DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

# NSW Survey Guide for Threatened Frogs

**A guide for the survey of threatened frogs and their habitats for the Biodiversity Assessment Method**

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Cover photo: Giant burrowing frog, *Heleioporus australiacus*. Ross Knowles/DPIE

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Environment, Energy and Science
Department of Planning, Industry and Environment
4 Parramatta Square, 12 Darcy Street, Parramatta NSW 2150
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (Environment, Energy and Science enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
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# Shortened forms

| Shortened form | Description |
|---|---|
| BAM | Biodiversity Assessment Method 2020 |
| BAM-C | Biodiversity Assessment Method Calculator |
| BAR | Biodiversity Assessment Report; includes Biodiversity Development Assessment Reports (BDARs), Biodiversity Certification Assessment Reports (BCARs) and Biodiversity Stewardship Site Assessment Reports (BSSARs) |
| BC Act | *Biodiversity Conservation Act 2016* (NSW) |
| BCAR | Biodiversity Certification Assessment Report |
| BDAR | Biodiversity Development Assessment Report |
| BOS | Biodiversity Offsets Scheme |
| BSSAR | Biodiversity Stewardship Site Assessment Report |
| DPIE | Department of Planning, Industry and Environment NSW |
| EP&A Act | *Environmental Planning and Assessment Act 1979* (NSW) |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999* (C'th) |
| GIS | geographic information system |
| GPS | Global Positioning System |
| IBRA | Interim Biogeographic Regionalisation for Australia |
| PCT | plant community type |
| SAII | serious and irreversible impact |
| TBDC | Threatened Biodiversity Data Collection |
| TEC | threatened ecological community |

# 1. Introduction

## 1.1 Purpose of this guide

The Biodiversity Assessment Method (BAM) (OEH 2017) was established by the NSW Department of Planning, Industry and Environment (the Department) for the purposes of assessing the impacts on biodiversity from development and clearing or improvements in biodiversity from management at a biodiversity stewardship site.

The purpose of this guide is to aid accredited persons (assessors) when they apply the BAM to survey for threatened frogs or their habitat. Under the BAM, all threatened frogs are treated as species credits (i.e. cannot be predicted by vegetation surrogates) and require appropriately timed on-ground surveys to determine the likelihood of occurrence at a development, biodiversity certification or biodiversity stewardship site. The guide has been prepared using a variety of expert sources and must be read in conjunction with the BAM.

In applying the BAM, a species survey must be conducted in accordance with threatened species survey guides published by the Environment Agency Head (BAM Section 5.3(2.b.)). Therefore, this guide must be applied, as a minimum, when conducting surveys for threatened frogs.

The guide will be reviewed and updated periodically to incorporate new information or to reflect any legislative or policy changes. A **threatened frog survey decision key** is provided in Appendix A. It steps through the approach to determine when a survey is necessary and the type of survey to be applied in accordance with this guide.

## 1.2 Background

In New South Wales, the *Biodiversity Conservation Act 2016* (BC Act), together with the Biodiversity Conservation Regulation 2017, outlines the framework for the Biodiversity Offsets Scheme (BOS). The BOS is underpinned by the BAM (OEH 2017), which creates a transparent, consistent and scientifically based approach to biodiversity assessment and offsetting.

In the context of the BOS, threatened frogs include critically endangered, endangered or vulnerable species and populations as listed under Schedule 1 of the BC Act[1]. The methods and techniques specified here may provide guidance for other threatened species assessment processes such as the assessment of significance and species impact statements required under section 7.3 and Division 5 (respectively) of the BC Act. For frog species listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as critically endangered, endangered or vulnerable, the Commonwealth may require a targeted threatened frog survey using other methods or techniques than those specified in this guide.

The guide refers to land being assessed for threatened frogs as the **subject land**. The subject land is where Stage 1 of the BAM is applied to assess the biodiversity values of the land. It includes land that may be a development site, clearing site, land proposed for biodiversity certification, or land proposed for a biodiversity stewardship agreement. All direct, prescribed and indirect impacts on biodiversity values arising from proposed development, clearing or biodiversity certification must be assessed and described in the Biodiversity Development Assessment Report (BDAR) or Biodiversity Certification Assessment Report (BCAR) (BAM Subsections 9.1.2, 9.1.4 and Section 9.2).

[1]Currently there is one frog population listed as an endangered population under the BC Act – the tusked frog population, Nandewar and New England Tablelands bioregions. There are currently no species listed as having critically endangered populations under the BC Act.

## 1.3 Survey data and biodiversity credits calculations

Under the BAM all threatened entities are allocated to one of two biodiversity credit classes: 'ecosystem' or 'species' credits. Biodiversity credit classes are used to quantify the loss in biodiversity values from the impact of a proposed development or biodiversity certification, or the gain in biodiversity values from the effect of management actions on a stewardship site.

**Ecosystem credits** apply to threatened entities where the likelihood of occurrence of the entity or elements of a species' habitat can be predicted by vegetation surrogates and/or landscape features, or for which targeted survey has a low probability of detection. Ecosystem credits measure, in credits, the threatened ecological communities (TECs) and/or threatened species habitat for a species that can be reliably predicted to occur with a plant community type (PCT) and other PCTs generally.

**Species credits** apply to species where the likelihood of occurrence of the species or elements of suitable habitat for that species cannot be confidently predicted by vegetation surrogates and/or landscape features but can be reliably detected by survey. Species credits measure, in credits, the predicted increase/improvements in, or the loss of, individuals of threatened species or their habitat.

All threatened frogs are species credit species, primarily due to their specialised breeding habitats that are not clearly aligned with specific PCTs. The BAM requires either a targeted species survey or an expert report to determine the presence of a species credit species on the subject land[2].

The information gathered from the targeted species survey is entered into the Biodiversity Assessment Method Calculator (BAM-C). The BAM-C operationalises the BAM by generating the number and type of credits on the subject land.

The BAM-C requires survey data as well as the information contained in tools such as the Threatened Biodiversity Data Collection (TBDC), BioNet Vegetation Classification database (includes a Plant Community Type Identification Tool and associated vegetation condition benchmarks), Over-cleared landscapes database (Mitchell Landscapes) and Directory of Important Wetlands database, to determine credit requirements.

## 1.4 Objectives of a targeted threatened frog survey

The objectives of a targeted threatened frog survey in relation to the BAM are to:

1. establish, with a high level of confidence, the presence of a threatened frog species at the subject land, and
2. where threatened frog species are present, collect data to determine the area of suitable habitat within the subject land, which will be used to calculate species credits.

The targeted threatened frog survey aims to minimise 'false-negatives' (i.e. the species is reported as absent from a site when it is present). A high level of confidence in the survey results is assumed if undertaken by an appropriately skilled person (refer to Section 2.2 of this guide), at the appropriate time (e.g. month, time of day) and in accordance with this guide.

[2] Presence of a species credit species can be assumed at a proposed development, clearing or biodiversity certification site but cannot be assumed at a biodiversity stewardship site (Section 5.2 of the BAM).

# 2. Overall approach to the targeted threatened frog survey

## 2.1 Take a systematic approach

The guide describes a systematic approach to targeted threatened frog survey. Two elements need to be incorporated into the planning phase of the species assessment:

1. survey design to maximise the likelihood of detection of the targeted threatened frog species (including consideration of seasonal and temporal constraints), and
2. field survey techniques to ensure appropriate survey effort across a large proportion of suitable habitat on the subject land, and at an appropriate intensity.

## 2.2 Identify the skills of the threatened frog surveyor

The targeted threatened frog survey must be undertaken by someone with appropriate experience who has good frog identification skills, particularly in distinguishing calls, and a strong knowledge of frog ecology. An appropriate threatened frog surveyor is someone who can demonstrate their relevant experience and qualifications in field survey for threatened frog species, and preferably experience with the target species.

The surveyor's skills can be demonstrated by relevant qualifications and the following:

- a history of experience in survey methods (e.g. aural/visual surveys, call playback, dip-netting, acoustic recorders) and demonstrated success in threatened frog identification in NSW, and/or
- a resume giving details of threatened frog survey projects in the relevant region and target species, including employers' names and periods of employment (where relevant).

Surveyors must have the required **licences and ethics approvals** and a clear understanding of the protocols required for the management of disease given the serious impacts that the amphibian chytrid fungus has on frog populations.

The threatened frog surveyor does not need to be an assessor under the BC Act for the purpose of preparing a Biodiversity Assessment Report (BAR) [3] under the BAM. The experience and qualifications (including licence numbers) of the surveyor must be documented in the BAR (see Section 2.11). **However, the BAR must be submitted by an assessor.**

It is important to note that the threatened frog surveyor is not equivalent to an 'expert' as defined in Box 3 of the BAM. To be considered an 'expert', a person must demonstrate a high level of knowledge in relation to particular biodiversity values (such as a threatened frog species), as the opinion of an expert replaces the need for a field survey. Expert status is determined by the Environment Agency Head.

[3] This guide uses the general term Biodiversity Assessment Report (BAR) to refer to any of the assessment reports required by the BAM, including: the Biodiversity Development Assessment Report (BDAR), Biodiversity Certification Assessment Report (BCAR), or a Biodiversity Stewardship Site Assessment Report (BSSAR).

## 2.3 Create a list of threatened frogs

Section 5.2 of the BAM details the series of filters applied to generate the list of species credit species likely to occur on or use the subject land. Filters include the species biodiversity credit class (i.e. is a 'species credit' species), distribution (as per IBRA subregion associations), association with PCTs identified on the subject land, and the native vegetation cover in the surrounding landscape as well as the patch size of native vegetation on and around the subject land.

Based on these filters the BAM-C generates a list of species credit species that require targeted survey. Additionally, if there are past records of a threatened species on the subject land, and the species is not in the list, it must also be targeted for survey.

In accordance with Section 5.2 of the BAM the surveyor may further refine this list where:

- all habitat constraints[4] listed for the species in the TBDC are absent from the subject land, or
- all habitat constraints or microhabitats on which the species depend are sufficiently degraded such that the species is unlikely to use the subject land, or
- the location of the subject land does not meet any geographic limitations[5] listed for the species within the IBRA subregion, or
- an expert report[6] is prepared (in accordance with Box 3 of the BAM) stating that the species is unlikely to be present on the subject land.

To help determine whether a threatened frog species meets the above criteria the surveyor can interrogate information on the species available in the TBDC, on the DPIE threatened species profile application or any additional sources of information such as scientific journals and research reports.

The justification, including information sources, for removing a threatened frog from the list (thus assuming it is not present on the subject land) must be documented in the BAR.

All remaining threatened frogs are to be assessed further in accordance with the BAM and this guide[7].

## 2.4 Optimise the time of year for the survey

The TBDC provides general guidance on the appropriate time to survey for species credit species. The information is also displayed in the survey matrix section of the BAM-C; however, the TBDC must always be referred to as it contains the most up-to-date survey information. For frogs, survey times are selected based on breeding seasons, when frogs are most easily detected (Lemckert & Mahony 2008). Outside of the breeding season, frogs disperse into terrestrial habitats surrounding the breeding site (Tyler 1998; Lemckert 2004; Penman et al. 2005b). During non-breeding, frogs are secretive and reduce calling, making them difficult to detect. It is important to note that for some frog species, the calling season of males is narrow, meaning surveys must be carefully timed. For example, *Litoria*

[4] Examples of habitat constraints include, but are not limited to, rocky areas, swamps, waterbodies, fallen/standing timber. Habitat constraints associated with a species are identified in both the TBDC and the BAM-C.

[5] Examples of geographic limitations include, but are not limited to, particular local government areas within an IBRA subregion, or above a defined altitude. These are identified in the BAM-C and the TBDC.

[6] Note that an expert, for the purposes of preparing an expert report, needs to demonstrate skills and experience additional to those of the threatened frog surveyor, see Box 3 of the BAM. The expert report must be authored by the expert and attached to the BAR.

[7] Assessment of the presence of these species must be undertaken at a development site but is optional at a stewardship site (and if not undertaken, species credits will not be generated).

*subglandulosa* usually only call from September to December; corroboree frogs for only two to three weeks per year; and *Litoria brevipalmata*, only a few nights in a year, during (not after) periods of heavy seasonal rainfall.

The surveyor may survey outside the times identified in this guide (and the TBDC) but only when there is a justified reason; for example, due to spatial or temporal variation in temperature or breeding seasons with timing documented and justified in the BAR.

In some situations, surveying at the accepted time to detect threatened frogs may not be possible or feasible, for example where project timeframes are constrained. The proponent may choose to use an expert report (in accordance with Box 3 of the BAM) to assess the species' presence on the subject land. Alternatively, for proposed development, clearing or biocertification, the species can be assumed to be present. A species credit species cannot be assumed to be present at a biodiversity stewardship site (see Section 5.2 of the BAM).

## 2.5 Optimise the meteorological conditions for the survey

Frogs are particularly responsive to climatic conditions. Being ectotherms with permeable skin makes them prone to desiccation and lower activity during cooler, dry conditions. Surveys during dry, windy and/or cold conditions, when frogs reduce activity, should be avoided. Note that windy conditions not only desiccate frogs, but also disperse calls. Calling is energetically costly for males and they will reduce calling in conditions that minimise breeding opportunity (e.g. Wells & Taigen 1989; Grafe et al. 1992).

The importance of rainfall as a positive influence on frog activity is well recognised. Less well recognised is the impact of heavy rainfall on stream breeding species. Flooding and rapidly flowing water are dangerous to frogs (e.g. risk of being swept away) and prevent the safe deposition of eggs. Stream breeding frogs tend to cease calling during such conditions.

Heavy rainfall also poses problems for standard survey methods. Rain mutes the sound of calling frogs (see Willacy et. al. 2015) and creates a reflective environment that reduces the efficacy of eyeshine to locate frogs. These factors should be considered when timing surveys.

Consideration must also be given to the time of day/night. Although little studied, anecdotal evidence suggests most species of frog call actively at the beginning of the evening when conditions are warmest, with calling trailing off as the night progresses. However, for some species calling can extend into the day or later in the night, during suitable conditions.

The survey effort described in this guide assumes surveys are undertaken in favourable conditions and seasons for each target species, as outlined in Chapter 3 below, and these must be recorded in the BAR.

## 2.6 Identify areas of potential habitat on the subject land

Potential habitat for frog species will consist of breeding habitat, generally a waterbody, and non-breeding habitat, the foraging and sheltering area used by frogs for most of a year (Lamoureux & Madison 1999; Hazell et al. 2001; Hazell et al. 2003; Lemckert 2004). Typically, non-breeding habitat is native vegetation. These habitat components must be connected sufficiently to facilitate movement (e.g. Hamer 2018). Roads, urban areas and highly cleared habitats act as barriers to frogs.

Surveys to detect the target species within the subject land will be required if suitable breeding and/or non-breeding habitat is present. Frogs present a complicated assessment as breeding habitat may be absent on the subject land but if it is located within breeding migration distance (indicated by buffers identified in Chapter 3) and suitable non-breeding habitat is present on the subject land, a survey is required.

Detection will rely on locating frogs during breeding events, allowing breeding habitat to be identified. In this scenario the species polygon is based on mapping suitable non-breeding habitat connected to, and within migration distance of, breeding habitats. Therefore, determining presence may require survey of breeding habitat beyond the subject land. Where this is not possible due to access or other restrictions, an expert report may be used in place of survey.

Breeding habitat is well defined for most species. Non-breeding habitat is generally broad and may be related to one or more vegetation types. Information on the habitat in which to survey for each species is provided in Chapter 3 of this guide.

The surveyor will need to conduct onsite assessments to confirm the accuracy of any desktop assessment of habitat features or vegetation communities, because:

- mapping and digital data may not accurately represent all topographic details
- the history of the site and its disturbance cannot be reliably evaluated from imagery
- microhabitat features are not easily evaluated remotely.

Where an expert report is used as an alternative to survey, the expert report must address how these features have been evaluated.

## 2.7 Prepare a field survey plan

A field survey plan is to be prepared based on the list of threatened frog species likely to occur on the subject land (Section 2.3) and the habitat characteristics of the subject land (Section 2.6), as well as in accordance with Section 5.3 of the BAM.

The following steps outline a **generalised** method used to create a survey plan:

1. Identify areas of the subject land considered potential habitat for the target species. Only those parts of the subject land that are considered potential habitat require survey (refer to Chapter 3 for details).
2. Determine the survey methods and effort to be used for each target species (refer to Chapter 3 for details).
3. Determine the appropriate time of year to undertake the survey.
4. Select survey sites based on 1. and 2. Select dates for survey based on 3., **allowing flexibility for unfavourable conditions** (an essential consideration for frog surveys).

If multiple target species share similar habitat and require the same method of survey (e.g. *Mixophyes iteratus* and *Mixophyes balbus* or *Heleioporus australiacus* and *Pseudophryne australis*), the survey effort for these species can be combined.

The field survey plan should also include reference sites, wherever possible (see Box 1).

## 2.8 Determine the required field survey effort

The guide uses **standard effort assumptions.** Unless otherwise stated, all field survey effort is expressed as total effort using **standard methods** such as along a 500 metre transect, 50 square metres of water area (tadpole searches) or a minimum number of days/nights (call recorders). Recommended methods may be interchangeable (e.g. ‘aural surveys or tadpole searches’) and the guide clearly states where this is the case. Typically, aural-visual surveys are preferred and, in many instances, **must** form at least part of the survey effort.

All surveys must be repeated as required for the target species. Time allocated to the surveys is the minimum number of minutes that must be spent on the ground when undertaking a survey (not person minutes of survey effort) to reasonably expect any resident

frogs to be detected. As a rule, four separate surveys are required, with exceptions being noted in the species-specific information in Chapter 3.

Any measurement using a **GPS** requires a positional accuracy of 10 metres or less.[8]

### Box 1: Use of reference sites

An important consideration when undertaking surveys for frogs is the use of available reference sites. These are locations where the target species is known to exist. Typically, they will be within 10 kilometres of the subject land, but may be further, and it is up to the surveyor to determine a suitable reference for the work being completed.

Frogs can be responsive to highly localised weather events, especially explosive breeders that rely on temporary waterbodies (e.g. *Litoria brevipalmata*, Lemckert et al. 2006). Predicting the activity of a frog species at a given location can be difficult; the reference site can be checked prior to a BAM survey to demonstrate that conditions are suitable to detect the target species. If individuals of the target species are actively calling or moving around the reference site, it is reasonable to assume that any target frogs present at the survey site would also be active and detectable. Conversely, if there is no activity at the reference site then surveys at the impact site cannot provide a reliable determination of absence and should not be undertaken.

The successful use of a reference site also demonstrates the skill of the surveyors in detecting the target species.

The location, conditions and results of survey at reference sites should be clearly documented in the BAR.

The use of reference sites is strongly recommended, but it is recognised there will not always be a reference site known or readily available. In such cases the determination of occupancy needs be based on standard field surveys, or habitat assessment and the decision on presence/absence justified in the BAR. If uncertainty exists the situation may be best addressed using an expert report.

## 2.9 Use one or more standard survey methods

The following is a summary of the survey methods for threatened frogs as applied in this guide.

### 2.9.1 Aural-visual surveys

Aural-visual surveys are a combination of listening for the calls of frogs and searching for individuals along a transect. *One survey night* covers a minimum 120-minute period of listening for calling frogs and conducting a visual search along a 500 metre transect in breeding habitat along, around or through a suitable waterbody (unless another transect length is specified in the species descriptions in Chapter 3 of this guide). Where there is insufficient habitat to accommodate a 500 metre transect a pro-rata effort is to be applied with all available habitat being searched.

An aural-visual survey commences with an aural survey where the surveyor/s listens for calls (in silence and darkness), for a minimum of five minutes. It is important to remain still, as frogs may hide if they see/feel movement. In general, loud noises are to be avoided (but

[8] As reported by the GPS accuracy estimate.

see survey techniques for species of *Pseudophryne*). The aural survey process is repeated every 50 metres of the transect (i.e.11 points on a full 500 metre transect or six points where only 250 metres of habitat is available).

The visual survey detects frogs via 'eyeshine'. Suitable habitat is scanned along the transect, around and between aural survey points, using a headlamp with a minimum of 200 lumens brightness. Focus should be on the habitats in which individuals would be expected to be active. Walking slowly and quietly whilst undertaking the visual search will assist in noticing moving frogs (e.g. those fleeing disturbance). A minimum of five minutes should be taken to cover each 50 metres of transect with a visual search, regardless of the number of surveyors involved. An aural-visual survey on a 500 metre transect requires a minimum time commitment of 11 blocks of five minutes listening and 10 blocks of five minutes of visual searching, totalling 105 minutes on the transect.

Aural-visual surveys should include a **call-playback** component where a loudspeaker is used to broadcast the advertisement calls of target threatened frogs to elicit either an advertisement or territorial response call. Call playbacks are completed at the same location as the aural survey and should be undertaken after the aural survey for each point. The call is broadcast continuously through the speaker for a period of no less than two minutes and responses are typically heard within the first minute. The playback period is followed by a two-minute listening period to detect any late responses or responses masked by the sound of the broadcast call. Volume of the call playback should be audible over a distance of at least 20 metres. Any frogs heard responding that were not calling initially should be recorded.

***Thus, a survey that includes call playback requires an additional four minutes every 50 metres of transect where there is suitable breeding habitat (44 extra minutes of survey).***

Call mimicking can be used for a few species of the genus *Pseudophryne* that respond to any strong sound, detected through vibration, presumably identifying this as the call of a conspecific. The territorial call will differ to some degree from the standard advertisement call.

Not all species are responsive to call playbacks (e.g. *Heleioporus australiacus*) and some species may respond to calls of other species (e.g. *Mixophyes* spp.). Resident males, if not already calling, are likely to avoid undertaking calling activity to reduce predation risk and/or to conserve energy. Call playbacks may provide insufficient stimulus to produce a response.

One transect should be repeated for every 1000 metres of suitable breeding habitat (up to five kilometres). Surveys are repeated over multiple nights and/or seasons to account for climatic or cyclical variability in anuran breeding behaviour. The timing, amount of time and length of habitat surveyed must be documented in the BAR.

### 2.9.2 Acoustic recorder

Using this survey method *one recorder night* is completed when a single recorder, capable of recording and storing calls automatically, is set out for an entire night. For most species, recording should commence before sunset and be discontinued after dawn. Recorders must be placed every 50 metres of suitable habitat unless otherwise stated (i.e. 11 recorders for 500 metres of suitable habitat). The recording microphone must be waterproof and placed in a position that maximises the likelihood of detection (i.e. facing appropriate habitat and within reasonable range to detect calls). The efficiency of acoustic recorders is impacted by heavy rains. If heavy rains occur, another recording night may be necessary.

Call recorders must remain in place for a minimum of 14 days during the prescribed survey period (unless otherwise stated in a profile), enabling reasonable coverage of environmental conditions. For a 500 metre transect this will require 11 recorders for a minimum of 14 days/nights each (i.e. total of 154 recorder days). The number of records should be reduced accordingly for shorter transects. Completing subsets of recording (e.g. 15 minutes per half

hour) may assist in reducing data analysis, but any likely negative impacts on detectability resulting from this will need to be addressed in the report.

Frog choruses are typically complex and 'noisy', making it difficult to distinguish the calls of individual species. Commercial programs that can consistently and accurately analyse frog calls are not yet readily available. ***Call analysis should only be completed by someone with demonstrated knowledge and skill in identifying the call of the target species from recordings***. Evidence of the suitability of this person must be included in the BAR.

### 2.9.3 Tadpole search

*One tadpole search* is completed when an identified breeding waterbody has been surveyed. The tadpole search is undertaken by sweeping a fine meshed net (minimum 30 centimetres diameter head – see Anstis 2013) through the water for 10 minutes per 50 square metres of waterbody surface area. Sweep netting is completed by sweeping a net backwards and forwards through the water. Sampling should cover all parts of the water column up to a minimum of two metres from the bank. Sweeping must include areas of vegetation (as far as is practical) and cover areas of the waterbody suitable for the target species. Sweeps should be made at about one metre per second.

Wetlands of more than approximately 1000 square metres in surface area should be searched by sampling sub-units that are stratified by available suitable habitats for a minimum of 180 minutes.

The net should be checked for tadpoles at least every third sweep. If a tadpole is present and requires examination, it should be transferred into a plastic bag containing water from the survey site to prevent shock. Tadpoles must be identified only when in water to avoid the distortion of identifying features.

Captured tadpoles can be checked using Anstis (2013). Some tadpoles are easily identifiable to species, but the majority are difficult and can only be confidently assessed by an expert. Alternatively, tadpoles can be collected and raised until they have metamorphosed, thus allowing identification as froglets but only with specific ethics approval. For these reasons, tadpole searches should only be conducted in addition to other recommended survey methods and only for select species. Tadpole searches are clearly not suitable for threatened species that do not have an aquatic larval stage.

### 2.9.4 Surveying for frogs

The efficacy of techniques to survey frogs is not well understood. Further research is needed to enable the calculation of detection probabilities and properly understand the survey effort required to achieve certainty in survey outcomes. Many species of frogs are difficult to detect; significant experience is required to apply survey methods and identify species (e.g. distinguishing the call of *Litoria brevipalmata* vs *Litoria latopalmata*). Therefore, a conservative approach has been used in assigning survey technique and effort. To minimise false negatives only those methods that are reasonably well understood have been incorporated into the guide. Supporting technical information regarding survey methods and effort is provided in Appendix B and the guide will be modified as new information on detection effort and survey success becomes available.

## 2.10 Do a preliminary evaluation of efficacy

Preliminary surveys should be evaluated against an expected outcome to assess the efficacy of survey effort and identify any problems that will affect results (e.g. weather). The use of reference sites is strongly recommended (see Box 1). Alternatively, the results of published surveys using similar methods from the same or similar regions could be used to

evaluate the efficacy of survey. Many threatened frog species have very low observation rates and assessing the detection rates of more commonly observed species can assist in providing an indication of the effectiveness of the survey.

Supporting information on estimating expected outcomes is provided in Appendix C. Any apparent problems with survey effectiveness and steps taken to ameliorate these must be documented in the BAR.

## 2.11 Document the survey results

### 2.11.1 Biodiversity Assessment Report (BAR)

The BAR must be prepared in accordance with the BAM and requires targeted survey documentation for species credit species including timing, design, method, effort and results (see Appendices K, L and M of the BAM).

- **Timing:** the date, start and end time, and data on the weather conditions for surveys must be reported. For aural-visual surveys weather conditions should be recorded at the start and end of each transect using a portable metrological station. If this is not possible, remote recordings collected from weather stations can be reported. Conditions recorded should cover at least:
    - minimum/maximum temperatures
    - rainfall in the previous 24 hours, seven days and month
    - humidity
    - barometric pressure
    - wind (at least on a scale of 0–3)
    - cloud cover
    - moon phase.
- **Method:** a description of the survey methods used, including notes and explanations of any variation from the methods recommended in this guide.
- **Effort:** the type, number and GPS location of all surveys and/or acoustic recording devices, the number of search/net hours, method used to assess acoustic recording surveys, and the surveyor's qualifications/experience. Notes should be included on factors that may affect effort (e.g. weather, equipment failure) and any ameliorative steps taken (such as the replacement of equipment).
- **Critical habitat features:** for some species it is important to include data collected on habitat variables that are critical for a species to be present. These are listed for any species where such information is needed but is most typical for water pH for acid swamp dependent species. The presence/absence of introduced fish should also be noted.
- **Identification:** total number and types of **all** species observed/captured or recorded acoustically. Evidence needs to be provided for each threatened species located including georeferenced photos and/or suitable call recordings that clearly demonstrate presence. For aural-visual surveys, surveyors are encouraged to use the Australian Museum FrogID app to record frog calls and submit for species identification. FrogID is a national citizen science project led by the Australian Museum developed to better understand and help conserve Australia's frogs. The project relies on a mobile app, available for free for Android and iOS, which allows frog calls to be recorded and submitted to the Australian Museum for identification. Please make a note with the recording that it is for a BAM assessment and each identification will be confirmed by at least two FrogID validators.

**Note:** Where the species is at risk of a serious and irreversible impact (SAII), the BAR must also address the assessment requirements in Section 9.1 of the BAM. These assessment requirements are not part of this guide.

### 2.11.2 Mapping the species polygon

A species polygon must be mapped in accordance with the BAM (Box 2) for each of the target species located on the subject land.

The species polygon must:

- use the unit of measure identified for that species in the TBDC
- contain the habitat constraints or other suitable microhabitats or features associated with that species, and any buffer area identified for species in the TBDC
- include additional areas where management actions are proposed to be used to restore or create new areas of suitable habitat for a threatened species at a biodiversity stewardship site
- take into consideration information within the TBDC for the species in regard to any requirements on the size or shape of the species polygon
- use GPS to confirm the location of the species polygon on the best available ortho-rectified aerial image of the subject land.

For threatened frogs, the species polygon must include any suitable breeding habitat linked directly to the recorded individual/s. The polygon must also include complementary and essential non-breeding habitat that is based on known or expected distances that frogs migrate (Figure 1) (Alex & Green 2005; Lemckert 2004; Semlitsch & Bodie 2003; Sinch 1990), or in the case of some species, include connecting corridors to link together waterbodies to allow metapopulation processes (Figure 2). Details of specific species polygon requirements and estimates of migration distances are included within the profile for each species in Chapter 3.

**Note:** The BAM will only generate credits for impacts on, or improvements in, native vegetation condition. Where breeding habitat is a waterbody the species polygon must include the waterbody and associated suitable buffer area (see Figures 1 and 2). However, credits are only calculated for the native vegetation within the buffer area. For a development or clearing proposal, or biocertification, impacts on the waterbody must be assessed as a prescribed impact in accordance with the BAM. Prescribed impacts do not form part of an assessment for a biodiversity stewardship agreement. The approach to assess and determine suitable offset requirements for a prescribed impact is not part of this guide.

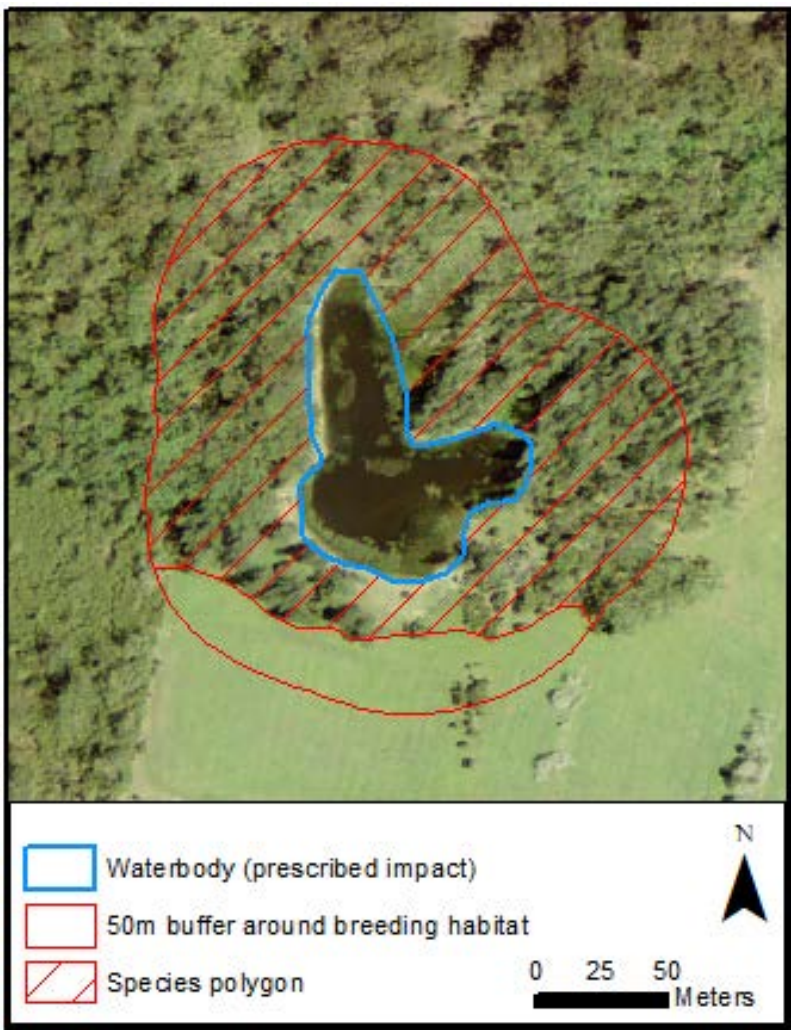


**Figure 1 Example of a frog species polygon**

The breeding habitat (waterbody (inner outlined area)) is the prescribed impact. The outer line is the 50 m buffer and the hatched area is the vegetation buffer that will generate credits in the BAM-C.

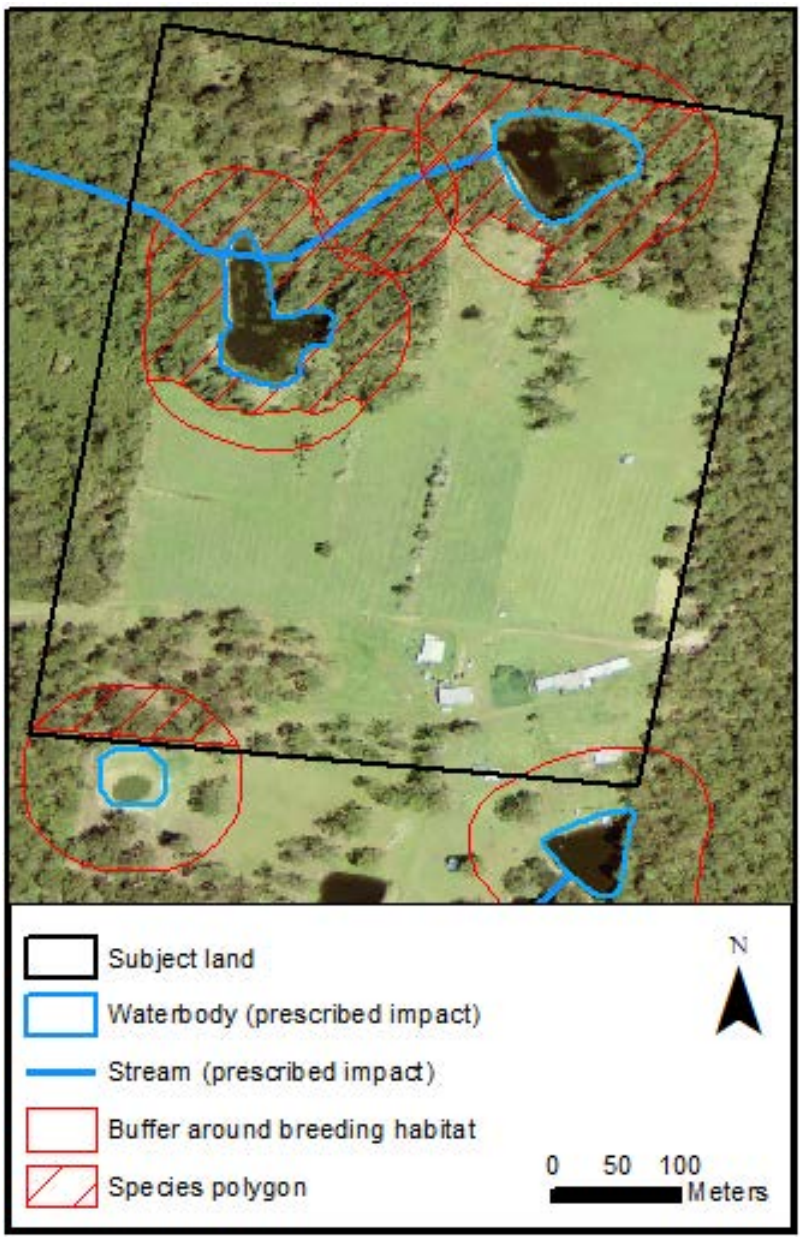


**Figure 2 Example of creating frog species polygons on subject land**

The rectangle shows the subject land. The breeding habitats (waterbodies (the inner outlined area) and stream (thicker line)) are prescribed impacts. The outer lines around the breeding habitats show the buffer zone, and the hatched areas are the vegetation buffer that will generate credits in the BAM-C. Note that breeding habitat offsite can still generate a vegetation buffer on the subject land.

# 3. Specific requirements for assessing threatened frog species

The survey objective is to determine, with a high level of confidence, the species presence on the subject land and, if present, to map the extent of habitat as a species polygon. Suitable survey requirements for each threatened frog species are provided below. Some basic requirements for surveys include:

- Four surveys should be conducted for each species in order to provide a reasonable level of confidence in results.
- These can be aural-visual surveys only, but for some species may include other survey methods used as an alternative to all or some of the aural-visual surveys.
- All surveys should be conducted within the first two to three hours after sunset, unless otherwise specified.
- Each survey replicate must be independent, meaning surveys must be conducted on different days. Surveyors must demonstrate that the surveys are undertaken across days with suitable but varied weather conditions with an expectation that the first and last surveys are a minimum of 14 days apart.

The *total effort* listed per method for each species is the minimum effort required to complete surveys.

## 3.1 Tusked frog *Adelotus brevis* – Nandewar and New England Tableland Bioregions

| **Site** | **500 m transect of suitable breeding habitat** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Oct. – Feb. | 480 mins | 4 |
| Acoustic recorder | Oct. – Feb. | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural-visual or acoustic recorder surveys are completed as transects running along the edges of identified suitable breeding habitat.

**Potential habitat:** All breeding habitat including still or very slow-flowing sections of permanent streams or pools (e.g. farm dams) located on the subject land. Non-breeding habitat is suitable native vegetation surrounding the breeding site and located on the subject land.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer incorporating any PCTs with which the species is associated, within a 500 metre radius from the top of bank.

## 3.2 Pouched frog *Assa darlingtoni*

| **Site** | **1 ha of suitable breeding habitat** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| 200 m aural call transect | Sept.– March | 120 minutes | 4 |
| Acoustic recorder | Sept.– March | 154 recorder days | 1 x 14 days |

**Survey methods:** While it is observed that this frog will call by day and night when seasonal rainfall and temperature are suitable, it has an unusual calling phenology. Strongest calls occur prior to dawn (4am to 6am) and after dusk (8.30pm to 11pm). In the survey period it is most effective to have recorders set to cover these periods.

There is also a marked refractory period. When suitable rainfall has occurred earlier in the season, this frog may not call at all in subsequent rain events, possibly because reproduction has been completed.

To avoid false negatives, it is necessary to focus surveys at times when there have been insignificant past rainfall events, such as spring and early summer, during and immediately after the first good falls of rain (i.e. >50 millimetres in the previous 72 hours). Calling is also likely to be affected by altitude-associated temperature gradients, with activity at higher locations occurring later in summer.

Aural or acoustic recorder surveys must be completed along 200 metre long transects located within areas of potential habitat. Aural surveys can be carried out during the day or night in suitable conditions with a minimum survey time of 30 minutes per 200 metre transect. Acoustic detectors are to be set for a minimum of 14 days of continuous recording. One transect is to be completed for every hectare of potential habitat.

**Potential habitat:** The species does not breed in free water. Suitable habitat consists of montane areas (usually >600 metres in altitude, however the species is known to occur at lower altitudes, to approximately 100 metres) within PCTs associated with the species. It typically prefers areas of moisture such as deep leaf litter and rocky scree slopes. Eggs are laid under damp leaf litter, logs, rocks or anywhere on the forest floor.

**Species polygon:** The species polygon boundary should align with any suitable vegetation type linked directly to the record and a buffer incorporating the PCTs with which it is associated within a 50 metre radius from the edge of the calling area.

## 3.3 Sloane's froglet *Crinia sloanei*

| **Site** | **500 m transect of suitable breeding habitat** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | July – Aug. | 480 minutes | 4 |
| Acoustic recorder | July – Aug. after flooding rains | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural-visual or acoustic recorder surveys are completed as transects running around potential breeding habitat. This species is highly detectable if surveys are undertaken at the right time (in winter after wetland breeding habitat has filled) (Knight 2015). The survey may be completed using aural-visual surveys alone or combined with acoustic recorders. The call is very similar to that of the plains froglet (*Crinia parinsignifera*) and may be hard to distinguish in a large chorus of *Crinia* spp.

**Potential habitat:** Breeding habitat consists of still or very slow sections of permanent and temporary streams as well as pools (e.g. farm dams) with vegetation located on the subject land. Non-breeding habitat includes waterbodies and areas of native and non-native vegetation (including areas of cleared rural grazing land).

Sloane's froglet is also known to move between breeding and non-breeding waterbodies; connectivity between these habitats is important to maintain population processes.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 100 metres radius from the top of bank. Where relevant the buffer should also include minimum 50 metre wide corridors of native or non-native vegetated areas linking the available waterbodies.

## 3.4 Wallum froglet *Crinia tinnula*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | All year after flooding rains | 480 mins | 4 |
| Acoustic recorder | All year after flooding rains | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural-visual surveys or acoustic recording are completed using transects that run through (or if too deep, then around) available breeding habitat. The survey may be completed using either method but can only be undertaken following recent flooding of the target waterbodies (Simpkins et al. 2014). Calling can occur at any time, therefore acoustic recorders should be set for a 24-hour cycle. Tadpole surveys are not recommended as individuals are small, difficult to catch and hard to distinguish from other common *Crinia* spp.

**Potential habitat:** Suitable breeding and non-breeding habitat consists of still waterbodies located in acid swamplands (pH<5.5), wallum heaths, open vegetation on sand plains, and flooded areas of swamp forests within the PCTs associated with the species. The acidity of the water must be recorded in the BAR to demonstrate suitable breeding habitat.

Non-breeding habitat is any area of suitable PCT located on the subject land.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the top of bank.

## 3.5 Giant burrowing frog *Heleioporus australiacus*

| Site | 500 m transect of suitable breeding and adjacent habitat 50 $m^2$ water surface (tadpoles) | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Sept. – May | 960 mins | 8 |
| Tadpole searches | Feb. – May | 10 mins/50 $m^2$ of surface area | 8 |

**Survey methods:** Aural-visual surveys or tadpole searches. Aural-visual searches are completed as transects running through areas of native vegetation located within 300 metres of suitable breeding habitat. These are completed within a week of heavy rainfall (e.g. >50 millimetres in 24 hours, >100 millimetres over three days). Tadpole searches are completed within areas of identified suitable breeding waterbodies, surveying at night when tadpoles are most active. Acoustic detection is not likely to be effective due to the very limited and unpredictable calling by males (Penman et al. 2005a; Recsei 1997).

**Potential habitat:** Suitable breeding habitat consists of ephemeral flowing streams that have permanent pools, or in upland swamps, and are located within native vegetation. Most typically breeding occurs in streams with a bed width of up to five metres (e.g. 2nd order and 3rd order streams) and upland swamps located on suitable geologies. Non-breeding habitat is native vegetation adjacent to the breeding sites.

Non-breeding habitat is any area of PCT on the subject land that is located within 300 metres of suitable breeding habitat as individuals can be expected to migrate up to 300 metres from breeding habitat to establish territories of essential non-breeding habitat.

**Species polygon:** The species polygon boundary should align with suitable aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 300 metres radius from the top of bank.

## 3.6 Green and golden bell frog *Litoria aurea*

| **Site** | **500 m transect of suitable breeding habitat<br>50 m$^2$ water surface (tadpoles)** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Nov. – March | 480 mins | 4 |
| Acoustic recorder | Nov. – March | 154 recorder days | 1 x 14 days |
| Tadpole search | Nov. – March | 10 mins/50 m$^2$ of surface area | Up to 2 |

**Survey methods:** Aural-visual or acoustic recorder surveys can be completed along the edges of suitable breeding habitat or, if feasible, through shallow wetlands. Tadpole surveys can be used to replace up to two of the aural-visual surveys. Tadpole searches should target areas of shallow and open water where the tadpoles are likely to congregate. If the plague minnow (*Gambusia holbrooki*) is present this method is not recommended. The presence of the plague minnow should be recorded.

Surveys should sample the available range of waterbodies on the subject land. Sweep netting should target areas of open water.

**Potential habitat:** Suitable breeding and non-breeding shelter habitat consists of any waterbody with emergent aquatic vegetation and without the plague minnow (*Gambusia holbrooki*), although the green and golden bell frog will still occasionally breed in sites with this introduced pest fish. Foraging habitat and migratory habitat are areas of native and non-native vegetation.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 200 metres radius from the top of bank. The polygon should include minimum 50 metre wide corridors of native and non-native vegetated areas linking the available waterbodies, where relevant.

## 3.7 Booroolong frog *Litoria booroolongensis*

| **Site** | **500 m transect of suitable breeding habitat** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Oct. – Dec. | 480 minutes | 4 |

**Survey methods:** Aural-visual surveys are completed as transects running along the edge of suitable stream breeding habitat. These frogs are highly detectable using spotlight surveys along rocky sections of stream (Hunter & Smith 2013). The species is similar in appearance to stony creek frogs (*Litoria lesueurii/wilcoxii*); distinguishing between them generally requires physical examination. Call recording devices are unlikely to work effectively in the noisy stream environments where this species occurs.

**Potential habitat:** The species requires permanent, or near permanent river environment with rocky structures (bedrock or cobble). Suitable breeding habitat consists of rocky structures in shallow water along the riparian zone, and non-breeding habitat is any habitat within the riparian zone (generally within 50 metres of the high water mark).

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the top of bank.

## 3.8 Green-thighed frog *Litoria brevipalmata*

| **Site** | **500 m transect of suitable breeding habitat<br>50 m$^2$ water surface (tadpoles)** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Spring – autumn after flooding rains | 240 mins | 2 |
| Tadpole surveys | Spring – autumn after flooding rains | 10 mins/50 m$^2$ of surface area | 2 |

**Survey methods:** A combination of aural-visual surveys and tadpole searches are completed within or around the edges of potential breeding habitat. An aural-visual survey should be used when the frogs are expected to be calling; this is to be followed by a search of the breeding site for tadpoles and metamorphosing froglets approximately 30 to 60 days later (Lemckert et al. 2006). The calling period for this species is very short, usually lasting one or two nights during or immediately after (<24 hours) flooding, but with some ongoing precipitation. Flooding typically occurs as a result of heavy rainfall (>50 mm in 24 hrs), but smaller combined rainfall events may inundate the site. The breeding site must be flooded at the time of the survey.

If a breeding site has previously been flooded (within three months), frogs will not attempt a second breeding event. This typically leads to only one breeding event occurring within the breeding season.

The species occurs in a range of habitats from rainforest and moist eucalypt forest to dry eucalypt forest and heath, typically in areas where surface water gathers after rain. It prefers wetter forests in the south of its range but extends into drier forests in northern New South Wales and southern Queensland. Surveys should target larger depressions or flooding swamp areas (>5 metres X 10 metres in diameter), usually identifiable by flood tolerant vegetation (Lemckert et al. 2006).

The call of the green-thighed frog is similar to that of rocket frogs (e.g. *Litoria latopalmata*) that can breed in the same habitats. Individuals heard will need to be checked to ensure correct identification.

**Potential habitat:** Suitable breeding habitat is any semi-permanent or ephemeral waterbody of >25 square metres in surface area located within native vegetation or immediately adjacent to or within 10 metres of native vegetation. Non-breeding habitat is native vegetation adjacent to the breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 100 metres radius from the top of bank.

## 3.9 Yellow-spotted tree frog *Litoria castanea*

| Site | 500 m transect of suitable breeding habitat<br>50 $m^2$ water surface (tadpoles) | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Nov. – Dec. | 120 mins | 4 |
| Acoustic recorder | Nov. – Dec. | 154 recorder days | 1 x 14 days |
| Tadpole search | Nov. – Dec. | 10 mins/50 $m^2$ of surface area | Up to 2 |

**Survey methods:** Aural-visual or acoustic recorder surveys can be completed along the edges of suitable breeding habitat or, if feasible, through shallow wetlands. Tadpole surveys can be used to replace up to two of the aural-visual surveys. Tadpole searches should target areas of shallow and open water where the tadpoles are likely to congregate. If the plague minnow (*Gambusia holbrooki*) is present, the method is not recommended; however, the presence of the plague minnow should be recorded.

Confirmation of the species' presence would need to be supported by photographic evidence or call recordings, given it is potentially extinct.

**Potential habitat:** Suitable breeding and non-breeding habitat consists of any waterbody with emergent aquatic vegetation and preferably does not contain the plague minnow (*Gambusia holbrooki*). Foraging habitat and migratory habitat are areas of native and non-native vegetation.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 200 metres radius from the top of bank. Where relevant it should include minimum 50 metre wide corridors of native and non-native vegetated areas linking the available waterbodies.

## 3.10 Davies' tree frog *Litoria daviesae*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Sep. – Jan. | 480 mins | 4 |
| Acoustic recorder | Sep. – Jan. | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural-visual surveys or acoustic recorder surveys are completed as transects set along potential breeding habitat.

**Potential habitat:** The species is found in association with permanent, slow-flowing small streams above 400 metres elevation, mostly in the headwaters of eastern-flowing streams, although it does occur in the headwaters of the western-flowing Peel River.

Suitable breeding habitat consists of permanent streams. Non-breeding habitat is adjacent native and non-native vegetation (listed as suitable PCTs).

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 100 metres radius from the top of bank.

## 3.11 Littlejohn's tree frog *Litoria littlejohni*

| **Site** | **500 m transect of suitable breeding habitat<br>50 $m^2$ water surface (tadpoles)** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | July – Nov. | 480 mins | 4 |
| Acoustic recorder | July – Nov | 154 recorder days | 1 x 14 days |
| Tadpole searches | July – Nov. | 10 mins/50 $m^2$of surface area | Up to 2 |

**Survey methods:** Aural-visual surveys or acoustic recorder surveys should be completed along areas of potential breeding habitat, noting that the species prefers dams and pools in some parts of its range and rocky streams in other parts. Tadpole surveys can be used to replace up to two of the aural-visual surveys. Tadpole searches should target areas of open water in potential breeding habitat. Tadpoles are relatively distinctive and should be detectable if present.

**Potential habitat:** The species breeds in the upper reaches of permanent streams and in perched swamps, being rock pools and sandstone, and peaty pools. Non-breeding habitat is heath-based forests and woodlands where individuals shelter under leaf litter and low vegetation.

Suitable breeding habitat consists of a range of still or slow-moving waterbodies including permanent streams, pools, ponds, swamps and dams, located within areas of suitable native vegetation. Non-breeding habitat is native vegetation located within 300 metres of breeding sites, through which the species can migrate to locate non-breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 300 metres radius from the top of bank.

## 3.12 Olongburra frog *Litoria olongburensis*

| **Site** | **500 m transect of suitable breeding habitat (call) and one 50 m x 2 m transect for each 2 ha of suitable breeding habitat (visual)** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Aug. – March | 120 mins | 1 |
| Visual searches | Aug. – March | 180 person mins | 3 |

**Survey methods:** An initial aural-visual survey is to be completed along a transect located around the edge of potential breeding habitat to avoid trampling vegetation. Additional

surveys are to be completed as visual searches along transects running through potential habitat to look for individuals on emergent vegetation (DSEWPAC 2011). Surveys are best undertaken during the warmer months of the year (minimum 15°C air temperature), when ephemeral or semi-permanent wetlands are widely inundated with water, when wind strength is minimal and relative humidity is maximal (Lewis & Goldingay 2005; Shuker & Hero 2013; Lowe et al. 2016; Shuker et al. 2016). A single diurnal survey can be included as one of the visual searches.

**Potential habitat:** This species is an 'acid' frog confined to the coastal sandplain wallum swamps. Life cycles have been adapted to the acidic pH (2.8–5.5) water of these wetlands. Frogs are highest in abundance in relatively undisturbed wallum swamps. Breeding habitat is characterised by the presence of emergent sedges, with upright plants. Recording the acidity of the water is required to demonstrate the suitability of the habitat for breeding.

Suitable breeding and non-breeding habitat consists of any wetland that provides an acid swamp environment. Non-breeding habitat is PCTs associated with the species.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the top of bank.

## 3.13 Peppered tree frog *Litoria piperata*

| **Site** | **500 m transect of suitable breeding habitat** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual survey | Oct. – Jan. | 480 mins | 4 |

**Survey methods:** Aural-visual surveys are completed along transects in areas of potential breeding habitat. Visual and genetic confirmation of the species is essential as there are currently no known extant populations, and the call of the species is unknown. Any record of this species would require photographic evidence and the collection of DNA material via skin swabs.

**Potential habitat:** Suitable breeding habitat consists of permanent rocky streams. Non-breeding habitat is suitable native vegetation located adjacent to the breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 500 metres radius from the top of bank.

## 3.14 Southern bell frog *Litoria raniformis*

| **Site** | **500 m transect of suitable breeding habitat<br>50 m² water surface (tadpoles)** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Oct. – Jan. | 480 mins | 4 |
| Acoustic recorder | July – Nov. | 154 recorder days | 1 x 14 days |
| Tadpole search | Oct. – Jan. | 10 mins/50 m² of surface area | Up to 2 |

**Survey methods:** Aural-visual surveys or acoustic recorders should be completed along the edges of suitable breeding habitat or, if practical, through shallow wetlands. Tadpole surveys can be used to replace up to two of the aural-visual surveys. Tadpole searches should target areas of shallow and open water where the tadpoles are likely to congregate. If the plague minnow (*Gambusia holbrooki*) is present, the method is not recommended; however, the presence of any plague minnows must be recorded.

**Potential habitat:** Suitable breeding and non-breeding shelter habitat consists of any waterbody with emergent aquatic vegetation and preferably without the plague minnow (*Gambusia holbrooki*). Foraging habitat and migratory habitat are areas of native and non-native vegetation connected to the identified breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 200 metres radius from the top of bank. Where relevant this should include minimum 50 metre wide corridors of native and non-native vegetated areas linking the available waterbodies.

## 3.15 Spotted tree frog *Litoria spenceri*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual survey | Nov. – Feb. | 480 | 4 |
| Visual survey (daytime) | Nov. – Feb. | 120 | Up to 2 |

**Survey methods:** Aural-visual surveys are completed along and within areas of potential breeding habitat. Diurnal surveys can be used to replace up to two of the nocturnal aural-visual surveys. Diurnal visual surveys can be used to detect frogs basking on rocks in and adjacent to the breeding stream (Gillespie & Hollis 1996).

**Potential habitat:** The species occurs among boulders or debris along naturally vegetated, rocky and fast flowing upland streams and rivers.

Breeding habitat is any such suitable rocky stream habitat located on the subject land. Non-breeding habitat is PCTs associated with the species adjacent to the breeding site.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 500 metres radius from the top of bank.

## 3.16 Glandular frog *Litoria subglandulosa*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Oct. – Dec. | 480 mins | 4 |
| Acoustic recorder | Oct. – Dec. | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural-visual surveys or acoustic recorder surveys are completed as transects set along potential breeding habitat.

**Potential habitat:** The species is located in stream habitat in rainforest, moist and dry eucalypt forest and in subalpine swamps above 500 metres. Suitable breeding habitat consists of permanent streams. Non-breeding habitat is native and non-native vegetated areas surrounding the breeding stream.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 200 metres radius from the top of bank.

## 3.17 Alpine tree frog *Litoria verreauxii alpina*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Sept. – Dec. | 480 mins | 4 |

**Survey methods:** Aural-visual surveys are completed around the edges of potential breeding habitat. Surveys using call recorders are unsuitable for this species as the whistling tree frog (*Litoria verreauxii verreauxii*) intergrades with the alpine tree frog making calls indistinguishable.

**Potential habitat:** The species inhabits riparian swamps and pools located in upland areas (typically above 1000 metres ASL). Individuals breed in natural and artificial wetlands including ponds, bogs, fens, streamside pools, stock dams and drainage channels that are still or slow-flowing. Non-breeding habitat is native and non-native vegetation adjacent to the breeding habitat.

**Species polygon:** The species polygon boundary should align with identified aquatic breeding habitats linked directly to the record and a buffer zone, incorporating the PCTs with which the species is associated, of 100 metres radius from the top of bank.

## 3.18 Stuttering frog *Mixophyes balbus*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Sept. – March | 480 mins | 4 |
| Acoustic recorder | Sept. – March | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural-visual or acoustic recorder surveys undertaken along transects in suitable breeding habitat, along identified streams with permanent pools. Suitable streams are those of first to even fourth order, depending on the location. The species often calls below cover (masking eyeshine), but responds readily to call playbacks, which should be included in surveys during the breeding season.

**Potential habitat:** The species is found in rainforest and wet, tall open forest in the foothills and escarpment on the eastern side of the Great Dividing Range.

Suitable breeding habitat consists of permanent or ephemerally flowing streams with permanent pools located within areas of listed suitable native vegetation (PCTs). Non-breeding habitat is native vegetation located within 500 metres of a breeding site; the species is known to move long distances from breeding sites.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 500 metres radius from the top of bank.

## 3.19 Fleay's barred frog *Mixophyes fleayi*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Sept. – March | 480 mins | 4 |
| Acoustic recorder | Sept. – March | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural-visual or acoustic recorder surveys are completed along permanent streams located within areas of potential breeding habitat. The species responds readily to call playback (Newell et al. 2013); this should be included in aural-visual surveys.

**Potential habitat:** The species occurs along stream habitats from first to third order streams, but not in ponds or ephemeral pools, within rainforest and wet eucalypt forest of the escarpment and foothills. It is usually close to streams with a complex of gravel riffle beds above pools.

Suitable breeding habitat consists of permanent flowing streams located within areas of native vegetation, typically intact rainforest. Non-breeding habitat is native vegetation adjacent to, and within 500 metres of, a breeding site.

**Species polygon:** The species polygon boundary should align with breeding streams linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 500 metres radius from the top of bank.

## 3.20 Giant barred frog *Mixophyes iteratus*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort** | **Number of repeat surveys** |
| Aural-visual surveys | Oct. – March | 480 mins | 4 |

**Survey methods:** Aural-visual surveys are completed within areas of potential breeding habitat. The species does not call regularly, therefore aural surveys alone are not recommended but can be used as part of an aural-visual survey if undertaken during the breeding season; however, they are readily detected by eyeshine when active.

**Potential habitat:** The species occurs along freshwater streams with permanent or semi-permanent water, generally (but not always) at lower elevation. It may occasionally occupy large open bodies of water (e.g. ponds and dams) in the riparian zone. Moist riparian habitats are favoured for the deep leaf litter, used for shelter and foraging, as well as open perching sites on the forest floor. The species will use streams with a fringe of vegetation in otherwise cleared lands. Males seem to confine most activities to the riparian zone.

Suitable breeding habitat consists of large (>4 metres wide) permanent and semi-permanent flowing streams located on the subject land. Eggs are laid on undercut banks above large slow-moving or still pools or areas of water (Knowles et al. 2014), with breeding occurring after periods of rainfall when streams have receded post flooding. Non-breeding habitat is any suitable vegetation (native or non-native) adjacent to identified breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the top of bank.

## 3.21 Painted burrowing frog *Neobatrachus pictus*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Year round following heavy rain | 240 mins | 2 |
| Acoustic recorder | Year round following heavy rain | 4 call days | 2 |

**Survey methods:** Aural-visual or acoustic recorder surveys are completed around the edges of, or if shallow enough, through potential breeding habitat. The calling period is short, lasting one or two nights during or immediately after (<24 hours) flooding. Flooding occurs as a result of heavy rainfall (typically >50 millimetres in 24 hrs) and surveys must be conducted when the site is inundated. However, they should not be undertaken if the site has been flooded within the previous three months, as frogs are unlikely to attempt a second breeding event. Acoustic recorder surveys are not expected to be effective more than 48 hours after rain. Tadpole surveys are not recommended, as they cannot be distinguished from those of *N. sudellae*, which may occur in the same habitat.

**Potential habitat:** The species is known from areas of open grassland, mallee, woodland, farmland and cleared areas and is usually found in or around flooded areas after periods of heavy rainfall, including grassy marshes, lagoons, flooded claypans, temporary roadside pools, ditches, mallee swales and farm dams.

Suitable breeding habitat consists of temporary pools and flooded areas, while non-breeding habitat is native vegetation in the surrounding area.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 200 metres radius from the edge of identified breeding habitat.

## 3.22 Mountain frog *Philoria kundagungan*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural surveys | Sept. – Jan. | 480 minutes | 4 |
| Acoustic recorder | Sept. – Jan. | 154 call days | 1 x 14 days |

**Survey methods:** Aural or acoustic recorder surveys are completed within areas of potential habitat. Calling can occur at any time but is most frequent during the early part of the day (before 11am) and where temperatures are >17°C. Acoustic recorders should be set for a 24-hour cycle to capture nocturnal/diurnal calling and daily changes in temperature. A high concentration of acoustic recorders is required to capture the typically soft calls from individuals inhabiting muddy burrows. One recorder should be set within 10 metres of every identified suitable calling point and left recording for 14 days. Trampling of potential breeding habitat should be avoided whilst surveying.

Tadpole and visual surveys are unsuitable as the species does not have a free-swimming aquatic tadpole phase and it primarily occurs below ground, respectively.

**Potential habitat:** The species is known from areas with continually high moisture levels above elevations of 800 metres and is most common in subtropical and temperate rainforests. It is found in shallow burrows in mud, concealed by leaf litter or rocky scree, in the headwaters and along the edges of constantly flowing streams or around permanent soaks.

Suitable breeding habitat consists of seeps and soaks in gullies or along streams on the subject land and located in areas of native vegetation. Non-breeding habitat is native vegetation linked to the breeding site.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the edge of identified breeding habitat.

## 3.23 Loveridge's frog *Philoria loveridgei*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural surveys | Oct. – Jan. | 480 mins | 4 |
| Acoustic recorder | Oct. – Jan. | 154 call days | 1 x 14 days |

**Survey methods:** Aural or acoustic recorder surveys are completed within areas of potential habitat. Calling can occur at any time, therefore acoustic recorders should be set for a 24-hour cycle. A high concentration of acoustic recorders is required to capture the typically soft calls of the species. One recorder should be set within 10 metres of every identified suitable calling point and left recording for 14 days.

Tadpole and visual surveys are unsuitable as the species does not have a free-swimming aquatic tadpole phase and it primarily occurs below ground, respectively.

**Potential habitat:** The species is known from areas of continually high moisture, being most common in subtropical and temperate rainforests. It is found in shallow burrows in soil, moss or in leaf litter at headwaters and along the edges of constantly flowing streams or around permanent soaks in highland forest; however, this species is less tied to headwater stream environments than the other *Philoria* species and is known to occur at lower elevations in the boggy margins of second and third order streams. It can also be found in artificial habitats created by road drainage systems and walking tracks.

Suitable breeding habitat consists of seeps and soaks in gullies or along streams on the subject land located in areas of native vegetation. Non-breeding habitat is native vegetation within 50 metres of suitable breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the edge of identified breeding habitat.

## 3.24 Philoria pughi *Philoria pughi*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural surveys | Sept. – Jan. | 480 mins | 4 |
| Acoustic recorder | Sept. – Jan. | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural or acoustic recorder surveys must be completed within areas of potential habitat. Calling can occur at any time therefore acoustic recorders should be set for a 24-hour cycle. A high concentration of acoustic recorders is required to capture the typically soft calls of the species. One recorder should be set within 10 metres of every identified suitable calling point and left recording for 14 days.

Tadpole and visual surveys are unsuitable as the species does not have a free-swimming aquatic tadpole phase and it primarily occurs below ground, respectively.

**Potential habitat:** The species is known from areas of continually high moisture including seeps and soaks, located in subtropical and temperate rainforests and wet sclerophyll forest at high elevations (>800 metres altitude). It is found in shallow burrows in soil, moss or under leaf litter in headwaters, along the edges of constantly flowing streams, or around permanent soaks in highland forest. The species is also found in outcrops where water seeps from the rocks leaving a permanently wet environment.

Suitable breeding habitat consists of seeps and soaks, typically in gullies or along streams, in areas of native vegetation on the subject land. Non-breeding habitat is native vegetation located within 50 metres of suitable breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the edge of identified breeding habitat.

## 3.25 Philoria richmondensis *Philoria richmondensis*

| **Site** | **500 m transect of suitable breeding habitat** | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural surveys | Sept. – Jan. | 480 mins | 4 |
| Acoustic recorder | Sept. – Jan. | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural or acoustic recorder surveys must be completed within areas of potential habitat (Willacy et al. 2015). Calling can occur at any time therefore acoustic recorders should be set for a 24-hour cycle. A high concentration of acoustic recorders is required to capture the typically soft calls of the species. One recorder should be set within 10 metres of every identified suitable calling point and left recording for 14 days.

Tadpole and visual surveys are unsuitable as the species does not have a free-swimming aquatic tadpole phase and it primarily occurs below ground, respectively.

**Potential habitat:** The species is known from areas of continually high moisture including seeps and soaks, located in subtropical and temperate rainforests. It is found in shallow burrows in soil, moss or in leaf litter in headwaters, along the edges of constantly flowing streams, or around permanent soaks in highland forest. The species is also found in outcrops where water seeps from the rocks leaving a permanently wet environment.

Suitable breeding habitat consists of seeps and soaks in gullies or along headwater streams in areas of native vegetation on the subject land. Non-breeding habitat is native vegetation within 50 metres of suitable breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the edge of identified breeding habitat.

## 3.26 Sphagnum frog *Philoria sphagnicolus*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural surveys | Aug. – Jan. | 480 mins | 4 |
| Acoustic recorder | Aug. – Jan. | 154 recorder days | 1 x 14 days |

**Survey methods:** Aural or acoustic recorder surveys must be completed within areas of potential habitat. Calling can occur at any time therefore acoustic recorders should be set for a 24-hour cycle. A high concentration of acoustic recorders is required to capture the typically soft calls of the species. One recorder should be set within 10 metres of every identified suitable calling point and left recording for 14 days.

Tadpole and visual surveys are unsuitable as the species does not have a free-swimming aquatic tadpole phase and it primarily occurs below ground, respectively.

**Potential habitat:** The species is known from areas of continually high moisture, including seeps and soaks, located in subtropical temperate and warm temperate rainforests and some wet sclerophyll forests. It is found in shallow burrows in soil, moss or under leaf litter in headwaters, along the edges of constantly flowing streams, or around permanent soaks in highland forest. The species is also found in outcrops where water seeps from the rocks leaving a permanently wet environment.

Suitable breeding habitat consists of seeps and soaks in gullies or along streams in areas of native vegetation on the subject land. Non-breeding habitat is native vegetation within 50 metres of suitable breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the edge of identified breeding habitat.

## 3.27 Red-crowned toadlet *Pseudophryne australis*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Year round | 480 mins | 4 |

**Survey methods:** Aural-visual surveys must be completed within areas of potential habitat. Call playback involving loud sounds to which the male responds can be undertaken any time of the year, if there has been sufficient recent rainfall to stimulate activity. Surveys should not be conducted if three significant rain events (>50 millimetres of rain in 24 hours) have occurred in the previous two months, nor during periods of heavy rainfall.

The use of acoustic recorders is not recommended as the calls of the red-crowned toadlet are relatively soft and difficult to distinguish from species of the same genus. Calling can occur during the day, and especially so in the cooler months. Surveys should be conducted in daylight hours if a reference site indicates that calling is occurring at that time.

**Potential habitat:** The species is found only on Triassic sandstones, and within that area, it uses areas of heathland and woodland.

Suitable breeding habitat consists of ephemeral streams or pools located within areas of native vegetation on Triassic sandstones. Non-breeding habitat is native vegetation within 100 metres of suitable breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 100 metres radius from the top of bank.

## 3.28 Southern corroboree frog *Pseudophryne corroboree*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Jan. | 480 mins | 4 |

**Survey methods:** Aural-visual surveys must be completed within areas of potential habitat. The species has a very narrow calling season (usually a three week window each year; DECC 2007). Call playback involves loud sounds to which the male responds and can be completed at any time of the day. ***Note surveys for this species cannot be carried out without direct permission from DPIE***.

**Potential habitat:** Suitable breeding habitat consists of pools and seepages in sphagnum bogs, wet heath, wet tussock grasslands and herbfields in low-lying depressions. Non-breeding habitat is native vegetation within 50 metres of suitable breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 50 metres radius from the edge of the breeding habitat.

## 3.29 Northern corroboree frog *Pseudophryne pengilleyi*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Feb. – March | 480 mins | 4 |

**Survey methods:** Aural-visual surveys must be completed within areas of potential habitat. The species has a very narrow calling season (usually a three week window each year; DECC 2007), therefore reference sites are essential to determine appropriate survey times. Call playback involves loud sounds to which the male responds and can be completed at any time of the day. The species has high detectability using this technique at the right time of year (Scheele et al. 2012). Care should be taken in analysing recordings as calls of the different *Pseudophryne spp.* are similar.

**Potential habitat:** Suitable breeding habitat consists of pools and seepages in sphagnum bogs, wet heath, wet tussock grasslands and herbfields in low-lying depressions. Non-breeding habitat is suitable native vegetation within 200 metres of suitable breeding habitat.

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 200 metres radius from the edge of identified breeding habitat.

## 3.30 Mahony's toadlet *Uperoleia mahonyi*

| Site | 500 m transect of suitable breeding habitat | | |
|---|---|---|---|
| **Survey method** | **Survey period** | **Total effort for a 500 m transect** | **Number of repeat surveys** |
| Aural-visual surveys | Oct. – March | 480 mins | 4 |

**Survey methods:** Aural-visual surveys are to be undertaken around potential breeding sites. These should be completed in areas of temporarily flooded wetlands or swales and will involve listening for the calls of male frogs. Calling individuals must be captured to confirm identity as calls are difficult to distinguished from other more common *Uperoleia* spp. Call recorders are not recommended. Visual surveys are not recommended as the species is cryptic with small eyes, reducing visible 'eyeshine'.

Surveys should target permanent and temporarily flooded swamps and depressions, which are typically, but not exclusively, on white sands (Clulow et al. 2016). Waterbodies must be at least 70% full prior to survey (Webster & Clulow 2019). Water level and acidity, as it is typically found in association with acid swamps, must be reported in the BAR.

**Potential habitat:** The species inhabits ephemeral and semi-permanent swamps and swales. Known records occur in heath or wallum habitats, almost exclusively associated with leached (highly nutrient impoverished) white sand. Commonly associated with acid paperbark swamps, Mahony's toadlet is also known to occur in wallum heath, swamp mahogany–paperbark swamp forest, heath shrubland and Sydney red gum woodland. Recent studies suggest intact vegetation adjacent to and within waterbodies is an important habitat feature for this species.

Suitable breeding habitat consists of ephemeral and semi-permanent swamps and swales that occur within areas of native vegetation. Non-breeding habitat is similar swampy native vegetation located within 400 metres of suitable breeding habitat (Webster & Clulow 2019).

**Species polygon:** The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 400 metres radius from the top of bank of the breeding site.

## 3.31 Survey requirements for frog species at risk of a serious and irreversible impact

A serious and irreversible impact (SAII) is listed under the BC Act as an impact that is likely to contribute significantly to the risk of extinction of a threatened entity[9]. The BAM requires additional information be provided in the BAR for any impact on a species considered at risk of an SAII (see Section 9.1 of the BAM).

Currently, eight frog species and one population fall into this category: *Adelotus brevis* (tusked frog) population in the Nandewar and New England Tableland bioregions, *Litoria castanea, Litoria piperata, Litoria spenceri, Litoria subglandulosa, Mixophyes balbus, Mixophyes fleayi, Pseudophryne corroboree* and *Pseudophryne pengilleyi.*

[9] For further information on serious and irreversible impacts see the Guidance to assist a decision-maker to determine a serious and irreversible impact.

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# Appendix A – Threatened frog survey decision key

**1. Do I need to survey for a threatened frog?**

a. Is the species predicted to occur on the subject land, based on the BAM-C and/or an observation record?

i No..... **survey not required**

ii Yes ..... go to 1b

b. Where a species has listed habitat constraints or known microhabitats are these degraded to the point where the species would no longer use the site (Section 2.3)?

i Yes ..... **survey not required, document in the BAR**

ii No..... **survey required**, go to 2

**2. Threatened frog survey steps**

a. Choose survey approach (Chapters 2 & 3)

i Conduct survey..... go to 2b

ii Expert report..... go to 2b

iii Assume present (development and biocertification sites only) ..... go to 2b

b. Is the species present?

i Yes ..... **map species polygon (breeding and non-breeding habitat) and document in BAR** ..... go to 2c

ii No..... **document in BAR**

c. Is the species at risk of SAII?

i Yes ..... **address Section 9.1 of the BAM**

ii No..... **document in BAR**

# Appendix B – Supporting information

Additional details on the survey approaches recommended in this guide are provided below.

## A.1 Identification of breeding frogs

Identification of breeding frogs is an important requirement of this guide (see Section 1.4). Identification must be done by a suitably qualified frog surveyor (see Section 2.2).

For the purposes of this guide a breeding frog is defined as either:

- a male frog of the target species that is calling, is in amplexus or is located at a suitable breeding site and has well-developed secondary sexual characteristics, or
- a female frog of the target species that is located at a breeding site and is in amplexus or is fully gravid based on the presence of eggs within the body cavity.

Frogs in breeding condition congregate around breeding sites in locations suitable for calling and/or egg deposition. If a frog located in breeding condition is determined not to be at a breeding site then the reasons for this determination need to be included in the BAR. Typically, multiple males will be present at a breeding site. Females are rarely located.

To avoid confusion or ambiguity the following advice is provided:

### Determining sex

Male frogs are usually identified by calling (female frogs in Australia do not produce advertisement calls) and are clustered around a suitable breeding site; however, males in breeding condition can also be identified by the presence of either a vocal sac, which is observable as a darkened patch of skin on the throat (compared to the rest of the under-side), typically being reddish in colouration due to the presence of the blood vessels innervating the skin, and often develops into a clear sac (Figure 3a,b).

**Figure 3** **Indications of vocal sacs on male frogs: a) darkening at sides of throat for *Mixophyes fasciolatus* (male on top); b) yellowed and darkened throat area for calling *Litoria latopalmata***

For some species there is little change in the throat colouration or texture, and they may otherwise be distinguished by the presence of nuptial pads on the thumbs of the front legs (Figure 4), noting that frogs only have four digits on their ‘hands’. The pads are used to grip onto the female frog and are dark brown or black. For the giant burrowing frog, the nuptial pads consist of large black spines on the thumbs and there are also smaller spines over various parts of the hands (Clulow & Swan 2018). Male tusked frogs have clearly enlarged heads (representing more than a third of their body length; Barker et al. 1995).

**Figure 4** **Nuptial pads from male frogs (photos courtesy of Stephen Mahony): a) *Litoria aurea*; b) *Limnodynastes dumerilii***

Females frogs ready to produce eggs are termed ‘gravid’ and their greatly distended bellies are obvious, with the egg mass regularly constituting more than a third of their gravid body mass. The eggs may be visible through the thin skin layer of the lower belly and groin, but the gravid state is more likely evident as a distended belly with the shapes of eggs showing (Figure 5).

**Figure 5** **A gravid female *Pseudophryne* showing a distended belly with the bulging shape of eggs clearly visible through the skin of the belly**

## A.2 Survey techniques

The guide predominantly recommends the identification of calls as the means of determining the presence of breeding frogs. A suitably experienced frog ecologist can identify, to species, the majority (>95%) of Australian frogs by their call. To date it is understood that Australian frogs call at frequencies that are audible to human ears, and the calls are sufficiently different in frequency and structure that a practised ear can distinguish even similar calls (e.g. the tusked frog compared to the common striped marsh frog; the giant barred frog compared to the great barred frog). Frogs are often cryptic and call from concealed locations. Attempting to locate individuals visually is difficult, identification through calls is often a more accurate means of survey.

However, in a few genera the calls are sufficiently similar between species that identification by call alone may be problematic (e.g. genera *Philoria, Pseudophryne* and *Uperoleia*). Usually there are sufficient geographic disjunctions that allow for clear identification. In some

instances, the capture of a frog may be the only means to ensure a positive identification. For non-calling frogs, the captured frog can provide information about the sex and reproductive status that can assist in determining breeding habitat.

A brief discussion of the key points of frog survey methods are provided.

## Aural-visual surveys

Aural-visual surveys are the most commonly used means of undertaking frog surveys. The main limitation is the periodic nature of calling, limiting surveys to the breeding season. For some species the calling period is limited and unpredictable, or heavily dependent on unpredictable weather events. Surveyors need to carefully plan field work to ensure the season and conditions are suitable to ensure calling. The use of a reference site (where the target species is known to be present) on the same day/night of the planned survey, is recommended.

Repeat surveys are required to address uncertainty around the exact timing and/or conditions that trigger calling and breeding. Under suitable conditions aural-visual surveys enable a surveyor, experienced in distinguishing calls, to rapidly and accurately survey a number or range of potential breeding habitats (e.g. habitat that is scattered irregularly and uncertainly along breeding streams or within areas that are flooded).

Choruses of frogs are often complex, consisting of hundreds and sometimes even thousands of frogs calling concurrently. Identifying the call of a threatened species in such circumstances requires considerable skill. The surveyor must be familiar with male calling microhabitat (e.g. at the base of emergent vegetation, floating in the water, or under litter several metres from the edge of the water) and targeting this to maximise the chance of identifying the target species (e.g. bleating tree frog *Litoria dentata*). Inexperienced frog surveyors will have difficulty hearing and distinguishing calls of the target species. Likewise, it is important that recorders are placed close enough to the target calling frog to detect and distinguish the call from that of other frogs.

## Call playback

The limitations of call playback have already been documented throughout the guide. The BAR must include the method of call playback applied, the equipment used and the survey effort.

## Acoustic recorders

Acoustic recorders have microphones and software sensitive to calls at lower frequencies in the audible spectrum (as opposed to bat recorders). Recorders can be set for specific periods of time, or to record across an entire night or 24-hour period.

There are several issues that need to be considered when using recorders.

First, recorders need to be placed close to the target species to capture calls; interference or sound masking can occur as a result of other frogs calling. Recorders generally only capture frog calls within 50 metres when interfering noise is insignificant. In a large chorus of explosive breeding frogs, such as calling after a rainfall event, interference will significantly reduce the effective recording distance to less than 10 metres.

The effective recording distance suitable to detect the target species must be documented and justified in the BAR.

Second, recorders provide a huge volume of data to be analysed. There is currently no commercially available tool that can successfully analyse all frog calls and so reduce analysis time. Choruses of frogs typically result in overlapping and interfering sounds that do

not provide discreet units of sound that can be processed (as opposed to most bat calls). There are instances where individual calls may be more likely to be recorded and 'training' programs are available that may be used to sort through the data to rapidly locate candidate calls for the target species (e.g. Willacy et al. 2015). These can then be individually assessed to confirm their identity. An example of this application can be found for the giant barred frog (*Mixophyes iteratus*) in Croker and Kottege (2012).

Information on the type of recorder used, the method to analyse the recordings and the experience and skills of the analyser must be documented and justified in the BAR.

At a minimum the recorder should:

- be designed for passive recording and remote deployment (equipped with timer activated recording and suitable weatherproofing)
- record the detection range of all target frog species, and
- have a recording capacity (battery and data storage) capable of lasting at least several full nights of recording.

## Tadpoles and sweep nets

Sweep nets are required to have a mesh size sufficiently small to be able to trap the target tadpoles. The net must be able to move through the water to catch fleeing tadpoles and to extend into target microhabitats (e.g. within emergent vegetation, along the bottom of the waterbody or through the upper water layers). Obstructions such as rocks, emergent vegetation, and logs and sticks can impede sampling and should form part of the assessment of appropriate survey techniques. Material must be cleared from the net on a regular basis to ensure tadpoles are not injured as sweeps are undertaken.

Tadpoles are generally easier to catch at night when they forage, darkness also masks the approaching net.

Most tadpoles are difficult to identify without considerable experience, suitable equipment and knowledge of their identifiable features (Anstis 2013). There are exceptions (e.g. giant burrowing frog) but photographic evidence or a willingness to raise the tadpoles may be required to ensure accurate identifications. Animal ethics and licence approvals are necessary.

In general, dip netting is labour intensive, its success is limited and identification of captured tadpoles difficult. It is rarely used in standard frog surveys; however, the presence of tadpoles, which can persist for days to weeks depending on the species, confirm breeding activity (see Anstis 2013). For example, the green-thighed frog (*Litoria brevipalmata)* calls on only one or two nights during and/or following heavy rainfall and locating reference sites is difficult due to distances between breeding populations. An appropriate tadpole survey a minimum of two weeks and no longer than four weeks after a major rain event is an effective means to survey wetlands for this frog.

It is quite common for frogs to partition the seasonal timing of calling, such that the species calling at a site at one time of year are different from those calling at the same site at a different time (e.g. early or late in spring). One way to overcome this issue and obtain information on the community of frogs that breed at a site is to use tadpole surveys.

## Disease considerations

The amphibian chytrid fungus has been linked to severe declines in the world's amphibian populations, including the extinction of several species and the serious decline of many others. The frogs of New South Wales have been particularly impacted and the fungus is likely to be present throughout the coastal plain, Great Dividing Range, Western Slopes and

Western Plains. It is only in the dryer inland areas of the state that the fungus may not be active. Frog hygiene protocols (Saving our Species Hygiene Guidelines (PDF 1.2MB)) have been introduced for frog surveys and must be followed for surveys conducted in accordance with this guide. The basic requirement is that equipment must be cleaned or changed between survey sites to prevent the transfer of the fungus. Machinery must be washed down when travelling between sites, and captured frogs and tadpoles must be held in isolation. Abiding by these protocols will reduce the potential for spread of this and other diseases.

## Alternative methods

There are a range of additional methods for capturing individuals (e.g. pitfall traps, funnel traps, bait traps, road transects) or for pinpointing the location of breeding sites (e.g. transmitters). However, these methods tend to be labour and/or resource intensive, generally less effective or efficient (or this is uncertain) and/or not suited to the specific survey objectives of the NSW BOS and, therefore, are not recommended in this guide.

# Appendix C – Estimating expected results

The use of a suitable reference site for a target species demonstrates the adequacy of survey timing, the skills and capabilities of the surveyors, and provides confidence in the actual survey results. However, it is not always possible to use reference sites. Alternatively, survey adequacy can be evaluated against survey success. Preliminary results can be considered against expected results to identify any potential problems with survey timing and/or effort. Ideally this should be done in the field so that alterations to surveys can be adaptive and immediate (e.g. sampling additional nights).

A good indication of expected results can be gained from examining the results of other surveys that have applied similar methods in similar regions or habitats. Non-target and common frog species often provide an excellent indication of whether a survey has been adequate, especially in the case of explosive breeding species where breeding is triggered by episodic events like flooding. For example, if a survey for the painted burrowing frog recorded no calls for any species that breed in similar situations (e.g. giant banjo frogs, *Limnodynastes interioris*) this would indicate survey conditions were unsuitable.

There are limited published studies on the likelihood of detecting more common Australian frogs using different methods, but those available are presented in Table 1.

There are a range of factors that impact the estimation of survey success, but weather conditions are likely most important. Koch and Hero (2007) provide one of the few attempts to determine conditions that would allow for a 95% detectability of a species (see also Willacy et al. 2015). Temperature was identified as the main driver of activity with recommendations to survey when air temperatures exceeded 18°C. Lemckert et al. (2006) only recorded calls of the green-thighed frog after rainfall exceeding 50 millimetres in a 24-hour period and breeding activity linked to flooding, which can occur with lesser rainfall events. Simpkins et al. (2014) reported a similar response for the wallum froglet, where breeding occurred once the acid swamps filled. The level of rainfall required to fill the swamps depended on previous weather conditions.

These responses are often referred to as ‘refractory periods’. It is entirely possible for a survey to be conducted after heavy rainfall, at warm temperature, within the dates provided in this guide and the target frog is inactive and not detected. These situations occur when there has been a previous rain event earlier in the season, possibly several weeks or months, triggering a breeding event. Since females of most frogs lay only one clutch of eggs a season (i.e. per year for most species), they will not breed on the second rain event, even if it is suitable. These false negatives can be avoided by examination of seasonal rainfall patterns, and possibly the use of tadpole surveys to determine habitat occupancy.

Some common explanations of poor survey results include:

- **Weather:** The survey may be affected by unsuitable weather conditions (wind, rain, cold).

  *Solution: Avoid surveying in unsuitable weather, reject and redo any survey affected by poor weather or suitable conditions.*

- **Season:** Successful surveys for frogs are highly dependent on choosing the correct calling season for a species. Surveys outside the designated breeding season are unlikely to detect the species as non-breeding frogs are generally very difficult to detect, leading to false negative outcomes.

  *Solution: Survey in the correct breeding season and during suitable weather. Use a reference site to demonstrate breeding activity was occurring at the time of the survey.*

- **Unsuitable habitat selection:** Each frog species generally has preferred breeding habitat and spending large periods of time in inappropriate habitat when suitable habitat is being ignored will provide poor results.

  *Solution: Be certain of the type of breeding habitat chosen by the species and target that habitat.*

- **Equipment failure:** Equipment can fail to operate as expected; for example, recorders run out of batteries/ data storage/ timer failed.

  *Solutions: Always check recorder logs and data for unexpected low results, and after sampling ensure batteries/ timer/ memory, resurvey as required. While costly, some level of redundancy in recorders can be considered.*

## Estimating expected likelihood of detecting threatened frog species

Threatened frogs can generally be expected to have a lower detection rate than more common species simply because they are rare. It is also true that many threatened frogs are naturally cryptic reducing detectability.

Few studies have assessed the detection rates of the threatened Australian frogs in this guide, with the exception of the southern bell frog (*Litoria raniformis*). Studies completed in different landscapes have provided inconsistent results. Heard et al. (2006) determined the probability of detecting this species in the Melbourne area and found that detectability varied greatly dependent on the method used (Table 2). Wassens et al. (2017) studied the same species in the Riverina area and reported different results using the same methods with similar intensities. These studies indicate prevailing environmental conditions have a substantial effect on detection rates. They also reiterate the need for surveyors with demonstrated experience to undertake surveys and the importance of the use of reference sites.

Other studies include Lemckert et al. (2011), who found the northern corroboree frog was undetected in 32 of 137 monitoring surveys of known breeding sites, indicating a detection rate of 77%, and Penman et al. (2008), who investigated survey success for *Heleioporus australiacus* and noted that pitfall trapping provided detection rates ranging from one individual in 800 trap nights (Penman 2005) to up to one individual in 3000 trap nights (Kavanagh & Webb 1998). In another example, road transects targeting the same species provided detection of 11 individuals in approximately 250 nights of targeted survey, with 10 of these being located in one area over one night (Penman et al. 2008).

Unpublished surveys provide some additional information on the detectability of threatened frog species. Ongoing monitoring of the giant barred frog in the Port Macquarie area at six sites sampled each in spring, summer and autumn, has detected the species on one kilometre transects on all but two transects sampled over four years (>95% detection rate). More than 90% of detected individuals were recorded by visually locating the frogs through eyeshine. Monitoring for the green-thighed frog in the same area, however, has provided a less than 33% detection rate at sites known to be used by the species.

**Table 1 Sample frog surveys demonstrating effort and results across different methods and locations in New South Wales**

| Study | Location | Species | Method | Effort | Probability of detection |
|---|---|---|---|---|---|
| Parris 2001 | Northern NSW | *Litoria pearsoniana* | Aural-visual | 100 m transect | 0.67 |
| Wassens et al. 2017 | Riverina | *Crinia parinsignifera* | Adult aural-visual<br>Tadpole sweep net | 30 mins<br>5 mins | 0.93<br>0.00 |
| Wassens et al. 2017 | Riverina | *Limnodynastes fletcheri* | Adult aural-visual | 30 mins | 0.61 |
| Wassens et al. 2017 | Riverina | *Limnodynastes interioris* | Adult aural-visual | 30 mins | 0.27 |
| Wassens et al. 2017 | Riverina | *Limnodynastes tasmaniensis* | Adult aural-visual<br>Tadpole sweep net | 30 mins<br>5 mins | 0.91 |
| Wassens et al. 2017 | Riverina | *Litoria peronii* | Adult aural-visual<br>Tadpole sweep net | 30 mins<br>5 mins | 0.83 |

**Table 2 Probability of detection of threatened frogs in New South Wales**

| Study | Location | Species | Method | Effort | Probability of detection |
|---|---|---|---|---|---|
| Penman et al. 2008 | South-east NSW | *Heleioporus australiacus* | Aural-visual survey | >1 hour | <0.01 |
| Lemckert et al. 2011 | NSW Southern Highlands | *Pseudophryne pengilleyi* | Aural-visual survey | 30 mins | 0.77 |
| Heard et al. 2006 | Melbourne | *Litoria raniformis* | Diurnal visual survey | 30 mins<br>5 mins | 0.70 |
| Heard et al. 2006 | Melbourne | *Litoria raniformis* | Tadpole sweep net survey | 30 mins | 0.11 |
| Heard et al. 2006 | Melbourne | *Litoria raniformis* | Aural-visual survey | 30 mins | 0.35 |
| Wassens et al. 2017 | Riverina | *Litoria raniformis* | Tadpole sweep net survey | 30 mins | 0.27 |
| Wassens et al. 2017 | Riverina | *Litoria raniformis* | Visual survey | 5 mins | 0.00 |
| Hunter & Smith 2013 | South-west Slopes | *Litoria booroolongensis* | Aural survey | 500 m stream transects | 1.00 |
| Knight 2015 | Riverina | *Crinia sloanei* | Aural survey (call-response technique) | Wetland scale | 0.81 |
| Scheele et al. 2012 | Kosciuszko National Park | *Pseudophryne pengilleyi* | Aural survey (call-response technique) | Bog habitat scale | 0.91 |
| Hunter 2000 | Kosciuszko National Park | *Pseudophryne corroboree* | Aural survey (call-response technique) | Bog habitat scale | 0.85 |