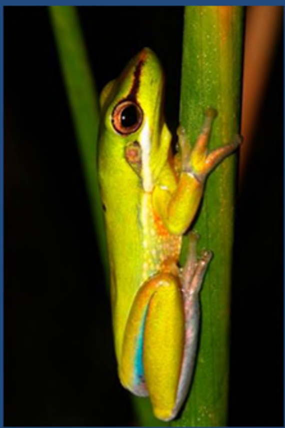
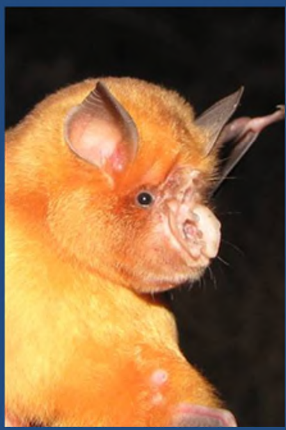
Terrestrial Vertebrate Fauna Survey Guidelines for Queensland

June 2022 (V 4.0)





Queensland Government

Prepared by: Queensland Herbarium and Biodiversity Science, Department of Environment and Science.

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June 2022 Version 4.0

Table of Contents

Table of Contents 3

List of Figures 5

List of Tables 6

List of Appendices 6

Version Control 7

1. Introduction 9
   - 1.1. Purpose of this Document 9
   - 1.2. Legislative and Policy Framework for Fauna Surveys 9

2. The Survey: Getting Started 10
   - 2.1. Define the Objectives of the Survey 10
   - 2.2. Skill and Experience Level Required 10

3. Fauna Survey Stages 10
   - 3.1. Stage 1 – The Scoping Document 10
   - 3.2. Stage 2 – The Field Survey 13

4. Sampling: The Assessment Unit and Site Selection 14
   - 4.1. Defining the Survey Area 14
   - 4.2. Delineation of Assessment Units within the Survey Area 15
   - 4.3. Replication and Location of Survey Sites 18
   - 4.4. Sampling Adequacy and Power 19
   - 4.5. Setting up a Generic Fauna Survey Site 23
   - 4.6. When to Conduct Surveys 24

5. Factors Affecting Fauna Survey Results 27
   - 5.1. Imperfect Detection 27
   - 5.2. Sources of Variation during Surveys 28

6. Data Management 29
   - 6.1. Essential Data Requirements 30
   - 6.2. Datasheets and Electronic Data Collection Tools 31
   - 6.3. Taxonomy and Nomenclature 32
   - 6.4. Data Storage 32
   - 6.5. Data verification 33

7. Biosecurity Risk 33
7.1. Observer Health 34
7.2. Animal Health 35
7.3. Taking Voucher Specimens 36
8. Generic Survey Methods for a Site 37
8.1. Pitfall Trapping 39
8.2. Funnel Trapping 41
8.3. Active Diurnal and Passive Nocturnal Searches 42
8.4. Small Mammal Trapping 44
8.5. Cage Trapping 45
8.6. Diurnal Bird Survey 46
8.7. Camera Traps 47
8.8. Acoustic Recording 49
8.9. Call Playback 51
8.10. Spotlight Search 52
8.11. Microbat Echolocation Call Detection 54
8.12. Scat and Sign Search 57
8.13. Incidental Records 61
9. Targeted Survey Methods 62
9.1. Amphibian Searches 62
9.2. Freshwater Turtles 63
9.3. Elliott Trapping 65
9.4. Funnel Trapping 65
9.5. Sand Plots and Track Plots 66
9.6. Wetland Birds (Waterbirds) 67
9.7. Targeted, Active Microbat Echolocation Call Detection 69
9.8. Roost Searches for Microbats 69
9.9. Roost Searches for Flying Foxes 70
9.10. Harp Trapping for Microbats 72
9.11. Mist Netting for Microbats 74
9.12. Trip Lining for Microbats 75
9.13. Camera Trapping 75
9.14. Automated Acoustic Recording 77
9.15. Nocturnal Vehicle Transects 79

9.16. Hair Tubes 80
9.17. Predator Scat Collection 81
9.18. Call Playback 81
9.19. Artificial Nesting/Roosting Boxes 82
9.20. Thermal Imaging 83
9.21. Wildlife Detection Dogs 85
9.22. eDNA Sampling 87

10. Habitat and Condition Assessment 88

11. The Final Report 90
11.1. Executive summary 90
11.2. Introduction 90
11.3. Methods 90
11.4. Results 91
11.5. Discussion and Recommendations 91
11.6. References 91

12. Glossary 92

13. References 96

14. Appendices 105

List of Figures

Figure 1: Delineation of assessment units for an area. 17

Figure 2: Generic vertebrate fauna and habitat survey site layout. 23

Figure 3: Generic vertebrate fauna and habitat survey site layout for narrow linear assessment units. 24

Figure 4: Pitfall and funnel trap array. 40

Figure 5: Pit and funnel trap set up. Note the use of shades over the funnel traps. 41

Figure 6: Elliott traps set for small mammals. Note the trap placement in a shaded position (left), or with a cover of leaf litter for insulation in a more exposed position (right). 45

Figure 7: Latrine site of the yakka skink. 58

Figure 8: Feed-marks made by yellow-bellied gliders in Queensland for sap feeding; a) active feed marks in spotted gum *Corymbia citriodora*; b) recently active feed marks in *C. citriodora*; and inactive feed marks in c) *C. citriodora*; d) grey gum *Eucalyptus longirostrata*; and e) scribbly gum *E. racemosa* (Eyre and Goldingay 2005). 59

Figure 9: Koala in hold position on *Corymbia citriodora* showing (a) opposable digits on the front paw and (b) koala scratch marks on *Eucalyptus major*. 61

Figure 10: Wildlife detection dog working on black-tailed dusky antechinus (*Antechinus arktos)* surveys in Border Ranges NP. Photo by Canines for Wildlife. 86

Figure 11: Plot layout for a BioCondition site assessment. 89

List of Tables

Table 1: Definition of broad condition states for delineating assessment units. 16

Table 2: General guide to the optimal times of year and conditions for vertebrate fauna surveys.. 25

Table 3: Essential data to be recorded for each site and/or sighting during the field survey. 30

Table 4: Summary of recommended terrestrial fauna survey methods to use as a minimum at generic survey sites during each survey period. 37

Table 5: Recommended species calls to play within each bioregion and habitat type. 52

Table 6: Tree species utilised for sap feeding by yellow-bellied gliders in Queensland. 60

List of Appendices

Appendix A: Useful Sources of Information and Data... 105

Appendix B: Equipment.. 108

Appendix C: BioCondition Assessment Guide... 114

Version Control

This version (Version 4.0) of the Terrestrial Vertebrate Fauna Survey Guidelines for Queensland includes updated changes as follows:

1. Handling Animals (Chapter 7) is renamed Biosecurity Risk and has been updated. Observer Health (Section 7.1) has been updated and Minimising Animal Stress (Section 7.2) renamed Animal Health and updated. Guidelines and links on Animal Ethics (Section 7.3) have been updated, and Appendix B (Collection of Voucher Specimens) removed.

2. A new section on Acoustic Recording (Section 8.8) has been added to Generic Fauna Survey Methods for a Site (Chapter 8).

3. Guidelines on Automated Acoustic Recording (Section 9.14), Camera Trapping (sections 8.7 and 9.13), Spotlight Search (Section 8.10) and Microbat Echolocation Call Detection (sections 8.11 and 9.7) have had minor updates.

4. Thermal Imaging for Nocturnal Fauna (Section 9.20) in Targeted Survey Methods (Chapter 9) has had a substantial update and renamed Thermal Imaging.

5. A new section on Wildlife Detection Dogs (Section 9.21) has been added to Targeted Survey Methods (Chapter 9).

6. A new section on eDNA Sampling (Section 9.22) has been added to Targeted Survey Methods (Chapter 9).

7. General update of links and relevancy.

The previous version (Version 3.0) included minor changes to:

1. Trapping procedures (i.e. Pitfall, Funnel, Elliot, Cage and Harp trapping) and related ethical considerations following further advice from the Queensland Department of Agriculture and Fisheries Animal Ethics Committee. The first check of Pitfall, Funnel, Elliot and Cage traps should be conducted within 2 hours of sunrise; if death occurs and is considered likely to continue then trapping is to cease until appropriate amelioration methods are in place or adverse conditions subside. It is now strongly advised and preferable that all bats be released from harp traps before dawn. For further details please see the appropriate sections.

2. Departmental information and document template changed in line with new Department of Environment and Science publishing protocols.

3. Updated website links throughout the document.

An earlier version (Version 2.0) included some minor differences from Version 1.1, including:

1. Minor updates to Section 3.1.4 on Permit requirements.

2. Updated Section 7 and throughout the document regarding animal ethics considerations and recommendations.
3. Changed and updated method recommendations for Sections 8.7 and 9.13 on Camera Trapping.
4. Changed and updated method recommendations for Section 9.6 on Wetland Birds
5. Updated survey method recommendations for Section 9.9 on Flying Fox counts
6. Updated website links throughout the document.

1. Introduction

1.1. Purpose of this Document

This document outlines the Department of Environment and Science (DES) minimum requirements, standards, and appropriate practice for the survey of terrestrial vertebrate fauna in Queensland. The guidelines aim to provide a practical guide for the preparation, implementation and reporting of terrestrial fauna surveys and facilitate consistency and comparability of fauna data obtained during the surveys across time and space.

In Queensland, reports on species diversity, abundance and in some cases the ecological processes likely to be modified by proposed impacts, may be required as part of Queensland government policy, regulation and legislation. These guidelines have been prepared for use by anyone in Queensland wishing to undertake systematic and standardised terrestrial vertebrate fauna surveys for inventory, monitoring and/or research purposes.

The survey approach and standards outlined in this document are intended to provide systematic data on terrestrial vertebrate species relative abundance and composition patterns, in addition to presence-absence and presence-only data. The guidelines are therefore reasonably prescriptive and technically detailed, to support adequate sampling and reporting on terrestrial vertebrate fauna as required for compliance (Thompson and Thompson 2020). Therefore, these methods can be used to obtain either a) repeat sample data, if monitoring change is a key objective of the survey, and/or b) comprehensive, standardised inventory data of vertebrate species, including species of conservation interest, if that is the key objective of the survey. While it is acknowledged that invertebrate biodiversity is also important in biodiversity assessments, invertebrate survey methods are outside the scope of this document.

1.2. Legislative and Policy Framework for Fauna Surveys

In Queensland, all native terrestrial vertebrate animals and their breeding places are protected under the *Queensland Nature Conservation Act 1992*. The Act mandates gathering information and identifying critical habitats so as to effectively manage and protect Queensland native fauna and flora. The Department of Environment and Science (DES) is responsible for administering the Act. Consequently, any activity that results in an impact or interference upon native animals falls within the objects of the Act. There are a number of guidelines and information sheets that pertain to the Act, which can be accessed via Wildlife Online on the Queensland Government website.

There are specific Commonwealth and State legislation and associated policy documents that are particularly relevant to fauna assessment and surveys, that provide guidance and direction regarding why systematic fauna assessments and surveys should be undertaken in Queensland. In general a fauna survey is required:

- If a proposed action is likely to have a significant impact on matters of national environmental significance, such as species and ecological communities listed under Sections 18 and 18A of the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*.
- To allow the Department of Environment and Science (DES) to evaluate Environmental Impact Statements (EIS) pursuant to Chapter 3 of the *Queensland Environmental Protection Act 1994*, where the Act requires that an EIS report has adequately addressed the Terms of Reference (TOR) for mining, petroleum and gas projects and their associated activities. Under the TOR there is a requirement to describe the existing ecological values that may be affected by a project, including biological diversity, existing integrity of ecological processes, habitats of threatened or near threatened species. Fauna surveys may be required to satisfy these TOR.

However, the conduct of fauna surveys need not always be triggered by legislation or policy. Many Natural Resource Management groups, local government and universities are interested in standardised fauna surveys for assessment, monitoring or research for planning, management, offsets and environmental accounting purposes.

2. The Survey: Getting Started

2.1. Define the Objectives of the Survey

For any inventory or monitoring program, a critical first step is the clear articulation of a set of objectives. The objectives of the survey should clarify up front the purpose of the survey. The purpose will determine the design of the survey and drive appropriate site selection. If the purpose is to detect change, the site selection for a survey needs to use a clear stratified approach based on major habitat types, including the identification and use of control sites within major habitat types, sufficient replicates within strata, and measures of fauna diversity and species relative abundance. This is necessary to make meaningful comparisons between the habitat types within the study area, as well as with data from similar habitat types outside of the study area.

2.2. Skill and Experience Level Required

The survey approach and methods outlined in this document requires people with high-level skills and experience in scientific literature review, new and existing data synthesis, Regional Ecosystem (RE) identification, survey site selection, fauna survey techniques (including installing, setting and checking of traps), species identification, animal handling, habitat assessment and report writing. The senior investigator should be an ecological scientist with appropriate qualifications and demonstrated experience in fauna survey and assessment. Skills and expertise in the survey and identification of particular taxa (e.g., bats, herpetofauna, and birds) may be spread across the survey team members. It may be necessary for consultants to liaise with others due to variable expertise and local knowledge. Details of qualifications and experience of survey personnel should be provided in the final assessment report (Chapter 11: The Final Report).

3. Fauna Survey Stages

3.1. Stage 1 – The Scoping Document

Prior to undertaking any survey, conduct a desktop review of available published and unpublished literature, and information from relevant databases to provide a description of what is known about the terrestrial fauna in the area of interest. This may also include an assessment of known threats and identification of potential threats that may be relevant in the area of interest following development or management change. Mitigation strategies may then also be initiated. A reconnaissance visit is also advisable, mainly to assist with generic and targeted site selection (see Section 3.2 and Chapter 4) and general familiarisation with the survey area. There are broadly four components to Stage 1; collation of existing data; review of published and unpublished literature; field reconnaissance; and reporting.

3.1.1. Collation of Existing Data

Species information, including collation of existing records - if any - for the survey area, can be obtained from the following databases (details are provided in Appendix A):

- Field guides
- Wildlife Online (WildNet) and Wetland Information Capture System (WIC)
- Queensland Museum
- Nature Conservation Act 1992
- Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)
- Essential Habitat Mapping
- The Atlas of Living Australia (ALA)
- Local expert advice
- Targeted threatened species survey guidelines
- Regional ecosystems mapping and REDD

3.1.2. Literature Review of Species and Management Impacts upon Fauna

A literature review of the ecological requirements and conservation status of faunal taxa that occur or may occur in the area of interest will provide evidence of an understanding of their ecological needs, and potential impacts of proposed development. The review will also ensure that the design of the assessment and survey is based on most recent and relevant information, particularly regarding habitat requirements, threatening processes and behavioural aspects that may influence detection during surveys.

There will be cases where there is insufficient literature or knowledge regarding individual species, or species groups, and their response to management impacts. In these cases, it is worth introducing the concept of the precautionary principle and its potential application during an assessment (Thompson and Thompson 2010). One way of exercising the precautionary principle during the literature review is to broaden the scope by reporting on relevant information from similar ecosystems and/or species.

3.1.3. Reconnaissance Visit

A reconnaissance visit to the area of interest is recommended for several reasons, including:

- Verification of desktop collated data, particularly the regional ecosystem mapping, location of wetlands, waterpoints, roads, fences etc.
- Check accessibility such as road condition, and any potential hazards for field workers in the area.
- Opportunity to look for specific habitat such as restricted or endangered ecosystems and best-on-offer reference sites (Table 1) or evidence of species of conservation concern.
- Opportunity to gain information from the locals on management, fauna sightings, access issues, sensitive or indigenous sacred areas, property rights.

3.1.4. Obtaining Permits and Ethics Approval

All of Queensland's native plants, mammals, birds, reptiles, amphibians, some fish and invertebrates, and wildlife and natural resources found within protected areas, are protected by the *Nature Conservation Act 1992* and its Regulations. Various Research Permits may be required, depending on where the surveys are to be conducted. A 'Permit to take, use, keep or interfere with cultural or natural resources' is required when working within protected areas. In non-protected areas, A 'Protected animal scientific or educational purposes permit' (Scientific Purposes Permit) will be required. For activities on tenure listed under the *Forestry Act 1959*, such as state forests, forest reserves and timber reserves, both a Scientific Purposes Permit and a Permit to Collect may be required for some activities. Note that, depending on the tenure where the survey is to be undertaken, more than one permit may be required. If working in areas covered under the *Marine Parks Act 2004* (i.e. area of water or land subject to tidal influence), then permits may be required from the Department of National Parks, Recreation, Sport and Racing. See the Queensland Government website for information on the permit application process. Before applying, discuss the project with the permit processing officer for the relevant region.

If working in Aboriginal lands on non-protected areas, or local government reserves, specific permits may be required for access and ecological assessment purposes. Note that permit applications undergo a native title assessment as required under the *Native Title (Queensland) Act 1993*, to determine if they need to be referred to native title parties for comment.

Animal ethics approval is needed for research, survey and/or monitoring involving vertebrates under the *Animal Care and Protection Act 2001* where activities such as trapping, census leading to disturbance of animals (such as spotlighting or call play-back), abnormal interruption of behaviour or marking/tagging are involved. If it has been identified that a fauna survey is needed, then ethics approval will be required. A list of activities that require approval from an Animal Ethics Committee (AEC) can be found on the Queensland Government website.

The *Animal Care and Protection Act 2001* requires applicants to comply with the Australian Code for the care and use of animals for scientific purposes (8th Edition 2013), prepared by the National Health and Medical Research Council and located the Australian Government website. An approved permit from a registered AEC indicates that a decision has been made on the basis that the use of animals is justified and that welfare of animals has been considered. An AEC uses three central guiding principles to assess applications.

- The replacement of animals with other methods.
- The reduction in the numbers of animals used.
- The refinement of techniques used to reduce the adverse impact on animals.

In these guidelines, we provide recommendations specific to each survey method with the aim of minimising disturbance and maintaining animal welfare during field surveys.

Applicants for a Scientific Purposes Permit who wish to band birds or bats will need to obtain an Australian Bird and Bat Banding Scheme Banding Authority from the Australian Government.

3.1.5. The Scoping Document

Information gathered during Stage 1 of the survey will provide the background and descriptive information required for Stage 2 of the survey. A report outlining the outcomes of Stage 1 will effectively form an important component of the final report. As a minimum, the Stage 1 report should provide the following information:

- Purpose, background, and scope of the project.

- Desired outcomes and related objectives of the project.
- Ecological description of the area of interest (the survey area), including information on;
  - Location.
  - General physical properties such as climate, topography, soils, regional ecosystems.
  - Current and historic tenure, land use and management.
- Description of the ecological value of the area of interest at the local, regional, and national scales.
- Extent and diversity of regional ecosystems and broad condition state (i.e. remnant, regrowth or non-remnant; see Section 4.2).
- Summary of the extent and source of terrestrial fauna data for the area of interest.
- List of fauna species and their conservation status that have been detected in the area or evidence to suggest species likely to occur in the area.
- Summary of adequacy of surveys in the area of interest including the identification of data gaps (spatial, temporal and/or taxonomic).
- Overview of what is required to adequately meet the objectives of the project. If the collated information will adequately address the objectives of the project and no further surveys are warranted, then this needs to be justified. If further survey effort is identified (i.e. Stage 2), then outline the proposed methods and approach. Provide a clear indication of the taxonomic groups and/or species of conservation concern that will be the focus of the surveys.
- Review of the conservation status and management requirements of fauna taxonomic groups and/or species, as relevant to the scope and objectives of the project (i.e. fire impacts, general disturbance impacts, impacts of proposed development etc).
- Evidence of permit and ethics approval, if surveys are required.
- Description of the constraints and limitations on the Stage 1 assessment, including a summary of potential limitations if Stage 2 field surveys are required.

3.2. Stage 2 – The Field Survey

The first stage of the assessment will have identified the list of species that may occur in the area of interest - including significant species (e.g., based on the Terms of Reference if for an EIS) - and the gaps in data or information required to meet the objectives of the assessment. The purpose of the field survey is to systematically survey the area of interest using standardised methods that will address the identified gaps.

The majority of this document provides prescriptive, technical guidelines on the field survey component of vertebrate fauna assessment, such as: site selection and site set up (Chapter 4); factors that can affect fauna surveys (Chapter 5) which must be given due consideration before (i.e. survey design), during, and after the survey (analysis of the collected data and reporting). Advice on survey data management and storage is provided in Chapter 6; and Chapter 7 outlines issues associated with the biosecurity risks associated with fauna surveys, including observer health, animal health, handling of fauna and animal ethics. The guidelines also provide details on two types of fauna survey approach. They are generic fauna survey methods (Chapter 8), and targeted fauna survey methods (Chapter 9), and can be used singularly or together in an area, depending upon the objectives and requirements of the project. Habitat and condition assessment approaches that may be used in association with the fauna survey sites are provided in Chapter 10.

The generic fauna survey methods (Chapter 8) involve a suite of methods that if used collectively, aim to provide a near-complete list of terrestrial vertebrate fauna species. Generic methods are provided for the following taxonomic groups: amphibians, reptiles, diurnal birds, nocturnal birds, small terrestrial mammals, medium-large terrestrial mammals, and arboreal and volant mammals including microbats.

The targeted fauna survey methods (Chapter 9) focus on specific significant species that are unlikely to be detected effectively during the generic surveys due to cryptic behaviour or localised habitat requirements (e.g., cave-roosting bat species). Targeted surveys for species are based on the ecology, habitat requirements and behavioural aspects of the species of interest. Survey guidelines are currently being developed by DES and will be posted on the Queensland Government website as they become available. Targeted surveys also refer to those habitats that are often restricted in the landscape, and therefore unlikely to be incorporated in the general stratification of the area of interest but are important for biodiversity e.g.,, wetlands, rocky outcrops, springs.

In general terms, a fauna survey for inventory purposes will use both generic and targeted survey methods. Incidental sightings of species or signs of species can be recorded during any time of the generic and or targeted survey. These records will not provide information that can be analysed in relation to the design of the survey but can contribute to the overall list of species for the survey area.

4. Sampling: The Assessment Unit and Site Selection

4.1. Defining the Survey Area

The survey area is the area within which all survey effort (assessment units, generic survey sites and target survey sites) is focused. The extent of the area to be assessed will depend on the objective of the assessment e.g., whether it is to assess the impact of a development or to assess the management impacts on faunal values of a specific parcel of land tenure such as a national park or grazing property. The general physical properties of the survey area e.g., climate, geology, soils and vegetation should be described in the final report, as should information on its past and present land use and tenure.

Sampling species diversity and populations over large survey areas is problematic because logistically, it may not be feasible to survey a large area entirely. However, there is a requirement to draw inferences on faunal populations in the survey area, and this needs to be based on an adequate sample. Consequently, a robust stratification of the survey area, based on the objectives of the assessment, and adequate replication of sample sites representing the various stratified units, is an important step in the initial stages of survey design.

4.2. Delineation of Assessment Units within the Survey Area

A key step in fauna survey design and the appropriate selection of generic survey sites is the stratification of the survey area. Stratification involves the partitioning of an area into assessment units (or strata) that are relatively homogenous environmentally, which are then used to determine the location and number of sites that are needed to adequately assess the survey area. The environmental information upon which an assessment unit is delineated will depend on the objective of the survey, but fauna habitat or vegetation type and broad condition are key data layers as these are dominant drivers of fauna assemblages. Stratified sampling provides an objective and cost-effective approach to fauna survey design, and ensures that variation in the environment, which may affect species, is adequately sampled.

The description and mapping of Regional Ecosystems (REs) in Queensland (Sattler and Williams 1999) provides an excellent basis for the stratification of the survey area and the construction of terrestrial fauna survey assessment units. In some cases, it will be reasonable to use the Broad Vegetation Groups (BVGs) (i.e. similar floristic composition and/or same land zone (Queensland Herbarium 2012). An RE that only has a limited distribution in the survey area may be problematic to use in the stratification but may be sampled for fauna using the targeted survey approach.

The broad condition state can be an important qualifier in the stratification of the survey area and delineation of assessment units, as different suites of species are often associated with particular condition states (Kutt and Woinarski 2007; Eyre et al. 2009). Definitions of broad condition states that can be used in the stratification to delineate assessment units are provided in Table 1. Except for the Best-on-offer (BOO), the broad condition states listed in Table 1 are digitally available as mapping for use in a Geographical Information System (GIS). Assessment units based on RE by broad condition state can then be mapped and area statements derived with GIS (Figure 1) using pre-clear RE mapping to identify what RE the regrowth is likely to be, and similarly for non-remnant areas to ascertain what the RE was. Note that the use of any or all of these broad condition states will be determined by the objective and purpose of the survey.

A spatial product which will help in delineating areas by vegetation condition state is output from the Spatial BioCondition model framework, which aligns with Queensland's regional ecosystems and BioCondition vegetation condition assessment frameworks (DES 2021). Output from the Spatial BioCondition framework is a continuous index representing the spectrum of vegetation condition states. This output can then be classified to represent broad condition states at a property-level scale. Output from the Spatial BioCondition program will be released on a bioregional basis, with South East Queensland and Brigalow bioregions to be released first by 2023.

As an example, in Figure 1 six assessment units (AU) have been delineated for a survey area. AU1 represents a non-remnant area of brigalow and belah RE 11.9.5 (as mapped using the pre-cleared RE mapping); AU2 is non-remnant poplar box woodland RE 11.9.7; AU3 is regrowth of RE 11.9.5; AU4 is regrowth of RE 11.9.7; AU5 is remnant RE 11.9.5; and AU6 is remnant RE 11.9.7.

Table 1: Definition of broad condition states for delineating assessment units.

Condition state	Definition
Best-on-Offer remnant vegetation	Best-on-Offer (BOO) vegetation represents reference areas of remnant vegetation (see definition below) that are in relatively functional condition (i.e. relatively pristine approximating pre-European vegetation), and where dominant threatening processes are minimised. BOO sites are likely to be water-remote (e.g., > 6 km from permanent water; Fensham and Fairfax 2008), or with historically low grazing pressure, located in intact landscapes with benign fire-regimes, and with little clearing of woody vegetation or weed encroachment or mechanical disturbance. The BOO sites should be at least 1 km from contrasting land use, should have zero to low non-native plant cover, and should exclude areas subject to recent major management change (Eyre et al. 2017).
Remnant vegetation	Remnant vegetation is defined under the *Vegetation Management Act 1999* as vegetation shown on a regional ecosystem or remnant map. Remnant vegetation is defined as vegetation where the dominant canopy has greater than 70% of the height and greater than 50% of the cover relative to the undisturbed height and cover of that stratum and dominated by species characteristic of the vegetation's undisturbed canopy. In grassland ecosystems, remnant status is assigned to grasslands that; – have not been ploughed in the last 15 years (generally detectable on Landsat imagery) and; – contain >20% of the native species normally found in the ecosystem under the same ecological and seasonal conditions (as defined in benchmark documents or REDD) and; – have a high ratio of native species to exotic species (>5:1). Remnant vegetation can still be subject to disturbance such as selective timber extraction, fire, and grazing (Neldner et al. 2005).
High-value regrowth	High-value regrowth vegetation is defined under the *Vegetation Management Act 1999* Amendment Act 2018 as vegetation that has not been cleared in the last 15 years. Under the Act the definition applies to leasehold land for agricultural or grazing purposes, freeholds and indigenous land and occupational licences. For the purposes of survey stratification, the definition (and associated available mapping) can be used across tenure.
Non-remnant vegetation	Non-remnant vegetation is defined as all vegetation that is not mapped or described as remnant or regrowth vegetation, as defined above. It may contain scattered habitat features e.g., large trees, woody debris.

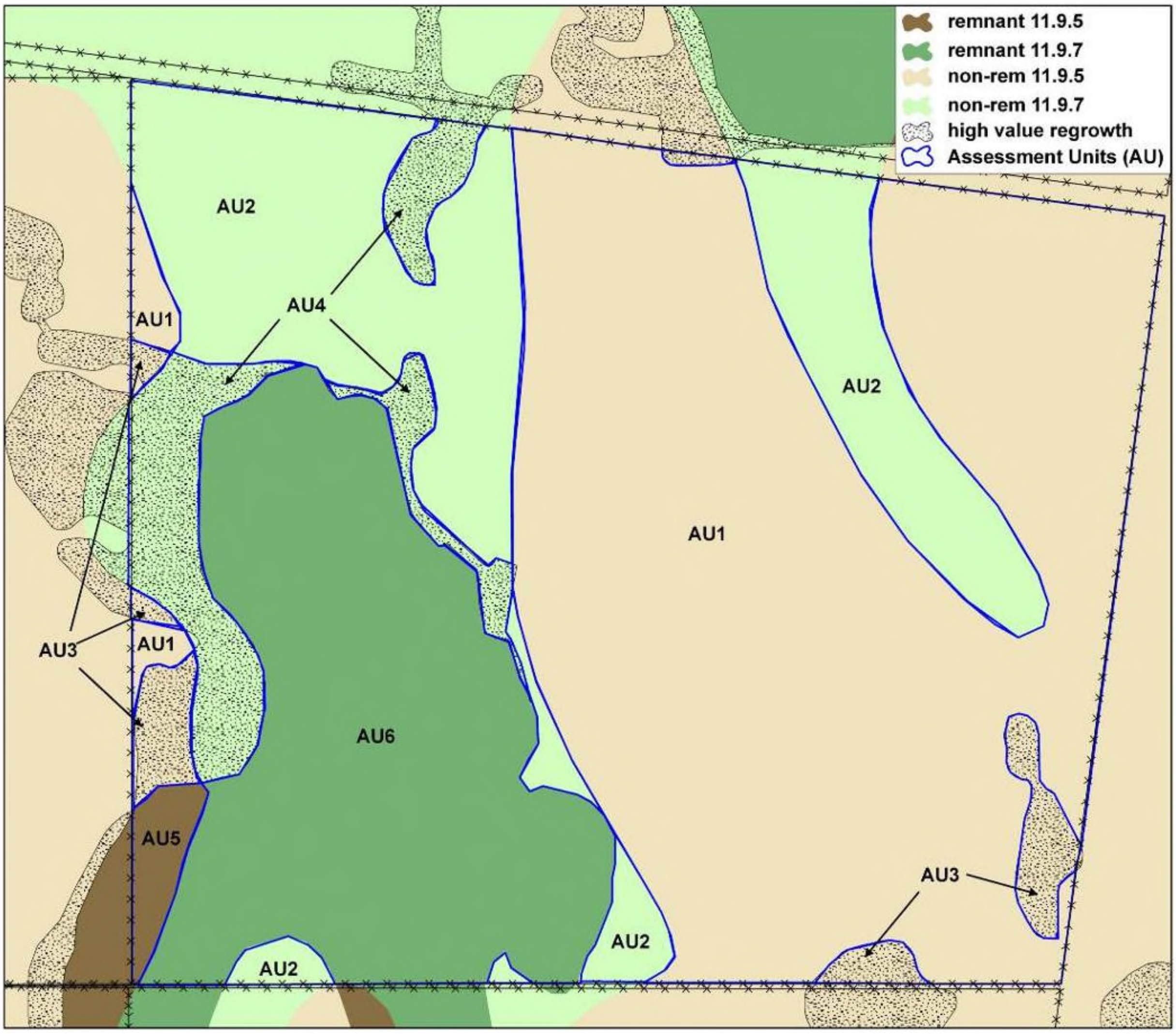


Figure 1: Delineation of assessment units for an area.

To assist with the stratification and delineation of assessment units as determined by the objective and purpose of the survey, it is useful to generate a map of the survey area with GIS showing the extent and types of assessment units. For planning purposes, other useful information, which is usually available digitally, or can be obtained using Geographic Positioning Systems (GPS), include roads, watering points, areas of direct impact (e.g., mining), and the location of fence lines. The assessment unit mapping can be used in advance of conducting field assessments to plan the locations of the generic and targeted survey sites.

To date, pre-clear and remnant RE mapping has been completed for all of Queensland at scales which range from 1:50 000 (e.g., South East Queensland and Wet Tropics) to 1:100 000 (e.g., rangeland bioregions), where a single mapped polygon may contain several REs (heterogeneous polygons). In the case of heterogeneous polygons it is reasonable, for the purpose of digitally delineating assessment units, to assign the assessment unit as the RE covering the highest proportion in the polygon. However, the actual RE at each field site should be recorded. Pre-clear and remnant regional ecosystem data can be downloaded from the Queensland Government QSpatial website. The hard copy maps and digital data can be used to produce a map specific for the area. The applicability of the RE mapping should be assessed in the field during the Stage 1 reconnaissance to check it is relevant at the scale the survey is being conducted, and that potential areas to survey have not been recently (i.e. < 1 year) impacted by wildfire or mechanical disturbance events (unless the disturbance is relevant to the purpose of the survey).

Assessment units will not necessarily occur as continuous tracts and can occupy two or more discrete areas. However, a discrete assessment unit should not be sampled unless it is larger than 2 ha in area, to accommodate the dimensions of a generic survey site (see Section 4.5). Areas less than 2 ha in area may, however, be sampled as a targeted survey site.

4.3. Replication and Location of Survey Sites

The number of generic survey sites to establish within a survey area will depend on how many assessment units there are to sample. As a minimum, three ‘replicate' generic survey sites should be established per assessment unit, to reduce spatial variability in fauna assemblages and increase precision in the estimation of population characteristics (NB: if the assessment unit is highly restricted in extent, it may not be possible to establish three replicate sites). If resources and logistics allow, then it is recommended that more replicates sites are established and surveyed, as this will further improve sampling adequacy and reduce 'noise' in the data during analysis (see Section 4.4). The location of the site within the assessment unit must be representative of the RE and condition state, or other entity as determined by the objective of the assessment and should be at least 50 m from a road and 100 m from a dam or other major disturbance. Terrestrial fauna survey sites should be positioned sufficiently far apart that individuals are unlikely to be detected at different survey sites. This will ensure the data are independent if certain analytical procedures are to be performed on the data. As a rule of thumb, we recommend that generic sites are located at least 1 km apart from each other. However, fauna sites do need to be clustered to facilitate efficient and adequate servicing of sites (e.g., trap checking) during a survey period. Site location will also be constrained by available access. Many fauna survey sites are in close proximity to accessible roads and tracks, which may introduce a spatial bias. Consequently, it is advisable to acknowledge access issues in the limitations section of the report, particularly if a bias is suspected or identified during the data analysis.

If the objective of the survey is to evaluate the impact of a development (before and after) on the terrestrial fauna within the survey area, sites within the assessment units must be delineated as ‘impacts' and ‘controls'. ‘Impact' sites will be those located in (or adjacent to) assessment units that will eventually be affected directly or indirectly by the proposed development. These must be ‘paired' with ‘Control' sites located in assessment units identified as REs in a BOO condition state. These BOO sites constitute areas within the survey area (or near-by) that contain the natural variability of the attributes of an ecosystem which has been relatively unmodified since European settlement, and that will not be impacted upon by a development. It is important to locate controls in BOO sites because within regional ecosystems mapped or described as remnant, there is still likely to be a gradient of condition state, based on the degree of disturbance. The control sites must be the same RE as the impact sites. This ‘multiple data points (e.g., monitoring or time series data) at multiple control and impact sites' type approach, effectively comprises a series of reassessments at the survey sites before and after the disturbance. The advantage of this approach is that it will help discriminate variation or change in faunal populations due to an impact or disturbance from change or variation arising from natural drivers (see Section 5.2).

Alternatively, if 'before and after' surveys are not possible, then a space-for-time substitution can be used, where sites showing discrete levels of disturbance/impact are selected for surveying. Again, BOO sites must be selected as controls, and adequate replication of the sites representing the various levels of impact will be required.

4.4. Sampling Adequacy and Power

4.4.1. Species Accumulation Curves

The use of species accumulation curves as a tool to report on fauna survey adequacy – particularly for environmental impact assessments – is highly recommended (Thompson and Thompson 2007b, 2010), yet they are rarely used (Thompson et al. 2007). For fauna surveys where there is no obvious plateau in the species accumulation curve, it may be concluded that sampling was inadequate to estimate species richness. This information is important to report for appropriate decision-making regarding the results of the fauna surveys.

Species accumulation curves plot the cumulative number of species detected within a defined sampling area (such as survey sites within a particular assessment unit) on the y-axis against increasing levels of survey effort on the x-axis (Thompson and Thompson 2007b). The shape of a species accumulation curve is influenced by the relative abundance and diversity of species detected using a particular standardised method (Thompson and Withers 2003), and by the order in which individuals are detected (Gray et al. 2004). To reduce the potential for bias which may be introduced by the order in which species are added to the curve, the sample order may be randomised (Colwell and Coddington 1994). If a species accumulation curve is to be used to estimate adequacy of survey effort, then randomising the order of the sample helps to minimise the effect that variation in the number of species detected daily as a consequence of variable daily environmental conditions and provide a more accurate and smoother curve (Thompson and Thompson 2007b).

There are several different species accumulation curves that can be used to estimate the number of species within a taxon for a particular area (e.g., assessment unit). Freely available software, such as EstimateS (Colwell 2013) allows simple calculation of species accumulation curves and determines estimates of species richness for reporting purposes. EstimateS can be used to calculate non-parametric species richness estimators for abundance-based data (Chao 1 and Abundance-based coverage estimator ACE) and for sample-based data (Chao2, incidence-based coverage estimator ICE, first and second order Jackknives, and Bootstrap). It should be noted that there is no guarantee that any of the methods provide a truly reliable estimate of the total number of species for an area (Burgman and Lindenmayer 1998). However, it is generally recommended that Chao 2 or ICE be used to estimate species richness, but only where there is adequate data (Thompson and Thompson 2010). The more reliable information to derive from species accumulation curves is the predicted increase in species richness given additional survey effort (Burgman and Lindenmayer 1998). Chao et al. (2009) provide an explicit technique (including a spreadsheet calculator) for estimating the additional survey effort required to detect a given proportion of species present at survey sites, although even this estimate will typically increase with further survey effort.

It is important to note that while species richness in an assessment unit is important, it is the significant species that are likely to be those that remain undetected. Species-specific targeted survey methods and/or increased intensity of generic survey methods are therefore vital.

4.4.2. Statistical Power and Sufficient Sampling

The setting of a sufficient sample size to obtain an appropriate level of statistical power is now regularly advocated for impact assessment and monitoring programs (Fairweather 1991; Field et al. 2007). Basically, the sampling design of the assessment or monitoring program needs to be capable of detecting an impact on the value of interest (e.g., vertebrate fauna species richness) with adequate power. If the objective of the survey is to demonstrate whether an impact has caused a change in faunal populations, then there is a requirement to show adequacy in survey effort. A statistical power test can provide this and is usually conducted prior to the survey to determine how many sites and/or samples are required to determine an impact. A power test may not be necessary if the objective of the survey is to provide an inventory of species in the survey area.

Statistical power testing (Box 1) requires testing for the null hypothesis, e.g., that a specified pressure has no impact upon the variable of interest. The incorrect rejection of the null hypothesis is known as a **Type I error**. In a fauna impact assessment scenario, a Type I error would lead to the incorrect conclusion that an impact has occurred to change the abundance of a species when in fact there has been no impact. The probability of a Type I error occurring is often known as the significance level, which is typically set at $P = 0.05$ (equivalent to a 95% probability that if a change is detected by the analysis, it is a real effect and not due to chance). However, the significance level can be set at any reasonable level by stakeholders or whoever is conducting the hypothesis test, usually at a level to avoid making a Type I error. Increasing the level will increase the likelihood of rejecting the null hypothesis, thereby concluding that there has been an impact, however this increases the likelihood that inherent variation in the data is misinterpreted as an impact (Burgman and Lindenmayer 1998).

Another error is the **Type II error**, where a conclusion is made that no impact exists when in fact it does. The probability of a Type II error tends not to be routinely calculated, but related to this is the concept of power, whereby Power = 1 – the probability of a Type II error. The level of the probability of a Type II error is dependent on the probability of the Type I error, the sample size, the effect size, or level of impact to be detected and the inverse of the variability inherent in the data. Thus, the appropriate sample size can be calculated in a power analysis, when the effect size and acceptable Type I and Type II errors are specified. Consequently, increasing the sample size will help reduce the probability of a Type II error, because this usually reduces the variance (Fairweather 1991).

Power tests are best used prior to the survey for design purposes i.e. to determine an appropriate sample size. They can also be used post-survey, to retrospectively evaluate if any non-significant results are due to inadequate sampling. A power analysis program e.g., DuPont and Plummer (2018), can be used to determine either:

- the power, given the values of the Type I error, the sample size and the effect size and sample data, or;
- the sample size, given the values of the Type I error, power and sample data (see Box 2 for an example).

For broadscale monitoring purposes, Woinarski et al. (2004) used power analyses to show that more than 1000 sample sites were needed for most species to be 90% (power of 0.9) certain of detecting a 20% change in abundance, and with a 10% chance (*P*= 0.1) of accepting a Type I error. If power testing reveals that the number of samples required to adequately reject the null hypothesis is logistically prohibitive and too expensive, then there are alternatives, such as adjusting the tolerance for reliability and error (Burgman and Lindenmayer 1998). Ensuring that the stratification and sampling design meets the objectives of the surveys, and minimising sources of variation in the data (see Section 5.2) can greatly improve the power of the data being collected.

Box 1: Statistical power definitions.

Statistical power is a function of the amount of change (or effect size) to you want to detect, the level of uncertainty you are willing to accept, the sample size, the variance of the indicator used, and the statistical model you use for testing. These are all related by the equation:

$$\text{Power} \propto \frac{ES \times \alpha \times \sqrt{n}}{\sigma}$$

Where:

ES = Effect size

α = Type I error rate

n = sample size

σ = standard deviation of the sample population

This equation basically translates as Statistical power is proportional to the effect size multiplied by the alpha-level of the test (Type I error rate), multiplied by the square root of the sample size, and divided by the standard deviation of the variability of the data.

Effect size - the level of impact required to be detected by a study, given that there is an effect. Large values for the effect also increase the power of the test. It must be specified prior to the power analysis. Because effect size can only be calculated after you collect data, you may initially need to use an estimate of effect size for power analysis.

α - Type I error rate, or significance level you want to use. For power analyses it is usually set at *P* = 0.05 but can also be *P* = 0.1.

NOTE: the results of a power analysis depend on the statistical test being used. For example, a different number of samples may be needed to detect a 10% change for a regression model than for an ANOVA model.

Box 2: How many samples?
An example using the **PS Program** (Dupont and Plummer 2018) on prior data.

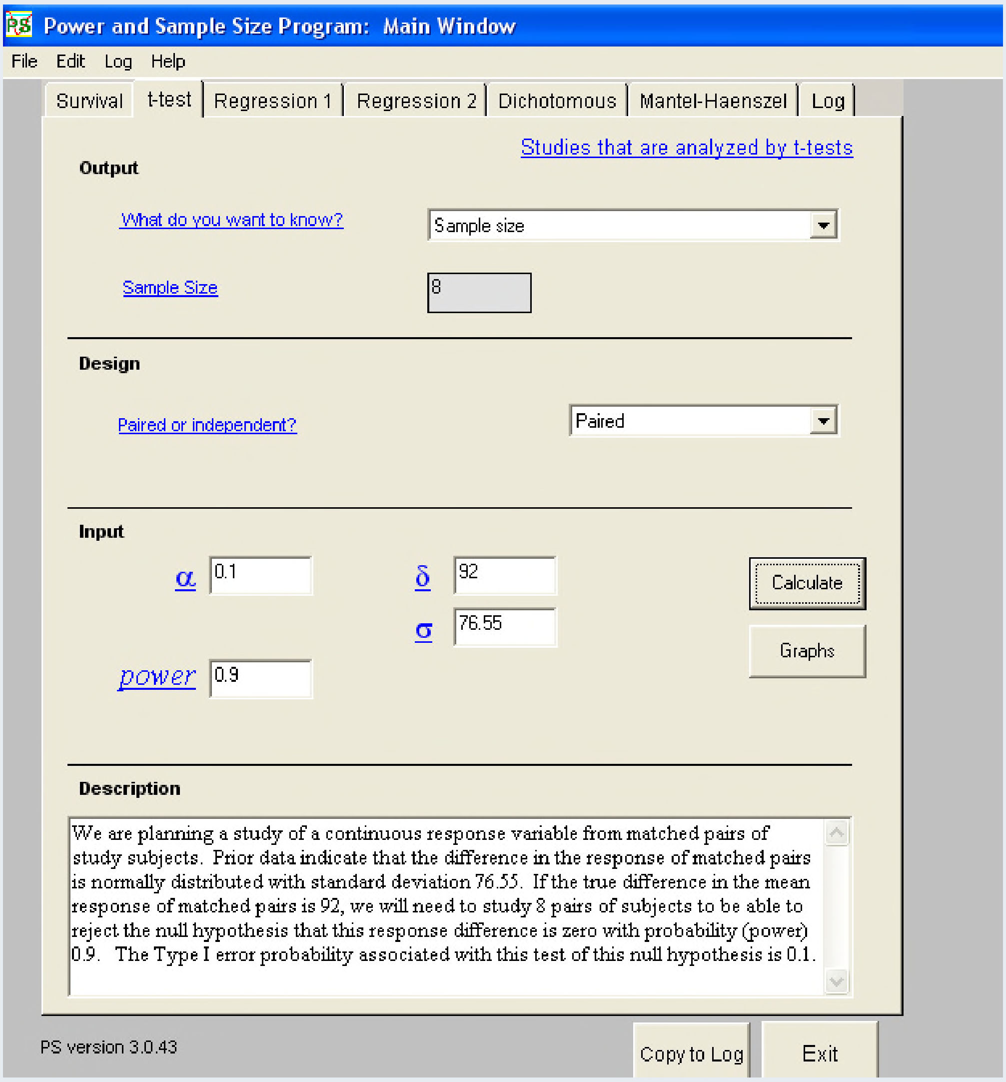
In the mulga lands we wished to investigate the null hypothesis that clearing in the landscape has no effect on the abundance of small passerine woodland birds (SPWB). To start with, seven sites in remnant vegetation in intact landscapes ('control' sites) were sampled, and these were paired with seven sites in remnant vegetation in predominantly cleared landscapes.

To determine sample size using the PS program using a paired t-test, we decided to use a **Type I error probability (α) of 0.1** (i.e. if a change is detected by the analysis there is 90% probability that it is a real effect and not due to chance) and set the **power at 0.9** (i.e. if a change occurs there is a 90% probability that it will be detected by the analysis).

From the initial survey, we calculated the;

Mean relative abundance of SPWB in the intact landscapes	= 152.7
Mean relative abundance of SPWB in the cleared landscapes	= 60.7
Therefore, the difference in population means (δ)	= 92
Standard deviation of the sample population (σ)	= 76.5

These values were entered into the program as shown below, and the sample size calculated was 8 sites per treatment (i.e. a total of 16 sites) was required to reject the null hypothesis, with a power probability of 0.9.



4.5. Setting up a Generic Fauna Survey Site

Setting up a defined-area generic survey site is essential if the objective of the survey is to compare data between sites over space (inventory) or within sites over time (monitoring). This is because the site constitutes an area within which survey effort is constrained, meaning that the data obtained are standardised for ongoing scientific use. We recommend a generic survey site be 1 ha in size, typically in the configuration of a 100 m x 100 m plot, within which the recommended generic terrestrial vertebrate fauna and habitat assessment methods are conducted (Figure 2).

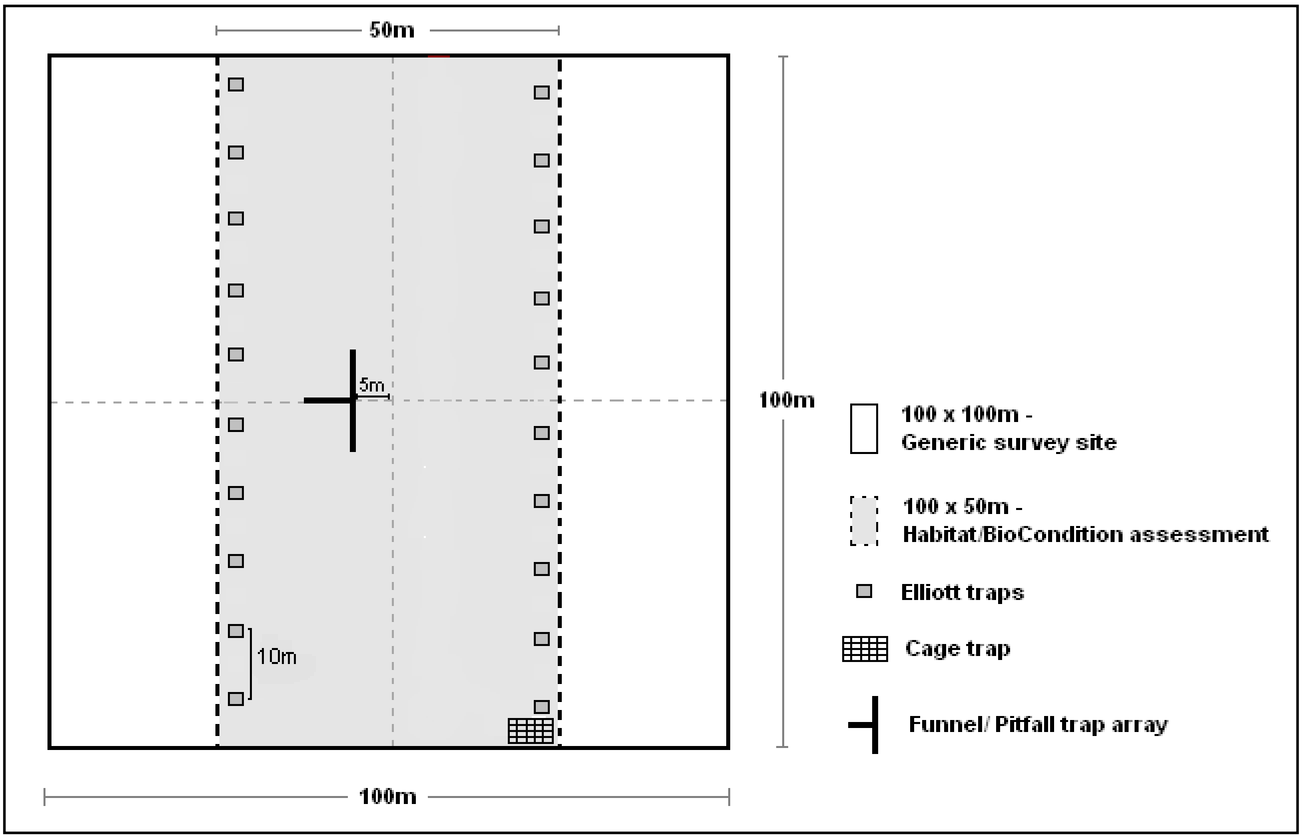


Figure 2: Generic vertebrate fauna and habitat survey site layout.

NB: Traps may not necessarily follow a straight line, depending on vegetation structure and individual trap placement.

In narrow, linear assessment units (e.g., riparian REs), it may be necessary to adjust the configuration of the survey site so that it is contained wholly within the unit, but the sampled area is still 1 ha. This can be achieved by extending the length of the survey site to 200 m but reducing the width of the plot to 50 m (Figure 3).

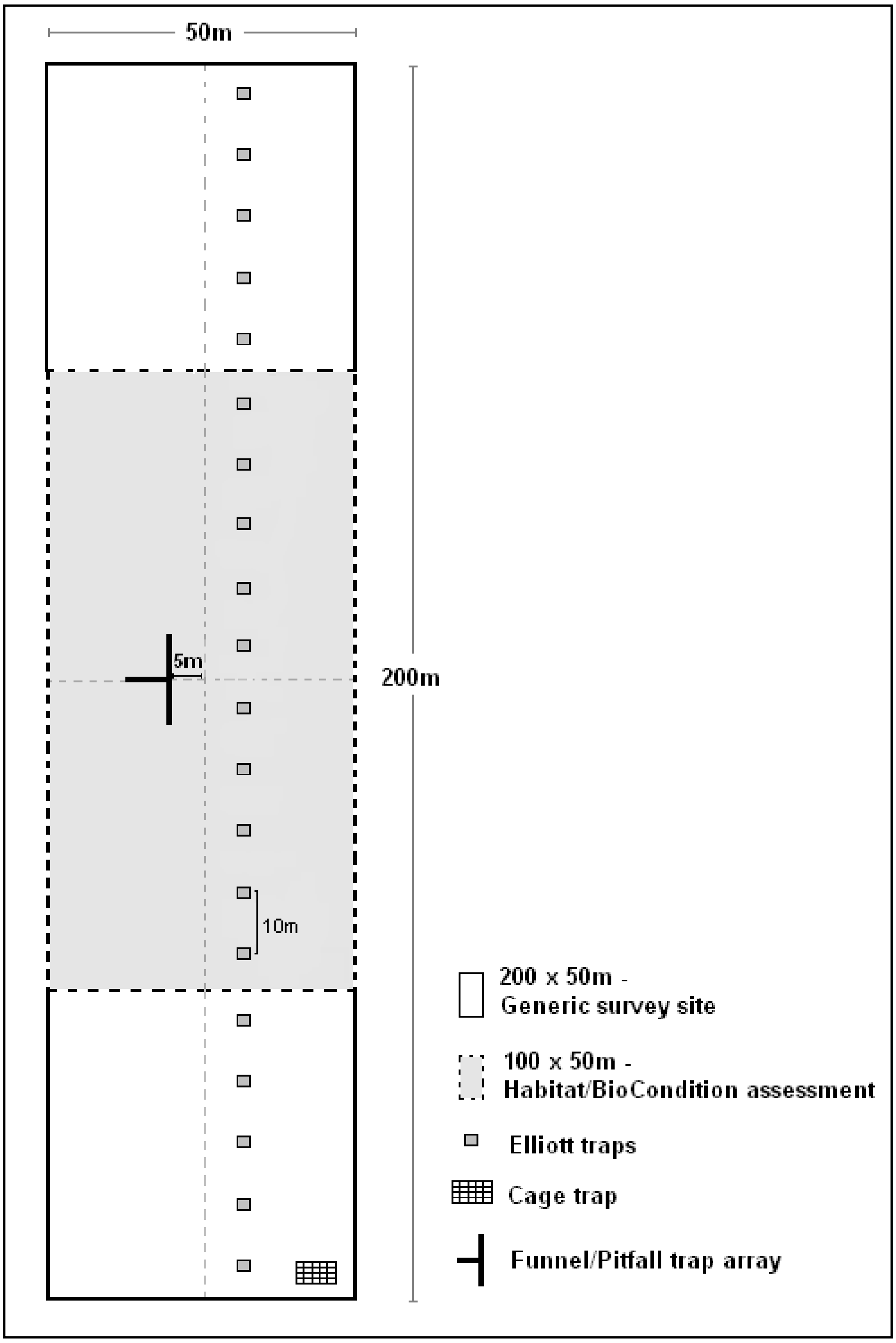


Figure 3: Generic vertebrate fauna and habitat survey site layout for narrow linear assessment units.

4.6. When to Conduct Surveys

Patterns of faunal activity and estimates of relative abundance or presence-absence of species, varies temporally in response to the time of day (day versus night), seasonal changes (e.g., spring versus winter) as well as between years (e.g., rainy year versus drought year). There are also logistical issues related to fauna surveys and seasons, such as road closures during monsoons. Throughout Queensland and within bioregions, optimal times of the year to undertake a fauna survey can vary considerably, depending on the locality and the local environmental drivers. For efficiency, surveys for each of the major vertebrate groups are usually conducted concurrently, although this may not always be the optimal time for all groups. Some vertebrates such as amphibians, irruptive and nomadic mammals and birds have population cycles and movements, both local and widespread, more closely associated with stochastic events such as episodic heavy rainfall events, than to the regular turn of the seasons. These species will require targeted surveys after such events to enhance detectability. Table 2 provides a guide on the optimal times of year to survey terrestrial vertebrate fauna, on a bioregional basis, and typically coincides with peak activity in reptiles. Single season terrestrial fauna surveys will not provide an adequate sample for either simple inventories or impact studies (Thompson and Thompson 2010). To increase precision in the data collected, at least two surveys undertaken in different seasons will be a minimum requirement, particularly if one survey is conducted during drought conditions. Repeat surveys over different years would also be highly desirable, but not always practicable.

Table 2: General guide to the optimal times of year and conditions for vertebrate fauna surveys.

Bioregion	Survey timing	Rationale
Brigalow Belt (BRB)	Spring to early Summer (Sept - mid Nov)	As temperatures begin to warm up after winter there is a peak in vertebrate activity with the commencement of breeding activity in many species. Exact timing is dependent on the timing of the onset of spring, when temperatures begin to warm but before summer temperatures become too high as many species, especially reptiles, become less active. Rainfall is also a major trigger for increased activity in many species. This period can be very dry so conducting a second survey during moist periods is critical.
	Autumn (March - mid May)	A second survey should be undertaken after summer as the temperatures decrease but before the onset of cold winter nights. This coincides with another active period including dispersal and migration of many species. It is also more likely to be moist than during the spring-early summer period, and also coincides with grass seeding and growing season (important for granivores).
Cape York Peninsula (CYP)	Early Wet Season (Nov - Jan)	During the early wet season vertebrate activity is high as animals start to move around with the building humidity. Surveys should coincide with this period if possible (access can also be problematic later in the season). If frogs are a particular target, then surveys should occur at the beginning of the wet season *as well as* after the first decent rains in December-January. The onset (and end) of the wet season is variable each year and surveys should take this into account.
	Early Dry Season (May - July)	A second survey should be undertaken in the early dry season while vegetation is still green and some moisture remains, before temperatures get too high and fires haven't yet impacted on mammal numbers.
Central Queensland Coast (CQC)	Spring (Sept - mid Nov)	As per BRB.
	Autumn (March - mid May)	

Bioregion	Survey timing	Rationale
Channel Country (CHC)	Spring (mid-August - Oct)	As per BRB except spring surveys should be conducted earlier as activity decreases with the higher daily temperatures. Activity will be highest in years with good rainfall.
	Autumn (March - May)	
Desert Uplands (DUP)	Spring (Sept – mid-Nov)	As per the BRB.
	Autumn (March - May)	
Einasleigh Uplands (EIU)	Early Wet Season (Nov - Jan)	As per CYP.
	Early Dry Season (May - July)	
Gulf Plains (GUP)	Early Wet Season (Nov - Jan)	As per CYP avoiding the hottest and coldest (overnight minimums) months.
	Early Dry Season (May - July)	
Mitchell Grass Downs (MGD)	Spring (Sept - early Nov)	Rainfall is variable in this bioregion: in the north it tends to fall in summer (Dec – Feb) with the monsoon, while in the south it is less predictable. Therefore, surveys should be conducted outside the extremely hot summer period and the cold (overnight) winter period, ideally following rain.
	Autumn (Late Feb - May)	
Mulga Lands (MUL)	Spring (Sept - mid Nov)	As per the BRB.
	Autumn (March - early May)	
New England Tablelands (NET)	Spring (mid Sept - Nov)	As per the BRB.
	Autumn (late Feb - April)	
North West Highlands (NWH)	Early Wet Season (Nov - Jan)	As per CYP, avoiding the hottest and coldest (overnight minimums) months.
	Early Dry Season (May - July)	
South East Queensland (SEQ)	Spring (mid Sept - mid Dec)	As temperatures begin to warm up and particularly after the first storms when animal activity peaks.
	Autumn (late Feb - April)	The second survey should be conducted when high summer temperatures begin to drop and before the onset of colder overnight temperatures.
Wet Tropics (WET)	Early Wet Season (Nov - Jan)	As per CYP.
	Early Dry Season (May - July)	

5. Factors Affecting Fauna Survey Results

5.1. Imperfect Detection

Sources of uncertainty inherent in biodiversity sampling include species detection and observer bias (Wintle et al. 2004). Fauna assessments mostly rely on the use of relative abundance or presence-absence as the main measurements of biodiversity for analysis and reporting purposes. These measurements assume that the probability of detecting the species of interest is equal to 1, or that the species will be detected if present. Detection probabilities are much less than 1 (meaning that a species may not be detected even though it is present). This is due to several variables that influence detection and cause variation in the data (see Section 5.2). Species presence at a site is confirmed through direct observation of the animal or indirect observation of signs. However, it is virtually impossible to confirm that a species is truly absent from a site. False-absence rates (recording a species is absent when in fact it is present but undetected) are an important source of variation during analyses of the data, particularly when they are low (MacKenzie et al. 2002; Tyre et al. 2003; Wintle et al. 2004).

Methods have been developed that allow the unbiased estimation of the probability that a species occupies a site (e.g., MacKenzie et al. 2002; Tyre et al. 2003). However, these methods require at least some of the sites to be surveyed on more than one occasion during the survey period. Useful methods available to estimate a single visit probability of detection are a generalised zero-inflated binomial model designed by Wintle et al. (2004) or using the software program PRESENCE (Hines 2011). These methods will provide an estimate of how many surveys are required to detect a species, which is useful when considering naturally rare and cryptic species as well as more common species. If only one sample is undertaken at a site, then probabilities of detection must be calculated and reported on.

To improve the probability of detecting species, fauna survey methods must be based on multiple visits (where a 'visit' incorporates an active search and/or a trap night) within a survey period, and there needs to be at least one repeat survey conducted in a different season (Kutt and Woinarski 2007; Thompson and Thompson 2010). A single visit at a site within a survey period is inadequate for the detection of most fauna species. Generally, it is recommended that a site be visited/sampled at least three times (within a survey period) to minimise the probability of a false absence (Field et al. 2005; MacKenzie and Royle 2005) and/or, that more sites are sampled. Tyre et al. (2003) suggests that when false-absence rates are < 50%, then greater efficiency is gained by increasing the number of sites, rather than increasing the number of repeat visits to a site. Increasing the number of repeat visits increases the probability that the species will be detected if it is present. This in turn reduces variability in estimates of the species' detectability (and occupancy), and results in a corresponding increase in the statistical power to detect a change (Field et al. 2005). The loss in statistical power to detect a change in occupancy is greater for inadequate sampling per site, than for an inadequate number of sites in the landscape (Field et al. 2005).

Ideally, it is advisable to have estimates of detection probabilities for species prior to the survey, to assist with optimal design and implementation of the survey (Field et al. 2005). For example, the detection probability of a yellow-bellied glider *Petaurus australis* occupying a site is 0.4 (Eyre 2007), therefore there is a 1 - 0.4 = 0.6 probability that the glider will not be detected during a single sample at a site within a survey period, when in fact it is present at a site. This false-absence rate can be reduced to an acceptable level (e.g., 85% chance of detection) by undertaking four surveys at the site i.e. (1-0.4) x (1-0.4) x (1-0.4) x (1-0.4) = 0.13, or there is an 87% chance of detecting a yellow-bellied glider with four surveys, if it is present.

However, knowledge of detection rates for most species are rarely available, and information is sparse on a local area basis - particularly for rare species and microbats. Consequently, the generic survey methods recommended in these guidelines are designed to minimise temporal variation and improve detection rates through multiple visits to a site. The number of visits recommended is based on best available knowledge and current best practice. For example, because the yellow-bellied glider false absence rate for southern Queensland is known, it is recommended that a minimum of four spotlight/call playback surveys to a site (two during the first survey period, and two during the second survey period) as the minimum number of surveys to adequately detect the yellow-bellied glider and other arboreal mammals. It is also recommended to survey as many replicate sites as possible within the survey area, as this may also increase detection for many cryptic species with low detection probabilities. The multiple-visit methods outlined in these guidelines will not only increase the probability of detecting a species at a site but will also allow the estimation of detection probabilities using PRESENCE or the Wintle (2004) approach. These detection probabilities can then be reported on in the final report, to give an indication to the reader on false-absence rates, particularly for significant species of conservation concern. In the case of impact assessments, knowledge of false-absence rates will assist decision makers to make informed decisions regarding conservation measures and survey adequacy (Wintle et al. 2005).

5.2. Sources of Variation during Surveys

There are many sources of spatial and temporal variation which can profoundly influence the detectability of terrestrial vertebrate fauna during surveys (Maron et al. 2005). The most common influences include:

- Observer bias – The more observers conducting surveys, the greater the variation will be due to inherent variation between observers' fauna survey skills. Observers with greater experience in fauna survey (in each ecosystem) are much more likely to detect species than observers with relatively minimal experience and will have less variation in detection skills over time (as experience increases so will detection rates). They are also less likely to misidentify species. Other observers may have better eyesight, or hearing with which to detect fauna or faster reflexes when catching mobile species (e.g., skinks). Different observers may exhibit biases in amount of time spent searching different parts of the site or microhabitats during area-searches. Some observers may not be as diligent in differentiating between similar, co-habiting species.
- Prevailing climatic conditions at the time of the survey – Conditions like very low or very high temperatures, cloud cover, wind, and rainfall.
- Seasonal and other environmental conditions – Factors that vary seasonally (e.g., nectar availability influencing nectar foragers or drought or major rainfall events influencing relative abundance of some rodents particularly in arid and semi-arid areas), monthly (e.g., lunar phases – bright moonlight has been shown to influence detectability of many microbat species, feathertail gliders *Acrobates pygmaeus* and greater gliders *Petauroides volans*) and even daily (e.g., time after dawn or dusk, – diurnal birds are more active and detectable at dawn).
- Equipment bias – Some equipment and methods will more effectively detect some species than others (e.g., spotter scopes, cameras, ultrasonic bat detectors).
- Trap competition – This may be an issue in Elliott or cage trapping where a species may avoid entering a trap because of competitive pressure or interference exerted by another species (e.g., burrowing bettongs in arid areas; Moseby et al. 2009).
- Bait type – Peanut butter and oats is good general-purpose bait for the survey of small to medium-sized mammals (Menkhorst and Knight 2004, Paull et al. 2011), although the use of other baits or additives can increase detection rates of some target species (e.g., pistachio essence mixed with generic bait to attract long-nosed potoroos *Potorous tridactylus*).

- Habitat – habitat with dense vegetation may render some survey techniques, particularly those that rely on search effort, less effective due to reduced visibility.
- Species behavioural ecology – wide-ranging species, such as those with large home areas e.g., powerful owl *Ninox strenua* or those that locally migrate with resource pulses may be temporally absent from the survey site, even if it is within their home range area. Other species may be less likely to call, or respond to detection techniques such as call playback, at certain times of their breeding cycle.

These influences can be minimised by:

- Not undertaking surveys during inclement weather.
- Undertaking multiple survey visits to a site during the survey period (as recommended in these guidelines).
- Undertaking surveys during at least two survey periods in different seasons (see Table 2 as a guide).
- Recording conditions at the time of each survey in a systematic and standardised manner, as this will allow incorporation of these data as 'covariates' during data analysis, or at least allow a simple analysis to determine the level of influence the prevailing conditions may have had on the fauna data collected during the survey. The datasheets provided to accompany this document (search the Queensland Government website) include fields specific to each survey method for the standardised recording of variables most likely to exert an influence on the fauna data collected using the method.
- Training survey staff as a group against a standard prior to the surveys to improve repeatability (precision) and accuracy by reducing bias in the application of survey techniques and approaches (Kelly et al. 2011).
- Observer bias can be reduced by alternating observers (if more than one) among sites. Alternatively, the same observer or group of observers (in the case where more than one observer can undertake a particular method, such as herpetofauna searches) can undertake all the surveys across sites for a particular method.

6. Data Management

Appropriate data management is a key requirement of any fauna survey. After deciding the purpose of the survey, sampling design and site selection, some of the things to consider are:

- How to store, verify and maintain the data.
- Who is responsible for the data.
- How to process the data.
- Who may require the data (e.g., government, proponents or landholders) and in what format.

6.1. Essential Data Requirements

To ensure the information collected will be useful into the future, the following data must be recorded, for each site and/or sighting, during the field survey:

Table 3: Essential data to be recorded for each site and/or sighting during the field survey.

Data required	Reason
Location description	Detailed description including a regional and local context. This ensures that coordinate locations can be verified.
Location coordinates	Latitude and longitude in decimal degrees or map grid reference (zone, easting and northing). Preferably recorded using a GPS (Global Positioning System).
Location Datum	This is the standard position or level that measurements are taken from (e.g., DES standard is GDA94; others are AGD84, AGD66). This is especially important to record if coordinates are from maps older than 10 years.
Location precision	Accuracy of the coordinate location, recorded in metres. The distance of the sighting/record from the coordinates may also need to be factored in. Location precision should also reflect the area around the coordinates over which records were collected.
Date	Including day, month and year of survey.
Observer Name/s	Name of the person/s responsible for the identification of the species.
Taxon Name	Species identification to the most precise level that can be accurately and confidently identified. In most cases this would include a scientific name with genus and species (e.g., *Macropus giganteus*). Subspecies should be recorded if known. In other cases recording to 'species pair' level (e.g., *Litoria jungguy/L. wilcoxii, L. serrata/L. myola*) where a species can be separated only by genetic analysis, is appropriate, or at generic level (Genus spp.) if there is any doubt about identification to species or 'species pair' level. For birds, common names are acceptable if using a standard checklist (e.g., Birdlife Australia maintain a current working list of Australian Birds).
Species code (optional)	A unique taxonomic coding system, such as the Census of Australian Vertebrate Species on the Department of Climate Change, Environment, Energy and Water website), to aid in rapid, accurate (spelling and taxonomy) entry of species data.
Number or Count of Individuals	Presence of the species assumes a minimum of one individual, so record the lowest number that can be accurately counted or estimated.
Observation Type	Whether the animal(s) were seen, heard, identified from remains, etc.
Reliability	Reliability of the sighting. Data should not be recorded when the identification of the species is uncertain unless a specimen or photo can be taken for later identification. Specimens lodged with public institutions attract the highest reliability. However, collection of specimens should occur only when the identification is uncertain, and identification cannot be made from photographs.

Survey Effort	Survey effort is especially important to record if using a standard or commonly used search method (e.g., area and/or time limited searches).
Time	The time when the sighting occurred or when the search was performed (e.g., 08:10 – 08:40)
Assessment Unit	Relatively homogenous unit usually based on vegetation type (e.g., RE), used for sampling the survey area
Habitat Description	The habitat where a species was recorded can change with time and disturbance (seasonal changes as well as clearing, fire, drought, etc). A minimum description should include the RE and broad condition state. If this is not possible, then a simple habitat description using a standard technique can help to verify vegetation mapping in some cases. The standard technique used should be reported (e.g., Tall closed *Eucalyptus grandis* forest - Walker and Hopkins 1998).
Prevailing survey conditions	Prevailing conditions refer to the climatic or an environmental variable that may influence the detection of fauna during surveys e.g., rainfall, wind, moon phase and flowering. These data can be standardised to allow analysis of the degree of influence.
Life History	Age, sex, breeding, or reproductive condition of the individual, if known, can value-add sighting records.
Comments	Any extra information

6.2. Datasheets and Electronic Data Collection Tools

All fauna survey or incidental sightings require certain minimum data (refer to Section 6.1) to be recorded. Depending on the project and its purpose, additional types of data will also be required.

Standardised data sheets containing the required data categories provide a convenient, inexpensive, and effective way to ensure that the required data are recorded in a consistent format. It is important to remember that any survey may have important historical ramifications (e.g., at the extreme, perhaps even the first or last record of a species) and may need to be interrogated many years down the track. So it is highly desirable that completed datasheets are legible and archived.

It is recommended that datasheets should contain the following characteristics:

- Fields for recording all essential data (including about the environmental conditions at the time of the survey) and specifying units if appropriate
- Code descriptions if codes are to be used in data recording
- Extra space for recording notes that do not fit into specific categories.

Datasheets specific to the faunal survey methods outlined in these guidelines (e.g., diurnal bird survey; pitfall trapping) can be downloaded from the Queensland Government website.

Alternatively, electronic data collection applications (apps), that allow the collection of data using a smartphone or tablet, can also be utilised to record data in a consistent, standardised format. They can be built to contain the same characteristics of a datasheet. The benefits of using data collection apps are that they eliminate the use of paper datasheets, allow stronger validation rules (e.g., mandatory data or specific codes) and allow data to be quickly exported for data analysis and reporting. To build a well-functioning field app that can successfully capture data in remote areas requires following best practices for offline data collection, including, synchronising or backing-up your data regularly. Establish a standard operating procedure (SOP) with your field team to minimise the risk of offline data being lost by scheduling when data will be synchronised to a server or backed up on multiple devices (e.g., multiple tablets or external hard-drives) if internet connectivity cannot be established.

6.3. Taxonomy and Nomenclature

Recording, storing, and sharing biodiversity data requires an authoritative taxonomic framework of scientific classification. Ideally, this would contain all published scientific names, all common names (if available), an up-to-date classification based on the best available taxonomy, show whether it is the current name for a species or a synonym, and relationships to other checklists of importance to the community (e.g., classifications used in state legislations, red lists, CITES lists).

There is currently no single resource that includes all of this information from over 200 years of printed literature. Data recorders need to be aware that taxonomic revisions are continually taking place and that even key field guides and reference texts can contain out-of-date taxonomy and nomenclature. It can be difficult to stay abreast of taxonomic changes as they are often published in a large range of journals.

In more recent times, some of this information has been consolidated for some taxonomic groups in online resources, such as the checklists of scientific names for taxon groups which are available as bulk data downloads from the Australian Biological Resources Study on the Australian Government website.

The scientific names in section 7 of the *Queensland Nature Conservation (Animals) Regulation 2020* follow the names used in a recognised database or the names used by the Queensland Museum. Examples of recognised databases include WildNet and the Australian Faunal Directory.

6.4. Data Storage

Converting data into a usable format for later processing, analysis and reporting requires digital data storage. This may be as simple as a flat spreadsheet (e.g., Microsoft Excel) or electronic app platform. For larger datasets and where more complex comparisons need to be made between collected attributes, it is far better to store data in a database (commonly a relational database but also non-relational), using readily available software such as Microsoft Access, MySQL, SQL, or Oracle.

An advantage of using dedicated databases is that they can limit data input errors by ensuring, for example, that numeric data are numbers and alpha data are characters. Look-up tables can also restrict entered data to specific, pre-determined choices or categories. This can also streamline data entry (when not using field apps), allowing codes (e.g., scientific names which can be prone to spelling mistakes) to be input rather than complete names or phrases. In some cases, computerised databases can also be matched with statistical packages for compatibility, e.g., Excel spreadsheets can be directly uploaded into most statistical programs. It is essential that any database is associated with metadata or data dictionary, listing all data elements, their definitions, how and where they are used and who is responsible for them.

All projects requiring a Scientific Purposes Permit (therefore, any projects that trap or otherwise "interfere" with vertebrate fauna in Queensland) are required to return a minimum amount of data to Department of Environment and Science (DES). Digital permit return forms are available from the Queensland Government website by searching for 'return of operations'. Permit return forms are in a digital Excel format to facilitate storage and return of data.

6.5. Data verification

When using paper datasheets, the first stage of data verification occurs prior to data entry when the recorder checks the sheets immediately after a survey for completeness and errors making sure all appropriate fields have been completed. Once data entry into the database has occurred the entered data needs to be checked for accuracy and inconsistencies against the original datasheets. This ensures the data are accurately entered with any inconsistencies being corrected.

When using field apps for data collection, that contain inbuilt validation rules, the steps for data verification are reduced to confirming that the correct survey data is assigned to the correct site and has imported (or synchronised) completely without any errors or missing data.

For any data collected, spatial verification of where sites are located using mapping tools should also be undertaken to ensure the site coordinates and locality information are accurate and occur in the correct position.

7. Biosecurity Risk

Undertaking surveys and handling animals carries inherent biosecurity risks – particularly relating to diseases, and pest plants and animals. All individuals have obligations under Queensland's Biosecurity Act 2014 to manage biosecurity risks that are:

- under your control
- reasonably expected

Individuals and organisations must:

- take all reasonable steps to prevent or minimise biosecurity risk
- minimise the likelihood of causing a biosecurity event and
- limit the consequences if an event happens.

Steps to prevent or minimise biodiversity risks:

- **Come clean, go clean** - before entering a survey area, ensure shoes, clothing, vehicles and survey equipment are free from weed seeds, dirt, soil or debris. Take reasonable steps to clean excess dirt and debris before leaving the survey area too.

- **Spot and report anything unusual** - if this is the first time you have noticed a pest or disease, and you think it may have an impact on human health, the environment, social amenity, or the economy, report it immediately to Biosecurity Queensland on 13 25 23.

- **Take reasonable steps to be informed about pests and diseases** visit Wildlife Health Australia and the survey area's local government website for more information on specific risks for the area.

Not meeting biosecurity obligations can result in compliance consequences, including permit amendments/cancellation through to prosecution. Being aware of the biosecurity implications for human, animal and ecosystem health is an important step in survey planning.

7.1. Observer Health

Diseases that affect both animals and humans are called zoonoses and may be passed between animals and between animals and humans via bacteria, protozoa, fungi, viruses, and parasites. Examples of zoonoses which may affect people working with wildlife, or in outdoor environments exposed to wildlife, domestic or feral animals include Leptospirosis, Q Fever, Ornithosis (Psittacosis) and Australian Bat Lyssavirus (ABLV). Zoonotic diseases are known to be present in Australian native animals and may be contracted from both ill and apparently healthy animals. Pathogens may be transmitted thorough inhalation, ingestion, via bites or scratches, vectors (e.g., bites of tick, mites, or mosquitoes) or via body fluid contact with skin or mucous membranes. Therefore, basic precautions should be taken to prevent the transfer of disease and minimise the risk of personal infection. Such precautions include:

- Practising good personal hygiene
- Using personal protective equipment (PPE) such as gloves, boots, etc.
- Providing prompt and effective first aid treatment to cuts and scratches
- Cleaning all survey equipment between surveys
- Not eating, drinking or smoking whilst handling animals
- Washing field clothes and equipment that has come into contact with animals' blood or body fluids
- Obtaining vaccinations appropriate to your work situation e.g., rabies vaccine or QFever and/or maintaining adequate titre levels against Australian Bat Lyssavirus before handling bats (see below)
- Knowledge and familiarisation with C3 bat protocol (person bitten or scratched by bat, see below)
- People diagnosed with or suspected to have Covid-19 should not have any contact with Australian wildlife.

Anyone who becomes ill within two months of a survey involving handling of animals should see a medical practitioner and be informed of the potential exposure to zoonoses. Further information on zoonoses can be obtained on the Queensland Health website.

Australian Bat Lyssavirus (ABL) is a rabies related virus that can spread from infected bats to humans via a bite, scratch or by being exposed to bat saliva through the eyes, nose, or mouth (mucous membrane exposure). It is assumed that any bat in Australia could potentially carry the virus. Pre-exposure vaccination is essential for anyone who is occupationally exposed to bats, with a risk of being bitten or scratched. This is a course of three rabies vaccine injections, given over one month (days zero, seven and 28). The vaccine does not offer protection until after the third dose. Adequate titre levels must then be maintained and basic precautions, such as the use of gloves to handle bats, should be taken to prevent being bitten or scratched (Qld Health 2020).

C3 (risk category 3) bat protocol: If bitten or scratched immediately wash the wound gently and thoroughly with soap and water and apply an antiseptic with anti-viral action such as ethanol-based hand sanitiser or iodine solutions if available. Proper cleansing of the wound is the single most effective measure for reducing transmission. If bat saliva contacts the eyes, nose, or mouth, it is necessary to flush the area thoroughly with water. Seek medical attention as soon as possible, as post-exposure vaccination is required, even those who have already received pre-exposure vaccinations (Qld Health 2020). For more information visit the Queensland Health website.

To date there have been no detections of the virus which causes Covid-19 (or closely related viruses) in Australian wildlife, however globally there are reports of transmission from humans to domestic and wild animals in domestic, zoo and laboratory situations (WHA 2021). Therefore, to avoid any possibility of Covid-19 becoming endemic within wildlife populations, people with Covid-19 should avoid contact with wildlife.

7.2. Animal Health

The role of wildlife diseases and pathogens in biodiversity decline and loss is becoming increasingly recognised (Scheele et al. 2019; Kophamel et al. 2022). This includes well publicised examples such as amphibian chytrid fungus, psittacosis in parrots and Tasmanian devil facial tumour disease. Animal health can also be affected by pathogens, diseases and invasive weeds in their habitat e.g., myrtle rust (*Austropuccinia psidii*) and root-rot fungus (*Phytophthora cinnamomi*) infecting plants, and wild tobacco weeds causing flying-foxes to come into contact with paralysis ticks. But there is multitude of less well recognised, as well as emerging diseases and pathogens which have the potential to cause great harm to wildlife. Some are already known from wild populations of fauna in Queensland (e.g., *Nannizziopsis* and Herpesviruses in reptiles, Petersen et al. 2020; Okah et al. 2021), while others have had impacts internationally but not yet made it to Australia (e.g., White-nose syndrome in bats, Hoyt et al. 2021).

Identification, management, and treatment of wildlife diseases are outside the scope of these guidelines but are available from Wildlife Health Australia. If there is evidence of disease of abnormal pathogen presence in wildlife populations, contact experts for advice as soon as possible and maintain good records.

Good hygiene practices and appropriate handling techniques should be incorporated into the design and planning of surveys, rather than reactively follow disease emergence. All survey gear coming in contact with animals should be cleaned (e.g., 8% bleach solution is a good minimum standard) before entering a new survey area. Surveys with higher threat risks for disease introductions or transmission, including those with suspected/known disease outbreaks, or with threatened species, should adopt more stringent measures.

- Be aware of disease transmission risks and take steps to manage these risks.
- Develop hygiene and risk protocols to identify and manage risk for each survey.
- Indirect or direct contact between animals captured during survey work should be minimised – especially those that would not normally be contact with each other.
- Any known or suspected cases of an emergency animal disease should contact the Biosecurity Queensland on 13 25 23 or the National Emergency Disease Watch Hotline on 1800 675 888.

Specific recommendations aimed at minimising animal stress during surveys are provided for each survey method in the Terrestrial Vertebrate Fauna Survey Guidelines for Queensland. These guidelines aim to assist those undertaking terrestrial fauna surveys in preparing animal ethics applications (see Queensland Government website) and provide recommendations to ensure the welfare of animals used in assessment and research in Queensland. Various Standard Operating Procedures (SOPs) were consulted in the preparation of the guidelines, including Collection of Voucher Specimens (see next section), Use of Pitfall Traps (AEC 2009a) and Wildlife Surveys (AEC 2009b).

7.3. Taking Voucher Specimens

There is a need for accurate identification of species during surveys, and sometimes vouchering specimens can be the best or only means to ensure accurate identification, both in the present and in the future should a taxonomic revision occur. A voucher specimen is usually, but not always, a dead animal. A voucher specimen serves as a basis of further study and is retained as a reference. A ‘type’ specimen is a particular voucher specimen on which the taxonomic description of that taxon is based. The collection of voucher specimens remains an integral part of scientific research and species assessment. Voucher specimens should become part of publicly accessible scientific reference collections such as the Queensland Museum. Voucher specimens should be properly collected, preserved, and stored, or - if no other alternative - maintained live in a humane manner so that they can be delivered in good and useful condition to the museum where they are appropriately housed and curated. Documentation to accompany the specimens must include date of collection, location of collection and names of the collectors. Issues relating to the ethical collection of voucher specimens are available on the Animal Ethics Infolink.

The decision to take, and the number of specimens to voucher will vary depending on the species, the location of the survey area and/or the conservation status of the species. We do not recommend vouchering threatened species (listed as vulnerable, endangered or critically endangered under state or federal legislation), unless specifically advised by the museum. Check with Queensland Museum curators before commencing the survey.

If specimens are prepared or fixed with 10% formalin prior to submission to the museum, a genetic sample should first be taken (e.g., tail tip, ear clip or a piece of liver or other tissue). Sampled tissue quantity should be large enough to allow sub-sampling (dividing) but requires enough fixative volume (>50% of vial) to be effective. The genetic sample should be stored in 100% ethanol (or >70% short term) and labelled with the same tag number as the whole specimen which should be stored in 70% ethanol after fixing with formalin. Specimens can also be temporarily fixed using 70% ethanol allowing a viable genetic sample to be taken later, prior to fixing with formalin. Taking a genetic sample value-adds to the specimen, enabling future genetic analysis or identification; and may help to reduce the number of specimens needed in the future for taxonomic or other studies.

8. Generic Survey Methods for a Site

The generic survey methods constitute a suite of standard approaches that when used in combination aim to provide estimates of species occurrence, relative abundance, diversity and composition of multiple vertebrate taxa for a site. Consistency in the application of the methods and configuration of traps is important, as this will allow comparison among surveys and sites, spatially and over time, as well as comparison with other surveys that use the same standard methods. The standard survey methods described in this Chapter (summarised in Table 4) are recommended for use at each generic survey site.

The equipment required for each survey method is provided in Appendix B: and corresponding data sheets for each method can be downloaded from the Queensland Government website (search for the Fauna Survey Guidelines).

There may be compelling reasons to vary or add to the overall effort at a generic survey site, as determined by the habitat and landscape being surveyed e.g., a potential microbat flyway may exist on a site, allowing placement of a harp trap. Survey teams may also be limited in particular skills (e.g., bat identification), or specialist equipment (e.g., camera traps, bat detectors) for the appropriate survey of some taxa, thereby negating the use of particular methods. Or there may be prior knowledge or overwhelming evidence to suggest a particular method will yield low detection rates of the target species in an area (e.g., use of cage traps are not recommended unless *Tiliqua* spp. and medium-sized mammals are specifically targeted; Thompson and Thompson 2007a). In these cases, justification will need to be provided in the final report as to why these methods (Table 4) were not used.

Table 4: Summary of recommended terrestrial fauna survey methods to use as a minimum at generic survey sites during each survey period.

Method	Minimum effort per survey period	Data type*	Amphibians	Reptiles	Diurnal birds	Nocturnal birds	Small terrestrial mammals	Med-large terrestrial mammals	Arboreal and volant mammals	Microbats
Pitfall trapping	Four buckets at 7.5 m intervals on T-design; 45 m fence for four nights	P-A; RA	✓	✓			✓			
Funnel trapping	Six funnels 3 m in on distal ends of T-design; 45 m fence for four nights	P-A; RA	✓	✓						
Diurnal active search	Two x 30 person-min searches within two different 50 x 50 m quadrants of the survey site	P-A; RA	✓	✓			✓			

Method	Minimum effort per survey period	Data type*	Amphibians	Reptiles	Diurnal birds	Nocturnal birds	Small terrestrial mammals	Med-large terrestrial mammals	Arboreal and volant mammals	Microbats
Nocturnal active search	Two x 30 person-min searches within the 100 x 100 m survey site	P-A; RA	✓	✓			✓			
Elliott trapping	20 traps at 5-10 m intervals along 100 m transect; open for four nights	P-A; RA					✓			
Cage trapping#	One trap per site open for four nights	P-A						✓		
Diurnal bird survey	Six x 5-10 min area searches within 100 x 100 m survey site	P-A; RA			✓					
Camera trapping	One camera per site for minimum of four nights	P-A; RA		✓ part			✓ part	✓		
Call playback	Two sessions of call playback of relevant species at midpoint of survey site	P-A; RA				✓			✓	
Spotlight	Two 30 person-minute spotlight search within 100 x 100 m survey site	P-A; RA				✓		✓	✓	
Echo-location call detection	One bat detector for three nights	P-A; RA								✓
Scat and sign search	Scat and sign search can coincide with the systematic diurnal active searches, within 50 x 50 m quadrates of the survey site. Otherwise, incidental.	P-A if system-atic otherwise P		✓		✓		✓	✓	
Incidental	Incidental detection of any species	P	✓	✓	✓	✓	✓	✓	✓	✓

* P-A = Presence-Absence; P = Presence only; RA = Relative Abundance.
# It is not necessary to utilise cage trapping if camera traps have been deployed.

8.1. Pitfall Trapping

8.1.1. Description and Purpose

Pitfall trapping targets small, predominantly ground dwelling amphibians, reptiles and mammals. The technique consists of buckets or PVC pipes dug into the ground so that their rim is flush with the surface. These buckets are connected by a vertical barrier (drift fence) that blocks the path of small animals, directing them towards the buckets until they fall in and are trapped. Many pitfall trapping designs have been used in surveys; from single buckets to multiple buckets arranged in differing configurations (e.g., Friend et al. 1994; Hobbs et al. 1994; Thompson et al. 2005). The design selected may be influenced by the habitat being surveyed or the target species. For example, 20 litre buckets tend to catch more reptiles, particularly larger lizards and geckos (Friend et al. 1989), whilst PVC pipes with a smaller diameter and deeper drop retain more small mammals (Thompson et al. 2005).

To standardise pit trapping across sites several aspects need to be considered: the type of drift fence, the number, size and arrangement of buckets and the duration of trapping. The recommended pitfall design targets predominantly reptiles (although also effectively traps small mammals and amphibians) and provides a good compromise in terms of effort with the side-arm design covering greater area and dimension. The recommended design has also been widely employed across Queensland and northern Australia (e.g., Gambold and Woinarski 1993; Kutt and Fisher 2011; Kutt et al. 2012). The 'T' design also appears to be the most effective configuration given an effort of four buckets and 50 m of drift fence (Kutt and Vanderduys 2014).

8.1.2. Design and Procedure

- Locate pitfall array near centre of generic survey site, offset by approximately 5 m to one side (see Figure 2 and Figure 3). Array can be placed in another location on site if the centre location is unsuitable (e.g., logs, rock outcrop, roots or ants nests).
- We recommend a "T"-shaped design (Figure 4) with four 20 L buckets.
- 7.5 m of drift fence (30 - 40cm high) between buckets with 7.5 m beyond the last buckets, utilising steel pegs to support the fence vertically.
- Open for four consecutive nights per survey period.
- Traps should be checked carefully 2–3 times a day with the first check within 2 hours of sunrise (this is important as captured nocturnal animals should not be exposed to dehydration and heat).

8.1.3. Ethical Considerations

- Traps must be thoroughly checked early in the morning before temperatures become too hot. This also reduces the risk of predation by diurnal predators such as goannas.
- Shelter should always be provided in the bottom of the buckets to reduce predation and exposure (heat, cold and dehydration) of trapped animals. Dehydration can be a problem, especially for amphibians, so measures should be put in place to reduce this risk (e.g., moistening the soil).
- Floats should be added to the bottom of buckets (e.g., piece of closed cell foam or cork) to reduce the risk of drowning from unexpected rain or storms. Buckets must be closed if they begin to fill with water and should not be reopened until the risk of drowning has passed.
- Ants predating trapped animals can be a problem so locate pitfall traps away from obvious ant nests and be vigilant for ant activity. If they become a problem (i.e., they are attacking captured

animals) and cannot be controlled through the use of low toxicity insecticides, then traps should be closed immediately.

- Consider weed and pathogen spread when using equipment in multiple locations as soil, seeds and spores can be transported in and on buckets, pegs and drift fence.
- Exercise caution when checking pitfalls as they will trap venomous animals including snakes and spiders. Personnel should be trained to remove venomous snakes.
- If a death occurs, trapping method is to be stopped at that site if any further mortality is considered likely. Trapping may only continue once amelioration methods have been implemented or prevailing adverse conditions have subsided. For example:

    (a) Cause of death: heavy rainfall filling trap causing drowning; Amelioration: ensure float in place at bottom of trap to assist animal to remain out of water or cease trapping until rainfall event has subsided.

    (b) Cause of death: ants/centipedes attacking trapped animals; Amelioration: ensure sufficient repellent applied around trapping site to minimise presence of ants and other invertebrate predators to the point where the possibility of attack is minimised.

    (c) Cause of death: trap received too much sun and heat during the middle of the day: Amelioration: ensure further shade provided to trap to ensure exposure is minimised.

If, however, the death is considered accidental/random and unlikely to occur again, trapping may continue.

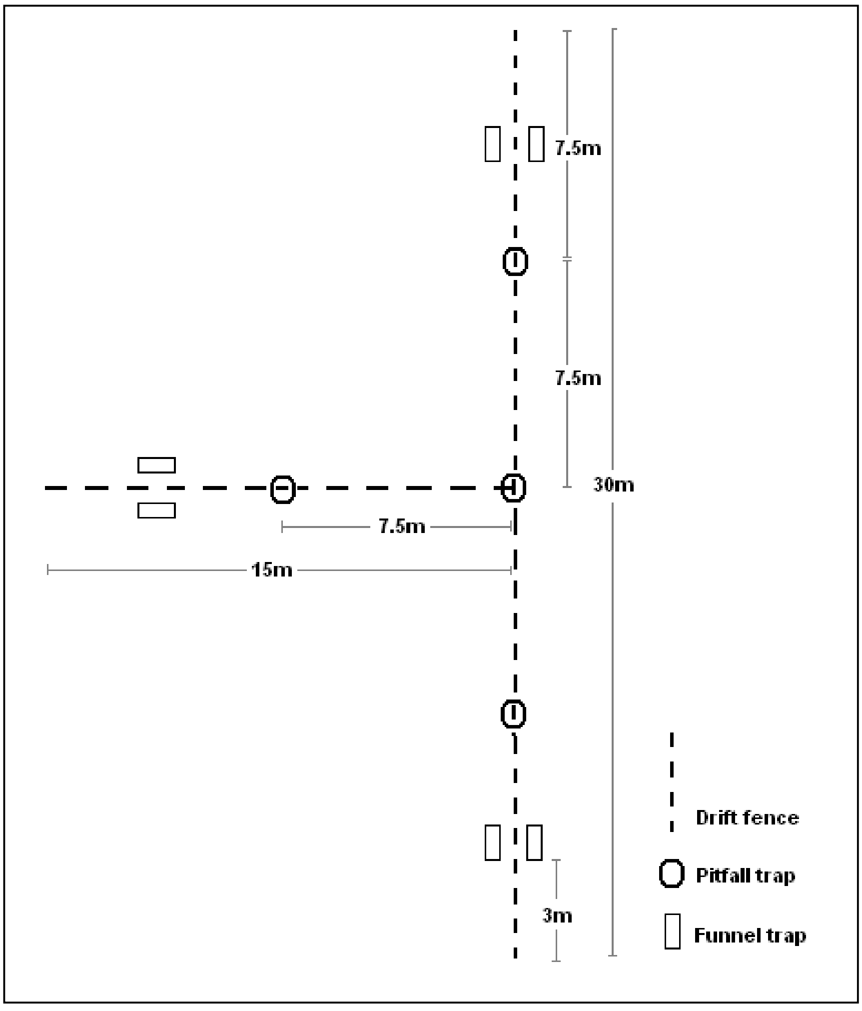


Figure 4: Pitfall and funnel trap array.

8.2. Funnel Trapping

8.2.1. Description and Purpose

Funnel traps are a funnel-shaped trap made from soft mesh (typically shade cloth) that directs animals into a holding area. This is difficult for herpetofauna to escape from due to the funnel shaped entrances (Figure 5). In a terrestrial situation funnel traps are usually used in association with a drift fence like in pitfall trapping. They can be added onto the pitfall array or used independently to target areas that may be challenging to install pitfall buckets.

Funnel traps are a useful addition to pitfall trapping as they catch a number of reptile species that can escape from pit buckets or species that simply rarely fall in. They are particularly useful for trapping snakes (elapids, colubrids and pythons), dragons (agamids), monitor lizards (varanids), larger ground skinks (e.g., *Ctenotus* and *Egernia*), large legless lizards and arboreal species that come to the ground to move around such as arboreal geckoes. While funnel traps are designed to target herpetofauna, they may also catch ground-dwelling birds, small mammals, and invertebrates.

To standardise funnel trapping across sites, similar aspects as in pitfall trapping need to be considered, including number of funnel traps; type of drift fence; length of fence and distance between funnel traps along the fence; and the duration of trapping. The recommended funnel trap design utilises the pitfall trapping array as these two methods complement each other to target a broader suite of herpetofauna.

Figure 5: Pit and funnel trap set up. Note the use of shades over the funnel traps.

8.2.2. Design and Procedure

- Locate six funnel traps with the pitfall array, in pairs; three metres from the ends of the drift fence (see Figure 4).

- Ensure traps are placed tightly against the drift fence with no gaps between the trap and fence, e.g., use drift fence pegs and tamp soil around the bottom edges.
- Open for four consecutive nights (as per pitfall trapping).
- Check funnel traps carefully 2-3 times each day with the first check within 2 hours of sunrise. Special attention should be given to the folded areas around the funnel entrance and to all seams. A good method is to hold the whole trap up against the light after the first check in situ.
- When checking funnel traps look out for holes made by small rodents that are occasionally trapped, and repair or replace trap immediately. Undetected holes will mean captured reptiles will escape.

8.2.3. Ethical Considerations

- Traps must be thoroughly checked early in the morning before temperatures become too hot. This also reduces the risk of predation by diurnal predators such as goannas.
- Always provide shelter over the top of the funnel traps to reduce exposure (heat, cold and dehydration) of trapped animals. We recommend at least 70% shade-cloth however silver roof insulation or dense vegetation are alternatives.
- Dehydration can be a problem, especially for amphibians, when humidity is low. Using vegetation cover or moistening the soil under the funnel can reduce this risk.
- Ants predating trapped animals can be a problem so locate funnel traps away from obvious ant nests and be vigilant for ant activity. If they become a problem (e.g., they are attacking captured animals) and cannot be controlled the traps should be immediately closed.
- Consider weeds and pathogens when using equipment in multiple locations as these can be transported and spread via dirty funnel traps.
- Take care when checking funnel traps as they may trap venomous animals; personnel should be trained in the removal of venomous snakes.
- If a death occurs, trapping method is to be stopped at that site if any further mortality is considered likely. Trapping may only continue once amelioration methods have been implemented or prevailing adverse conditions have subsided. For example:

    (a) Cause of death: ants/centipedes attacking trapped animals; Amelioration: ensure sufficient repellent applied around trapping site to minimise presence of ants and other invertebrate predators to the point where the possibility of attack is minimised.

    (b) Cause of death: trap received too much sun and heat during the middle of the day: Amelioration: ensure further shade provided to trap to ensure exposure is minimised. If, however, the death is considered accidental/random and unlikely to occur again, trapping may continue.

8.3. Active Diurnal and Passive Nocturnal Searches

8.3.1. Description and Purpose

Active searching primarily focuses on detecting reptiles and amphibians but will also detect small terrestrial mammals and signs of other somewhat cryptic species (e.g., tracks, scats, nests and feeding signs such as platelets of button quail).

Active searching involves scanning for active animals as well as turning rocks and logs, raking through leaf litter, looking under bark and in crevices and other suitable microhabitat for cryptic animals. During these searches other signs of animals (tracks, scats and other traces) should also be recorded where they can confidently be attributed to species. Nocturnal searches are also undertaken to detect those animals active during the night. These nocturnal searches are predominantly observational with little destructive searching and involves scanning for active reptiles, looking for eye-shine and listening for activity.

Observer bias in active searches is often underestimated; not only do some people possess or develop better search abilities than others, but there can be differences in the amount of time spent looking up or down, focusing near or far, or biases towards types of microhabitats searched (e.g., raking litter, versus peeling exfoliating bark versus looking under logs or rocks). With experience and training these biases can be reduced.

8.3.2. Design and Procedure

Active diurnal searches

- A minimum of two active diurnal searches are conducted per survey period.
- Each diurnal search is conducted for 30 person-minutes (generally two people for 15 minutes) during an appropriate time of day (not during extremely hot or cold periods).
- Diurnal searches are conducted on a 50 x 50 m area with each of the two searches conducted on different quadrants of the 100 x 100 m generic survey site. If revisiting the site during another season or survey period the remaining two quadrants should be actively searched.
- The two searches should be conducted on different days with at least one of the searches conducted in the morning, as the most productive time is generally in the morning when temperatures rise and reptiles are basking and starting to become active. This optimal window for searching will vary depending on the season and the weather on adjacent days.

Passive nocturnal searches

- Two nocturnal searches are conducted per survey period.
- Each nocturnal search is predominantly observational and conducted for 30 person-minutes.
- Nocturnal searches are conducted across the entire 100 x 100 m generic survey site.
- The two searches should be conducted on different nights although they can be within the same 24 h period as a diurnal search.

8.3.3. Ethical Considerations

- During active searches, always replace habitat to the best of your ability, such as re-rolling rocks and logs back into place and do not remove whole sheets of exfoliating bark if you can identify the animal without removing the whole section.
- If you are working in a fragile environment (e.g., sandstone escarpment) every attempt should be made to keep damage from actively searching to a minimum.
- Any captured animals should be released at the site of capture as soon as possible after identification.

8.4. Small Mammal Trapping

8.4.1. Description and Purpose

Small mammals are most often captured using collapsible aluminium box traps known as Elliott or Sherman traps. These are boxes of various sizes with a spring-loaded flap that is triggered to close when a pressure plate inside the trap is activated. Once baited, these traps are designed to target small to medium sized mammals (dependent on trap size) but will also occasionally trap reptiles, amphibians, and small birds (e.g., quails).

8.4.2. Design and Procedure

- 20 'Type A' (330 x 100 x 90 mm) Elliott traps (or equivalent) per generic survey site. Increased effort will be required to target threatened species occurring in an area (see Section 9.3).
- Place baited Elliott traps ten metres apart in two roughly parallel lines 25 m either side of the centre transect of the generic survey site, starting from five metres (Figure 2). In the case of a narrow, linear assessment unit place the Elliott traps approximately ten metres apart down the transect centre, starting from five metres (Figure 3). It is helpful to number all traps, to minimise the risk of accidentally missing a trap during trap checks.
- Locate each trap to reduce exposure of trapped animals to the sun, wind and rain (e.g., under shrubs or beside logs). This will also increase trap success (Tasker and Dickman 2001).
- Open for a minimum of four consecutive nights during a survey period.
- Traps can be baited with vegetable based and/or meat-based baits depending on the target species. Commonly used bait ingredients include peanut butter, rolled oats, honey (although may attract ants), vanilla essence, vegetable oil, aromatic oils (e.g., sesame oil, truffle oil or pistachio essence), fish (e.g., sardines) and commercial dry or moist pet foods. For general fauna surveys the recommended bait base ("universal bait") is rolled oats mixed with peanut butter to a consistency where they just hold together in a bolus (other ingredients can be added as desired).
- Check Elliott traps each morning within 2 hours of sunrise as per pitfall and funnel trapping. Elliott traps without adequate shelter should be closed and have the bait removed at this time to prevent animals entering during the day as the risk of heat exposure is particularly high. If there is any doubt the Elliott traps should be closed and reopened before dusk.

8.4.3. Ethical Considerations

- Captured animals must be protected from exposure to very hot, cold and wet conditions in traps. Traps heat up very quickly in the sun and must be cleared as early as possible after sunrise and preferably closed through the day.
- Take care not to block burrow entrances with traps.
- Add insulation material inside Elliott traps particularly when trapping during cold (< 10°C) and/or wet periods, to provide protective bedding for captured animals. Suitable insulating materials include coconut fibre or leaf litter. Avoid materials which will absorb moisture (e.g., cotton wool) or whose fibres will catch around feet (wool or polyester fibre).
- During wet periods, a plastic bag can be wrapped around the rear three-quarters of the trap, particularly where low overnight temperatures are expected. Slope traps to allow drainage.
- Ants predating trapped animals can be a problem so locate Elliott traps away from obvious ant nests and be vigilant for ant activity. If they become a problem (e.g., they are attacking captured animals) and cannot be controlled the traps should be immediately closed. Avoid using baits that attract ants if they become a problem.

- Corvids (crows and ravens) can be a predation risk as they quickly learn to open traps. Close Elliott traps if they become a problem.
- Appropriately dispose of bait, to avoid attracting feral animals.
- Maintain bait quarantine i.e., do not use baits removed from traps at one site at another site.
- If a death occurs, trapping method is to be stopped at that site if any further mortality is considered likely. Trapping may only continue once amelioration methods have been implemented or prevailing adverse conditions have subsided. If, however, the death is considered accidental/random and unlikely to occur again, trapping may continue.

Figure 6: Elliott traps set for small mammals. Note the trap placement in a shaded position (left), or with a cover of leaf litter for insulation in a more exposed position (right).

8.5. Cage Trapping

8.5.1. Description and Purpose

Cage traps come in many different sizes and designs (e.g., Cat, Possum, Bolton, Tomahawk), but are basically wire-mesh shaped to form a rectangular box. The trap has a door that closes when a baited trigger or a floor mounted pressure plate is activated. They are most commonly used to capture medium sized mammals. However, recent studies (e.g., de Bondi et al. 2010) have shown camera trapping to be more cost effective and successful for detecting medium to large sized mammals, and it is recommended that, if possible, camera traps are used instead of cage traps.

8.5.2. Design and Procedure

- Cage trapping is only required if not undertaking camera trapping or if demographic or life history information is required.
- At least one cage trap at the start of the Elliott trapping line (see Figure 2 and Figure 3), offset several metres from the centre line.
- Open for a minimum of four consecutive nights.
- Traps can be baited with vegetable based and/or meat-based baits, depending on target species. Commonly used bait ingredients include peanut butter, rolled oats, honey, vanilla essence, vegetable oil, aromatic oils (e.g., sesame oil or truffle oil), sardines, chicken and commercial dry or moist pet foods. For general fauna surveys the recommended bait base is rolled oats mixed with peanut butter to a consistency where they just hold together in a bolus (other ingredients can be added as desired) and/or chicken.
- Traps should be checked within 2 hours of sunrise and closed.

8.5.3. Ethical Considerations

- Avoid heat and sun exposure by clearing traps as early as possible after sunrise, and close traps through the day.
- Place shade-cloth, hessian sack or similar over the top of the cage to provide shelter and security for any captured animals.
- Be aware that some marsupials (e.g., bandicoots, potoroos) can eject young from the pouch upon release. Always check if the animal has pouch young, as a soft release may be necessary depending on the species. A soft release involves having the female and young in a hessian sack in a shaded/protected spot and allowing them to exit the bag in their own time.

8.6. Diurnal Bird Survey

8.6.1. Description and Purpose

The recommended diurnal bird survey technique is a non-intrusive active area search technique that provides a direct census of diurnal bird species occurrence and abundance. This method requires highly skilled observers with substantial experience in bird observation, species identification (both visual and auditory) and knowledge of Australian bird distribution and migration patterns. A high quality pair of binoculars (10 x 40 or 10 x 50 magnification) for each observer is essential. Bird activity during the day fluctuates widely, and the best time to survey is typically the early morning. Other factors such as inclement weather, particularly rain and wind, greatly reduce detection of bird species and surveys should not be conducted during such times. Nectar availability can also influence abundance and composition of nectar feeding diurnal birds (McFarland 1986; McGoldrick and Mac Nally 1998); therefore it is imperative to record the abundance of flowering at the survey site on the datasheet. If terrestrial island surveys are conducted, tide status should be recorded.

8.6.2. Design and Procedure

Diurnal bird surveys are conducted within the 100 x 100 m survey site by one observer for five minutes, on at least six occasions within a survey period. Longer (up to ten min) may be required in complex habitats. (NB this area/time search equates with the Birds Australia bird survey standard, which is a 2 ha search for 20 min). This survey approach is based on protocols used extensively throughout Queensland and Northern Australia (e.g., Woinarski et al. 2000; Hannah et al. 2007; Kutt et al. 2012). The recommended approach of repeated sampling over multiple days and at different times of the day has been shown to improve detectability and provide the best estimates of species richness at a site (Perry et al. 2012).

- Each site is surveyed for birds six times per survey period.
- Each survey involves the observer walking slowly and quietly through the site for five to ten minutes, looking and listening for birds, taking a different path on each occasion. Walking through the site tends to increase detection of cryptic species and also serves to flush ground-dwelling species (Craig 2004).
- Where practicable, two of the bird counts should be done in the early morning (< 2 h after sunrise), two in mid-morning (2 to 4 h after sunrise), and the remaining two during less optimal times in the day (between 4 h after sunrise and 2 h before sunset).
- Only birds seen or heard within the site are counted, avoiding counts of the same individuals more than once each survey. Aerial hunters/feeders/scavengers such as raptors, wood swallows and bee-eaters are included if they are hunting, feeding, or searching directly over the

site. Birds flying overhead can be recorded as ‘off-site’ and included with the incidental records for the survey area but should not be analysed relative to the survey site.

- To vary the survey times at each site, surveys should, where practical, be conducted in a different order each day.
- Surveys at each site should be spread over different days during the survey period and between different observers if more than one observer is present in a survey period.
- Avoid undertaking bird surveys during inclement weather, as this significantly reduces detection rates.

8.6.3. Ethical Considerations

- Avoid close range inspection of birds during breeding and feeding and resting at staging locations during migration.

8.7. Camera Traps

8.7.1. Description and Purpose

Camera trapping involves setting a fixed digital camera to capture images or video of animals which pass in front of the camera or are lured by bait. The most commonly used, cost effective, commercial camera traps use passive infrared (PIR) to detect heat and motion to trigger. These require a temperature differential between ambient and animal body temperature, combined with movement within the detection zone (Meek and Pittett 2012; Rovero et al. 2013). Other non-PIR triggering options are available and include: time lapse photography (often available on commercial available cameras with PIR), where an image is taken at pre-set time intervals; active infrared (AIR), where a beam between two AIR devices is broken (e.g., Hobbs and Brehme 2017); treadle or pressure plates, using the weight of an animal; seismic sensors (vibrations); magnetic circuit sensors; and normally-open-normally-closed switch sensors (Meek et al. 2012).

Camera trapping has become a mainstay technique used in Australia and around the world as a useful tool to aid in wildlife inventory, monitoring and research. It is a non-invasive survey technique ideally designed to detect medium to large sized animals as they pass, although it is possible to detect and accurately identify smaller animals with the correct survey design and equipment (Meek et al 2012, Gray et al. 2017, Welbourne et. al. 2020). Research indicates higher detection rates can be achieved for many medium to large sized mammals over some traditional techniques and should be utilised in preference to cage trapping for inventory surveys (de Bondi et al. 2010; Claridge et al. 2010). Camera traps have advantages over many of the traditional trapping techniques including the ability to be deployed for extended periods of time and the ethical benefits of not needing to capture and handle animals.

Camera trapping can be used for a wide range of purposes from targeting species (see targeted camera trapping Section 9.13) through to more generalist multi-species inventory surveys on the generic survey sites (Meek et al. 2012). Inventory surveys are typically implemented using PIR sensing cameras due to their commercial availability, cost effectiveness and set-up ease. There are currently two broad types of camera trap available: infrared flash and white flash (Meek and Pittett 2012; Rovero et al. 2013). Infrared flashes tend to be less obvious to wildlife than white flash, creating fewer disturbances, which is an important consideration for behavioural observations (Meek et al. 2012). There are pros and cons with both camera trap types and variation both within and between models and brands. White flash cameras provide full colour images, even at night, often with better resolution than infrared models (Meek et al. 2012). In Australia, this makes white flash cameras particularly useful as researchers often rely on colouration and pattern to differentiate many species, especially small mammals (Meek et al. 2012; Rovero et al. 2013).

Fauna species that are more reliably identified from images taken by infrared flash camera traps depends on the camera model features (e.g., sensor size, lens quality, shutter speed and aperture) and set-up, but generally include medium to large sized mammals (e.g., bandicoots, phascogales, quolls, macropods, foxes and cats) and medium to large reptiles such as monitors. With quality white flash cameras, a targeted set-up (focal length, detection area and settings) and experienced observers, many small animal (mammals, amphibians and reptiles) species can be readily identified (e.g., Nelson et al. 2010; Meek et al. 2012; Hobbs and Brehme 2017; Gray et al. 2017; Dundas et al. 2019; Welbourne et al. 2020).

Selecting camera trap type (infrared vs white flash), brand and model can be complicated and depends on the intended purpose (Meek et al. 2012; Rovero et al. 2013). Users should consult more detailed, up-to-date guides on characteristics of camera traps prior to purchasing equipment (e.g., Meek et al. 2012; Rovero et al. 2013) as the intended purpose and camera trap performance (e.g., Heiniger and Gillespie 2018) is important when deciding. Using the same camera model, settings and set-up is important if comparisons between sites are required (e.g., control and impact). Using different models of camera, or the same camera with different settings will result in biased data and misleading and inaccurate findings.

8.7.2. Design and Procedure

Camera technology is continually advancing, and these recommendations should be used as a starting point only and users should refer to current publications, guides and experienced practitioners to determine appropriate camera trapping designs and procedures for their specific needs.

- For inventory on standard sites, we recommended a white flash camera as the sharper, colour night-time images will aid in identification of small mammals, with an appropriate camera and setup. If only targeting medium to large animals or the survey area is known to have few or easily identified/differentiated (on size, shape, and body characteristics such as tail length) small animals then an infrared flash camera will be suitable. Whether an infrared or white flash camera is utilised should be decided on a case-by-case basis, depending on the desired project outcomes.
- Place at least one camera randomly on the 100 m x 100 m site. Additional cameras will increase detection rates and can reduce deployment times.
- Cameras should not be placed on an animal trail if results are to be used to compare relative abundance; however, animal trails are a good place to site cameras for inventory surveys.
- Avoid heavily vegetated areas as vegetation can cause false triggering or obscure animals in images. Some vegetation may need to be cleared. Where possible aim the camera in a southerly direction (or south-easterly) to avoid sun shining directly onto the camera lens and to reduce false triggers.
- Securely attach camera 30 – 50 cm from the ground on a tree or post, directed downward towards the bait which should be about 1.5 – 2 m from the camera and in the centre of the camera frame. A reference scale should also be included in the photo frame to aid in identification. Note that this set-up should be adjusted to achieve the best results from the model camera you use and the target species in the survey area. As a rule, the camera trap should be set at a height equivalent to the core of the target species' body (Meek et. al. 2012), with the distance from the bait matching the focal distance of the camera. The focal length on some camera model lenses can be modified (typically by the manufacturer or supplier) to

improve image quality at the desired focal distance and improve the identification likelihood for the size of the target species group (e.g., small mammals). Note that detection sensors (e.g., PIR) may also need to be modified to suit any new focal length.

- Camera traps should be deployed for as long as possible with a recommended minimum of four nights but ideally for longer than two weeks (Paull et al. 2011) and up to approximately five weeks (Kays et al. 2020). Long deployments should consider the change in detection probability associated with the bait deployment time and consider the potential benefits of replenishing bait (Gray et al. 2017).
- Ensure the camera programming is consistent across all cameras to be deployed (e.g., sensitivity settings, numbers of photos per trigger and interval between photos, image size or video length). Also, to make the data collected as useful as possible, try to set up the cameras in a consistent manner to maintain similar detection probabilities (Meek et. al. 2012).
- Cameras can be baited with vegetable based and/or meat-based baits depending on the target species and personal choice (e.g., two cameras could be installed at each site but baited differently). Commonly used bait ingredients include peanut butter, rolled oats, honey, vanilla essence, vegetable oil, aromatic oils (e.g., sesame oil or truffle oil), sardines, chicken and commercial dry or moist pet foods. For surveys on the generic survey sites the recommended bait base is rolled oats mixed with peanut butter (Paull et al. 2011; Rendall et al. 2021) to which other ingredients can be added as desired. Commercially available pheromones can also be sprayed near the bait to lure in feral animals such as foxes; these are a recommended addition.

8.7.3. Ethical Considerations

- Using bait, or the presence of the camera (noise, shining in the sun, flashes) may alter behaviour or increase predation risk, so long deployments should monitor this risk.
- The bait cage, if employed, should be designed to ensure animals cannot injure themselves (e.g., potential tooth damage). We recommend a PVC container with fine stainless-steel mesh or similar, pegged to the ground or accessible bait fastened in place so that the bait remains in the camera frame for an extended period.

8.8. Acoustic Recording

8.8.1. Description and Purpose

Sound recordings of animals (e.g., bats, arboreal mammals, birds, frogs, insects) and the environment help ecologists identify species, monitor species populations, assess species diversity, track changes that occur in biota through time and across landscapes and to understand possible reasons behind change. Recordings can be used to understand the behaviour of animals or identify long term environmental change, either due to negative effects (e.g., habitat loss or climate change) or positive factors (e.g., habitat restoration or remedial works). Both audible and ultrasonic sounds are of value. Ultrasonic sounds are dealt with under sections 8.11 and 9.7 of this guide.

Hand-held acoustic recording (active recording) and automated acoustic recording of audible sounds (passive recording; Section 9.14) can each play a part in the study of natural systems, and while hand-held recorders allow focussed effort, good quality recordings and personal context, automated recordings permit acoustic surveys to be undertaken for extended periods of time simultaneously over broad areas, thus increasing the opportunities to discover rare or inconspicuous species and environmental events.

Recording can be used as a general survey technique to identify all vocalising species, but this is generally not undertaken because of:

- the vast volumes of data requiring analysis and the time required to do so in terms of person hours
- lack of automated identifiers for more common species
- the variety of calls given by many species
- mimicry by some species which can be confusing.

Recording surveys are useful when it comes to the identification of single or a few species or rare and threatened species. The study of single or a few species might be considered restrictive, but it is more manageable. Ultimately the level of focus hinges on the aims of the study.

A field of science which has grown in the past decade because of improved technological solutions is that of soundscape ecology or eco-acoustics. This science examines the soundscape, which can be considered as a collection of acoustic events that occur in any given location. These acoustic events are of:

- biological origin, animal vocalisations
- natural but inanimate origin, such as rain, thunder, wind, surf
- human origins, such as speech and
- machine origin, for example planes.

Soundscape ecology/eco-acoustics studies collections of sounds and seeks to understand the interactions between sounds within soundscapes, the differences between soundscapes and the role that underlying ecosystem processes play in determining the qualities of a soundscape (e.g., Tucker et al. 2014). Acoustic indices are frequently used as a means of summarising the information contained within a soundscape. An acoustic index is essentially a statistic, that is, a single value to summarise some aspect of the distribution of acoustic energy in a recording.

8.8.2. Design and Procedure

Decide target species, community, scale of study that is required. This will permit selection of type of recording equipment and quantity of gear required. Recordings may last just seconds or may occur over extended periods.

Analysis of sound recordings is typically carried out using spectrograms. There are numerous off the shelf computer packages that convert sounds to these visual, two-dimensional representations of sound known as spectrograms. These plot time on the x-axis and frequency on the y-axis. Sound amplitude is typically represented within the intensity of colour within the spectrogram. A waveform plot can further provide information on the intensity of sound.

Spectrograms assist the location of calls within the sound palette and determination of origins, e.g., species, natural condition, wilderness application. Species identification will be for individual species, target species or communities depending on the aims of the study. Soundscape analyses may be used to identify ecological processes and change.

8.8.3. Ethical Considerations

Recording of sounds is usually non-invasive and unobtrusive, but there may be brief disturbances associated with deployment.

8.9. Call Playback

8.9.1. Description and Purpose

Many nocturnal bird species occur in naturally low population densities, are wide-ranging, and call infrequently (Kavanagh and Peake 1993). Hence, detection can be haphazard without play back of pre-recorded calls to elicit a response (Kavanagh and Peake 1993; Debus 1995). The use of large owl call playback more than doubles the detection rate of most large owl species (Debus 1995). Detectability of smaller nocturnal bird species such as southern boobook *Ninox novaeseelandiae* and Australian owlet nightjar *Aegotheles cristatus*, and the arboreal marsupial yellow-bellied glider *Petaurus australis* also increase with playback of large owl calls. Smaller, cryptic arboreal species such as squirrel glider *P. norfolcensis* and sugar glider *P. breviceps* can also respond to owl call playback.

Seasonality appears to have minimal effect on response rates, at least for large owls (Kavanagh and Peake 1993; Loyn et al. 2002) and yellow-bellied gliders (Eyre 2007). However, in southeast Queensland, November to March is recommended as the best time to target marbled frogmouth *Podargus ocellatus plumiferus* populations by call playback (Smith and Hamley 2009).

8.9.2. Design and Procedure

- Conduct the call playback session at the centre of the generic survey site.
- Perform a call playback session on two occasions, on different nights, at each site during the survey period. Where practical, conduct one session within one hour of dusk, and the second session more than one hour after dusk.
- Do not undertake call playback sessions during inclement weather, as this significantly reduces responses, as well as reduces observer capacity to hear responses.
- The recommended species calls to play within each bioregion and habitat type are shown in Table 5. These species are typically rare in the landscape and call playback increases their detectability. If desired, additional nocturnal calls can also be broadcast to detect other nocturnal birds and mammals (e.g., koala, sugar glider, squirrel glider, yellow-bellied glider, brush-tail possum, barn owl, tawny frogmouth, bush stone-curlew, frogs).
- Begin with a five minute listening period for un-elicited calls, followed by broadcasting of pre-recorded calls of each species that could possibly occur in the area based on the bioregion and habitat type (Table 5). If the call of powerful owl *Ninox strenua* is to be played, then it should be played earlier in the sequence, as its call does not appear to inhibit responses by other species. If the call of masked owl *Tyto novaehollandiae* is to be played, then it should be played later in the sequence due to its often quieter response. If marbled or Papuan frogmouth *P. papuensis* calls are to be played, they should precede any owl calls.
- Play each call for three minutes, followed by a two minute listening period.
- Calls need to be played loud enough so that the softest call (e.g., masked or grass owl) can be heard 100-200 m away.
- Following the sequence of playback calls, listen for calls and spotlight the area for five minutes.
- In many instances, call response can be delayed by up to half an hour. Therefore, we recommend conducting the call play back session before the spotlight session (Section 8.10), to increase the likelihood of hearing a delayed response.
- Calls heard can be recorded on the datasheet as on-site (within the 100 x 100 m area), near site (within 50 m of the boundary of the site) or offsite (> 50 m of the boundary of the site).

Table 5: Recommended species calls to play within each bioregion and habitat type.

Species	Bioregions to target*	Habitat type to target
powerful owl	NET, SEQ, BRB, CQC	Wet sclerophyll, dry sclerophyll and rainforest types adjacent to sclerophyll forest.
rufous owl	BRB (north), CQC, EIU, WET, CYP, GUP (coastal)	Closed forests (RF types, riparian monsoonal forest etc); more open forests (wet or dry) adjacent to the closed forest types.
barking owl	All bioregions but rare and localised in SEQ, CHC, MGD	Large variety of forests and woodlands. Usually adjacent to watercourses in drier regions. Not usually associated with wet forests or rainforest.
masked owl	NET, BRB, SEQ, CQC, DEU, EIU, CYP, GUP	Large variety of forests and woodlands, therefore play call in all wooded habitats.
sooty owl	SEQ, BRB (far south-east), CQC, WET	Rainforest types and wet sclerophyll.
grass owl	All bioregions (irruptive and nowhere abundant)	Dry and wet heathlands, grasslands, crops.
marbled frogmouth	SEQ CYP	Subtropical rainforest Riparian monsoon forests and rainforests and adjacent *Melaleuca* / eucalypt woodlands.
Papuan frogmouth	CYP, WET	Rainforest and monsoon forests and adjacent wet sclerophyll forests; mangroves.

*See Table 2 for full names of Bioregional abbreviations.

8.9.3. Ethical Considerations

Limit call playback sessions to one per night per site, to avoid significant disturbance to normal behaviour of nocturnal animals, particularly during the breeding season.

8.10. Spotlight Search

8.10.1. Description and Purpose

Spotlighting along a walked or driven transect is a well-used method to obtain estimates of nocturnal arboreal mammal incidence and abundance in wooded habitats (Braithwaite et al. 1988; Goldingay and Sharpe 2004). Spotlighting also targets medium to large terrestrial nocturnal mammals such as bettongs and quolls. Other nocturnal taxon groups can also be detected during a spotlight transect (e.g., frogs, geckoes, nocturnal snakes, nocturnal birds, small terrestrial mammals, spiders), however the spotlighting method described here specifically targets arboreal and large terrestrial mammals, because these taxa are not readily detected by other standard methods (except for camera traps for medium to large terrestrial mammals).

The recommended spotlighting survey technique at the generic survey sites is a non-intrusive search that will provide information on arboreal and volant mammal species occurrence and relative abundance. We recommend a high-quality pair of binoculars (e.g., 10 x 40 magnification) for each observer.

A host of different factors affect the detectability of mammals during spotlighting; so understanding the target species' behaviour, life histories and ecology will improve the survey methodology (see

Wayne et al. 2005 for review). The probability of detecting nectarivorous species such as the *Petaurus* spp. (sugar, squirrel, mahogany and yellow-bellied gliders) and flying foxes increases significantly if the overstorey trees are in flower. Arboreal marsupials can have differing diel activity periods, e.g., yellow-bellied gliders are more likely to be detected close to dusk (Eyre 2007), green ringtails *Pseudochirops archeri* are most active in the two hours before dawn (Proctor-Gray 1984). Season, weather, and moon phase also affect different species in different ways (see Wayne et al. 2005). Bright moonlight lowers detectability for ringtail possums *Pseudochirops* and *Pseudochirulus* spp. in the wet tropics (Laurance 1990) and greater *Petauroides volans*, sugar and feathertail gliders *Acrobates* spp. in southern Queensland (Eyre 2004). Therefore, to reduce variation in the data because of survey conditions, repeat traverses of transects is highly recommended (Goldingay and Sharpe 2004).

Thermal imaging devices (see Section 9.20) are increasingly being used in combination with standard spotlighting searches (e.g., Augusteyn et al. 2020; Pocknee et al. 2021; Underwood et al. 2022). This trend will no doubt increase as the technology continues to advance.

8.10.2. Design and Procedure

- Spotlighting surveys are conducted within the 100 x 100 m generic survey site for 30-person minutes. Carry binoculars to assist with species identification. More than one observer can spotlight the site at the one time (e.g., two observers spotlight the site for 15 minutes).
- Survey each site by 30-Watt spotlight on two occasions during the survey period on different nights, once close to dusk (< 1 h after dusk) and once later (> 1 h after dusk), typically after the call playback session (Section 8.8).
- Do not undertake spotlighting surveys during inclement weather, as this significantly reduces detection rates. If this is unavoidable, record prevailing conditions on the datasheets.
- Spotlighting often relies on the detection of eye shine, which can be difficult in densely vegetated sites. Record an index of vegetation density on the associated datasheet.
- Each spotlight survey involves an observer/s walking slowly and systematically through the 100 x 100 m generic survey site (e.g., spotlighting up and back the middle 100 m transect in sparsely vegetated sites, or spotlighting up one side of the 100 m x 100 m area and then spotlighting back the other side of the 100 m x 100 m area in more densely vegetated sites).
- If the site is lacking woody vegetation (e.g., a grassland, a cleared paddock or an arid regional ecosystem), then it is acceptable to reduce the effort spent spotlighting the site. In these situations, a 10-person minute search is sufficient. It is important to note this on the datasheet.
- Animals seen or heard can be recorded as on-site (within the 100 x 100 m area), near site (within 50 m of the boundary of the site) or offsite (> 50 m from the boundary of the site).

8.10.3. Ethical Considerations

- Be aware that exposure to white light temporarily reduces the night vision of birds and mammals, potentially interfering with foraging ability (e.g., nocturnal birds feeding nestlings) and increasing predation risk.
- Avoid prolonged exposure of animals to the spotlight beam: use the direct beam only to locate the animal. For longer observation periods, dim the light, or point the main beam of light away from the animal, or use an infrared beam/red filter or a thermal or night vision device.

8.11. Microbat Echolocation Call Detection

8.11.1. Description and Purpose

Microbats typically rely on echolocation for orientation and foraging in flight. These echolocation calls are usually well above the frequency range audible to humans, but can be used to survey microbats. Bat detectors are a non-invasive method designed to record the echolocation calls emitted by bats as they fly past a microphone. These recordings can then be viewed as sonograms and analysed using appropriate software by experienced personnel to identify species or species groups. Bat detectors are an appropriate tool for species inventory, assessing levels of bat activity, and can be used to monitor the use or occupancy of different habitats through time.

There are a number of different types of bat detector commercially available, which are suitable to survey bat fauna. Bat detectors use one (or more) of four basic techniques (heterodyne, frequency-division, time expansion or direct sampling) to detect and record bat echolocation calls. Some modern detection equipment enables all four of these techniques using only a single unit. Older equipment may be limited to only one or two. An understanding of the four techniques is necessary to allow the user to select suitable equipment. These techniques are briefly described below.

Heterodyne

This is the simplest method for detecting bat echolocation calls. The detector is manually tuned to a target frequency so that only a narrow range of bat echolocation call frequencies (within a 10 kHz bandwidth of the tuned frequency) will be detectable and made audible in real time (Pettersson 2004a). This is achieved using a variable-frequency oscillator and mixer circuit (Limpens and McCracken 2004). In some models of heterodyne detectors an automated scanning function is available. Bat species are then identified in the field based on a combination of echolocation call frequency, sound, and the appearance and flight behaviour of the bat (Limpens 2004). This can require considerable experience on the part of the observer (Limpens 2004). In addition, the signal cannot be recorded in a form that would allow independent verification of the species identification or record. Therefore, heterodyne bat detectors should be used only to augment other recording techniques and are best used in order to actively target particular species of interest.

Frequency Division

In bat detectors using Frequency Division, incoming signals are converted to a square wave and divided by a constant factor known as the division ratio (this also makes the ultrasonic signals audible). Bat echolocation calls are typically composed of a fundamental frequency and one or more harmonics. This technique does not retain information on the amplitude (loudness) of the call, and only the loudest or dominant component of the call will be processed (usually the fundamental frequency but can be the strongest harmonic present instead) (Corben 2004; Pettersson 2004a). However, such detectors have the ability to monitor a broad band of bat echolocation call frequencies in real time, whilst recording the frequency and timing parameters necessary for differentiating or identifying bat calls to species in a manner that requires low computing power and storage requirements (Corben 2004; Messina 2004). This makes them well suited for multi-species surveys and both active and passive monitoring (Walsh et al. 2004).

Zero-Crossings Analysis is often used in conjunction with Frequency Division in order to visually display bat calls at the original frequency for analyses. The time intervals between successive zero crossings of the digitised square wave are measured, and the frequency computed from the reciprocal to produce time by frequency graphs (Corben 2004). A familiar Australian example of a detection system using both Frequency Division and Zero-Crossings Analysis techniques would be earlier versions of Anabat (Titley Scientific). Current equipment from this company adds the ability to use all four techniques detailed in this section

Time Expansion

Time Expansion is a technique that preserves and records the harmonic, amplitude, pulse structure and timing information (full spectrum) of the detected bat echolocation calls. The detected signal is stored in a looped memory, and played back at a slower speed in order to record it. Playback is slowed by a constant factor, usually 10, so that a 1 second capture of ultrasound will be played back over 10 seconds, reducing the frequency components of the call by a ratio of 10 (Ahlén 2004). The resulting signal will obviously be longer and the frequencies correspondingly lower than the original. 'Slowing down' the signal requires a lower sampling rate, circumventing the high data processing requirements necessary to record full spectrum bat calls (BCM 2012), which was a problem in the past (see below). These detectors also have the ability to monitor a broad band of bat echolocation call frequencies at once, making them suitable for multi-species surveys (Walsh et al. 2004), but the calls are not audible in real time. In addition, they can only monitor calls for a small portion of the time, as new calls cannot be record while the playback/recording process is occurring (Limpens and McCracken 2004; Jones et al 2004). This can result in missed species if bat activity is particularly high (Messina 2004). Time expansion is often used in conjunction with heterodyne of frequency division techniques in order to use the system for active monitoring.

Direct Sampling

Echolocation calls emitted by bats can also be sampled directly without being transformed first by the bat detector. This technique preserves and records the harmonic, amplitude, pulse structure and timing information (full spectrum) of the calls instantaneously (BCM 2012). These detectors have the ability to monitor a broad band of bat echolocation call frequencies at once, making them suitable for multi-species surveys (Walsh et al. 2004), and can be used for both active and passive monitoring. However, as this is a direct recording technique, the bat calls will not be audible in real time without transforming the signal in some way first (ie by combining this technique with heterodyne or frequency division). Recording echolocation calls directly requires high speed sampling (usually > 300 kHz, but preferably 500 kHz) and a large memory or storage capacity (Pettersson 2004b; Agate 2008). For example, a 500 kHz sampling rate with 12 bit resolution will require 1 GB of storage space for every 35 minutes (Waters and Gannon 2004). In the past, such a system was not particularly convenient to use in the field because of the expense, computer processing power, and the high digital storage capacity required (Waters and Gannon 2004). Now there are several commercially available bat detector systems that have incorporated high speed sampling hardware into a small, power efficient package that can be field deployed (e.g., equipment produced by Titley Scientific, Pettersson Elektronik, Wildlife Acoustics, and others), and which take advantage of the falling costs of flash memory and miniaturisation of components.

The choice of bat detector (heterodyne, frequency-division, time expansion or direct sampling) used to sample the bat fauna, will depend on the purpose and design of the survey or research, how the detector is to be deployed (passive or active), personnel, budgetary and time constraints (Limpens and McCraken 2004; Walsh et al. 2004). Regardless, bat detectors must be used with an understanding of their limitations (e.g., detector frequency response, climatic variables and their influence on call detection volume, species call intensity), deployed in a way that maximises the possibility of making high quality recordings of the greatest number of species (or in a way that maximises the detection of targeted species). Identifications made from acoustic recordings must also be made in a manner that is justifiable and allows independent verification (see Section 11.4).

Bat detectors are quick and easy to set up in the field (without specialist training) and can be automated to run unattended for extended periods (one or more nights) allowing multiple sites to be sampled simultaneously. Depending on the quantity and quality of data recorded, a substantial amount of time and/or expense (if outsourcing call identifications) may be required to analyse the recorded echolocation calls in order to identify species. The identification of echolocation calls to species requires prior knowledge of the bat species present within the area of interest. It also requires considerable expertise, including a sound understanding of bat ecology as well as a good knowledge of the call repertoires of species in the survey region, via access to, or development of, a regional library of reference calls (library of bat calls recorded from individuals identified in the hand, showing call variability for an area).

Reference calls can be collected using a hand held bat detector and spotlight after releasing a captured bat. Using a hand held detector will result in higher quality recordings of bat calls than other techniques, as the bat detector can be orientated towards the bat and allows the freedom of movement to follow bats on foot.

It should be noted that not all bat species can be easily distinguished by their calls, with identification to species level being difficult or impossible in some cases. In these situations it is acceptable to group species at the genera level (e.g., *Nyctophilus* spp.) or into a species complex (e.g., *Scotorepens greyii/Mormopterus eleryi*). Targeted bat trapping techniques (see sections 9.10, 9.11 and 9.12) can also be useful in distinguishing many of these species. Targeted trapping also aids in the detection of bat species that emit low-intensity echolocation calls, as these species need to be close to the microphone to be detected and are therefore under-represented in surveys that rely solely on bat detectors (de Oliveira 1998; Lawrence and Simmons 1982). Therefore targeted capture techniques used in conjunction with bat detectors are recommended across the survey area. Microbats typically rely on echolocation for orientation and foraging in flight. These echolocation calls are usually well above the frequency range audible to humans, but can be used to survey microbats. Bat detectors are a non-invasive method designed to record the echolocation calls emitted by bats as they fly past a microphone. These recordings can then be viewed as sonograms and analysed by experienced personnel to identify species or species groups.

8.11.2. Design and Procedure

- The way in which the bat detector is set up on a survey can significantly affect the quality of the dataset (see Weller and Zabel 2002), as can the type of weather proofing used to protect the microphone in passive setups (Britzke et al. 2010, Corben 2011).
- At generic survey sites we recommend a passive monitoring approach, i.e. setting the bat detector up to automatically monitor and record bat calls unattended.
- Set one bat detector on the generic survey site to record continuously for a minimum of three nights (dusk until dawn) during each survey period. NB: while this effort may be adequate for species inventory, measures of bat activity and monitoring of populations will require more than six to eight full nights of sampling per site (Hayes 1997, Fischer et al. 2009).
- The recommended placement is at the centre of the survey site, elevated off the ground and orientated in the direction with the least amount of vegetation. The bat detector should be relocated if the centre of the site is unsuitable (e.g., dense vegetation). If using detectors which allow only frequency division (e.g. early Anabat), set the division ratio to 8 rather than 16.

- Where practical avoid carrying out call playback surveys on the same nights the bat detector is deployed.
- It is vital to calibrate bat detectors prior to the survey to achieve a uniform detection range and sensitivity among units. For an example see Larson and Hayes (2000).
- Sample during warm, calm, dry nights wherever possible. Time periods should be extended if sampling is affected by adverse weather conditions (very cold, very wet or very windy) (Hayes 1997; Hayes 2000; Milne et al. 2005; Fischer et al. 2009).
- Sites from different types of assessment units or 'Impact' and 'Control' sites should be sampled simultaneously if data are to be statistically compared during the analysis. This will depend upon the objectives of the assessment.

8.11.3. Ethical Considerations

- Nil animal ethics issues. Bat detectors are non-invasive and unobtrusive.

8.12. Scat and Sign Search

8.12.1. Description and Purpose

Secondary signs of animals provide indirect records of the activity of a species at a site and include tracks, scratches, feeding marks, scats, nests or roosts, hair or feathers and bones or carcasses. Observation of secondary signs usually occurs opportunistically while undertaking survey activities on generic survey sites or targeted sites, or generally within the survey area when travelling between sites. Records of secondary signs provide information on species presence only, not presence/absence data or abundance data. An index of activity, incidence or abundance can be derived if systematic methods are used such as scat counts or sand plots (see Section 9.5).

Gathering physical evidence of the secondary sign is highly recommended particularly if identification to species level is equivocal, and/or the secondary sign is suspected to have been caused by a significant species.

8.12.2. Design and Procedure

The design and procedure for observing and recording common kinds of animal secondary signs in Queensland are each described in more detail below.

Tracks

Tracks can be in the form of foot prints or drag marks (e.g., snakes), left in soft substrate such as mud or sand. Foot prints, if identified to species level, are a useful way of determining whether a species is present at a site or within the survey area. The substrate and amount of vegetation cover on the site will determine how conducive the site is to detecting animal presence by tracks. In most cases, tracks will mostly be observed along unpaved roads throughout the survey area, unless sand plots are used in strategic areas (Section 9.5). Even experienced personnel may have difficulty in accurately identifying tracks to species level, particularly if the substrate is particularly soft or hard (this changes the shape of the print). Digital photographs of tracks (with scale e.g., coin, ruler, lens cap) should be taken as a record, and may be interrogated by additional experts to assist with identification. Tracks are best viewed early in the morning or late in the afternoon when long shadows give the track more depth and detail. Systematic searches can be carried out in the 100 x 100 m area in 15 person-minutes (see Moseby et al. 2012).

Scats

For many animals, scats can be a characteristic size and shape which allows them to be identified to species level (Triggs 2004). If scats can be identified to species, then scat counts can provide an estimate of a species relative abundance if counted within a specified area such as the 50 x 50 m active diurnal reptile search plot area at each generic survey site. Scats, or faecal-pellets, from koala *Phascolarctos cinereus* found at the base of trees are often used as evidence of koala presence, or presence-absence if a systematic approach is used (e.g., Callaghan et al. 2011). Scats found incidentally on a survey site or within the survey area can be used as an indication of species presence on the site or within the survey area.

Scats from some species can be aggregated in localised latrine sites (e.g., yakka skink *Egernia rugosa*, Figure 7). Latrine sites provide an excellent means for indication of species presence but not relative abundance. Analysis of contents within predator scats can be useful in determining the presence of prey species which may otherwise remain undetected within the survey area (Paltridge 2002).

If physical evidence is required or if scats cannot be identified in situ, then collect a sample in a sealed bag or jar, and/or take photographs with scale (e.g., lens cap, pencil, ruler or coin) with notes on its location (e.g., under log, latrine site). If scats are to be collected then take precautions (see Section 7.1) to minimise exposure to disease (e.g., zoonoses such as Toxoplasmosis).

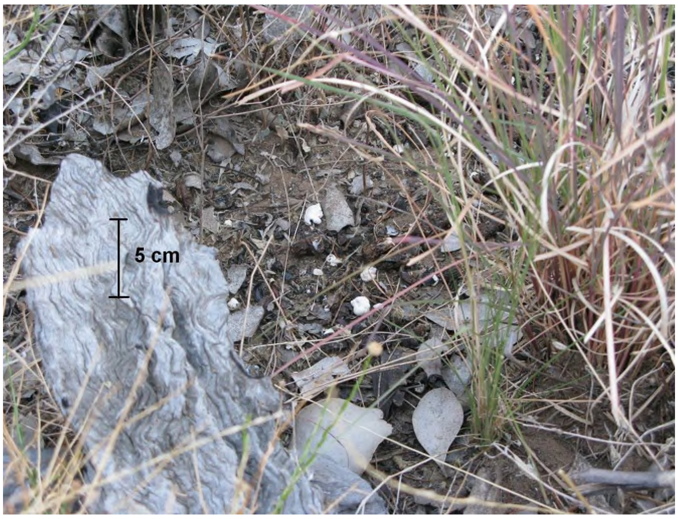


Figure 7: Latrine site of the yakka skink.

Feeding marks on trees

Some species leave distinctive feeding marks on the trunks of trees. This is particularly the case of the *Petaurus* spp. including the mahogany, squirrel, sugar and yellow-bellied glider (Goldingay 2000; Jackson 2001; Ball et al. 2009). These gliders use their teeth to incise tree bark for sap-feeding. Yellow-bellied gliders tend to make the largest and most distinctive marking on trees, typically V-shaped incisions, which facilitate sap flow (Figure 8). Yellow-bellied glider feed-marks have been effectively used to determine the distribution of the species throughout its range (e.g., Mackowski 1986; Bradford and Harrington 1999; Eyre and Goldingay 2005). However, it is important to make a note of the activity status of any feed marks, as they can persist for a long time and, if long inactive, may not be a good indicator of glider presence. Feed marks can be determined as potentially active if the edges of the marks are furred, sap looks white and encrusted, and fresh scratch marks are evident around the incision (Figure 8a). Feed marks that have been used recently (i.e. within the last three months) usually have a reddish sap crystallising from the feed marks, and the development of scar tissue around the incision may be evident (Figure 8b). Feed marks that are not being used (inactive) by gliders are often partially or fully covered over with scar tissue (Figure 8c, d and e).

In Queensland, particular tree species have been identified as important for yellow-bellied gliders for sap feeding (Table 6). If these tree species are encountered during a survey, they should be closely inspected for signs of yellow-bellied glider sap feeding. Take photographs (with scale, e.g., lens cap or coin) of any marks suspected to be signs of feeding for confirmation by experts, if needed.

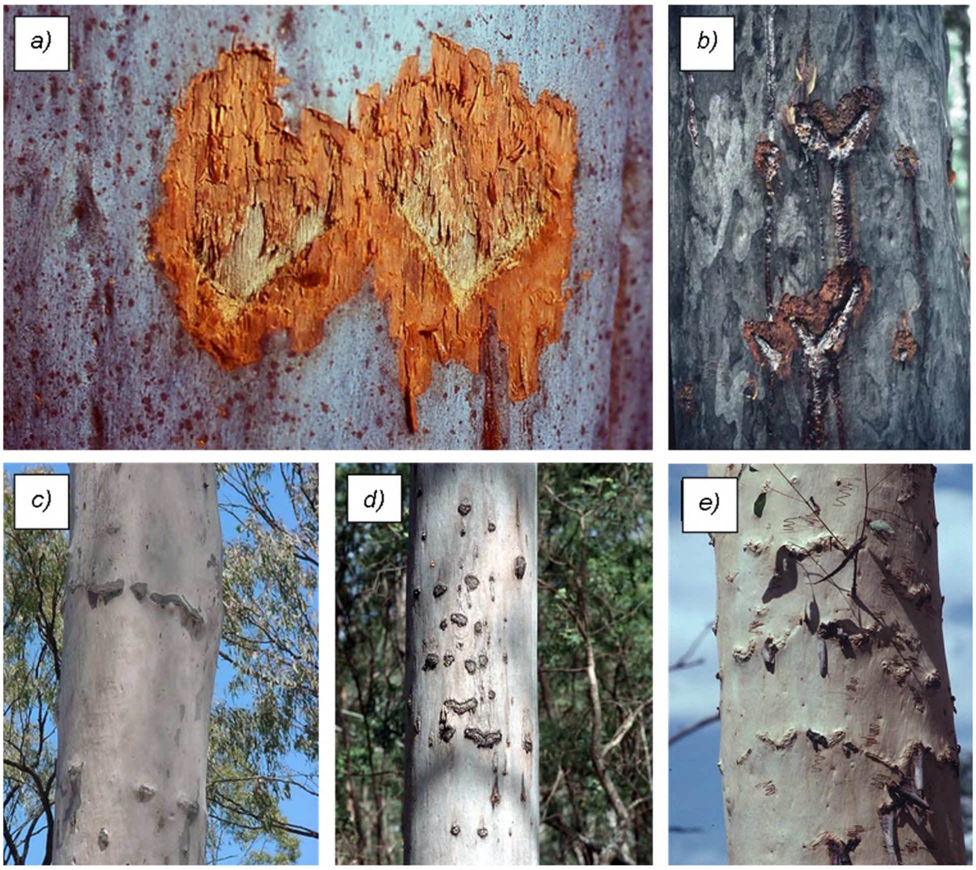


Figure 8: Feed-marks made by yellow-bellied gliders in Queensland for sap feeding; a) active feed marks in spotted gum *Corymbia citriodora*; b) recently active feed marks in *C. citriodora*; and inactive feed marks in c) *C. citriodora*; d) grey gum *Eucalyptus longirostrata*; and e) scribbly gum *E. racemosa* (Eyre and Goldingay 2005).

Table 6: Tree species utilised for sap feeding by yellow-bellied gliders in Queensland.

Tree species	Common name	Bark type	Region where used for sap
Angophora leiocarpa	**smooth-barked apple**	**gum**	**Southern and central Qld**
Corymbia citriodora	**spotted gum**	**gum**	**Southern and central Qld**
Corymbia intermedia	**pink bloodwood**	**bloodwood**	**Southern and central Qld**
Eucalyptus biturbinata	**grey gum**	**gum**	**Southern and central Qld**
Eucalyptus grandis	**rose gum**	**gum**	**Central and occasionally southern and northern Qld**
Eucalyptus longirostrata	**grey gum**	**gum**	**Southern and central Qld**
Eucalyptus major	**grey gum**	**gum**	**Southern and central Qld**
Eucalyptus melliodora	**yellow box**	**gum**	**Southern Qld**
Eucalyptus moluccana	**gum-topped box**	**gum**	**Southern and central Qld**
Eucalyptus tereticornis	**forest red gum**	**gum**	**Southern and central Qld**
Eucalyptus racemosa	**scribbly gum**	**gum**	**Southern and central Qld**
Eucalyptus resinifera	**red mahogany**	**stringybark**	**Central and northern Qld**
Eucalyptus laevopinea	**silvertop stringybark**	**stringybark**	**Central Qld**
Eucalyptus sphaerocarpa	**Blackdown stringybark**	**stringybark**	**Central Qld**

(Based on Quin et al. 1996 and Eyre and Goldingay 2005).

Scratches on trees

Arboreal mammals and large, arboreal varanids often leave scratch marks on smooth-barked trees, which are made by their claws as they climb up the tree. Small arboreal mammals (feathertail gliders and sugar gliders) rarely leave scratch marks on trees, and marks left by larger possum, glider and varanid species are usually difficult to accurately attribute to a particular species. However, scratch marks made by koalas can be distinctive. This is because, on the front paw of a koala, two digits are opposed to the other three. They also tend to leave pock-like marks from their sharp claw-tips when they hold on to a tree (Figure 9). If scratch marks are found that are thought to have been caused by a koala, then it is recommended that photographs (with scale e.g., coin, lens cap, ruler) are taken for confirmation.

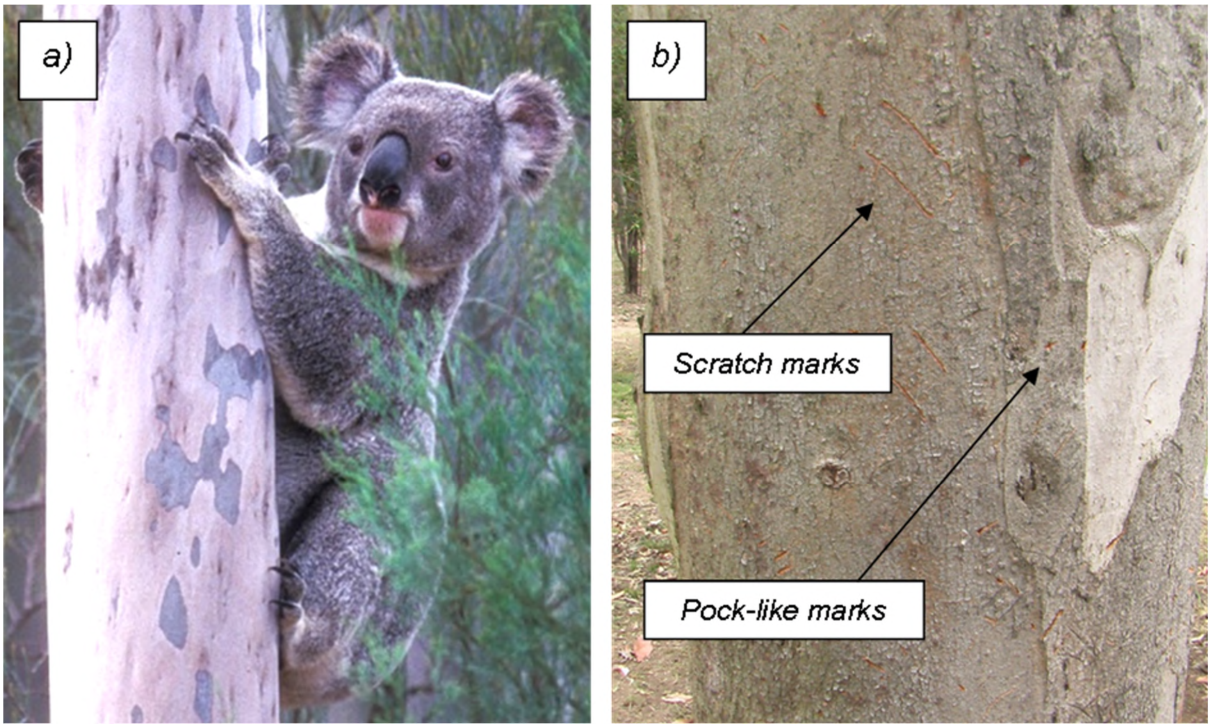


Figure 9: Koala in hold position on *Corymbia citriodora* showing (a) opposable digits on the front paw and (b) koala scratch marks on *Eucalyptus major*.

Hair, feathers, bones, slough, nests, feeding stations and carcasses

Hair, feathers, bones, nests, feeding stations and carcasses are often distinctive, allowing species identification. Intact slough (shed skin) of reptiles can be inspected for scale counts and distinctive features (e.g., keeled scales). These types of secondary signs can be used to indicate presence of a species within the survey area, but not necessarily presence of a species at a generic site. This is because the remains could have been transported to the site from elsewhere by another animal.

Samples of hair, feathers, slough, nests, bones or carcasses can be collected as physical evidence if belonging to a significant species and/or if identification is problematic in situ. Appropriate hygiene precautions need to be applied to protect workers from potential infections and transfer of parasites and diseases (see Chapter 7).

8.12.3. Ethical Considerations

- Inspection of fauna secondary signs does not involve handling or trapping animals and therefore has a minimal direct impact on fauna.

8.13. Incidental Records

Any species observed on a generic survey site (i.e., within the 100 x 100 m plot area) during non-survey activities (e.g., walking into the site, checking traps etc.), that is not observed or captured during the standard surveys, should be recorded as an incidental on-site record for that site. There is a specific datasheet that can be used to record these species (download from the Terrestrial Fauna Survey Guidelines page on the Queensland Government website). Likewise, incidental sightings - particularly of significant species - made off-site but within the survey area should also be recorded.

9. Targeted Survey Methods

A targeted survey site is specifically selected to target a particular species, taxon or suite of taxa, usually because of particular habitat features (e.g., rocky outcrop or wetland). Therefore, the generic survey methods may not be suitable, depending on the target species or group. This chapter outlines methods that can be used at non-generic sites to target specific faunal groups. For some methods, effort can be standardised to provide information on relative abundance. In any case, if the aim of a targeted method is to detect the presence of a significant species, as based on the Queensland Nature Conservation Act (NCA) or the Environmental Protection and Biodiversity Conservation (EPBC) Act, then sufficient effort must be applied to ensure that the species is detected if it is present. This is particularly the case if the target species is listed as Vulnerable, Endangered or Critically Endangered under the NCA or the EPBC Act.

Targeted survey approaches for each significant species are being progressively developed, and will be posted on the Queensland Government website as they become available. For EPBC listed species, survey guidelines are available on the Australian Government website (available for bats, birds, frogs, mammals and reptiles).

9.1. Amphibian Searches

9.1.1. Description and Purpose

The detection of frogs is one of the most variable amongst all faunal groups, as their activity is patchy at both temporal and spatial scales. They are strongly influenced by weather conditions and many are only conspicuous at breeding locations when weather conditions are suitable (e.g., after heavy rain). Within any one area, different species can employ different breeding strategies, which affects detectability. For example, in the tropical north, some species are breed early in the wet season, whilst others are triggered by large rainfall events (Dostine et al. 2013). To add to this, frogs can be extremely diverse in habit, being terrestrial, arboreal, burrowing or aquatic and being found from rainforest to desert ecosystems.

Therefore, in addition to the active searches and pitfall trapping conducted on the generic sites, amphibians should be specifically targeted in suitable habitat such as streams, wetlands, ephemeral pools and other water bodies.

9.1.2. Design and Procedure

There are many different techniques used to detect amphibians and the most appropriate method will depend on the target species or group of species and their habits.

Stream or water body surveys

Observer/s walks through suitable habitat systematically searching for frogs, tadpoles and egg masses and listening for calling adult males. This technique requires skilled observers, with substantial experience in frog survey and identification (visually and by call) (Crump and Scott 1994). The area or length of stream/water body surveyed and the time spent searching should be recorded, along with weather conditions as these affect frog activity.

Aural transect surveys

Observer/s walk quietly through suitable habitat listening for calling adult male frogs. This technique allows for increased area coverage per effort. Length of transect and time spent conducting the survey should be recorded. The transect width can be determined by the strength of the call of the target species (some species can be heard for > 100 m whilst others are only audible within metres). Zimmerman (1994) recommends locating at least six calling males in order to determine the width of the transect and therefore the approximate area searched.

Aural point surveys

All calling male frogs heard from one vantage point are recorded. Depending on the area of suitable habitat it may be beneficial to conduct fixed point surveys at regular intervals. Time spent listening should be recorded. Dostine et al. (2013) recommend at least three surveys to sample most of the frog fauna with this technique. Fixed point census can also employ automated call recorders (Section 9.14) and/or call playback of frog calls (Section 9.18).

9.1.3. Ethical Considerations

- Minimise habitat disturbance at breeding sites.
- Avoid chemical contact with the environment and animals while handling (e.g., insect repellent).
- Be aware that handling individuals for examination may affect their behaviour or cause heat stress in some species.
- Strict hygiene protocols should be implemented to minimise disease and pathogen (e.g., chytrid fungus) spread, particularly when working in areas with threatened, stream-breeding frogs. For further details refer to the Queensland Hygiene protocol for handling amphibians, available from the Queensland Government website.

9.2. Freshwater Turtles

9.2.1. Description and Purpose

Survey areas that contain suitable, large water bodies should be targeted for freshwater turtles. From a distance some turtles are difficult to distinguish from others, often requiring capture of the animal for a positive identification. Therefore, the methods outlined below all involve the capture of animals, although highly experienced personnel may be able to identify some species without capture.

9.2.2. Design and Procedure

Turtle surveys in freshwater areas of Queensland should employ one or more of the following capture techniques (Tucker 1999; Limpus et al. 2002; Hamann et al. 2004; Limpus et al. 2011) or consider using eDNA (Section 9.22).

Visual survey

Survey from boat or bank during daylight hours for basking turtles using binoculars and/or spotting scope and camera equipment to verify identification. This technique can be used as the first step in ascertaining turtle species and distribution along a watercourse but should be followed up by capture techniques as detailed below.

Snorkelling

- Turtles are located visually by snorkelling along the sides and bottoms of streams and are captured by hand.
- Snorkel transects can also be used to quantify density through timed searches where turtles are visually identified, counted and sexed (where possible) but not captured (e.g., see Freeman 2010).
- Success of this technique is limited by water clarity and is increased by employing experienced personnel.
- Time spent snorkelling and number of snorkelers should be recorded to indicate effort.
- Presence of crocodiles in many Queensland catchments will limit the use of techniques such as snorkelling. Snorkelling should be initially conducted in day light to become familiar with any submerged hazards. For safety reasons, only employ this activity when there is limited stream flow.

Spotlighting

- Spotlight through sections of stream by boat or walk along banks at night capturing turtles with a large hand net (i.e. fish landing net).
- Water clarity, depth and experience all affect rates of capture.
- Total person-hours of spotlighting should be recorded to indicate effort.

Trapping

- Numerous trap designs can be employed and will be influenced by the target species. Some of the traps designs include:
  - Submerged collapsible crab pots with wide funnel openings and a line to a surface marker
  - Floating modified collapsible crab pots with internal floats.
  - Hoop-traps with an attached holding pen accessed via a one-way entrance. These traps can be set with the top of the holding pen above water (so trapped turtles or platypus can breathe) or fully submerged.
  - Cathedral traps are modified submerged collapsible traps with an additional chamber above that is accessed via a vertical one-way entrance from the lower baited chamber. The upper compartment is suspended out of the water so that turtles can surface to breathe.
- A variety of baits can also be used (and will also be influenced by the target species), including beef heart, bread, banana, apple, lettuce, peanut butter and sardines. Beef heart is good default bait due to its attractiveness to a range of species and ease of handling (Hamann et al. 2004).
- Record the effort in terms of total trap hours or trap nights.

Seine netting

- Seine nets with a mesh size ranging from 5.5 – 15.2 cm can be used singly or in combination as a block of nets at the downstream end of a riffle zone or narrow section of channel. Numerous personnel are positioned side by side (if possible within arm's length of each other) upstream and proceed slowly towards the net, feeling the substrate, under logs and the edges of undercut banks.
- Seine or block nets are prohibited apparatus for fishing in fresh waters (see Queensland Government website). Extra permits from fisheries will be required if using this technique.

9.2.3. Ethical Considerations

- Submerged traps should be checked every 1-2 hours, depending on water temperature (more frequent checking in warmer water).
- Floating traps or those with a portion suspended out of the water should be checked at least once every 24 hours.
- By-catch of other species such as platypus or water rat in submerged traps is a potential issue and should not be employed where capture of these species is likely.

9.3. Elliott Trapping

9.3.1. Description and Purpose

Elliott trapping can be used to target specific significant small mammals (e.g., water mouse *Xeromys myoides*, Hastings River mouse *Pseudomys oralis*) by trapping in suitable habitat within the survey area. More intensive Elliott trapping effort, over that conducted on generic survey sites may be recommended in the Significant Species Targeted Survey Guidelines to detect these often rare and elusive small mammals.

9.3.2. Design and Procedure

- Target any significant small mammal species that may occur within the habitats occurring across the survey area, as determined by the desktop study.
- Select suitably sized Elliott traps (or similar) based on the body mass of the target species.
- Bait type should be selected to maximise capture rates of the target significant species.
- Effort in these situations will be variable depending on the habitat and the potential target species. Details of trapping effort should be recorded (e.g., the number of traps for the number of nights, with information on how they were deployed).

9.3.3. Ethical Considerations

- See Section 8.4.3
- Trapping in intertidal zones requires vigilance, as the incoming tide poses a drowning risk.
- Repeated capture of some dasyurids over consecutive nights (e.g., mulgara *Dasycercus* spp.) poses an unacceptable health risk to the animals. Animals should be marked (e.g., fur clip) prior to release and traps closed if recapturing individuals.

9.4. Funnel Trapping

9.4.1. Description and Purpose

Funnel traps are a versatile trapping method for many reptile species and can be utilised in a diverse range of habitats where it can be difficult or impossible to pitfall trap (e.g., rocky outcrops). They can be effectively used to target active burrow systems and other potential reptile macrohabitat where minimal disturbance is preferable. In many targeted situations the use of a drift fence may not even be required, as use of natural features (e.g., rocks, logs and long grass) can aid in directing herpetofauna into the traps. Even placement in the open in the vicinity of active burrows and other structures has surprising success and can be used to verify the presence of species such as the yakka skink (D. Ferguson and M. Mathieson *unpubl. data*).

9.4.2. Design and Procedure

- Funnel traps should be utilised with or without drift fence to target reptiles in habitats that are otherwise difficult to trap in (e.g., rocky escarpments, scree slopes and wet areas where pitfall traps would fill with water) and often have more specialised species (e.g., rock inhabiting specialists).
- Effort in these situations will be variable depending on the habitat and the potential target species. Details of trapping effort should be recorded (e.g., the number of traps for the number of nights, with information on how they were set up).
- Check funnel traps carefully 2-3 times a day with the first check within 2 hours of sunrise. Special attention should be given to the folded areas around the funnel entrance and to all seams.

9.4.3. Ethical Considerations

- See Section 8.2.3

9.5. Sand Plots and Track Plots

9.5.1. Description and Purpose

Identification of fauna from tracks is often done opportunistically, but there are a number of ways to use track identification as a formal survey method. The first is through Track Plots (see Moseby et al. 2012) which uses track-based monitoring within a defined search area in a repeatable and standardised way. This method is most commonly employed in arid areas with a sandy substrate suitable for leaving imprints. A 2 ha track-plot method has been accepted by a wide range of stakeholders as the national standard for track-based monitoring (Moseby et al. 2012).

The second method, Sand Plots, relies on creating (bringing sand in) or modifying (clearing litter from suitable substrate and raking or sweeping it smooth) discrete areas to increase the quality of tracks. The technique involves laying a smooth damp sand pad across an unsealed road which, if desired, can be baited to increase animal activity. Active, baited sand plots can also be placed throughout the habitat to record the tracks of animals attracted to the bait. Sand plots are particularly useful for monitoring activity of feral animals (e.g., foxes and cats) and they can also be used to detect other species that leave distinctive tracks. Activity indices (e.g., the Allen activity index; Allen et al. 1996, Engeman et al. 1998) can be calculated from the number of tracks but these are not always good measures of animal abundance. However, the advent of camera trap technology and its increased certainty of species identification and ease of use has reduced the use of formal sand plot surveys.

9.5.2. Design and Procedure

- Footprints are most identifiable in firm, slightly damp sand (a clay component helps hold the footprint).
- Track identification is best done early in the morning with the sun behind the observer, when tracks are fresh and before the sand has dried and the wind has blurred the imprint.
- Identification of footprints also takes into account the gait, including the position of the front feet relative to the back feet and the locomotion type (quadrupedal, bipedal; hop, bound or stride).
- Measurements should be taken with a tape measure or ruler and recorded to the nearest millimetre, preferably on flat ground where the animal is travelling at an even pace. Measurements taken should include track length, width, group width and group length (see Moseby et al. 2012) and should be repeated at least five times.

- If confirmation is required of threatened species or unidentified tracks, take photographs including a scale (e.g., a ruler, a 50c coin). Avoid using the camera flash.

Track plots

- A 2-ha search area (200 x 100 m) should be searched in 30 person minutes, covering as much area as possible by zig-zagging up one side of the plot and back down the other.
- As well as tracks, this method can also be used to record burrows, diggings, or scats.

Sand Plots

- If suitable substrate occurs naturally in the study area then a patch can simply be cleared, moistened and raked smoothed, otherwise suitable sand will need to be brought in.
- Sand plots across a road should be at least 2 m wide to provide information on stride length.
- Sand plots on roads are typically spaced 200 - 500 m apart, although spacing is dependent on target species and the distances they travel.
- Sand plots away from roads need to be large enough to ensure the footprints of any animal investigating the bait are left in the sand.
- If using bait, it is preferable that it is buried as this reduces the likelihood of birds removing it.

9.5.3. Ethical Considerations

- If sand is brought in, ensure that it is weed and pathogen free.

9.6. Wetland Birds (Waterbirds)

9.6.1. Description and Purpose

Queensland wetlands provide extensive and globally important habitat for around 170 species of waterbird, comprising both resident and migratory species. Waterbirds fall into two broad groups, shorebirds, and other waterbirds; these are described in detail on Wetland*Info*.

Waterbirds are conspicuous and abundant components of Queensland's vertebrate fauna and are subject to several international agreements due to the migration of many species. Migratory waterbirds are a Matter of National Environmental Significance under the *EPBC Act 1999*. The numbers and breeding of waterbirds are used in the application of three of the criteria for identifying a Wetland of International Importance under the Ramsar Convention on Wetlands. Therefore, information is frequently needed by wetland managers, other decision makers and the wider community on the presence, species composition, numbers, and breeding of waterbirds. However, as waterbirds are highly mobile animals and potentially occur in large aggregations of mixed species, surveys can present great challenges and require a targeted approach.

As waterbirds essentially are birds that are dependent on wetlands at some stage of their life cycle, a good understanding of wetland habitats provides a sound basis for designing a survey of waterbirds. There are a diverse range of wetland types, including rivers, waterholes, creeks, estuaries, shallow bays, lakes, swamps and springs. Artificial wetlands such as reservoirs and farm dams may also provide significant habitat for waterbirds. Maps of natural and artificial wetlands for Queensland at 1:100 000 scale, which can be used to design targeted surveys, can be downloaded from Wetland*Info*. Natural wetlands are also delineated in the regional ecosystem (RE) mapping.

9.6.2. Design and Procedure

- Inventory to build up a comprehensive baseline on waterbirds at a wetland requires surveys over all seasons, multiple years, and wet and dry decades. Three years of quarterly surveys would provide a minimum baseline. Inventory data can be compiled using an 'area search' strategy, attempting to cover as much of the site as possible in the shortest practical time within one day. Multiple detection and counting methods that serve the purpose of inventory can be employed.
- The survey area should be maximised, and the use of small quadrats is often unsuitable. The survey design should strive to minimise the perturbations arising from known or possible waterbirds movements at the full range of spatial and temporal scales.
- Specific methods have been described for the survey of shorebirds, under the auspices of the Shorebirds 2020 program (Australasian Wader Studies Group, BirdLife Australia). The Queensland Wader Study Group follows similar protocols.
- Aerial surveys are the only practical option for surveying waterbirds in huge wetland sites and systems and where ground access is impractical. Standard methods, including details of aircraft type, flying height and speed, and how to design sampling (transects) and extrapolate results, have been applied in programs such as the annual Aerial Survey of Waterbirds in Eastern Australia.
- A basic method for ground surveys of waterbirds involves an area search, by walking around the shore of the entire wetland, or - for large wetlands - scanning from vantage points using binoculars and a spotting scope. Scopes also facilitate systematic counting and enable small and/or distant birds to be identified; shorebirds that have been marked with leg flags, which may be uniquely labelled, can often be recognised. Birds that fly into and out of the wetland during the survey should be recorded. All habitats/vegetation at the wetland site should be investigated. Equipment to facilitate moving through a wetland (rubber boots; wader-boots; canoe; boat) may be needed in some situations to investigate dense vegetation or areas not visible from the shore.
- Call playback can be used to elicit a response from cryptic species such as Lewin's rail *Rallus pectoralis*. Call playback can be standardised following the approach described in Section 8.8.
- High resolution photographs can aid review of species composition, distinguishing similar species, identification of sexes, and confirmation of estimates of numbers.
- Record the start and finish time, prevailing survey conditions (e.g., conditions that may have constrained the survey such as rain, wind direction). Other information that can assist interpretation of the survey include: the boundaries (mapped) and the available habitat (e.g., water depth or extent).
- Ideally, results from inventory and monitoring of waterbirds should be interpreted in the context of results from flyway-wide, national or regional programs.

9.6.3. Ethical Considerations

- Avoid disturbing breeding, especially at colonies when young in tree nests (e.g., cormorants, darters) may jump out if observed too closely
- Avoid disturbing birds that are roosting (e.g., loafing on the shore at high tide), and birds resting at staging areas through migration – especially in the weeks before departure on long continuous flights to overseas destinations.
- Avoid overuse of call playback, to minimise disturbance to normal wetland bird behaviour, particularly during the breeding season. Minimise time using playback at any one site and maximise the interval between the visits to the site.

9.7. Targeted, Active Microbat Echolocation Call Detection

9.7.1. Description and Purpose

Active monitoring requires the continued presence of an observer to survey the bat fauna with a bat detector, and can be carried out via walking or vehicle transects. The technique is used to target particular areas of interest such as creeks, rocky outcrops, and potential flyways, and is particularly useful for detecting species in the Rhinolophidae and Hipposideridae families (DEWHA 2010).

9.7.2. Design and Procedure

- Active monitoring via walking transects can be used to cover small areas of interest, or if the survey area is small, one transect could encompass the entire survey area. Active monitoring via vehicle transects can be used to increase coverage of larger project areas.
- Walking transects must be a minimum of one hour in duration beginning at dusk, for a minimum of two nights per transect. Walk at a comfortable pace, and orientate the bat detector towards the bat when recording calls.
- Observations of the bat can be made with a spotlight at the same time. This may help with identifications if the species has obvious distinguishing features.
- For vehicle transects, speed must be kept < 10 km/hr.
- Do not locate any part of walking or vehicle transects within the immediate vicinity of a passive monitoring station.
- Record a GPS track of the entire transect (preferred) or GPS co-ordinates of the transect beginning and end to show areas surveyed.

9.7.3. Ethical Considerations

- Nil animal ethics issues. Bat detectors are non-invasive and unobtrusive.

9.8. Roost Searches for Microbats

9.8.1. Description and Purpose

Microbat species are limited by the availability of roost habitats within an area, and some species can only be surveyed by capture at the roost (e.g., *Taphozous australis*). Therefore, it may be necessary to search for roosts in order to determine if bats roost within a project area, whether the proposed development or activity will impact on roosting habitat, and or verify whether a particular species is present.

Entering caves or mine shafts should be avoided, unless shown to be safe to do so through prior inspection by engineers or cavers. Cave and mine inspections should only be undertaken by personnel with appropriate experience, training and safety equipment.

9.8.2. Design and Procedure

- Searches for microbat roosts should incorporate the following:
  - caves, mines, boulder piles, and rock crevices
  - tree hollows and stags (obvious or large hollows)
  - buildings, bridges, culverts, drains
  - fairy martin *Petrochelidon ariel* and scrub wren nests (e.g., Kerivoula papuensis roosts in abandoned yellow -throated scrubwren *Sericornis citreogularis* nests; Schulz 1999; Law and Chidel 2004).
- Any damage to prospective or known bat roosts such as removing rubble blocking corridors or bark sheets from trees is unacceptable, even if these activities would increase the effectiveness of the search. Such actions can impact significantly on the microclimate and suitability of the roost (Thompson 2002).
- Small roost sites can be found by shining light briefly into cracks and crevices in boulder piles, under bridges, and in drains or culverts, for bats or signs such as urine stains and fresh guano.
- Assess prospective caves, mines or tree hollows, and known roosts for occupancy by watching a minimum of 30 minutes for bats emerging at dusk, or by using bat detectors, cameras, or video recorders at the roost entrance.
- A bat detector placed near the entrance can be used to identify emerging species, but a few bats may be caught very carefully by hand or with hand nets if necessary.
- Larger caves or mines can be entered at night to look for signs of bats such as urine stains, fresh guano, or remains. A few individuals may still also be present in the roost. Avoid entering roosts during the day.
- In cooler regions, take care to avoid waking bats from torpor in winter roosts.
- Estimates of microbat numbers can be obtained by counting the bats as they emerge from the roost. This may be necessary to monitor the impact or disturbance of the proposed development or activity on a roost. Counts need to be repeated over several nights to obtain an average.

9.8.3. Ethical Considerations

- Every effort should be made to minimise the level of disturbance to the bats, particularly at maternity roosts.
- Entering such roosts during the day can have negative impacts on sensitive species such as *Rhinolophus philippinensis* and *Rhinonicteris aurantia*, by causing mass exodus of and even abandonment of the roost (DEWHA 2010).
- If roost searches are conducted at times of the year when females are heavily pregnant or have young, roost searches must not include methods that could cause distress or the abandonment of young (e.g., entering the roost).

9.9. Roost Searches for Flying Foxes

9.9.1. Description and Purpose

Flying foxes are highly mobile and will move great distances in response to flowering and fruiting events, which vary in timing and location among seasons and years (Hall and Richards 2000; Westcott et al. 2011). Individuals can change camps regularly and entire regions or camps can be colonised or vacated within relatively short periods (Westcott et al. 2011). They are also relatively difficult to detect away from known roost sites (Westcott et al. 2011).

As a result, the importance of the survey area and the potential impact of a proposed development or activity on the roosting and foraging habitat of these species could be underestimated if camps or individuals are not present at the time of survey (DEWHA 2010). Therefore, in addition to searches for flying fox camps, the presence of food plants should also be used to assess the potential importance of the survey area to the species. The primary native food plants for most species of flying fox are well known and diet lists native plant species are available for reference e.g., Hall and Richards (2000), Bradford et al. (2022), CAUL (2022).

If a camp is present in a survey area, it may be important to know if it is temporary, semi-permanent or permanent (occupied year-round and used for breeding).

9.9.2. Design and Procedure

- Flying fox camps are conspicuous and readily found by walking transects during the day within the survey area, watching for flying bats and listening for their distinctive calls.
- In remote areas camps may be located using aerial surveillance from a light plane or UAV.
- The survey area should also be assessed for the presence of plant species known to be consumed by flying foxes.
- Individuals using the site for foraging can be surveyed by spotlighting whilst walking transects at night.
- If estimates of flying fox numbers are required to monitor the impact or disturbance of the proposed development or activity on a camp, bats can be counted most efficiently and cost-effectively using two methods: ground counts and fly-out counts (Murphy et al. 2008).
- If camp counts are required, perform these in the summer months when the numbers peak; with nearly all reproductive females (lactating females and their pups) and males (dominant males establishing and defending territories) present in camps (Nelson 1965; Fox et al. 2008; Westcott et al 2011).
- Consider the use of thermal imagery for performing counts (Section 9.20) however this technology will not distinguish between species in mixed camps.

Ground Counts

- Flying-foxes can be counted during the day while they are in the camp. This method is considered to be at least as good, and often superior to fly-out counts (Westcott et al 2011; 2012). Ground counts also have the advantage of allowing species identification (e.g., for threatened species) in mixed camps and collection of other data on population structure (Westcott et al 2011).
- The counting method used will be influenced by the camp accessibility, visibility, tolerance of disturbance, and the size of the camp (Westcott et al. 2011).
- Small camps (< 1000 animals) can be counted directly by walking through the camp counting the animals in each roost tree.
- Larger camps (> 1000 animals) it may be necessary to use sample counts such as transect sampling or point sampling (see Westcott 2011 for more detail). Both transects and point counts can be used to estimate the density of flying-foxes and the occupied proportion of the total camp area, determined by GPS mapping or aerial photography (e.g., Google Earth) and estimate the total numbers present in the camp (Westcott et al. 2011).

Fly-out Counts

- Flying-foxes can be counted in the air as they leave the camp at dusk. Several streams of bats may head in different directions and several people may be required to count large colonies, each counting a different stream.
- It is important to understand the proportion of the population being counted (Westcott and McKeown 2004; Westcott et al. 2012).
- Counts need to be repeated over several nights to obtain an average.
- This method becomes less effective at larger camps with higher numbers in fly-out streams (Murphy et al. 2008; Westcott et al. 2011). At larger camps there are issues with the accuracy and precision of counts, risk of failing to count all streams, as well as the need for larger numbers of experienced or appropriately trained observers (Murphy et al. 2008; Westcott et al. 2011; 2012.)

9.9.3. Ethical Considerations

- Every effort should be made to minimise the level of disturbance to the bats.
- If conducting searches when females are likely to be heavily pregnant or have young, do not include methods (such as repeatedly walking through the interior of the camp) that could cause distress or the abandonment of young.

9.10. Harp Trapping for Microbats

9.10.1. Description and Purpose

Standard harp traps consist of two banks of vertically strung nylon lines held in a rigid aluminium frame above a large calico holding bag, and mounted on adjustable legs. Bats flying along a flyway are (generally) unable to detect the lines and get caught between the banks of nylon line and slide down into a large, plastic-lined cloth holding bag, where the bats are unable to climb out. Standard two-bank harp traps (1.8 x 2.35 m or 4.2 m^2 of catching area) are most commonly used, although there are many harp trap designs.

Harp trapping is useful for resolving the presence of species whose calls cannot be separated or identified using many bat detectors, such as long-eared bats *Nyctophilus* spp., and for collecting abundance and demographic information such as sex, age or breeding condition, which cannot be obtained using bat detectors. Harp traps will also catch species such as golden-tipped bat *Kerivoula papuensis* which are able to detect and avoid mist nets (Francis 1989).

However, the identification or separation of some species in the hand is not possible. For example, *Scotorepens greyii* and *S. sanborni* cannot be distinguished morphologically, while *Vespadelus* species identifications are based on penis morphology so females will invariably be grouped at the genus level. These species can be identified by their echolocation calls, and bat detectors will be useful in resolving the presence of such species.

9.10.2. Design and Procedure

- Harp traps are most suited to restricted flyways in well vegetated areas, such as along creeks and tracks, preferably placed where fringing vegetation abuts the trap edges on both sides and above. Traps can also be effective in open areas if placed in the ‘right’ location, such as under over hanging branches, lone trees or small bridges (Lumsden and Bennett 2005; Churchill 2008).

- A minimum of two trap nights per sampling site may be adequate to inventory common species present within the sampling area (Mills et al. 1996). More intensive sampling effort is required to capture rare or listed species (Schulz 1999).
- Only trap during warm, calm, dry nights whenever possible. However, as bursts of bat activity can occur between rain showers, traps can be set if light rain is likely to be intermittent. Time periods should be extended if sampling is affected by adverse weather conditions (very cold, wet or windy).
- Harp traps are usually left set all night and preferably checked before dawn, allowing sufficient time to identify and release bats while it's dark. However, to reduce the likelihood of captured bats dying due to dehydration, cold or predation during the night, and allow lactating females to return to their young, harp traps must be checked more often during the night when;
  - time permits,
  - lactating females are present,
  - sensitive species such as orange leaf-nosed bat *Rhinonicteris aurantia* are present,
  - there are adverse weather conditions (very cold or very wet), or
  - predatory animals (e.g., *Antechinus* spp.) are common.
- Release bats close to their point of capture; let them fly off in their own time. If the bat has entered torpor, warm it gently by holding the calico holding bag under your jacket. Give it time to warm up and allow it to fly off in its own time.

9.10.3. Ethical Considerations

- Do not capture bats at times of the year when females are likely to be heavily pregnant or have young attached which may become dislodged.
- It is strongly advised and preferable that all bats be released from harp traps before dawn, allowing enough time for the animals to return to a roost or find a suitable roost site for that day (*i.e.* they should be released when it is still dark). Retrieving bats from harp traps after dawn should be an exception to general practice (e.g., faecal samples need to be collected from particular species requiring individual bags). In such cases, the animals are to be kept hanging in calico bags, in a quiet, cool, humid environment (e.g., in still air under a building, shielded from predators) to ensure they are not exposed to drying air currents or risk of predation. Species known to be more sensitive to captivity (*Rhinolophus spp.*, *Hipposideros spp.*, *Rhinonicteris spp.*), should not be held captive during the day. Extra precautions need to be taken where capture of these species is possible. These precautions should include:
  - Always clearing traps before dawn.
  - Clearing traps more frequently through the night.
  - Moving traps out of flyways or removing harp trap capture bags after the final pre-dawn check to eliminate the possibility of late captures during the transition to full daylight.

9.11. Mist Netting for Microbats

9.11.1. Description and Purpose

Mist nets consist of fine nylon or Terylene netting with a mesh size of 28 - 50 mm (be aware some suppliers may specify these as 14 x 14 mm - 25 x 25 mm) which is usually held in tension between two poles. The height of the net is divided into 'benches' or 'shelves', each with a loose pocket of netting that helps entangle the captured bats. Mist nets come in a range of lengths, depths and bench numbers, but mist nets 12 m long x 3 m deep with four benches are most commonly used to catch bats in Australia.

Mist nets are more versatile than harp traps and can be used in a wider variety of habitat types and locations to capture bats, including open areas. Like harp trapping, mist netting is useful for resolving the presence of species whose calls cannot be separated or identified using bat detectors, and for collecting abundance and demographic information.

9.11.2. Design and Procedure

- Mist nets are ideal for catching bats over isolated and/or shallow water bodies such as water tanks and watercourses, in the arid and semi-arid zone, and other open habitats (Churchill 2008; Vonhof 2002). They can also be used near stands of vegetation in open areas or across flyways in denser vegetation, or suspended in the canopy of tall forests.
- 'Ultra-thin' 0.08 mm nylon monofilament mist nets are preferred over traditional 2 ply polyester nets as they are more difficult for bats to detect.
- Mist nets are set for 3-4 hours after sunset and must be monitored constantly. Nets should be closed (furled) when not attended. A minimum of three people are required to safely carry out this capture technique.
- Move the location of the mist net every night. Trapping success decreases when nets are placed in the same locations on consecutive nights.
- Mist nets should be placed to utilise the screening effect of background vegetation and overhead features, several nets can be used together in a pattern to 'guide' bats into the net. Good descriptions of how to place mist nets and various net patterns are given in Helman and Churchill (1986), Churchill (2008), and Finnemore and Richardson (2004).
- Over water, nets must always be set with the bottom pocket well clear of the water's surface to ensure trapped bats do not become immersed, and that the net can be reached adequately if it is necessary to stand in the water to retrieve bats.
- Only net during warm, calm, dry nights whenever possible. However, as bursts of bat activity can occur between showers, traps can be set if light rain is likely to be intermittent. Avoid mist netting during heavy rain or very windy conditions as this makes the nets too difficult to handle.
- Quickly and gently remove captured bats as soon as possible to reduce any chances of injury and stress. If more bats are being caught than can be safely dealt with, the net should be furled as soon as all bats are removed.
- Release bats close to their point of capture; let them fly off in their own time.

9.11.3. Ethical Considerations

- Mist nets must only be used by trained and competent personnel.
- Be particularly vigilant at times of the year when females are likely to be heavily pregnant or carrying young as they may become dislodged.
- Do not use mist nets to capture bats at the entrance of caves or mines unless there is some prior knowledge of the number of bats within, and the number is not large.

9.12. Trip Lining for Microbats

9.12.1. Description and Purpose

Trip lining can be used to catch bats where small water bodies such as dams and waterholes, are present. Trip lining involves stringing a high tensioned nylon line above the surface of the water. As bats skim the water's surface to drink or forage, they hit the lines, trip and fall into the water. The bat will swim to the waters' edge where they can be picked up.

9.12.2. Design and Procedure

- Trip lining is useful wherever small water bodies are present, particularly in arid areas where water is scarce and other capture techniques are difficult.
- Avoid trip lining dams with lots of aquatic vegetation as bats may become snared or climb out of the water onto floating vegetation and fly off.
- Nylon line (with a 3 kg breaking strain) is strung across the water body 5 - 10 cm above the water surface, and held in place by tent pegs or drift fence stakes at the water's edge. Lines can be strung at regular intervals in a zigzag or grid pattern. Make sure the line is taut and doesn't drop into the water (Churchill 2008).
- Never leave a trip line unattended. This technique is more efficient if carried out by a minimum of two people.
- Bats will swim in the opposite direction of light so when a bat lands in the water, shine a light on the bat causing it to swim in the opposite direction, towards the other person with no or low-powered light. Quickly retrieve the bat once it reaches the water's edge.
- Captured bats must be kept in a dry place off the ground immediately.
- Release bats close to their point of capture while it is dark. If the bat has entered torpor, gently warm it by holding the calico bag under your jacket. Give it time to warm up and allow it to fly off in its own time.
- Remove the nylon line and tent pegs from the site before leaving.

9.12.3. Ethical Considerations

- Do not trip line larger water bodies, as bats may become over-exerted if they have to swim too far to reach the edge.
- Do not trip line when bats are likely to be carrying newborn young.
- Be prepared to enter the water to rescue bats if necessary.

9.13. Camera Trapping

9.13.1. Description and Purpose

Camera trapping involves using a remotely triggered camera to capture images or video of animals which pass in front of the camera or are lured by bait. Camera traps are complex and there are a vast range of brands and models on the market with a broad array of features and specifications. These features and specifications are rapidly developing, and as a relatively non-invasive method there are many, varied applications where camera traps are useful. Camera trapping has been demonstrated to be a far more successful method than many trapping techniques for many cryptic or wary vertebrate species including quolls, bandicoots and other small to medium-sized mammals (e.g., de Bondi et al. 2010; Claridge et al. 2010; Burnett 2010). Camera traps are also a useful tool to monitor the presence, abundance and activity of many feral animal species such as pigs, cats and foxes (e.g., Robley et al. 2008; 2010 Vine et al. 2009).

Camera traps can and should be employed to target a range of wildlife, only being limited by the resolution and image clarity (for accurate identification) and trigger mechanism (i.e. will the camera reliably trigger on your target species), which varies significantly between brands and models (sensitivity can also vary significantly within some models). The decision of camera trap type and features should be based upon the research question and needs to take into account factors such as the target species (e.g., size, behaviour and body temperature), habitat, climate and attributes of the site (i.e., trail or focal point such as water point or baited lure or not) (Meek et al. 2012; Rovero et al. 2013). With these factors in mind the user can then determine broad camera trap type based on the following two key camera features:

- Trigger type – Passive infrared (PIR) sensor vs non-PIR sensors such as time lapse photography, where an image is taken at pre-set time intervals; active infrared (AIR), where a beam between two AIR devices is broken; treadle or pressure plates, using the weight of an animal; seismic sensors (vibrations); magnetic circuit sensors; trip-lines; and normally-open-normally-closed switch sensors (Meek et al. 2012). The most commonly available have PIR sensors that require movement and a temperature differential between the target and background, typically greater than 2.7°C (Meek et al. 2012). This means PIR triggers can be unreliable when ambient temperatures are within the body temperature range of the target species (Meek et al. 2012; Rovero et al. 2012) or if the target is an ectotherm (i.e., amphibian or reptile). If this is the case, non-PIR sensors should be investigated to suit the target species.
- Flash type – white (LED or incandescent) or infrared (low-glow or no-glow). White flash is critical when colour images are required at night for identification (e.g., small mammals) or individual pattern recognition, such as for mark-recapture (Meek et al. 2012; Rovero et al. 2013). Infrared flashes tend to be less obvious to wildlife than white flash, creating less disturbance, which is an important consideration for behavioural observations (Meek et al. 2012).

Once broad camera trap type has been decided, specifications or features of brands and models can be examined to match camera performance with the target species and research question. Features to examine include, trigger speed, detection zone and area, sensor sensitivity, flash intensity and regulation, number of images per trigger, recovery time, power consumption, image resolution, clarity and sharpness, robustness, and ease of programming and set-up (Meek et al. 2012; Rovero et al. 2013).

In addition to camera traps deployed on the generic survey sites we recommend specifically targeting any special landscape features and areas identified in the desktop study that may support threatened species known to be successfully detected by camera traps (e.g., quolls *Dasyurus* spp., rock-wallabies *Petrogale* spp., *Antechinus* spp., and *Phyllurus* spp.).

9.13.2. Design and Procedure

Any targeted camera trapping design needs to be specifically adapted to optimise detection of the target species in its particular habitat. In consultation with species profiles, experts and current published literature consider the:

- Model and brand of camera (trigger speeds, trigger sensitivity, image quality, focal length etc), noting that some companies are willing to modify certain features (e.g., focal length and PIR sensor type/sensitivity or trigger mechanism) to improve the detection and identification of your target species.

- Duration of deployment based on number of camera units and research indicating trapping success. Consider evaluating detection probabilities of your target using the selected camera trapping equipment or even trialling multiple models or setups to determine the most effective.
- Placement of the camera trap (e.g., up a tree for an arboreal species) and type of lure or bait used (if any) and how this is presented and what it means for analysis. Selection of an appropriate lure should improve the detection of cryptic threatened species.
- Standardise the camera set-up where possible (detection area and settings) and where individual animals cannot be differentiated define what constitutes an event (e.g., Meek et al. 2011 defines a new event as a gap in visitation of more than 2 minutes), especially if the aim is to determine relative abundance.

9.13.3. Ethical Considerations

- Using a bait lure may increase detectability of target species but may alter behaviour or increase predation risk (if predators are also spending more time around the lure).
- If using a bait cage (area/animal specific) ensure animals cannot injure themselves (e.g., potential tooth damage).
- White flash cameras, while they increase the number of positive identifications, may alter the behaviour of particular species e.g., nocturnal carnivores (reviewed in Meek et al. 2012).
- If targeting long term breeding effort of colonial breeding birds, ensure camera deployment does not involve disturbing active nests.

9.14. Automated Acoustic Recording

9.14.1. Description and Purpose

Birds, frogs, bats (see Section 9.7), insects (not covered here) and some mammals, such as the arboreal species, create sounds that can be readily recorded using automated recording systems. Many vertebrate calls are identifiable, but challenges arise when vocal repertoires of species are complex, vocal mimicry occurs and there are distinct regional dialects, particularly among birds (Brandes 2005). Automatic recording devices allow acoustic surveys for extended periods of time and are useful to detect specific acoustically conspicuous species, particularly in combination with species recognition algorithms and expert listeners (Frommolt et al. 2008; Obrist et al. 2010). Software is rapidly developing which allows implementation of automated detection and recognition algorithms, however, these rarely cover all species to be expected, remaining challenging when working in taxon-rich communities (Obrist et al. 2010).

Therefore, at this time, automatic recording is best used to target rare or elusive species with acoustically distinct calls, unless large amounts of time can be invested into analysing recordings to obtain complete species inventories or developing call recognition software for isolating target species.

9.14.2. Design and Procedure

- Any automatic recording design needs to be specifically adapted to optimise detection of the target species (or group) in its habitat. Consider the:

- Model and brand of recording system (recording level, microphone sensitivity and robustness, scheduled recording or triggered on event recording, recording quality, etc.)
- Duration of deployment, time/s of day recording (*e.g.,* morning bird chorus) and length of recording based on the number of units and information on peak calling periods for the target species or group. This can greatly reduce the quantity of recording requiring analysis.

- Detection area (or space) - basically the area around the recording system where calls of the target species can be recorded and identified. The detection area will vary between species and with changing environmental conditions as the rate sound waves travel through air varies with temperature and humidity. Arrays of recorders can be used to increase the detection area, assess differences in detectability of target species from different acoustic recording devices and to assess positions of animals (e.g., Leseberg et al. (2022)

- Standardise the recording set up where possible (unit calibration, settings and position in environment), particularly if the aim is to determine acoustic indices. Habitat type (transmission conditions), abundance and detectability of target species, as well as the sensitivity and the area covered by the recorder influences the number of systems to be deployed and the recording program (the schedule, length of recording, etc.).

- Ensure the batteries are adequately charged and the memory card (or recording device) is large enough to capture all the data associated with the recording settings and duration of deployment.

- An automatic recording system can generate very large quantities of recordings (depending on the programming, length of deployment, number of units, etc.), resulting in extensive volumes of calls to analyse. Targeting known calling times can greatly alleviate volumes of call analysis. Whilst software is available to automatically identify species, they are most successful at extracting individual species with acoustically distinct calls. Analysing recordings manually to identify all species recorded is time consuming and requires highly skilled personnel, very familiar with the target group of animals (e.g., birds). It is effective to use available software to convert sounds to spectrograms.

- Storage and curation of calls will need consideration. Large volumes of sound may need to be stored and appropriate computing storage facility will need to be assigned. If prudence has been exercised with regard to targeted survey duration, then this may be minimised. Further thought should be given to whether all raw recordings should be stored or if compromise can be made. This may depend on need for proof, improvements in knowledge of calls, etc.

9.14.3. Ethical Considerations

- Nil animal ethics issues; automatic recording systems are non-invasive and unobtrusive, although disturbance to habitat should be minimised during deployment of acoustic recorders.

9.15. Nocturnal Vehicle Transects

9.15.1. Description and Purpose

Roads and tracks dissecting the survey area provide opportunities to conduct vehicle based spotlighting and herpetofauna transects. Vehicle based transects allow for more extensive areas to be surveyed efficiently, whilst also adding a greater element of surprise to the animals, given the speed of approach (Wayne et al. 2005). Nocturnal vehicle transects using experienced personnel are useful to detect a wide range of nocturnal fauna, particularly those occurring at relatively low densities within the survey area. The technique is useful in detecting many nocturnal birds (e.g., owls and nightjars), arboreal and terrestrial mammals (e.g., dasyurids, macropods, gliders and possum), reptiles (e.g., snakes, lizards and geckoes) and amphibians on, or crossing the track.

9.15.2. Design and Procedure

Nocturnal vehicle transects can be broadly separated into spotlighting and searching the road for herpetofauna. Depending on the objectives, track condition, number of personnel and their experience these can be done concurrently or as separate surveys. For safety reasons, vehicle transects should only be undertaken on roads and tracks with limited other vehicular traffic.

Vehicle Spotlighting

- Drive at a constant speed (~5 – 10 km/hr) with observers scanning the vegetation on either side of the road with handheld spotlights (50 – 100 W). When eye shine is detected, the vehicle is stopped and binoculars used to aid in identification.
- Detectability and consequently speed is influenced by habitat complexity. The influence of observer expertise on the detection of arboreal marsupials has also been recognised (Goldingay and Sharpe, 2004; Wayne et al. 2005), highlighting the need to use experienced personnel.
- Effort should be recorded as the length of the driven transects (with defined starting and finishing points) and what the constant speed was since detection is strongly influenced by the survey speed. The time taken to drive the transect should also be recorded, however this will be influenced by the number of animals detected, given it takes time to stop and identify species.

Herpetofauna Transect

- Searching for herpetofauna on or crossing tracks is best done on well-maintained tracks with limited vegetation and debris as this will obscure animals and decrease detection rates.
- Drive at a constant speed (~10 km/hr) with the driver and front passenger scanning the road for any animals crossing or basking (as the road is often warm, reptiles will take advantage of this warmth). When an animal is detected, stop the vehicle and identify the species.
- Effort should be recorded as transect distance and the constant speed at which it was conducted. The time taken to drive the transect should also be recorded, however this will be influenced by the number of animals detected given it takes time to stop and identify species.

9.15.3. Ethical Considerations

- Avoid prolonged exposure of animals to the spotlight beam. For longer observation periods, dim the light or use an infrared beam or a red filter.
- Exercise personal care when identifying potentially venomous animals or when stopping on roads when other traffic is present.

9.16. Hair Tubes

9.16.1. Description and Purpose

Hair tubes are a relatively non-invasive method used to detect small to medium sized mammals that requires infrequent monitoring by personnel. Hair tubes are a cylinder or funnel-shaped device with adhesive tape on the inside; animals are attracted to the bait and their hairs adhere to the inside of the tube as they attempt to reach the bait. Subsequent analysis of specific characteristics of the hairs enables identification to species (Brunner and Coman 1974, Brunner et al. 2002), although closely related species have similarities and can be difficult to distinguish. Hair tubes can also provide DNA material. Success of hair tubes varies appreciably with locality, species, trap design and the practitioners' personal experience in hair identification (Bertram et al. 2001, Nelson 2006, Harris and Nicol 2010). Many report that the use of hair tubes are largely ineffective for the detection of terrestrial mammals (compared to other methods), mainly because of the effort involved in setting them up and subsequent analysis of the hair samples (Eyre et al. 1997; Mills et al. 2002; Thompson and Thompson 2010). As such, it is recommended that hair tubes be used for targeted surveys, rather than as a routine method at the generic sites.

However, hair tubes remain a cost effective way to increase detection effort targeting cryptic small to medium sized mammals (e.g., quolls), as they can be left deployed for an extended period and once set require little further attention.

9.16.2. Design and Procedure

- Deploy hair tubes when targeting habitats that may contain rare and cryptic species. Ideally used in conjunction with other techniques (camera, Elliott and pitfall trapping) to cost effectively increase the total sampling area.
- The layout of the hair tubes will depend upon habitat and target species but typically they are spaced 5 - 10 m apart in a linear or grid arrangement making sure they are securely fixed in place.
- Hair tubes should be deployed for as long as the bait remains viable with a recommended minimum of four nights, but ideally for longer than 2 weeks.
- Effort and layout should be recorded (e.g., 20 hair tubes, 10 m apart for 12 nights)
- Hair tubes are best baited with vegetable based baits. Commonly used bait ingredients include peanut butter, rolled oats, honey, vanilla essence, vegetable oil and aromatic oils (e.g., sesame oil or truffle oil). The standard bait base is rolled oats mixed with peanut butter to which other ingredients can be added depending on personal preference and target species.
- Analysis should be conducted by experienced personnel or outsourced to experienced practitioners in order to maximise the reliability of the results (Bertram et al. 2001).

9.16.3. Ethical Considerations

- As long as the hair tubes are secured in place, the non-invasive nature of hair tubes means they have few ethical concerns.

- Sometimes small reptiles or frogs can get stuck to the adhesive tape. To prevent animals becoming stuck, ensure that no adhesive tape is on the floor or lower sides of the hair tube. Check hair tubes for the first few days to ensure there is no bycatch. If an animal is stuck, do not pull it off as this will probably cause damage. Vegetable oil is useful to help free the animal.

9.17. Predator Scat Collection

Predator scats (including dog *Canis familiaris*, fox *Vulpes vulpes* and quoll *Dasyurus* spp.) can be found on the generic site but more likely along tracks and roads. These can be identified in situ (see Triggs 2004) and recorded as incidental records for the survey site and/or survey area, or collected for further identification through analysis of grooming hairs. Remains of prey species may also be identified, from hairs and bone fragments in the scat. Similar to hair tubes, analysis of predator scats by an appropriate expert will require extra resources (time and budget).

9.18. Call Playback

9.18.1. Description and Purpose

Point count surveys are frequently used to collect information on presence-absence of species and numbers; particularly of birds. Call playback is a technique frequently used to overcome problems of non-detection of species due to their cryptic or shy behaviours, low levels of detectability (possibly because of habitat) or because of infrequent calling by the target species. Call playback refers to the broadcasting of vocalisations of a species by means of a tape recorder or some electronic device through a speaker(s) in order to increase the probability of detection.

Care needs to be exercised in the use of this technique and the interpretation of results. Playback surveys may interfere with the normal behaviour of species, possibly making them vulnerable to predation, interrupting breeding behaviours or rendering them unresponsive due to habituation. Choice of call is another important consideration for species that have more than one call. Calls that may be appropriate in one situation may not be in another. Variation in responsiveness to calls may also depend on factors such as time in the breeding cycle, the sex of an individual and various environmental variables, such as time of day, weather, and season. These factors may also influence detectability of a response. A wide range of calls are available as commercially available recordings of different species (frogs, birds and mammals).

While standard techniques for undertaking call playback at the generic survey sites have been described in this document for owls and arboreal mammals, there are many species for which call playback has or could be used to elicit response. For example, the playback of calls of black-breasted button-quail *Turnix melanogaster* at particular times of year and when done in concert with the deployment of models, enhances the chance of visually observing males and/or females.

9.18.2. Design and Procedure

- In any use of the call playback technique, it is important to establish a listening time before the playback commences.
- Punctuate the call sequences with silence so that the response (vocalisation or movement) can be detected. Species will respond in different ways (again depending on time of year, weather, behavioural motivation, etc.), for example, they may call back, move toward the source of the playback or move away from the source of playback.
- Listen for some period after call playback to detect any further responses. In some cases, a vocal response may occur, but only after some considerable period has elapsed.

- Call playback of target species can follow the standard technique outlined in Section 8.9, i.e. 2 minute listening period before call playback begins, followed by 3 minutes of call playback, followed by a further 2 minutes of listening (which may coincide with a pre-playback listening period if calls are being played in sequence one after each other).

9.18.3. Ethical Considerations

- Limit sessions to one per day/night per targeted site, to avoid significant disturbance to normal behaviour of nocturnal animals, particularly during the breeding season.

9.19. Artificial Nesting/Roosting Boxes

9.19.1. Description and Purpose

A wide variety of Australian vertebrates use natural hollows in trees for shelter and nesting. Hollow use is species-specific and determined by a range of factors that may include hollow entrance size, height above ground, whether the hollow is in a branch or the trunk, and hollow depth and volume (Gibbons and Lindenmayer 2002). Artificial roosting boxes provide an alternative hollow resource for hollow-dwelling species, particularly where natural hollows are limited (Smith and Agnew 2002), and provide a means for detecting species that might otherwise go undetected, e.g., eastern pygmy possum *Cercartetus nanus* (Beyer and Goldingay 2006). Nest boxes come in a number of shapes, sizes and forms and there is a vast literature to be consulted to establish the type of artificial nest/roost box that may be required for a particular application (e.g., Goldingay 2009).

Nest boxes are not a suitable tool for detecting fauna in areas that are to be visited just once or even a few times, but if a site is to be repeatedly visited then nest box deployment may be useful.

9.19.2. Design and Procedure

- Box designs vary enormously in dimensions, construction material and entrance sizes, so careful consideration needs to be given to the type of design required for the target species. It may be necessary to hang a range of box types to maximise potential inhabitants.
- Boxes should be hung so that they allow tree expansion and do not restrict growth. In hanging a box, consideration should be given to aspect, height etc., in relation to the known ecology of the species being targeted. Boxes may also be placed on poles if no suitable trees are available or may be partially buried for burrow nesting species.
- Following deployment of boxes there may be a waiting period before fauna begin to utilise the resource. These delays should be built into the sampling design. Waiting periods vary enormously between studies.
- Boxes can be checked at whatever frequency is suitable. Checking may require accessing boxes by climbing (e.g., ladders), mechanical means (e.g., cherry picker) or may be minimal or non-interventionist by use of cameras probed into boxes or set up at entrances.
- If boxes are to be left in situ for extended periods, they may require future maintenance (e.g., to remove ant or wasp nests) or replacement.
- Consider whether alternation of existing habitat features (e.g., drilling entry holes into already hollow limbs or trunks) could be used instead of boxes (Rueegger 2017).

9.19.3. Ethical Considerations

- An ethics permit would be required if animals are going to be handled. Handling should be kept to a minimum and boxes only visited for short periods to reduce stress on inhabitants. Passive sampling using camera recorders or tag recorders placed in boxes could circumvent any need to disrupt box life.

- Artificial nest boxes should only be used if natural nest sites are known to be a limiting resource.

9.20. Thermal Imaging

9.20.1. Description and Purpose

Thermal imaging, or thermography, is increasingly being used as an effective technique to detect mammals and, to a lesser extent, birds, in wildlife inventory, research and monitoring. Thermal imaging devices detect infrared radiation (heat) emitted from and reflected off objects in the field of view (FOV). This is affected by the amount of heat emitted/reflected, and the amount which reaches the microbolometer or detector. The absorbed heat causes a change in the electrical resistance of the device which is used to create an image. No illumination is necessary so images can be captured in complete darkness or during daylight hours, particularly for mammals and birds obscured by vegetation. By contrast, night vision devices (not covered by this manual) require some ambient light and amplify it and. Night vision devices will not work in very dark conditions or detect well camouflaged animals or those obscured by vegetation, but generally provide better images of animals in low light conditions compared to thermal imaging devices.

Thermal imaging provides an effective, non-invasive method for the survey of fauna for which there is sufficient contrast in temperatures, so is not suitable for ectotherms such as reptiles and amphibians. The use of this technique in wildlife survey has been around since the 1970s, however it is only in more recent years that the technology has improved to detect smaller heat differences (as low as 0.01°C) and the devices have become more affordable and available, and hence much more widely employed in this sector. The technique has outperformed other methods for detecting a range of terrestrial mammals across different habitats in Australia, including arid zone small mammals (Augusteyn et al. 2020; McGregor et al. 2021), and arboreal mammals in open forest (Vinson et al. 2020; Witt et al. 2020) and rainforest (Pocknee et al. 2020; Underwood et al. 2022).. Thermal infrared imaging has been successfully applied in assessing the occupancy and population size of microbat and flying-fox colonies (Hristov et al. 2008; Mills et al. 2010; McCarthy et al. 2021). Use in bird surveys is less common but has been used successfully for waterbirds (Austin et al 2016; Afán et al. 2018), but only led to higher detections than diurnal bird surveys for a small number of species of woodland birds (Mitchell and Clarke 2019). This technique is often best employed in conjunction with existing techniques (e.g., spotlighting, camera trapping) and testing of the technology is recommended to understand the advantages and limitations of the specific device selected to use in the survey.

9.20.2. Design and Procedure

- A wide range of thermal imaging devices are available, with the technology continually advancing. Choosing which thermal monocular, binocular, scope or camera to use in the survey will be determined by a range of factors including survey aims, environmental and operating conditions, recording need and budget. Other features which should be considered are:
  - Thermal sensor and Display resolution: detectors with 480 x 640 pixels are the minimum standard for good images which are easy to visualise. The distance at which objects can be imaged is limited by the optics chosen and the size of the imaging sensor. Choose those appropriate for the specific requirements of the survey,
  - Refresh rate (Hz): Higher refresh rates (e.g., > 30 Hz) will provide better real time information.

- Detection range and Field of View (FOV) e.g., a walking transect in open or closed forest using a handheld monocular would benefit from a wider FOV and may not need larger detections ranges. Conversely, multiple exit points from a bat roost may require multiple units deployed to adequately encompass the subjects.
- Operating temperature: many devices have a operating range of -20 to 50° C but others operate under more extreme conditions with higher and lower ranges.
- Durability: more powerful optics can result in a more fragile unit. Some manufacturers include shockproof and or waterproof features.
- Colour modes: some people find certain colours difficult to view. Usually white or black provides the best perceived image as a screen can display more shades of grey than colours.
- Battery life: some units come with integrated features, such as Wi-Fi and Bluetooth connectivity which draw on the battery. Consider the battery life, opportunities to recharge during the survey or need for spare batteries.
- Recording: images can be viewed through the device or captured as photographs or videos depending on the device. Media can be connected to external storage of devices, depending on the unit chosen.
- Other features to be considered: rangefinder, connectivity, compass and ability to zoom (e.g., 1x to 4 x variable magnification).

- Record model type and specific settings with the survey information.
- Weather conditions may affect the performance of the thermal infrared device, and the behaviour of the fauna of interest. Record factors such as temperature, humidity, barometric pressure, and wind speed as survey covariates.
- Standardise survey effort where possible for repeatability.
- Large volumes of data can be created, particularly with video recording. Consider data storage and curation and whether all raw recordings should be stored.
- Analysing recordings manually to identify all species recorded can be time consuming and require highly skilled personnel, very familiar with the target group of animals (e.g., arboreal mammals, ground mammals, waterbirds). Automated image analysis and machine learning-enabled classification techniques offers considerable promise in this field (e.g., Lethridge et al. 2019; McCarthy et al. 2021).

9.20.3. Ethical Considerations

- Thermal infrared imaging is a non-invasive technique and presents fewer ethical considerations in comparison to most search or trapping techniques. It is often employed in conjunction with other techniques e.g., spotlighting, camera trapping. Refer to ethical considerations for these techniques (sections 8.10.3 and 8.7.3).
- If using with a Unmanned Arial Vehicle (UAV) (drone), be aware that wildlife can respond idiosyncratically to the presence of the UAV. Permits will be required for use, depending on the survey, the survey area and UAV specifications. Refer to the SOP for UAV Monitoring of Wildlife (Gonzalez and Johnson 2017).

9.21. Wildlife Detection Dogs

9.21.1. Description and Purpose

Wildlife detection dogs, or conservation scent detection dogs, are domestic dogs trained to detect the scent of a particular species of animal (or indeed, taxa from all kingdoms) (Grimm-Seyfarth et al. 2021). The method makes use of dogs' powerful sense of smell, their ability and willingness to both be trained, and work with a human handler. With over 200 million olfactory receptor cells, dogs can recognise specific odours at concentrations of up to 500 parts per trillion (Johnston 1999). Dogs search by working through a landscape using olfaction to detect odour on the ground or in the air. One of the main advantages of detection dogs is their ability to locate one or more target species or specific traces (e.g., scats, odour of live animals, buried eggs, etc.) independent of many other factors including species rarity, its behaviour, the physical environment and environmental conditions (DeMatteo et al. 2019).

Not all dogs are suitable candidates for wildlife detection dogs, or all people suitable wildlife detection dog handlers (DeMatteo et al. 2019). A detection dog and handler team are a highly skilled technical 'tool'. They should be able to demonstrate both in a controlled (test) situation that mimics the field environment, as well as the field situation, that they can successfully locate the target scent as well as ignore similar, non-target scents.

Detections of target species by wildlife detection dogs are consistently more successful and efficient compared to other methods, particularly for rare and cryptic species (Grimm-Seyfarth et al. 2020; Bennett et al. 2022). For some species, wildlife detection dogs are demonstrated to be more efficient and cost effective regardless of species density e.g., finding koala scats (Critescu et al. 2015). There can be upfront costs and time commitment to using wildlife detection dogs and acquiring taxa odour and non-target odour for training purposes. However, there are significant cost and time efficiencies to using a detection dog team once trained. Like all survey tools, the decision to use wildlife detection dogs needs to be based on the best tools for the proposed research or program. For example, it may not be the most cost-effective technique if the taxon is common and readily detected using other methods. Clearly defined survey goals for the target species, including number of required samples, effectiveness of the currently used survey tools, potential seasonality, habitat conditions, study duration and budget will help to determine if a detection dog should be considered.

9.21.2. Design and Procedure

- Dogs can be trained to detect the odour of either live animals or their sign (scats, feathers, eggs, nests, remains, etc.)
- Detections dogs are especially useful for cryptic or rare/low density taxa, for scats and signs, in areas with difficult terrain and where standard survey methods cause habitat disturbance (reviewed by Bennett et al. 2022).
- Typical training times for a new scent are in the order of weeks to months for an experienced wildlife detection dog, and 12-18 months for training an inexperienced (new) dog. Previously trained detection dogs should generally not be trained on a new odour which would be expected to co-occur with the new target taxon (exceptions are when trained to find scats or other signs which can then be identified to species by the handler).
- Availability of a material for a 'scent training library' may be a limiting factor for extremely rare and cryptic species e.g., if the only material available is 'very old scats', then the dog may only target very old scats. Similarly, the scent training library should contain non-target samples (i.e., odour from similar species that could be co-occurring with the target species).

- Standardised searches limited by both time and defined area may not be ideally suited to scent searches (reviewed in DeMatteo et al 2019) and may require modification e.g., more search time might be required in very complex vegetation or under certain weather conditions (Leigh and Dominick 2015). However, the dogs can be directed to follow their noses in an area defined by the handler e.g., belt transect or fully work a defined plot.
- Comparative search effort can be replicated by applying the same survey effort across sites whether defined by either area/transect length or search time. The main difference between a detection dog search and a human visual search is that human search tends to be linear, whereas a dog will usually work in zig zag to pick up odour on the wind as it passes by the odour location.
- Dogs work best when off leash and able to independently search within the handler's command using whistle, voice, and hand signals (Figure 10).
- Testing is required in controlled and field situations to demonstrate the dog-handler team are effective in locating the target scent and ignoring non-target scents.

9.21.3. Ethical Considerations

- Dogs need to be trained not only to locate the target species, but also ensure the target animal is not harmed or stressed.
- Sites need to be clear of 1080 and other canid bait and traps. Maps of baiting in adjacent areas are required and a risk assessment undertaken for potential impact on dog teams.
- Detection dog search fatigue needs to be monitored by the handler and may be affected by weather conditions. The daily work schedule should be designed to ensure dog welfare including sufficient rest breaks between searches. This will maximise search effort, consistency, and welfare.

Figure 10: Wildlife detection dog working on black-tailed dusky antechinus (*Antechinus arktos)* surveys in Border Ranges NP. Photo by Canines for Wildlife.

9.22. eDNA Sampling

9.22.1. Description and Purpose

Environmental DNA (eDNA) barcoding and metabarcoding is a method for detecting species from minute quantities of their DNA shed in the environment. Shed DNA can be from scats, skin cells, hair, urine, mucus or after the animal's death from decomposing remains. Samples can be taken from the environment via water, sediment, air or even from scats of predator species. The DNA is extracted, and then amplified using general or universal primers in polymerase chain reaction and sequenced using next-generation sequencing.

The technique can be used for specific target species (eDNA Barcoding) using species-specific primers to amplify the eDNA of that species. More recently, universal primers can amplify signals from all DNA traces, so that all species (eDNA Metabarcoding) can be analysed and compared to existing DNA databases. Decreasing costs for processing samples and new sequencing technologies means that this technology is continuing to rapidly develop (Lahoz-Montfort and Tingley 2018).

Currently this technology is most successful with species that have an interaction with the aquatic environment such as frogs, some reptiles, platypus and species not covered by these guidelines such as fish and aquatic invertebrates (e.g., Lugg et al. 2017; West et al. 2021) however internationally it has also been used to detect general mammal fauna within the catchment in water samples (Sales et al. 2020).

9.22.2. Design and Procedure

- While eDNA can be found anywhere, it currently is easiest to detect in aquatic environments.
- Sample collection does not require specialised skills or equipment, but care must be taken to avoid contamination and stored to maintain DNA viability.
- Viability of eDNA depends on the amount of shed DNA present, and the environmental conditions – DNA will break down more rapidly with exposure to sunlight and high temperatures.
- Availability of reference samples may be a limiting factor for detecting very rare, data deficient or cryptic species. However, the DNA of closely related species can be used for comparison.
- If using to detect a single target species, testing of DNA shedding rates into various substrates (water, sediment, soil) is required (West et al. 2021). Sampling higher volumes of substrate may be required for species with low shedding rates.
- The method may have low geographic accuracy (e.g., the upstream in the catchment for aquatic samples) and be more useful for understanding landscape-level distribution and diversity.
- This method can be more cost-effective and have higher detection probabilities compared to traditional methods such as trapping (Lugg et al 2017).
- EDNA metabarcoding technique may best used alongside other traditional as well as non-invasive methods (e.g., camera traps) to maximise species detection.

9.22.3. Ethical Considerations

- Nil ethical concerns as the technique does not require interaction with the animal.
- Disturbance to habitat should be minimised when collecting samples.

10. Habitat and Condition Assessment

As a minimal requirement, a standardised description of the habitat that is being surveyed for fauna should be undertaken at any generic or targeted survey site. Information on the location, landform, vegetation structure, regional ecosystem, and disturbance characteristics of sites can be recorded in a standardised manner that is compatible with current ecological data recording systems in Queensland (e.g., Wetland Information Capture System, WildNet, CORVEG, BioCondition, Melzer at al. 2011, McDonald *et al.* 1998). In association with the Terrestrial Vertebrate Fauna Survey Guidelines, a site description datasheet is provided on the Queensland Government website.

In Queensland, the BioCondition vegetation assessment framework has been developed to provide a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values (Eyre et al. 2015). BioCondition is the recommended approach for the rapid assessment of habitat condition at the generic survey sites. BioCondition is a site-based and quantitative procedure that can provide a score along a continuum of 'functional' through to 'dysfunctional' condition from a biodiversity perspective. The BioCondition score is based on a comparison between measurements of specific site-based attributes and a benchmark value for each of those attributes, specific to a particular RE. A benchmark value is the average value obtained from reference sites, which are mature and long undisturbed sites or "Best On Offer" (BOO) sites. If a condition score is not required under the objectives of the survey, then the BioCondition method can be used to simply assess, quantitatively, key vegetative attributes. BioCondition provides systematic methods for the assessment of ten site-based attributes and three landscape-scale attributes. The assessable field-based attributes are: number of large trees, tree height, recruitment of native woody perennial species, tree canopy cover, shrub canopy cover, length of coarse woody debris, native plant species richness, weed cover, native perennial grass cover and litter cover, which are assessed within a nested plot design based on a 100 x 50 m plot (Figure 11). A BioCondition field assessment guide is provided in Appendix C: .

BioCondition, benchmark documents and protocols for assessing reference sites are available on the BioCondition page of the Queensland Government website. At this stage, many REs have not yet been benchmarked. In these cases, or if an assessment needs to be undertaken during less optimal conditions, then benchmark data can be obtained by locating and measuring the relevant attributes at a local reference site. Reference site assessment does require skilled observers with experience in botanical and habitat assessment.

Depending on the objectives of the assessment, additional habitat features may need to be measured to appropriately assess habitat suitability, which are not addressed in the BioCondition method e.g., rock cover, abundance of tree-hollows, dead trees, or the diversity and arrangement of vegetation strata. Advice on appropriate sampling of these features can be obtained from the Queensland Herbarium.

Standards for full floristic and vegetation assessment in Queensland relevant to the Regional Ecosystem mapping framework are provided by Neldner et al. (2005). We recommend that the 'secondary' site assessment standards outlined in this document are followed for structure and floristics (CORVEG).

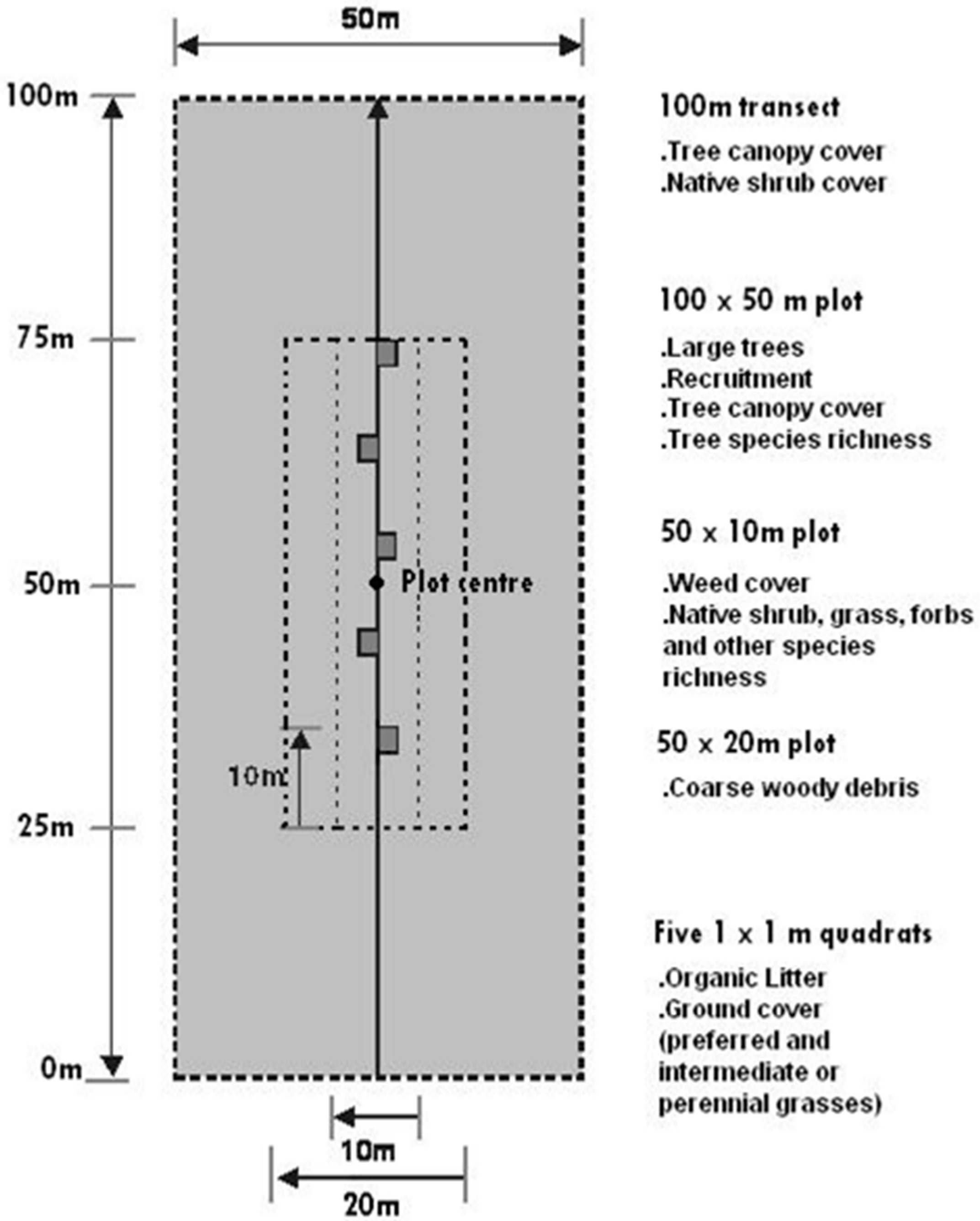


Figure 11: Plot layout for a BioCondition site assessment.

11. The Final Report

Preparation and content of the final report will clearly depend on the needs of the client, and the objectives of the survey or Terms of Reference. If the Scoping Document was prepared during Stage I of the fauna assessment, then much of the information collated for that report will be useful for the final report. Regardless of the purpose and client needs, the final report should broadly follow the standard format for scientific reporting, and include the following sections; Executive summary; Introduction; Methods; Results; Discussion; References; Appendices. It will be appropriate to include sections of the Stage 1 Scoping document where relevant e.g., the literature review in the introduction. Each section of the final report should contain at least the following information, as relevant and appropriate:

11.1. Executive summary

- Provide a concise summary of the objectives, scope, methods and results from the survey and key recommendations.
- Figures or tables are not usually included in the executive summary.

11.2. Introduction

- Describe, identify and generally introduce the where, why, when and for whom the fauna assessment and survey was conducted.
- If the survey was conducted for an impact assessment, outline the type of proposed development (e.g., mining, residential) and details relating to the likely impacts of the development upon fauna and habitat.
- Provide the general and specific objectives of the fauna assessment and survey.
- Provide the background research e.g., literature review and outcomes from the Stage I interim report.
- Provide details on the permits, authorisations and animal ethic approvals issued, including type of permits, dates issued, permit numbers, expiry dates, contact name to whom the approvals were granted.
- Provide details on the names, qualifications and experience of the fauna assessment team who undertook the surveys and production of the report.

11.3. Methods

- Describe the area of interest (the survey area), including information on the:
  - Location (include a map if possible);
  - General physical properties such as climate, topography, soils, the location and extent of REs, including REs of conservation concern;
  - Current and historic tenure, land use and management.
- Describe the stratification of the survey area and the delineation of assessment units (what data was used in the stratification, how many assessment units were delineated).
- Describe the selection of generic and/or targeted survey sites within the survey area, including number of replicate sites per assessment unit, and total number of sites selected (use a map to show the distribution of the survey sites. Site should be uniquely identified using an appropriate naming convention and locations (AMGs and/or latitude and longitude) can be provided in an appendix to the report.

- Provide details on prevailing environmental conditions during the survey e.g., fine, unseasonal rainfall, drought, heavy flowering.
- Describe the survey methods used and associated effort (e.g., as outlined in this document).
- Specify the taxonomic nomenclature used for the fauna and flora.

11.4. Results

- Use tables, maps and photographs to assist with summarising the results.
- List all species and their conservation status (under the *Nature Conservation (Animals) Regulation 2020* and under the EPBC Act 1999), or whether they are an introduced species, detected during the survey. The list can be presented as a table, which also includes the sites and assessment unit (or RE, or broad habitat type, or whatever was used to stratify the survey area) the species was detected in, and relative abundance.
- Summarise the condition of the habitat/assessment units sampled e.g., distribution of important habitat features such as large trees and coarse woody debris.
- If known, report species detection rates.
- Results from statistical power tests should be reported to demonstrate sampling adequacy, particularly if no significant impacts upon fauna are to be concluded in the report.
- Use species accumulation curves to assess the adequacy of the survey data for the reporting of fauna species lists or estimates of species richness by extrapolation for habitats or assessment units.

11.5. Discussion and Recommendations

The discussion of the report must be framed to address the objectives of the survey, and based on the survey results as well as the information gathered during the Stage I scoping exercise. From the discussion, key recommendations can then be made.

- Discussion of significant species detected in the survey area in relation to their range, habitat, breeding, foraging and shelter requirements, landscape considerations (e.g., connectivity of habitat, patch size) and their current level of conservation protection (such as any requirements of protected area management plans), and potential impacts of any proposed development.
- Discussion of key habitat (e.g., rocky outcrops) and habitat features (such as large trees, coarse woody debris) in the survey area and potential impacts of any proposed development.
- It is advisable to adopt the precautionary principle when making recommendations. The precautionary principle basically assumes that a significant species is likely to inhabit the survey area, based on the Stage 1 review and availability of suitable habitat, even if it was not detected during the Stage 2 field surveys. Reasons may be provided why the species may not have been detected during the surveys.
- Discuss the limitations associated with the survey which may have had an impact upon the results and/or survey adequacy, for example;
  - Storms or inclement weather
  - Inaccessibility
  - Resource limitations (time, skills, equipment failure etc).
  - Inadequate sampling and/or effort (as determined by the power analyses and species accumulation curves)

11.6. References

- List references used throughout the report using a standard scientific format.

12. Glossary

Term	Definition
Animal Ethics Committee	A committee constituted in accordance with the terms of reference and membership laid down by the Australian Code for Practice for the Use of Animals for Scientific Purposes.
Arboreal	An arboreal animal is one which spends large amounts of time inhabiting or frequenting trees.
Assessment unit	Relatively homogenous unit that is one Regional Ecosystem in one broad condition state (remnant or non-remnant).
Bat detector	An electronic device designed to detect the echolocation calls of microbats, making them audible and/or visible in order to record and analyse the characteristic calls for specific species etc.
Benchmark	A quantitative description of a Regional Ecosystem that represents the median or average characteristics of a mature and relatively undisturbed ecosystem of the same type.
'Best on Offer' (BOO)	Here refers to sites, or condition values of sites, where the patches of vegetation that have been least impacted by local disturbances. Instructions for finding or establishing reference or BOO sites can be found in the BioCondition Reference site manual from the Queensland Government website.
BioCondition Score	The score assigned to the survey site that indicates its condition relative to the benchmarks set for the RE being assessed, as per the BioCondition method. The score can be expressed as a percentage, on a scale of zero to one, or as a category. The BioCondition manual can be downloaded from the BioCondition section of the Queensland Government website.
Biodiversity	The diversity of life forms from genes to kingdoms and the interactions and processes between.
Broad Vegetation Group (BVG)	BVGs are a higher-level grouping on an ecological basis of vegetation units or regional ecosystems. Mapping can be downloaded from the Queensland Government Qspatial website.
Canopy	The layer formed collectively by the crowns of adjacent trees or shrubs in the case of shrublands. It may be continuous or discontinuous. The canopy usually refers to the ecological dominant layer.
Carcass	A dead animal's body.
Condition state	Based on the state of the vegetation relevant to biodiversity, where condition is defined as the similarity in key features of a regional ecosystem with those of the same regional ecosystem in its reference state i.e. the state of vegetation where the natural variability of an RE is relatively stable and unmodified since the time of European settlement, or the 'best on offer'.
Covariate	In statistics, a covariate is a variable that is possibly predictive of the outcome under study. A covariate may be of direct interest or it may be a confounding or interacting variable.

Term	Definition
Diameter at breast height (DBH)	DBH is a measure of the size of the tree and is consistently measured at 1.3 m from the ground. On sloping ground, DBH is measured on the high side of the tree from bare earth ground level. Ensure that the tape is horizontal or at a tangent to the trunk when reading the diameter. On leaning trees, on level ground, 1.3 m is measured from the underside of the lean. If a whorl, bump scar or other abnormality occurs at the 1.3 m mark, measure the diameter at a nominated height (measured in whole 0.1 m increments) above the defect. If a representative measure as described above cannot be taken (e.g., presence of strangler figs), a reasonable estimate of the diameter should be made viewing the tree from two different directions. For multiple stems (i.e. when the tree divides below 1.3 m), a diameter is recorded for each stem.
Drift fence	A vertical barrier that blocks and directs the path of small animals. It usually connects pitfall traps and funnel traps, increasing their effectiveness.
Echolocation	The emission of high frequency soundwaves and interpretation of the returning echoes to determine the direction and distance of objects in the path of the sound beam. Used by bats for orientation and foraging in flight.
Generic survey site	A systematically selected survey site at which a suite of standard methods are employed to survey the occurrence, incidence and/or abundance of vertebrate species in the following taxa; amphibians, reptiles, birds and mammals.
Grass	A collective term for the following plant life forms: tussock grass which forms discrete but open tussocks usually with distinct individual shoots; hummock grass which are coarse xeromorphic grasses with a mound-like form often dead in the middle e.g., spinifex *Triodia*; other grasses of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.
Hair tube	A baited cylinder or funnel-shaped device containing adhesive tape which samples hair from small to medium sized mammals.
Herpetofauna	Reptiles (e.g., turtles, snakes, lizards, crocodiles) and amphibians (frogs).
Irruptive species	A sudden, dramatic and rapid increase in a species population.
Large tree	A living tree identified as ‘large’ by a DBH threshold as defined in the benchmark document relevant to a RE (Benchmark documents can be downloaded from the Queensland Government website). In some REs a different large tree threshold will be identified for eucalypt and non-eucalypt species due to the variation in potential size of these two tree types. For the purpose of defining large trees, eucalypts include trees of genera *Angophora, Eucalyptus, Corymbia* and *Lophostemon*. If a large DBH threshold is not provided in the benchmark document, then generic thresholds of >20 cm DBH for non-eucalypts and >30 cm DBH for eucalypts can be used.
Landscape Context	Relates to the size, connectivity and the context or neighbourhood landscape that the site sits within.
Non-native plant	Any plant that is not a native species in the area of interest
Non-remnant vegetation	Non-remnant vegetation is vegetation that fails to meet the structural and/ or floristic characteristics of remnant vegetation. It may include regrowth, heavily thinned or logged, significantly disturbed vegetation and cleared areas. Non-remnant vegetation may retain significant biodiversity values and includes areas mapped as ‘high-value’ regrowth.

Term	Definition
Person minutes	A measure of effort to describe the amount of time spent during active or passive searches. It is based on the time in minutes of one person undertaking the search. i.e. 30 person minutes = one person searching for 30 minutes, or two people searching for 15 minutes etc.
Pitfall array	The layout of pitfall traps, drift fence and funnel traps on the generic site.
Pitfall trap	A bucket, pipe or container buried with the rim flush with the ground surface; designed to capture animals when they fall in.
Precautionary principle	The principle that, if there are threats of serious or irreversible environmental damage, lack of full scientific certainty must not be used as a reason for postponing measures to prevent threatening processes. (*Nature Conservation (Administration) Regulation 2017*).
Quadrant	Relates to the 50 x 50 m quarter plot of the whole 100 x 100 m generic survey plot.
Ramsar Convention	The Ramsar Convention on Wetlands was the first modern treaty between nations aimed at conserving natural resources. Signed in Ramsar, Iran, in 1971, it keeps a register of Wetlands of International Importance. There are currently five Ramsar-listed wetlands in Queensland.
Reference library (bat call)	A collection of bat calls for each species in a region showing call variability for that region. Calls are recorded from individuals identified in the hand, then released.
Reference site	A site that represents an example of a Regional Ecosystem in its reference state, i.e. the natural variability in attributes of an ecosystem relatively unmodified since the time of European settlement. As not all RE's will have examples of totally unmodified states, reference sites represent the "Best On Offer" (BOO) reference state for that RE in a local area. Data obtained from reference sites are used to establish benchmarks for each of the attributes used within BioCondition (the Assessment of Reference Sites manual is available as a companion document to the BioCondition manual)
Regional Ecosystem (RE)	REs are vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform, and soil (Sattler and Williams 1999).
Remnant vegetation	Remnant vegetation is defined as vegetation where the dominant canopy has greater than 70% of the height and greater than 50% of the cover relative to the undisturbed height and cover of that stratum and dominated by species characteristic of the vegetation's undisturbed canopy.
Scat	An animal's solid waste material (i.e. faeces).
Shrub	Woody plant that is multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m tall.
Significant species	Those species listed as threatened under the Queensland Nature Conservation Act 1992 (NCA) or the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC).
Slough	The shed skin (outer dermal layer) of a reptile.

Term	Definition
Sonogram/ spectrogram	A visual representation showing how sound varies over time, for example a time by frequency graph visually depicting bat calls.
Statistical power	The likelihood of correctly rejecting the null hypothesis; depends on the sample size used in the test, the effect size to be detected and the variability inherent in the data
Survey area	The survey area is the area within which all survey effort (assessment units, generic survey sites and target survey sites) is focused.
Survey period	The period of time it takes to complete a round of fauna surveys at a group of survey sites within the survey area.
Targeted survey site	A survey site which is specifically selected to target a particular taxon or suite of taxa, usually because of particular habitat features (e.g., rocky outcrop, wetland, and abundance of hollow trees). Typically, less than the full suite of standard methods (compared to a generic survey site) is employed to survey the occurrence, incidence and/or abundance of vertebrate species of one or more of the following taxa; amphibians, reptiles, birds and mammals.
Taxon	Organisms comprising a particular taxonomic entity or group (e.g., class, family, genus, species, subspecies, variety)
Taxonomic groups	In this document, taxonomic groups refer to: amphibians, reptiles, diurnal birds, nocturnal birds, small terrestrial mammals, medium-large terrestrial mammals, arboreal and volant mammals and microbats.
Terrestrial fauna	Animals which live predominantly or entirely on land as opposed to in water. Our definition here includes amphibians and freshwater turtles (Family Chelidae).
Track	Imprints (e.g., drag marks, footprint etc.) left behind by an animal visible on ground surfaces which they cross.
Tree	Woody plants, more than 2 m tall with a single stem or branches well above the base.
Ultrasonic sound	The frequency of sound above the upper limit of human hearing, which is about 20 kilohertz.
Varanid	Reptiles belonging to the family Varanidae (genus *Varanus*). Also known as monitors or goannas.
Voucher specimen	Any specimen, usually, but not always, a dead animal, which serves as a basis of scientific study and is retained as a reference in a museum.
Volant	An animal that can fly or glide or is capable of flight or gliding.
Wetland	Areas of permanent or periodic/intermittent inundation, whether natural or artificial, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m. See Wetland*Info* for more information on wetland definitions and assessment.

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14. Appendices

Appendix A: Useful Sources of Information and Data

Field guides

Local and state-wide field guides provide information on species known, broad distributions as well as useful knowledge of their habitat and ecology. Note that distribution maps may be incomplete for some species, given a lack of knowledge on species particularly in the more remote areas of Queensland.

Wildlife Online

The Department of Environment and Science (DES) administers a wildlife database (WildNet) containing recorded wildlife sightings and listings of plants, fungi, protists, mammals, birds, reptiles, amphibians, freshwater fish, marine cartilaginous fish and butterflies in Queensland (Wildlife Online). This website provides access to a list of wildlife that the department has recorded for areas such as national parks, state forests and local government areas, or areas defined by the user, based on collated species lists and wildlife records acquired through a range of sources. Sources include specimen collections, research and monitoring programs, inventory programs (including extension activities), literature records, wildlife permit returns and community wildlife recording programs. Wildlife lists for local government areas, basins and NRM body regions can be viewed online via the WildNet database. The wildlife list generated will contain the kingdom name, class name, family name, scientific name, common name, flag for introduced species, status under the *Nature Conservation Act 1992*, status under the *Environment Protection and Biodiversity Conservation Act 1999* and the number of records for the record category selected and the number of specimens for each species recorded in the survey area. The wildlife list can be generated for a selected area, a defined area or for a specific point. As the department is still in the process of collating and vetting wildlife data, it is possible the information given is not complete, or there may be some error attached to it (e.g., incorrect locality or misidentification). Furthermore, the absence of a species from the list does not mean that it does not occur there, but only that records are not held within the database as a consequence of no, or inadequate, prior survey effort.

Queensland Museum

The Queensland Museum holds a significant electronic database associated with its zoological collections. This database includes taxonomic and locality data for living and fossil faunas throughout Queensland as well as other areas in the Indo-west Pacific. This database can be searched at a cost and the data provided for specific purposes to which you agree by accepting a set of terms and conditions. Areas between two latitudes and longitudes (in degrees and minutes) can be searched. Search results are e-mailed in an ASCII tab-delimited file. Output coordinates in degrees and minutes and the datum AGD66 are used. Data is made available by filling out a data search request form.

Information on species and ecosystems of conservation concern can be obtained from the following sources:

Nature Conservation Act 1992 (NCA) listings

For species currently listed see the *Queensland Nature Conservation (Animals) Regulation 2020*. As there are regulation changes from time to time, this website should be checked before preparing for a survey and at reporting.

Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The Australian Government's key environmental legislation identifies threatened species and ecological communities across Australia and is administered by the Department of Environment. Distribution maps can be used to identify communities and species that are relevant to different areas within Queensland, which may coincide with the survey area. www.environment.gov.au/epbc/protect/species-communities

Vegetation Management Act 1999 (VMA) Essential Habitat Mapping

These are maps of regional ecosystems produced by Department of Natural Resources and Mines (DNRM) that indicate known or potential habitat for species that are endangered, vulnerable, and rare or near threatened. *Vegetation Management Act 1999 (VMA) Essential Habitat Maps* are used when assessing applications to clear vegetation under the *Vegetation Management Act 1999*. The Queensland Spatial Catalogue provides a portal to display, select and download spatial data produced by the Queensland Government, including Essential Habitat mapping, SEQ koala habitat mapping and regional ecosystem mapping. These spatial products can also be viewed via Queensland Globe.

The Atlas of Living Australia (ALA)

Through the Atlas, users can obtain information on what species information is available in a particular area, by using an explore tool to get information from a 5 or 10 km radius from a coordinate. The ALA collates data from a variety of sources and as such it is possible that there are inaccuracies and/or incomplete data present in the output. Therefore, as with Wildlife Online, the absence of a species from the list does not mean that it does not occur there. Only that those records are not held within the database as a consequence of no, or inadequate, prior survey effort. The website provides access to a variety of information about Australian biodiversity- animals, plants, fungi and microorganisms, including:

- species pages;
- species names list;
- species identification information;
- more than 23 million occurrence and distribution records;
- information on key Australian biological collections;
- mapping tools.

Local Expert Advice

Natural resource managers and/or experts who have worked in the survey area may be able to provide information on additional species of interest that may require targeted surveys.

Existing spatial (mapping) information relating to the study area can be obtained from the following sources

Regional ecosystems (REs)

These are vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil, and are the primary vegetation mapping product in Queensland. Acquisition of digital remnant RE mapping is a key layer for delineating assessment units in the survey area. The applicability of the RE mapping should be assessed in the field to check if it is relevant at the scale at which the assessment is being conducted. REs are defined at scales which range from 1:50 000 (e.g., South East Queensland) to 1:100 000 (e.g., rangeland bioregions) and a single polygon may contain several mapped REs (heterogeneous polygons). The Queensland Government provides free digital RE maps (in pdf format) of areas based on the provision of a Lot on Plan number or based on a central co-ordinate. The Regional Ecosystem Description Database (REDD) provides current descriptions of the REs and their conservation status (under both the VMA and NCA) can also be downloaded from www.qld.gov.au. It is provided in two formats, Microsoft Access and Microsoft Excel.

The Biodiversity Assessment and Mapping Methodology (BAMM)

This mapping methodology provides a consistent approach for assessing biodiversity values at the landscape scale in Queensland. The BAMM is based on the regional ecosystem mapping from the Queensland Herbarium and incorporates a range of biodiversity related data. It is being used by the DES to generate Biodiversity Planning Assessments (BPAs) for each of Queensland's bioregions. The BAMM first uses existing data to assess ecological concepts such as rarity, diversity, fragmentation, habitat condition, resilience, threats, and ecosystem processes in a uniform and reliable way across a bioregion. These criteria are used to filter available data and provide a "first-cut" or initial determination of significance. This initial assessment is generated on a geographic information system (GIS). The second stage relies more upon expert opinion than on quantitative data to refine the results of the first stage. It uses expert knowledge to identify features such as wildlife corridors and areas with special biodiversity values (e.g., centres of endemism or wildlife refugia), and includes data that may not be available uniformly across the bioregion. BPAs have been completed for a number of bioregions within Queensland and can be downloaded from the Queenland Government QSpatial catalogue (under the 'biologic and ecologic' topic category). The packages include GIS data and expert panel reports. The method is available for download from the Queensland Government website. AquaBAMM provides a similar assessment for wetlands and waterways, and can also be downloaded.

Appendix B: Equipment

Generic Survey

Site Set Up

- Star pickets x 2 (if permanently marking site for ongoing monitoring)
- GPS to record site location (coordinates)
- Flagging tape to mark site boundaries
- Compass to guide site orientation
- 100 m tape measure
- Minimum/Maximum thermometer (used for all trapping and searches)
- Datasheets (for the site plus all trapping and searching methods)

Pitfall Trapping

- Four 20L buckets and lids
- Drift fence - One 15m length and one 30m length (e.g., Canvacon or aluminium fly-wire)
- 30 – 50 steel pegs, approximately 50cm long
- Four pit shades (e.g., high density foam)
- Set-up tools (shovel, crowbar, mallet, mattock)
- Calico catch bags
- Plastic bags, plus gloves or freezer bags for handling frogs
- Snake handling equipment

Funnel Trapping

In addition to pitfall trapping equipment:

- Six funnel traps
- Funnel shades (>70% shade-cloth or similar)

Active Searches

- Searching tool (rake, jemmy bar or similar)
- Calico catch bags
- Plastic bags, plus gloves or freezer bags for handling frogs
- Hand lens
- Head torch (for nocturnal searches, or to examine hollows during diurnal searches)
- Thermometer
- Timing device

Small Mammal Trapping

- 20 Type A Elliott traps (or similar)
- Bait mix
- Calico catch bags
- Spare trap parts

Cage Trapping

- Two cage traps
- Bait
- Shade/shelter

Diurnal Bird Survey

- Timing device
- Binoculars (10 x 40 or 10 x 50)
- Field guide

Camera Trapping

- Remotely triggered camera (including batteries, memory card and manual)
- Bait
- Bait cage (optional but recommended)
- Card reader/viewer (optional)

Call Playback and Spotlight

- Timing device
- MP3 / iPod / mini disc / CD player with nocturnal bird calls
- Speakers or megaphone
- Spotlight (recommend 30 Watt) and battery
- Thermometer
- Binoculars (10 x 40)
- Head torch

Microbat Echolocation Call Detection

- Bat detector (including batteries and memory card(s))
- Memory card reader/writer
- Associated software (e.g., CFC Read, AnalookW, BATSOUND)
- Weather proofing
- Mounting apparatus to ensure detector is elevated off the ground

Scat and Sign Search

- Clip-seal bags to collect scats and other traces for later ID
- Gloves to reduce exposure to zoonotic diseases
- Camera to document tracks and other signs
- Field guide

Targeted Surveys

Amphibian Searches

- Head torch
- Dip-net and clip-seal bags (if identifying tadpoles or egg masses)
- Timing device
- Equipment to undertake hygiene protocols (see hygiene protocol for handling amphibians)
  - Single use gloves or lightweight plastic bags
  - Disinfectant and scrubbing equipment

Freshwater Turtles

- Turtle traps including securing ropes and floats (design choice based on target species)
- Binoculars and/or spotting scope and tripod
- Camera for identification
- Appropriate bait
- Snorkelling gear (mask, snorkel, fins)

Wetland Birds (Waterbirds)

- Binoculars and/or spotting scope and tripod
- MP3 / iPod / mini disc / CD player calls of target wetland birds
- Hand held clicker/counter
- Speakers or megaphone
- Timing device
- Field guide
- Camera including telephoto lens or appropriate zoom function
- May be required: waders, canoe or boat

Roost Searches for Microbats

- Binoculars
- Hand net
- Face masks if entering larger cave roosts
- Bat detector (optional)
- Calico bat bags (small enough to weigh bats in)
- Spring balances
- Callipers
- Head torch and torch (red filter over lights)
- Note book

Roost Searches for Flying Foxes

- Binoculars
- Head torch
- Hand held clicker/counter for fly out and walk-through counts

- Camera including telephoto lens or appropriate zoom function
- High resolution maps of camp

Harp Trapping for Microbats

- Harp trap(s)
- Reel of nylon line and spares kit
- Calico bat bags (small enough to weigh bats in)
- Spring balances
- Callipers
- Head torch

Mist Netting for Microbats

- Mist net, including poles and ropes
- Scissors
- Calico bat bags (small enough to weigh bats)
- Spring balances
- Callipers
- Head torch

Trip Lining for Microbats

- Reel of nylon line (3 kg breaking strain)
- Tent pegs
- Hammer
- Flagging tape
- Dip net
- Calico bat bags (small enough to weigh bats)
- Spring balances
- Callipers
- Spotlight and head torch

Camera Trapping

- Remotely triggered camera (including batteries, memory card and manual)
- Bait
- Bait cage (optional but recommended)
- Card reader/viewer (optional)

Automated Acoustic Recording

- Automatic recording set-up (including batteries, memory card and manual)
- Download and programming software.
- Analysis software.

Nocturnal Vehicle Transects

- Vehicle
- Spotlight (recommend 50 - 100 Watt) and head torch
- Binoculars (10 x 40)
- Snake handling equipment (if required)
- GPS

Hair Tubes

- Hair tube devices (including adhesive tape or wafer).
- Pegs to fix hair tube in place
- Bait ingredients
- Vegetable oil in case small non-target animals become stuck.
- Sealed, labelled bags to place collected sample in
- Lab Analysis equipment (microscope, slides, etc).

Predator Scat Collection

- Clip-seal bags
- Information tags (indicating collection location and date)
- Gloves

Call Playback and Spotlight

- Timing device
- MP3 / iPod / mini disc / CD player with calls of target species
- Automated play back function on the playback device if required
- Speakers or megaphone
- Decoys (optional)
- Spotlight (recommend 30 Watt)
- Thermometer
- Binoculars (10 x 40)
- Head torch if survey conducted at night

Artificial Nesting/Roosting Boxes

- Boxes and wire (with tree protection) for hanging from trees
- Ladder or cherry picker or climbing ropes
- Gloves
- Snake cam (optional) or automated camera (optional)

Thermal Infrared Imaging

- Thermal infrared camera
- Video camera
- S-Video/Audio/Video cable
- Mini-DV tapes (60 minute)

- Data logger/Weather meter
- Infra-red thermometer
- Tripod
- Batteries for thermal infrared and video cameras

Post Fieldwork Processing

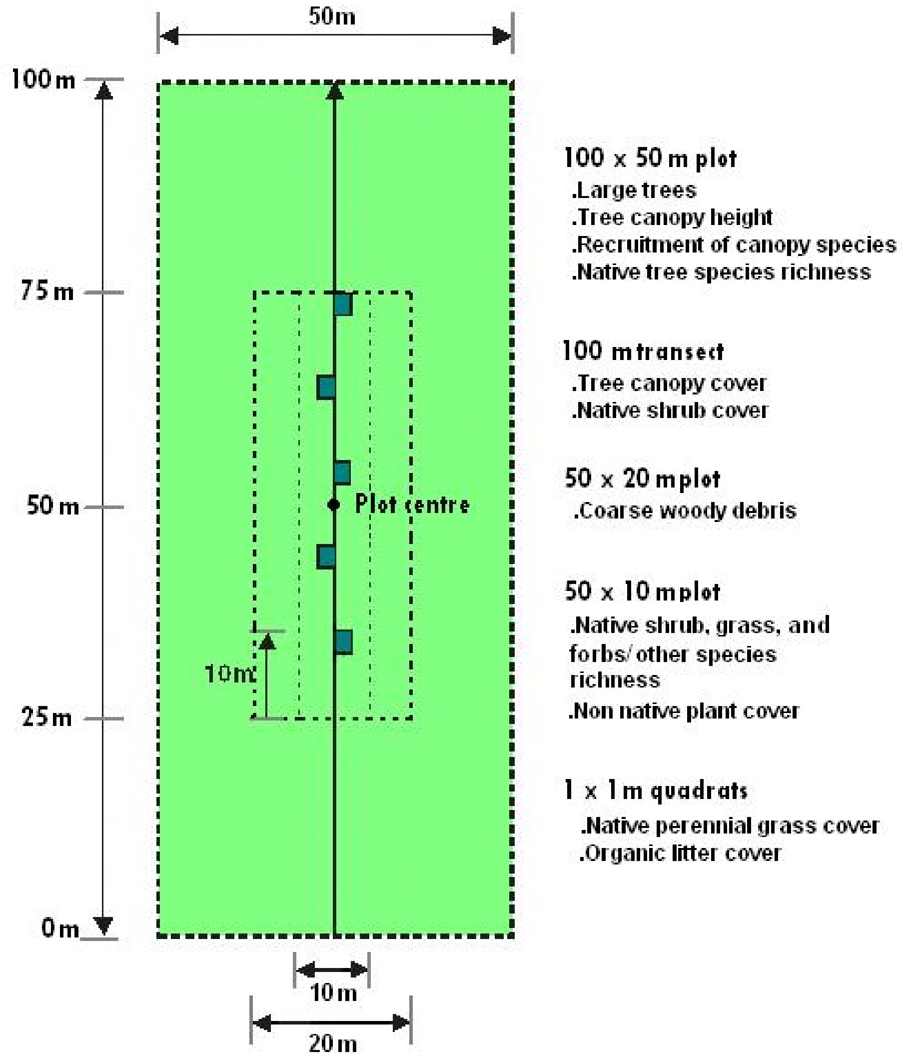
- Firewire video cable
- Laptop/PC computer
- External/portable hard drive
- Automated detection and tracking software

Appendix C: BioCondition Assessment Guide

NB: IT IS STRONGLY RECOMMENDED THAT THE BIOCONDITION MANUAL IS CONSULTED IN THE FIRST INSTANCE, TO ASSIST WITH CLARIFICATION OF DEFINITIONS AND ASSESSMENT APPROACH. The BioCondition manual can be downloaded from the Queensland Government website. If no benchmark documents are available for the REs to be surveyed, then it may be advisable to use the reference site assessment approach (see Eyre et al 2017; available on the Qld Government website). This approach will take longer to undertake, but will provide more quantitative measures on certain attributes, and will allow the derivation of benchmarks if the site being assessed is in a reference or BOO state.

Step 1: Plot layout

The site can be marked with a 100 m transect that follows the contour i.e. along a slope as opposed to up or down a slope. Mark the 50 m point on the transect with a star picket or temporary marker—this point acts as the centre of the assessment site. Record the compass bearing that the transect follows from the zero point, and also record the location of the zero metre point by GPS.



Step 2: Field assessment

Start at the centre of the plot (50 m mark on the transect), and record the site number, Regional Ecosystem (RE), the date of assessment and the property or location name. Using a GPS, mark the position of the 50 m point on the transect. Take landscape photos north, south, east and west (see the BioCondition manual for hints on taking photos), to provide a record of the tree and shrub layers and the general condition of the site. The assessment of the 10 site-based attributes is conducted within five assessment areas on the 100 x 50 m site, as shown below.

Step 3: 50 x 10 m sub-plot measurements

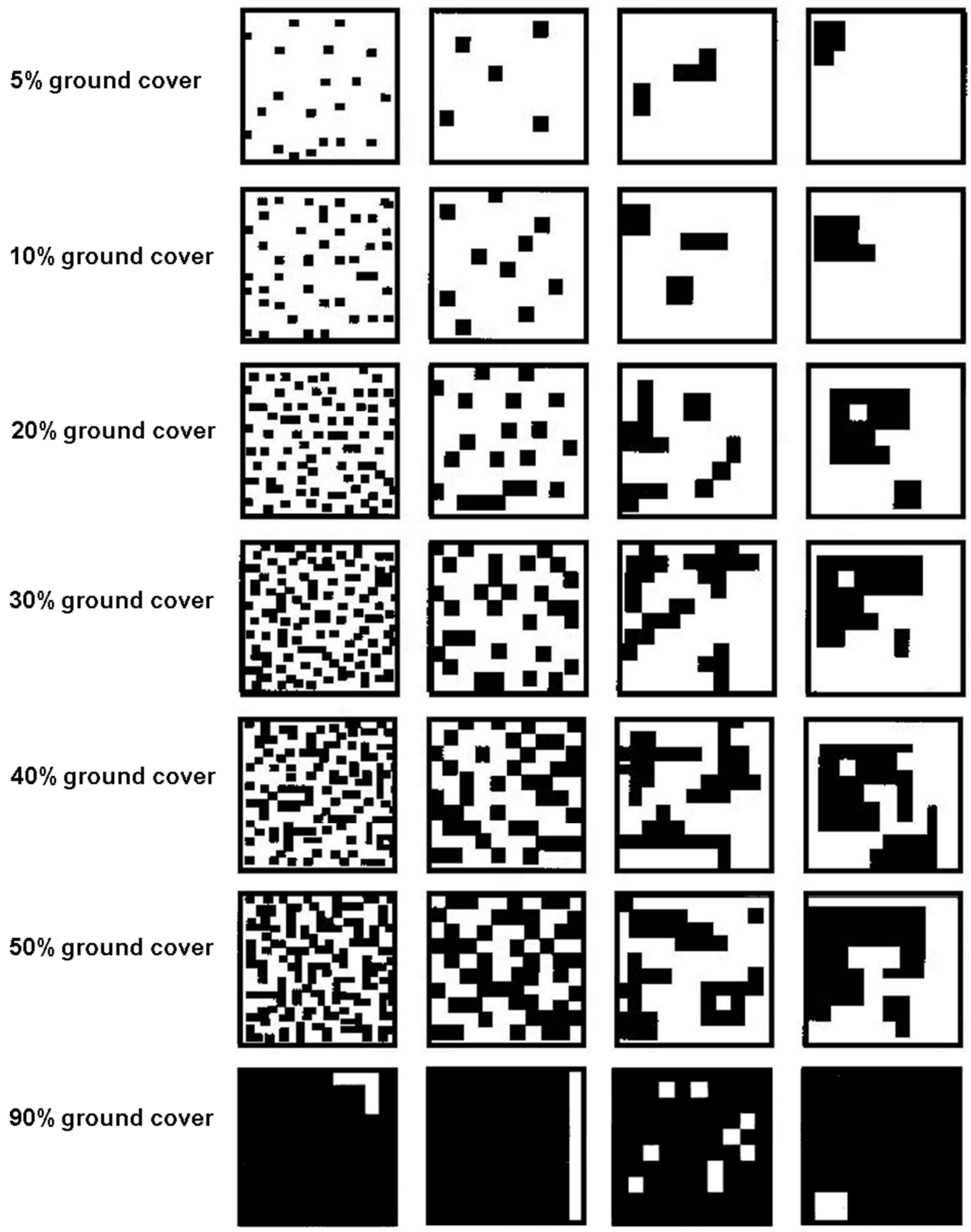
- 50 x 10 m sub-plot, incorporates 25 m to 75 m along the transect, and encompasses 5 m either side of the transect.
- Native plant species richness is assessed by slowly walking along each side of the centre-line and tallying the number of species in each of three life-forms: shrubs, grasses and forbs/other. Tree species richness is assessed in the 50 x 100 m plot.
- Non-native plant cover is assessed by estimating the cover of exotic species as a component of the overall vegetation cover. The estimate can be improved by dividing the 50 x 10 m plot into smaller areas and then averaging the cover estimate over the entire area. For example, 20 x 5 x 5 m (10 plots each side of the tape).

Step 4: 50 x 20 m sub-plot measurements

- 50 x 20 m sub-plot, incorporates 25 m to 75 m along the transect, and encompasses 10 m either side of the transect.
- Coarse woody debris is assessed by measuring the length of all logs >10 cm diameter, 0.5 m in length and within the 50 x 20 m sub-plot. Logs are assessed if 80% of the log is in contact with the ground. Measure only the portion of the log that is greater than 10 cm diameter or lies within the sub-plot, i.e. only measure the length of the log to the boundary of the sub-plot.

Step 5: 1 x 1 m quadrat measurements

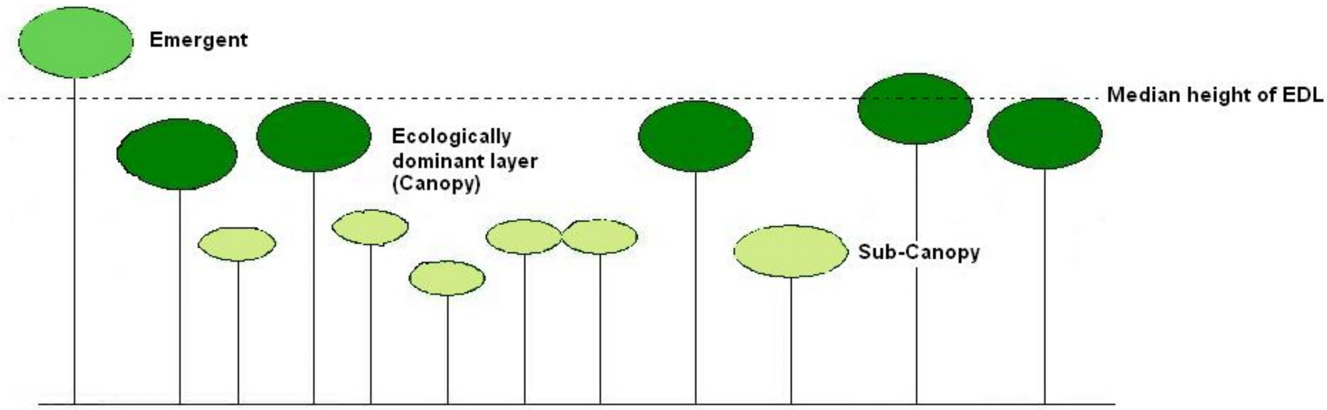
- Five 1 x 1 m quadrats, starting at the 35 m point, located 10 m apart, on alternate sides along the transect. If the quadrat location coincides with a feature such as a tree or large log it is acceptable to move the quadrat 1 m up or down the transect. Assess each of the ground cover components so that the cover totals 100% (see figure below as a guide on cover estimates). Although not all components are used in the scoring, assessment of all attributes improves the ability to estimate cover of the assessable attributes. Spot photos can be taken of each quadrat to document change in ground cover over time.
- Native perennial grass cover refers to the percentage cover of native perennial grasses, assessed within each of the five 1 x 1 m quadrats and averaged to give a value for the site. Depending on the nature of your assessment all perennial grasses can be assessed, or the native perennial grass cover can be split into those species listed in the land type documents as preferred and intermediate or as non-preferred.
- Organic litter is assessed by estimating the cover of fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter from the five quadrats and then averaged.



Step 6: 100 x 50 m plot measurements

- Visualising or marking out 25 m either side of the transect line forms the larger assessment area of 100 x 50 m. A greater need arises for precision when assessing the numbers of large trees (i.e. measuring the distance to trees that appear to be ‘borderline’ within the site). Refer to the benchmark document to determine if there are separate benchmarks for the canopy, emergent and/or subcanopy layers. If more than one layer is identified in the benchmark document, then assessment of each layer is required for the recruitment, canopy height and cover attributes.
- Number of large trees is assessed by counting the number of trees within the 100 x 50 m plot area over a certain size threshold, as recorded on the benchmark document for the RE that you are assessing. If no benchmark exists for the RE of interest, use the threshold of 30 cm DBH for ‘eucalypt’ trees (genera Eucalyptus, Corymbia, Angophora, Lophostemon and Syncarpia) and 20 cm DBH for ‘non-eucalypts’.

- Recruitment of canopy species is assessed by observing the proportion of the dominant canopy (EDL) species regenerating (<5 cm DBH) within the 100 x 50 m plot area. Only one regenerating individual is required of each species (e.g., if there are four dominant species of trees then four species need to occur as regeneration to get 100%).
- Tree canopy height (measured to the top of the highest leaves) refers to the median canopy height in metres (see figure below), estimated for trees in the EDL (canopy layer). If there are emergent and/or subcanopy layers identified in the benchmark document, median height of these layers needs to be assessed also. The median canopy height is the height that has 50% of canopy trees larger and smaller than it. It is recommended that a clinometer or hypsometer be used if available.
- Tree species richness is the count of different tree species.



Step 7: 100 m transect measurements

100 m Transect: tree canopy and shrub canopy cover are assessed along the 100m transect using the line intercept method.

- Tree canopy cover refers to the estimation of the percentage canopy cover of the living, native tree canopy overlapping the 100 m transect. For this attribute, in the majority of cases, only the cover of the trees making up the canopy layer is included. The canopy equates to the ecologically dominant layer (EDL) for forests and woodlands. However, if the benchmark document lists values for more than one layer, then the heights and covers of these layers are assessed separately. Assessors walk along the transect line and record the start and finish distance of tree canopies that overlap the transect line. If overlapping trees are in the same layer then they can be recorded as the one tree group.
- Native shrub canopy cover uses the same method as for tree canopy cover using a vertical projection of shrub crowns downwards and above the line.