THE ECOLOGY AND CONSERVATION STATUS OF THE **GROWLING GRASS FROG** (*Litoria raniformis*) WITHIN THE MERRI CREEK CORRIDOR.

INTERIM REPORT: DISTRIBUTION, ABUNDANCE AND HABITAT REQUIREMENTS.

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Merri Creek, Bald Hill area, 26th February, 2002.
Quarry pond habitat of *L. raniformis*, north of Cooper Street, 11th January, 2002.

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SUMMARY

The Growling Grass Frog (*Litoria raniformis*) is a member of the 'Bell Frog' species complex, a group of large frogs found across the south-east, south-west and extreme north of Australia. *Litoria raniformis* was formerly common and widespread in the Australian Capital Territory, New South Wales, Victoria and South Australia. Populations of the species have been subject to severe reductions in abundance and distribution over much of their former range, particularly during the last 20-25 years. Subsequent to these declines, *L. raniformis* has been listed as vulnerable under the *Commonwealth Environment Protection and Biodiversity Conservation Act* 1999. It is currently listed as threatened in Victoria under the *Flora and Fauna Guarantee Act* 1988, and is recognised as vulnerable by the Victorian Department of Natural Resources and Environment.

Populations of the *L. raniformis* appear to have been once widespread in the Merri Creek Corridor (MCC). However, population declines and disappearances have been noted, as have significant regional habitat changes. Concern for the regional status of this frog has been highlighted by several recent infrastructure developments. This study was initiated during November 2001 in response to these concerns, with the objective of gathering the information required to formulate a comprehensive regional strategy for the long-term conservation of *L. raniformis* in the MCC.

This interim report details progress made during the first season of the study, a three month survey of *L. raniformis* populations within the MCC and adjacent catchments within the northern basalt plain.

Surveys for *L. raniformis* were conducted between 12th December 2001 and 15th March 2002. This involved assessment of 136 individual field sites (70 stream sites and 66 standing water bodies) within the Merri study area, incorporating sites on and near the Aitken, Curly Sedge, Darebin, Edgars, Kalkallo, Malcolm, Merlynston, Merri and Yuroke Creeks. Within this area, 47 stream transects were also spotlight surveyed, and 51 additional sites were briefly inspected. Call recognition and active searching (during both the day and night) confirmed the presence of *L. raniformis* at 41 of the 136 sites, with a total of 160 individuals recorded. One hundred and ten historical records (pre-2001) of *L. raniformis* within the Merri study area were collated.

Three main variables were identified from the statistical analyses of the habitat data as exerting a major influence upon the distribution of *L. raniformis* within the Merri Creek Catchment – they were:

- Distance from survey site to nearest waterbody occupied by *L. raniformis*;
- Proportion of the waterbody banks with emergent vegetation;
- Proportion of waterbody area with submerged vegetation.

Examination of the current distribution, as perceived in this study, reveals that there are distinct clusters of occurrences around aggregations of waterbodies, with only scattered records between these clusters. Considering the apparent distribution and the range of potential threats evident in the Merri Creek area, it appears likely that the populations of *L. raniformis* studied here may be dependent upon a relatively small number of localities in which successful reproduction occurs. As such, the overall Merri population may actually comprise a series of largely discrete sub-populations centred on each breeding locality.

Threats identified as potentially exerting a major influence on the conservation of the species in the MCC include:

- Habitat reduction and fragmentation by development and removal of various waterbodies;
- Reduction in quality of remaining habitat due to: changes in flow regimes, changes in water quality, changes in available over-wintering habitat, over-grazing in some areas, and presence of introduced fish;
- Disease (*i.e.* Chytrid fungus), with unknown implications for population maintenance.

Interim guidelines advanced for the conservation of *L. raniformis* in the MCC include:

- Further research to identify those waterbodies crucial for recruitment and population maintenance;
- Provision of enhanced habitat and perhaps additional habitat in important locations within clusters, and as potential 'stepping-stones' between clusters, with the identification of optimal areas for these activities to be derived from the targeted work of the second year of the study and detailed meta-population modelling;
- Protection of off-stream habitat currently present in former quarry holes, as these represent the most likely foci for reproduction in local clusters;
- Further investigation of key habitat parameters, such as water quality, water regimes, and presence of introduced fish.

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1.1.1. The Growling Grass Frog (*Litoria raniformis*)

(i) Ecology

The Growling Grass Frog (*Litoria raniformis*)[1] is a member of the 'Bell Frog' species complex (Anura: Hylidae), a group of large, attractive frogs found across the south-east, south-west and extreme north of Australia (Barker *et al.* 1995). *Litoria raniformis* inhabits inland regions of the Australian Capital Territory, New South Wales, Victoria and South Australia (Barker *et al.* 1995, Thomson *et al.* 1996, Osborne *et al.* 1996). Until recently, the species was thought to be widespread and common over much of Victoria, with the exception of the alpine areas of the north-east and the dry interior of the north-west (it does occur on the floodplain of the Murray River) (Brook 1982).

A detailed review of the current knowledge of the ecology of *L. raniformis* is presented by Pyke (2002). Current descriptions of the species' ecology are poor; however, brief accounts of habitat use, movement patterns, seasonal activity, reproduction and diet are provided by several authors and are summarised below. Fundamental patterns in each of these characteristics are similar to those of the closely-related Green and Golden Bell Frog (*Litoria aurea*) (Pyke 2002), and therefore data collected from this species are also included in the following discussion.

Available information on the habitat and ecological requirements of *L. raniformis* suggest that the species requires permanent or largely-permanent still water bodies for reproduction (Hero *et al.* 1991, Barker *et al.* 1995, Ashworth 1998, Landy 1999, Williams 2001, 2002). Recent studies on *L. aurea* have shown a similar pattern (Goldingay and Lewis 1999, Hamer *et al.* 2002), although, Pyke and White (1996) concluded that *L. aurea* prefers ephemeral water bodies in which to breed. Gillespie (1996) records breeding activity by Victorian specimens of *L. aurea* within permanent and ephemeral water bodies. Both *L. raniformis* and *L. aurea* inhabit streams of varying size, but usually only within slow-flowing sections with dense in-stream vegetation (Gillespie 1996, Williams 2001, Robertson and Heard 2002).

The assemblage of aquatic vegetation present at sites inhabited by *L. raniformis* and *L. aurea* is typically diverse, particularly in emergent species such as sedges (*Gahnia* spp.), rushes (*Bolboschoenus* spp., *Eleocharis* spp., *Juncus* spp., *Typha* spp., *Schoenoplectus* spp.) and water ribbons (*Triglochin* spp.) (Gillespie 1996, Pyke and White 1996, Ashworth 1998, Pyke and White 2001, Williams 2001, Robertson 2000, Hamer *et al.* 2002, Robertson and Heard 2002). Other terrestrial habitat attributes appear important for *L. raniformis,* which has been recorded utilising thick vegetation cover at ground level, rocks or other solid ground cover for shelter and over-wintering refugia (Gillespie and Clemann 1999).

[1] The common name presently adopted by NRE for *Litoria raniformis* is 'Growling Grass Frog'. The species is listed as 'Southern Bell Frog' in Commonwealth legislation (*EPBC Act 1999*). It has also been called 'Warty Bell Frog' or 'Warty Swamp Frog' in some popular literature.

Meta-population dynamics may significantly influence the long-term viability of *L. raniformis* populations. The species is known to move large distance between breeding and foraging areas throughout the active season, usually at night when rain is falling (Barker *et al.* 1995). Indeed, specimens have been recorded travelling up to one kilometre in a night (K. Jarvis pers. com.). Recent studies on *L. aurea* suggest that these frogs move over similar distances to *L. raniformis,* and require a network of water bodies in which to forage, breed and shelter (Goldingay and Lewis 1999, Patmore 2001, Pyke and White 2001, Hamer *et al.* 2002). However, the importance of landscape variables, such as habitat connectivity and the spatial distribution of water-bodies, remains poorly understood for both species.

Specimens of *L. raniformis* are active throughout the warmer months of the year, generally September to March (Barker *et al.* 1995, Anstis 2002). As with most frogs, daily activity peaks after dark when calling, foraging and dispersing behaviours occur. However, all members of the Bell Frog complex are well known for their diurnal habits, spending long periods basking in direct or filtered sunlight (Barker *et al.* 1995, Pyke and White 2001). Breeding may occur primarily in spring, and is probably stimulated by the combination of warm weather and rain events (see Landy 1999). Males call throughout the active season, mainly at night but occasionally during the day (Williams 2001, Anstis 2002). Females produce large clutches of eggs (>3000), and the larvae (tadpoles) may persist in the wetlands for many months, growing to between 85-110mm total length (Anstis 2002). The species is generally inactive during the winter months. It may occupy communal shelter (Copland 1963) and over-wintering sites (P. Robertson pers. obs.). Seasonal and daily activity periods appear similar to those reported for *L. aurea* (Pyke and White 2001 and references therein).

No dietary studies have been published for *L. raniformis*; however, frogs of this species appear to take a wide range of invertebrate prey, supplemented by small vertebrates including other frogs (Pyke 2002). *Litoria aurea* has been recorded feeding on a wide range of terrestrial and aquatic invertebrates, primarily at night (Pyke and White 2001). However, specimens have been observed feeding on tadpoles of their own kind and those of the Striped Marsh Frog (*Limnodynastes peronii*) during daylight hours (Miehs and Pyke 2001). Captive specimens of *L. raniformis* readily devour their own tadpoles (R. Trayer, Melbourne Zoo, pers. com.).

(ii) Conservation status

Populations of *L. raniformis* have been subject to reductions in abundance and distribution over much of their former range, particularly during the last 20-25 years. Perhaps most striking of these retractions are those observed within the Southern Tablelands of NSW and the ACT. In this region, *L. raniformis* was formerly common and sympatric with its sister species, *L. aurea* and the Yellow Spotted Bell Frog (*Litoria castanea*) (Thomson *et al.* 1996, Osborne *et al.*1996). Only *L. aurea* has been recorded from the Southern Tablelands since 1980, at only one site (Osborne *et al.* 1996, Patmore 2001). Within Victoria, similar population reductions were recorded for *L. raniformis* during the drought periods of the early 1980’s (P. Robertson pers. obs.). Although no systematic review has been conducted, this frog appears to have disappeared from parts of its former range across the state. Subsequent to these declines, *L. raniformis* has been listed as vulnerable under the *Commonwealth Environment Protection and Biodiversity Conservation Act* 1999 (EPBC). The species is currently listed as threatened in Victoria under the *Flora and*

Fauna Guarantee Act 1988 (FFG), and is recognised as vulnerable by the Victorian Department of Natural Resources and Environment (NRE 2000).

Several causes for the declines observed in *L. raniformis* and other members of the Bell Frog complex have been proposed. Habitat alteration, drought, disease, introduction of exotic fish, increasing soil salinity, pollution from industrial or agricultural runoff and global climate change (including increased ultraviolet radiation) may all be implicated (Osborne *et al.*1996). It is unknown if one over-riding factor is common to all populations or if separate factors are effecting individual populations simultaneously. It is probable that a complex interaction between many or all of these factors is involved. Therefore, it is imperative that the conservation status and threats to remaining populations of *L. raniformis* within Victoria be investigated over a range of landscapes. It is envisaged that the FFG action statement currently under preparation for *L. raniformis* will give broad guidelines for these activities; however, there is an urgent need to implement conservation measures in the vicinity of major urban centers, where development and habitat alteration threaten the immediate survival of extant populations. This is particularly the case within northern fringe of Melbourne.

1.1.2. The Merri Creek Corridor

(i) Physiography

The Merri Creek Corridor (MCC) lies within Melbourne's northern basalt plain; a gently undulating, volcanic landscape that stretches north from the suburb of Northcote to the Great Dividing Range, between the Plenty River in the east and the Moonee Ponds Creek in the west (McLellan 1994, Anon. 2001, Savio 2001). According to Beardsell (1997), the corridor may be divided into two broad biophysical zones based upon elevation.

The Merri Lowland Volcanic Plain encompasses the flat terrain of the lower and middle sections of the Merri Creek (Beardsell 1997). Extensive tracts of native grassland once occurred on the rich basaltic soils of this area, interspersed with shrub and scrub communities along watercourses and atop stony knolls (Frood 1992, Faithfull 1994, Beardsell 1997). Box woodlands previously occurred on several mudstone outcrops that occur in the region (e.g. Summerhill, Craigieburn - Schulz and Webster 1991).

The Merri Upland Volcanic Plain consists of the northern reaches of the Merri Creek, from Donnybrook north to the Great Dividing Range (Beardsell 1997). Characteristics of the landscape, soil and vegetation are similar to those described above; however, several prominent volcanic cones (Bald Hill, Mt Fraser) occur in the center of this area (see McLellan 1994).

(ii) Hydrology

The catchment of the Merri Creek consists of a series of predominantly ephemeral streams. From north to south, tributaries of the Merri are the Bald Hill, Kalkallo, Malcolm, Aitken, Curly Sedge, Edgars and Central Creeks. Most of these streams are less than five kilometres in length, have shallow banks and are composed of a series of narrow pools.

The Merri Creek itself was previously an intermittent stream over much of its length (Beardsell 1997). The Merri rises in the foothills of the Great Dividing Range north-east of Wallan and is mostly a shallow, meandering stream from this point through to the present location of Summerhill Rd. At many points south of this location, the creek runs through deep gorges where past water-flow has cut through the overlying basalt to the sedimentary soils below (McLellan 1994, Beardsell 1997).

Two additional streams lie within the northern basalt plains just outside of the catchment of the Merri Creek. To the east, the Darebin Creek rises in the low hills around Upper Plenty and flows through the volcanic plains of Epping and Bundoora, before reaching the Yarra River. To the west, the Yuroke Creek begins in the catchment of Greenvale Reservoir and flows south some eight kilometres to its junction with the Moonee Ponds Creek. Both streams were largely ephemeral, having low-rainfall catchments (see Beardsell 1997).

In addition to these watercourses, an array of standing water bodies was once present within the MCC (Beardsell 1997). Freshwater meadows, shallow freshwater marshes and deep freshwater marshes were probably present in a number of localities, particularly on the floodplain of the larger streams. Freshwater meadows often formed in depressions around stony knolls, either by the collection of rainwater runoff or an uprising of natural spring water (Beardsell 1997).

(iii) Current landscape

Large sections of the MCC have been severely altered since European settlement. Agricultural practices, urban and industrial development and resource extraction (basalt, sedimentary clays) have variously destroyed, degraded and fragmented the ecosystems present (Beardsell 1997). Most terrestrial plant communities have been seriously depleted, particularly grasslands and grassy woodlands (Faithfull 1994). Nonetheless, areas of national (2), state (6) and regional (11) conservation significance remain in the area (Beardsell 1997).

Hydrology of the landscape has been altered to meet the needs of agriculture. Freshwater meadows and marshes have been widely drained and converted to pasture, while most of the ephemeral creeks have been damned at many points along there length. Vegetation communities associated with these water bodies, such as grassy wetlands and aquatic herbfields, are now rare on the basalt plains (Faithfull 1994). Today, standing water bodies consist mainly of farm dams, quarry holes or other artificial structures (Beardsell 1997). The lower sections of most streams are used to carry storm water run-off and thus display a year round, but erratic flow regime. Their waters are often heavily polluted (Anon. 2002).

1.2. Study objectives

Populations of the Growling Grass Frog (*L. raniformis*) appear to have been once widespread in the MCC (Schulz and Webster 1991, Beardsell 1997). However, population declines and disappearances have been noted in line with the regional habitat changes described above (Beardsell 1997, B. Casey, G. Turner, R. Valentic pers. com.). Concern for the regional status of this frog has been highlighted by several recent infrastructure developments, particularly the proposed Craigieburn Bypass of the Hume Highway (Williams 2001, 2002, Robertson 2002).

This study was initiated during November 2001 in response to these concerns, with the objective of gathering the information required to formulate a comprehensive regional strategy for the long-term conservation of *L. raniformis* in the MCC (Robertson and

Scroggie 2001). The research is a collaborative effort of the Friends of Merri Creek (FOMC), the Merri Creek Management Committee (MCMC) and the Victorian Department of Natural Resources and Environment (DNRE).

We divided the key ecological information required to meet this objective into four main groups, all of which are to be addressed by a field study that spans at least two breeding seasons. These components are:

- The distribution and status of *L. raniformis* populations within the region, including the recognition of any areas of habitat considered critical for long-term population viability;
- Habitat use and requirements, including temporal patterns of habitat use on a local and regional scale;
- Movements patterns of the frog on a local and regional scale;
- Other conservation requirements, such as knowledge of the frogs demography, reproductive biology and meta-population dynamics.

This interim report details progress made during the first season of the study, a three month survey of *L. raniformis* populations within the MCC and adjacent catchments within the northern basalt plain. This work addresses the first two requirements listed above and operated with five specific aims:

- Undertake a comprehensive survey of all water bodies in the Merri Creek Corridor and adjacent catchments of the Darebin and Yuroke Creeks, to determine their use by *L. raniformis*.
- Examine relevant habitat attributes at all sites surveyed, to determine factors influencing the distribution of the species (including potential threats at these sites).
- Investigate the spatial distribution of water bodies utilised by the species.
- Repeatedly survey a selected subset of water bodies, to investigate temporal changes in the use of those water bodies.
- Determine the historical distribution of the *L. raniformis* within the study area.

2. METHODOLOGY

2.1. Study area

All components of this study were conducted within an area encompassing the Merri Creek Corridor and adjacent catchments of Yuroke and Darebin Creeks; an area of some 350 square kilometres (Figure 1). Surveys for *L. raniformis* were undertaken along all streams in this area that contained either flowing or still water, including the Aitken, Central, Curly Sedge, Darebin, Edgars, Kalkallo, Malcolm, Merlynston, Merri and Yuroke Creeks. Standing water bodies were also surveyed throughout this broader area, with preference being given to those close to a permanent water-course.

2.2. Field survey

Surveys for populations of *L. raniformis* across the Merri study area were conducted between 12th December 2001 and 15th March 2002, during the known active season of this species (Barker *et al.*1995). Fieldwork focussed on assessing the habitat attributes and frog utilisation of as many discrete survey sites as possible, in order to quantify the frogs response to regional habitat variability. Discrete survey sites were divided between individual standing water bodies and specific sites along each of the streams visited. Definitions for both site classes are as follows:

- ***Standing water body*** - any body of still water that does not usually exhibit a flow of water contiguous with another water-body. This incorporates sites of varying permanency, but this year was confined to those that held some standing water at the time of survey.

- ***Stream survey site*** - a segment of streambed 50 m in length, that did not overlap with any other section surveyed in this manner. This site length was considered appropriate after an initial field appraisal revealed that specimens of *L. raniformis* and its habitat are often clumped in stream sections of this size along the Merri Creek (see also Williams 2001). For the purposes of this study, artificial conduits of water such as earthen drains and ditches were classed as stream sites, as their structural characteristics were essentially the same as the smaller streams surveyed. Stream sites were only surveyed if they contained at least a partial cover of standing or flowing water at the time of this study.

Searches for *L. raniformis* were also conducted along extended sections of each stream within the study area to provide a greater understanding of the frogs distribution along these watercourses. These searches were often carried out over 500 m or more of stream bank, and will be herein referred to as ‘transect surveys’. A number of water bodies that were unsuitable as discrete survey sites (due to constraints of time or accessibility) were also searched briefly for the frog and its habitat. These sites will be herein referred to as ‘additional sites’. In all cases, attempts were made to examine each locality from which previous records of *L. raniformis* were available in this study area (see below).

2.2.1. Site selection

(i) Stream survey sites

A total of 70 individual sampling points were used to examine the in-stream habitat requirements of *L. raniformis* across this study area. Stream sites were located along the majority of water-courses present (Table 1, Appendix 1), and placed evenly along the Merri Creek itself between Moomba Park Reserve in Fawkner, to just north of Ford St, Wallan (Figure 1). Site selection followed a semi-random design.

Stream survey sites were placed to coincide with the transect surveys. In both cases, stream coverage followed a 'kilometre on, kilometre off' pattern to provide an even spread of survey effort. One square kilometre grid cells of the Australian Map Grid (Map Datum AGD '66) were used to delineate kilometre long segments of each survey stream, and those cells to be examined were selected using either a current edition 'Melways' or a series of 1:25,000 topographic maps. One stream survey site was randomly located within each of these grid cells, along the 500 metres of stream bank with the best road access.

AMG coordinates for the downstream limit of each pre-selected 500 m stream segment were calculated using the maps described above. In the field, a hand held Global Positioning System ('Garmin 12XL' 12 channel GPS) was used to locate these points by walking along each stream to the appropriate easting or northing, depending upon stream orientation. Once located, the position of each survey site was determined by pacing a random number of steps (between 0-500) upstream of these starting points. All numbers were taken from a random number table generated in Microsoft Excel. Once completed, a further 50 steps were paced upstream to identify the upstream limit of each survey site. Both upstream and downstream boundaries of each survey site were marked with flagging tape for later relocation.

To increase sample sizes, we treated each stream locality in which groups of *L. raniformis* were recorded during the transect surveys, as additional stream survey sites. Sites were erected such that the position of these frogs along the stream became the center of a survey site. Site boundaries were subsequently marked by pacing 25 steps up and downstream of the frog locality. The procedures used to measure the abundance of frogs and attributes of the habitat present at these sites did not differ from those undertaken within randomly located sites (see below).

(ii) Standing water bodies

Standing water bodies surveyed for *L. raniformis* were distributed widely within the study area, but were usually associated with each of the watercourses listed above. Standing water bodies examined during the survey period included ponds, dams, swamps and quarry holes (Table 1, Appendix 1). Constraints of time and accessibility did not allow all standing water bodies to be surveyed during the study period; however, those examined represented the range of off-stream habitats available to *L. raniformis* within the northern basalt plain.

Table 1. **Field sites surveyed for *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments. Standing water bodies are grouped by sub-catchment according to their location.**

Waterway	*Stream Sites*	*Standing Water Bodies*
Aitken Creek	3	4
Central Creek	1	0
Curly Sedge Creek	2	13
Darebin Creek	12	15
Edgars Creek	4	3
Kalkallo Creek	0	1
Malcolm Creek	2	4
Merlynston Creek	0	3
Yuroke Creek	4	7
Merri Creek		
Fawkner	2	0
Campbellfield	3	5
Craigieburn	6	0
Donnybrook	11	6
Merriang	7	0
Somerton	11	0
Wallan	2	4
Total	***70***	***66***

Figure 1. **The distribution of sites surveyed for *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments.**

(see over for fold-out A3 sheet)

2.2.2. Habitat assessment

The habitat present at each survey site was assessed using a series of standardised techniques. Assessments at each random stream site and standing water body were undertaken upon their location, while stream sites erected around frog localities were generally assessed the following day. To eliminate observer bias, habitat variables were measured by the same observer throughout (GH). Some variables were restricted to either standing water bodies or stream survey sites, and several measurements differed between the two types of survey site. These variations will be described where appropriate below.

The selection of variables sampled during this study was based upon two factors; their usefulness in describing the biophysical attributes of each survey site, and their similarity to those used within comparable studies on *L. aurea* (Pyke and White 1996, Hamer *et al.* 2002). Variables chosen can be assigned to six broad categories.

(i) Physiognomy

Each survey site was classified into one of seven physiographic categories. Sites were defined as either a standing water body or stream site and subsequently classified as a pond, dam, swamp, creek, drain, ditch or quarry according to definitions provided in Table 2.

Measurements of site dimensions and water depth varied slightly between the two classes of survey site. For standing water bodies, length and width measurements were recorded by pacing the maximum distance of each axis. These paces were latter calibrated against a known distance and measurements transformed to the metric system. The dimensions of several large water-bodies that were unable to be pace-measured, were recorded in metres using digital maps of the study area. Mean water depth was calculated from five measurements distributed evenly over the water surface. Measurements were made using a pre-marked dowel measuring stick in each case; however, if water depth exceeded one metre, depth was visually estimated in 50 cm increments. Within stream sites, stream width (width of the water's surface) was visually estimated in 50 cm increments at five points along the bank, ten metres apart. Water depth was also measured at each of these points, always at midstream following the procedures described above. Mean and maximum measurements for stream width and water depth were recorded throughout.

Several compositional characteristics were noted at each site. Definitions of the variables used in these descriptions are provided in Table 2. The substrate of each water-body was classified as either bare-rock, rock-rubble, gravel, sand or mud. Composition of the perimeter ground layer, defined as the two metre wide strip of ground surrounding each water body at a distance of one metre from the water's edge, was assessed visually. The mean cover of bare-rock, bare-soil, mown exotic grasses, sparse exotic grasses, dense exotic grasses and native grasses was estimated over this entire area. The predominant aquatic and terrestrial shelter types available at each site were classified as artificial debris, vegetation, rock or timber following procedures described by Pyke and White (1996). Lastly, the structure of each stream site was described by visually estimating the percentage of the stream length that was a pool, run, riffle or vegetation choke.

Table 2. Definitions of each variable category used to describe the physiognomy of all sites surveyed for *Litoria raniformis* within the Merri Creek corridor and adjacent catchments.

Variable	*Definition*
Type of water body	
Pond	Small, artificial body of stagnant water created by minor excavations
Dam	Body of still water of varying size, excavated within farm land in a low lying or natural gully area, traps surface water
Swamp	Body of shallow, fluctuating, still or near still water located in a flat, low lying area
Creek	Tributary of a river with flowing water of varying speed, generally narrow and shallow, but interspersed with pools of slower, deeper water
Drain	Artificial conduit of water generally found around structures such as roads and fence lines
Ditch	Long, narrow excavation of varying depth which holds or conducts water sporadically
Quarry	Excavation made for taking stone from bedrock, generally with sheer rock walls, traps surface and spring water
Stream composition	
Pool	Wide, deep sections of the stream with slower flow
Run	Narrow, swift flowing stream section
Riffle	Wide, shallow and swift flowing stream section
Vegetation choke	Shallow section of the stream with a dense cover of vegetation across the waters surface
Substrate	
Bare-rock (BR)	Continuous beds of exposed rock
Rock-rubble (RR)	Fractured bed of exposed rock
Gravel (GR)	Pebbles bigger than $1mm^3$
Sand (S)	Mean grain size $1mm^3$ or less
Mud (M)	Fine silt
Shelter sites	
Artificial	Artificial structures such as building debris and garbage
Vegetation	Vegetation cover, including aquatic and terrestrial forms
Rock	Natural or artificial outcroppings of rock that provides rock crevices or hollows beneath surface rock
Timber	Fallen timber, branches and foliage
Perimeter ground layer	
Bare-rock (BR)	Any rock substrate in the form of solid rock beds, fractured rock beds or isolated boulders
Bare-soil (BS)	Soil with no vegetation cover
Mown exotic grasses (MEG)	Exotic grasses that are trimmed by a mower on a regular basis
Sparse exotic grasses (SEG)	Short, open exotic grasses
Dense exotic grasses (DEG)	Tall, dense exotic grasses
Native grasses (NG)	Native perennial grasses

(ii) Hydrology

The hydrology of each survey site was described using two measures adapted from Pyke and White (1996). Water flow was classified as still, slow or rapid according to the definitions provided in Table 3. The nature of the water present at each site was quantified by classifying it into one of four categories: 0 (sporadic), 1 (ephemeral), 2 (semi-permanent) or 3 (permanent) (Table 3). In the absence of any historical data, the hydrological dynamics of each site were estimated using a combination of site characteristics such as water depth, water source, plant species present and vegetation structure.

Table 3. Definitions for each variable category used to describe the hydrology of all sites surveyed for *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments.

Variable	*Definition*
Water flow	
Still	No flow
Slow	Regular flow at less than one metre per minute
Rapid	Regular flow at greater than one per minute
Water Permanency	
0	Water bodies that fill sporadically (at least once every five years) with fluctuations in annual rainfall. The presence of water in these sites may be short lived after a filling event
1	Ephemeral or seasonal water bodies. Water bodies that fill yearly with average rainfall and contain water for months at a time
2	Permanent water bodies that display high seasonal fluctuations in water level. These water bodies may be susceptible to completely drying out during drought years
3	Permanent water bodies that display a relatively stable year round water level. These water bodies are not susceptible to drying out in drought years, although water-level may be reduced.

(iii) Vegetation

Foliage cover estimates were used to quantify the vegetation structure at each survey site. Foliage cover is herein defined as the percent of the ground surface that would be obscured by vegetation if a given area was viewed from directly above. Site vegetation was divided between emergent, submergent, floating and fringing vegetation (see Table 4) and visual assessment used to estimate the mean, maximum and minimum percent foliage cover of these vegetation groups at each site. Emergent vegetation growing along the bank (perimeter of the water body, including the first two metres of the water surface and one metre of bank above the water line) was assessed separately from that growing throughout the water body proper (all areas covered by standing or flowing water). Foliage cover estimates for submergent and floating vegetation were made over the entire water surface, while fringing vegetation was assessed within the first five metres of bank leading up from the waterline. In all cases, site-wide cover estimates were based upon a sample of measurements taken at five evenly distributed sampling points.

Due to the often patchy distribution of vegetation within these sites, a visual estimate of the extent of vegetation cover at each site was added to the above procedure. The extent of vegetation cover was recorded as the percent of the site area (or specifically, the area of the appropriate zone) over which each vegetation form occurred.

Species lists for each vegetation category were compiled at each survey site. Species lists were restricted to the dominant vascular plant species; however, the presence of two forms of algae was recorded throughout due to their potential importance as calling stages for adult male frogs, oviposition sites and food resources for tadpoles. Plants were identified with the aid of the 'Flora of Melbourne' (SGAP 2001).

Site photographs were also used to record vegetation structure and composition. All photographs were taken using a Minolta X-300 35 mm SLR camera equipped with a 28 mm wide-angle lens. Depending on site characteristics, the position from which each photograph was taken varied to maximise the descriptive ability of each shot. However, all photographs were orientated horizontally in an effort to capture both banks of the water body and the entire water surface.

Table 4. Definitions for each vegetation category sampled at all sites surveyed for *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments.

Vegetation category	*Definition*
Emergent vegetation	Any semi-aquatic plant species in which the foliage grows primarily above the water surface
Submergent vegetation	Any aquatic plant species in which the foliage grows primarily below the water surface
Floating vegetation	Any aquatic plant species in which the foliage floats upon the water surface, including Water Ribbon (*Triglochin procera*) and the upper foliage layer of submergent species
Fringing vegetation	Any terrestrial tree or shrub species growing within five metres of the waters edge

(iv) Presence of predatory fish

Exotic fish have been implicated in the decline of several Australian frog species, including the Green and Golden Bell Frog (*L. aurea*) (Morgan and Buttemer 1996, Pyke and White 2001). We recorded the presence of both exotic and native fish species at each site surveyed for *L. raniformis* to assess their influence on frog distribution. Any fish seen during the habitat assessment or subsequent spotlight survey (see below) was identified to species level and a rough estimate of abundance recorded. If particular species were not recorded within a stream site but were known from within one kilometre of that site (up or downstream with no impassable barriers), we classed that species as a probable inhabitant of the site. No systematic sampling of fish species was undertaken due to time constraints, restricting our data set to presence records. Fish species were identified using McDowall (1996).

(v) Spatial distribution

For each surveyed site, we calculated the distance to the nearest site known to be occupied using a custom computer program, written in the *R* statistical programming language (Ihaka & Gentleman, 1996).

(vi) Disturbance

Livestock trampling of bank-side and in-stream vegetation occurs at many of the sites surveyed during this study. We categorised the level of damage caused by livestock trampling at each site as high (significant trampling such that the bank is de-vegetated), moderate (trampling frequent but bank-side vegetation remains in place), low (trampling evident but it does not disturb the bank-side vegetation) or none (no trampling evident). Other factors disturbing frog habitat were noted, including recreational disturbance, artificially high water-bird populations (a common feature of many man-made water-bodies) and proximity to storm water drains.

2.2.3. Survey methods

Surveys for *L. raniformis* were conducted primarily at night using hand-held spotlights (‘Wattco.’ 55 W halogen lights), a commonly used and effective technique for detecting Bell Frogs (Ashworth 1998, Williams 2001, Hamer *et al.* 2002, Robertson and Heard 2002). Surveys were carried out by teams of two people between the hours of 20:30 – 02:00 on nights with mild temperatures and moderate to low wind. Nocturnal activity by *L. raniformis* is enhanced by these weather conditions, particularly if light rain is falling (Williams 2001).

Visual inspection, call recognition and limited active searching (turning surface debris) were employed in all cases. At the beginning of each survey, a standard period of ten minutes was spent listening for frog calls from the water’s edge. Call imitation was conducted during the last five minutes of this period, in an attempt to stimulate a response from any male *L. raniformis* that was present but not calling. The abundance of calling males from all frog species present was recorded during this period. Following this, each site was systematically searched for active frogs following general procedures outlined by Crump and Scott (1994). Spotlights were used to scan all surfaces of the water body whilst traversing its length, focussing on inspecting aquatic vegetation. Individual *L. raniformis* were detected either by direct encounter or the identification of this species’ distinctive eye-shine (see Williams 2001). Upon location, the time of discovery, AMG co-ordinates, behaviour and microhabitat of each frog were recorded. All frogs were also assigned to one of three size classes: metamorphling (specimens 30 mm or less in total length), sub-adult (specimens between 30-50 mm total length) or adult (specimens above 50 mm in total length). Frogs that could be easily captured by hand or net were measured (snout to groin length to the nearest millimetre) using a small tape measure and weighed (to the nearest 0.1 gram) using a Pesola spring balance. Sexually active males were identified by the presence of swollen nuptial pads and brown throat color. The abdomen of each female frog was inspected for the presence of mature oocytes (eggs), visible through the translucent body-wall.

Survey periods varied with water body size and habitat complexity, but generally lasted for around 30 minutes. At the completion of each survey, the total abundance of each size class of *L. raniformis* was tallied, as was the abundance of all other frog species observed (including tadpoles).

Weather conditions were recorded at the beginning of each survey period. Air temperature (to the nearest degree) and relative humidity (to the nearest five percentage points) were determined using a whirling psychrometer. Water temperature was measured to the nearest 0.1^{o}C, one metre from the shoreline, using an ISM digital pocket thermometer. Cloud cover, rain, moonlight, wind velocity and wind direction were recorded in combination with a brief description of general weather patterns experienced prior to, and during, the survey period. All weather variables were re-recorded at the end of the survey period if it extended beyond 60 minutes. Where possible, we referenced nightly frog activity at each survey site against that observed at localities in which the frog was known to occur. The suitability of weather conditions during each survey could be assessed from these comparisons.

In addition, a total of 47 transect surveys was carried out at night using the techniques of detection described above. Call imitation was often used to locate calling male frogs by stimulating a response during breaks in their chorus. The data collected during each of these searches matches that described above; however, the AMG co-ordinates of each start and end point were recorded throughout.

Due to the diurnal habits of *L. raniformis*, surveys analogous to those described above were also conducted during daylight hours at most sites. Diurnal surveys coincided with habitat assessments. They focussed on searching the entire site for specimens basking in direct or filtered sunlight. Sites, dates and overall sampling effort are summarised in Appendix 1. A further fifty-one additional sites were visited during daylight hours throughout the survey. The location of each site (including AMG co-ordinates) was recorded and notes kept on their general characteristics, particularly habitat attributes. Each site was briefly inspected for basking, calling or sheltering *L. raniformis*. Details including date, time and search effort were recorded along with the abundance of any frog species observed.

Measures to reduce the possible spread of infectious pathogens (such as ‘chytrid’ fungus) between the survey sites were implemented in accordance with standards described by the New South Wales National Parks and Wildlife Service (NPWS 2001). For the purposes of hygiene management, water-bodies with no probable interchange of specimens were considered separate sites (NPWS 2001) and the following measures were used to mitigate the spread of disease between them:

- Footwear was thoroughly disinfected (saturated with ‘Toilet Duck’) at the commencement of fieldwork and between each survey site;
- Equipment used in the field was cleaned as above between each survey site. Disposable equipment (such as any plastic bag used to temporarily house individual frogs) was securely housed within an air-tight container and disposed of after use at each site;
- Wetlands were only approached on foot to eliminate car tyres as a source of transmission.

Within sites, a ‘one bag - one frog’ policy was maintained throughout, with only plastic bags being used to hold frogs. All used bags were placed in a ‘clip lock freezer bag’ and disposed of after use.

2.3. Historical records

Data on the historical distribution of *L. raniformis* within the study area were gathered from a number of sources. All records recorded within the Atlas of Victorian Wildlife were obtained from the Arthur Rylah Institute for Environmental Research. Data were also extracted from several unpublished fauna survey reports pertaining to this study area, particularly Beardsell (1997) and Williams (2001). The final approach involved interviewing several private herpetologists and field naturalists who have experience with populations of *L. raniformis* within the MCC. In all cases, the following data were recorded (if known):

- Date, time and location including AMG co-ordinates;
- A description of weather conditions experienced at the time of the observations, including air temperatures;
- The abundance, behaviour and microhabitat of *L. raniformis* observed and;
- Relevant comments, including the fate of each known population and reasons for their decline (if appropriate).

2.4. Data analysis

Analysis of the field data concerning the distribution of *L. raniformis* in the study area was carried out with the intention of developing a statistical model to explain the observed pattern of presence/absence, and to allow prediction of the likely patterns of distribution of the frog within unsurveyed portions of the study area, and more generally within other parts of the species geographic range. The primary purpose of the modelling procedure was to provide a formal framework for considering the processes which determine the distribution of *L. raniformis*, and to use this model to gain insight into the conservation requirements (particularly habitat requirements) of the species and the likely responses of the species to processes which modify components of its habitat.

The available data collected consisted of an assessment of the presence or absence of *L. raniformis* at each of the study sites, together with a large set of measured habitat variables at each of the sites. Statistical modelling proceeded with the aim of discovering patterns of association between habitat variables and the presence of the species; hence the statistical methodology is purely correlative, and needs to be interpreted with some caution.

A variety of suitable statistical techniques exist for the analysis of the relationship between patterns of presence/absence and measured habitat variables in ecology. Recent reviews of the literature concerning these methodologies (Guisan and Zimmerman 2001; Guisan *et al.* in press) suggest that a variety of techniques have proven to be useful and reliable in this context. In this study, we considered three varieties of statistical model which have proven to be useful and reliable for analysing these kinds of data. These statistical models are:

1. Generalized linear models (GLM: McCullagh and Nelder 1989).
2. Generalized additive models (GAM: Hastie and Tibshirani 1990).
3. Regression tree analysis (RTA: Brieman *et al.* 1984).

All three of these modelling strategies were explored during initial analyses of the data-set; however, these analyses revealed that the predictions and goodness-of-fit of the three strategies were essentially concordant.

It was considered that in general, and in this instance, Regression Trees had several advantages over GLMs and GAMs. These advantages can be summarised as:

1. Lack of formal statistical assumptions: alternative methods (e.g. GLM, GAM) make specific assumptions about the sampling distributions of the data, the nature of dependencies between variables, and the scaling of predictor variables. Regression trees are robust to “badly behaved” data and do not make any of these assumptions (Brieman *et al.* 1984, De’ath and Fabricius 2000).
2. Automatic detection of interactions between predictor variables (Brieman *et al.* 1984, De’ath and Fabricius 2000, Venables and Ripley 2002).
3. Ease of interpretation of the resulting statistical model: the model is depicted as a dendrogram (tree diagram) which classifies the sites into groups on the basis of simple dichotomous partitions of the habitat variables.

For the purposes of this report only analyses using Regression Tree Analysis are presented. A regression tree model is constructed by repeatedly splitting the data into two mutually exclusive groups on the basis of the predictor variables, so as to maximise the within-group similarity with respect to the response variable (in this case the presence or absence of *L. raniformis*). The splitting procedure is then reapplied to the two resulting groups separately; this procedure is repeated until no further improvement in within-group response-variable homogeneity is possible. In order to reduce the complexity of the resulting model, the fully-fitted tree model may then be “pruned” by applying a cost-complexity algorithm, which trades of the explanatory power of more complex models against the generality and interpretability of more simple models. The finally-selected regression tree model is depicted graphically as a dendrogram, with the partitioning rules superimposed at the tree-nodes.

More detailed discussion of the methodologies and algorithms for fitting of regression tree models to data are provided by Brieman *et al.* (1984) and Venables and Ripley (2002). The use of regression tree methods in the analysis of ecological data is discussed by Bell (1996), Rejwan *et al.* (1999), Anderson *et al.* (2000), De’ath and Fabricius (2000) and De’ath (2002).

Fitting of the regression tree model to the *L. raniformis* presence/absence data led to a predicted probability of occurrence for each site. These predicted probabilities were compared to the observed pattern of presences and absences at each site using Receiver Operating Characteristic (ROC) analysis (Zweig and Campbell 1993). The predicted probabilities of occurrence at each site (determined from the regression tree model) were first converted to predicted presences and absences at a range of threshold probability values between zero and one. For each threshold value, the proportion of presence sites correctly classified (Sensitivity) and proportion of absence sites correctly classified (Specificity) was calculated. The sets of Sensitivity and Specificity values were plotted against each other to form the ROC plot. In theory, the ROC plot of a statistical model with poor predictive power will describe a straight line across the diagonal of the plot, while a model with excellent predictive power will describe a concave curve which approaches the upper right hand corner of the ROC plot. The area underneath the ROC curve (AUC) provides a good quantitative index of the predictive ability of statistical models for binary outcomes such as presence/absence data (Zweig and Campbell 1993, Fielding and Bell 1997, Manel *et al.* 1999a,b, 2001, Pierce and Ferrier 2000). A model of poor predictive ability will have AUC ~ 0.5, while the AUC of a model with excellent predictive ability will approach unity. The area under the ROC curve for the fitted regression tree model was calculated by numerical integration, and it's 95% confidence interval was estimated using the nonparametric method of DeLong *et al.* (1988).

The *R* statistical software environment (Ihaka and Gentleman 1996) including the add-in library *rpart* (Therneau and Atkinson 2002), was used for the regression tree analyses presented in this report. A version of the *roc* package for S-PLUS (Mahoney and Anderson 2001), modified by MP Scroggie to ensure compatibility with the *R* statistical environment was used for calculation of the Receiver Operating Characteristic statistics.

3. RESULTS

3.1. Field survey

The field component of the survey was completed by the 15th March, 2002. This involved the survey and habitat assessment of 136 individual field sites (70 stream sites and 66 standing water bodies) for *L. raniformis* within the study area, incorporating sites on the Aitken, Curly Sedge, Darebin, Edgars, Kalkallo, Malcolm, Merlynston and Yuroke Creeks. Within this area, 47 stream transects were spotlight surveyed, and 51 additional sites were briefly inspected for the frog and its habitat. All survey sites and stream transects are shown in Figure 1, with summary details of frogs from sites and transects presented in Appendices 1 and 2 respectively.

Call recognition and active searching (during both the day and night) confirmed the presence of *L. raniformis* at 41 of the 136 sites, with a total of 160 individuals recorded (see Appendix 1). *Litoria raniformis* was not detected at 95 sites. With the addition of a further 46 frogs recorded within the above locations but away from any specific survey sites (see Appendix 2), a total of 206 individuals was recorded.

Frog abundance was low within all survey sites examined (Figure 2), and records comprised largely adult male specimens (83% of the 145 frogs for which sex was positively identified). The largest populations of *L. raniformis* recorded during this survey were associated with the Merri Creek in the vicinity of O'Herns Rd and further north, around the township of Donnybrook. However, the largest populations occurring within the study area are undoubtedly those occurring within several quarry holes across the mid-sections of the study area, particularly the quarry holes north and south of Cooper Street, Somerton; McKimmies Road Quarry, Bundoora; Wollert landfill site, Wollert (see Appendix 1); and the quarry holes adjacent to the headwaters of Edgars Creek on Cooper Street (see Appendix 3).

Our survey data are likely to misrepresent overall population sizes at these sites for two reasons: 1) much of the season's breeding activity within these sites probably occurred before the commencement of this survey (12/12/01) and; 2) we were unable to spotlight survey most of the quarry sites due to safety concerns of the relevant landholders.

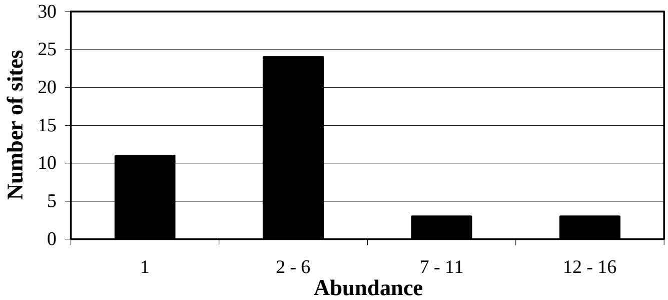

Figure 2. **The distribution of abundance of *Litoria raniformis* across all forty-one survey sites (stream sites and standing water bodies) in which the frog was located within the Merri study area between 12/12/01 - 15/3/02.**

The great majority of *L. raniformis* recorded during the present survey was located amongst aquatic vegetation (Figure 3). Stands of emergent vegetation, particularly Cumbungi (*Typha* spp.), Rushes (*Eleocharis sphacelata*, *Schoenoplectus tabernaemontii*) and Mud Dock (*Rumex bidens*) were favoured basking sites during the day. At night, frogs were often located in open sites amongst these vegetation types, perhaps using these elevated sites to ambush passing insect prey. Floating vegetation, primarily dense stands of Water Ribbon (*Triglochin procera*) and Pond-weed (*Potamogeton crispus*, *P. pectinatus*, *P. tricarinatus*), were favoured as calling sites for male frogs during the night. Several microhabitat classes located adjacent to waterbodies were also recorded to be used during the survey period. Bank-side grasses were frequently utilised by basking frogs, generally in positions that allowed a quick escape (1 - 1.5 m) to the water. At night, frogs were occasionally located sitting motionless on bare, cattle-trampled stream banks, again probably waiting to ambush prey. Pasture adjacent to waterbodies may also be utilised by frogs, either foraging for insect prey or during overland dispersal movements - in particular, we recorded large numbers of adult frogs active within exotic pasture in the vicinity of the Merri and Kalkallo Creeks (Donnybrook Road crossings) on several warm, rainy nights in January and February.

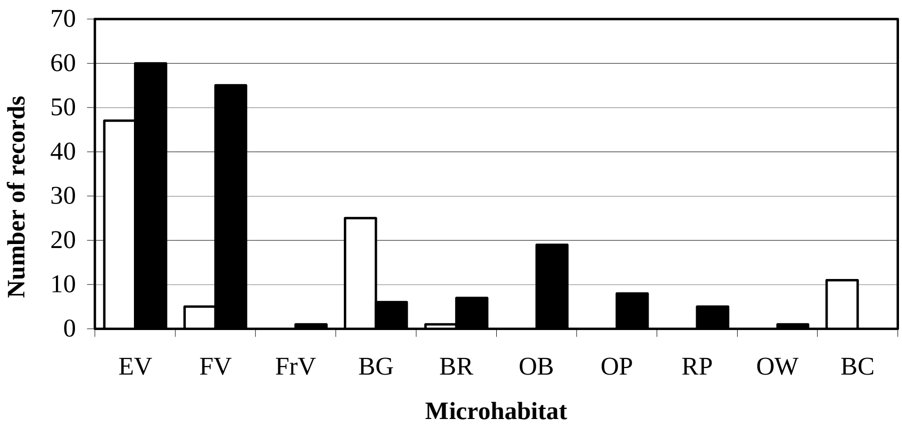

Figure 3. Microhabitat records obtained from all *Litoria raniformis* located within the Merri study area between 12/12/01 - 15/3/01.

Records are divided between those taken during the day (open columns) and those recorded at night (solid columns). Note that the total number of records (251) is higher than the number of individual frogs (206), as records were obtained from some frogs during both the day and at night. Microhabitats are: EV - emergent vegetation, FV - floating vegetation, FrV - fringing vegetation, BG - bank-side grasses, BR - bank-side rock, OB - open bank, OP - open pasture, RP - rock in pasture, OW - open water, BC - under bank-side cover.

Reproductive activity recorded during the survey was restricted almost entirely to observations of calling males. No individuals were observed in amplexus, spawn was not recorded, and tadpoles of *L. raniformis* were observed at only two sites. Note however, that specific sampling for tadpoles was not undertaken. Similarly, metamorphlings of this species were recorded at only two sites - Wollert Landfill and the McKimmies Road Quarry. Of those specimens measured, adults (defined here as >50 mm) were observed in the greatest numbers (Figure 4). The largest specimen observed during the survey was a female measuring 92 mm snout - groin length.

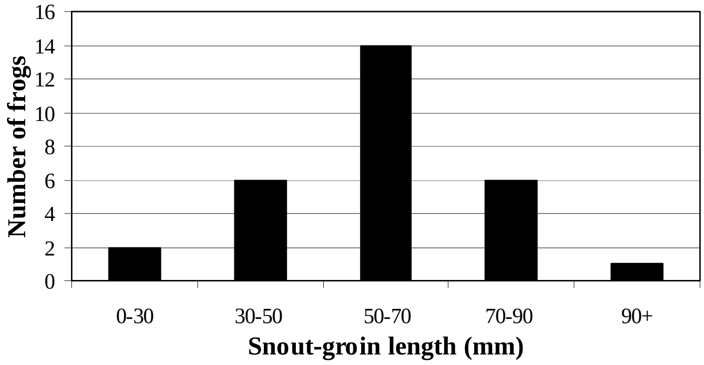

Figure 4. The distribution of snout-groin length recorded from twenty-nine *Litoria raniformis* captured and measured within the Merri study area between 12/12/01 - 15/3/02.

Calling males were recorded throughout the survey period (17/12/01 - 26/2/02), generally on warm nights with a slight breeze and high humidity. In particular, activity was high on nights after thunderstorms with light rain; however, calling was also occasionally recorded on cool, windy nights. Several repeat visits were made to sites on the Yuroke and Merri Creeks where frogs had been recorded early in the survey period. At two of these sites (centred on O'Herns Road) the number of calling males, and their favoured calling sites, remained consistent over four standard surveys between the 19/12/01 and 28/1/02. It is unknown if the same individuals were involved; however, it appears likely.

In addition to the records obtained during the current survey, seventeen records of *L. raniformis* from within this study area during the 2001-2002 season were provided by other field workers (A. Organ, Biosis Research P/L; L. Williams, Ecology Australia P/L) and private individuals (see Appendix 3). Perhaps of most note here are records of significant populations within quarry holes at the Epping Waste Disposal site (Cooper Sreet, Epping) and the former quarry sites north and south of Cooper Street (including those adjacent to the O'Herns Road Swamp). The distribution of all records of *L. raniformis* obtained during the 2001 - 2002 season is shown in Figure 5.

3.2. Historical records

One hundred and ten historical records (pre 2001) of *L. raniformis* within the Merri study area were gathered during the course of this study (see Appendix 4). Significant historical records include specimens located within the southern reaches of the Merri Creek around Campbellfield (in the vicinity of Barry Rd and Pipeworks Market), along sections of Central Creek south of Mahoney's Rd, sites on both the Aitken and Malcolm Creeks in Craigieburn, and the Darebin Creek north of Epping. No specimens of *L. raniformis* were located in the vicinity of these sites during the 2001 - 2002 season - there may have been recent declines in these areas. Figure 5 shows all records extracted from the Atlas of Victorian Wildlife database and those available from other sources (Appendices 3 and 4).

Figure 5. The distribution of sites at which *Litoria raniformis* has been recorded from within the Merri Creek Corridor and adjacent catchments – all sources.

(see over for fold-out A3 sheet)

3.3. Analyses of factors influencing the distribution of *L. raniformis.*

The detailed habitat assessment data are not included in this report, but are available upon request.

The three variables identified from the statistical analyses of the habitat data as exerting a major influence upon the distribution of *L. raniformis* within the Merri Creek Catchment were:

- Distance from survey site to nearest waterbody occupied by *L. raniformis*;
- Proportion of the waterbody banks with emergent vegetation;
- Proportion of waterbody area with submerged vegetation.

Details of these analyses are discussed further below.

3.3.1. Regression tree model

Of the measured habitat variables, a subset of eight (presented in Table 5) was considered as potentially most likely to influence the pattern of presence/absence of *L. raniformis* in the study area. A regression tree model for the presence/absence of *L. raniformis* at 133 study sites was then generated using these candidate variables. Following consideration of the cost-complexity plot for the full fitted model, the tree was pruned to reduce the number of nodes from seven to four; the resulting reduction in model complexity being found to have minimal effect on the predictive accuracy of the model. The pruned regression tree is depicted graphically in Figure 6.

The fitted regression tree model revealed a very strong effect of distance to the nearest occupied site on the probability of occurrence of *L. raniformis.* Sites distant from other occupied sites were very unlikely to be occupied. In addition, the extent of emergent and submerged vegetation within waterbodies also effected the probability of occurrence of *L. raniformis*, with occupied sites generally having greater amounts of these vegetation types. Hence, the probability of occurrence of *L. raniformis* at ponds in the study area is influenced both by attributes of the waterbodies themselves, and by the location of these waterbodies.

Table 5. Variables included in regression tree analysis.

Variable Code	Variable definition and notes
Category	Whether the waterbody was a stream or standing waterbody
Permanent	Permanence of the waterbody assessed on a subjective ordinal scale from 0-4
Flowclass	Flow-rate of waterbody on a subjective ordinal scale from 0-4
EVWExtent	Proportion of the waterbody area with emergent vegetation
EVBExtent	Proportion of the waterbody banks with emergent vegetation
SVExtent	Proportion of waterbody area with submerged vegetation
FVExtent	Proportion of waterbody area with floating vegetation
nearocc	Distance from waterbody to nearest waterbody occupied by *L. raniformis*

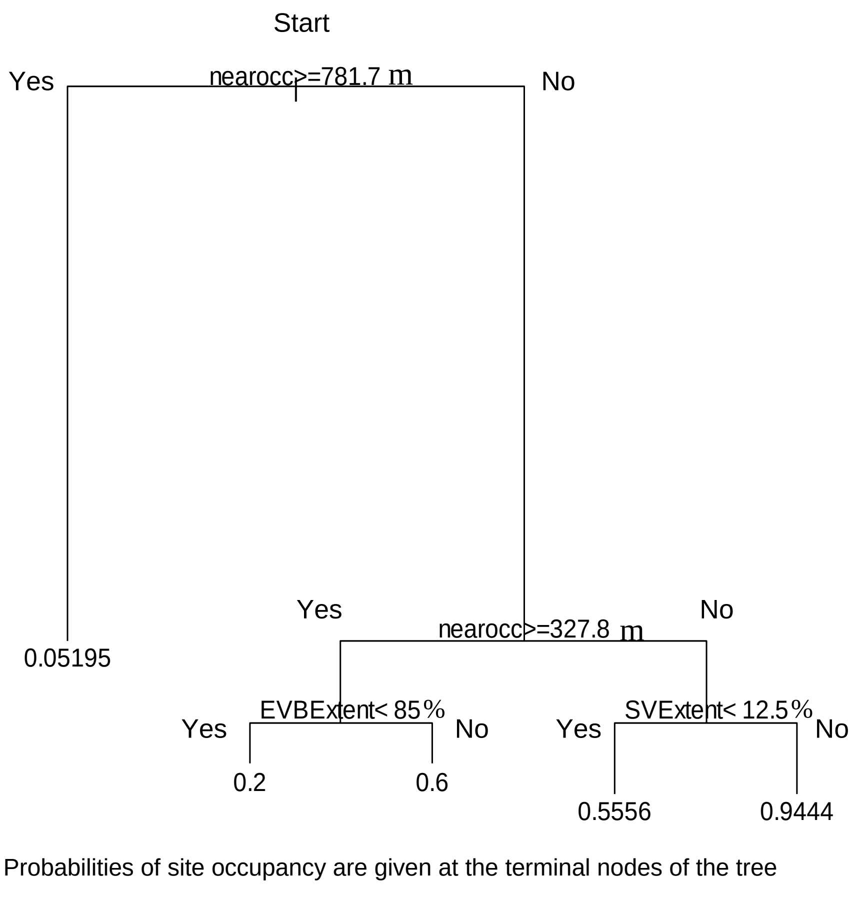

Figure 6. Regression tree model for the presence/absence of *Litoria raniformis* across 133 waterbodies within the Merri Creek Corridor and adjacent catchments.

Starting at the top, each branching point (node) comprises a logical dichotomous split in the data. Following the successive splits leads to a predicted probability of occurrence for *L. raniformis* at each of the study locations (numbers at ends of branches of the tree). The lengths of each successive branch are correlated to the proportion of variance explained by each split; i.e. the first split (nearocc >=781.7m) explains the greatest proportion of variance in the observed pattern of presences and absences.

3.3.2. Model evaluation

The predictions of the model were compared to the actual pattern of presence/absence using Receiver Operating Characteristic (ROC) analysis (Zweig and Campbell 1993, Fielding and Bell 1997, Pierce and Ferrier, 2000). The ROC plot for the fitted regression tree model is presented in Figure 7. The area under the ROC curve was 0.90 (95% confidence interval: 0.83 - 0.96), indicating a very good level of discriminatory ability in the statistical model. More formal evaluation of statistical models of ecological presence/absence data requires checking of the model using additional data not used in the initial model-fitting procedure (Guisan and Zimmerman 2000) – testing of the model presented here against a comparable data set collected at another geographically separate locality is highly desirable. Nevertheless, the essential simplicity of the fitted model, and its goodness-of-fit to the data suggest that some confidence in its predictive and explanatory power is warranted.

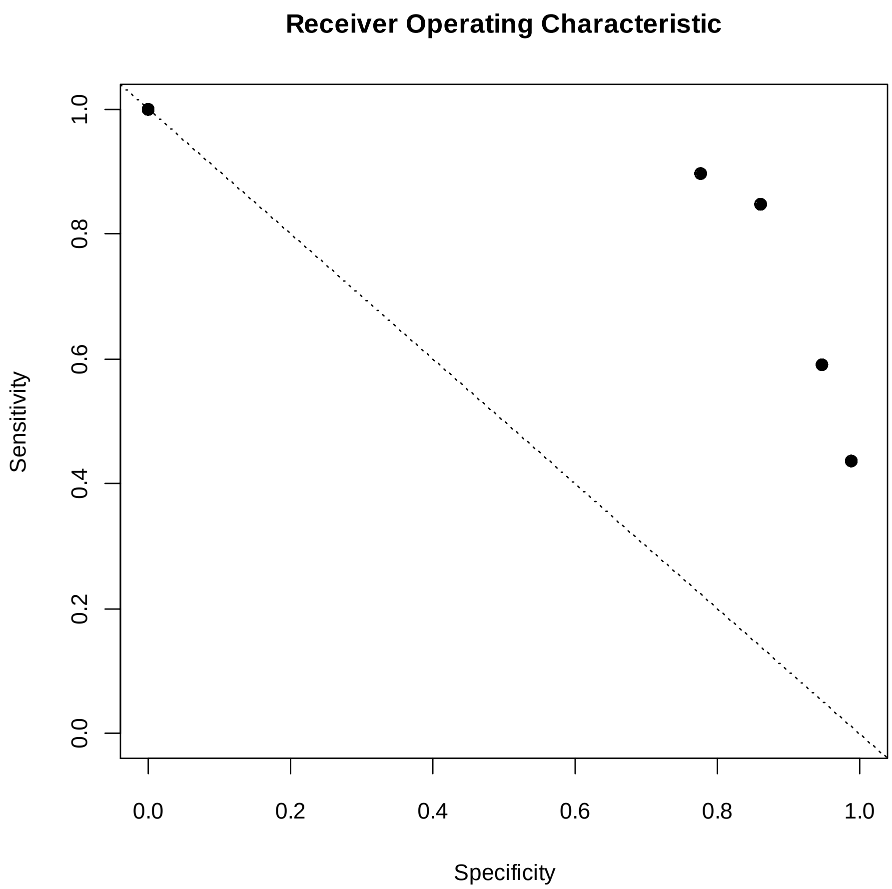

Figure 7. Receiver Operating Characteristic (ROC) plot of the regression tree model for the presence of *Litoria raniformis* across the Merri Creek Corridor and adjacent catchments.
The area under the ROC curve was 0.90, with a 95% confidence interval of 0.83 - 0.96. The diagonal line denotes the ROC curve of a model with predictive ability no better than chance. The curve described by a model with very high predictive ability will approach the upper right-hand corner of the plot (i.e., the area under the curve will be close to unity). See methods for further explanation of ROC methodology.

4. DISCUSSION

This survey has enabled a better understanding of the distribution and habitat requirements of *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments. The species is distributed throughout the study area, with most records centred on waterbodies associated with the major drainage lines. Examination of the current distribution, as perceived in this study (yellow symbols in Figure 5), reveals that there are distinct clusters of occurrences around aggregations of waterbodies, with only scattered records between these clusters. When compared with the historical distribution (orange symbols in Figure 5), it is apparent that the species has disappeared from many sites that were formerly inhabited, particularly sections of the Merri Creek below Coopers St. No frogs were recorded along several largely ephemeral creeks including the Edgars, Aitken and Malcolm Creeks. All frogs located along the Darebin Creek were associated with quarry holes, and may have originated from these sites rather than the from the creek-line itself (see below). Nonetheless, one must be cautious in interpreting these data, as the 2001-2002 season was unusually dry, and many waterbodies that had held water in previous years were dry for the duration of this survey.

Considering the apparent distribution and the range of potential threats evident in the Merri Creek area (see below), it appears likely that the populations of *L. raniformis* studied here (particularly those from the more fragmented environs of the south of the study area) may be dependent upon a relatively small number of localities in which successful reproduction occurs. In these circumstances, the overall Merri population may actually comprise a series of largely discrete sub-populations centred on each breeding locality. Each of these sub-populations may, in turn, be spread across a series of clustered waterbodies which are of varying quality for reproduction, foraging and shelter. Our analyses of the factors influencing the distribution of *L. raniformis* within the study area is strongly indicative of this pattern, given that the suitability of a site as frog habitat was most dependant upon the proximity of that site to another frog population.

Populations structured in this way are often referred to as ‘meta-populations’. The viability of a meta-population depends upon the degree of ‘connectivity’ between its component sub-populations, which, in turn, is heavily reliant upon habitat connectivity and the opportunities for movements available to individual animals. In nature, population levels of organisms (particularly frogs) can be highly variable over time, and local extinctions can occur due to poor seasonal conditions, disease etc. Therefore, habitat patches (clusters of waterbodies in our case) need to be close enough to each other to allow individual frogs to move between them, and thus recolonise areas that may have been subject to a local extinction event. If, in the landscape as a whole, there is inadequate connectivity between local sub-populations (or ‘clusters of sites’), then the local extinction rate will exceed the recolonization rate, and the whole meta-population will drift towards extinction. Conservation in such systems needs to have as a focus the maintenance of habitat patches which have maximal value as connections or ‘stepping stones’ (e.g. those that are between clusters of sites). Ideally, multiple recolonization linkages need to be maintained between as many extant populations as possible, and linkages placed between isolated sites.

A secondary level of population structuring may be operating within the *L. raniformis* populations - that is, one based on movements <u>within</u> clusters of sites rather than <u>between</u>

clusters. While the viability of the meta-population may be dependent on the capacity for recolonization of a cluster following local extinction (based upon infrequent long-distance movements of few individuals), the viability of a particular sub-population may be dependent on the capacity for many individuals of the population to move between sites within a local cluster. There is some evidence for these shorter-distance movements of populations (Patmore 2001), with many individuals moving to a different waterbody in a cluster when conditions within one become unsuitable. The scale of these 'short-distance' movements is not known, but is likely to be less than the 780 metres identified in the regression tree model. Consequently, conservation management should also aim to facilitate such movements by providing suitable habitat between waterbodies, by minimising the distance between waterbodies in a cluster, by maximising the number of waterbodies in a cluster, and by optimising the variability of these waterbodies such that suitable conditions are always temporally available within a cluster.

A preliminary identification of potential clusters of sites in the Merri Creek Corridor and adjacent catchments is presented in Figure 8. At this stage, the shaded areas on Figure 8 are intended primarily to aid planning of further research work, but also to guide the location of interim conservation and management measures. They were established by placing ~780 metre 'buffers' around groups of sites, this being the distance indicated by the regression tree model beyond which frog dispersal movements may be less likely.

The areas shaded yellow in Figure 8 each indicate a 'focal cluster' of sites, each cluster potentially representing a sub-population of *L. raniformis*. Future study to examine habitat use, recruitment and population demography should focus upon these areas. As these areas are potentially of major importance for maintaining the overall meta-population, management should aim to maximise the number of sites, and the habitat variability of these sites, in each cluster.

The areas shaded green in Figure 8 each indicate apparently minor clusters comprising few sites, or isolated sites. It would be expected that the viability of populations in such areas may be lower, and that in the absence of larger 'focal' clusters nearby they could rapidly decline – however, the individual characteristics of waterbodies within these areas will also be a major factor in determining their viability. These areas may also comprise important movement corridors, or stepping-stones of sites, between 'focal' clusters. As such, conservation measures should aim to enhance this function – management could also increase the numbers of sites within these minor clusters to increase their potential viability. Some of these areas require further survey to determine whether additional sites remain currently undetected.

The areas shaded blue in Figure 8 each indicate potential habitat for *L. raniformis,* within which movements between clusters may be possible and important for meta-population maintenance. As such, conservation measures should aim to enhance this function, one possibility being the creation of 'stepping-stone' waterbodies. Furthermore, some of these areas were not surveyed at sufficient intensity – existing sites may be currently undetected.

Note that further work may greatly modify the identification of the zones tentatively identified in Figure 8. They were based upon work in one year only, and in a relatively poor year for frog activity (low rainfall). The presence of historical sites beyond the three zones identified, and remote from other known sites, indicates that in a 'wet' year many more sites may be identified, and other movement corridors may be important.

Figure 8. Preliminary identification of 'habitat management zones' for *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments.

(see over for fold-out A3 sheet)

4.1. Perceived threats and their potential management

The apparent decline of *L. raniformis* within the study area may be attributed to a range of factors. Continued habitat alteration poses an immediate threat to several of the populations identified here.

The lower reaches of many waterways pass through industrial and housing estates, where they have often been converted to surrogate storm water drains. The erratic nature of flow regimes is greatly exaggerated in such areas, and most of the important off-stream habitat has been destroyed. The habitat within these streams is often choked by Cumbungi (*Typha* spp.) and Common Reed (*Phragmites australis*), shading out other important aquatic plants, particularly submergent vegetation – perhaps a feature of artificially elevated nutrient levels in the streams.

Although water quality was not assessed during this study, it may affect *L. raniformis* populations - storm-water run-off carries high concentrations of heavy metals, nutrients and suspended solids into the stream environments across the study area, but particularly within the Merri Creek south of Coopers St (Finlay *et al.* 1997). The lack of recent records of *L. raniformis* in the Merri Creek south of Cooper Street is coincident with high levels of heavy metal pollution in this section of the stream. It appears likely that most frogs located within stream sites in the south of the study area (e.g. Darebin Creek south of McKimmies Road) metamorphosed within nearby quarry holes or other off-stream water-bodies. Tadpole development may be affected by in-stream water quality in these areas. As such, water-quality testing should be considered a priority for future work during the coming breeding season.

Another practise which is rapidly destroying or degrading the habitat of *L. raniformis* within the study area is the use of former quarry holes for landfill. At a number of locations across the study area, populations inhabiting these water-filled quarry holes are at imminent risk of extinction due to landfill. Of most concern are populations found within the quarry holes south of Cooper Street, the McKimmies Road quarry in Bundoora (note that a conservation strategy is being implemented for this population; Robertson 2001), and the Wollert landfill site. As mentioned above, these sites may represent core breeding areas for *L. raniformis* within the study area; they are permanent, often support dense aquatic vegetation, appear to have acceptable water quality, and are free of predatory fish. Because of the historic decline in the number and extent of natural off-stream wetlands in the study area, these artificial wetlands in former quarry holes assume a major importance for the species - without such sites, the future of *L. raniformis* in the Merri Creek Corridor may be in jeopardy. Consequently, we suggest that securing these populations should be an immediate priority for the conservation of *L. raniformis* within the Merri study area. Their significance for other threatened fauna, including aquatic birds and raptors, has been noted previously (Beardsell 1997).

Across the north of the study area, hydrological changes to many streams have historically brought about considerable changes to the frog habitat, possibly both positive and negative. The ephemeral sections of most streams are dammed at many points along their length, causing much of the stream bed to remain dry for extended periods (particularly for streams such as the Edgar's and Darebin Creeks). These areas are often heavily grazed, denuding remaining aquatic habitats of both emergent and submergent plant species. The lack of records from the Aitken and Edgars Creeks, and the upper reaches of the Darebin and Malcolm Creeks, may be attributable to these factors.

Formerly suitable habitat found along lower sections of the Malcolm Creek in Craigieburn is currently being degraded by extensive housing development, a factor likely to place increasing pressure upon the species throughout the study area.

In concert with these structural habitat changes, additional factors may be further limiting frog recruitment levels within the Merri Corridor. Evidence of successful breeding (the presence of metamorphlings) was obtained from only two sites during the current survey, both of which were former quarry holes. It is possible that the majority of reproductive activity during the 2001-2002 season occurred prior to this survey, and that breeding events were somewhat curtailed by the dry nature of the season. Nonetheless, predatory fish and disease may be perennial threats to population recruitment within this study area. Mosquito Fish (*Gambusia holbrooki*) are widespread, particularly within the Merri Creek. Many stream populations of *L. raniformis* located during this study occurred in sympatry with this introduced fish, and may indeed breed within these localities (B. Casey pers. com.); however, rates of metamorphosis at these sites could be affected by predation by this fish.

Chytrid Fungus may also be prevalent within the Merri populations of *L. raniformis*, and could be an important factor implicated in the decline of the species. We recently (26/7/02) found evidence of *L. raniformis* dying, apparently with chytrid fungus infection (yet to be confirmed, PR pers. obs.), at one site within the study area.

4.1.1. Habitat considerations

The habitat model[2] illustrates that the occurrence of *L. raniformis* is influenced both by the location of sites in the landscape, and by the actual structure (i.e. habitat features) of the sites. Hence, conservation planning and management need to take account of both of these considerations. This has important implications for any proposals to create new or 'replacement' habitat, and for the management of existing habitat patches. Within the Merri system, the creation of off-stream habitats could be an important method by which to promote overall population viability. Guidelines for the construction or enhancement of habitat should have two foci:

- to enhance the size of clusters, and the key habitat characteristics for reproduction within them (and thus sub-population size and distribution) and;
- to link clusters to increase the distribution of the overall population in the landscape and to enable movements which may ameliorate the effects of local extinctions.

Construction and enhancement would obviously initially concentrate on establishing and improving those habitat features that were identified in our interim habitat analyses as important determinants of the species' presence – extensive emergent vegetation around the margins, and submerged vegetation in the waterbody.

A meta-population model of the system could allow prediction of the effects of habitat patch creation (or deletion) on the viability of the regional meta-population, and subsequently guide the optimal placement of these conservation efforts. It would allow

[2] (It should be pointed out that the habitat model still requires validation – that is, testing its predictive value against data from another population. (This may be possible with data to be collected in the Kerang area by ARI - M. Scroggie and N. Clemann pers. comm.).

prioritization of existing sites for conservation and restoration, as well as assisting in selection of the optimal placement of any newly-created habitat patches.

4.2. Directions for further work

Unfortunately, many aspects of the above discussion remain merely informed speculation. Further work will be required to better understand the factors influencing the conservation status of *L raniformis* within the Merri Corridor, and thus produce more rigorous management guidelines for the entire population. In particular, we urgently need to identify the potentially small subset of occupied waterbodies in which successful reproduction occurs, and we need to understand the characteristics of these waterbodies, their seasonal conditions and variability, their interaction with other waterbodies, and their relative contribution to the long-term maintenance of the *L. raniformis* population. Until we have this understanding, any habitat manipulation guidelines must be considered interim – however, we cannot afford to delay conservation measures.

Below we detail several key directions for further work upon *L. raniformis* considered vital to our understanding and long-term conservation of this frog within the study area:

- Tadpole/metamorphling surveys are crucial - we need to know which populations are recruitment sources, which patches are breeding habitat/non-breeding habitat, and the habitat parameters contributing to successful reproduction. This information will greatly influence our understanding of meta-population processes in the area, and priorities for preservation/enhancement of particular habitat patches.
- Predation by fish (including *Gambusia*) on *L. aurea* and *L. raniformis* has received much attention in the literature. Gathering some definitive data on this issue is a high priority, to determine whether predation is an important factor regulating population numbers or recruitment (comparisons between stream sites and standing water bodies are of particular interest in this regard). Surveys for fish could be carried out in conjunction with tadpole/metamorph surveys.
- Knowledge of movements within and between waterbodies, of dispersal movements, and of the temporal scale of such movements.
- Knowledge of over-wintering habitat requirements.
- Knowledge of life-history and demographic parameters which would enable population modeling and determination of critical stages for focus of conservation management.
- Information on survey effort required to accurately determine the presence of the species, i.e. - how many times do you need to visit a site to be certain of correctly classifying it as present/absent. This is a general problem with the current type of study - getting data on this question would be useful for all subsequent work on *L. raniformis.*

To address these information requirements, the following actions are proposed for the coming field season:

1. Repeated surveying throughout the activity period of a subset of the sites (both frogs present and absent) which were examined last season, to examine:
   - variation in frog abundance and reproductive activity;
   - tadpole abundance or presence/absence, and;
   - tadpole metamorphosis.

   This sampling would concentrate on three main clusters of sites associated with the Merri Creek – near O'Herns Road, Somerton, Donnybrook, and Merriang Park. Two additional, essentially isolated clusters would also be examined – Wollert Landfill and McKimmies Road Quarry/Darebin Creek sites. Various habitat parameters would be collected at these sites, including some not previously examined in detail (i.e. water quality and quantification of fish present).
2. Single survey visits to a random subset of sites examined last season, to investigate any seasonal differences in their utilisation. Also, repeated visits to some of these sites (including some with only low numbers of frogs found) within a short period to investigate detectability of frogs.
3. Single survey visits to sites not examined last season, to increase the consistency of geographic coverage of the survey, and to visit occupied sites which may have been brought to our attention since then (at which the habitat has not yet been assessed).
4. Detailed demographic monitoring, via intensive mark-recapture work, at sites within selected clusters. This will determine various population and life-history parameters, but importantly will also examine movements within and between waterbodies. This work is largely beyond the scope of the current study, but will be pursued as a post-graduate student project. It is envisaged that work in the Merri would form a major part of such a study, but that it would be important to also collect comparative information from other populations. There are possibilities to integrate with other studies of translocations, and with investigations of the effects of barriers to movements (and the utility of structures designed to reduce the effects of such barriers) within the Merri study area itself. Universities will be canvassed for suitable students – funding possibilities should be explored.
5. Investigation of microhabitat use, particularly during the non-active period, via radio-telemetry. These studies could integrate with the demographic study to augment data on individual movements, and would be undertaken at the clusters being examined in (1) above.
6. Further analyses to fit a meta-population patch-occupancy model to the existing data (Incidence-function metapopulation model, see Hanski 1994 for introduction to the concept, and Biedermann 2000 and Vos *et al.* 2000 for conservation based examples). These kinds of models may prove instructive for guiding future research priorities even if we have not measured all of the parameters (i.e. if the values of certain parameters in the model do not influence its predictions much, then spending time and effort getting an accurate measurement of that parameter is unnecessary). Once one of these models is fitted to the data, it can generate predictions for the effects of habitat destruction or creation, effects of new barriers, etc. (This component could be done without further fieldwork.)
7. Validation of the habitat model by testing its predictive value with data collected from another area. Studies planned in the Kerang area may provide a comparative data-set.

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Appendix 1. Locality data and survey details recorded from all sites surveyed for *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments.

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person mintues)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Hearns Swamp, Beveridge	320875	5850326	9/3/02	20	15	0	0	0	0	0	0
Yuroke Ck, Broadmeadows	315649	5828648	17/12/01, 28/12/01, 12/3/02	48	100	12	0	0	0	0	3
Yuroke Ck, Broadmeadows	315593	5828665	17/12/01, 28/12/01, 12/3/02	42	19	4	0	0	0	5	0
Yuroke Ck, Broadmeadows	315586	5828713	17/12/01, 28/12/01, 12/3/02	24	40	1	0	0	0	1	1
Yuroke Ck, Broadmeadows	315308	5827736	18/12/01, 12/3/02	20	17	0	0	0	0	0	0
Shankland Wetland, Broadmeadows	315460	5830492	18/12/01	13	80	2	0	0	0	0	0
Shankland Reserve, Roxburgh Park	316469	5832065	18/12/01, 12/3/02	30	190	0	0	0	0	0	0
Artificial lake, Roxburgh Park	316499	5832776	18/12/01, 12/3/02	18	40	0	0	0	0	0	0
Artificial lake, Roxburgh Park	316621	5832441	18/12/01, 12/3/02	18	50	0	0	0	3	0	0
Recreational pond, Greenvale Reservoir	314176	5832306	28/12/01, 12/3/02	15	40	0	0	0	0	2	0
Recreational pond, Greenvale Reservoir	314090	5832394	28/12/01, 12/3/02	12	40	0	0	0	0	3	0

Appendix 1. (contd.)

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Recreational pond, Greenvale Reservoir	314009	5832520	28/12/01, 12/3/02	15	32	0	0	0	0	4	1
Jack Roper Reserve, Broadmeadows	318112	5826064	6/2/02		110	0	0	0	0	1	1
Wetland below Jack Roper Reserve, Broadmeadows	318289	5825921	6/2/02		90	0	0	0	0	0	1
Drainage line, Broadmeadows	319321	5826692	28/12/01		70	0	0	0	0	0	0
Darebin Ck, Broadmeadows	328170	5826699	7/1/02		60	0	0	0	0	0	0
Drainage line, Bundoora	328102	5827103	7/1/02		80	1	0	0	0	0	0
Darebin Ck, Bundoora	326882	5829068	5/2/01		80	0	0	0	0	0	0
Darebin Ck, Bundoora	327181	5827385	2/1/01, 5/1/02	40	240	14	0	0	0	0	0
McKimmies Rd Quarry, Bundoora	327621	5827802	11/1/02	40		2	0	0	0	0	0
McKimmies Rd Quarry, Bundoora	327538	5827477	11/1/02	60		5	0	0	0	0	0
Merri Ck, Cambellfield	321239	5828814	13/12/01, 15/1/02	28	54	0	0	0	0	0	0
Settling pond, Cambellfield	321181	5828882	13/12/01, 15/1/02	36	35	0	0	0	5	0	11
Settling pond, Cambellfield	321245	5828920	13/12/01, 15/1/02	20	35	0	4	0	4	0	8

Appendix 1. (contd.)

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Merri Ck, Cambellfield	321103	5827218	20/12/01, 15/1/02	22	60	0	0	0	0	0	0
Settling pond, Cambellfield	321101	5827287	20/12/01, 15/1/02	23	80	0	0	0	5	0	0
Small pond, Cambellfield	321071	5827195	20/12/01, 15/1/02	20	25	0	0	0	2	0	0
Former Quarry, Cambellfield	322170	5830501	21/12/01	35		15	0	0	0	0	0
Merri Ck, Cambellfield	321350	5830863	19/1/02	25	30	0	1	0	0	0	0
Dam on Malcolm Ck, Craigieburn	316106	5838042	21/12/01		60	0	0	0	3	0	0
Malcolm Ck, Craigieburn	317103	5837871	21/12/01		56	0	0	0	2	0	0
Dam on Malcolm Ck, Craigieburn	315503	5840115	21/12/01		40	0	0	0	0	0	2
Merri Ck, Craigieburn	320197	5839532	21/12/01		96	0	0	0	0	0	0
Merri Ck, Craigieburn	320205	5839345	21/12/01	50	130	10	0	0	0	0	0
Merri Ck, Craigieburn	319181	5835971	24/12/01, 29/12/01		104	0	0	0	0	0	0
Merri Ck, Craigieburn	319181	5836771	29/12/01		62	0	0	0	0	0	0
Aitkon Ck, Craigieburn	318040	5835655	6/3/02		30	0	0	0	0	0	0

Appendix 1. (contd.)

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Dam on Aitkon Ck, Craigieburn	314752	5836916	24/12/01		40	0	0	0	0	0	0
Dam on Aitkon Ck, Craigieburn	314902	5836719	29/12/01		40	0	0	0	3	0	0
Dam opposite Nubrik, Craigieburn	320327	5836203	18/1/02	14	20	0	0	0	0	0	0
Dam opposite Nubrik, Craigieburn	320492	5836165	18/1/02	16	30	0	0	0	5	0	0
Merri Ck, Craigieburn	319708	5838421	18/1/02, 27/1/02	55	165	0	1	0	1	0	0
Merri Ck, Craigieburn	319902	5838688	18/1/02, 27/1/02, 31/1/02	70	64	3	1	0	0	0	0
Malcolm Ck, Craigieburn	318202	5837627	7/2/02	25	30	0	0	0	0	0	0
Farm dam, Craigieburn	315369	5840074	7/2/02	18	22	0	0	0	0	0	0
Dam on Malcolm Ck, Craigieburn	315820	5839320	7/2/02	30	32	0	0	0	0	0	0
Dam on Aitkon Ck, Craigieburn	314578	5837280	13/2/02	15	48	0	0	0	1	0	0
Aitkon Ck, Craigieburn	315891	5836356	13/2/02	38	60	0	0	0	0	0	1
Aitkon Ck, Craigieburn	317393	5836207	13/2/02, 6/3/02	30	38	0	0	0	0	0	0

Appendix 1. (contd.)

	AMG		Survey Details			Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Pond within the Craigieburn Golf Course	315848	5836540	13/2/02	58	76	0	0	0	1	0	0
Settlement pond, Craigieburn Nubrik	320620	5836492	26/1/02	30	62	0	0	0	1	0	0
Settling pond, Craigieburn Nubrik	320485	5836535	26/1/02	62	60	0	0	0	5	0	0
Dam at Craigieburn Nubrik	320998	5837401	26/1/02	15	48	0	0	0	1	0	1
Pond at Craigieburn Nubrik	320387	5836783	26/1/02, 28/1/02	30	140	1	0	0	20	0	15
Dam at Craigieburn Nubrik	320437	5837277	26/1/02, 28/1/02	31	54	0	0	0	0	0	0
Settling pond, Craigieburn Nubrik	320463	5836569	26/1/02, 28/1/02	25	52	0	0	0	1	0	0
Merri Ck, Donnybrook	320827	5844061	6/1/02	45	84	1	1	0	0	0	0
Merri Ck, Donnybrook	319527	5842816	6/1/02	30	96	3	0	0	0	0	0
Dam on Spring St, Donnybrook	320636	5843192	6/1/02, 7/1/02	30	92	3	0	0	0	0	0
Farm dam, Donnybrook	319695	5842859	6/1/02, 7/1/02	30	34	0	0	0	0	0	0
Merri Ck, Donnybrook	319589	5842802	6/1/02, 7/1/02	25	30	4	0	0	0	0	0

Appendix 1. (contd.)

	AMG		Survey Details			Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Merri Ck, Donnybrook	319713	5843010	6/1/02, 7/1/02	30	30	5	0	0	0	0	0
Merri Ck, Donnybrook	319804	5843142	6/1/02, 7/1/02	30	30	0	0	0	0	0	1
Merri Ck, Donnybrook	321075	5844373	6/1/02, 8/1/02	40	15	2	0	0	0	0	0
Merri Ck, Donnybrook	321016	5844183	6/1/02, 8/1/02	35	45	1	0	0	0	1	0
Farm dam, Donnybrook	318256	5842504	20/1/02, 23/1/02	29	90	5	0	0	1	0	0
Merri Ck, Donnybrook	320106	5840958	20/1/02	96	80	0	0	0	0	0	0
Merri Ck, Donnybrook	319453	5841574	20/1/02	100	90	0	0	0	0	0	0
Farm dam, Donnybrook	320005	5842780	20/1/02, 23/1/02	28	60	1	0	0	0	0	0
Farm dam, Donnybrook	323027	5842713	20/1/02, 23/1/02	25	62	0	0	0	2	1	0
Farm dam, Donnybrook	320691	5842802	20/1/02, 23/1/02	17	52	0	0	0	0	0	0
Farm dam, Donnybrook	320232	5841925	20/1/02, 23/1/02	11	40	0	0	0	2	0	0
Merri Ck, Bald Hill, Donnybrook	322194	5845832	26/2/02	76	50	1	0	0	0	0	0
Merri Ck, Bald Hill, Donnybrook	321624	5846216	26/2/02	42	70	0	0	0	0	0	0

Appendix 1. (contd.)

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Darebin Ck, Epping	326293	5831399	10/1/02		60	0	0	0	0	0	0
Darebin Ck, Epping	326495	5832481	10/1/02		60	0	0	0	0	0	0
Dam on Darebin Ck, Epping	326766	5832895	10/1/02		60	0	0	0	0	0	0
Darebin Ck, Epping	326980	5832869	10/1/02		60	0	0	0	1	0	0
Darebin Ck, Epping	327342	5834156	10/1/02	15	30	0	0	0	0	0	0
Darebin Ck, Epping	327547	5834515	10/1/02	43	68	0	2	0	2	1	0
Farm dam, Epping	322736	5832729	31/1/02	30	19	0	0	0	0	0	0
Farm dam, Epping	323966	5832525	31/1/02	19	15	0	0	0	0	0	0
Farm dam, Epping	322884	5834343	31/1/02	16	15	0	0	0	0	0	0
Merri Ck, Fawkner	321306	5826016	20/12/01, 3/2/02		75	0	0	0	0	0	0
Central Ck, Fawkner	321963	5825987	1/2/02	35	42	0	0	0	0	0	0

Appendix 1. (contd.)

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Merri Ck, Fawkner	321584	5826004	3/2/02	30	81	0	0	0	0	0	0
Merri Ck, Merriang	325110	5850603	17/1/02, 25/1/02	28	14	0	0	0	0	0	0
Merri Ck, Merriang	323985	5847833	17/1/02	27	90	0	0	0	0	0	0
Merri Ck, Merriang	325078	5848128	17/1/02	108	141	1	0	0	0	0	0
Merri Ck, Merriang	324863	5849064	24/1/02	26	58	2	0	0	0	0	0
Merri Ck, Merriang	325281	5848481	24/1/02	25	60	1	0	0	0	0	0
Merri Ck, Merriang	324855	5848745	24/1/02, 25/1/02	30	74	7	0	0	0	0	0
Merri Ck, Merriang	325420	5851727	15/2/02, 17/2/02	78	54	0	0	0	0	0	0
Small pond, Reservoir	325987	5824338	30/12/01		60	0	0	0	0	0	0
Darebin Ck, Reservoir	326012	5824145	30/12/01		80	0	0	0	0	0	0
Darebin Ck, Reservoir	326693	5825170	30/12/01		70	0	0	0	0	0	0
Merri Ck, Somerton	321197	5831239	19/12/01		74	0	0	0	0	0	0
Merri Ck, Somerton	320968	5831395	19/12/01		45	0	0	0	0	0	0

Appendix 1. (contd.)

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Merri Ck, Somerton	320177	5832494	19/12/01		130	3	0	1	0	0	0
Merri Ck, Somerton	319703	5833002	19/12/01, 28/1/02	20	110	5	0	0	0	0	0
Merri Ck, Somerton	319746	5833136	19/12/01, 11/1/02, 19/1/02, 28/1/02	56	272	5	0	0	0	0	0
Curley Sedge Ck, Somerton	320047	5833227	19/12/01		50	2	0	0	0	0	0
O'Herns Swamp, Somerton	320514	5832862	19/12/01		20	0	0	0	0	0	0
Merri Ck, Somerton	319271	5833890	20/12/01, 11/1/02, 12/2/02	56	140	13	0	0	0	0	0
Merri Ck, Somerton	319183	5835103	20/12/01, 18/1/02		74	0	0	0	0	0	0
Quarry hole, Somerton	320611	5832421	11/1/02	98		0	0	0	0	0	0
Small wetland, Somerton	320539	5832897	11/1/02	50		0	0	0	0	0	0
Merri Ck, Somerton	319613	5833429	11/1/02	58	80	2	0	0	0	0	0
Merri Ck, Somerton	319298	5834891	18/1/02	30	54	0	0	0	0	0	0
Farm dam, Somerton	321368	5832876	31/1/02	19	15	0	0	0	0	0	0
Dam within the Craigieburn Grasslands, Somerton	319852	5834419	31/1/02	20		0	0	0	0	0	0

Appendix 1. (contd.)

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Curley Sedge Ck, Somerton	320382	5834232	28/1/02, 31/1/02	35	30	0	2	0	0	0	0
Merri Ck, Somerton	320590	5832180	14/2/02, 18/2/02	65	46	0	2	0	0	0	0
Merri Ck, Somerton	320424	5832340	14/2/02, 15/2/02	50	90	4	0	0	0	0	0
Edgars Ck, Thomastown	324154	5827326	9/1/02		68	0	0	0	0	0	0
Edgars Ck, Thomastown	324163	5828155	9/1/02		82	0	0	0	0	0	0
Edgars Ck, Thomastown	324119	5829793	1/2/02		30	0	0	0	0	0	0
Edgars Ck, Thomastown	323897	5826250	9/1/02	41	54	0	0	0	0	0	0
Drain on Station St, Wallan	323288	5856544	14/12/01, 17/1/02	15	56	0	0	0	0	0	2
Ditch on Station St, Wallan	323088	5854809	14/12/01, 17/1/02	18	50	0	0	0	1	0	0
Drain at Wallan Water Treatment Plant	323043	5854956	14/12/01, 17/1/02	15	36	0	0	0	1	0	2
Dam on Station St, Wallan	323136	5854992	17/1/02, 25/1/02	30	66	0	0	0	0	0	2
Merri Ck, Wallan	323540	5856628	25/1/02	26	38	0	0	0	0	0	0
Merri Ck, Wallan	323674	5854131	7/3/02	32	42	0	0	0	0	0	1

Appendix 1. (contd.)

	AMG			Survey Details		Frogs Recorded (maximum abundance)					
Stream or water body	Easting	Northing	Date/s surveyed	Diurnal Search Effort (person minutes)	Nocturnal Search Effort (person minutes)	*Litoria raniformis*	*L. ewingii*	*L. verreauxii verreauxii*	*Limnodynastes tasmaniensis*	*Lim. dumerilii dumerilii*	*Crinia signifera*
Darebin Ck, Wollert	328057	5836852	10/1/02	28	48	0	0	0	0	0	0
Darebin Ck, Wollert	327853	5836258	10/1/02	28	48	0	0	0	0	0	0
Large dam east of Bindts Rd, Wollert	327660	5835873	10/1/02, 22/2/02	25	11	1	0	0	0	0	0
Small farm dam, Wollert	327652	5835800	10/1/02, 22/2/02	15	60	3	0	0	0	0	0
Pond opposite the weigh bridge, Wollert Landfill	327419	5837371	18/2/02, 22/2/02	24	70	1	0	0	0	0	0
Quarry hole, Wollert Landfill	327383	5837715	18/2/02	15	20	6	0	0	0	0	0
Quarry hole, Wollert Landfill	327252	5838312	18/2/02	30	34	5	0	1	5	0	5
Quarry hole, Wollert Landfill	327442	5837880	18/2/02	15	20	0	0	0	0	0	0
Large waterbody within the Wollert Quarry	326810	5838163	18/2/02	10	75	1	0	0	0	0	0
Small quarry hole, Wollert Landfill	327383	5837715	18/2/02	30	30	0	0	0	0	0	0
Small pond, Wollert Landfill	327305	5838031	18/2/02	15	20	2	0	0	0	0	0
Small dam within the Wollert Landfill site	326980	5832283	18/2/02, 22/2/02	20	30	0	0	0	10	0	0

Appendix 2. Additional records of *Litoria raniformis* located during transect surveys within the Merri Creek Corridor and adjacent catchments. All frogs listed are those located on sections of stream that were outside specific survey site boundaries. Type of record: S = seen, H = heard.

Location	AMG (Datum: AGD66) Easting	Northing	Survey Date	Time	Abundance (each age/sex class)	Raw Abundance	Type of Record
Merri Creek, Mineral Springs property, Donnybrook	321042	5844408	6/01/02	22:20	1AM	1	S, H
Merri Creek, upstream of Donnybrook Rd crossing	319717	5843032	6/01/02	0:15	6A	6	S, H
Merri Creek, upstream of Donnybrook Rd crossing	319704	5843145	6/01/02	0:40	1A, 1AM	2	S
Merri Creek, downstream of Donnybrook Rd crossing	319573	5842799	6/01/02	1:40	1AF	1	S
Merri Creek, downstream of Donnybrook Rd crossing	319666	5842803	6/01/02	1:45	1AF	1	S
Merri Creek, downstream of Donnybrook Rd crossing	319662	5842791	6/01/02	1:45	3AF	3	S
Merri Creek below the trainline crossing, Donnybrook	320040	5841166	20/01/02	22:15	1AF	1	S
Merri Creek below the trainline crossing, Donnybrook	320083	5841029	20/01/02	22:50	1AF	1	S
Merri Creek above the trainline crossing, Donnybrook	319852	5841203	20/01/02	22:30	1A	1	S
Kalkallo Creek at Donnybrook Rd crossing	318727	5843001	20/01/02	23:10	1SA	1	S
Kalkallo Creek at Donnybrook Rd crossing	318707	5843009	20/01/02	23:17	1AF	1	S
Kalkallo Creek at Donnybrook Rd crossing	318714	5842987	20/01/02	23:23	1AF	1	S
Kalkallo Creek at Donnybrook Rd crossing	318720	5842972	20/01/02	23:28	1AF	1	S
Kalkallo Creek at Donnybrook Rd crossing	318710	5842989	20/01/02	23:30	1AF	1	S
Kalkallo Creek at Donnybrook Rd crossing	318705	5842983	20/01/02	23:36	1AF	1	S
Kalkallo Creek at Donnybrook Rd crossing	318701	5842979	20/01/02	23:40	1AM	1	S

Appendix 2. (contd.)

Location	AMG (Datum: AGD66) Easting	Northing	Survey Date	Time	Abundance (each age/sex class)	Raw Abundance	Type of Record
Kalkallo Creek at Donnybrook Rd crossing	318700	5842987	20/01/02	23:55	1AM	1	S
Kalkallo Creek at Donnybrook Rd crossing	318761	5842976	20/01/02	0:00	2AF	2	S
Kalkallo Creek at Donnybrook Rd crossing	318735	5842975	20/01/02	0:14	1AF	1	S
Merri Creek SE of Bald Hill	322370	5845795	26/02/02	23:05	1AF	1	S
Merri Creek SE of Bald Hill	322419	5845821	26/02/02	23:25	1AF	1	S
Merri Creek within 'Merri Park'	324650	5848023	17/01/02	22:15	2AM	2	H
Merri Creek within 'Merri Park'	325084	5848137	17/01/02	23:05	1A	1	S
Merri Creek within 'Merri Park'	324641	5848000	17/01/02	22:10	2A	2	S
Merri Creek within 'Merriang Park'	324827	5848894	24/01/02	23:35	1AF	1	S
Merri Creek within 'Merriang Park'	324853	5848935	24/01/02	23:49	3A	2	S
Merri Creek within 'Merriang Park'	324952	5848974	24/01/02	23:59	1A	1	S
Merri Creek within 'Merriang Park'	324882	5848735	24/01/02	22:35	1A	1	S
Merri Creek within 'Merriang Park'	324934	5848738	24/01/02	23:06	1A	1	S
Merri Creek, between O'Herns Rd and Patullos Lane	319567	5834057	11/01/02	20:42	1S	1	S
Merri Creek below Patullos Lane	319269	5833880	12/02/02	0:15	1S	1	S
Merri Ck, below Freight Dr	320498	5832197	14/02/02	22:56	1AF	1	S
Merri Ck, below Freight Dr	320507	5832184	14/02/02	23:05	1?	1	S

Appendix 3. Additional records of *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments by other fieldworkers during the 2001-2002 season.

Location	AMG (Datum: AGD 66)		Date	Time	Abundance (each class)	Source	Comments
	Easting	Northing					
Northern Quarry Hole, Epping Tip	324110	5830580	13/12/01	?	1A	A. Organ (Biosis Research)	Specimens recorded active on basalt close to the water's edge. See AO for details regarding habitat within these quarry holes. Each are apparently typical quarry hole sites with extensive basalt cliffs and rock piles, clear water and dense growths of *Potamogeton pectinatus*. AO reports no breeding activity within this site during the 2001-2002 season.
Northern Retarding Basin, Epping Tip	324140	5830680	24/10/01	?	6AM	A. Organ (Biosis Research)	Specimens recorded calling from the water's edge. AO reports no tadpoles or metamorphs located within this site despite the presence of calling males.
Southern Quarry Hole, Epping Tip	324140	5830260	10/01/02	?	29A	A. Organ (Biosis Research)	Specimens recorded calling, sheltering beneath basalt and active on the water's edge. Several specimens calling from open water (probably floating amongst *Potamogeton*). AO reports recording *L. raniformis* tadpoles from this site during the season.
Adjacent to Southern Quarry Hole, Epping Tip	324286	5830180	10/01/02	?	1AM	A. Organ (Biosis Research)	Lone specimen recorded in a small water-body above quarry hole.
Merri Creek, downstream of O'Hern's Rd	319700	5832800	15/11/01	20:15	2AM	L. Williams (Ecology Australia)	Males calling around 100 m apart. Further details not available.
Merri Creek, upstream of Summerhill Rd	320063	5839750	26/11/01	20:30	1AF	L. Williams (Ecology Australia)	Specimen active within pool with abundant Water Ribbon (*Triglochin procera*)
Curley Sedge Creek, upstream of O'Hern's Rd	320047	5833227	27/11/01	20:45	1AM	L. Williams (Ecology Australia)	Calling from bank-side vegetation (primarily *Juncus* spp.)
Former quarry hole (northern most) south of Coopers St	322170	5830501	19/12/01	14:00	5AM	L. Williams (Ecology Australia)	Calling at water's edge
Former quarry hole (south-east most) south of Coopers St	322000	5830000	19/12/01	14:00	3AM	L. Williams (Ecology Australia)	Calling at water's edge
O'Hern's Swamp, Somerton	320514	5832862	15/11/01	23:20	2AM	L. Williams (Ecology Australia)	Calling from emergent vegetation?
Water-body south of O'Hern's Swamp	320524	5832791	15/11/01	23:30	5AM	L. Williams (Ecology Australia)	Calling

Appendix 3. (contd.)

Location	AMG (Datum: AGD 66)		Date	Time	Abundance (each class)	Source	Comments
	Easting	Northing					
Merri Creek, upstream of O'Herns Rd Somerton	319482	5833521	27/11/01	?	3AM	Paul Oliver & Aaron Grigo	Specimens calling from unknown locality and microhabitat
Merri Creek below Patullos Lane	319271	5833890	27/11/01	19:00	10A	Paul Oliver & Aaron Grigo	Specimens seen active amongst emergent and floating vegetation
Merri Creek, pool upstream of Patullos Lane	319582	5834064	27/11/01	20:00	4A	Paul Oliver & Aaron Grigo	Specimens active and calling amongst dense Water Ribbon (*Triglochin procera*) foliage mid-stream
Merri Ck directly above Donnybrook Rd	319600	5842950	30/03/01	?	1A	Landholder	Specimen active on the lawn of house close to Merri Creek. Identity confirmed with photo
Kalkallo Ck at Donnybrook Rd crossing	318707	5843009	22/01/02	23:00	1AF	Rob Valentic	Specimen crossing Donnybrook Rd bridge over Kalkallo Creek during light rain
Former quarry north of Coopers St	320611	5832421	16/11/01	?	10-20AM	Brendan Casey	Chorus of specimens within the remaining Former quarry hole north of Coopers St. Recording of chorus provided by BC

Appendix 4. **Historical records of *Litoria raniformis* within the Merri Creek Corridor and adjacent catchments.**
Data presented include those obtained from the Atlas of Victorian Wildlife, those obtained from local naturalists, and those of Williams (2001).

Location	Co-ordinates		Date	Abundance (each class)	Type of Record	Source
	Longitude	Latitude				
Atlas of Victorian Wildlife						
Bundoora - Yan Yean Road	14504	3742	20/04/64	?	M	AVW
Craigieburn	14456	3736	17/09/66	?	M	AVW
Darebin Creek, Preston - West Heidelberg	14502	3744	19/03/72	?	M	AVW
Roughly 2 km south of Cambellfield	14458	3741	2/12/86	10?	O	AVW
Within 2 km of La Trobe University	14503	3743	20/12/86	2?	O	AVW
Roughly 2 km west of Greenvale	14451	3738	27/01/87	1?	S	AVW
Roughly 2 km west of Greenvale	14451	3738	6/02/87	1?	O	AVW
Roughly 2 km west of Airport West	14452	3743	11/05/88	1?	O	AVW
Roughly 2km south-west of Summerhill	14457	3737	15/06/88	24?	O	AVW
Roughly 2 km north of Wollert	14502	3735	23/06/88	2?	O	AVW
Roughly 2 km east of Ridley Hill	14457	3734	4/07/88	1?	O	AVW
Roughly 2 km north-east of Wollert	14503	3735	4/07/88	1?	O	AVW
Within 2 km of Erinbank High School	14454	3741	2/08/88	2?	O	AVW
Roughly 2 km south-west of Bald Hill	14458	3731	20/09/88	6?	S	AVW
Roughly 2 km south of Wollert	14502	3737	29/09/88	1?	S	AVW

Appendix 4. **(contd.)**

Location	Co-ordinates		Date	Abundance (each class)	Type of Record	Source
	Longitude	Latitude				
Roughly 2 km north of Woodstock	14502	3732	4/10/88	2?	O	AVW
Roughly 2 km north-west of Plenty Gorge	14504	3734	5/10/88	1?	O	AVW
Within 2 km of Bald Hill	14459	3730	18/10/88	1?	O	AVW
Roughly 2 km north of Woodstock	14502	3732	25/10/88	1?	O	AVW
Roughly 2 km north of Darrawiet Gium	14455	3723	23/12/88	1?	H	AVW
Roughly 2 km north-west of Quarry Hill	14503	3736	31/12/88	1?	O	AVW
Roughly 2 km north of Wollert	14502	3735	15/02/89	1?	S	AVW
Roughly 2 km north-west of Thomastown	14458	3739	15/08/89	?	O	AVW
Roughly 2 km south of Hearne's Swamp	14459	3727	14/11/89	2?	O	AVW
Roughly 2 km north-east of Mickelham	14454	3733	18/12/89	2?	O	AVW
Roughly 2 km north-west of Thomastown	14458	3739	31/01/90	?	O	AVW
Within 2 km of Bundoora Park	14502	3742	28/02/91	2?	O	AVW
Within 2 km of Kingsbury	14502	3743	4/03/91	3?	O	AVW
Within 2 km of Lalor Park Primary School	14502	3741	5/03/91	1?	O	AVW
Roughly 2 km south-west of Aitkon Hill	14453	3738	17/05/91	2?	O	AVW
Roughly 2 km north-west of Plenty Gorge	14504	3734	4/10/91	2?	O	AVW
Roughly 4 km south of Summerhill	14458	3738	4/10/91	300?	O	AVW

Appendix 4. (contd.)

Location	Co-ordinates		Date	Abundance (each class)	Type of Record	Source
	Longitude	Latitude				
Within 2 km of Mill Park	14504	3740	7/11/91	100?	O	AVW
Roughly 2 km west of Beveridge	14458	3728	11/11/91	1?	O	AVW
Roughly 2 km west of Beveridge	14458	3728	24/11/91	4?	O	AVW
Roughly 2 km east of Ridley Hill	14457	3734	24/11/91	1?	O	AVW
Roughly 2 km south-west of Donnybrook	14457	3733	28/11/91	1?	O	AVW
Roughly 2 km north of Edward's Lake	14459	3742	3/03/92	2?	O	AVW
Boral Quarry, Donnybrook	14458	3730	3/02/95	?	O	AVW
Boral Quarry, Donnybrook	14458	3730	3/02/95	?	T	AVW
Shankland Wetlands, Broadmeadows	14454	3739	15/10/96	2?	H	AVW
Shankland Wetlands, Broadmeadows	14454	3739	26/01/97	1?	H	AVW
Shankland Wetland, Broadmeadows	14454	3739	4/10/99	1?	H	AVW
Thomastown-Bundoora	14502	3738	10/04/00	1?	S	AVW
Thomastown	14502	3741	10/04/00	3?	S	AVW
Epping Waste Facility	14502	3741	28/09/00	27?	S	AVW
O'Hern's Rd between Curly Sedge and Merri Creeks	14457	3737	9/11/00	1AM	H	AVW
Curly Sedge Creek 200m N of O'Hern's Rd	14457	3737	9/11/00	1A	S	AVW
Curly Sedge Creek	14457	3737	9/11/00	1AM	S	AVW

Appendix 4. **(contd.)**

Location	Co-ordinates		Date	Abundance (each class)	Type of Record	Source
	Longitude	Latitude				
O'Hern's Rd	14458	3737	9/11/00	1AF	S	AVW
Curly Sedge Creek 150m N of O'Hern's Rd	14458	3738	9/11/00	2A	S	AVW
100m S of O'Hern's Rd	14458	3738	9/11/00	2?	S	AVW
Nubrik Property	14458	3736	2/12/00	3?	H	AVW
Curly Sedge Creek	14457	3736	4/12/00	2S	S	AVW
Swamp 100m S of O'Hern's Rd	14458	3738	4/12/00	1AM	H	AVW
Merri Creek about 20m downstream of Summer Hill Rd	14457	3734	6/12/00	2?	H	AVW
100M N of O'Hern's Road on Merri Creek	14457	3737	11/12/00	2AM	S	AVW
100M N of O'Hern's Road on Merri Creek	14457	3737	11/12/00	1AM	H	AVW
100M N of O'Hern's Road on Merri Creek	14457	3737	11/12/00	1AF	S	AVW
Merri Ck north of O'Hern's Road	14457	3737	11/12/00	15?	S	AVW
Merri Creek north of O'Hern's Road	14457	3737	11/12/00	1AM	S	AVW
Merri Ck north of O'Hern's Road	14457	3737	11/12/00	5A	S	AVW
Merri Creek N of O'Hern's Road	14457	3737	11/12/00	1AF	S	AVW
Merri Creek N of O'Hern's Road	14457	3737	11/12/00	1AF	S	AVW
Merri Creek N of O'Hern's Road	14457	3737	11/12/00	3AM	S	AVW
Merri Creek N of O'Hern's Road	14457	3737	11/12/00	15A	S	AVW

Appendix 4. (contd.)

Location	Co-ordinates		Date	Abundance (each class)	Type of Record	Source
	Longitude	Latitude				
Merri Creek N of O'Hern's Road	14457	3737	11/12/00	5A	S	AVW
Merri Creek S of O'Hern's Road	14457	3738	12/12/00	5AM	S	AVW
Confluence of Curly Sedge and Merri Creek's	14457	3738	12/12/00	1AM	H	AVW
Swamp adjacent to O'Hern's Road	14458	3738	12/12/00	2?	H	AVW
Merri Creek just below O'Hern's Road crossing	14457	3738	31/01/01	3FP	T	AVW
McKimmies Rd Quarry	14502	3741	16/03/01	77?	T	AVW
Roughly 2 km east of Summerhill	14459	3736	0/0/1986	?	O	AVW
Within 2 km of Lalor East Primary School	14502	3741	0/0/1986	?	L	AVW
Within 2 km of Lalor East Primary School	14502	3741	0/0/1986	?	L	AVW
Within 2 km of Bundoora Park	14502	3742	0/0/1986	?	O	AVW
Within 2 km of Kingsbury	14502	3743	0/0/1986	?	O	AVW
Within 2 km of Lalor East Primary School	14502	3741	0/0/1989	?	O	AVW
Braelands, Merri Creek, 3.5 km NE of Donnybrook	14459	3730	0/1/1993	?	H	AVW
Braelands Wetlands, 2.4 km E of Donnybrook	14459	3732	0/1/1993	?	H	AVW

Appendix 4. (contd.)

Location	Co-ordinates		Date	Abundance (each class)	Type of Record	Source
	Easting	Northing				
Additional Records - Local Naturalists						
Merri Creek, sections below Barry Rd, Cambellfield	321075	5827200	1970-75	50-60A	S	B. Casey
Small marsh just west of Gowrie station, Fawkner	319800	5825400	1970-75	Adults	S	B. Casey
Wetland west of the Merri Ck at Jukes Rd, Fawkner	321625	5824950	1970-1975	Adults	S	B. Casey
Merri Ck, just east of Baker's Rd, Coburg North	320775	5822300	1970-75	Tadpoles	S	B. Casey
Central Creek below Davidson St	322070	5825775	1976-1979	'Many'	S	R. Valentic
Merri Ck, directly east of McBryde St, Fawkner	321875	5825400	1977	'Many'	S	R. Valentic
Aitkon Ck, north-east of Mitford Cr, Craigieburn	318050	5835700	1979	'Many'	S	R. Valentic
Johnstone St, Westmeadows (Moonee Ponds Ck, Yuroke Ck)	315000	5827150	c. 1980	'Many'	S	C. Stevenson
Merri Ck east of Freight Drive, Somerton	320800	5831975	7/08/82	2A	S	R. Valentic
Merri Ck, north-east of Freight Dr, Somerton	320425	5832325	14/08/82	2SA	S	R. Valentic
Merri Ck, north-east of Freight Dr, Somerton	320500	5832325	26/08/82	10?	S	R. Valentic
Merri Ck below Barry Rd, Cambellfield (Humphreys Hill)	321200	5828550	11/12/82	1A	S	R. Valentic
Merri Ck north of Coopers St, Cambellfield	320800	5831600	2/04/83	1A	S	R. Valentic
Merri Ck below Barry Rd, Cambellfield	321200	5828550	7/05/83	3A, 1J	S	R. Valentic
Merri Ck east of Freight Drive, Somerton	320400	5832400	12/05/83	1A	S	R. Valentic
Merri Ck, east of Freight Drive, Somerton	320750	5832000	24/06/83	3A, 4SA	S	R. Valentic

Appendix 4. (contd.)

Location	Co-ordinates		Date	Abundance (each class)	Type of Record	Source
	Easting	Northing				
Merri Ck east of Freight Drive, Somerton	320700	5832075	13/09/85	1J	S	R. Valentic
Curley Sedge Ck, upstream of O'Herns Rd	320075	5833208	11/07/93	1SA	S	R. Valentic
Merri Ck below Barry Rd, Cambellfield	321200	5828800	1993	12A	S	C. Stevenson
Merri Ck above the trainline crossing, Donnybrook	319812	5841197	Winter 2000	'Many'	S	R. Valentic
Additional Records - Williams 2001						
O'Herns Swamp	320514	5832862	30/11/00	?	S/H?	Williams 2001
Small wetland to the east of O'Herns Swamp	320539	5832897	30/11/00	1AF	S	Williams 2001
Merri Creek just below the Summerhill Rd bridge	320205	5839345	6/12/00	2AM	H	Williams 2001
Merri Creek just below the Summerhill Rd bridge	320205	5839345	11/12/00	2AM	H	Williams 2001
Merri Creek, c. 800m upstream of Craigieburn Rd East	319181	5836771	12/12/00	1A?	S	Williams 2001
Merri Creek, c. 100m section downstream of Summerhill Rd	320205	5839345	14/12/00	1A?	S	Williams 2001
Wetland within the Lalor Golf Course	322186	5829153	20/12/00	1AM	H	Williams 2001
Merri Creek, c. 500m section north of Summerhill Rd	320210	5839500	3/01/01	4AM, 1AF	S/H	Williams 2001
Merri Creek at the railway crossing north of Summerhill Rd	319927	5841194	8/01/01	1AM	H	Williams 2001
Curly Sedge Ck, between 400m and 700m upstream of O'Hern's Rd	320190	5833130	30/11/01	3AF	S	Williams 2001