessment of the impact of a proposed development. Many bat species are limited by the availability of roost habitats, especially cave-dwelling species, or tree-dwelling species in heavily cleared agricultural landscapes. Significant effort needs to be made to determine if bats roost within a project area, and whether the development will be impacting primarily the foraging or roosting habitat of a particular species.

Caves, mines, boulder piles and rock crevices

Locating roosts in caves and mines begins at the desktop stage. Topographic and geological maps should be examined for known caves and mines, though many of these may not be shown on maps. Caving groups, government departments (mines and environment), local councils, park rangers, forestry workers, landowners, the Australasian Bat Society Inc. and Indigenous communities may be useful sources for such information. Most small caves and crevices will only be located by an on-site survey. This is particularly true in gorge and escarpment country that has had little or no previous survey effort.

Three options are available to assess whether bats use a particular cave or mine as a roost. The preferred method is to detect bats as they leave or enter the roost by simply watching, using bat detectors, or using cameras or video recording. Some bat species will visit caves at night, and in some situations it may be appropriate to distinguish this from daytime roosting using a cloth barricade over the entrance in conjunction with acoustic detection.

A second option is to enter the cave or mine at night to look for signs of bats (urine stains, fresh guano, remains). These methods are preferred because they cause minimal or no disturbance to the bats.

The third method is to enter the cave or mine during the day and observe bats as they roost. This activity has significant potential to cause disturbance to the resident bats (Richards and Martin 2001). Species such as *Rhinolophus philippinensis* and *Rhinonicteris* aurantia may vacate a cave or mine for several weeks or months following entry by bat researchers (K. Armstrong, C. Clague, L. Hall, unpubl. observation). Particular care must be taken to avoid waking bats from torpor in wintering roosts in temperate regions. If it is necessary to capture bats in a cave, hand nets as described in Finnemore and Richardson (2004) are useful. Bats are less sensitive to red light, so red light filters should be used on torches for inspection of bats in the roost.

Personal safety is an important issue when working in caves and particularly mines. Armstrong and Higgs (2002) provide a good overview of the risks and procedures for safe practice (see also Mitchell-Jones 2004; Bat Conservation Trust 2007).

Sometimes the use of harp traps and mistnets for capturing bats as they exit caves may be required to verify species identification (Helman and Churchill 1986). However, great caution should be used when trapping cave and mine entrances. It is prudent to estimate how many bats use the cave or mine before trapping––by visual inspection on the night before.

Tree roosts

Many microbat species have diurnal roosts in tree hollows or under exfoliating bark, while megabats roost on tree branches and twigs amongst the foliage. Microbats that roost in tree hollows and under bark are difficult to find. Watching hollows of suitable size for emerging bats at dusk is sometimes fruitful. Small video cameras can be used to investigate hollows for roosting bats (Reardon 2001). Roost sites can be found using radio-tracking techniques as described below.

Flying fox camps are usually conspicuous, and readily found by walking transects and watching for flying bats and listening for their distinctive calls. To locate flying fox camps in remote areas, aerial surveillance from a light plane can also be used.

Buildings, bridges, fairy martin nests

Many bat species are capable of roosting in a variety of natural and constructed sites. Daytime searches of buildings, under bridges (in holes and crevices) and disused fairy martin nests (in overhangs and road culverts, under bridges) should form part of bat surveys.

The presence of food plants for flying foxes

Flying fox populations and individuals are highly mobile, and they can commute great distances in response to flowering and fruiting events which can vary in timing and location among seasons and years. An assessment of the relative importance of a project area to these bat species needs to be based on more than one survey.

The primary native food plant species for flying fox species are well known (Hall and Richards 2000) and the presence of these plant species at a site should be used to assess the potential importance of the site to flying foxes (P. Eby, unpubl.).

Around 100 plant species are known to form the diet of the grey-headed flying fox, suggesting that food plant surveys would usually require assistance from an experienced botanist.

Radio-tracking

Radio-tracking has become a very useful tool for studies of foraging and roosting ecology in bats (Campbell 2001; Lumsden et al. 2002 a,b). Transmitters weighing 400 mg allow studies on very small species of bat (Law and Anderson 2000). Transmitters usually have a signal life of about 8 days and are detectable to up to one kilometre at ground level and up to 15 km from the air.

Radio-tracking is not a primary survey tool, but can be employed to establish whether roosts of threatened species occur within a project area, particularly for proposals that involve the destruction of trees. It is also a technique used for establishing the foraging range of a species.

Chemi-luminescent tagging

Light tagging is not a primary survey tool, but is a useful technique for observing foraging behaviour, establishing the foraging range of a species, locating roosts and for tracking bats during recording of reference calls. A small chemi-luminescent light stick (30 mm x 2.2 mm) can be glued to the fur using a non-toxic glue (Barclay and Bell 1988; Hovorka et al. 1996). Once the stick is activated, it glows brightly for a few hours and can be seen up to several hundred metres away.

Survey effort

Most of the Australian literature (reports and published papers) on survey effort has been directed towards species inventory rather than targeted at particular species. However, this body of work provides some useful insights into the survey effort required for more abundant species and, by inference, the effort required to locate less abundant and rarely encountered species.

Harp traps

The studies of Schulz (1999), Law (2004) and Turbill and Ellis (2006) are instructive in terms of expected effort for harp trapping.

Schulz (1999) discussed harp trap success rate in a study targeting the rare golden-tipped bat Kerivoula papuensis. Effort was expressed as the average number of bats caught per 100 harp trap nights, stated for several species at three sites. Over all localities, it found that on average 37 per cent of species required 20 or more trap nights to be detected. Law (2004) working in southern NSW dry sclerophyll forest found that 14 trap-nights were required to record > 90 per cent of species present. Turbill and Ellis (2006) studied the south-eastern form of the Eastern greater long-eared bat Nyctophilus timoriensis and captured 118 individuals from a total of 8266 bats, with an effort of 1628 trap nights at 39 study areas. Clearly, rarer or more cryptic species require significant effort, and some surveys may not detect them even if they are present.

The most widely referenced work on harp trapping is that of Mills and colleagues (1996) which examined the survey effort for harp traps and bat detectors to estimate the species composition in forest landscapes in south-east Australia. This work suggested that two to three nights of harp-trapping is adequate to estimate the number of species in a survey area. However, two separate trapping sessions were required to accumulate the total number of species caught, which was a total of 32 trap nights. The data also show that 14–38 per cent of species were only trapped once per 16 trap nights, a figure similar to Schulz (1999).

The only published study that has attempted to assess the probability of capture of a targeted species is Law and Chidel (2004). Using capture rates of the golden-tipped bat *Kerivoula papuensis,* they determined that two traps set for five nights (in habitat appropriate to that species) were required in order to have a greater than 90 per cent probability of detecting this species in their study site. Although the results of this study cannot be extrapolated to nationally threatened bat species, this study provides a very useful example of how to determine the trapping effort required to detect the majority of other species.

The studies above suggest that for rare or uncommon species, considerable trapping effort is required if trapping is the sole method used to detect bats. Trapping should be used in conjunction with other recommended methods.

Mistnets

There is little in Australian literature to use as a guide for determining effort for mist-netting. The location, habitat and target species have a strong influence on capture rate. For example, two mist nets set over a dam 5 m in diameter in arid mallee during summer, captured 378 bats comprising eight species in 90 minutes, which included 14 Nyctophilus timoriensis south-eastern form (T.B. Reardon, unpubl. data). This contrasts markedly with the results from Schulz (1999) that showed that from 172 mist-net hours no Kerivoula papuensis were captured, although they were commonly captured in harp-traps at the same site.

Echolocation call detectors

Many survey standards recommend that 30–60 minutes of echolocation call survey per night for four to five nights is adequate for inventory surveys, whilst other studies state that recordings must be made across the entire night (de Oliveira 1998; Law et al. 1998; Duffy et al. 2000; Richards 2001). While many bat species are active soon after dusk, it is well known that the data from a stationary detector will rarely detect all species present at a site within one hour after dusk.

As with trapping, reports and published literature mostly deal with the effort required for inventory surveys, and the effort required to encounter 90 per cent of species in a particular landscape. The difficulty is interpreting how much extra effort is required for the remaining 10 per cent of detectable species in those landscapes, and how relevant it is to extrapolate this level of effort to other landscapes or species.

Combining methods

Many authors have recommended the use of a combination of trapping and echolocation call recording as the most efficient approach for bat inventory surveys (for example, Mills et al. 1996; Duffy et al. 2000). It is clear that for many of the nationally threatened species a combination of techniques will be the most effective approach to their detection.

NATIONAL SURVEY GUIDELINES FOR THREATENED BAT SPECIES

Rationale of the survey guidelines for threatened bat species

These survey guidelines are not prescriptive but rather guidelines to allow consultants to plan and conduct satisfactory surveys for each of the threatened bat species. The techniques and survey effort recommended are designed to detect a species if it is present, or to satisfy the argument that a species is not present or is present at very low abundance. Considerably more effort will be required to establish with reasonable certainty that a species is not present or is present in very low abundance, compared with establishing its presence. This is an important but often overlooked principle.

The survey guidelines also recognise that the abundance of each species can vary greatly throughout its known distribution. To account for this, the effort recommended is based upon detecting a species in areas of relatively low abundance within its known distribution.

Animal welfare and licensing considerations

An important consideration for capture-based surveys is the stress caused to bats by the survey process itself. For the purposes of many projects, once the presence of a threatened species in a project area is confirmed, it may be appropriate to cease further survey work. As an example, following the detection of threatened species in a cave or an abandoned mine, no further visitation of the site should need to be undertaken in most cases. However, non-invasive assessment such as the daytime placement of electronic bat detectors at entrances can be used to collect additional data on the approximate number of individuals or relative level of activity. The opportunity to collect further data to assist in formulating subsequent actions can be taken, but only if it can be collected non-invasively (remote detection rather than capture or roost disturbance). Seeking further advice from experts and regulatory authorities whilst still in the field may be prudent (after first liaising with the client).

Those conducting field surveys should consider whether there are alternatives to daytime searches or trapping of roost sites. In addition, the impact of trapping should be considered and nightly schedules modified to ensure that trapped bats are not left unattended for lengthy periods. Mist nets must be attended constantly, and harp traps should be checked at least once during the night. Captured bats should be released at night, and those recovered at dawn must be kept in suitable ambient conditions for release the following night. Exceptions might be some physiologically fragile species than can be released back into known roosts nearby. Safety concerns on mine sites might limit the opportunity to work at night, however if survey approaches need to be modified accordingly, non-invasive techniques should be chosen over harp trapping which may result in threatened species being left in traps until after sunrise.

The legislative and animal welfare requirements vary amongst states and territories in Australia and consultants must be aware of their legislative obligations. Consultants should ensure that they have the necessary permits and approvals required to undertake surveys for the threatened species. The approaches in each species account to follow are regarded by experienced bat researchers as being appropriate for the species, and are described in accordance with the guiding principle that they be conducted in a way that minimises disturbance to the species. However, consultants should be aware that individual state or territory regulatory bodies may impose certain conditions in relation to surveying nationally threatened species. These may relate to capture, specimen collection, duration of holding after capture, disturbance of bats in a place of refuge, or disturbance to a breeding site.

These survey guidelines do not recommend that specimen collections are made for the purposes of identification, due to the threatened status of the species. Alternatives such as non-lethal tissue biopsies (such as a small plug of wing membrane) could be made after the appropriate state or territory permissions are given.

Species profiles

A separate account for each Australian threatened bat species is provided. These profiles are a summary only and relevant literature should also be consulted prior to a survey. The profiles contain the following headings:

Identification: an explanation of how to identify the species using external morphological characters, with comments on how to distinguish it from similar species.

Echolocation call: notes on whether the species can be distinguished reliably from its echolocation call characteristics.

Distribution: current knowledge, or extrapolations based on suitable habitat, of the distribution boundaries of the species.

Roosting and foraging habitat: brief notes on the known roost preferences, foraging habitat and behaviour are given as a guide to aid the selection of survey sites or to direct searches.

Seasonal considerations: information and recommendations for the appropriate season in which to conduct surveys, given the likelihood of bats being present or the times at which they breed.

Recommended survey approach: the combination of techniques recommended for detecting the target species. Particular equipment or techniques might be recommended specifically, or alternatively indicated as not being useful for the detection of a species. **The list of techniques and equipment should be considered a minimum requirement.**

Survey effort guide: The effort recommended for a survey, to be interpreted as a reasonable attempt to verify that the species is present, or to satisfy an argument that the species is either absent or present at very low abundance. It is based on a hypothetical project site of 50 hectares in size and of relatively uniform landform and vegetation composition.

Survey sites or project areas may range in size from a single to thousands of hectares, and be either relatively uniform or contain a variety of landforms and vegetation types. The survey effort guide should be used as a reference for modifying survey effort to accommodate different sites.

For example, a project site of 500 hectares with uniform landform and vegetation composition might only require the same survey effort as the 50 hectare model site, provided that sampling sites are chosen across the project site. If however the 500 hectare site contained several distinct vegetation types (rainforest, woodland, riparian) or significant landform types (gorge country, plains, caves) then sampling effort should be increased and stratified to give adequate coverage and representation. When undertaking a survey on a project site significantly larger than 50 ha you should consider contacting Commonwealth and state/territory environment departments to discuss the appropriate level of effort.

Some justification of the sampling effort used, in reference to the survey guidelines, would be expected in the report.

The effort guide is based on the following use of techniques:

- **Mistnets:** the number of mistnets per night is based on a standard net, 12 m in length and 3 m in height, set for three hours. Nets should be set just before sunset and monitored constantly until the end of the netting session.
- **Harp traps:** harp traps should be set before sunset and left open overnight. Traps should be checked at least once during the night and then at dawn.
- **Unattended bat detectors:** bat detectors are capable of recording and storing bat calls automatically for an entire night. Bat detectors should be set recording before sunset and stopped after dawn.
- **Attended bat detectors:** the use of hand-held detectors for walking or driving transects, recording emergence flights from roosts, or monitoring flyways, is recommended as an adjunct to unattended detectors. They can be especially useful for recording bats with strongly directional calls, or those that display curiosity for light sources such as headtorches (leaf-nosed and horseshoe bats, and possibly other species).
- **Roost searches:** details of potential roosts examined should be presented, along with a demonstration of area covered, and a tally of search hours.

Some consultants may have access to a relatively limited number of detectors, traps and mistnets. To provide equity in the opportunity for consultants to undertake work, effort is expressed as total effort for a minimum number of nights. For example, 12 trap nights for a minimum of three nights enables four traps to be used for three nights, or two traps for six nights.

Key references: recent publications or reports that have information or further references that will be helpful for designing surveys for the species. For each species, the accounts from the Action Plan for Australian Bats (Duncan et al. 1999), authoritative species guides (Churchill 1998, 2008; Van Dyck and Strahan 2008) and the Commonwealth's species profiles and threats database (SPRAT: Department of the Environment, Water, Heritage and the Arts 2009) will be particularly useful. Those involved with surveying areas in which nationally threatened bat species might occur should be familiar with the key references listed for each species.

Bare-rumped sheath-tailed bat

Saccolaimus saccolaimus nudicluniatus

Status: Critically Endangered

Identification

Distinguished from other sheath-tailed bats by its dark reddish brown fur that is usually flecked with white patches and a bare rump. Individuals from the Northern Territory may be slightly larger (forearm: Northern Territory: 77.1 – 80.0 mm, Queensland: 72.3 – 77.2 mm) and almost black on the dorsal fur compared to Queensland individuals (Churchill 1998, 2008). It is not distinguishable readily in flight from some other sympatric sheath-tailed bat species *(Taphozous australis, T. troughtoni, T. georgianus and possibly T. kapalgensis).* A throat pouch is present in males but rudimentary in females.

Saccolaimus saccolaimus and the Yellow-bellied Sheathtail-bat *S. flaviventris* can be difficult to distinguish, and in some cases can only be identified by genetic analysis (Milne et al 2009). Any Saccolaimus captured during a survey needs to be carefully identified. Taking a tissue sample to verify the identification should be considered. See Milne et al 2009 for further information on identification.

Echolocation call

Reference calls of this species in Australia have been collected only recently from three vouchered individuals (Milne et al., 2009). Pulse shape is curvilinear and the characteristic frequency ranges between 19.4 and 23.4 kHz (mean = 20.8 kHz), which is similar to *S. saccolaimus* in Malaysia and Brunei, and also to other Australian sheath-tailed bat species sympatric with S. saccolaimus (Heller 1989; Milne et al. 2003). The species may have an audible component to its call (fundamental harmonic not recorded by ultrasonic bat detectors) (Murphy 2002; Payne et al. 1985).

Distribution

North-eastern Queensland and the top end of the Northern Territory. Known from 19 localities (Milne, 2009), with most records from Queensland. Probably occurs as far as the eastern Kimberly in Western Australia but this is yet to be confirmed (Milne et al 2009).

Roosting and foraging habitat

Considered to be an obligate hollow-roosting species (Milne et al 2009). Compton and Johnson (1983) report roosts occurring in poplar gum *Eucalyptus platyphylla* near Townsville, Queensland. Murphy (2002) observed a colony (up to 15 individuals) roosting in a dead stag of a Darwin stringybark *E. tetradonta* on Cape York, Queensland. In both cases, the entrances to the roosts were about 7 m above the ground. A colony of 40 individuals was found in a large fallen tree in the Northern Territory (Churchill 1998, 2008). In the Northern Territory, studies indicate that potential habitat consists of woodlands and forests extending from coastal and adjacent inland areas throughout the top end, with one record approximately 150 km inland on a sandstone plateau (Milne et al 2009). May also roost in buildings, caves and rock crevices. Nothing is known of its foraging behaviour in Australia but it is presumed to feed on aerial insects well above the tree canopy. Known habitats include poplar gum woodland and Darwin stringybark woodland in Queensland, and Darwin woollybutt *E. miniata* woodland in the Northern Territory (Churchill 1998, 2008).

Seasonal considerations

Many of the records for this species are from specimens collected during the period August to April. Although virtually nothing is known about seasonal movements of this species, it is recommended that surveys be conducted between August and April.

Recommended survey approach

There are few indicators for an effective strategy for detection of this species from their past records. Many records have resulted from accidental discovery when roost trees fell or were cut down (Churchill 1998, 2008; Milne, 2009). Murphy (2002) noted that bats quickly vacated the roost upon minimal disturbance. Compton and Johnson (1983) reported that five specimens were "collected as they flew over a waterhole" – the method of collection was not explained. The paucity of records of the bare-rumped sheath-tailed bat in Australia probably indicates that the species is either very rare, or difficult to capture and detect. The approach to its detection should rely on several methods.

1. *Acoustic detection*. Ultrasonic call recordings should be made. Recent collections of reference echolocation calls of S. saccolaimus (Milne et al., 2009) have shown that pulse and call sequence characteristics are similar to several other species that are sympatric with both populations *(Chaerephon jobensis, Mormopterus beccarii, Saccolaimus flaviventris;* Milne 2002). Despite possible difficulties in separating these species acoustically, echolocation recordings should be an important part of surveys. Some features of calls might be suggestive of the species, and the basis for further survey effort. Until a diagnostic reference call for this species is obtained, acoustic techniques cannot be used to draw conclusions about species presence.

   Given the potential difficulty of diagnosing this species from calls, representative putative call sequences must be presented in reports, along with appropriate measurements (see Milne 2002 for a guide). As wide call variability was obtained using an ANABAT recorder (Milne et al., 2009), the suitability of other call recording systems may be worth investigation.

   Passive monitoring from stationary detectors should be considered a minimum requirement. Bat detectors (Anabat or other frequency division, or time-expansion detector; unattended) should be located in forest or woodland and ideally placed several metres above the ground (in trees or on poles), orientated upwards (at least 45°) towards gaps in the vegetation AND at waterholes/dams or in watercourses. Unattended detectors should be left overnight.

   Given that this high-flying species will not be attracted to headtorches like some other species, attended monitoring with a hand-held detector will not increase the likelihood of their detection. However, walking or driving transects with hand-held detectors can achieve greater coverage of large project areas. Transects should be conducted for a minimum of two hours.

2. *Trapping.* Nets should be set to capture foraging bats above or just below the tree canopy, and over isolated waterholes. Forest or woodland edges may also be fruitful sites to trap. Possible trapping and detecting sites may be determined by conducting watches at dusk to observe bats emerging from potential hollows or spouts. Mistnets should be set over isolated waterholes and creek lines, and in woodland or forest; set as high as possible (preferably >8 m from the ground) near the tree canopy. Nets should be attended throughout. Note that this species has never been successfully caught in harp traps.

3. *Roost searches.* Hollow bearing trees should be investigated by observing and making acoustic recordings of bats emerging at dusk (if hollows are high in the tree), or by inspecting hollows closer to the ground during the day with a small video camera. These activities should be undertaken if the project proposal includes the destruction of hollow bearing trees.

Survey effort guide

For large project areas with greater landscape complexity, traps, nets and detectors should be distributed to represent the major habitat types. A combination of all techniques should be used. Survey effort involving tree hollow searches or monitoring should be georeferenced using GPS and presented on maps.

Project area	<50 ha	
Survey techniques	**Total survey effort**	**Minimum number of nights**
Mistnets	16 mist-net nights	4
Unattended bat detectors	16 detector nights	4
Tree roost survey/inspection	1–2 hours per survey day.	

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Greater large-eared horseshoe bat

Rhinolophus philippinensis (large form)

Status: Endangered

Identification

Recognisable as a rhinolophid from the characteristic noseleaf morphology, especially the pointed lancet on the upper portion, and distinguishable based on its remarkably large ears and noseleaf. Ears and noseleaf often have a noticeable yellow hue. Similar in general morphology to the lesser large-eared horseshoe bat *Rhinolophus philippinensis* (small form). The greater large-eared horseshoe bat has forearm length of 53–59 mm and ear length of 29–33 mm, compared to the small form with a forearm length of 50–53 mm and ear length of 25–27 mm (Cooper 1998).

Echolocation call

Unique and identifiable readily based on call frequency. The greater large-eared horseshoe bat has a call dominated by a characteristic constant frequency (CF) tone at 28–32 kHz, while the lesser large-eared horseshoe bat has a characteristic CF component at c. 40 kHz.

Note that Churchill (1998) has confused the distribution, size and echolocation call frequency of these two forms, and has been corrected in Churchill (2008). An updated account with correct information is also available on the department's species profile and threats database (Department of the Environment, Water, Heritage and the Arts 2009).

Distribution

Northern Queensland, from Iron Range south to Townsville and west to the karst regions of Chillagoe and Mitchell-Palmer. The southern limit of its range has not been determined, and it may be present south of Townsville at Mt Elliott and Cape Cleveland (Pavey and Kutt 2008).

Roosting and foraging habitat

Roosts in caves, mines and road culverts but also known to roost in hollows at the base of trees. Forages in a variety of habitat types including rainforest, paperbark forest and tropical eucalypt woodland (Churchill 1998, 2008). Foraging usually occurs below the vegetation canopy <8 m (Pavey 1999) although this species has been recorded foraging at >25 m in the rainforest canopy (Whybird 1996).

The greater large-eared horseshoe bat is particularly prone to stress caused by disturbance at roost sites (Hall et al. 1999). Cave and mine roost sites may be abandoned for long periods (months) even after minor disturbance such as human entry into the roost area. Although some mine and cave sites have a resident population, others may be used irregularly.

Seasonal considerations

There is no published information that suggests a suitable time of year to conduct surveys for this species.

Recommended survey approach

In the field, bats should be detected primarily by non-invasive means, consistent with the philosophy of minimising the impacts of surveys on individuals or colonies. Characteristic echolocation call frequency and pulse structure are diagnostic and are unlikely to be confused with any other Australian bat species. However, care should be taken that the calls are not confused with calls of *Rhinolophus megaphyllus* where the fundamental frequency is emitted (c. 34–37 kHz; best confirmed by spectrographic analysis; C. Clague unpubl.). The use of electronic bat detectors is therefore the best means of non-invasive survey, though trapping could be used in some situations.

Recommended acoustic detection devices include the Anabat ZCA system (recording to CF card), though other frequency-division and time expansion detectors connected to digital (or speed controlled) recorders can be used. Heterodyne detectors can be used to locate the species, but calls should be recorded at each site with another system, and examples presented in reports in a manner that allows independent verification of the identification. In all cases, but especially with analogue recordings, a calibration tone should be included to control for tape speed variation or to verify the correct division or time expansion ratio (which should be stated). Call sequences representing positive identifications should contain at least 4 consecutive pulses and the displays be presented with 10 kHz intervals.

This species may be encountered as by-catch in general bat assemblage surveys. In forest habitats where subterranean roost sites are unknown or not expected, trapping can be employed to target this species. Harp traps are recommended over mistnets for this species.

1. *Prior to the survey.* Determine whether there are known roosts in caves or mines in the area by examining topographic and geological maps, and contacting the Department of Environment and Resource Management (Queensland Parks and Wildlife Service), Department of Employment, Economic Development and Innovation (Primary Industries and Fisheries), caving groups, bat researchers and local councils. When on site, further information should be sourced from local residents, mining companies and traditional owners.

2. *Passive acoustic detection.* A range of potential roost habitats can be examined by passive detection with unattended recorders placed facing the entrance of underground mines and caves. Presence can also be assessed at foraging sites such as vegetation corridors (forest tracks), open windows in rainforest, and near watercourses in woodland. Unattended detectors should be left overnight.

3. *Active acoustic detection.* Transects of two hours minimum duration should be conducted beginning at dusk with hand-held (attended) acoustic detectors and headtorches. Recordings should be made along the entire length of the transect, and GPS tracks kept so that the level of effort made can be indicated. Transects can be made along established tracks through vegetation, along watercourses or around rocky outcrop where roosts might be expected. Likely roost habitats such as culverts and boulder piles should be included. Boulder piles should be surveyed during periods of emergence after dusk, either from point locations that are actively monitored (and simultaneously recorded) or using stationary passive units. Point locations for surveying should be a minimum of 150 m apart, and as much as possible of the circumference of the boulder pile should be surveyed. Sufficient time should be allocated for this. Driving transects can be used in addition, but not as a replacement for walking transects.

4. *Roost searches.* Daytime entry of subterranean structures such as mines and caves should not be undertaken to avoid risking the safety of personnel and disturbance to resting bats. Bats should be detected without capture as they emerge from a subterranean roost.

5. *Trapping.* Given that this species might also roost in forest habitats (tree hollows, amongst vegetation), trapping can be employed, especially as part of whole-assemblage bat inventory surveys. Harp traps can be set overnight in forest flyways, riparian zones, and over watercourses. The entrances of caves and mines should not be trapped. Harp traps should be cleared at least once close to midnight, and then by sunrise. Captured individuals should be released at night only, with bats cleared in the early morning kept at room temperature under high humidity conditions until the following night, or released into known roosts nearby.

Survey effort guide

A second survey is recommended (to be conducted 3–6 months after the first) if the first survey fails to detect this species. It is recommended that GPS tracks of hand-held detector night transects are presented to demonstrate the level of effort undertaken.

Project area	<50 ha	
Survey techniques	**Total survey effort**	**Minimum number of nights**
Unattended bat detectors	16 detector nights	4
Attended bat detectors	6 detector hours	3
Harp traps	16 trap nights	4

Key references

Churchill SK 1998. *Australian bats.* Reed New Holland, Frenchs Forest, New South Wales. [note information on the greater and lesser large-eared horseshoe bats has been mixed]

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Semon's leaf-nosed bat

Hipposideros semoni

Status: Endangered

Identification

Distinguished from *Rhinolophus* species by the absence of a pointed lancet on the upper nose-leaf. Distinguished readily from other sympatric small leaf-nosed bats based on the presence of two wart-like protuberances on the upper nose-leaf – one in the centre and another on the posterior edge, forearm length is between 42–50 mm and is intermediate compared to *Hipposideros diadema* and *H. ater;* and greater ear length compared to *H. cervinus* (Churchill 1998, 2008). Ears are particularly long and acutely pointed. Allopatric to the very similar *H. stenotis.*

Echolocation call

Distinctive and diagnostic based on the non-overlap with other hipposiderids and rhinolophids of the characteristic frequency of the CF tone. Males and females have different characteristic frequencies: c. 75 kHz (♀) and c. 95 kHz (♂) (Coles 1993; de Oliveira and Schulz 1997; O. Whybird and C. Clague, unpubl.).

Distribution

Coastal Queensland from Cape York to just south of Cooktown (Thomson et al. 2002). The southern limit is unclear, though Coles and colleagues (1996) recorded calls on the Mt Windsor Tableland. There is suggestion of an outlier population at Kroombit Tops, near Gladstone (Schulz and de Oliveira 1995). A second unconfirmed isolate has been suggested in St Mary's State Forest near Maryborough based on an echolocation call recording (de Oliveira and Pavey 1995), though these need confirmation through better quality echolocation recordings or capture. Possibly on islands in the Torres Strait. Taxonomic relationship with *H. muscinus* from Papua New Guinea unresolved.

Roosting and foraging habitat

Known to roost in caves, rock fissures, mines, boulder piles, buildings, road culverts and tree hollows. Forages in tropical rainforest, monsoon forest and open savannah woodland (Churchill 1998, 2008).

Seasonal considerations

None known.

Recommended survey approach

In the field, bats should be detected primarily by non-invasive means, consistent with the philosophy of minimising the impacts of surveys on individuals or colonies. Characteristic echolocation call frequency and pulse structure are diagnostic and unlikely to be confused with any other Australian bat species. The use of electronic bat detectors is therefore the best means of non-invasive survey, though trapping could be used in some situations.

Recommended acoustic detection devices include the Anabat ZCA system (recording to CF card), though other frequency-division and time expansion detectors connected to digital (or speed controlled) recorders could be used. Heterodyne detectors can be used to locate the species, but calls should be recorded at each site with another system, and examples presented in reports in a manner that allows independent verification of the identification. In all cases, but especially with analogue recordings, a calibration tone should be included to control for tape speed variation and to verify the correct division or time expansion ratio (which should be stated). Call sequences representing positive identifications should contain at least four consecutive pulses and the displays be presented with 10 kHz intervals.

This species might be encountered as by-catch in general bat assemblage surveys. In forest habitats where subterranean roost sites are unknown or not expected, trapping can be employed to target this species. Harp traps are recommended because this species is particularly difficult to capture in conventional mist nets (monofilament nets are required).

1. *Prior to the survey.* Determine whether there are known roosts in caves or mines in the area by examining topographic and geological maps, and contacting the Department of Environment and Resources management (Queensland Parks and Wildlife Service), Department of Employment, Economic Development and Innovation (Primary Industries and Fisheries), caving groups, bat researchers and local councils. When on site, further information should be sourced from local residents, mining companies and traditional owners.

2. *Passive acoustic detection.* A range of potential roost habitats can be examined by passive detection with unattended recorders placed facing the entrance of underground mines and caves. Presence can also be assessed at foraging sites such as vegetation corridors (forest tracks), open windows in rainforest, and near watercourses in woodland. Unattended detectors should be left overnight.

3. *Active acoustic detection.* Transects of two hours minimum duration should be conducted beginning at dusk with hand-held (attended) acoustic detectors and headtorches. Recordings should be made along the entire length of the transect, and GPS tracks kept so that the level of effort made can be indicated. Transects can be made along established tracks through vegetation, along watercourses or around rocky outcrop where roosts might be expected. Likely roost habitats such as culverts and boulder piles should be included. Boulder piles should be surveyed during periods of emergence after dusk, either from point locations that are actively monitored (and simultaneously recorded) or using stationary passive units. Point locations for surveying should be a minimum of 150 m apart, and as much as possible of the circumference of the boulder pile should be surveyed. Sufficient time should be allocated for this. Driving transects can be used in addition, but not as a replacement for walking transects.

4. *Roost searches.* Daytime entry of subterranean structures such as mines and caves should not be undertaken to avoid risking the safety of personnel and disturbance to resting bats. Bats should be detected without capture as they emerge from a subterranean roost.

5. *Trapping.* Harp traps can be set overnight in forest flyways, riparian zones, and over watercourses. The entrances of caves and mines should not be trapped. Harp traps should be cleared at least once close to midnight, and then by sunrise. Captured individuals should be released at night only, with bats cleared in the early morning kept at room temperature under high humidity conditions until the following night, or released into known roosts nearby.

Survey effort guide

A second survey is recommended (to be conducted 3–6 months after the first) if the first survey fails to detect this species. It is recommended that GPS tracks of hand-held detector night transects are presented to demonstrate the level of effort undertaken.

Project area	<50ha	
Survey techniques	**Total effort**	**Minimum number of nights**
Unattended bat detectors	16 detector nights	4
Attended bat detectors	6 detector hours	3
Harp traps	16 trap nights	4

Key references

Churchill SK 1998. *Australian bats.* Reed New Holland, Frenchs Forest, New South Wales.

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Large-eared pied bat

Chalinolobus dwyeri

Status: Vulnerable

Identification

Medium-sized insectivorous bat with large ears, glossy black dorsal fur and a white band of fur along the sides of the belly adjacent to the wing membrane. As with other *Chalinolobus*, there are lobes extending from the corners of the mouth to the bottom of the ears. Weight 7–12 g, forearm length 37–44.5 mm (Churchill 1998, 2008).

Echolocation call

Has distinctive frequency modulated call, characteristic frequency 22–25 kHz, with the characteristic frequency in successive pulses alternating by c. 2 kHz (Reinhold et al. 2001; Pennay et al. 2004).

Distribution

Known from scattered localities in south-eastern Queensland, and New South Wales (central western NSW, the mid to north-eastern part of the state and as far south as Nowra). In Queensland, records exist from sandstone escarpments in the Carnarvon and Expedition Ranges and Blackdown Tablelands, and from volcanic rock types at Scenic Rim near the New South Wales/Queensland border. It has been recorded more often within New South Wales: from areas of volcanic strata at Coolah Tops, Mt Kaputar and the Warrumbungle National Park, distributed patchily in the sandstone areas of the Sydney Basin and the western slopes and plains including Pilliga Nature Reserve. Populations in north-eastern New South Wales, south-eastern Queensland, Shoalwater Bay and Blackdown Tablelands are likely to be isolated from each other (Hoye 2005).

Roosting and foraging habitat

Habitat requirements remain poorly understood. Known to roost in mines, caves, and rock overhangs, especially in sandstone outcrops and gorges. Also uses fairy martin nests and possibly tree hollows (Hoye and Dwyer 1995, Schulz 1998; Schulz et al. 1999). Recorded from a range of habitats, including wet and dry sclerophyll forest, Cyprus pine dominated forest, tall open eucalypt forest with a rainforest sub-canopy, sub-alpine woodland, but typically in association with sandstone relief. In south-eastern Queensland it has been recorded primarily from higher altitude moist tall open forest adjacent to rainforest (Schulz et al. 1999).

Seasonal considerations:

Surveys are best conducted from October through to March.

Recommended survey approach

The use of electronic bat detectors is the best means of non-invasive survey, and the most efficient in terms of data collection and area coverage. Trapping with harp traps and mistnets, and roost searches in caves, mines, rock overhangs, culverts and crevices could be undertaken to confirm presence or roosting.

Recommended acoustic detection devices include the Anabat ZCA system (recording to CF card), though other frequency-division and time expansion detectors connected to digital recorders could be used.

1. *Prior to the survey.* Determine the potential for rocky outcrops, caves and mines to occur in the area by examining topographic and geological maps, and contacting state government mines and forestry departments, Queensland Parks and Wildlife Service, caving groups, bat researchers and local councils. Where appropriate, information on caves and mines may be obtained from local residents.

2. *Passive acoustic detection.* A range of potential roost habitats can be examined by passive detection with unattended recorders placed in the vicinity of mines, caves and rocky outcrop, and also in foraging sites such as vegetation corridors and flyways, sandstone gorges, over watercourses, isolated waterholes and in representative vegetation types. Quality search-phase echolocation calls are diagnostic but these may not be recorded from bats emerging from underground roosts if bat detectors are placed at the entrance. Unattended detectors should be left overnight at multiple locations.

3. *Active acoustic detection.* For larger project areas, walking or driving transects using hand-held detectors may be used in conjunction with unattended detectors. Transects should begin at dusk.

4. *Roost searches.* Where no known roost sites have been identified in the planning stage, several hours may be required to conduct ground-based surveys for caves, mines, rock overhangs and crevices. For large project areas in gorge country, ground-based searching could be expected to take several days.

   Daytime entry of subterranean structures such as culverts, mines and caves should be undertaken carefully to avoid risking the safety of personnel and disturbance to resting bats. Identification can be made from capture within roosts. Disturbance resulting from capture of bats should be compensated by the collection of unambiguous and verifiable evidence of occupancy – in the form of photographs of the distinctive pelage, and external measurements.

5. *Trapping.* Success with trapping is most efficient in the vicinity of potential roosts. Harp traps and mistnets are useful for detecting this species, and can be set overnight in forest flyways, near scarps and cliffs and in riparian zones. Captured individuals should be released only at night, or into roosts during the day if these are known, and bats should be held for the minimum amount of time after being removed from traps and nets. If bats are cleared from harp traps in the early morning, they should be kept at room temperature until the following night. Reference calls should be recorded from individuals released after trapping so that identification information is available for verification.

Survey effort guide

A combination of techniques is recommended.

Project area	<50 ha	
Survey techniques	**Total effort**	**Minimum number of nights**
Unattended bat detectors	16 detector nights	4
Attended bat detectors	6 detector hours	3
Harp traps and/or mistnets	16 trap or net nights	4

Key references

Churchill SK 1998. *Australian bats.* Reed New Holland, Frenchs Forest, New South Wales.

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Spectacled flying fox

Pteropus conspicillatus

Status: Vulnerable

Identification

Identified readily by the presence of lighter colour fur encircling the eyes. There can also be varying amounts of paler fur on the shoulders and head, and the eye-rings of some individuals may not be distinct, giving them a similar appearance to the black flying fox *Pteropus alecto.* Further notes on identification in the key of in Churchill (1998, 2008). Head and body length is 220–240 mm, forearm and weight for males 160–180 mm and 580–850 g, and for females 155–175 mm and 500–650 g (Richards and Spencer 1998). Only rarely shares roost sites with sympatric little red flying fox *Pteropus scapulatus* and/or the black flying fox *P. alecto* (Tidemann et al. 2008; Hall and Richards 2000).

Distribution

North of Ingham to Cape York, between the McIlwraith and Iron Ranges, near-coast islands to the east of Cape York, and individuals may be found as far west as Chillagoe. Occasionally present on islands in the Torres Strait. Recent censuses have recorded the species at: Cairns area, Cassowary Coast (Freeman 2003), Mossman–Cooktown, Atherton Tableland and Mulgrave River–Innisfail (Garnett et al. 1999). Further information can be found in Shilton and colleagues (2008) and on the department's species profile and threats database (Department of the Environment, Water, Heritage and the Arts 2009).

Roosting and foraging habitat

Spectacled flying foxes form daytime camps, some of which are permanent, while others are transient, satellite or rarely occupied. The camps were once known to reach as high as 80,000 individuals, and a recent cyclone has caused reduction in numbers and a redistribution of the population (Shilton et al. 2008). The natural diet of the spectacled flying fox includes rainforest fruits, riparian zone flowers, *Melaleuca*, eucalypt and mangrove flowers and fruit. They also feed on cultivated fruits in gardens and orchards (Richards 1990a).

Seasonal considerations

Occupation of camps is highly seasonal. Camp movements are dependant upon seasonal fruiting and flowering of food plants (Richards 1990b).

Recommended survey approach

The primary method for surveying is to conduct visual searches for day roosts and night feeding sites. Before conducting fieldwork, it is important that information about the location of known camps is made for the area. In addition to surveys, a vegetation survey of the project area should be conducted to establish if significant stands of food plants are present.

1. *Prior to the survey.* A review of known flying fox camps should be conducted for the project area, and the wider general area. The locations of over 100 camps have been recorded and this information is available through the Queensland Parks and Wildlife Service (QPWS) and/or in the literature. Population counts have

also been conducted and there is a network of people with knowledge about camp location and seasonal movements. Often local people, orchardists, QPWS officers, the flying fox carer network and traditional owners will know if camps exist or have existed in the project area, and if so, whether they are occupied at the time of the survey.

2. *Field surveys for food plants.* During daytime surveys, a vegetation survey of the project area should be conducted to establish if significant stands of food plants are present. Food plants are listed in Richards (1990a, 1995) and Hall and Richards (2000), and potential food trees can usually be identified if light-coloured fruits are present (Richards 1990a), or if trees are heavily in flower. Potential food trees (those that are not fruiting at the time of survey) should be identified by a qualified botanist. A GPS location of these trees can also be taken for later spotlighting activities at night.

3. *Daytime field surveys for camps.* Searches should be conducted for day roosts or the presence of feeding activity using transects 100 m apart. Flying foxes are recognised easily from a distance while they roost or are in flight, and have distinctive audible calls. Other signs include their distinctive odour and droppings. Both the ground and foliage should be examined for flying fox scats. Some project areas may require access by boat. Note that this species rarely vocalises during rain and some periods of the day. For very large and/or inaccessible project areas, it may be necessary to conduct an aerial survey for camps from a light aircraft.

4. *Night time surveys.* Conduct walking transects (100 m apart) spotlighting for bats in flight, or at potential food trees that have been identified during the day for feeding bats. Smell can also provide a sign of their presence. Alternative methods may include night time audio recordings made at selected sites or fruiting food plants within the project area.

Survey effort guide

Small project areas can be surveyed easily within a day. Several repeat surveys throughout the year should be conducted, especially if known camps occur in the project area. Minimum effort required in addition to food plant survey:

Project area	<10 ha	10–50 ha	>50 ha
Survey technique	**Survey effort**		
Day survey	2 hours	6 hours	6 hours per 50 ha.
Night survey	3 hours	5 hours	5 hours per 50 ha/night

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Christmas Island pipistrelle

Pipistrellus murrayi

Status: Critically Endangered

Identification

Readily identified, being the only microbat species on Christmas Island. A small bat with dark brown fur and forearm length of 30–33 mm.

Echolocation call

Frequency modulated pulses with characteristic a frequency of 40–50 kHz; the only echolocating bat species present on Christmas Island.

Distribution

Found only on Christmas Island. Range has contracted significantly since 1995, with the species now restricted to a small area in the far west of the island (Lumsden et al. 2007; Lumsden and Schulz 2009, Christmas Island National Park unpublished data). This extent of occurrence encompasses areas within the Christmas Island National Park, and areas leased to Christmas Island Phosphates. The abundance of the Christmas Island pipistrelle has declined by 99 per cent since 1984 (Lumsden and Schulz 2009).

Roosting and foraging habitat

All roosts are in rainforest, both on the plateau and terraces (Lumsden et al. 1999, Lumsden et al. 2007). No roosts have been found in caves, rock overhangs or buildings (Lumsden et al. 1999, Lumsden and Tidemann 1999). In 1998, during the non-breeding season, single individuals and clusters of up to 47 bats were observed under exfoliating bark (dead canopy trees, predominantly *Tristiropsis acutangula* 6–20 m above the ground), under flaking fibrous matter on trunks of live Arenga listeri 15 m above the ground, in tree hollows (*Syzygium nervosum* 26 m above the ground), under dead fronds of live renga palms or Pandanus sp. 5–15 m above the ground, and under strangler figs against the trunk of the host tree (Lumsden et al. 1999). During the breeding season (in 2005), breeding colonies of up to 54 individuals were found under exfoliating bark on dead trees (Lumsden et al. 2007). In 2009, the only known occupied roost contained just four individuals (Lumsden and Schulz 2009).

Foraging occurs mostly in areas of primary rainforest, secondary regrowth of rainforest, and the ecotone between primary rainforest and secondary regrowth (Tidemann 1985; Lumsden et al. 1999). Foraging has been observed from 0.1–20 m above the canopy (Tidemann 1985; Lumsden and Cherry 199; Lumsden et al. 1999). It is an edge specialist, and probably also uses the top of the canopy as a foraging edge. Within primary rainforest, most foraging activity is concentrated along edges within small clearings, tracks, regenerating drill lines, and clearings resulting from treefalls (Lumsden and Cherry 1997).

Seasonal considerations

Previous surveys have been conducted throughout the year (Tidemann 1985; Lumsden and Cherry 1997; Lumsden et al. 1999; Christmas Island National Park unpublished data). Maternity colonies are formed in the early wet season from December, when young are born (Lumsden and Schulz 2007). Deployment of electronic bat detectors, harp traps and nets will be troublesome in the wet season because of inclement weather, but will not completely impede a survey. However, trapping during such periods when females are heavily pregnant or are carrying young should be avoided.

Recommended survey approach

This species has declined markedly since the early 1990s, and now fewer than 50 individuals are estimated to remain within a small area of the island (Lumsden and Schulz 2009). Intensive survey efforts during this time have established the area of occupancy, population size and possible causes of decline, forming the basis for management and conservation recommendations (review in Department of the Environment, Water, Heritage and the Arts 2009). Since January 2009, heightened efforts by biologists involved in this work and lobbying by others have sought to implement measures to save this species from its very imminent extinction. The most likely solution will be capture of the entire remaining population and the establishment of a captive breeding colony. Actions to save this species will be guided by the National Recovery Plan for this species (Schulz and Lumsden 2004; significantly updated information in Lumsden and Schulz 2009).

Given the perceived outcome of extinction in the wild, the recommended approach for surveying this species in these guidelines will concentrate on either locating remaining individuals, or monitoring those released after a captive breeding programme some time in the future. While individuals remain in the wild, extensive surveys are required before any mining activity.

Being the only echolocating insectivorous bat on the island, survey is relatively straightforward. It has a strong echolocation call and is therefore amenable to recording using Anabat or other detectors (including heterodyne detectors), though Anabat SD1 or CF-ZCAIM models will allow the most efficient collection and storage of large amounts of data. When they were in greater numbers they could be trapped using harp traps and mistnets, and could be observed flying just after dusk. The greatest consideration in any survey is therefore the amount of effort expended to establish its presence, or indeed its absence.

1. *Prior to the survey.* Familiarity should be gained with reports from previous surveys, and contact made with representatives from Parks Australia North and other bat specialists involved in previous surveys.

2. *Passive acoustic detection.* A range of potential roost and foraging habitats can be examined by passive detection with unattended recorders placed in a variety of edge habitats, tracks and flyways in primary and secondary forest and ecotones. Unattended detectors should be left overnight at multiple locations, for multiple nights.

3. *Active acoustic detection.* Walking and driving transects using hand-held detectors should be used to increase coverage of the area. Transects should begin at dusk and be of at least two hours duration. GPS tracks of transects should be kept to quantify effort and highlight areas yet to be surveyed.

4. *Roost searches.* Given that all roost records have been from vegetation, locating roost sites will be challenging, but might be required if the destruction of potential roost trees is part of a project proposal. In the past, the most successful method for finding roost sites was by capturing individuals and then subsequently radio-tracking them back to a roost. Tagging with chemi-luminescent sticks was also used to follow bats back to roosts. However, a radio-tracked or tagged individual may not necessarily lead back to a colony, and it is well known that individuals change roosts occasionally, even members of maternity colonies. The most useful approach that is currently being undertaken is to place detectors beneath potential roost trees.

5. *Trapping.* Trapping should be conducted only if there is a requirement to handle bats in accordance with the scope of a particular project. Establishing presence or absence can be undertaken solely through acoustic detection. If individuals do need to be captured, harp traps and mistnets can be set overnight in forest flyways and along tracks, and around the edges of small clearings in primary and secondary forest and ecotones. Captured individuals should be released only at night.

Survey effort guide

The standard survey effort for areas less than 50 ha is recommended. However, given that the species is limited to Christmas Island, and only a few individuals are ever likely to be present, a large effort would be required to give a meaningful result. As an example of this, Lumsden and colleagues (1999) sampled 84 sites across the island with bat detectors, trapped a subset of these, and drove a total of 2500 km in vehicle transects. The appropriate level of effort will be dependent on the purpose and scope of the survey, and might require even greater levels of effort than previously undertaken.

Project area	<50 ha	
Survey technique	**Total effort**	**Minimum number of nights**
Unattended bat detectors	16 detector nights	14
Attended bat detectors	6 detector hours	3
Traps (optional)	16 trap nights	4

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Grey-headed flying fox

Pteropus poliocephalus

Status: Vulnerable

Identification

Identified by the grey head and body fur, typically medium to dark grey, but occasionally silver. Body fur frosted on the back. It is distinguished from other Australian *Pteropus* by the thick leg fur that extends to the ankle, in contrast to other species where it extends to the knee. Head and body length is 230–290 mm, forearm 151–177 mm and weight 600–1000 g (Hall 1987; Tidemann 1999; Hall and Richards 2000; Eby and Lunney 2002; Churchill 1998, 2008). Can share day roosts (camps) with the black flying fox *Pteropus alecto* in coastal areas of northern and central New South Wales and southern Queensland, and the little red flying fox P. *scapulatus* throughout its range (Tidemann 1999; Hall and Richards 2000). Further notes on identification are in the key in Churchill (1998, 2008).

Distribution

A coastal belt from southern Queensland, New South Wales, eastern Victoria, and rarely into South Australia. Observed frequently west of the Great Dividing Range in northern New South Wales and southern Queensland, found infrequently in inland areas elsewhere. There are rare sightings of individuals on islands in Bass Strait. Further information can be found on the department's species profile and threats database (Department of the Environment, Water, Heritage and the Arts 2009).

Roosting and foraging habitat

The grey-headed flying fox is a highly colonial species. Camps of a few individuals to over 70,000 form during the daytime, usually in tall closed forest near streams, rivers or estuaries. While a few of these camps are permanent and occupied year round, most are temporary and seasonal. Individuals migrate in complex patterns in response to changes in food production. Sedentary individuals form the core population of continuously occupied camps. However, the majority are highly nomadic and move several hundred kilometres each year in largely unpredictable patterns.

They feed primarily on the nectar and pollen in eucalypt flowers and fleshy subtropical rainforest fruits, and around 100 species of plant have been recorded in their diet. Camps are formed in response to the location and timing of local flowering and fruiting events. An area will be occupied for a few weeks to several months until the food resource is exhausted. They will also feed on cultivated fruit trees in gardens and orchards.

Seasonal considerations

Presence will be dependent on food resources. The time and location of flowering and fruiting of diet plants varies among seasons and years. In particular, drought years can have a strong influence on eucalypt flowering times. Sites noted as important in one year or period may not be visited again in the following year. In short, the presence or absence of this species at a site during a particular time or year may not necessarily be indicative of the importance of that habitat area to the species.

Recommended survey approach

The grey-headed flying fox occupies most areas in their distribution in highly irregular patterns, and therefore surveys based on animal sightings are unlikely to be reliable. A more effective survey method is to search appropriate databases and other sources for the locations of camps, and to conduct vegetation surveys to identify feeding habitat.

1. *Prior to the survey.* A review of known flying fox camps should be conducted for the project area, and the wider general area. The location of many camps is known, and the information is available through databases held by the Department of Environment and Climate Change (NSW), Queensland Parks and Wildlife Service, the Victorian Department of Sustainability and Environment, the Australasian Bat Society and in the literature. There is a network of people with knowledge about camp location and seasonal movements. Often local people, orchardists, apiarists, parks officers and forestry workers, wildlife groups, the flying fox carer network and traditional owners will know if camps exist or have existed in or near the project area, and if so, whether they are occupied at the time of the survey.

2. *Daytime field surveys for camps.* The primary method for determining the presence of unrecorded day roosts is to conduct field surveys. Flying foxes are recognised easily from a distance while they roost or are in flight, and have distinctive audible calls that are heard most frequently in the early morning or under sunny conditions. Other signs include their distinctive odour and droppings. Both the ground and foliage should be examined for flying fox scats. Some project areas may require access by boat. Note that this species rarely vocalises during rain and some periods of the day. Roosts can also be located by surveying for animals exiting at dusk. For very large and/or inaccessible project areas, it may be necessary to conduct an aerial survey for camps from a light aircraft.

3. *Surveys of vegetation communities and food plants.* Vegetation communities within the core range of grey-headed flying foxes have been mapped and the significance of each community as feeding habitat has been ranked by Eby and Law (2008). The food plants that occur in each vegetation type are listed. A search of this database should be conducted to identify vegetation communities in the project area. Vegetation maps are based on modelled data and do not always accurately represent field conditions. Therefore, field surveys should be conducted by a qualified botanist to confirm the vegetation communities in the project area and the presence of food plants.

4. *Night time surveys.* Conduct walking transects (100 m apart) looking for feeding and flying bats. Smell can also provide a sign of their presence. Alternative methods may include night time audio recordings made at selected sites or fruiting food plants within the project area.

Survey effort guide

Consultants should demonstrate that they have sought information about the location of historic camps from the appropriate authoritative sources as outlined above. It should also be demonstrated that a comprehensive vegetation survey has been completed for the survey area, and a clear assessment of the contribution of the project area in terms of food plants, especially in relation to the broader region, is provided.

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South-eastern long-eared bat

Nyctophilus corbeni

Listed under the EPBC Act as Nyctophilus timoriensis (South-eastern form)

Status: Vulnerable

Identification

Similar in appearance to the sympatric Gould's Long-eared Bat; forearm 41–50 mm; identified following key in Churchill (1998, 2008). Identification should include analysis of the outer canine width (see Parnaby 2009).

Echolocation

Calls are not distinguishable reliably from other sympatric *Nyctophilus* species using Anabat detectors and processing with zero-crossing analysis. A recent method was described for separating *N. timoriensis* (central form) from two other sympatric Western Australian *Nyctophilus* species using variables derived from power analysis (Bullen and McKenzie 2002), but this might not provide unambiguous data on presence.

Distribution

Southern central Queensland, central western New South Wales, north-western Victoria and South Australia. There are only four records of this species from Victoria, all from the north-west of the state (Lumsden 1994). In South Australia, records are confined to north of the Murray River, east of Canegrass Station and south of the Barrier Highway, but the northern range limit in this state remains unclear (Ellis et al. 1999). It is present in several conservation reserves (review in Department of the Environment, Water, Heritage and the Arts 2009). Most abundant in the western extreme of its range in South Australia and central western New South Wales (in the Brigalow Belt South and Nandewar Bioregions), very rare in Victoria, and scattered in the remainder of New South Wales and Queensland (Turbill and Ellis 2006). Much of western Queensland has not been surveyed for this species (C. Clague, unpubl.).

Roosting and foraging habitat

Roosts in tree hollows, under exfoliating bark and possibly in the dense foliage. Usually found in semi-arid areas, including the mallee districts of South Australia, Victoria and western New South Wales and in grasslands, open woodland and dry sclerophyll forest in New South Wales and Queensland.

Occurs in river red gum forest, semi-arid woodlands and savannahs; box/ironbark/open forests and Buloke woodland in northern New South Wales and inland south-east Queensland, particularly in larger remnants with a well-developed understorey (Turbill and Ellis 2006). In South Australia, the species is confined to tall shrublands of the Murray River, roosting in hollows of *Eucalyptus gracilis.*

Seasonal considerations

Surveys best conducted on warmer nights from October through to April.

Recommended survey approach

The eastern greater long-eared bat should be surveyed using capture techniques.

1. *Prior to the survey.* In agricultural or other heavily modified landscapes, digital aerial photography of the study area can be examined to determine the size and pattern of vegetation remnants so that trapping effort can be planned.

2. *Passive acoustic detection*. Bat detectors can be used to identify areas used by long-eared bats, even if they cannot be identified to species level. Acoustic detection can then be followed up with an appropriate level of trapping.

3. *Trapping.* Mistnets and harp traps should be placed in woodland, mallee and forest, given that the species forages below the tree canopy, often to ground level. Equipment should be placed both in open fly-ways and within cluttered vegetation. If open water bodies (earth dams, fire dams, open top tanks and watercourses) occur in or near the project area, then significant effort should be given to mist-netting or harp trapping over the water. For project sites where there is no surface water, mistnets can be set over temporary water pools specifically constructed for the purpose of the survey.

Survey effort guide

Both harp traps and mistnets are effective for this species, and either can be used although harp traps have been employed successfully on a large scale in the past (Turbill and Ellis 2006). For large project areas with landscape complexity, traps and nets should be distributed so as to give good representation in the major habitat types.

In the past, *N. timoriensis* has been captured in harp traps at 33 per cent of sites at a rate less than one capture per 20 trap nights (Turbill and Ellis 2006). The species is uncommon in some areas but quite common in others. The recommended effort below might provide a reasonable opportunity to make a capture in the Brigalow Belt South and Nandewar Bioregions and possibly in South Australia, but elsewhere it would likely remain undetected. For this species, it is important to consider that failure to capture will not necessarily mean that a significant population of this species does not occur in the area.

Project area	<50 ha	
Survey technique	**Total effort**	**Minimum number of nights**
Harp traps	20 trap nights	5
Mistnets	20 mist-net nights	5

Key references

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Orange leaf-nosed bat (Pilbara form)

Rhinonicteris aurantia

Status: Vulnerable

Identification

Identified readily by small size, orange or pale fur colour and distinctive diamond-shaped noseleaf (Churchill 1998, 2008). Forearm length 45–50 mm.

Echolocation call

Distinct from all other species in the region; CF pulse structure with a characteristic frequency of 118–128 kHz.

Distribution

Known from 14 dispersed localities in the Pilbara region of Western Australia following the surveys of Armstrong (2001), and several others discovered since then as part of surveys undertaken by environmental consultants and as part of the Pilbara Biological Survey. However, only six of these records are confirmed as roost sites, all of which contain relatively large colonies and significant portions of the regional population (Bamboo Creek mine, Klondyke Queen mine, Comet mine, Lalla Rookh mine, Copper Hills mine, caves in Barlee Range Nature Reserve). Relatively small colonies are thought to exist near where bats have been detected in flight from acoustic recordings, near Yarrie, Pannawonica, Paraburdoo and Mt Vernon.

Roosting and foraging habitat

Roosts in disused mines, small caves in gorges (in the dip faces of inclined ironstone sedimentary features, or folded silcretes) and possibly other features such as granite rockpiles. Not likely to be in the shallow ‘bluff’ or ‘breakaway’ caves that are numerous on mesas and strike ridges, but it is possible that some structures might be used occasionally (for example, in similar habitats as the ghost bat *Macroderma gigas*; Armstrong and Anstee 2000). Forages in gorges, small gullies, larger watercourses and nearby its roosts. Often recorded over pools in gorges or more open watercourses. Night visitation of caves not used as a daytime refuge is common and can mislead assessments of roosting.

Seasonal considerations

Little information on seasonal patterns of movement is available, but it appears that bats may aggregate in roosts that contain warm, humid microclimates all year round, especially the largest subterranean features. While they may have only seasonal presence in some areas where only relatively shallow caves can be found, these habitats may actually be important for dispersal and gene flow within the region.

Recommended survey approach

Targeted surveys should incorporate a number of strategies, though in almost all situations, the species can be surveyed without the need for capture. Their echolocation call is diagnostic when recorded with the correct equipment, and they have a curiosity for small light sources such as headtorches, which brings them within range of hand-held electronic bat detectors. Detectors are the best means of non-invasive survey. However, the discovery of roost sites within a project will allow the best assessment of whether the species will be affected by a development, given that the lack of suitable roost sites is known to limit their distribution. Other activities can be used to assess roost occupancy, or augment an assessment of presence generally.

The following points should be noted for this species:

- their ultra-high echolocation frequency is not detected particularly well by the Anabat microphone, but these can still be employed usefully as described below.
- this species is extremely sensitive to disturbance at their roost, and physiologically fragile (declines rapidly from water loss and stress following capture). Cave and mine entrances should not be trapped, since capture might cause individuals to vacate to less suitable roosts nearby.
- the daytime occupancy of *R. aurantia* in a cave/mine is difficult to determine because of their tendency to use some features as 'night roosts'. These are not used during the day, and the species has often been recorded flying into caves soon after dusk, rather than out of them. As a result, an alternative non-invasive method needs to be undertaken to confirm occupancy.
- obtaining accurate counts is not possible with this species using bat detectors placed at cave/mine entrances because of their tendency to fly about at entrances, or enter structures after sunset. An index of activity is the only practical way to assess usage and relative importance of a feature, and this measure will not necessarily correlate with colony size.

1. *Prior to the survey.* An important step prior to the survey is to determine whether there are known caves and mines in the project area. Information can be sourced from topographical and geological maps, aerial photography, the Department of Mines and Petroleum (Minedex and Tengraph), Department of Environment and Conservation and bat researchers. Where appropriate, on-site information on the location of caves and mines can be sourced from local residents and mining companies.
2. *Passive acoustic detection.* A range of potential foraging habitats can be examined by passive detection with unattended recorders placed in the vicinity of mines, caves and rocky outcrops, and in steep-sided rocky gorges containing pools, open watercourses containing ephemeral pools lined with eucalypts or tall melaleuca. Unattended detectors should be left overnight at multiple locations.

Recommended acoustic detection devices include the Anabat ZCA system (recording to CF card). These are best employed as passive detectors, or hand-held on night transects. Time expansion recorded digitally would be suitable when monitored. Other heterodyne detectors (set to 120 kHz) with electret microphones are effective for detecting the species in flight, but calls should be recorded with another system to allow independent verification from reports. The representation of pulse structure is most diagnostic in the time-frequency domain following ZCA. As with identifications made from Anabat recordings, those made with an alternative system based on raw signals from an Anabat II recorded to a MiniDisc recorder and analysed in a power spectrum should also be presented so as to allow independent verification. This could include images of power spectra and summary measurements. The following issues and requirements should noted for MiniDisc recordings:

- the rising high frequency sequences of *Vespadelus finlaysoni* can be distinguished from calls of *R. aurantia* better after ZCA
- call quality is lower using MiniDisc recordings
- the ZCA display will be recognisable to most bat call analysis specialists compared to the low quality spectrographic representation after FFT analysis
- recordings should be made over the entire night, and
- identification should also be confirmed from a minimum of two or more consecutive pulses (each > 4 ms duration) in a sequence within the characteristic range of the species (Armstrong and Coles 2007).

3. *Active acoustic detection*. Bats in flight can be detected by conducting night transects with a hand-held detector in habitats such as deep gullies and gorges, larger watercourses with pools, and along scarps containing caves. Transects should begin at dusk and be of two hours minimum duration in total. The likelihood of encountering the species can be greater on a transect than at a passive monitoring station, so the use of both is recommended. Georeferenced recordings should be made along the track.

4. *Trapping.* Trapping with harp traps set in watercourses has been successful on some occasions. Mist nets are unlikely to be useful because the bats can detect them easily. In most cases, unambiguous detection from echolocation recordings can replace the need for capture, thus avoiding disturbance to the species. Captured individuals should be released immediately, and only at night. They are unlikely to survive holding during the day, so bats removed from harp traps in the morning should be released into the deepest cave nearby (overhangs are not suitable). Cave and mine entrances should not be trapped to avoid unnecessary disturbance at roosts.

5. *Exploration for caves (potential roosts).* Searches can be conducted for relatively deep caves along mesa outcrops, in side gorges, deep gullies flanked by rocky outcrop, and beneath ephemeral waterfalls, with particular effort given in landscapes composed of Brockman Iron Formation and Marra Mamba Iron Formation. For large project areas in gorge and mesa country, searches could be expected to take several days. It may be economical to use a helicopter to identify the largest caves in one run, and follow these up on foot.

6. *Roost occupancy determination.* If night transects have identified a possible daytime roost, or if a relatively deep cave looks suitable as a roost of this species, emergence at dusk can be assessed without cave/mine entry. The entrance can be barricaded with a large piece of cloth for two hours beginning at sunset. A bat detector should record the signals coming from within the cave, and a second unit can record signals from outside – care should obviously be taken not to point the detectors in the opposite directions. Once the species is detected on the inside of the barrier, it can be taken down; or alternatively roost occupancy can be determined following later analysis by a specialist of the 'inside-facing' recordings made over the two hours.

Survey effort guide

Several hours per day may be required to conduct ground-based surveys for caves and mines. Examination of geological maps and aerial photography can be used to reduce the survey area to the most likely areas with gullies, gorges and rocky outcrop.

The following survey effort should be repeated twice, approximately six months apart since the species has the potential to be present in all seasons.

Project area	<50 ha	
Survey techniques	**Total effort**	**Minimum number of nights**
Unattended bat detectors*	16 detector nights	4
Attended bat detectors	8 detector hours	4
Harp traps (optional)	8 trap nights	4

* Number required dependent on the number of caves/mines; the numbers given here are provided as a guide.

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Southern bent-winged bat

Miniopterus schreibersii bassanii

Status: Critically Endangered

Identification

Distinguished from other sympatric bat species by its size (head and body length 52–58 mm; forearm 45–49 mm) (Churchill 1998, 2008). Wing length is almost two and a half times the length of the head and body, and the last phalanx on the third digit is around four times that of the middle phalanx, giving the appearance of a 'bent wing'. It has a short muzzle, high domed forehead and short ears.

Echolocation call

Calls are similar in frequency range to *Vespadelus regulus, V. vulturnus and Chalinolobus morio.* Good quality search phase calls are distinguishable using the Anabat system, but call identification should be undertaken by a competent person who has access to an appropriate regional reference call library.

Distribution

Within 200 km of the coast between Robe in South Australia, and Geelong in Victoria. Further information can be found on the department's species profile and threats database (Department of the Environment, Water, Heritage and the Arts 2009).

Roosting and foraging habitat

The southern bent-winged bat is an obligate cave dweller, occupying roosts in limestone caves, lava tunnels and small coastal caves. During October to March, the majority of the entire population gathers in either Bat Cave at Naracoorte, South Australia or Starlight Cave in Warrnambool, Victoria. In colder months, they are dispersed among as many as 100 caves throughout its distribution. It is generally the only species roosting in caves throughout its distribution. The only known exception to this is along the Glenelg River where the large-footed myotis *Myotis macropus* may also roost in shallow caves. The southern bent-winged bat may fly large distances from roost caves to foraging sites. Foraging has been recorded in tall eucalypt forest, heath, pine plantations, vineyards, and pasture, but wetlands are probably the prime foraging sites.

Seasonal considerations

During the colder months (April to September) the southern bent-winged bat will spend periods ranging from days to weeks in torpor, awaking to drink or move between caves. At present, a significant proportion of the total population cannot be accounted for in known caves during the cold season. Surveys need to be structured to account for the shifting population, given seasonal movements from wintering caves to maternity caves via transition caves.

Recommended survey approach

1. *Prior to the survey.* Determine whether there are known bat roosts in caves or tunnels in or near the project area. Most of the significant roost caves and tunnels are known for this species and their location can be sourced from regional offices of the South Australian National Parks and Wildlife Service, the Victorian Department of Sustainability and Environment, forestry departments, caving groups, bat researchers, local councils, and topographical maps. Where appropriate, on-site information on cave access should be sought from local property owners.

2. *Field survey timing.* Two seasonal surveys may be required – failure to record bats in the warm seasonal period would require that a second survey be conducted in the cold season. Between November to March, a range of activities can be undertaken, as described below. Between April to October, bats may be torpid and remain mostly in over-wintering roosts. During this period, a visual survey of all caves and tunnels should be conducted in the project area if they have not been previously recorded as bat roost sites.

3. *Cave and tunnel surveys.* All such structures that have not been previously recorded as bat roost sites in the project area should be surveyed. Roost occupancy can be determined by recording calls during exit or entrance flights using bat detectors, making video recordings of the exit or entrance flights or through visual inspection inside the cave or tunnel. Roost searches can be conducted during the day but red filters must be used on torches, and every effort should be made not to disturb bats. Night searches of caves for the presence of fresh bat guano is also an option. Any searches of roosts sites during winter must be done carefully and every effort must be taken not to arouse the bats from torpor.

4. *Passive echolocation recording.* In addition to the use of bat detectors at cave or tunnel entrances, unattended detectors should be set to record overnight in representative vegetation or land-use types within the project area. The Anabat system, or other frequency division or time-expansion detector, can be used to record calls.

5. *Trapping.* Harp traps or mistnets should not be used at the entrance to roost sites, but are an option in open habitats and project areas without caves or tunnels. Mistnets should be set over isolated waterholes, dams, creek lines, sink holes, and swamps. In forest or heath, nets should be set as high in the canopy as possible. Harp traps should be set in vegetation gaps, along forest tracks or roads.

Survey effort guide

During November–March, all caves and tunnels in a project area should be surveyed by observation or with bat detectors. For large project areas with no caves or tunnels, and with more landscape complexity, traps, nets and detectors should be distributed to represent the major habitat types. A combination of all techniques is required.

During April–October, all caves and tunnels in a project area should be surveyed visually.

Project area	<50 ha	
Survey techniques	**Total effort**	**Minimum number of nights**
Unattended bat detectors	16 detector nights	4
Harp traps	20 trap nights	4
Mistnets (optional but preferred if there are isolated water holes in project area)	12 net nights	4

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APPENDIX A

Recommendations of the Australasian Bat Society Inc for reporting standards for insectivorous bat surveys using bat detectors

Included in the survey guidelines for Australia's threatened bats for reference purposes.

What is the Australasian Bat Society Inc?

The ABS is a non-profit organisation and is the peak body representing bat conservation and research in Australasia. The ABS membership includes scientists, consultants, wildlife carers and interested individuals.

The ABS actively advocates for the conservation of bats and their habitat. The ABS encourages scientific research on bats and promotes high standards in the study of bats by providing input and advice to relevant government and non-government agencies, industry, landholders and to the general public.

Background to the development of these standards

Bats comprise around 25% of the native terrestrial mammal species in Australia. Field survey methods for bats include both capture techniques (mist nets and bat traps) and remote detection through the use of bat detectors.

Bat detectors offer significant advantages over capture techniques: they can be operated without specialist training, they are non-invasive and they do not require an operator to be present once they are set.

Unfortunately bat detectors also have limitations: the analysis of calls is complex; and not all bat species can be distinguished by their calls.

Senior bat researchers in the ABS have become concerned that many bat surveys, especially those reported in Fauna Impact Studies, were inadequate in terms of the survey effort (i.e. too low a number of detector nights, trap or mist-net nights) and had reliance solely on bat detectors where both capture and detecting techniques were required for adequate survey results.

Especially of concern was the lack of transparency in the identification of bat calls in many reports. Bat call analysis requires considerable expertise as well as good knowledge of the calls for the species in the survey region (usually having access to a regional reference call library). Many reports gave insufficient detail for independent assessment of the quality of call analysis.

The ABS conducted a workshop (that included both researchers and consultants) to develop a set of standards that if followed would improve the quality of bat surveys and allow independent assessment of reports. Given the difficulty of deriving a set of prescriptive instructions for the design of surveys covering all types of surveys and all bat species and habitats, the ABS concluded that the main thrust of the standards would address reporting standards for bat detector results and give some general guidelines for survey effort.

We recommend the adoption of the following standards.

AUSTRALASIAN BAT SOCIETY, INC.
ABN 75 120 155 626

Standards for reporting bat detector surveys

Recommendations of the Australasian Bat Society Inc. for reporting standards for insectivorous bat surveys using bat detectors

To whom this applies

Any agency or individual contracting a consultant to analyse bat calls should insist upon these standards as part of the contractual agreement.

Any person analysing bat calls using the Anabat detector system for research, consultancy or other purposes should apply these standards.

Reporting Standards

The ABS recommends that these be applied to impact statements, fauna assessments, survey reports, and research publications where bat detector recordings and call analysis have been used to identify bats.

Essential

The following must be included in the final report:

1. A description of the reference library used in the identification process.
2. Details of the number of detector hours undertaken during the survey.
3. A sample 'time versus frequency' graph of each species identified during the survey. These graphs must be of bats recorded and identified during the survey.
4. For species with similar call characteristics, a written description of the characteristics used to distinguish these species must be included in the methods.

Highly desirable

Inclusion of the following is strongly recommended:

1. An indication of the proportion of calls identified, i.e. the total number of calls processed and the percentage of these that were identified.
2. All the call files from a survey are deposited ultimately with the client or agency.

Additional suggestions on survey effort and methods

The ABS is concerned about the use of inadequate survey methods and insufficient survey effort in some surveys. However, it is difficult to recommend universal standards because each study will have different aims, target different species or bat communities, and will be conducted in different habitats. Conducting surveys for bats is a specialist task, and judgement based on experience is required when designing survey methods and effort.

The ABS suggest the following as a guide for acceptable standards for insectivorous bat surveys, fauna assessments, and research:

1. Since echolocation call analysis can rarely identify all species within a given area, it is important to determine which species could occur in the area prior to any survey, and whether all species (or a target species) are able to be distinguished solely from echolocation calls.

2. For most inventory surveys, capture techniques (i.e. using harp traps, mist nets or other methods where bats can be captured and identified) should be employed in conjunction with detector sampling.

3. Consultants or biologists who have relatively little experience with bat surveys, but who are engaged to conduct them, should contact a bat specialist to discuss the appropriate methods and level of survey effort.

4. Typical inventory survey effort should involve detector deployment for at least three complete nights in each major habitat type in the survey area.

5. Surveys should be conducted during the warmer months of the year and in good weather conditions.

6. Where possible, reference calls should be recorded from bats released during a survey.

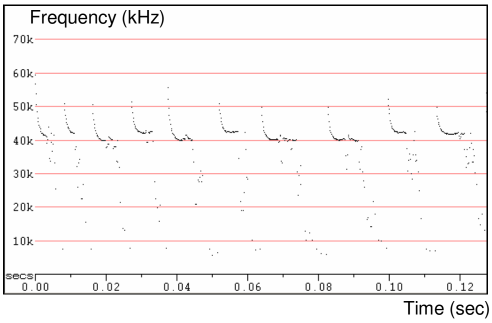
To follow is an example of an acceptable presentation of the essential components for a detector survey report (*see overleaf*).

Identification of echolocation call sequences recorded at Example Creek

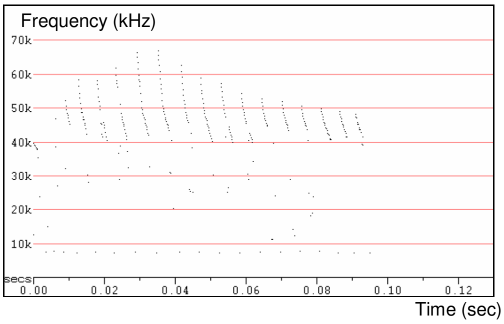
Reference library
Calls were identified using a library consisting of 250 reference calls from the Example Creek area, 1300 reference calls from the wider Illustration region, and the Smith (2000) regional bat call identification key.

Survey effort and identification rate summary
A total of 4000 call sequences was recorded at 6 sites over 3 nights. Of these, 1500 (35%) of the sequences could be identified confidently to species or genus level (see Table x). All calls recorded are stored on the CD attached to this report.

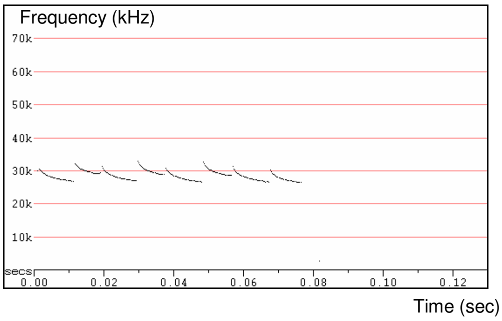
Example sequences
The calls of three species were identified from the Example Creek recordings. Additional calls were identified belonging to bats of the genus *Nyctophilus*, however these could not be identified to species as the calls of all three *Nyctophilus* species that occur in this area overlap almost entirely in most characteristics.



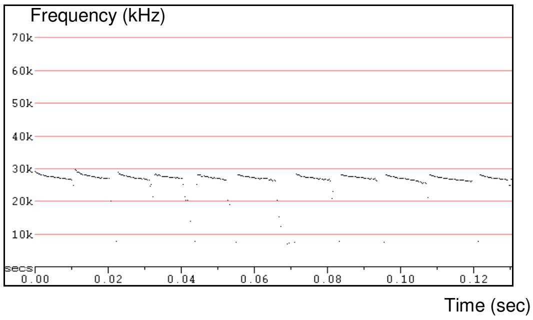
Little pied bat *Chalinolobus picatus* recorded at site 1 Example Creek.



Unidentified long-eared bat *Nyctophilus* sp. recorded at site 1 Example Creek.



Gould's wattled bat *Chalinolobus gouldii* recorded at site 2 Example Creek.



Inland free-tailed bat *Mormopterus* 'species 3' (*sensu* Adams *et al*. 1988) recorded at site 6.

Note: The calls of *C. gouldii* and *Mormopterus* 'species 3' are very similar, and overlap in characteristic frequency. Calls of *C. gouldii* were distinguished by the alternating characteristic frequency and broader frequency sweep, including a steeper initial section. Calls of *Mormopterus* 'species 3' were distinguished by the lack of alternating characteristic frequency, flatter pulse shape and the presence of harmonic traces in some pulses.

APPENDIX B

Recommended common names and current taxonomy

This list of recommended nomenclature was produced after discussion within the Australasian Bat Society (Armstrong and Reardon 2006), during the compilation of the third edition of 'Mammals of Australia' (Van Dyck and Strahan 2008). While there was not complete consensus on all common names, it does reflect the currently accepted taxonomic binomial or trinomial nomenclature and includes common names that the ABS recommends be used. It is an interim list, and will be updated following the publication of several taxonomic revisions currently in progress. It was produced before the designations of Churchill (2008), but will not be updated until supporting information for new nomenclature is published in the peer-reviewed literature.

Genus species **Authority**	**ABS common name**
Pteropodidae	
Pteropus poliocephalus Temminck, 1825	grey-headed flying fox
Pteropus alecto gouldi Peters, 1867	black flying fox
Pteropus scapulatus Peters, 1862	little red flying fox
Pteropus banakrisi Richards and Hall, 2002	Torresian flying fox
Pteropus brunneus Dobson, 1878	Percy Island flying fox
Pteropus conspicillatus Gould, 1850	spectacled flying fox
Pteropus macrotis epularius Ramsay, 1878	large-eared flying fox
Pteropus melanotis natalis Thomas, 1887	Christmas Island flying fox
Dobsonia magna Thomas, 1905	bare-backed fruit bat
Nyctimene robinsoni Thomas, 1904	eastern tube-nosed bat
Nyctimene cephalotes (Pallas, 1767)	northern tube-nosed bat
Syconycteris australis (Peters, 1867)	eastern blossom bat
Macroglossus minimus nanus Matschie, 1899	northern blossom bat
Megadermatidae	
Macroderma gigas (Dobson, 1880)	ghost bat
Rhinolophidae	
Rhinolophus megaphyllus Gray, 1834	eastern horseshoe bat
Rhinolophus megaphyllus ignifer Allen, 1933	northern horseshoe bat
Rhinolophus megaphyllus megaphyllus Gray, 1834	southern horseshoe bat
Rhinolophus philippinensis Waterhouse, 1843	large-eared horseshoe bat
Rhinolophus philippinensis (large form)	greater large-eared horseshoe bat
Rhinolophus philippinensis (small form)	lesser large-eared horseshoe bat
Hipposideridae	
Hipposideros ater Templeton, 1848	dusky leaf-nosed bat
Hipposideros ater aruensis Gray, 1858	eastern dusky leaf-nosed bat
Hipposideros ater gilberti Johnson, 1959	western dusky leaf-nosed bat

Hipposideros cervinus (Gould, 1854)	fawn leaf-nosed bat
Hipposideros diadema (Geoffroy, 1813)	diadem leaf-nosed bat
Hipposideros diadema inornatus McKean, 1970	Arnhem leaf-nosed bat
Hipposideros diadema reginae Troughton, 1937	Queensland diadem leaf-nosed bat
Hipposideros semoni Matschie, 1903	Semon's leaf-nosed bat
Hipposideros stenotis Thomas, 1913	northern leaf-nosed bat
Rhinonicteris aurantia (Gray, 1845)	orange leaf-nosed bat
Rhinonicteris aurantia (Gray, 1845) (Pilbara form)	Pilbara leaf-nosed bat
Emballonuridae	
Taphozous australis Gould, 1854	coastal sheath-tailed bat
Taphozous georgianus Thomas, 1915	common sheath-tailed bat
Taphozous hilli Kitchener, 1980	Hill's sheath-tailed bat
Taphozous kapalgensis McKean and Friend, 1979	Arnhem sheath-tailed bat
Taphozous troughtoni Tate, 1952	Troughton's sheath-tailed bat
Saccolaimus flaviventris (Peters, 1867)	yellow-bellied sheath-tailed bat
Saccolaimus mixtus Troughon, 1925	Papuan sheath-tailed bat
Saccolaimus saccolaimus nudicluniatus (De Vis, 1905)	bare-rumped sheath-tailed bat
Molossidae	
Tadarida australis (Gray, 1838)	white-striped free-tailed bat
Chaerephon jobensis colonicus (Thomas, 1906)	northern free-tailed bat
Mormopterus beccarii Peters, 1881	Beccari's free-tailed bat
Mormopterus loriae	little free-tailed bat
Mormopterus loriae cobourgiana Johnson, 1959	western little free-tailed bat
*Mormopterus loriae ridei** Felten, 1964	eastern little free-tailed bat
Mormopterus norfolkensis (Gray,1839)	east-coast free-tailed bat
Mormopterus sp. (form sp4 in Adams et al. 1988)	southern free-tailed bat
Mormopterus sp. (form sp 4 (PQR) in Adams et al. 1988)	south-eastern free-tailed bat
Mormopterus sp. (form sp 4 (O) in Adams et al. 1988)	south-western free-tailed bat
Mormopterus sp. (form sp 3 in Adams et al. 1988)	inland free-tailed bat
Mormopterus sp. (form sp 2 in Adams et al. 1988)	eastern free-tailed bat
Mormopterus sp. (form sp 6 in Adams et al. 1988)	bristle-faced free-tailed bat
Genus species Authority	**ABS common name**
Vespertilionidae	
Chalinolobus dwyeri Ryan, 1966	large-eared pied bat
Chalinolobus gouldii (Gray, 1841)	Gould's wattled bat
Chalinolobus morio (Gray, 1841)	chocolate wattled bat
Chalinolobus nigrogriseus (Gould, 1856)	hoary wattled bat
Chalinolobus picatus (Gould, 1852)	little pied bat
Falsistrellus mackenziei Kitchener, Caputi and Jones, 1986	western false pipistrelle
Falsistrellus tasmaniensis (Gould, 1858)	eastern false pipistrelle
Kerivoula papuensis Dobson, 1878	golden-tipped bat
Miniopterus australis (Tomes, 1858)	little bent-winged bat
Miniopterus schreibersii (Kuhl, 1817)	large bent-winged bat
Miniopterus schreibersii orianae Thomas, 1922	northern bent-winged bat
Miniopterus schreibersii oceanensis Maeda, 1982	eastern bent-winged bat
Miniopterus schreibersii bassanii Cardinal and Christidis, 2000	southern bent-winged bat

Murina florium Thomas, 1908	flute-nosed bat
Myotis macropus (Gould, 1855)	large-footed myotis
Nyctophilus arnhemensis Johnson, 1959	northern long-eared bat
Nyctophilus bifax Thomas, 1915	
Nyctophilus bifax bifax Thomas, 1915	eastern long-eared bat
Nyctophilus bifax daedalus Thomas, 1915	pallid long-eared bat
Nyctophilus geoffroyi Leach, 1821	lesser long-eared bat
Nyctophilus gouldi Tomes, 1858	Gould's long-eared bat
Nyctophilus howensis McKean, 1973	Lord Howe long-eared bat
Nyctophilus timoriensis (Geoffroy, 1806)	greater long-eared bat
Nyctophilus timoriensis major Gray, 1844	western greater long-eared bat
Nyctophilus timoriensis (Geoffroy, 1806): (central form)	central greater long-eared bat
Nyctophilus timoriensis (Geoffroy, 1806): (south-eastern form)	eastern greater long-eared bat
Nyctophilus timoriensis sherrini Thomas, 1915	Tasmanian greater long-eared bat
Nyctophilus walkeri Thomas, 1892	pygmy long-eared bat
Pipistrellus adamsi Kitchener, Caputi and Jones, 1986	forest pipistrelle
Pipistrellus murrayi Andrews, 1900	Christmas Island pipistrelle
Pipistrellus westralis Koopman, 1984	northern pipistrelle
Scoteanax rueppellii (Peters, 1866)	greater broad-nosed bat
Scotorepens balstoni (Thomas, 1906)	inland broad-nosed bat
Scotorepens greyii (Gray, 1843)	little broad-nosed bat
Scotorepens orion (Troughton, 1937)	eastern broad-nosed bat
Scotorepens sanborni (Troughton, 1937)	northern broad-nosed bat
Scotorepens sp.	un-named broad-nosed bat
Vespadelus baverstocki Kitchener, Jones and Caputi, 1987	inland forest bat
Vespadelus caurinus (Thomas, 1914)	northern cave bat
Vespadelus darlingtoni (Allen, 1933)	large forest bat
Vespadelus douglasorum (Kitchener, 1976)	yellow-lipped cave bat
Vespadelus finlaysoni Kitchener, Jones and Caputi, 1987	Finlayson's cave bat
Vespadelus pumilus (Gray, 1841)	eastern forest bat
Vespadelus regulus (Thomas, 1906)	southern forest bat
Vespadelus troughtoni Kitchener, Jones and Caputi, 1987	eastern cave bat
Vespadelus vulturnus (Thomas, 1914)	little forest bat

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FRONT COVER IMAGES (left to right)

Ghost bat *Macroderma gigas* (Robert Thorn) Spectacled flying-fox *Pteropus conspicillatus* (Mike Trenerry) Troughtons sheathtail bat *Taphozous troughton*i (Bruce G Thomson) Bats roosting, Ord River, Western Australia (Michelle McAulay)

BACK COVER IMAGES (left to right, top to bottom)

Ghost bat *Macroderma gigas* (Robert Thorn) Troughtons sheathtail bat *Taphozous troughton*i (Bruce G Thomson) Bats roosting, Ord River, Western Australia (Michelle McAulay) Spectacled flying-fox *Pteropus conspicillatus* (Mike Trenerry) Greater large-eared horseshoe bat *Rhinolophus philippinensi*s (Bruce G Thomson)

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