Australian Government

Department of the Environment, Water, Heritage and the Arts

# Survey guidelines for Australia's threatened frogs

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

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# HOW TO USE THESE GUIDELINES

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

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

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

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

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

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

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

# INTRODUCTION

A wide variety of survey techniques have been developed in order to cater for the diverse ecological and behavioural requirements of amphibian species (Heyer et al. 1994). The suitability of a given survey technique for a target frog species will be influenced by the species' general habits, preferred habitat and microhabitat, life history and behaviour (Heyer et al. 1994). Survey methods and techniques will also vary depending on individual survey requirements, for example, the approach for surveying for one identified species in a known locality will differ from the approach for surveying for a range of species where amphibian presence has not been confirmed. It is important to employ survey techniques most suited to the target species and the environment to maximise the probability of detection. It may be necessary to use multiple techniques and greater survey effort to establish the presence/absence of some threatened frog species.

As the current distribution maps for these species are predicted to change as new information becomes available, distribution maps for threatened frog species have not been provided in these survey guidelines. The department's protected matters search tool can be used to assess the likelihood of a threatened species being found in a specific area (see also Step 1 of 'Conducting surveys in six steps').

A number of factors can affect the probability of detecting a target species, and it should be noted that there have been few studies designed to rigorously test the different sampling strategies to determine optimal species-specific approaches. The ecology of the species, timing of the surveys, local environmental conditions, and observer competence can all affect the performance of survey techniques and the detection probability for the target species. A collective approach using results from single species studies provides a guide for the effectiveness of each technique relative to general biological traits of different frog species, and forms the basis of these survey guidelines.

The most commonly used techniques for sampling frog populations include:

1. **visual encounter surveys**
2. **call surveys**
3. **night driving**
4. **pitfall trapping**
5. **egg mass surveys, and**
6. **larval sampling.**

Table 2 (page 6) outlines the general advantages and disadvantages of these six sampling techniques and the traits of frog species for which the techniques are most appropriate.

## Scope of the survey guidelines

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

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

The taxa accounts relate to the 28 frog taxa that are classified as threatened under the EPBC Act as at June 2008 (Table 1). However, it is recognised that the EPBC Act threatened species list is dynamic and that survey guidelines are likely to be applied to some taxa not currently listed. With ongoing conservation programs, it is expected that the populations of some taxa will recover and can be removed from the list.

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

| Scientific name | Common name | Status under EPBC Act |
| --- | --- | --- |
| *Geocrinia alba* | White-bellied frog | Endangered |
| *Geocrinia vitellina* | Orange-bellied frog | Vulnerable |
| *Heleioporus australiacus* | Giant burrowing frog | Vulnerable |
| *Litoria aurea* | Green and golden bell frog | Vulnerable |
| *Litoria booroolongensis* | Booroolong frog | Endangered |
| *Litoria castanea* | Yellow-spotted tree frog | Endangered |
| *Litoria littlejohni* | Littlejohn's tree frog | Vulnerable |
| *Litoria lorica* | Armoured mistfrog | Critically endangered |
| *Litoria nannotis* | Waterfall frog | Endangered |
| *Litoria nyakalensis* | Mountain mistfrog | Critically endangered |
| *Litoria olongburensis* | Wallum sedge frog | Vulnerable |
| *Litoria piperata* | Peppered tree frog | Vulnerable |
| *Litoria raniformis* | Growling grass frog | Vulnerable |
| *Litoria rheocola* | Common mistfrog | Endangered |
| *Litoria spenceri* | Spotted tree frog | Endangered |
| *Litoria verreauxii alpina* | Alpine tree frog | Vulnerable |
| *Mixophyes balbus* | Stuttering frog | Vulnerable |
| *Mixophyes fleayi* | Fleay's frog | Endangered |
| *Mixophyes iteratus* | Southern barred frog | Endangered |
| *Nyctimystes dayi* | Lace-eyed tree frog | Endangered |
| *Philoria frosti* | Baw baw frog | Endangered |
| *Pseudophryne corroboree* | Southern corroboree frog | Endangered |
| *Pseudophryne covacevichae* | Magnificent brood frog | Vulnerable |
| *Pseudophryne pengilleyi* | Northern corroboree frog | Vulnerable |
| *Spicospina flammocaerulea* | Sunset frog | Endangered |
| *Taudactylus eungellensis* | Eungella day frog | Endangered |
| *Taudactylus pleione* | Kroombit tinker frog | Vulnerable |
| *Taudactylus rheophilus* | Tinkling frog | Endangered |

## Table 2. Comparison of survey techniques.

Techniques most commonly used to determine the presence–absence of frogs.

| Technique | Target/species trait | Advantages | Disadvantages |
|---|---|---|---|
| 1. Visual encounter surveys | Active or obvious species | Inexpensive, non-destructive, ideal for opportunistic surveys | Unsuitable for cryptic or secretive species |
| 2. Call Surveys | | | |
| a) Audio strip transects and static call surveys | Most species; especially good for prolonged breeders | Quick and non-destructive; may detect cryptic species. | Only suitable during calling period, only detects calling males (non calling individuals will be undetected). |
| b) Automated call recording | Most species | Not labour intensive, recordings can be made over several days and in different conditions | Technical and equipment constraints, limited to area around recorder, equipment costs |
| 3. Night driving | Large and small active species | Large areas can be surveyed in a short time, large and small species may be detected with visual and aural encounters | Requires road to bisect suitable habitat. Driving speed may affect the detection of smaller species |
| 4. Pitfall trapping | Terrestrial and fossorial species | May detect cryptic species, can detect active but non-calling frogs | Not suitable for tree frogs (some tree frogs can be captured if funnel traps are added), expensive and labour intensive installation, use may be limited by hard substrates, effectiveness dependent on weather conditions and season. |
| 5. Egg mass surveys | Species with conspicuous eggs | Extends detection time for “explosive” breeders, may detect cryptic species that are breeding but not calling | Not suitable for species with cryptic eggs, may have narrow temporal window for sampling |
| 6. Larval sampling | Species with aquatic larval stage | May detect species for which adults have not been detected | Labour intensive sampling of specific microhabitats, larvae are difficult to identify to species |

# PLANNING AND DESIGN OF SURVEYS

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

Effective surveys of rare or cryptic frog species require careful planning to exploit the biology of the target species to maximise the probability of detection. This process should always begin with a thorough examination of the literature to identify the best times, locations and techniques for surveys. This document provides a basis for effective surveys for frog species currently listed as threatened at a national level in Australia.

Where possible, surveys should be conducted during the breeding season when frogs are most active. In many cases surveyors will need to employ multiple survey techniques, during repeated surveys of both the target survey site and a reference site, to detect rare or cryptic species. The personnel required to conduct such surveys will require knowledge of the local frog assemblages and specifically may need to be capable of identifying not only adults of the target species, but the breeding calls of males and the often difficult to identify larvae (tadpoles). Surveyors will also require an intimate knowledge of the preferred habitats and activity patterns of the target species if surveys are to be reliable. Finally, although in some cases it may be relatively easy to declare a species *present* at a site, great emphasis must be placed on ensuring adequate survey effort has been employed at appropriate sampling times and in weather conditions, to allow surveyors to confidently claim a target species is *absent* from a site.

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

## Site selection and assessment

For most surveys considering threatened species, an initial assessment of species location records mapped on an appropriate scale within the local area will assist in establishing suitable survey techniques, effort and timing. While historical records can have limitations in quality of data, they do provide an important starting point. Historical records can be limited by the level of accuracy when compared with the modern use of GPS, but they may contain important descriptive information that will assist in the construction of a rigorous survey effort. Databases that should be consulted will include primary literature, museum records and collated information held by state government agencies dealing with threatened species management. The identification of reference sites is also a matter of considerable importance in training field staff and establishing the absence of a threatened amphibian species from a site.

## Data and identification

Correct information regarding the locality and identification of species is crucial to the accuracy of all survey results and should be provided to relevant state agencies responsible for the management of threatened species.

## Determining presence-absence and detection probabilities

MacKenzie and Royle (2005) provide an excellent summary of how to deal with the problem of imperfect detection when conducting occupancy studies. They include a consideration of the practical steps necessary for designing such a study. A possible solution to overcome the effect of false negatives is to conduct multiple surveys of sampling units over a relatively short period of time to minimize the possibilities of false absences. They recommend a modelling approach that uses the results from multiple surveys to estimate detection probabilities that lead to unbiased estimates of occupancy. It is based on a likelihood-based method for estimating site occupancy rates when detection probabilities are less than one. This method is effective where the surveyor is dealing with a species that occurs at some level of detection in the area that is being considered. Examples of the use of this approach in surveys for several species listed as threatened under the EPBC Act are available and include *L. raniformis* (Heard et al. 2006) and *L. verreauxi alpina* (Brown et al. 2007).

The most suitable field survey approach to adopt is not so straightforward when levels of detection are low and/or levels of occupancy are low. This situation is not uncommon when dealing with species that are of conservation concern. Some threatened species are cryptic and their detection may thus be difficult, but many occur in small numbers or are widely spaced in nature such that the level of occupancy makes detection very difficult. For example Penman and colleagues (2005) found that the burrows of the threatened giant burrowing frog *(Heleioporus australiacus)* are spaced across the forest floor up to one kilometre from breeding streams and individuals had activity areas of several hectares that were somewhat exclusive. When this wide spacing is combined with burrowing behaviour it is evident that the species will be difficult to detect in thick forest understorey. In these situations, quantitative measures of the confidence of occupancy and detection are often required.

Probability of occupancy in such situations is not related to detection probabilities. It may be that a site has been isolated for some time and no population of the species remains. However, this is an unknown. In such a case, the question is how much effort is required to be certain that a low probability of detection for a species will not affect the assessment of probability of occupancy. In these circumstances it is necessary to use reference sites where the probability of detection can be determined. Using repeated surveys at reference sites to obtain a probability of detection, it is possible to calculate the number of surveys necessary at the subject site to reach a 95 per cent probability of detecting the species if it is present. This approach assumes homogeneity of habitats and detection probabilities, although this assumption is rarely met in natural systems. If the probability of detecting the species (given presence) varies among sites, then occupancy will be underestimated. It is necessary to be cautious and rely on a high level of probability of detecting the species. Stauffer and colleagues (2002) discuss the approach of determining the number of surveys required to reach a 0.95 per cent probability of detecting the species at a site if it was present; that is, a 0.05 per cent probability of declaring the species as falsely absent. Logistics must be taken into consideration where reference sites are required. It should be recognised that when detection probability is low the optimal choice of the number of repeat surveys is very large. In most practical situations it is likely that surveyors would not be able to conduct the many surveys and satisfy the necessary assumptions. MacKenzie & Royle (2005) recommend as a general strategy that when occupancy is low, more effort should be devoted to sampling more sites; and when occupancy is high more effort should be devoted to repeat surveys.

## Frog handling and hygiene protocols

These guidelines do not include detailed frog handling and hygiene protocols or advice on pathogen and disease management. The state or territory agency responsible for the management of threatened species should be consulted regarding specific measures for the target species and/or area, and any relevant protocols complied with. In addition, the following precautionary procedures should be employed by all persons undertaking survey work (NSW DECC 2008):

- thoroughly clean and disinfect footwear at the start of fieldwork and between each sampling site
- thoroughly clean and disinfect nets, balances, callipers, bags, scalpels, headlamps, torches, wetsuits and waders etc between each sampling site
- spray/flush vehicle tyres with a disinfecting solution in high risk areas where necessary
- only handle frogs when necessary, and minimise of the risk of pathogen transfer between frogs by:
    - cleaning or disinfecting hands between samples or using a new pair of disposable gloves for each sample, and
    - adopting a ‘one bag, one frog’ approach to frog and larvae handling. Bags should not be reused.

Additional information on reducing the spread of chytrid fungus is available from the Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis.

# CONDUCTING SURVEYS IN SIX STEPS

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

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

### (i) Characterise the study area

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

### (ii) Establish the regional context

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

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

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

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

- the department's databases, including the protected matters search tool and species profiles and threats database (SPRAT) that allow you to enter the site of interest and generate predictive maps and information relating to threatened species distributions
- state, territory and local government databases and predictive models
- national and state recovery plans and teams for threatened species
- reference books such as *Reptiles and Amphibians of Australia* (Cogger 2000) or *Australian Frogs* (Tyler 1994)

- museum and other specimen collections
- unpublished environmental impact reports
- published literature, and
- local community groups and researchers.

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

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

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

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

Detection of threatened species can be improved by sampling during the seasons and weather conditions when the species are most conspicuous. Frog detection during non-breeding periods is often difficult, and requires active searching of microhabitats used for shelter sites or foraging areas, such as hollow logs, beneath rocks and among vegetation. Surveys during such times are not recommended as the risk of non-detection may be high and aestivating animals may be disturbed. If non-breeding surveys are required, experienced herpetologists should be employed to undertake searches of appropriate microhabitats.

If it is not possible to survey for target taxa that have been previously recorded in the general location of the study area during the appropriate time of day or season, it should be assumed that these taxa do occur in the study area if suitable habitat exists (NSW DEC 2004).

### Stage of life cycle

Effective sampling should be targeted towards sites and periods when species will be most likely detected. Many frog species tend to be most active and conspicuous during the breeding season when:

- males are heard calling
- males and females increase their movements to access breeding sites, and
- individuals are observed amplexing (mating) and eggs or larvae can be found.

Within these windows of opportunity, prevailing weather conditions will also influence the probability of detecting breeding or active frogs. For these reasons, identifying a nearby reference site where the species is known to occur may assist in determining peak activity periods to ensure field surveys are conducted at the most appropriate time (NSW NPWS 2003). However, this technique is suitable only for species that are prolonged breeders. Some species of frogs are explosive breeders and will call and breed only after specific rainfall events for brief intervals, in patterns as yet not well understood. For example, rainy weather on the current or previous day is important for stimulating activity in explosive breeders. The complex nature of these interactions may reduce the reliability of predictions gained from observations of a reference site for some species.

## Calling season

Calling periods of 28 species of endangered or vulnerable frogs are listed in Table 3. The table should only be used as a guide. In many cases males will only call during this period when certain weather conditions (such as rainfall) occur.

- Surveys associated with calling should be conducted under weather conditions conducive to breeding **within the periods outlined in this table.**
- Some species exhibit explosive breeding and will call on very few nights, whereas others have well defined prolonged breeding seasons and may call on the majority of nights during the breeding season.

## Larvae development period

Larvae are much more conspicuous than their adult conspecifics and usually persist at breeding sites for much longer periods of time.

Consequently, the window of opportunity to detect them and hence their probability of detection is often much greater. For some species larvae are the only reliable evidence of breeding activity and/or presence. Table 3 provides a guide for when larvae might be found for 28 species of threatened frogs.

## Environmental conditions during sampling

Activity patterns of frogs are highly dependent on local environmental factors such as humidity, rainfall and temperature (Duellman & Trueb 1986). These factors should be taken into careful consideration when determining when to sample for frogs.

As an extreme example, overnight freezing temperatures at a site may cause some frogs to retreat into microhabitat refuges, making such conditions (or the day following them) unsuitable for surveying frogs.

Frogs are highly sensitive to local weather shifts. It is recommended the use of reference sites nearby where the target species is known to occur, to determine if the species is likely to be active at the target survey site. Ideally, the reference site should be in the same drainage system and at a similar elevation to the target survey site to be informative of expected frog activity. If no individuals are found at the reference site, it is likely that environmental conditions are not conducive to frog activity and sampling at the target site is unlikely to be effective.

## Table 3. Calling periods and larval periods for nationally threatened frogs

| Species | Calling period | Larval period | References (below) |
|---|---|---|---|
| *Geocrinia alba* | Sep–Dec | No aquatic stage | 1, 2 |
| *Geocrinia vitellina* | Sep–Dec | No aquatic stage | 1, 2 |
| *Heleioporus australiacus* | Feb–April | Feb–May | 3, 5, 6, 36 |
| *Litoria aurea* | Sep–Jan | Sept–Apr | 4, 6, 7, 8, 9, 10, 48 |
| *Litoria booroolongensis* | Oct-Mar | Nov–Mar | 6, 49 |
| *Litoria castanea* | Sep–Jan | Sept–Feb | 37 |
| *Litoria littlejohni* | Feb–Aug | Feb–Oct | 38 |
| *Litoria lorica* | unknown | unknown | 11, 12 |
| *Litoria nannotis* | Jan–Dec | Jan–Dec | 13, 14, 15 |
| *Litoria nyakalensis* | Oct–Mar | Dec–Sept | 16 |
| *Litoria olongburensis* | Sep–Mar | Nov–Feb | 39 |
| *Litoria piperata* | Nov–Mar | Nov–Mar | 17 |
| *Litoria raniformis* | Aug–Feb | Sept–Feb | 9, 10, 40 |
| *Litoria rheocola* | Nov–Mar | Jan–Dec | 13, 18 |
| *Litoria spenceri* | Oct–Dec; Feb | Nov–Mar | 19, 20, 41 |
| *Litoria verreauxii alpina* | Sep–Dec | Nov–Jan | 21, 22 |
| *Mixophyes balbus* | Sep–Apr | Jan–May | Jan–May |
| *Mixophyes fleayi* | Sep–Mar | Oct–Mar | 23, 43 |
| *Mixophyes iteratus* | Sep–May | Sept–May | 23, 44 |
| *Nyctimystes dayi* | Sep–Apr | Sep–Apr | 15 |
| *Philoria frosti* | Sep–Dec | Sept–Jan | 24, 25, 26 |
| *Pseudophryne corroboree* | Jan–Feb | Aug–Dec | 27, 28, 29, 45 |
| *Pseudophryne covacevichae* | Dec–May | Sept–Mar | 30 |
| *Pseudophryne pengilleyi* | Jan–Feb | Aug–Dec | 28, 29 |
| *Spicospina flammocaerulea* | Oct–Dec | Oct–Jan | 46, 47 |
| *Taudactylus eungellensis* | Nov–May | Jan–Dec | 31, 32 |
| *Taudactylus pleione* | Sep–Mar | unknown | 33, 34 |
| *Taudactylus rheophilus* | Dec–May | Dec–May | 35 |

**References:** [1]Wardell–Johson & Roberts (1991), [2]Driscoll (1998), [3]Gillespie (1990), [4]White (1996), [5]Gillespie (1997), [6]Anstis (2002), [7]Littlejohn (1969), [8]Dankers (1977), [9]Brook (1980), [10]Humphries (1979), [11]Davies & McDonald (1979), [12]McDonald (1992), [13]Liem (1974), [14]Martin & McDonald (1995); [15]Richards (1992), [16]Richards et al. (1993), [17]Mahony et al. (1996), [18]Dennis & Trennery (1984), [19]Gillespie (1993), [20]Hero et al. (1995), [21]Green & Osborne (1994), [22]Smith (1998). [23]Goldingay et al. (1999), [24]Littlejohn (1963), [25]Malone (1985), [26]Hollis (1995), [27]Pengilley (1973), [28]Osborne (1989), [29]Hunter (2000), [30]McDonald et al. (2000), [31]Liem & Hosmer (1973), [32]McDonald (1990), [33]Clarke et al. (1999), [34]Czechura (1986), [35]Ingram (1980), [36]Recsei (1996), [37]White & Ehmann (1996), [38]White & Ehmann (1996b), [39]Ehmann (1996c), [40]Ehmann & White (1996), [41]Ehmann (1996a), [42]Mahony et al. (1996a), [43]Mahony et al. (1996b), [44]Mahony et al. (1996c), [45]Ehmann (1996b), [46]Wardell–Johnson et al. (1996), [47]Roberts et al. (1997), [48]Penman et al (2005), [49]Hunter (2007).

### Time of day/night

The most appropriate time for surveys is determined by the target species' biology and the sampling technique to be used. The daily timing of surveys can have a profound effect on the probability of detecting frog species. Surveys conducted when frogs are inactive will often fail to detect a species present at the site. Assessors should consult the available literature on the target species to determine the best time for surveys (with respect to the biology of the species). For example, if call survey techniques are to be employed the surveys should be conducted at the appropriate time of day or night of peak calling activity for males of the target species. A guide for survey timing and effort for the 28 threatened Australian frog species is included in the species accounts.

## Step 3: Determine optimal locations of the surveys

### Habitat stratification

In some circumstances, the study area of interest will be small enough to allow a comprehensive search of the entire area within a reasonable period of time. The size of what is a searchable area will depend on the nature of the target taxa and the habitat and topography of the study area. For example, searching for highly cryptic species in dense scrub will take far longer than searching for active, conspicuous species on riverbanks. If a comprehensive search is feasible, then sampling will not be required and the data collected will be representative of the entire area. In many cases, however, the study area will be too large to permit a complete search within a reasonable time frame, and selective searches or sampling procedures will be required (Royle & Nichols 2003).

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

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

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

### Macrohabitat use by frogs

It is generally the macrohabitat preferences of a given frog species that highlight the need for surveys in a particular area.

Broader preferences for specific habitat characteristics (for example, fast flowing rainforest streams) provide a framework for identifying potential sites for populations. A brief summary of the general macrohabitat preferences of some threatened Australian frogs is included in the species accounts. This information, along with more detailed descriptions in the cited literature, provides a guide for choosing the location of sampling sites and transects in the survey area.

### Microhabitat use by frogs

The term microhabitat refers to the fine scale preferences of frogs within their broader habitat. Frogs use different microhabitats for different activities, such as refuge sites, foraging areas and calling sites. The microhabitat preferences of a target species should be considered when choosing the survey technique to be used, and designing the method for applying the technique. For example, a visual encounter survey is most efficient when surveyors target their search time to microhabitats likely to be used by the target species at the time of the survey (for example, searching for active frogs on rocks near a stream), rather than searching all microhabitat types in the area (for example, searching all terrestrial surfaces). Likewise, automated call recording surveys will prove more successful if the microphone is placed near the preferred microhabitat of calling males (for example, emergent vegetation at a pond edge), rather than at any site in the breeding area (for example, on randomly selected ground near a pond). A brief summary of some of the microhabitat preferences of 28 species of threatened Australian frogs is included in the species accounts.

### Aquatic habitat use by larvae

Although larvae may sometimes prove to be easier to locate than adult frogs, they occupy very different microhabitats from their adult counterparts. Larval surveys must therefore take account of the habitat preferences particular to this life cycle stage.

The same principals apply as for surveying adults: surveys should be conducted in appropriate microhabitats for larvae to maximise the probability of detection. For aquatic larvae, microhabitat preferences often refer to specific ranges in water depth, water flow rate, pond permanency, water temperature and pH (Anstis 2002). The species accounts provide an outline of preferred aquatic microhabitats used by larvae of 28 species of threatened Australian frogs.

## Step 4: Establish sampling design and survey effort

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

## Spatial sampling

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

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

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

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

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

## Temporal sampling

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

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

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

## Step 5: Select appropriate personnel to conduct surveys

The single most essential component of any survey is competent observers (Resources Inventory Committee 1998). It is an expectation of assessors under the EPBC Act that surveys be conducted by appropriately experienced observers who have excellent identification skills, including familiarity with species' calls and a good knowledge of frog ecology, at least in relation to the taxa or group being targeted. Where calls will be important for detection, good hearing is essential, as hearing ability can strongly affect results of the survey. Observers should have recognised relevant skills or experience. Observers should also have access to appropriate optical equipment (that is, hand-lens or binocular microscope). The need for excellent field identification skills of observers cannot be overstated.

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

## Step 6: Document survey methods and results

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

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

It is important that reports contain suitable information to demonstrate the survey was sufficient to draw the conclusions. Documenting the survey effort will be particularly important for species that might be present at very low abundance in the project area.  Findings should be supported wherever possible by information such as: site photos showing equipment placement and habitat structure, summary tables with measurements and diagnostic observations from captures, and photos of frogs if no vouchers can be taken. Tabulated GPS coordinates of sites and equipment placement will allow precise determinations of occurrence within a project area.

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

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

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

# SURVEY METHODS

## Visual encounter surveys (VES)

A visual encounter survey (Crump & Scott 1994) involves field personnel walking through a defined area or distance for a prescribed time period, systematically searching for animals. This technique, also known as the 'time constrained search', requires that the observer search at a constant speed and intensity (Campbell & Christman 1982; Corn & Bury 1990). Another method is 'spatially constrained searches' where the observer searches a set area with a defined method and intensity over a variable time period. The survey is an effective technique for detecting frogs that are readily visible, and has the advantage of being useful for some species outside of the breeding season. For example, a typical survey might involve walking along a one kilometre stretch of creek for two hours searching for frogs that perch on rocks. The technique is not generally effective for species that reside underground, in thick vegetation, or in the canopy (Crump & Scott 1994).

Three experimental designs have been recognised for visual encounter survey: quadrant design, transect design and randomised walk design (Crump & Scott 1994).

*a) Quadrant design*

- Involves delineating a quadrant (for example, 25 m x 25 m).
- Quadrant sampled by walking parallel paths across plot and recording frogs within a set distance (for example, 2 m).
- Effective for small areas.

*b) Transect design*

Queensland EPA (2005) recommends that visual encounter survey involve nocturnal and diurnal surveys with two observers searching 100 x 50 m transects over a half hour period. Gillespie (1997) recommends 500 m transects along riparian habitat to be repeated on three occasions.

- Involves walking one or more transects of predetermined length.
- Used to sample across microhabitats.
- Recording frogs within a set distance (for example, two metres) of path.

*c) Randomised walk design*

- Involves choosing random directions and walking set distances (for example, 500 m) in each direction, in sequence.
- Recording frogs within a set distance (for example, two metres) of path.
- Allows for statistical comparisons among replicated walks in different areas.
- Effective for large areas.

*Field protocols and personnel*

- Before doing a visual encounter survey, the observer should specify the area to be surveyed, the search design to be used, the length of time for each survey, the searching distance from the observer or path, the intensity of the search, and the search pattern. The search pattern, for example, might be to examine all rocks along a stream for frogs, or to search only emergent vegetation along the edge of a water body.
- A survey for frogs can be conducted by day for some species, but most species are nocturnal and are more readily detected at night with the aid of a torch or spotlight.
- Detection is often related to activity; this technique is often more successful on rainy nights or on nights after rainfall.
- This method can involve any number of observers, provided that searching time is expressed in person–hours.
- Multiple observers are recommended to conduct a survey to maximise the possibility of detecting individual frogs. Experience in recognising eye reflection and familiarisation with frog calls will benefit the effectiveness of survey (NSW DPI n.d.).

*Equipment and data collection*

This technique requires minimal equipment: site maps, data book, pencils, compass, 100 m measuring tape, flagging tape, GPS and a torch or headlamp. Data collection is generally limited to the number of individuals observed, the size of the area searched (and number of transects, etc.), the time spent searching, and the number of observers. However, as with all detection methods for frogs, the observer should record date, time of day/night, water and air temperatures, and weather conditions. Weather conditions should include whether it has rained in the last 48 hours, and the rainfall amount, because frog activity is highly dependent on moisture (Crump 1994). Recording stream, pond and/or swamp conditions and water quality is important in all visual encounter survey (NSW DPI n.d.; UC 2003; Qld EPA 2005).

## Call surveys

Males of most frog species use species-specific calls during the breeding season to advertise their presence to females and to other males. Call surveys exploit this habit. Call surveys are efficient because calling frogs can be heard even if they are hidden from visual observation, which is often the case due to the small size, cryptic colouration or position, and/or their microhabitat use, and the observer's search image (Zimmerman 1994). In addition, both arboreal and terrestrial species can be surveyed simultaneously (Zimmerman 1994).

Call surveys do have some limitations. For example:

- They are generally only useful during the breeding period of each species, and only when conditions are conducive to calling. However, many Australian species have relatively lengthy calling seasons (Lemckert & Mahony 2008).
- This technique requires the observer to learn to identify the species-specific call of each target species (Osborne 1985), or to record any calls heard for subsequent analysis and to use appropriate equipment (microphones) suitable for different circumstances (Qld EPA 2005). There may also be variation in dialects between species based on geographic distance and the effect of this variation in maximising call responses is unknown (NSW DPI n.d.).

- Some species have calls that cannot be distinguished or are similar to other species. In such cases it is necessary to confirm the identity by observing individual animals.
- Calls may go unheard when using this method in areas of strong or fast running water due to background noise. Gillespie (1997) suggests call playbacks should be conducted every 100 m along the edge of a water body.
- Call playback surveys require that males respond to stimulation. Some frog species respond readily, others will only respond under certain environmental conditions. Therefore this technique may fail to detect some individuals or smaller populations (UC 2003).

Call surveys for frogs can be divided into two major types: audio strip transect and static call surveys (Zimmerman 1994).

## Audio strip transect survey

- Involves walking along designated transects (which traverse potential breeding habitats) with a tape recorder (manual recording) to listen for calling male frogs.
- To determine the width of the strip transect, the observer should locate at least six calling males of the target species in similar habitat and calculate the mean maximum distance at which calls can be heard and identified.
- Effective in large, or elongated, areas.

### *Field protocols and personnel*

- Field personnel should familiarise themselves with the breeding calls of all frog species that may be detected during the survey prior to initiating surveys, noting that temperature can strongly influence the speed (pulse rate and call repetition rate) of breeding calls for most species.
- If the observer is not conversant with the local species-specific breeding calls a portable tape recorder should be used to record any unfamiliar.
- Surveys should be carried out at times when males are most likely to call. For example, calling activity decreases throughout the night depending on species and environmental conditions.
- Some frogs call only during or soon after rainfall. Surveys should be planned to allow opportunistic surveys matching appropriate weather conditions.
- Repeated surveys are advisable, particularly for species that occur in low numbers or are particularly sensitive to prevailing weather conditions (for example, moisture or temperature) for breeding activity.
- Audio strip transect can be conducted by a single observer.

### *Equipment and data collection*

Commercially available recordings of regional frog calls on compact disc or cassette tape may be useful for familiarising field personnel with local frog breeding calls prior to the survey. A list of audio recordings for Australian frogs is given in Appendix A. Care should be taken to ensure that the selected recording clearly identifies the species heard, as some products include multi-species choruses without clearly identifying which call relates to the described species.

Transects can be set out with a 100 m measuring tape, compass and flagging tape. During the survey the observer will require a data book, pencils, torch or headlamp and hand-held tape recorder. Data collection is limited to the number of individuals heard (or an estimate of the size of the chorus), details of transects traversed and the time taken, number of observers, the date and time of the survey, temperature and weather conditions. Weather conditions should include whether it has rained in the last 48 hours, and the rainfall amount.

## Static (or point) call surveys

- Involves recording (manually or automatically) calling males at known breeding habitat (for example, farm dams or small ponds).
- Surveyor visits each discrete site and waits for a predetermined time (for example, 15 minutes) at a fixed point to listen for calling males. Calling may be stimulated by playing calls.
- Effective for selected fixed points.

**i) Manual call recording**

This method involves the observer visiting each discrete breeding site and waiting for a predetermined time at a fixed point to listen for calling males. For example, an observer may remain at each of several potential breeding sites identified within the study area for 15 minutes to listen for calling males. This method may be less time consuming than the audio strip transect method in situations where the distribution of breeding habitat is suitable, as the observer does not need to set out predetermined paths to traverse the area.

*Design*

The time spent listening at each of the fixed points should be predetermined. If multiple sites are surveyed, the time each is visited should be kept constant (where possible) to account for the influences of time of day/night on the calling activity of males (Osborne 1985). Randomising the order in which sampling points are visited across several nights of surveys will provide sufficient control.

*Field protocols and personnel*

- Observers should be familiar with all local frog species expected to be heard (Appendix A), or carry a hand-held tape recorder for later identification of calls. Note that temperature can influence the call speed of some species.
- Surveys should be repeated over multiple nights with conditions conducive to males calling (see audio strip transect outline).
- A single observer may be able to carry out a manual call recording survey, depending on the number of fixed points and the travel time between them.
- Torches and headlamps should be turned off for a few minutes prior to a recording session, as lights can suppress calling activity.

*Equipment and data collection*

This method requires the same equipment and preparation as the audio strip transect method, although there is no need for equipment to set out transects. However, a GPS and thermometer are useful. Temperature should be recorded as it may influence the features of calls and occurrence of calling.

**ii) Automated call recording**

This method uses a remote recording device, consisting of a microphone and cassette tape recorder attached to a timer, to record calling frogs in the absence of the observer. The automation of call surveys facilitates continuous sampling throughout the day and night, allows simultaneous sampling of multiple sites and reduces the need for personnel in the field (Peterson and Dorcas 1994). Use of this method is sometimes limited by the expense of recording equipment and the time required to listen to cassette tapes after surveys have been conducted.

*Design*

Recording duration and interval between recordings must be set on the timer according to the sampling regime required. These parameters are limited by the length of the cassette tape used. More frequent recordings of shorter duration will be useful for species that may only call for short periods of time each day/night, while less frequent and longer recordings may prove useful for species that are likely to call consistently for a long period during favourable conditions. The frequency with which personnel can attend to the equipment and change the tape will also influence the selection of an appropriate interval and duration of recording.

*Field protocols and personnel*

- Microphone should be made waterproof prior to employing the device.
- The microphone should be placed close to the microhabitat from which males would be expected to call, but care should be taken to ensure that the microphone cannot be submerged in the event of flooding.
- Depending on the site, the device may need to be camouflaged to avoid unwanted interference.
- The device should be employed and maintained across several days and nights to ensure that multiple periods with appropriate conditions for calling are included.
- The system is very efficient in reducing field personnel; a single person can maintain the systems by checking and changing tapes regularly, depending on the duration and interval selected.

Although automatic call recording is an efficient means of recording calling males, operators should note that a large chorus of a common species may drown out isolated calls of a rarer species on the tape, making identification difficult (Berrill et al. 1992).

*Equipment and data collection*

A typical automated recording setup includes a waterproof box containing a solid state timer which controls the cassette recorder. In some systems the timer requires a 12 V battery, and the recorder runs off a reduced voltage of 6 V. The microphone should be attached to the recorder with a long lead to allow it to be placed in an optimum position. The basic parts are readily available and not overly expensive. Data collection involves replaying the tapes and noting the frog calls heard. Rainfall events may also be audible on the tape. Using this basic system the observer should keep a record of the date and time tapes were recording, the duration and intervals used, and temperature and weather conditions. An alternative device which includes a data logger to record date, time and environmental variables may be used to keep simultaneous records of calls and additional variables (for technical details see Peterson & Dorcas 1994).

**iii) Call stimulation via playback**

In some frog species, present but non-calling males can be stimulated to call either by imitating the call or by playing a previously recorded call using a tape recorder. Call stimulation surveys exploit this habit to achieve a call survey that may require fewer repeated visits to a site to detect cryptic males, compared to unstimulated surveys (D. Hunter, pers. comm.). The technique requires that males will respond to the stimulation; although some species will respond readily during the breeding season, others will respond only under certain environmental conditions or not at all. In all cases, it is unlikely that 100 per cent of the males present at the site will respond. Therefore, by random chance this technique may fail to detect individuals at every site and/or very small populations.

Call playback is very effective for a range of species that are rarely detected by visual encounter methods (mostly because the species remain hidden), or have restricted calling periods but are aggressive when a conspecific call is played.

Call detection methods are applied in a hierarchy. The first step is to listen to calls as described  for static point call surveys. If none are heard there is the option to do a repeated survey, establish a remote recorder, or to elicit a response to call-playback. If the objective is to determine presence/absence of a species at a site the latter method may preclude the need for a repeat survey or remote call methods. When animals respond to a call the data is recorded as a presence. A non response cannot be regarded as an absence, since this may be a false negative (that is, animals were there but they did not respond).

*Design*

Call stimulation techniques may be employed during manual recording from fixed points at discrete breeding sites, or at designated points along a transect in larger breeding areas (see audio strip transect and manual call recording for design issues). In addition, due to variability in the success of this technique, call stimulations should be initially trialled at a reference site known to be inhabited by the target species. Trials should be conducted to determine the number of stimulations required to get a response, the environmental conditions under which a response is most likely, and if possible, the proportion of males likely to respond. These parameters should be taken into account when designing the survey at the target site.

*Field protocols and personnel*

- The technique involves visiting suspected breeding sites and replaying a recording of the species-specific breeding call for a designated period of time from either a fixed point or points along a transect.
- Volume of call playback should be audible over a distance of about 10 m. Use of overly load broadcast may deter calls in some species.
- Following the playback the observer listens for males to reply with either a threat call or breeding call. A variant of this technique has been developed for Corroborree frogs *(Pseudophryne corroboree, P. pengilleyi).* Males of these species respond to loud shouting from the observer (Osborne 1989; Hunter 2000).

- A single observer is sufficient for call stimulation surveys. In cases where human vocalisations are used, the survey should be restricted to a single observer who has been determined to produce the appropriate pitch for a response. It should be noted that some observers may have difficulty getting any males to respond where the response may be dependent on pitch.

### *Equipment and data collection*

For recorded stimulations the observer will require a portable cassette or compact disc player. The data recorded should include whether any males responded or not, or an estimate of the number of males responding. However, the number of males responding may not represent the total number of males present at the site, as some males will not respond to the stimulation. The observer should also record date and time of survey, and temperature and weather conditions.

## Night driving

Night driving surveys involve searching the road ahead from a slowly moving vehicle for frogs. Gillespie (1997) recommends 10 km road transects.

### *Design*

When suitable roads intersect the habitat to be surveyed, this technique allows observers to survey large areas in a short amount of time. It is therefore important to treat the sampling process as any transect-based method: the number and length of transects should be predetermined, as should the time for surveys and the speed of travel. Due to the efficiency of sampling transects from a vehicle, short roads may be traversed repeatedly in a night to increase survey time if required. Roads with a smooth and uniform surface (tar or concrete roads) are the easiest to see animals moving across or sitting on. It is harder on gravel or dirt roads, but surveys are still effective if the speed of the vehicle is reduced. However, night driving is less likely to detect arboreal species and small or sedentary terrestrial species (Campbell & Christman 1982; Shaffer & Juterbock 1994).

### *Field protocols and personnel*

Night driving surveys provide opportunities to survey for frogs using both visual and aural cues (Couch & Paton 2002).

- These surveys are conducted by searching the road ahead of a slowly moving vehicle for frogs. Hand held spotlights (30–100 W) are useful equipment.
- Upon detection it is usually necessary to stop the vehicle to identify the species.
- If the observers are familiar with the breeding calls of the target species, the drive can also be used to listen for calling frogs.
- Surveys should proceed with windows down and if the road nears suspected breeding sites, the vehicle should be turned off for a predetermined period of time to listen for the breeding calls of males.
- Busy roads may not be suitable transects due to the slow speed and frequent stopping necessary in these surveys.
- Night driving surveys are designed to detect active, mobile frogs and as such should be conducted during weather conditions conducive to frog activity (that is, during mild, humid conditions).
- In general, surveys should be conducted before midnight and during or closely following rainfall events.

- Repeated surveys are recommended to ensure that optimum weather conditions co-occur with surveys.
- Although a single observer can conduct night driving surveys, it is advisable to have a second observer in the vehicle as the driver's attention is shared between driving and searching for frogs.

*Equipment and data collection*

Minimal equipment is required for night driving. Observers will require a car, torch or headlamp, notebook and pencil. The distance travelled and location of frogs can be measured using the vehicle's odometer, although a hand-held GPS may prove useful for precise frog location data. A commercially available recording of frog calls (see audio strip transects) will assist in familiarising observers with breeding calls of target species. The data yielded will be number of frogs sighted per unit time and may include the location of individual frogs. Observers should also record location and length of transects (roads), speed of travel, time taken for survey, number of observers, the date and time of survey, and temperature and weather conditions including recent rainfall data (Crump 1994).

## Pitfall trapping

Pitfall traps are pipes, buckets or tins buried with the top flush with the ground designed to capture small animals. They are most efficient when used with a drift fence to direct animals into the buckets (Corn 1994; Enge 1997). Pitfall traps can readily capture relatively mobile, terrestrial frogs (Braithwaite 1983; Friend et al. 1989; Hone et al. 1992). Arboreal species are generally not suited to this method as they are less likely to encounter the traps and can usually climb out of the buckets. A few terrestrial species with above average jumping ability can also escape from pitfall traps (UC 2003). The problem of frogs jumping out of the traps can be solved by using a funnel (Qld EPA 2005), or by using narrow buckets (for example, a length of 150 mm PVC pipe) (NSW DPI n.d.).

*Design*

There are four design issues that need to be decided before setting pitfall traps (UC 2003);

- *bucket size* (traps greater than 30 cm in depth are recommended) (Braithwaite 1983; Friend 1984; Osborne 1985)
- *use of a drift fence* (fences effectively increase the area of ground from which the bucket can capture animals)
- *drift fence design* (traps in a row are useful when placed across a path expected to be traversed by frogs), and
- *bucket location* (buckets can be placed under the fence with one half protruding either side).

Queensland EPA (2005) suggests that a 10-day pitfall trapping design is most effective.

Pitfall trapping and collection should only be undertaken with the appropriate permits from the relevant state or territory authority.

*Field protocols and personnel*

- Pitfall traps must be buried with their tops flush with the ground.
- Drift fences, if employed, must be partially buried (for example, six cm underground) to prevent animals travelling underneath the fence (UC 2003).

- It is advisable to drill several small holes in the bottom of buckets to allow rainwater to drain away (Greenberg et al. 1994). However, in heavy clay soils where water may become trapped in surface soils, buckets with holes may flood from underneath (Doody 2003 pers. comm.). To prevent drowning of frogs in pits, add polystyrene rafts to buckets (NSW DPI n.d.; Qld EPA 2005).
- To ensure captured frogs do not desiccate, sponges should be placed in the bottom of buckets and kept moist (Greenberg et al. 1994). Sponges should be kept free from chemical treatments (for example, soaps). Sun-shades over pits and/or a dish of water in the bucket are other protective measures (Qld EPA 2005).
- Traps can be opened in the late afternoon and checked in the early morning to avoid captured animals overheating during the hotter mid-day. Traps should also be checked in the afternoon if they are to be left open all day and many diurnal captures are expected.
- It is important to remember that pitfall traps can capture all small terrestrial animals and care should be taken to ensure the welfare of more sensitive species that may be captured (for example, small mammals) (UC 2003) .

*Equipment and data collection*

Collection containers for drift fences may be made of plastic pipe (capped at the base), tins, or buckets. Care should be taken to select a trap design that can easily be fitted with a lid (for example, lidded buckets). Drift fences may be constructed from a variety of materials, but are commonly made of silt fencing, aluminium flashing, or gutter guard, and are held up with wooden or metal stakes. Silt fencing may be more economical for short term trapping projects, but is less durable and unsuitable for long term monitoring of sites. Data recorded are the number of captures per fence (long fence system) or per grid (grid system), and are eventually expressed as the number of captures per trap-night (number of nights trapping × number of traps open). Observers should also record the date and time, night-time temperature and weather conditions including recent rainfall. If relevant, record the location of the trap individuals were captured in and the inferred direction of movement.

## Egg mass and larval sampling surveys

Sampling larvae and egg mass is particularly useful when adults are difficult to detect and can help document current reproduction in a population. Larvae generally have a high probability of detection, and may provide the only reliable evidence of a targeted species' presence. Larval sampling also allows sampling outside the breeding season, which can be brief in explosive breeders (Hunter et al. 1998).

### Design

Egg mass can be detected through visual encounter surveys. Larvae can also be surveyed by employing visual searches (sweeping a dip net through aquatic microhabitats) or by setting underwater (funnel) traps (Griffiths 1985; Richter 1995; Shaffer et al.1994). Both of these survey methods should be conducted when larvae are potentially active or visible (Qld EPA 2005). Larvae are likely to be more active at night and thus more likely to be found in the water column rather than sheltering in litter or logs (NSW DPI n.d.). Care should be taken in utilising larval sampling alone, as identification of larvae can be difficult, and may require assistance from experienced frog experts or use of larvae keys (for example, Anstis 2002).

### A. Visual searches

Visual searches involve sweeping a dip net through suspected aquatic microhabitats to capture and identify the species of larvae present at the site. This technique is the most commonly used method for sampling larvae, and is particularly useful when sampling can be conducted while the observer remains on land, allowing minimal disturbance of the water prior to sampling (Shaffer et al. 1994).

Visual surveys should also include searching for egg masses. Although the form of the egg mass and its typical site of deposition is not reported for all the threatened species listed this method should not be overlooked. A description of egg mass and deposition site for many species is provided in Anstis (2002). This method is suited to species with conspicuous eggs and when exact breeding locations are known and accessible. The advantage of this technique is that it is useful for detecting cryptic species that are breeding but not calling. The disadvantage of this method is that there may be a narrow temporal window for sampling.

*Design*

There are two basic sampling techniques for visual larval sampling. For sampling smaller areas, the net is moved through the water column in a series of short sweeps with constant speed (e.g. sweep the net through one metre of water at a speed of about one metre per second). For larger areas, the net may be dragged along predetermined transects for a period of one to two minutes (Gillespie 1997). It is important to ensure a constant speed of movement. Larvae caught should be correctly identified and recorded (Gillespie 1997; Shaffer et al. 1994).

As with any sampling design involving fixed site or transect sampling, the observer must predetermine the location, size and number of areas to be sampled. These factors will be influenced by the amount of habitat available that matches the preferred larval habitat of the target species.

*Field protocols and personnel*

- Focus should be on sampling the appropriate microhabitat of the target species; this includes not only considering the vegetation type but also water depth and flow.
- Searches should be performed prior to disturbing the water at suspected breeding sites where possible, as some larvae are strong swimmers and can avoid capture.
- Field personnel should be practised in using larvae keys to assist in correct identification of captured larvae.
- Where key identification is difficult, consideration should be given to keeping and raising larvae to metamorphosis to confirm identification. Otherwise, larvae should be released at point of capture.
- A single observer may be sufficient to conduct visual searches.

*Equipment and data collection*

A basic dip net for larval sampling consists of a 30 cm diameter net with fine mesh and a long handle. Field personnel will require a larvae key (for example, Anstis 2002), 10X or greater hand-lens or binocular microscope, notebook and pencils. Data collected will be the number, length and approximate speed of sweeps with the net, the number and species of larvae captured, date, time, temperature and weather conditions.

### B. Funnel traps

The funnel trap technique is largely untested for the majority of Australian species so the number of days that traps need to be employed is unknown (Griffiths 1985; Richter 1995, Shaffer et al. 1994). Queensland EPA (2005) notes that funnel traps may trap non target species (that is, crayfish) that have the potential to kill and eat larvae. In addition, identification can be difficult, and may require assistance from experienced frog experts or the use of larvae keys (Anstis 2002).

The use of minnow-type funnel traps may be an effective means of capturing larvae (Griffiths 1985, Richter 1995), being very efficient in capturing larvae of three species in ricefields in NSW (S. Doody, unpubl. data.). An advantage of this technique is that traps can be checked at the surveyor's leisure, as the larvae get sufficient oxygen and food within the traps. However, caution is needed to adhere to strict time protocols where statistical comparisons are required.

#### *Design*

Traps can be employed along transects. Care should be taken to record how many traps were used and the duration and times they were employed. The number of traps to be employed will be influenced by the amount of larval habitat available.

#### *Field protocols and personnel*

- Traps should be set in water deeper than the height of the funnel to ensure efficient capture of larvae.
- The traps are not baited and are most effective when placed along banks or woody debris, which serve to concentrate the larvae into the trap.
- Traps should be tied to a stake or large debris. As this technique is untested for the majority of Australian species, the number of days traps need to be employed is unknown.
- The use of reference sites may prove useful, though larvae density will influence the time taken to detect species presence with funnel traps.
- A single observer is sufficient to carry out funnel trapping of larvae, but as with visual larvae sampling the observer should be practised in larval identification techniques.

#### *Equipment and data collection*

Equipment required for this technique includes commercially available minnow funnel traps, ropes and stakes to secure them, data book, hand-lens or binocular microscope, pencils and a larvae identification key (for example, Anstis, 2002). Observers should record the location and number of traps set, the number of days traps were set, the number and species of larvae captured, temperature and recent weather conditions. Flagging tape is useful in relocating traps.

## Combined approaches

It is often expedient to simultaneously combine two or more of the above techniques to determine the presence/absence of a frog species. By using sampling techniques that exploit different features of a species' biology, or different stages of the life cycle, the surveyor may maximize the probability of detecting rare or cryptic species (NSW DPI n.d., Qld EPA 2005, UC 2003). For example Woinarski and Gambold (1992) recorded that pitfall trapping combined with VES can potentially detect both active and refuging frogs at a site (UC 2003). Penman (2005) demonstrated that a combination of VES, night driving and larvae searches are effective for detecting the large terrestrial frog *Heleioporous australiacus;* and VES and call-playback is effective for the endangered bell frog *L. raniformis* (Heard 2007).

# PROBABILITY OF NON-DETECTION AND SURVEY EFFORT

Frog activity varies spatially, seasonally and temporally according to current or recent weather conditions (Duellman & Trueb 1986, Heyer et al. 1994). Consequently, the probability of detecting frogs will also vary. Repeat visits to a survey site may be required to ensure that all amphibian species present are detected (Pearman 1997). The probability of non-detection may be high for rare or cryptic species and those species that are only active for short periods of time, such as explosive breeders. Hence, the survey effort required to detect a species which is present will vary with season, habitat conditions, the targeted species' activity patterns and the sampling techniques used.

The probability of non-detection can be reduced by sampling species specific habitats and microhabitats at times of peak activity, and during weather conditions favouring activity. Surveys utilising more than one technique may also increase the detection probabilities as they may target more than one life history stage or behavioural state. Surveys must also be repeated to ensure that non-detection indicates true absence, rather than inactivity. A guide for survey methodology, timing and effort for the 28 threatened Australian frog species can be found in the individual species accounts.

Because many of the species considered here may have a patchy distribution, low population sizes, and cryptic habits, the sampling effort, including the area searched and the number of times sampled, will need to be high to achieve confidence of true absence. One-off, low-intensity searches of small areas are inadequate for rare species. Many researchers acknowledge that these species may go undetected at sites where they have previously been recorded. Ideally, sampling sites need to be visited on several occasions to reduce the sampling error associated with low detectability.

Work on some riverine species has demonstrated the importance of the appropriate scale of searches, especially for rare species with patchy distributions along watercourses (Gillespie & Hollis 1996; Holloway & Osborne 1996). Visual searches of 500–1000 m or more greatly enhance the probability of detection compared with searches over 100–200 m (Holloway, 1997).

# SPECIES ACCOUNTS—METHODS, EFFORT AND TIMING.

A separate account for each Australian threatened frog species is provided. These profiles are a summary only and relevant literature should also be consulted prior to a survey.

Methods and effort are expected, under suitable weather conditions, to detect threatened frogs. Effort must be considered relative to the area that is being surveyed and must therefore be explicitly described in spatial terms for any survey. Some justification of the sampling effort used, in reference to the survey guidelines, would be expected in the report. In the following description study site refers to an area measured in tens of metres up to one square kilometre, local area refers to the area within a five kilometre radius of the study site.

Where two survey method are provided, the first described is the most effective, followed by additional methods.

Habitat information: citations for habitat are included at the end of the section (refer to superscript numbering).

## *Geocrinia alba*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Permanently moist drainage depressions[1] | Not reported | Not reported | Depressions in clay under vegetation[2] | No aquatic larval stage. Eggs undergo direct development into metamorphs in burrows along riparian edges. |

### Timing of surveys

Under optimal weather conditions at the peak activity time.
*Seasonal*: September–early December
*Weather conditions:* After seasonal rainfall
*Time of day*: Nocturnal searches

### Methods

This species has an area of occupancy of 193 ha. It persists along the lower reaches of creek lines. Call detection surveys in riparian zone (riparian zones in jarrah forest in the Witchcliffe–Karridale area south west of Western Australia).

### Effort

A minimum of four nights under ideal conditions.

### Area to be covered

Study site area investigated at high intensity. Local area study should include reference sites where feasible.

Species habitat references: [1]Wardell-Johnson & Roberts (1993); [2]Roberts et al. (1990).

## *Geocrinia vitellina*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Permanently moist sites; for example, seepages[1,2] | Not reported | Not reported | Depressions in clay under vegetation[3] | No aquatic larval stage. Eggs undergo direct development into metamorphs in burrows along riparian edges. |

### Timing of surveys

Under optimal weather conditions at the peak activity time.
*Seasonal:* September–early December
*Weather conditions:* After seasonal rainfall
*Time of day:* Nocturnal searches

### Methods

This species has an area of occupancy of 20 ha. Call detection surveys in riparian zone (riparian zones in jarrah forest in the Witchcliffe–Karridale area south west of Western Australia).

### Effort

A minimum of four nights under ideal conditions

### Area to be covered

Study site area only given its limited distribution. Local area study should include reference sites where feasible.

Species habitat references: [1]Tyler (1997); [2]Tyler et al. (1994); [3]Roberts et al. (1990),

## *Heleioporus australiacus*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Wide range of forest types[1] | Burrows[1,2,3] | Forest floor[1,2,3] | Males call from burrows[1,4], amplexus in ephemeral pools, slow or standing water[2,5] | Permanent pools in streams or watercouses. Feed and shelter on bottom or banks. Clear water, pH 4.3–6.5, temperature 8.5–26.5 °C 6 |

### Timing of surveys

Under optimum weather conditions; that is, wet conditions. At time of peak activity for the species; that is, rainfall in spring and autumn.

*Seasonal:* September–March
*Weather conditions:* Within one week of heavy rainfall (September–March) (heavy rainfall is >50 mm in seven days)

### Methods

Using spotlight surveys on foot and by road. Best results during and immediately after rainfall. Accompanied by habitat assessment by appropriately experienced personnel.

Larvae are distinctive and can be collected by dip netting. Multiple sweeps in pools.

### Effort

A minimum of four nights under ideal conditions.

### Area to be covered

In the study site, spotlight surveys on foot should cover several square kilometres of track in suitable habitat.

In the local area, spotlight road transects should traverse up to 30 km in suitable habitat, repeated sections after a period of about one hour is suitable.

Species habitat references: [1]Gillespie (1990); [2]Lemckert & Mahony (2008); [3]Penman et al. (2005); [4]Littlejohn & Martin (1967); [5]Watson & Martin (1973); [6]Recsei (1996).

## *Litoria aurea*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Freshwater wetlands within the coastal zone, forest and farmland near freshwater bodies (both flowing and still, but not fast flowing). Often at disturbed sites with still water[1,2,3,4] | Low vegetation, rocks, under debris[1] | May go into forests in non breeding season. May forage in grassy areas. | Males call from within the water body or very close to the edge. Water bodies with sand, rock or clay substrate. Males on emergent plants.[1] | Still, shallow water that fluctuates in depth. May swim <30 cm from surface, or near bottom of water.[1] |

### Timing of surveys

Under optimum weather conditions; that is, warm and windless, following rainfall. At time of peak activity for the species.

*Seasonal:* September–March
*Weather conditions*: Within one week of heavy rainfall (October–February)(heavy rainfall is >50 mm in seven days)

### Methods

Using a combination of call detection, call playback and spotlight surveys.

Accompanied by habitat assessment by appropriately experienced personnel.

Larvae are distinctive but tend to be cryptic in behaviour. Can be collected by dip netting or trapping. Multiple sweeps in pools.

### Effort

A minimum of four nights under ideal conditions.

### Area to be covered

Small wetlands (<50 metres at greatest length) at the study site should be covered in a period of about one hour. Search banks and emergent vegetation. Larger wetlands (>50 metres) should be searched by sampling multiple units in a systematic manner.

Local area study should include reference sites where feasible.

Species habitat references: [1]Pyke & White (1996); [2]Gillespie (1996); [3]Hamer & Mahony (2007); [4]Heard et al. (2006).

## *Litoria booroolongensis*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Streams in wet and dry forest, woodland, and cleared grazing land.[1] | Under rocks or among vegetation near the ground along stream edges.[1] | On or near cobble banks or bedrock structures within stream margins, or near slow-flowing connected or isolated pools.[1] | Males call from exposed rocks in shallow flowing mountain streams.[2] | Eggs attached to or under rocks in pools or shallow sections of flowing streams.[2]<br><br>Larvae benthic, adhere to rocks, and are strong swimmers.[2] |

### Timing of surveys

*Seasonal:* December–February
*Weather conditions:* Temperatures greater than 10 degrees C, not raining, and not within three days after substantial rain events causing raised water levels in stream habitat

### Methods

Using a combination of larvae surveys, call surveys and nocturnal searches. Diurnal searches along rocky streams may also be useful, particularly in summer. Larvae resemble those of sibling species such as Litoria lesueuri.

### Effort

Minimum of four nights under ideal conditions.

### Area to be covered

Stream transect of a minimum 200 m.

Species habitat references: [1]Anstis et al. (1998); [2]Anstis (2002).

## *Litoria castanea*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Open woodlands, grasslands, and pastoral land on tablelands. Near permanent water with emergent vegetation [1,2] | Under debris and logs, beneath leaf litter and at the base of sedges[3] | Long grass, reeds and sedges at edge of water[3] | Males call from within the water body or very close to the edge[2] | Not reported |

**Note:** Formerly distributed on northern, central and southern tablelands of NSW. This species was presumed extinct, as it had not been seen in the wild since 1972, but was recently rediscovered.

### Timing of surveys

Under optimum weather conditions; that is, warm and windless. At time of peak activity for the species.

*Seasonal:* September–March
*Weather conditions:* Within one week of heavy rainfall (October–February) (heavy rainfall is >50 mm in seven days)

### Methods

Using a combination of call detection, call playback and spotlight surveys.

Accompanied by habitat assessment by appropriately experienced personnel.

Larvae resemble those of sibling species such as Litoria aurea and raniformis. Dip netting and trapping in larger ponds on streams, agricultural ponds and at wetlands.

### Effort

A minimum of four nights under ideal conditions.

### Area to be covered

Small wetlands (<50 metres at greatest length) should be covered in a period of about one hour. Search banks and emergent vegetation. Larger wetlands (>50 metres) should be searched by sampling multiple units in a systematic manner.

Local area study should include reference sites where feasible.

Species habitat references: [1]Tyler (1992); [2]Humphries (1979); [3]Cogger (2000).

## *Litoria littlejohni*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Undisturbed forested/wooded gullies with rocky streams[1,2,3] | Along streams and in forest [3] | Vegetation near streams[1] | Males call from low vegetation or ground at ponds or pools in streams [1,2] | Still water (from dams to flooded ditches)1 or slow moving pools in creeks, slightly acidic water[2] |

### Timing of surveys

Under optimum weather conditions; that is, after heavy rainfall on windless night. At time of peak activity for the species.

*Seasonal:* Active in autumn through winter months
*Weather conditions:* Within three days of heavy rainfall. Active in summer after heavy rainfall.

### Methods

Spotlight and call detection. Accompanied by habitat assessment by appropriately experienced personnel.

Larvae are distinctive, often observed at surface, and can be collected by dip netting. Multiple sweeps in pools.

### Effort

A minimum of four nights under ideal conditions, covering a range of stream structure.

### Area to be covered

Stream transect of a minimum of 200 m. Isolated pools in headwaters of streams and occasionally on ridges. Also occurs in ponds in forested habitats.

Local area study should include reference sites where feasible.

Species habitat references: [1]www.frogs.org.au/frogs/littlejohni.html; [2]Recsei (1996); [3]Barker et al. (1995).

## *Litoria lorica*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Rocky streams in tropical rainforest[1,2] | Unknown | On boulders in splash zone near waterfalls[3] | Little known. Eggs found under rocks in fast flowing water[4] | Unknown. Probably fast flowing water[5] |

### Timing of surveys

Under optimum weather conditions; that is, forest substrate and leaf litter wet. At time of peak activity for the species

*Seasonal:* September–March.
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Using a combination of spotlight surveys, call playback and call detection. Focus on small waterfalls, rocky shelfs along first to third order streams. Accompanied by habitat assessment by appropriately experienced personnel.

### Effort

A minimum of four nights under ideal conditions, covering a range of stream structure.

### Area to be covered

Stream transect of a minimum of 200 m. Focus on small waterfalls and rocky cascades.

Local area study should include reference sites where feasible.

Species habitat references: [1]Williams & Hero (1998); [2]Williams & Hero (2001); [3]Davies & McDonald (1979); [4]Hero et al. (2003c); [5]Robinson (1994).

## *Litoria nannotis*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Rocky, fast flowing streams in tropical rainforest[1,2] | Crevices between rocks in stream or behind waterfalls[3] | Rocks in fast flowing water, near waterfalls, trees and leaf litter up to 15 m away from stream[3,4,5] | Eggs have been found attached to rocks in fast flowing water[4,5] | Unknown |

### Timing of surveys

Under optimum weather conditions; that is, forest substrate and leaf litter wet. At time of peak activity for the species.

*Seasonal:* September–March
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Using a combination of spotlight surveys, call playback and call detection. Focus on small waterfalls, rocky shelfs along first to third order streams. Accompanied by habitat assessment by appropriately experienced personnel

### Effort

A minimum of four nights under ideal conditions, covering a range of stream structures.

### Area to be covered

Stream transect of a minimum of 200 m. Focus on small waterfalls and rocky cascades.

Local area study should include reference sites where feasible.

Species habitat references: [1]Williams & Hero (1998); [2]Williams & Hero (2001); [3]Hodgkinson & Hero; [4]Liem (1974); [5]McDonald (1992); (2001); [6]Hero & Fickling (1994).

## *Litoria nyakalensis*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| White water rapids and riffles in tropical rainforest streams[1,2,3,4] | Not reported | Rocks in streams or vegetation overhanging water[3] | Eggs laid under rocks in riffles[5,6] | Fast water near riffles, torrents and waterfalls. Found clinging to rocks or in burrows in sand[3,7] |

**Note:** This species has not been seen in the wild since 1995.

### Timing of surveys

Under optimum weather conditions; that is, forest substrate and leaf litter wet. At time of peak activity for the species.

*Seasonal:* October–March
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Using a combination of spotlight surveys, call playback and call detection. Focus on small waterfalls, rocky shelves along first to third order streams. Accompanied by habitat assessment by appropriately experienced personnel.

### Effort

A minimum of four nights under ideal conditions, covering a range of stream structures.

### Area to be covered

Stream transect of a minimum of 200 m. Focus on small waterfalls and rocky cascades.

Species habitat references: [1]Williams & Hero (1998); [2]Williams & Hero (2001); [3]Liem (1974); [4]McDonald (1992); [5]Richards (1993); [6]Hero & Fickling (1996); [7]Hodgkinson & Hero (2001).

## *Litoria olongburensis*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Near fresh water in coastal lowlands and sand islands[1] | Base of sedges, grass clumps and ferns[2,3] | Emergent vegetation around creeks, swampy areas, lakes[2,3] | Emergent vegetation in or near water[4] | Low pH, tannic fresh water[2,3,4] |

### Timing of surveys

Under optimum weather conditions; that is, on windless nights at time of peak activity for the species.

*Seasonal:* October–February
*Weather conditions:* Results will be enhanced if survey is within seven days of heavy rainfall.

### Methods

Using a combination of spotlight surveys on foot and call detection. Accompanied by habitat assessment by appropriately experienced personnel

### Effort

Foot transect through habitat using spotlight. Thorough searching of emergent vegetation for a period of up to two hours.

### Area to be covered

If habitat is large (swamp) the site should be accessed from several widely spaced locations. If habitat is relatively small the whole areas should be thoroughly inspected.

Local area study should include reference sites where feasible.

Species habitat references: [1]Hines et al. (1999); [2]Liem & Ingram (1977); [3]James (1996); [4]Ehmann (1996c).

## *Litoria piperata*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | **Refuge** | **Active** | **Breeding** | |
| Near streams in forests on tablelands[1,2] | Unknown | Dense vegetation or large rocks near fast flowing streams[2] | Unknown | Unknown |

**Note:** This species has not been seen in the wild since 1972, despite extensive surveys at know locations.

### Timing of surveys

Under optimum weather conditions; that is, following rainfall on warm and windless nights. At time of peak activity for the species.

*Seasonal:* Assumed to be October–February
*Weather conditions:* Within seven days of moderate rainfall. Not during flooding of streams.

### Methods

Using spotlight surveys. Focus on streamside vegetation and on exposed rocky shelves and banks. Accompanied by habitat assessment by appropriately experienced personnel.

Larvae unknown, but likely to be in pools in streams.

### Effort

A minimum of four nights under ideal conditions, covering a range of stream structures (pools, riffles, stretches).

### Area to be covered

Stream transect of a minimum of 200 m.

Species habitat references: [1]Gillespie & Hines (1999); [2]Barker et al. (1995).

## *Litoria raniformis*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Woodland or open, disturbed habitat near permanent, still water sources[1,2,3,4] | Soil cracks, flood debris, fallen timber[2] | In wet weather may move away from water to forage on ground in surrounding vegetation[2] | Males call while floating among reeds etc[5] | Hide in vegetation in shallow edges of water body and cruise between midwater and surface[5] |

### Timing of surveys

Under optimum weather conditions; that is, warm and windless. At time of peak activity for the species.

November-December in temperate, southern regions

Within one month of flooding in semi-arid regions (generally October–February)

### Methods

Using a combination of call detection, call playback and spotlight surveys.

Accompanied by habitat assessment by appropriately experienced personnel.

Larvae are distinctive but tend to be cryptic in behaviour. Can be collected by dip netting or trapping. Multiple sweeps in pools.

### Effort

A minimum of two nights under ideal conditions, covering a range of stream structures, billabong, farm ponds and dams, swamps and irrigation channels.

### Area to be covered

Small wetlands (<50 metres at greatest length) should be covered in a period of about one hour. Search banks and emergent vegetation. Larger wetlands (>50 metres) should be searched by sampling multiple units in a systematic manner.

Local area study should include reference sites where feasible.

Species habitat references: [1]Mahony (1999); [2]Ehmann (1996c); [3]Hamer & Mahony (2007); [4]Heard et al. (2006); [5]Anstis (2002).

## *Litoria rheocola*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | **Refuge** | **Active** | **Breeding** | |
| Fast flowing rocky streams in tropical rainforest[1,2] | Probably under rocks and debris but non-breeding activity is unknown.[3] | Rocks and vegetation near slower pools in generally fast flowing streams[4] | Males call from rocks in streams or vegetation overhanging water[5] | Cling to substrates in fast flowing, highly oxygenated sections of streams[5,6] |

### Timing of surveys

Under optimum weather conditions; that is, forest substrate and leaf litter wet. At time of peak activity for the species.

*Seasonal:* November–March
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Using a combination of spotlight surveys, call playback and call detection. Focus on rocky shelfs and riffle areas in first to third order streams. Accompanied by habitat assessment by appropriately experienced personnel.

### Effort

A minimum of two nights under ideal conditions. Should be repeated on at least four separate occasions during activity period.

### Area to be covered

Stream transect of a minimum of 200 m.

Species habitat references: [1]Williams & Hero (1998); [2]Williams & Hero (2001); [3]Tyler (1992); [4]Hodgkinson & Hero (2002); [5]Liem (1974); [6]Hero & Fickling (1996).

## *Litoria spenceri*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Rocky riffle and cascade streams in a variety of vegetation types[1] | In crevices between rocks or under large boulders in boulder races near streams[2] | Exposed rock banks along streams[1] | Eggs deposited beneath large river stones in water[3] | Slow flowing stream sections, shallow stream margins[4] |

### Timing of surveys

Under optimum weather conditions; that is, forest substrate and wet leaf litter. At time of peak activity for the species.

*Seasonal:* October–March.
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Using a combination of spotlight surveys, call playback and call detection. Focus on rocky shelfs and riffle areas in first to third order streams. Accompanied by habitat assessment by appropriately experienced personnel.

Larvae are distinctive but tend to be cryptic in behaviour. Can be collected by dip netting in riffle zone.

### Effort

A minimum of two nights under ideal conditions. Should be repeated on at least four separate occasions during activity period.

### Area to be covered

Stream transect of a minimum of 200 m.

Species habitat references: [1]Gillespie & Hollis (1996); [2]Ehmann (1996c); [3]Gillespie (2001); [4]Gillespie (1997).

## *Litoria verreauxii alpina*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Variety of vegetation types in high elevation areas, associated with a variety of water sources[1] | Under logs, stones and leaf litter[1] | Possibly rocky, well vegetated areas near streams[1] | Males call from vegetation at banks of pools, or partially submerged in water[1] | Pools[1] |

### Timing of surveys

Under optimum weather conditions; that is, following summer rains. At time of peak activity for the species.

*Seasonal:* November–January
*Weather conditions:* One week after heavy rainfall.

### Methods

Using a combination of call playback, call detection and spotlight surveys. Focus on banks around larger pools on second and third order streams. Accompanied by habitat assessment by appropriately experienced personnel.

Larvae are distinctive, often observed at surface, and can be collected by dip netting. Multiple sweeps in pools.

### Effort

A minimum of two nights under ideal conditions. Should be repeated on at least four separate occasions during activity period.

### Area to be covered

If habitat is large (swamp) the site should be accessed from several widely spaced locations. If habitat is relatively small the whole areas should be thoroughly inspected.

Species habitat references: [1]Hunter et al. (1998).

## *Mixophyes balbus*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Generally undisturbed forest close to moist gullies and permanent streams or springs[1,2] | Leaf litter and dense vegetation[3] | May range widely on forest floor in moist conditions[4,5] | Males call from beside streams, often while under leaf litter or in holes or on surface[5]<br><br>Eggs laid in nests hollowed out by females in gravel base or stream debris in shallow water. | Eggs are laid on bedrock or within gravel beds in flat shallow sections of streams<br><br>Larvae are bottom dwellers in pools or slowly moving water[6] |

### Timing of surveys

Under optimum weather conditions; that is, substrate and leaf litter wet. At time of peak activity for the species.

*Seasonal:* September–March
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Call playback and spotlighting while walking transect along stream or creek. Most suitably in riparian rainforest and wet sclerophyll forest. Detection by larvae presence. Road transects are effective after heavy rain.

Larvae are distinctive and can be collected by dip netting. Multiple sweeps in pools.

### Effort

A minimum of two nights under ideal conditions. Should be repeated on at least four separate occasions in activity period.

### Area to be covered

Stream transect of a minimum of 200 m. Local area study should include reference sites where feasible.

Species habitat references: [1]Gillespie & Hines (1999); [2]Mahony et al. (1996a); [3]Daly et al. (2002); [4]Mahony (1993); [5]Lemckert & Morse (1999); [6]Daly (1998).

## *Mixophyes fleayi*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | **Refuge** | **Active** | **Breeding** | |
| Streams in montane and lowland rainforest and adjoining open forest[1] | Leaf litter and among rocks[2] | On forest floor near streams, but at times some distance from water[2] | Males call from rocks within streams, to stream banks and sometimes under leaf litter[1] | Eggs are laid on bedrock or within gravel beds in flat shallow sections of streams[1] |

### Timing of surveys

Under optimum weather conditions; that is, substrate and leaf litter wet. At time of peak activity for the species.

*Seasonal:* September–March
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Call playback and spotlighting while walking transect along stream or creek. Most suitably in riparian rainforest and wet sclerophyll forest. Detection by larvae presence.

Larvae are distinctive and can be collected by dip netting. Multiple sweeps in pools.

### Effort

A minimum of two nights under ideal conditions. Should be repeated on at least four separate occasions in activity period.

### Area to be covered

Stream transect of a minimum of 200 m. Local area study should include reference sites where feasible.

Species habitat references: [1]Corben & Ingram (1987); [2]Lemckert & Brassil (2000).

## *Mixophyes iteratus*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Near larger streams in rainforest and moist hardwood forest[1] | Under leaf litter or dense vegetation[1] | May range up to 20 m from streams on forest floor[1] | Males call from the ground near streams[2] | Eggs are deposited above water in overhangs on banks.<br><br>Larvae are bottom dwellers in still or slowly flowing pools or at the sides of streams[2] |

### Timing of surveys

Under optimum weather conditions; that is, substrate and leaf litter wet. At time of peak activity for the species.

*Seasonal:* September–March.
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Call playback and spotlighting while walking transect along stream or creek. Most suitably in riparian rainforest and wet sclerophyll forest. Road transects are not effective.

Larvae are distinctive and can be collected by dip netting. Multiple sweeps in pools.

### Effort

A minimum of two nights under ideal conditions. Should be repeated on at least four separate occasions in activity period.

### Area to be covered

Stream transect of a minimum of 200 m. Local area study to include reference sites as mandatory.

Species habitat references: [1]Lemckert & Brassil (2000); [2]Anstis (2002)

## *Nyctimystes dayi*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Streams in rainforest and rainforest margins[1] | Unknown | Usually rocks and vegetation near streams, but may be some distance from water[1] | Males call from rocks and low foliage along rapidly-flowing sections of stream[1] | Clinging or sheltering under rocks in torrents and riffles in fast flowing streams[2] |

### Timing of surveys

Under optimum weather conditions; that is, forest substrate wet and leaf litter wet. At time of peak activity for the species.

*Seasonal:* September–March
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Spotlighting, call detection and call playback, while walking transect along stream or creek. Most suitably in riparian rainforest.

### Effort

A minimum of four nights under ideal conditions, covering a range of stream structure.

### Area to be covered

Stream transect of a minimum of 200 m. Local area study should include reference sites where feasible.

Species habitat references: [1]Czechura et al. (1987); [2]Davies & Richards (1990).

## *Philoria frosti*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Found near seepage lines in or near sub alpine sphagnum wetlands, heathland and in gullies within montane vegetation communities[1] | Not reported | Vegetation adjacent to seepage lines, up to 55 m from water[2] | Natural cavities in or under vegetation, logs, peat, soil and rocks[1,2] | Usually at oviposition sites, or in nearby pools[2] |

### Timing of surveys

Under optimum weather conditions. At time of peak activity for the species in late spring and early summer period.

*Seasonal:* November–January
*Weather conditions:* Rainfall is not a necessary component as bogs and small streams are fed by snow melt from higher plateaux.

### Methods

Call detection while conducting stream transect.

Larvae in foam nest or free living usually under protective cover. May be detected by lifting cover (logs and vegetation).

### Effort

A minimum of four nights under ideal conditions. Transects along suitable drainage lines.

Known extent of occurrence and area of occupancy is limited.

### Area to be covered

Stream transect of a minimum of 200 m. Study area to involve high intensity with repeated surveys over several periods to avoid non–detection. Local area study should include reference sites where feasible.

Species habitat references: [1]Hollis (1995); [2]Hollis (1997).

## *Pseudophryne corroboree*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Forest, sub alpine woodlands and heaths[1] | Beneath leaf litter, logs, rocks and dense ground cover[1,2] | On the ground near breeding pools and bogs, or in forests and heaths[1] | Males reside in breeding burrows in vegetation such as sphagnum moss, grass or sedges next to pools[1] | Long lasting pools in bog areas. Preferred pools are generally warmer than unused pools with a greater surface area.[1] |

### Timing of surveys

Active breeding season is limited to late December, January and early February. Surveys should be conducted in the middle period of their calling cycle for best outcome. Survey outside known calling period is unproductive.

### Methods

Call surveys and call playback in bogs and riparian areas. Males are consistent in their calling habits and constant in their call response. The search should include a listening period followed by a call playback.

Habitat searches for animals sheltering under logs etc. outside of the breeding times can find animals, but are inconsistent.

Larvae are not easy to find.

### Effort

A minimum of two consecutive days.

### Area to be covered

Study area to involve high intensity with repeated surveys over several periods to avoid non detection. Local area study should include reference sites where feasible.

Species habitat references: [1]Osborne (1990); [2]Pengilley (1973).

## *Pseudophryne covacevichae*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Seepage areas and streams in eucalypt forests and grazing areas on rhyolitic bedrock[1] | May shelter in leaf litter[1] | Not reported | Males call from the base of grass tussocks in seepage areas[1] | Larvae in small pools in first order streams[1] |

### Timing of surveys

Under optimum weather conditions i.e. wet conditions. At time of peak activity for the species; that is. rainfall in Summer to Autumn period at night.

### Methods

Using a combination of call detection and habitat searches. Survey should focus on soaks and depressions at the headwaters of streams or soaks on the sides of streams. Accompanied by habitat assessment by appropriately experienced personnel.

### Effort

A minimum of four nights under ideal conditions. Transects along suitable drainage lines.

### Area to be covered

Transect of a minimum of 200 m in soaks and wet areas. Study area to involve high intensity repeated surveys over several periods to avoid non-detection. Local area study should include reference sites where feasible.

Species habitat references: [1]McDonald et al. (2000).

## *Pseudophryne pengilleyi*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Woodlands, heathland and grassland above 1000 m[1] | Under debris[1] | On the ground in woodlands, heaths and near bogs[1] | • Sphagnum bogs,<br>• wet heaths,<br>• dense herb patches,<br>• fallen tussocks near bogs and seepages[1] | Bog pools and seepages[1] |

### Timing of surveys

Active breeding season is limited to late January and February. Surveys should be conducted in the middle period of their calling cycle for best outcome. Survey outside known calling period is unproductive.

### Methods

Call surveys and call playback in bogs and riparian areas. Males are consistent in their calling habits and constant in their call response. The search should include a listening period followed by a call playback.

Habitat searches for animals sheltering under logs etc. outside of the breeding times can find animals, but are inconsistent.

Larvae are not easy to find.

### Effort

A minimum of two consecutive days.

### Area to be covered

Study area to involve high intensity with repeated surveys over several periods to avoid non-detection. Local area study should include reference sites where feasible.

Species habitat references: [1]Pengilley (1973).

## *Spicospina flammocaerulea*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Permanently moist peat based swamps[1] | Not reported | Not reported | Males call from shallow pools, water seepages and large hollows containing water, or along stream edges [1, 2] | Not reported |

### Timing of surveys

*Seasonal:* October–December
*Weather conditions:* Most active after rainfall

Time of day: Nocturnal searches.

### Methods

Call surveys should be conducted during the known calling period. Males are known to call from shallow pools, water seepages and large hollows containing water, or along stream edges.

### Effort

A minimum of four nights under ideal conditions.

### Area to be covered

Study area to involve high intensity searches with repeated surveys over several periods to avoid non detection. Local area study should include reference sites where feasible.

Species habitat references: [1]Roberts et al. (1997); [2]Wardell–Johnson et al. (1996)

## *Taudactylus eungellensis*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | **Refuge** | **Active** | **Breeding** | |
| Rocky rainforest and wet sclerophyll forest streams[1] | Under rocks or in crevices[1] | Rocky sections of stream in splash zones of waterfalls and cascades[1,2,3] | Not reported | Large and relatively still mid stream pools. Seen among rocks, litter and detritus[4] |

### Timing of surveys

Under optimum weather conditions. At time of peak activity for the species.

*Seasonal:* September–March.
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Using a combination of diurnal observations of activity, spotlight surveys and call detection. Survey should occur by day and night. Focus on exposed rocky banks along streams and around larger pools on first and second order streams.

Accompanied by habitat assessment by appropriately experienced personnel.

### Effort

A minimum of four nights under ideal conditions. Covering a range of stream structure.

### Area to be covered

Stream transect of a minimum of 200 m in montane tropical, and subtropical rainforest.

Species habitat references: [1]Liem & Hosmer (1973); [2]McNellie & Hero (1994); [3]Retallick et al. (1997); [4]Retallick & Hero (1998).

## *Taudactylus pleione*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | Refuge | Active | Breeding | |
| Drainage lines and seepages in rainforest, often moist sites with no free surface water[1] | Deep cracks in rocks and boulder piles[2] | In leaf litter or among rocks along the edges of temporary pools and soaks[2] | Under small stones, palm fronds and debris near permanent and temporary streams[2,3] | Unknown |

### Timing of surveys

Under optimum weather conditions. At time of peak activity for the species.

*Seasonal:* September–March.
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Using call detection. Survey should occur by day and night. Focus on rocky scree banks in riparian zone along first order streams in subtropical rainforest and wet sclerophyll forest. Accompanied by habitat assessment by appropriately experienced personnel.

Larvae unknown (most likely hidden in scree banks).

### Effort

A minimum of four nights under ideal conditions, covering a range of stream structure.

Known extent of occurrence and area of occupancy is limited.

### Area to be covered

Stream transect of a minimum of 200 m, in subtropical rainforest and wet sclerophyll forest. Local area study should include reference sites where feasible.

Species habitat references: [1]Clarke et al. (1999); [2]Czechura (1986a); [3]Czechura (1986b).

## *Taudactylus rheophilus*

| Macrohabitat | Microhabitats | | | Larval habitat |
|---|---|---|---|---|
| | **Refuge** | **Active** | **Breeding** | |
| Near rocky streams in upland tropical rainforests[1,2,3] | Underneath boulders[4] | Under rocks, roots and logs in seepages and trickle areas next to streams[2] | Males call from under rocks or roots, sometimes half submerged[2,5] | Not reported |

**Note:** This species has not been seen in the wild since 1995.

### Timing of surveys

Under optimum weather conditions. At time of peak activity for the species.

*Seasonal:* September–March
*Weather conditions:* Not during heavy rainfall or stream flow. One week after heavy rainfall.

### Methods

Using a combination of diurnal observations of activity, spotlight surveys and call detection. Surveys should occur by day and night. Focus on riparian zone along first and second order streams. Accompanied by habitat assessment by appropriately experienced personnel.

### Effort

A minimum of four nights under ideal conditions. Covering a range of stream structure.

### Area to be covered

Stream transect of a minimum of 200 m, in montane tropical, subtropical and warm temperate rainforest.

Species habitat references: [1]Williams & Hero (1998); [2]McDonald (1992); [3]Liem & Hosmer (1973); [4]Marshall (1998); [5]Ingram (1980).

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# APPENDIX A: RECORDINGS OF AUSTRALIAN FROG CALLS

**Australian frog calls: Subtropical east**
Produced by John N. Hutchinson.
(www.naturesound.com.au)

**Australian frog calls: Tropical north east**
Produced by David Stewart, Nature Sound.
(www.naturesound.com.au)

**Australian frog calls volume 1**
Produced by David Stewart, Nature Sound.
(www.naturesound.com.au)

**Frog calls of north–eastern New South Wales**
Produced by David Stewart, Nature Sound.
(www.naturesound.com.au)

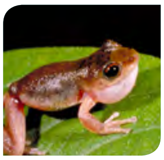
**Frog calls of the greater Sydney basin**
Produced by David Stewart, Nature Sound.
(www.naturesound.com.au)

**Frog calls of north-east Queensland (1995)**
Produced and narrated by Jean-Marc Hero.

**FRONT COVER IMAGES (left to right)**
Landscape (Geoff Heard) Growling Grass Frog (Daniel Gilmore) Southern Corroboree Frog (Steve Wilson) Lace-eyed Tree Frog (K. McDonald)

**BACK COVER IMAGES (left to right, top to bottom)**
Growling Grass Frog (Geoff Heard) Southern Corroboree Frog (Steve Wilson) Lace-eyed Tree Frog (K. McDonald) Growling Grass Frog (Sascha Healy) Landscape (Geoff Heard)





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