Charles Darwin University Animal Ethics Committee

Standard Operating Procedure:

Northern Territory guidelines for surveying for the ghost bat at the landscape scale (Ruykys, Hanrahan & Stokeld)

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Northern Territory guidelines for surveying for the ghost bat at the landscape scale

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Cover image: Still photograph of a ghost bat from video camera footage.

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1. Introduction

1.1. Purpose

These guidelines have been prepared with the aim of setting a standard for surveying for the ghost bat (*Macroderma gigas*) at the landscape scale. They pertains to surveying for the ghost bat in the Top End of the Northern Territory (NT); however, the survey method – possibly with some adaptations – could also be applied across the species' distribution in Queensland and Western Australia. This document is intended for use by land managers, environmental consultants, development proponents and/or researchers (henceforth 'surveyor'). To facilitate consistent collection of data and increase confidence in survey results, the method described in this document should be followed when surveying for the ghost bat at the landscape scale. However, since the survey method is novel, it is expected that further application across the species' distribution will improve its generality and functionality.

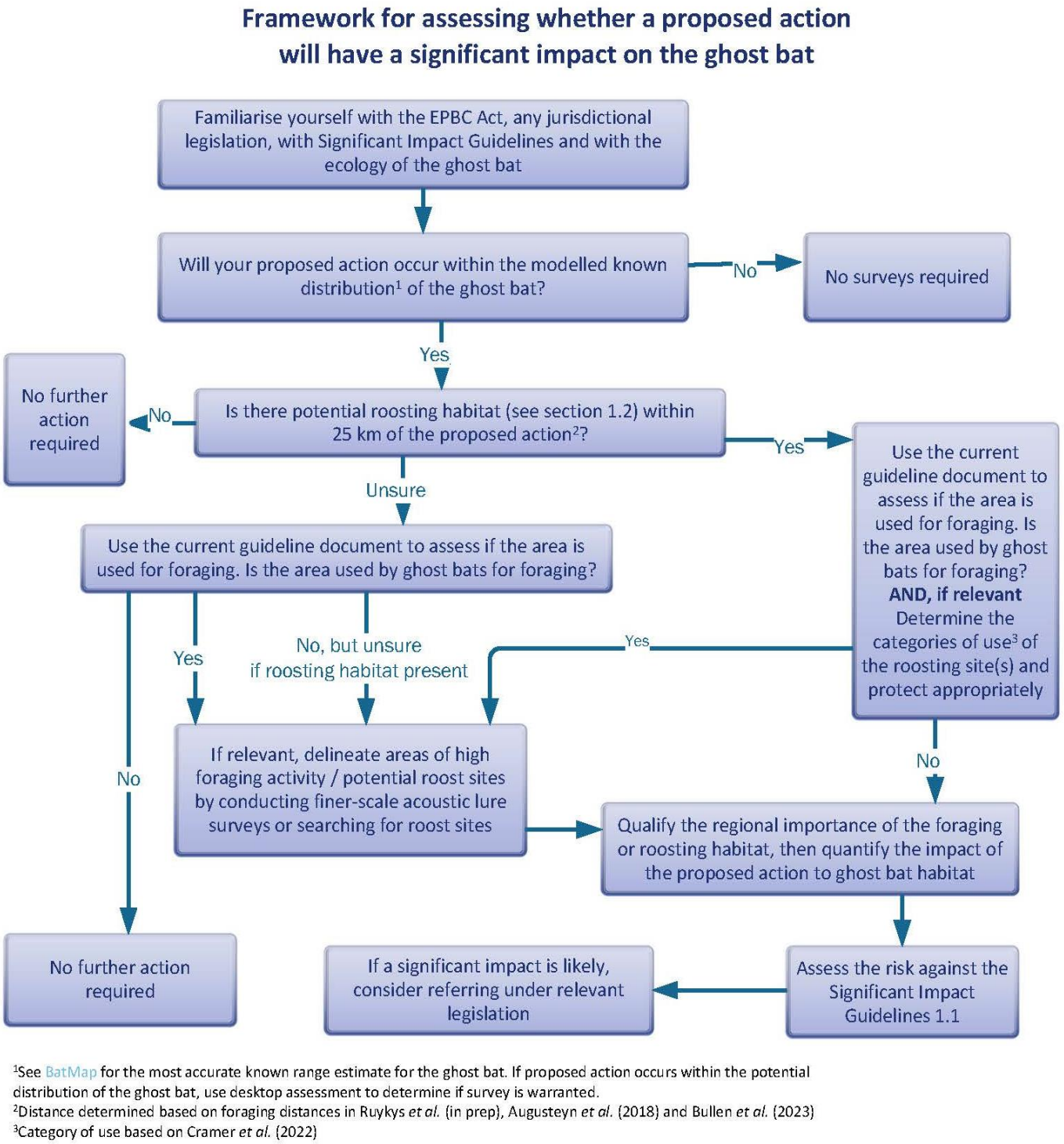
In the current context, 'landscape scale' relates to surveys at a broad spatial context. For example, the 'landscape scale' could be across thousands of hectares in an area in which the presence of the ghost bat is possible (i.e. within the modelled distribution of the species) but unconfirmed or poorly understood. The landscape-scale survey method does not replace site-specific survey methods, such as those that may be used at, or near, known or potential roost sites or specific habitat features (e.g. outcropping limestone or sandstone). Determining the use of roosts by ghost bats, and how to establish the significance of such roosts, is not discussed in the current document because high spatial and temporal variability in use of roosts necessitates focused survey effort. Furthermore, this facet of the species' ecology is the focus of current research. Questions on these aspects can be directed to the Flora and Fauna Division and/or species experts. Instead, this document describes how to conduct a landscape-scale survey, the results of which will help determine whether the surveyed area is likely to be within the foraging range of ghost bats. The survey method does not allow confirmation that the exact survey sites are used for foraging. Rather, it indicates that ghost bats either forage in the vicinity of the site or traverse the landscape close to the site while commuting to their foraging areas in the region. Results from survey sites should be interpreted relative to each other, at a landscape scale.

This document is intended to be used as survey guidance when proposals are being considered under relevant NT legislation (e.g. *Environment Protection Act 2019*). Figure 1 shows how the method fits within a framework for assessing whether a proposed action will have a significant impact on the ghost bat. The following points are also pertinent:

- Undertaking surveys for fauna is essential for informing decision-making around development impact and conservation planning. The nature and context of a proposed action will dictate the level of survey effort expected. Greater survey effort — including targeted surveys — and greater understanding of potential impacts, will be required for actions that will impact habitat (either roosting or foraging) that is critical to the survival of the ghost bat.

- Loss of habitat that is critical to the survival of the ghost bat is likely to result in a significant impact and referral under the *Environment Protection and Biodiversity Conservation Act 1999* is required.

- Actions unlikely to result in a significant impact on the ghost bat include those that:
    - are informed by surveys consistent with these guidelines and/or surveys at, or near, known or potential roost sites or specific habitat features;
    - avoid clearing habitat that is critical to the survival of the ghost bat;
    - maintain connectivity between regional roosts (including transitory roosts);
    - are designed to avoid and/or minimise both direct and indirect mortality to the ghost bat; and
    - have in place proven, monitored and adaptive management measures to control impacts from fire, pastoralism and invasive species.



[1]See BatMap for the most accurate known range estimate for the ghost bat. If proposed action occurs within the potential distribution of the ghost bat, use desktop assessment to determine if survey is warranted.
[2]Distance determined based on foraging distances in Ruykys *et al.* (in prep), Augusteyn *et al.* (2018) and Bullen *et al.* (2023)
[3]Category of use based on Cramer *et al.* (2022)

Figure 1 Flow diagram of how the landscape-scale survey method fits within a framework for assessing whether a proposed action will have a significant impact on the ghost bat. It should be noted that reference is made only to Commonwealth legislation (*Environment Protection and Biodiversity Conservation Act;* EPBC Act); however, in certain instances, other legislation may also be relevant (e.g. the Northern Territory's *Environment Protection Act 2019).*

1.2. Background

1.2.1. Ecology

Species description and distribution

The ghost bat is a large, carnivorous, echolocating species of bat within the superfamily Rhinolophoidea. It is the single representative of the family Megadermatidae in, and is endemic to, Australia. The ghost bat is globally unique in its appearance, having distinctive pale fur, long ears that are conjoined at the base, no tail, large eyes, an obvious nose-leaf surrounding the nostrils and a prominent tragus in the ear (Armstrong 2019). Some of these features facilitate the identification of the species in the video footage that is used in the current survey method.

The species' historical distribution incorporates southern Australia, including south-western Western Australia, the Flinders Ranges of South Australia and eastern New South Wales. There are also records of the species in the arid zone of central Australia from 1854, including in the Northern Territory (NT), but the last of these colonies was extirpated several decades ago (Churchill and Helman 1990).

Today, the ghost bat is restricted to tropical and sub-tropical northern Australia; specifically, to the Pilbara and Kimberley regions of Western Australia, the 'Top End' of the NT, and coastal and near-coastal eastern Queensland from Cape York to near Rockhampton (Figure 2; Australasian Bat Society – Bat Map 2022). Within this distribution, the ghost bat is found in a range of habitats, from open savanna woodland to arid spinifex hillsides. However, the species' area of occupancy is restricted by its reliance on underground roosts that have warm, humid microclimates and thus maintain individuals' heat and water balance (Armstrong *et al.* 2021).

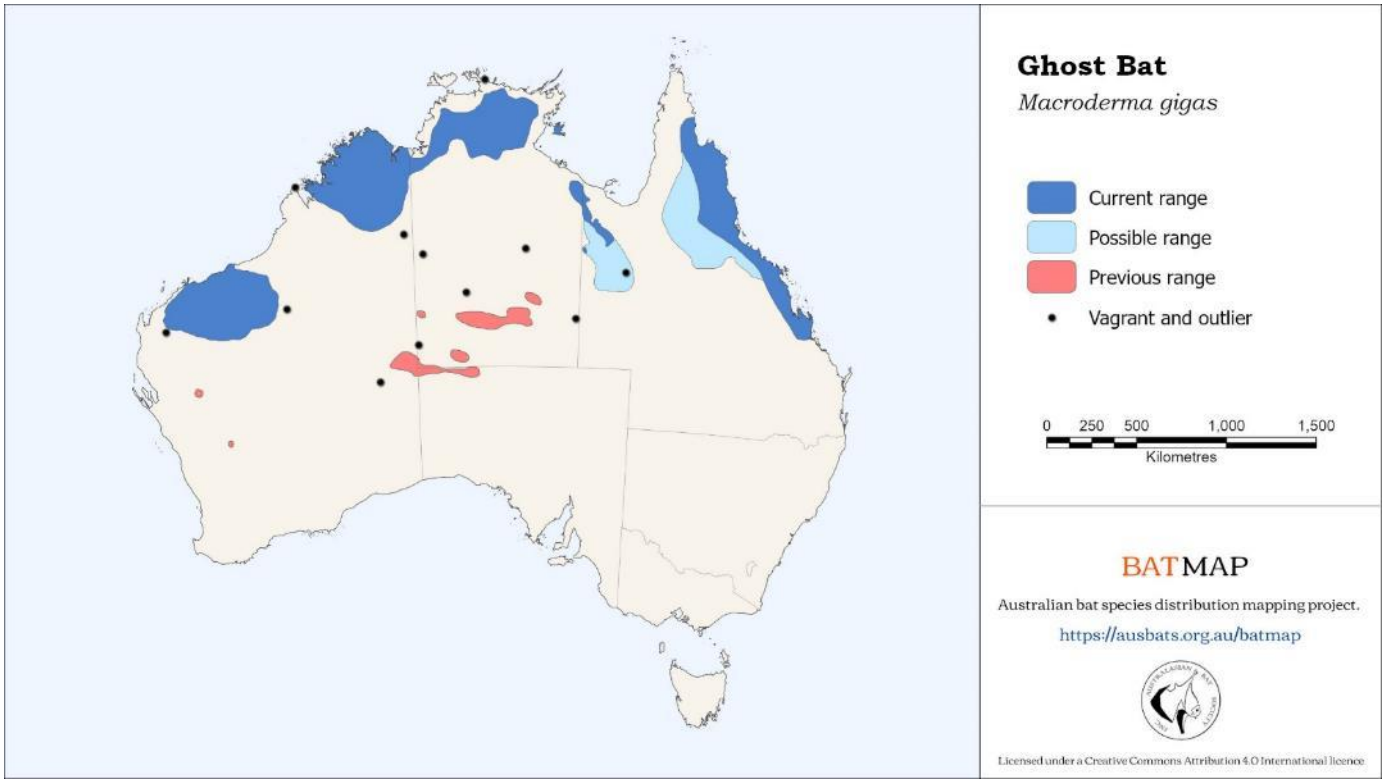


Figure 2. The estimated current, possible and previous range of the ghost bat. Source: Australasian Bat Society – Bat Map 2022.

Status

The ghost bat is currently listed as Vulnerable under both the *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999* and the IUCN Red List (Armstrong *et al.* 2021). In the NT, it is currently listed as Near Threatened under the *Territory Parks and Wildlife Conservation Act 1976*.

Ecology

The ghost bat roosts singly or in colonies of up to 1,500 individuals. The species uses subterranean structures as roosts; these include natural formations such as caves in sandstone, limestone and ironstone outcrops, and granite boulder piles. Disused mine sites are also used as permanent and seasonal roosts, while culverts and abandoned buildings (e.g. sheds) may be used in the short-term by dispersing individuals.

Ghost bats have been recorded foraging up to 25 km from the roost nightly, and even further when an intermediate over-day roost is used (Ruykys *et al.* in prep. a; b; Bullen *et al*. 2023; Augusteyn *et al.* 2018). Individuals hunt large invertebrates, as well as a range of vertebrate fauna (birds, reptiles, amphibians, ground-dwelling mammals, bats) that are of equal or lower weight to themselves (Milne *et al.* 2016). The ghost bat hunts using echolocation and active listening and watching. Prey is captured in the air or gleaned from trees or from the ground (Pettigrew *et al.* 1986). The species appears to use a variety of habitat and vegetation types, with the availability of perching trees for prey observation being an important feature.

1.2.2. Surveying for ghost bats

There is currently no common, agreed approach that standardises the method, effort or timing for surveying ghost bats and thus surveys are often not comparable temporally or spatially. The development of such standardised approaches was highlighted as a priority in the Conservation Advice for the ghost bat (Threatened Species Scientific Committee 2016). Furthermore, determining the presence or absence of the ghost bat is challenging and, as a result, often poorly executed during environmental impact assessments and referrals under the EPBC Act 1999. The *Survey Guidelines for Australia's Threatened Bats* (Australian Government 2010) pre-date the listing of the ghost bat and consequently do not provide species-specific advice on how to survey for it. Land managers, environmental consultants, researchers and/or other practitioners currently use a self-determined mixture of methods to survey for the species away from known roosts. Survey methods often include all of, or a selection from, the following; however, there are numerous limitations to these approaches, as follows:

- **Full-spectrum acoustic surveys:** this method is most suited to being used at potential roost entrances or at specific landscape features, such as gorges, where ghost bats may be 'funnelled' close to the acoustic detector. Although the ghost bat has a distinctive echolocation call, it is of low intensity ('soft') (Pettigrew *et al.* 1986), making the species difficult to reliably detect away from the roost with standard bat detectors. Furthermore, the ghost bat is a visual hunter and does not use echolocation to forage in the same way as do other echolocating bat species, meaning that production of echolocation calls is unreliable for the purposes of surveying (Kulzer *et al.* 1984). The species' louder social vocalisations are highly variable and also cannot be reliably detected away from the roost using bat detectors because animals only produce such calls either at the roost or sporadically in association with particular behaviours away from the roost (Hanrahan *et al.* 2019).

- **Spotlight surveys during call broadcast:** these are not standardised, may be biased by being undertaken close to known or suspected roost locations, may be undermined by regionalisation of calls (Hanrahan 2020), cannot be deployed at a landscape scale and may be influenced by distance from roost(s). Furthermore, white light should not be directed at roost entrances as this may cause disturbance and delay animals' emergence.

- **Live trapping**: is impractical for landscape-scale surveys and can be challenging because ghost bats have high visual acuity (Pettigrew *et al.* 1988). Furthermore, disturbance at roost sites is a documented threat to the species, as bats may not return to a roost for months or years after trapping, depending on how such trapping is undertaken (Armstrong *et al.* 2021). Consequently, trapping inside roosts or in the immediate vicinity of the entrance should be avoided unless it is for a specific, approved (by an animal ethics committee) research purpose. Trapping away from the roost using an acoustic lure is unlikely to be effective for landscape-scale surveys and, if attempted, should only be for an approved (by an animal ethics committee) research purpose.

- **Searching for, and within, caves and crevices that may be used as roost sites**: is likely to be biased to known or suspected roost locations, is challenged by the temporally variable occupancy of roosts (e.g. Toop 1985) and may inadvertently flush and/or disturb roosting individuals, which is a documented threat to the species (Armstrong *et al.* 2021). Furthermore, it may require experience in speleological exploration, is likely to be time-consuming and is impractical for landscape-scale surveys. Ideally, to minimise disturbance, when roost exploration is deemed necessary (e.g. for habitat mapping, collection of prey remains/scats etc.), roosts should be examined at night, after all resident bats have left to forage.

- **Counts using thermal imaging/infra-red cameras:** ghost bats are unlikely to be intercepted with video camera equipment while foraging unless an acoustic lure is used; as such, this method is more suited to roost-based surveys.

- **Faecal DNA analysis** (e.g. Ottewell *et al.* 2020): it is highly unlikely that ghost bat scats of sufficient freshness could be identified and collected in foraging areas. Scats may be found under feeding trees but these would be next to impossible to locate, plus exposure to the sun would rapidly degrade the DNA. As such, this method is more suited to roost-based surveys.

1.2.3. Acoustic lure recording

The survey method described in this document uses an acoustic lure (e.g. Hill and Greenaway 2005; Hill *et al.* 2015). The premise is that broadcasting acoustic stimuli (natural or synthetic) may increase bat detection rates by provoking a response that makes individuals more detectable. The ghost bat's curiosity and responsiveness to acoustic stimuli are well-established (e.g. Pettigrew *et al.* 1986) and the species is physically responsive to the broadcast of some of its own social vocalisations – including the 'squabble' (Hanrahan 2020; Hanrahan *et al.* 2022). The 'squabble' is an agonistic vocalisation produced during altercations, such as aggressive interactions over food or if a bat bumps into a roost mate while landing (Hanrahan *et al.* 2022). It is a harsh, noisy vocalisation produced by an aggressor and is highly variable in duration and intensity, with the duration appearing to be related to the intensity of the fight (Guppy *et al.* 1985; Hanrahan *et al.* 2022). Ghost bats respond to the broadcasting of their 'squabble' social vocalisation, and both males and females are equally attracted to this acoustic stimulus (Hanrahan *et al*. 2023).

A suitably attractive acoustic recording is required for this survey methodology. An effective acoustic lure track has been designed for the current method using full-spectrum recordings collected at roosts across the ghost bat's distribution in the NT (Hanrahan 2020). The track consists of several 'squabble' vocalisation recordings repeating for 2 minutes, followed by 2 minutes of silence. The purpose of the 2 minutes of silence is to allow any attracted ghost bats to leave the site and continue foraging. Surveyors who want to use the already-constructed acoustic lure track should seek access to it from Dr Nicola Hanrahan (NH) of Charles Darwin University (nicola.hanrahan@cdu.edu.au).

The acoustic lure track is provided under a conditional, non-exclusive licence. The terms of the license include that surveyors:

- must give credit to the recording creator, NH;
- can use the recording for commercial purposes, such as a consultant conducting landscape-scale surveys for ghost bats. However, a licence fee per survey will apply and a registration number will be provided when supplying the acoustic lure track. This registration number is 'single use' and assigned to a particular survey i.e. the acoustic lure track and registration number are not to be re-used across multiple surveys, even if those surveys are conducted by the same surveyor. The registration number must be identified in any report (published or unpublished) and must be associated with any fauna records arising from use of the acoustic lure;
- must not distribute the track to any other parties and, instead, must direct any other interested users to NH for access;
- must use the track in its current form without adaption (e.g. removal of silence periods);
- must only use the track for surveying ghost bats at a landscape scale, as stipulated in these guidelines. Users must request permission from NH if they wish to use the recording for other purposes e.g. to attempt to trap bats or to attract bats to alternative roosting habitat; and
- must not use the track in other ways that a reasonable person would consider to be unethical.

The transferability of the acoustic lure track to locations outside of mainland NT is currently unknown, since there are dialects among geographically distant ghost bat colonies (Hanrahan 2020). Thus, if applying the survey method outside of the NT (or on offshore islands), it may be necessary to obtain ghost bat vocalisations that are specific to the target location, ensuring that the 2 minutes of acoustic lure, 2 minutes of silence format is maintained. Contact NH if you would like to discuss track construction.

1.2.4. Considerations of animal welfare

Acoustic lures alter the behaviour of an animal and, as a result, care should be taken to not cause undue impact to individuals. The current survey method has been designed to be effective whilst still minimising disturbance. For animal welfare purposes, users should adhere with the following conditions:

- Using an acoustic lure is considered to be interfering with a native animal and will therefore require approval from an animal ethics committee, as well as from any other relevant authorities within the state or territory of operation. It is incumbent on the surveyor to determine what approvals they require, and to obtain those.
- Surveyors should:
    - broadcast the calls for the duration and at the intensity stipulated in these guidelines. More intensive broadcasting of the lure is unnecessary, may impact on foraging behaviour, and may result in habituation to the acoustic lure stimuli;
    - broadcast at the spatial distances stipulated in these guidelines. Narrower spatial distances will not increase detection probability (see Section 2.2); and
    - retain the 'silence' component between the 'squabble' call component.
- Those constructing their own acoustic lure tracks should be careful about who the track is distributed to and where it is stored i.e. the lure should not be uploaded to a public repository. This is to prevent unethical or excessive use of the lure e.g. for poaching, photography or 'twitching'.

- This is a novel method and the authors are keen to continuously improve and ensure that the use of the acoustic lure methodology does not negatively affect fauna. Any observations of adverse impacts to ghost bats or other species as a result of using this method should be reported to the authors at the earliest opportunity.

2. Survey guidelines

The survey method involves establishing a survey area and breaking it into a grid of acoustic lure sites that are spaced 5 km apart. Replicate surveys are conducted at each of the acoustic lure sites; for the surveys, ghost bats' social calls – specifically their 'squabble' vocalisation type – are used to draw individuals into the field of view of a video camera. Once ghost bats are detected in the landscape and/or once sites with higher relative activity are identified, a 'second-stage survey' can be undertaken, with the objective of delineating areas of high activity/potential roost sites. A 'second-stage survey' could involve conducting finer-scale (i.e. less than 5 km) acoustic lure surveys or on-ground searches of nearby geological formations for roost sites; however, whether this needs to be conducted should be determined by the objectives and scope of the project.

Details on the development of the method are provided in Ruykys *et al.* (2023) and this open access article should be consulted in parallel with the current document. For information on the study conducted to assess the response of ghost bats to their different social calls, refer to Hanrahan *et al.* (2024).

When using the current survey method, surveyors must follow the survey components that are identified as a survey standard. These components are identified throughout the document through the prefacing use of the word '**standard**'. Where there is flexibility in approach, the survey components are identified through the prefacing use of the word '**recommendation**' (or similar).

As a standard, the survey method involves six steps (Figure 3); these are detailed in the sections below.

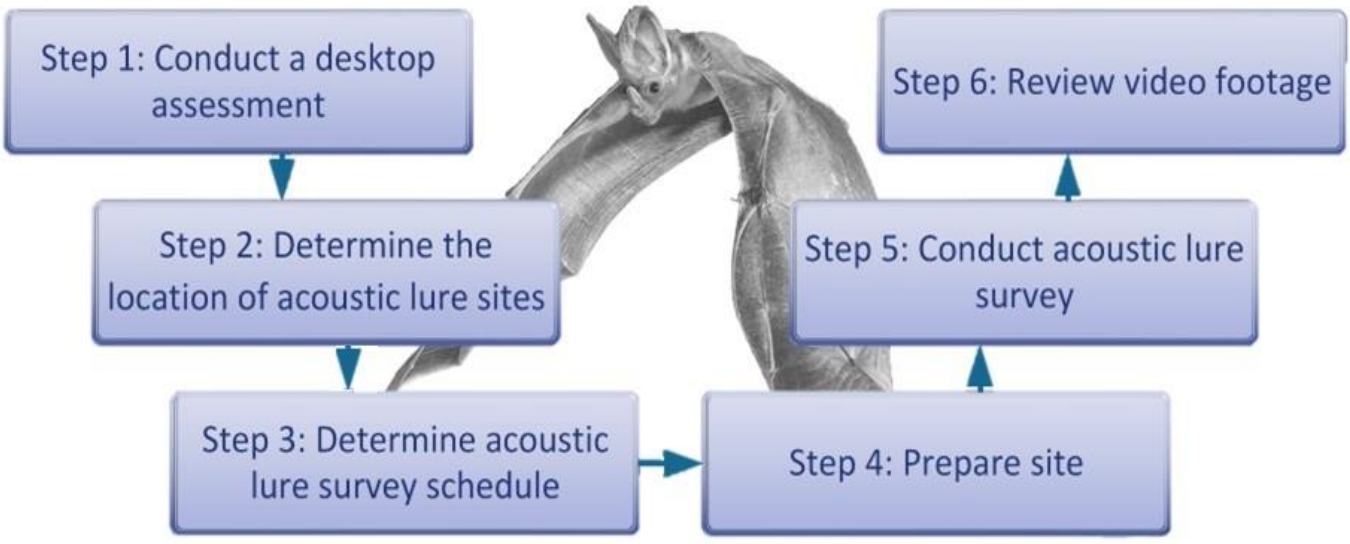


Figure 3 Six steps to planning and conducting a landscape-scale survey for ghost bats using the acoustic lure methodology. Image of ghost bat by B. Thomson.

2.1. Step 1: Conduct a desktop assessment

A desktop assessment will assist in determining if a landscape survey for ghost bats is warranted; it will also delineate the survey area. The use of spatial mapping software such as ArcGIS, QGIS or Google Earth Pro is recommended. The desktop assessment should map four levels of information: 1) the ghost bat's distribution; 2) ghost bat location records; 3) known or potential roosting habitat; and 4) potential foraging habitat within the flight range of known or potential roosting habitat.

Level 1) To determine if the project area is within (or close to) the currently known distribution of the ghost bat, the species' known and potential distribution can be viewed and downloaded as a layer from the Australasian Bat Society's portal BatMap. If the project area is within the species' potential distribution, the need for an acoustic lure survey should be assessed on a case-by-case basis, based on distance to the known ghost bat distribution, presence of suitable roosting habitat and/or local knowledge that suggests ghost bats may be present. Similarly, if the project area is outside the species' distribution but there are records (outlier) in proximity, the need for an acoustic lure survey should be assessed on a case-by-case basis. Distribution mapping has the potential to change, so surveyors should consult BatMap prior to each planned survey.

Level 2) Records of the ghost bat from the region of interest should be gathered and mapped as point data. For the NT, these data are available from the NT Government's *Fauna Atlas NT*, which is accessible through the NT Government's portal NR Maps. However, other sources — such as the *Atlas of Living Australia*, possibly local land councils / landowners, any local speleological society records and/or researchers or experts — could also be consulted, as relevant. It should be noted that some point location data are considered sensitive and are modified for public distribution. For example, in NR Maps, the coordinate values of ghost bat roost sites are rounded to 0.05 decimal degrees (approximately 5 km^2).

Level 3) Ghost bats have specific requirements for their roosting habitat (Section 1.2). To determine an appropriate survey area, the location of known or potential roosting habitat should be mapped. Layers that should be incorporated into such mapping include geological formations that have the potential to act as roosting habitat i.e. those that have the potential to be cave-, fissure- and crevice-forming, as well as the locations of historical mine workings. Geological formations of note are those that contain deeper limestone caves, tower karst and sinkholes, sandstone formations, granite boulder piles and ironstone. In the NT, areas of outcropping or underlying limestone (e.g. Tindall Limestone) and sandstone should be noted, together with any mapped sinkholes and karst features. Areas with relic mine shafts and adits should also be identified. Such information may be available from online national or jurisdictional datasets (e.g. in the NT, NR Maps), any local speleological society records and/or local knowledge. Mapping should be done at a scale that exceeds the proposed project footprint. This is to allow identification of roosting habitat that supports ghost bats, which may forage within a 25 km radius of the roost site (Figure 4).

Level 4) Ghost bats are known to forage in a range of vegetation types, including both native vegetation and vegetation that has been planted or disturbed by humans. As such, it is not possible to definitively stipulate what type of vegetation may or may not be used by the species for foraging. Native vegetation in the NT that is known to be used for foraging includes savanna woodland, shrubland and riparian vegetation, while human-modified vegetation includes plantations (e.g. sandalwood, mango), areas of native vegetation that are used to graze herbivores, and remnant vegetation adjacent to horticultural crops. Given this diversity, only potential foraging habitat that is within the flight range of potential roosting habitat is recommended for acoustic lure surveys. An exception to this may be a specific research proposal that aims to assess the use of a particular area of vegetation by ghost bats for foraging. Until further research is undertaken, a flight range of 25 km from a diurnal roost is considered to be an appropriate delineating distance.

It is incumbent upon surveyors to assess the likelihood of use of an area by ghost bats, based on the regional context in which the proposal occurs. Considerations at the regional context should include the scale of the project, the presence of ghost bat roosting habit even outside 25 km, potential interconnectivity amongst roosting/foraging areas, and the cumulative impact of the project, taking into account other projects in the area. The surveyor may also need to assess relative activity of ghost bats at a regional scale, thus inferring the relative impact of a project at a regional scale. If there is any uncertainty as to whether there is potential roosting habitat in the region, a survey using the current methodology should be undertaken.

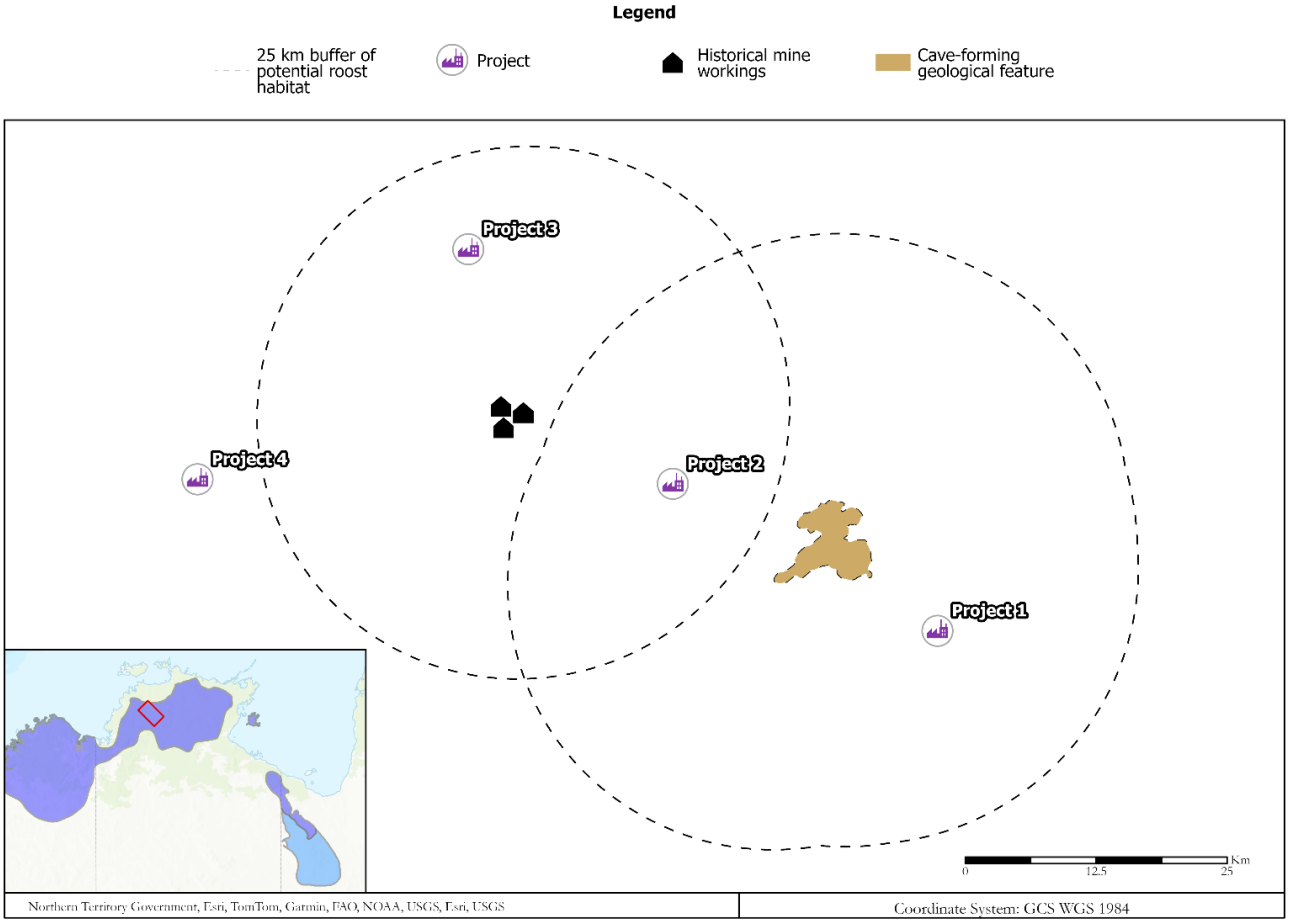


Figure 4 An illustrative example of a landscape within the current distribution of the ghost bat (inset) that has four proposed projects (1-4) and two types of features (human-made features such as historical mine workings and large culverts, and natural cave-forming geological features) that have the potential to provide roosting habitat for the species. A 25 km radius (representing the ghost bat's estimated maximum nightly foraging range) around each of the roosting habitat features is used here as a minimum indicator of the area that should be considered when assessing the presence of potential foraging habitat, noting that the acoustic lure survey may need to extend well outside this area. **Project 1** falls within 25 km of the cave-forming geological feature; therefore, surveyors should conduct landscape surveys for the ghost bat and include the geological feature in their survey design. **Project 2** falls within 25 km of both the mine workings and the cave-forming geological feature; therefore, the areas surrounding both habitat features should be included in the survey design. For **Project 3**, only the historical mine workings occur within 25 km and, as such, should be included in the survey design. **Project 4** does not occur within 25 km of any habitat features that provide roosting potential for the ghost and surveyors may, therefore, choose not to conduct landscape-scale surveys. The inset map places the example area within the ghost bats' current range. Purple = current range, light blue = potential distribution. The need for an acoustic lure survey in the potential distribution of the ghost bat should be assessed on a case-by-case basis.

2.2. Step 2: Determine the location of acoustic lure sites

To reiterate, the four levels of information in Step 1 above are to be used to delineate the survey area. Once the survey area has been determined, a grid of acoustic lure sites spaced 5 km apart and covering the entire survey area is to be drawn (Figure 5; Table 1). This distance is considered appropriate based on assessments undertaken during development of the survey method (Ruykys *et al.* 2023).

Greater distances (i.e. >5 km) may also be possible but confirmation of this requires broader testing of the method. Lesser distances (i.e. <5 km) are not recommended unless the survey is a finer-scale, 'second-stage survey' that is being conducted within 'hotspots' that were identified during the 'first stage' survey, or unless further testing of the current method (with appropriate assessments of detection probabilities) indicates that lesser distances are warranted. This recommendation is made because ghost bats are now known to regularly commute long distances (tens of kilometres) from their roost sites to their foraging areas and to have large home ranges (e.g. Ruykys *et al.* in prep. a; b; Bullen *et al.* 2023). The grid of survey sites in the current method will 'lure in' ghost bats as they are commuting over those distances; lesser distances do not increase detection probability. Rather, decreasing the distance would increase the time, resources and effort required, without improving surveyors' understanding of use of the landscape by ghost bats. If determining 'hotspots' of activity is of interest, decreasing the distance between acoustic lure sites could also increase the probability of double-counting individual(s) across multiple acoustic lure sites.

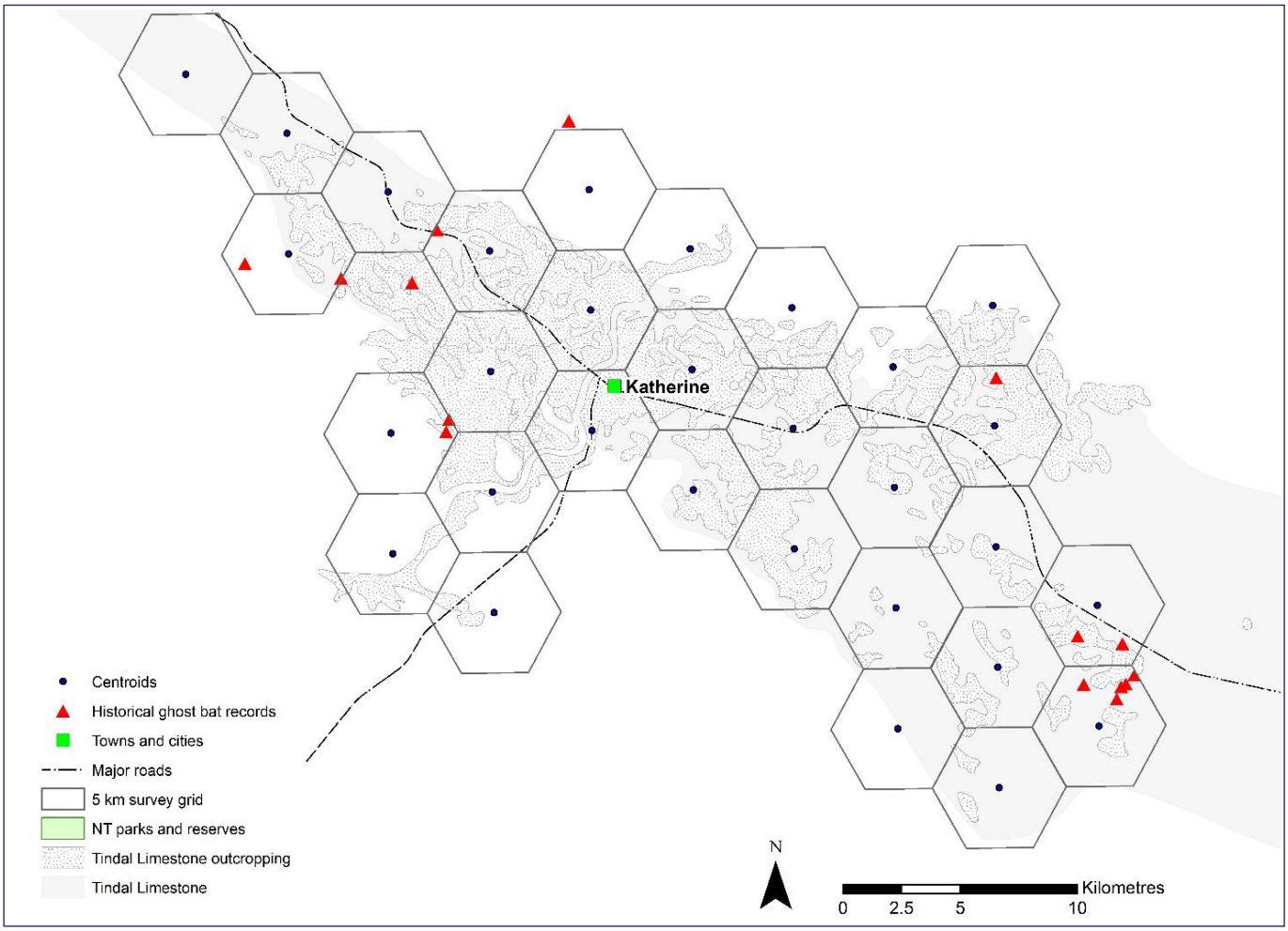


Figure 5 Example of mapping undertaken to select the survey area; this should incorporate relevant geology (in this case, Tindall Limestone) and any ghost bat records. Overlain onto this is a grid of hexagons, the centroids of which (5 km apart) form the acoustic lure sites.

Table 1 Survey standards and how to make modifications to the survey design when logistical or site suitability issues occur.

Survey standard	Purpose	Challenges	Solutions to challenges
Survey all acoustic lure sites in the grid	To establish understanding of the presence/absence and relative use of the area by the ghost bat	Logistical constraints (e.g. access issues) may prevent all sites in the grid being surveyed	- Prioritise sites that create as continuous a grid as possible. - Quantify the adequacy of the survey in reporting (Section 2.7)
Maintain 5 km spacing amongst all acoustic lure sites	To maximise distance from the other acoustic lure sites and decrease 'gaps' in the grid	Logistical constraints, such as accessibility, mean that some acoustic lure sites need to be moved (e.g. closer to tracks)	- Place the new acoustic lure site as close as possible to the original location - Move acoustic lure sites a maximum of 750 m from the original location
Conduct surveys in vegetated areas only, noting that non-native vegetation and vegetation in poorer condition are acceptable	To set acoustic lure sites in areas that are likely to be used / overflown by ghost bats	Areas with no vegetation, as well as urbanised and industrialised areas, should be avoided	- If an acoustic lure site falls within an urbanised or industrialised area, move it to an area of vegetation, while maintaining a maximum distance of 750 m from the original location

2.2.1. Special case: surveying on offshore islands

Ghost bats are known to inhabit offshore islands, including those off Western Australia's Kimberley coast and the NT's Groote Eylandt archipelago. When conducting surveys across island clusters, several islands may fall within the flight range of the ghost bat (~25 km). A suggested survey approach is to overlay a 5 km grid over all the islands that are within the flight range of the ghost bat. Move acoustic lure sites that would otherwise be in the ocean to the closest island, so that there is at least one site on each island within the grid. One acoustic lure site would be suitable if the island is less than 5 km^2 but more sites may be appropriate for larger islands. Acoustic lure sites that fall in the ocean can be dropped if the surrounding islands are already covered by sites.

2.3. Step 3: Determine the acoustic lure survey schedule

2.3.1. Survey timing

As a standard, surveys should not be conducted when females are in late gestation, are carrying pups or have dependent young in crèche in the roost. There is variability in the timing of reproduction across the ghost bat's distribution – including within a jurisdiction – and the currently published literature does not reflect this well. As such, where possible, local knowledge of the timing of reproduction should be used to guide the decision on the most appropriate month(s) for surveying. Based on the currently published literature, in the NT, ideal timing for surveys is from January, when juveniles are fully grown and largely independent (Hanrahan 2020) to June (pups are born in late July and August; Churchill 2008). In Queensland and the Pilbara region of Western Australia, published literature indicates that births occur from mid-October to late November, with young capable of flight by the end of January and weaned in

March (Douglas 1967; Toop 1985; Hoyle *et al*. 2001). This provides an April to September survey window. In the Kimberley region of Western Australia, the timing of reproduction is currently undocumented.

As a standard, periods of reproduction should be avoided because the use of acoustic lures during these times could disrupt females' ability to bring pups to independence by increasing energy expenditure when the female would otherwise be foraging or by delaying her return to the roost.

As a recommendation, to minimise confusion for both manual review of video footage and/or any automated processing of the same, surveys should not be conducted when juvenile ghost bats are likely to be present, as their smaller size and more erratic flight make positive identification more challenging.

2.3.2. Replicate surveys

As a standard, to account for imperfect detection, at each acoustic lure site, two surveys (i.e. replicates) must be conducted at a minimum. However, surveyors are strongly encouraged to calculate detection probabilities for their own survey region and/or survey period and to conduct the number of surveys that the analysis identifies is necessary to obtain appropriate detection probabilities.

In the Katherine area of the NT, based on two surveys at each acoustic lure site, the cumulative detection probability was 0.75 (i.e. 75% likelihood of detecting a ghost bat in one of two surveys, if it occurs at the acoustic lure site). For the Katherine area, three or five surveys at each acoustic lure site would be required to obtain detection probabilities of 0.80 and 0.95 respectively, and to tighten the confidence interval around the occupancy estimate (Ruykys *et al.* 2023). To reiterate, until further analyses of detection probabilities are conducted across the ghost bats' range, as a standard, a minimum of two replicate surveys is to be conducted at each acoustic lure site.

2.3.3. Acoustic lure survey schedule

As a standard, all replicate surveys at any one acoustic lure site must be run on non-consecutive nights. The purpose of this is to reduce interference across nights; for example, a ghost bat could conceivably return on night two to the location at which it heard social calls on night one.

As a standard, it is also critical that surveys not be conducted at adjacent sites on the same night. Instead, acoustic lure sites run on the same night must be as far apart from each other as possible, with an absolute minimum distance of 10 km maintained between all sites run on one night. The purpose of this is to minimise interference among acoustic lure sites, as surveying adjacent (5 km apart) acoustic lure sites simultaneously may introduce bias; for example, by adjacent acoustic lure sites being unknowingly located under animals' standard flight paths.

Given the need to run surveys at an acoustic lure site on non-consecutive nights, and to survey sites as far apart from each other as possible, detailed planning for the order in which acoustic lure sites are to be run must be conducted. This requires considering the spatial configuration of acoustic lure sites to be run on any one night within the context of the entire survey, so that the sites that are run on the last few nights are not within 5 km of each other. Allocating 'mop-up' night(s) at the end of each survey block is also recommended. This is because issues in the field (e.g. camera battery failure, acoustic lure files fail to broadcast, site access issues) mean that there is often a need to run or re-run surveys at sites at which there were failures. Accounting for at least one 'mop up' night is recommended but more may be required.

An example survey schedule is provided in Table 2 for a survey area around Elsey National Park, NT (Figure 6). Note that this survey used a fishnet method to map the survey area, with acoustic lure sites placed at the centroid of each hexagon (i.e. centroids were 5 km apart). See Appendix 1 for a detailed description of this approach.

Table 2 Example schedule for surveying, based on having four sets of equipment and thus surveying four acoustic lure sites per survey night (noting that the schedule excludes sites 08, 12, 14, 16, 18, 19, 23 and 24 that were run during a previous survey).

Night	Sites to be surveyed
1	Set up sites 04, 10, 15, 20
2	Set up sites 02, 07, 09, 13
3	Set up sites 04, 10, 15, 20 for their 2nd replicate
4	Set up sites 02, 07, 09, 13 for their 2nd replicate
5	Set up sites 03, 06, 11, 21
6	Set up sites 01, 05, 17, 22
7	Set up sites 03, 06, 11, 21 for their 2nd replicate
8	Set up sites 01, 05, 17, 22 for their 2nd replicate
9	'Mop-up' night

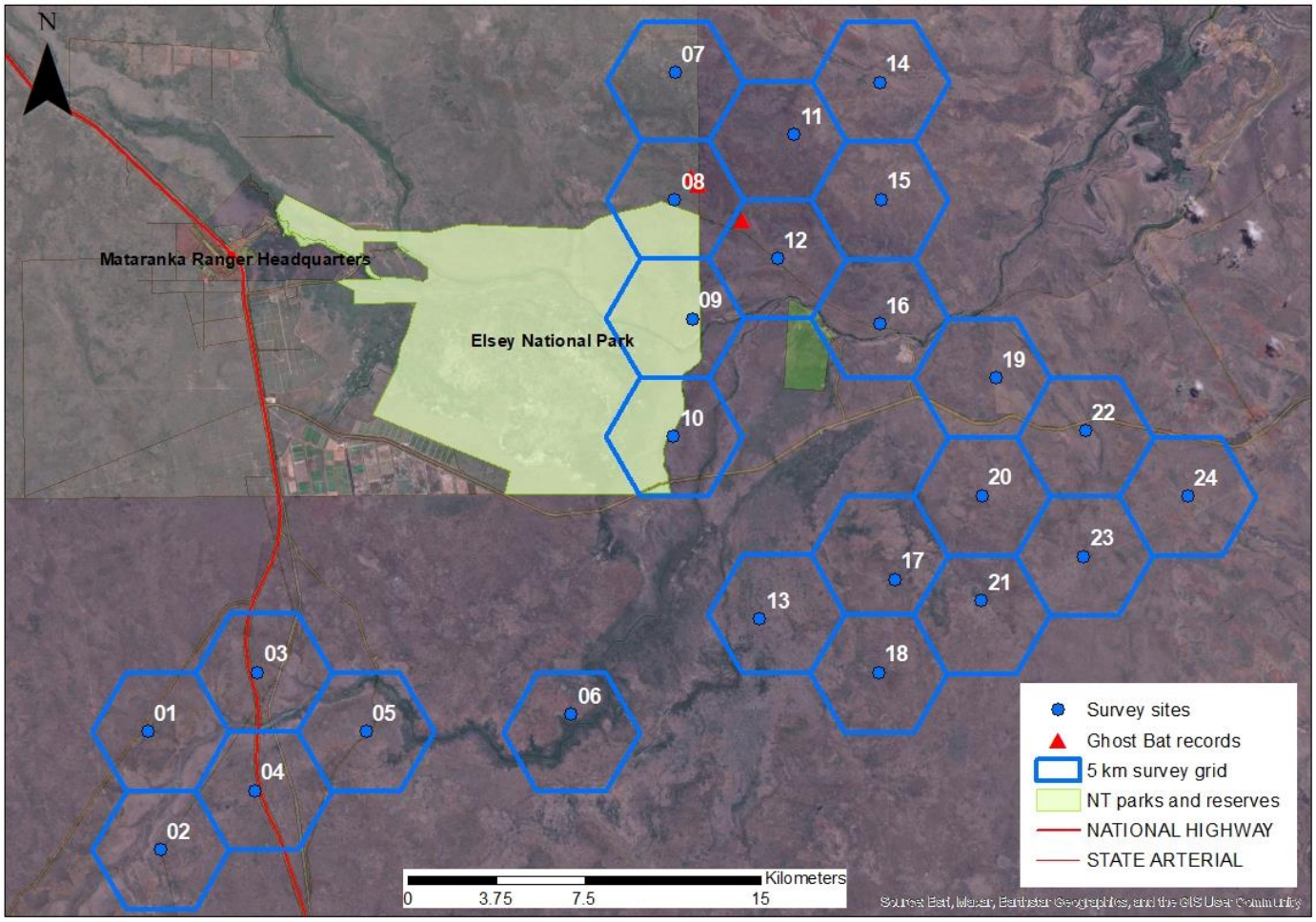


Figure 6 Survey area associated with the example schedule in Table 1.

2.4. Step 4: Prepare the site

A step-by-step procedure to set up each acoustic lure survey site is provided in Appendix 1. The equipment required for surveys is detailed in Appendix 2, an example datasheet is provided in Appendix 3 and tips for trouble-shooting are in Appendix 4. The following is a summary of the survey method; the appendices should be consulted for detail.

An open area is needed in order to clearly observe the attracted bat. To allow comparability among sites and surveys, site layout should be standardised. At each acoustic lure site, an area of approximately 15 m x 4 m (based on the approximate field of view of the video camera [Sony FDR-AX33 Handycam 4K] used by the authors, noting that this area may need to be adjusted if a video camera with a substantially wider field of view is used by surveyors) is to be selected in front of a tall, straight, sturdy tree ('reference tree'). In regions without trees, if a reference tree is unavailable, an alternative marker is acceptable. This should be straight and of a sufficient height to vertically fill the frame of the video camera's field of view.

Choose an area in front of the reference tree that contains no or few shrubs and flatten any ground vegetation that is over 50 cm as much as possible. Install a fence dropper 10 m in front of the reference tree. Attach to the fence dropper a speaker that is capable of playing the ghost bat 'squabble' vocalisation and that emits sound in 360° (note that many speakers are circular but only emit sound on 1-2 faces, rather than in 360°). Depending on the set-up, this may involve leaving in a waterproof container that is proximate to the speaker a tablet that has Bluetooth© connection and the required audio files pre-loaded.

Place a video camera a further 5 m in front of the speaker and fence dropper (Figure 7). The video camera needs to have infra-red recording capability to enable differentiation of the morphological features that are used to identify the ghost bat. The entire acoustic lure site (approximately 15 m x 4 m) needs to be illuminated by infra-red light and this is generally not possible using a video camera's inbuilt infra-red lamps; therefore, an external infra-red lamp (a minimum power of 18 W is recommended for sufficient illumination) is also required. The lamp is to be positioned so that it illuminates the acoustic lure site without the surrounding equipment causing shadows (Figure 8). The angle at which the video camera and infra-red lamp are set will likely vary with the equipment used. However, irrespective of the make and model(s) of equipment used, as a standard, the fence dropper and reference tree are to be in direct alignment, in the horizontal centre-point of the field of view of the video camera, and the strip of reflective tape is to be at bottom centre of the video imagery (Figure 9). This ensures a field of view that is slightly up from direct horizontal, which maximises the detection of the aerial space in which ghost bats fly.

Authors' tip: To aid in estimating the size of the bat in the recorded video, a narrow, vertical strip of reflective tape can be adhered at approximately 68 cm from the top of the fence dropper, equating to the approximate wingspan of a ghost bat.

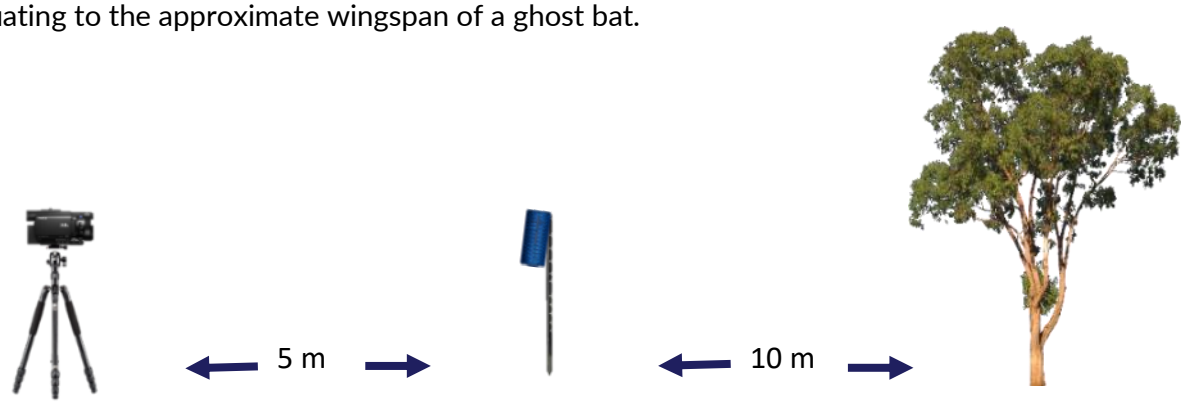


Figure 7 Diagrammatic representation of the set-up for the acoustic lure survey of ghost bats.

Figure 8 Set-up of an infra-red lamp directly underneath the video camera on a tripod, and showing one approach for water-proofing the camera. Note that the 12 V battery to which the infra-red lamp is attached is underneath the tripod but not photographed in this instance.

Figure 9 Behind-camera view of the vertical alignment that is to be instated from the video camera to the fence dropper and through to the reference tree (noting that, in this photograph, the speaker is not yet attached to the fence dropper).

2.5. Step 5: Conduct the acoustic lure survey

As a standard, commence playing the acoustic lure track 30 minutes after sunset (specifically, civil twilight). Ghost bats typically begin exiting the roost 20-30 minutes after sunset; therefore, beginning the acoustic lure track 30 minutes after sunset targets the period when ghost bats are most likely to be travelling to foraging areas. Region-specific vocalisations should be used. For animal welfare reasons, the acoustic lure track should only be used during the natural emergence period i.e. beginning 30 minutes after sunset, and at night.

As a standard, run the survey for 120 minutes. To optimise detection of ghost bats at least once in a survey period (if the species is present), a within-night survey period of 120 minutes is required, particularly in areas where cumulative probability analyses have not been conducted. If surveyors choose to deviate from this, they should justify why 120 minutes of surveying was not undertaken. At a minimum, this would involve providing data from a cumulative detection probability analysis. If a particular acoustic lure site's single-night survey period is shorter than 120 minutes due to equipment failure or surveyor error, this should be noted in the results (see Section 2.7). The 120 minute survey period pertains to the minimum requirement for *within* a single survey night at a single acoustic lure site; this does not override the need to conduct a minimum two nights of sampling per acoustic lure site (i.e. replicate surveys).

As a standard, play the acoustic lure at a consistent volume across all acoustic lure sites. The volume at which the acoustic lure has been played during surveys completed by the authors in the NT has averaged 81 decibels (dB). A speaker that allows broadcast of the acoustic lure at least at this volume should be used; however, the maximum volume that should not be exceeded is currently unknown. As such, animal welfare should be considered if surveyors use speakers that broadcast at volumes substantially greater than approximately 81 dB.

Authors' tip: Using supplemental battery power and an audio file (e.g. 'background roost' playlist) preceding the acoustic lure track allows multiple acoustic lure sites to be set up in one afternoon. The duration of the preceding audio file will need to be adapted in the field to ensure the acoustic lure survey still starts 30 minutes after sunset. See Appendix 1 for details.

Authors' tip: When planning your survey, consider the time it will take to retrieve the equipment, download data and charge the equipment so that it is ready to be reinstalled at the next set of acoustic lure sites (Figure 10). Equipment can be retrieved either on the night of the survey (after the survey period) or the following morning. Footage from the video camera must be downloaded after each survey night, ensuring that data management procedures are followed (see Section 2.6).

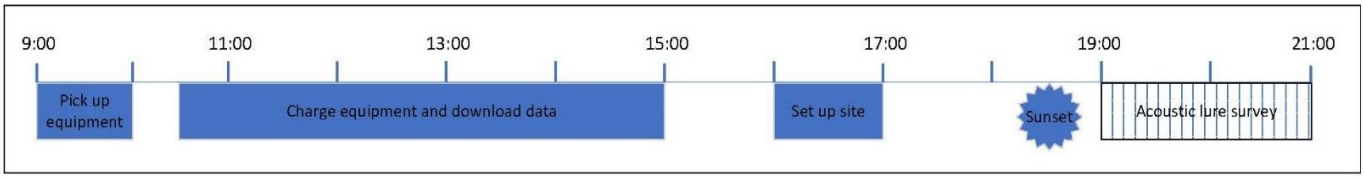


Figure 10 An indicative 12-hour timeline (09:00 – 21:00) illustrating the steps involved in each survey day when sunset is at 18:30. The time for collecting the previous night's equipment and setting up sites will increase as more sites are added, and time for travel between sites should be taken into consideration.

2.6. Step 6: Review video footage

As a standard, video footage retrieved from the video cameras must be managed such that the video files can always be linked to the survey site and survey date. To facilitate this and as a back-up, surveyors must state the date and time, site identification and replicate number at the commencement of the video recording for each survey site.

Manual review of video footage is required until motion analysis and/or deep machine learning can reliably differentiate ghost bats from other bats, fauna and moving objects. To reduce observer error and instate consistency, manual review should be undertaken by one, or a small number of, observers who are experienced in distinguishing ghost bats. The following approach should be followed as a standard:

- Review of video footage must be undertaken by people who are trained in ghost bat identification and the survey method, as well as in the use of the relevant tracking spreadsheet. Video footage that can be used for training purposes is available from the authors. Furthermore, until experience is obtained, it is possible to send short video clips to the authors for species confirmation. The authors can be contacted on nicola.hanrahan@cdu.edu.au and/or laura.ruykys@nt.gov.au.
- Video footage from one night must be reviewed by the same individual, not split into numerous 'snippets' and reviewed by numerous observers.
- Approaches that would predictably lead to inconsistency in outputs should be avoided e.g. apportioning review of video footage to citizen scientists via online platforms.

Authors' tip: Watching the video footage in a darkened room is helpful for observing lured bats in sufficient detail for identification. Manual review can be undertaken comfortably at a playback speed of up to 1.5 times the real time; however, portions of videos may need to be re-watched multiple times at a reduced speed (for example, x0.5 real time) and/or paused for confirmation of species. A video player such as VLC media player works well for this.

Authors' tip: Bats can pass by the camera's field of view rapidly and sometimes only once; therefore, constant observation of the screen is required while the video is playing.

Authors' tip: An acoustic detector placed next to the acoustic lure may assist with identifying ghost bats from other bat species (K. Armstrong, *pers. comm*. 2024). However, it should be noted that: i) ghost bats do not consistently use echolocation when in flight; ii) the acoustic lure may mask any echolocation pulses from ghost bats; iii) no ghost bats were detected acoustically during the study by Ruykys *et al.* (2023), despite ghost bats routinely flying with 1 m of bat detectors; iv) expertise is required to identify bats – particularly ghost bats – via their echolocation call; and v) the analysis of acoustic recordings will add significant analysis time to a project. Therefore, we recommend targeting times when only adults are present and using the list below to confirm species morphologically and behaviourally.

Morphology (Churchill 2008; see figure on cover page and video footage provided as appendices to Ruykys *et al*. (2023)) and behaviour are used to distinguish ghost bats from other bat species on the video footage. Positive identification is via a combination of the following features:

- ☐ relatively large size (see authors' tip on using reflective tape), though noting that an animal's increasing proximity to the video camera can distort the observer's perception of body size. Also note that lateral views of the bat (c.f. dorsally or from behind) preclude assessment of wingspan;
- ☐ pale colouration;
- ☐ large ears that are joined above the head;
- ☐ shining white eyes (not always noticeable but particularly evident if an individual is flying towards the camera);
- ☐ circling, gliding, 'dropping in' vertically and/or hovering flight behaviour at the speaker, rather than the flitting often undertaken by other bat species;
- ☐ a slower flight speed and more 'gliding' flight trajectory than that of other bat species; and
- ☐ often, multiple passes past the fence dropper as individual(s) investigate the sound source.

The response variable depends on the objective of the survey. It may be any of the following:

- presence/absence of ghost bats in the survey area
- presence/absence of ghost bats at a particular survey site
- the total number of passes by ghost bats past the vertical plane between the video camera and the reference tree as a measure of activity (Hanrahan *et al*. 2024). This allows determination of 'hotspots' of activity plus could be used for occupancy modelling (MacKenzie *et al.* 2006) and potentially trends in activity in that survey area/survey site over time (i.e. monitoring relative activity). It should be noted that the number of passes by ghost bats is **not** an indication of ghost bat abundance (inferred or extrapolated) at the survey site or in the survey area.

It is recommended that, whilst viewing video footage, surveyors record:

- both the video and actual ('real') time at which a ghost bat was detected in each of the video files. A custom-made spreadsheet to use during review of video footage is available from the authors. This contains formulae to calculate the length of video footage that needs to be reviewed within each of the video files, based on the time at which the video recording commenced, time of sunset and the time the survey period commenced.
- the total number of passes by ghost bats past the fence dropper. Note: if a ghost bat flies close to, but does not physically cross the vertical plane from the video camera to the reference tree, it is not counted as a 'pass'. Any passes behind the reference tree are also not counted because species identification and/or calculating the number of passes at that distance can be erroneous. However, if no other ghost bats are recorded at that acoustic lure site on that survey night and the bat can be confidently identified as a ghost bat despite not crossing the vertical plane, it should still be noted as a ghost bat and the record entered into appropriate database(s) (see Section 2.7).
- the identity of any other noteworthy fauna species.

2.7. Reporting

Upon completion of the survey, a report should be written. As a standard, this should include the following information:

1. The qualifications, suitability and level of experience of the surveyors involved;
2. The permit, approval and/or authorisation under which the survey was conducted;
3. If the acoustic lure track created by N. Hanrahan is used, the registration number for that particular survey that was provided when the acoustic lure track was supplied;
4. An explanation of the basis by which the survey area was delineated and a map thereof, showing potential habitat and existing ghost bat records;
5. The timing of the survey and the reasoning for it;
6. The brands of the equipment (video camera, infra-red lamp, speaker and, if used, tablet) used and settings thereof, including the average volume (in decibels) at which the acoustic lure was played and the maximum power of the infra-red lamp;
7. Survey effort and adequacy, including number of acoustic lure sites, number of replicates at each acoustic lure site, duration of acoustic lure for each replicate, whether all surveys commenced 30 minutes after sunset, and an assessment of the appropriateness of the survey effort (e.g. though analyses of detection probability for the survey area). See example below;
8. What proportion of the habitat potentially suitable for/used by ghost bats was surveyed and the total survey area (e.g. counted using the area of hexagons, if these are used). See example below;
9. The results of the survey, including:
    a. species presence or absence at each survey site;
    b. any assessment of 'hotspots' of activity (if applicable);
    c. a map showing the location of detected ghost bats;
    d. if ghost bats were detected, information on date of detection, location (using WGS84, GDA94 or GDA2020 as the datum), observer and, if applicable, number of passes. Such data should be submitted to a relevant jurisdictional database e.g. *Fauna Atlas NT* and must be associated with the acoustic lure registration number that was provided with the acoustic lure track (if provided by N. Hanrahan);
    e. if ghost bats were detected, to confirm identification, still photographs or clips from the video footage as examples of what was being identified as a ghost bat. If ghost bats were detected at multiple survey sites, provide one still photograph or snippet of video footage from each survey site on each night;
    f. if applicable, delineate areas of high activity / potential roost sites, such as through an assessment of relative activity, by conducting finer-scale acoustic lure surveys or searching geological formations for roost sites.
10. For development proposals, qualify the importance of the foraging and/or roosting habitat and the impact of the proposed action on the ghost bat. Assess the risk from the proposed development against Significant Impact Guidelines, to determine if a referral is required.

An example covering the seventh and eighth points above is as follows (noting that this example relates in part to the survey area delineated in Figure 6, which only shows the 'east side' survey sites):

"A total of 30 sites were surveyed for the ghost bat, consisting of 17 sites on the east side and 13 sites on the west side of the study area. For the east side, this equated to a survey area of 368.6 km^2 (maximums of ~30 km long, 26 km wide) and, for the west side, a survey area of 281.8 km^2 (maximums of ~40 km long, 14 km wide). A further 11 sites on the east side and three sites on the west side overlie Tindall Limestone but, due to access and/or timing constraints, were unable to be surveyed during the current study. Thus, only approximately 68% of potential ghost bat habitat in the study area was surveyed in the current work.

Replicate surveys were successfully undertaken at 16 of the 17 survey sites on the east side and 12 of the 13 survey sites on the west side (i.e. two survey sites only had a single survey). However, issues relating to access, equipment failure and/or operator error led to inconsistencies in survey effort. Specifically, on the east side, eight of the 33 experimental periods commenced later than the requisite 30 minutes after sunset; this ranged from being 4 minutes to 73 minutes late. Furthermore, four of the 33 experimental periods on the east side finished prior to the requisite 2 h survey duration; this ranged from the experimental time being only 48 minutes to 1 h 55 min long. On the west side, five of the 25 experimental periods commenced later than the requisite 30 minutes after sunset (range 6 minutes to 50 minutes late), while a further one of the experimental periods finished 30 minutes prior to the requisite 2 h survey duration (i.e. 1.5 h survey duration only). Overall, these inconsistencies in commencement in survey time and duration mean that the current results should be interpreted with caution due to an increased likelihood of false absences and/or underestimates of the number of passes at survey sites."

2.8. Further research

These guidelines are based on current research and will be improved by collective input from users, as well as by further research. Ruykys *et al.* (2023) details the areas for further research/future development of this survey method. These are summarised as follows:

- Further assessment of effectiveness around roosts with a population of <20 ghost bats
- Assessment of detection probabilities using the survey method in regions outside of Katherine, NT
- Development of tools that make reviewing video footage more efficient (while maintaining efficacy in species identification). This could be through applying motion analysis, machine learning or other artificial intelligence tools. However, a key lesson from preliminary assessment of the same is that automation may confuse juvenile ghost bats with other, smaller species. Furthermore, ghost bats that are further from the video camera are more difficult to differentiate from other bats, given the distortions produced by distance. Thus, some manual evaluation will likely always be required
- A more detailed assessment of any influence of moon illumination on the activity of ghost bats, as this then influences survey timing
- Whether there is any relationship between ghost bat activity and distance from roosts, particularly for isolated roosts
- Whether region-specific vocalisations produce a higher response by ghost bats.

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Appendix 1: Detailed fieldwork procedure

This appendix details, step-by-step, the procedure used in Ruykys *et al.* (2023). The equipment used in Ruykys *et al.* (2023) is included in Appendix 2. If using different brands of equipment, surveyors will need to make their own adaptations, ensuring that the minimum parameters and key aspects detailed in Appendix 2 remain consistent. A timeline outlining a daily schedule is provided in Figure 10.

Each afternoon: set up

1) Determine order of sites

- Assuming that there are multiple, determine the order in which the acoustic lure sites that are to be run that night should be set up. Equipment should be apportioned such that sites that are set earlier are allocated a 12 V DC lithium battery power bank (attached to the video camera) or else a long-range video camera battery. As a reference (noting that other brands may be used), the equipment used in Ruykys *et al.* (2023) allows the following approximate durations for recording footage:
    - Sony 'normal' battery (provided with video cameras) = ~ 3 h 30 min
    - Sony long-range video camera battery = ~ 6 h 30 min
    - 12 V battery = ~ 8-10 h, but video camera may automatically time out after an undetermined number of hours within this period

2) Find locations and choose a reference tree

- Navigate to the nominated location and assess its suitability. The immediate survey site should be vegetated and free of infrastructure such as fences. It should also be in a safe location (to minimise risk of theft of equipment). Beyond that, sites do not need to be in any particular condition, as any influence of fire/grazing etc. on ghost bat presence is currently unknown. However, information on the same should be included on the datasheet.

- After determining suitability, search for an exact location that has open vegetation, with a tall, sturdy tree to use as a reference tree. The reference tree marks the boundary of the survey site and allows for consistency across locations in determining the level of ghost bat activity. The reference tree should be a large tree that vertically fills the video camera's frame. The reference tree must have 15 m of relatively clear area in front of it. The following trees should not be selected as a reference tree: those that would blow around in moderate winds, those at substantial leans, or those that are visually 'crowded' by other vegetation (e.g. shrubs).

- Mark the chosen location on a GPS, even if it is at the originally-designated centroid. Nomenclature should be logical e.g. site number followed by the word SET. For example, Site01SET.

- If the survey is a replicate survey at the survey site, ensure that the equipment is set up exactly at the same location and using the same reference tree.

3) Clear the area

- Clear an area measuring 15 m by approximately 4 m in front of the reference tree by flattening any grass/seedlings present. Use a rake hoe or other tool to do so.

4) Place the speaker

- Using the measuring tape, measure 10 m from the reference tree – this is where the fence dropper and speaker will be placed.

- Using the mallet, place the fence dropper part-way into the ground, ensuring approximately 1 m of fence dropper remains above the ground. Ensure that the side of the dropper that has the reflective tape on it is facing towards the video camera.

- Attach the speaker to the fence dropper by threading the carabineer through the hole at the top of the dropper.

- Once set to run (see below), and if one is being used, place the tablet inside the waterproof plastic tub and place the tub at the base of, or close to, the fence dropper, ensuring that the tablet is in the shade. Do not clip the lid onto the tub unless rain is expected; it is better to have airflow so that the tablet does not overheat.

4) Place the video camera

- Measure a further 5 m in the same direction – place the video camera here.

- Set up the tripod so that the video camera will sit approximately 1 m high.

- Attach the infra-red lamp followed by the video camera to the tripod using a bolt. The infra-red lamp should be located directly underneath, and in line with, the video camera's lens. The maximum power of the infra-red lamp used in Ruykys *et al.* (2023) was 18 W; however, the maximum power/ illumination of the survey area that should not be exceeded is currently unknown. As such, animal welfare should be considered if surveyors use an infra-red lamp with a higher power than 18 W.

- For protection from the elements, particularly rain, it is recommended that the video camera be placed into a 'structure' such as an upside-down rectangular ice-cream container that has a hole cut into one side. In this case, the lid of the ice-cream container should be placed directly on top of the bracket holding the lamp, and under the video camera.

- The video camera needs to face the reference tree, with the fence dropper vertical and central in the field of view. It is useful to draw a white line on the casing that is around the video camera's screen, at the exact half-way mark of the video screen. Then vertically align the white line with the reflective tape on the fence dropper and with the reference tree. The reflective tape should be just visible at the base of the video camera's field of view. If it is difficult to see this because of sunlight, use a head torch i.e. one person illuminates the reflective tape using the head torch and the second person aligns the video camera.

- Attach the power cable from the infra-red lamp to the 12 V battery and place the battery upright on the ground. Ensure that the infra-red lamp is on. The light is difficult to see in daylight, so cup hands around the lamp and see if there is a slight red glow outside each of the lamp bulbs. Also check that the light sensor on the infra-red lamp is fully covered.

5) Set up the video camera

- Make sure that the SD card is inserted

- If an external portable battery is being used to power the video camera, attach this by threading the cord from the portable battery through a hole in the ice-cream lid. Turn on the portable battery by pressing the power button.

- Open the video camera viewer; the video camera will turn on (can take longer than anticipated). Check the number of hours of the video camera battery; for the Sony FDR-AX33 Handycam 4K video camera, this flashes up briefly in the top right-hand corner of the screen when you first turn

on the video camera. Ensure that the number of hours displayed will allow the video camera to record through to the end of the experimental period (current time + 30 minutes after sunset + 2 hours experimental time).

- Turn on the night mode by pressing the button under the camera viewer.
- Turn on the manual focus by pressing the button to the side of the lens.
- Focus the video camera on the fence dropper and speaker by manually turning the focus ring. If a Sony FDR-AX33 Handycam 4K video camera is used, the manual focal distance should be 0.3, though 0.2 is also acceptable. Other distances are not to be used for this video camera, as they are blurry in the final recording (even if they do not look blurry when setting up). If a different video camera is used, an appropriate manual focus distance must be tested prior to fieldwork, and instated during fieldwork. Automatic focus should not be used on any video camera, as the continual refocussing on individual movements (e.g. of insects) prevents the entire field of view from being continuously monitored for ghost bats.
- Pull out the eyepiece
- Close the camera viewer on the side
- Press the record button. Check that 'REC' is visible on the screen and that the red light is on at the front of the video camera. If that is the case, the video camera is recording. It should be noted that the Sony FDR-AX33 Handycam 4K video camera cannot be pre-set to turn on at a certain time and with the correct settings (night mode and manual focus at 0.3). Consequently, at least if this type of video camera is being used, recording must commence at the time of surveyors' departure.
- Say the following information clearly and loudly: location, date, time, and which replicate it is for that acoustic lure site. Verbalising the time allows cross-checking when reviewing the video footage, to ensure the survey time commenced when expected.
- Place the ice-cream container (or similar) over the video camera, ensuring the camera lens is not obscured.

6) Set up the acoustic lure broadcast

- If one is being used, link the tablet to the speaker using Bluetooth© and turn the volume on both the tablet and speaker to maximum. Once the speaker volume is at maximum, a beep will sound.
- Construct a playlist for that survey site, noting that the default for the Ultimate Ears Boom 3 speaker used in Ruykys *et al.* (2023) – and likely other – speakers is to switch off after 15 min of not playing sound. As such, an audio file that does not disturb the natural soundscape of the survey site is needed to prevent the speaker from switching off before the commencement of the survey. An audio file (.wav) that consists of a recording from ghost bat roosts across the NT (but that is devoid of ghost bat vocalisations) is used to keep the speaker on ('background roost' playlist) (Hanrahan 2020). Another soundtrack may be used, as long as it does not disturb the natural soundscape of the survey site. The acoustic lure broadcast should not be used prior to the survey time (i.e. 30 minutes after sunset). The duration of the 'background roost' playlist depends on the time of day that the equipment is set up at that site (see example of timing below).

- To construct a playlist, open VLC media player (or suitable alternative) and navigate to the folder that contains the audio files. Next to each file, click the three dots and press 'Add to playlist' in the following order:
    1. A 'beep' file so that it is clear to the surveyor that the playlist has commenced and to standardise testing the volume of the broadcast.
    2. The number of ghost bat 'background roost' recording files that are required to keep the speaker on, such that broadcasting the acoustic lure commences at 30 minutes after sunset (see example below).
    3. The repeating track of 2 min of the 'squabble' acoustic lure followed by 2 min of silence that is run for the 120-minute survey period. If recordings are those provided by N. Hanrahan, the acoustic lure track may be received as multiple files. If so, it should be ensured that files are added in numeric order.

- Once the time is appropriate for the duration of that particular playlist, highlight the 'beep' track and press 'Play'. You may need to wait for a few minutes before pressing 'Play'. For example, if you arrive at 4:45 pm and sunset is at 7 pm, the experimental time starts at 7:30 pm (i.e. 30 min. after sunset). You may build your playlist to commence at 5 pm (i.e. 2.5 h of 'roost background' files plus 2 h of acoustic lure track) but you may finish creating the playlist at 4:55 pm. WAIT until 5 pm before pressing 'Play' on the playlist so that the experimental time starts exactly at 7:30 pm. You should hear the 'beep' – this indicates that the playlist has commenced. Using a sound level meter, note the volume at which the 'beep' sounds and record this on the datasheet.

- Place the tablet in the waterproof plastic tub at the base of, or near, the fence dropper, ensuring that the tablet is in the shade. A failure to do this may lead to the tablet overheating and the site failing.

7) Complete the datasheet

- Fill in the datasheet whilst progressing through the steps above and now ensure that it is complete

- Take the following two photographs and record their identifications on the datasheet:
    - One demonstrating the topography and vegetation at the acoustic lure site; ideally, this should be from close to the video camera
    - One of the set-up of the video camera itself

Retrieval either after the survey period or the following morning

- Retrieve equipment from all acoustic lure survey sites

- Transfer the video imagery from the SD cards to an external hard drive, then format the SD cards. Note that, if using a Sony FDR-AX33 Handycam 4K video camera, each video file is approximately 51 minutes in duration, so there will be multiple files from one night of recording at one acoustic lure site. To avoid confusion, a logical filing structure should be established and followed.

- Charge the external battery packs, video cameras, speakers and tablets. Note that the equipment detailed for use in the equipment list (Appendix 2) can take up to ~5 h to fully charge, so this should be accounted for when planning for the survey.

Appendix 2: Equipment list

The following equipment is required to undertake the landscape-scale survey at one acoustic lure site only, if replicating the approach used by the authors (Ruykys *et al*. 2023). However, it is likely that surveyors would need to survey multiple acoustic lure sites per night. The replicates of equipment required will thus depend on how many sites are to be surveyed simultaneously per night. Items that would need to be multiplied by that number are indicated with a *.

Surveyors may vary the equipment used but should ensure that minimum parameters remain consistent, including the use of a video camera with infra-red recording capacity, that the acoustic lure site is illuminated, and that a speaker that emits sound in 360° is used.

- Sony FDR-AX33 Handycam 4K video camera or an equivalent video camera that has infra-red recording capacity (i.e. night mode feature)*
- 'normal' battery for video camera
- video camera battery charging cables (provided with video camera)*
- long-range battery for the video camera (e.g. Sony 'extended life' battery)
- infra-red lamp (TECHview Long Range Infrared Spotlight, model QC-3654 with 18 W maximum power or an equivalent infra-red lamp)*
- infra-red lamp bracket*
- 12 V battery with appropriate leads to connect to, and power, the infra-red lamp*
- bolt for connecting video camera to infra-red bracket, plus spares*
- tripod onto which to attach the video camera*
- video camera protective enclosure (e.g. rectangular ice-cream container)*
- 12 V DC lithium battery power bank with an AC inverter (e.g. Powertech model MB-3748)*
- Ultimate Ears Boom 3 speaker or equivalent speaker that emits sound in 360° (note that many speakers are circular but only emit sound on 1-2 faces, rather than in 360°) and, if being used, has Bluetooth© connection*
- galvanised steel fence dropper ('fence dropper'), with large hole at the top and a horizontal strip of reflective tape at 68 cm from its top (this provides a reference point in the video imagery; the length from the top of the fence dropper is a ghost bat's wing length)*
- carabineers for attaching the speaker to the fence dropper*
- mallet
- tablet with Bluetooth© connection and with the required audio files of ghost bat calls (both 'background roost' and 'squabble' calls) pre-loaded into a media player (VLC media player is recommended)*
- protective snap-lock plastic containers or similar for protecting the tablet, and possibly silicone for absorbing any relictual moisture (only necessary in the build-up and wet seasons)*
- 128 GB SD card (1 for each video camera) plus spares, if available*
- 20 m measuring tape
- Sound level meter
- External hard drive (at least 1 TB)
- Secure digital (SD) card reader
- Laptop
- Head torch
- Other relevant equipment e.g. if camping, a generator so as to re-charge equipment each day

Appendix 3: Example datasheet

Text in red is considered essential to record.

GHOST BAT SURVEY DATASHEET

Date: _____

Deployers: _____

Fieldtrip no.: 1 2 3 4

Night no. (within trip): 1 2 3 4

Site ID: _____

Property name: _____

Location-related

Location: Latitude: _____ Longitude: _____

GPS used: Person 1 Person 2

GPS waypoint ID: _____

Habitat description: _____

Recent fire? Burnt Unburnt Comment: _____

Grazing pressure: Low Medium High

Camera for habitat photo: _____

Photo #: _____

Video camera (VC) set-up:

VC deployed: #1 #2 #3 #4

SD card deployed: _____

Camera for set-up photo: _____

Photo #: _____

Time set: _____

Time collected: _____

Status at collection: _____

Weather at deployment: _____

Weather in last 24 h: _____

Comments, including sound level meter volume (in dB): _____

Appendix 4: Trouble-shooting

Note: Some points are only relevant if the surveyor is following the approach of, and using the same equipment as the authors.

Issue	*Comment / solution*
Infrared lamp not turning on	Light can be difficult to see in daylight. Cup hands around the lamp and see if there is a slight red glow. Ensure power cable is correctly attached to the 12 V battery – red to red and black to black. Check that the light sensor on the infrared lamp is covered fully.
The video camera re-sets its settings, especially if it becomes wet.	Re-set all the obvious settings appropriately (location, date, time etc.). Ensure that the video file format is set to AVCHD.
Video camera won't go into manual focus when in night mode	Daylight too bright. Set manual mode first and then choose night mode.
Video camera records in 4K file format, which flattens the battery and decreases the SD card's duration.	Ensure that the camera is recording in the lowest-resolution setting. Also, it should be in AVCHD.
Track not returning to start point	On some tablets, if you have previously played any of the tracks part way through, the tablet will automatically return to that point once the track ends. This can be fixed by pressing on each track in the playlist and moving the point to the end of the track and allowing it to move into the next track. Continue this until all tracks are back at the start. Alternatively, on some tablets, you can clear all open windows and re-launch VLC.
SD card error – data doesn't write onto SD card	Ensure that the SD card isn't locked. To do that, ensure that the little tab on the top left-hand side of the SD card is in the 'unlocked' position (i.e. *not* next to the lock symbol).
SD card error – upon retrieval, video camera says that there was an SD card error and asks if you want to retrieve data	At this stage, close the screen and take the video camera back to base. There, remove the SD card and see if data are on it. If not, then re-insert SD card into video camera and see if you can retrieve the imagery at that point.
Video camera says that its settings need to be configured and asks for the location, date and time.	Work through the questions, ensuring that you select your location in the global map, and then that you insert the correct date and time. The video camera should be fine after its settings are re-configured.