546

ABC NEWS

Rare giant burrowing frog in world-first captive breeding program at Melbourne Zoo

ABC Gippsland / By Mim Cook

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Giant burrowing frogs have small areas of habitat in East Gippsland and Central Victoria. *(Supplied: Rohan Bilney)*

When PHD student Danielle Wallace ventured into the East Gippsland bush last August, she set off a chain of events that led to Melbourne Zoo scientists trudging out of the same forest with tadpoles in their backpacks several months later.

Key points:

- Melbourne Zoo scientists are involved in the first captive conservation program for the giant burrowing frog
- The rare frog, *Heleioporos* australiacus, is found in remote parts of East Gippsland, much of which has been fire-affected
- Zoos Victoria and the Arthur Rylah Institute have taken tadpoles to Melbourne to study them and breed them

Now for the first time, the critically endangered and quite clandestine giant burrowing frog is being monitored in captivity at Melbourne Zoo, with an aim to protect and rebuild the population of this mysterious species.

Ms Wallace, a PHD student in veterinary sciences at Melbourne University, is studying amphibians. Finding the giant burrowing frog in far East Gippsland was a mixture of good luck and knowing exactly what the rare frog's call sounds like.

"It was really quiet so I turned off my torch and all of a sudden a frog starts calling, 'Boop boop boop boop,'" she said.

"Over the next five minutes all these different frogs started calling, which was just amazing because these frogs are so hard to find hardly anyone hears them.

"We kind of ran around the creek all excited and found at least five other frogs calling from their burrows.

"I was on cloud nine.

"Then here was this gorgeous male calling from his burrow and I picked him up and showed him to my workmate and burst into tears because I was so excited."

Danielle Wallace cried when she found this g burrowing frog. *(Supplied)*

'They're incredibly hard to find'

Arthur Rylah Institute researcher Nick Clemann has helped with the field work to locate the population that Ms Wallace found.

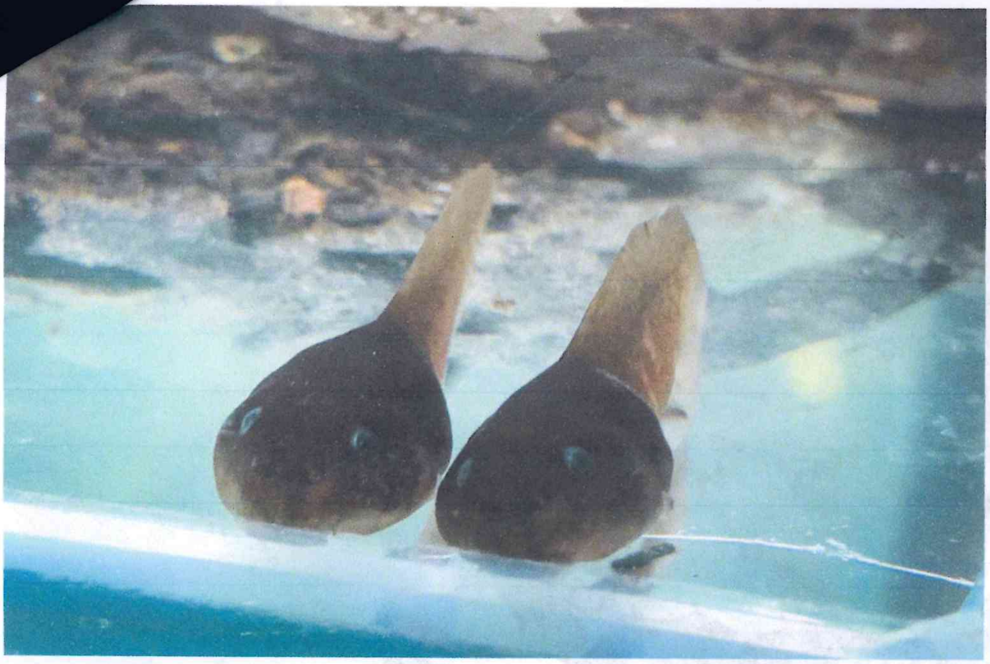
It's this ground work that has led to Melbourne Zoos' recent tadpole retrieval process.

"It's incredibly hard to find and incredibly unpredictable, " Mr Clemann said.

"When someone finds one, that same person can go back to the same spot, and in the same conditions, and won't find a thing.

"If they don't need to be out and about, then they won't be.

"They are really good at doing nothing."



Frog experts have collected giant burrowing frog tadpoles from East Gippsland to start a captive breeding program at Melbourne Zoo. *(Supplied: Zoos Victoria)*

'Luck was on our side'

Zoos Victoria threatened species biologist Deon Gilbert said it was challenging finding the tadpoles and then transporting them from the forest to the zoo.

"Before we headed out we didn't actually know if we'd find anything," he said.

"The ponds that the tadpoles develop in can actually dry out pretty quickly.

"We hiked out to one of the few breeding sites. It's really quite confronting going out to these breeding sites because they're in heavily-logged areas.

"It's not that typically pristine picture you paint of this really pristine forest. The forest has been heavily disturbed on numerous occasions.

"Fortunately enough, the third pond we found had some large, well-developed tadpoles sitting in it. Many of these field scientists had been out to these ponds and never seen a tadpole.

> "I think, for a change, luck was on our side — to be able to share this moment with colleagues was pretty exhilarating."

Giant burrowing frog tadpoles can grow to almost 8 centimetres in length. This is a helpful clue when identifying them but, Mr Clemann says, "it's not easy ID-ing taddies".

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Researchers collect tadpoles from a waterway in an area that was heavily affected by last summer's bushfires. *(Supplied: Melbourne Zoo)*

The group of scientists then put the tadpoles into plastic bags and hiked out of the bush.

"The tadpoles are all healthy and going well," Mr Gilbert said.

"What we've learned about them so far is that they are hungry, they chomp food 24/7."

Ms Wallace said she was happy that her discovery meant more would be learned about giant burrowing frogs and how best to protect them.

"Knowing these tadpoles are safely at the zoo, knowing the species could be protected, it means so much to me and probably to the frogs too," she said.

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Spatial ecology of the giant burrowing frog (Heleioporus australiacus): implications for conservation prescriptions

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Abstract

Management of threatened anurans requires an understanding of a species' behaviour and habitat requirements in both the breeding and non-breeding environments. The giant burrowing frog (Heleioporus australiacus) is a threatened species in south-eastern Australia. Little is known about its habitat requirements, creating difficulties in developing management strategies for the species.Weradio-tracked 33 individual H. australiacus in order to determine their habitat use and behaviour. Data from 33 frogs followed for between 5 and 599 days show that individuals spend little time near (<15 >m) their breeding sites (mean 4.7 days for males and 6.3 days for females annually). Most time is spent in distinct non-breeding activity areas 20–250m from the breeding sites. Activity areas of females were further from the breeding site (mean 143 m) than those of males (mean 99 m), but were not significantly different in size (overall mean 500m2; males 553m2; females 307m2). Within activity areas, each frog used 1–14 burrows repeatedly, which weterm home burrows. Existing prescriptions are inappropriate for this species and we propose protection of key populations in the landscape as a more appropriate means of protecting this species.

Keywords

frog, giant, ecology, heleioporus, burrowing, spatial, prescriptions, australiacus, implications, conservation

Disciplines

Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

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Spatial ecology of the giant burrowing frog (*Heleioporus australiacus*): implications for conservation prescriptions

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Abstract. Management of threatened anurans requires an understanding of a species' behaviour and habitat requirements in both the breeding and non-breeding environments. The giant burrowing frog (*Heleioporus australiacus*) is a threatened species in south-eastern Australia. Little is known about its habitat requirements, creating difficulties in developing management strategies for the species. We radio-tracked 33 individual *H. australiacus* in order to determine their habitat use and behaviour. Data from 33 frogs followed for between 5 and 599 days show that individuals spend little time near (<15 m) their breeding sites (mean 4.7 days for males and 6.3 days for females annually). Most time is spent in distinct non-breeding activity areas 20–250 m from the breeding sites. Activity areas of females were further from the breeding site (mean 143 m) than those of males (mean 99 m), but were not significantly different in size (overall mean 500 m^2; males 553 m^2; females 307 m^2). Within activity areas, each frog used 1–14 burrows repeatedly, which we term home burrows. Existing prescriptions are inappropriate for this species and we propose protection of key populations in the landscape as a more appropriate means of protecting this species.

Introduction

Many anuran species have distinct breeding and non-breeding habitats (e.g. Pearson 1955; Kelleher and Tester 1969; Schwarzkopf and Alford 2002; Schabetsberger *et al.* 2004), but most research on frog habitat use has examined the breeding habitat requirements of a species. Non-breeding habitat requirements of anurans have remained largely unstudied (Lemckert 2004), even though it is recognised that managing the complementary breeding and non-breeding habitats as a unit is an essential step in the conservation of species using multiple habitats throughout the year (e.g. Richter *et al.* 2001; Semlitsch and Bodie 2003).

Burrowing anuran species, as a group, have rarely been studied and little is known of their patterns of habitat use. Studies by Pearson (1955), Bamford (1992), Dodd (1996) and Jansen *et al.* (2001) suggest that most, if not all, burrowing frog species have complementary breeding and non-breeding habitat use patterns, and that burrowing anuran species may occupy non-breeding sites at greater distances from breeding sites (i.e. waterbodies) than non-burrowing species (e.g. Dodd 1996), and possibly for longer periods (e.g. Pearson 1955). Burrowing frog species may therefore present a greater challenge for conservation because they require larger areas of habitat to complete their life cycles.

The giant burrowing frog (*Heleioporus australiacus*) of south-eastern Australia is a listed threatened species under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* and corresponding state legislation in both states in which it occurs, making its management a high priority. However, the lack of knowledge about its ecology (Tyler 1997; Lunney *et al.* 2000) and hence its management remains a difficult challenge. Individuals breed in intermittently flowing streams running through areas of native vegetation (Penman *et al.* 2006*a*). In the southern portion of its range the species is considered to be associated with a variety of dry forest communities (Littlejohn and Martin 1967; Gillespie 1990; Webb 1991; Lemckert *et al.* 1998; Penman *et al.* 2005*a*), whereas in the northern portion it is considered to be more commonly associated with heath communities (Mahony 1993; Daly 1996). Data from a small number of frogs followed for a short time suggest that individuals spend most of their time in forest areas away from riparian zones (Lemckert and Brassil 2003), following the patterns of the other burrowing species studied. The frog has not been recorded in areas cleared of native vegetation throughout its range (Penman *et al.* 2004). This information suggests that management of this species needs to be based on managing breeding and non-breeding habitat as a unit.

In this paper, we examine the movements and habitat use of a population of *H. australiacus* and compare information on microhabitat between 'used' and random points to try to determine what may be valuable site attributes for this species. We then use these data to assess the efficacy of the various conservation management prescriptions established for this species.

Materials and methods

The study was conducted in a 200-ha area of Nullica State Forest in the south-east of Australia (37°2′S, 149°54′E) ~10 km

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north of the township of Eden. Most of the site is classified as lowland dry shrub forest and the gully areas are classed as hinterland wet shrub forest (Keith and Bedward 1999). These forests are open sclerophyllous coastal forests with the dominant canopy species being red bloodwood (*Corimbya gummifera*), blackbutt (*Eucalyptus pilularis*) and blue stringybark (*E. agglomerata*). These areas have a heath understorey dominated by *Acacia longifolia*, *Hakea sericea* and *Pteridium esculentum*.

We used radio-telemetry to examine the behaviour and habitat use of individual *H. australiacus*. Frogs were initially located using nocturnal road transects and pitfall trapping (Penman 2005). Individuals were implanted with single-stage 2-g transmitters supplied by Sirtrack, New Zealand. The animals were anaesthetised with MS-222 (tricaine methane-sulfonate) (Ruth Consolidated Industries, Annandale, Australia) and then the transmitters were surgically implanted (Penman *et al.* 2006*b*). Frogs were located using a Titley Regal 2000 receiver in conjunction with a Yagi-style antenna to identify the general location of the frog and a loop wand antenna to identify the exact location of the burrow site. All tracking gear was supplied by Titley Electronics, Australia.

Thirty-three frogs (19 male, 13 female, one subadult male) were tracked between February 2002 and April 2004. Individuals were followed for periods of between 5 and 599 days, with a median tracking period of 108 days per frog, and between three and nine frogs were tracked simultaneously. Locations were obtained daily for the majority of the study with measurements being taken on 518 days, resulting in a total of 3303 location records from 256 unique non-breeding sites and eight breeding sites. Tracking effort was consistent throughout each season across the 26 months of the study. Each separate frog location was plotted by measuring the bearings and distances from known points. These points were transferred to ArcView Geographic Information System (ESRI, USA) for analyses. At each point we also recorded whether the frog was active or sheltering and, if so, whether it was in a burrow or above ground.

Movement patterns and activity areas were analysed using the Animal Movement Extension (Hooge and Eichenlaub 1997). Activity areas were defined using the minimum convex polygon (MCP) method. Bootstrapping with replacement was used to determine the number of sites required for an activity area to reach a relatively stable size. Animals tracked for only a short time (<30 days) were excluded from the analyses.

The data suggested that we were observing non-overlapping ranges. To test this we used ArcView GIS to estimate the probability that the exclusivity of activity areas could occur by random chance. To do this we used ArcView GIS to randomly place the activity areas (size and shape) of all frogs found within Areas 1 and 2 separately (Fig. 1). We then recorded the number of activity areas that overlapped another in each of 100 replicates.

A series of habitat measurements were taken at each of the 256 distinct non-breeding record sites and 100 random sites to determine whether there was an association between the characteristics of the burrow sites. Random sites were selected from areas within the study area where frogs were not observed. Measurements were taken for an area of 1 m^2 centred on the frog site or a random point. The measurements taken were: the

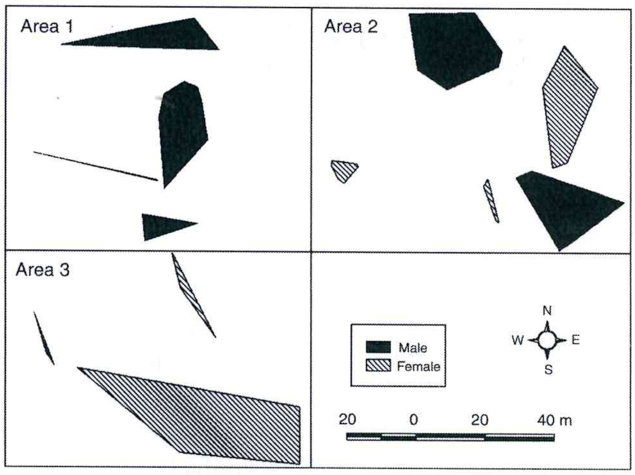

Fig. 1. Examples of the non-overlapping activity areas of *Heleioporus australiacus* for three clusters of frogs within the study area.

proportion of ground cover that comprised leaves or bare ground (i.e. 'burrowable' area), rocks, woody debris and vegetation, the soil type, average leaf litter depth (within 1 m^2), leaf litter depth above burrow, distance to the road, vegetative cover provided by the canopy, understorey or subcanopy (3–15 m), shrub layer (0.5–3 m) and ground cover (0–0.5 m), distance to the nearest small tree (diameter at breast height (dbh) <100 mm), distance to the nearest large tree (dbh >100 mm) and distance to the nearest known or potential breeding site.

A comparison was made between the habitat selectivity of the two sexes using a multivariate analysis of variance (ANOVA). All factors were initially included and then non-significant factors were removed in a stepwise manner (Rosenthal and Rosnow 1985). The number of sites was not consistent between individuals, therefore to fulfil the assumptions of ANOVA (Sokal and Rohlf 1995) we used an average of the habitat conditions for all of the sites used by a frog. Frogs for which fewer than three non-breeding site records were available were removed from the dataset, resulting in mean non-breeding habitat conditions for a total of 17 males and 11 females.

Habitat associations were examined using a forwards continuation-ratio model (Guisan and Harrell 2000) in SAS ver. 8.2 (SAS Institute Inc., USA). These models are used for ordinal data and model the ratio of the two probabilities $\Pr(Y=j|x)$ and $\Pr(Y>j|x)$ (Ananth and Kleinbaum 1997); that is, the model predicts the probability of being in a group (j) given that the sample is taken for those data that are either in group j or higher on the ordinal scale. The ordinal factor used in this analysis was based on site usage. Random sites were assigned a value of 0, sites where an individual sat on the surface were assigned a value of 1, burrows that were only visited once (single-use burrows) were assigned a value of 2 and burrows that were visited more than once (multiple-use burrows) were assigned a value of 3. Continuation ratio models allow us to simultaneously model the probability of being a random site when all sites were considered (i.e. values of 0, 1, 2 or 3), the probability of an animal sitting on the surface when all frog sites were considered (i.e. values of 1, 2 or 3) and the probability of a frog using a burrow once when all burrow sites were considered (i.e. values of 2 or 3). We used extended continuation-ratio models, which allow for different slopes for all of the x values (Guisan and Harrell 2000). Continuation ratio models were run using Generalised Estimating Equations (Liang and Zeger 1986) to remove any potential effects of pseudoreplication by repeatedly measuring the habitat of an individual. Variables were tested individually and those significant at the 0.05 level were used to build the final model. The area under the curve (AUC) value from the receiver operating characteristic (ROC) curve with the traditional academic point system (Swets 1988) was used to measure the fit of the model (Thuiller *et al.* 2003). The ROC curve represents the relationship between the true positive (sensitivity) and the false positive fraction (1-specificity) of the model over a range of threshold values (Woodward 1999). A good model maximises the true positive values and minimises false positive values.

Results

Breeding activity

Frogs were recorded moving to breeding sites only rarely during our study. Frogs undertook breeding migrations between February and April (Fig. 2), and once in October 2002. Only 4 of the 13 adult females and 10 of the 19 adult males were observed entering a breeding site during the period when they were tracked. Migrations to breeding sites were always associated with rainfall events, moving on the night of, or within 10 days of, rainfall of more than 20 mm.

Six discrete breeding sites were used by the frogs tracked in this study. Four of the sites were situated in semipermanent pools in first- and second-order streams and the other two sites were roadside ponds (for more details see Penman *et al.* 2006*a*). Individual frogs spent only 1–12 days at a breeding site, with a mean of 5.00 ± 0.89 days. There was no significant difference between males and females in the time spent in the breeding site (males mean 4.6 day and females 6.3 days; $t = -0.837$, d.f. = 4, $P = 0.450$). When at a breeding site, individuals either burrowed into the ground or sheltered under vegetation or woody debris. The points where frogs sheltered

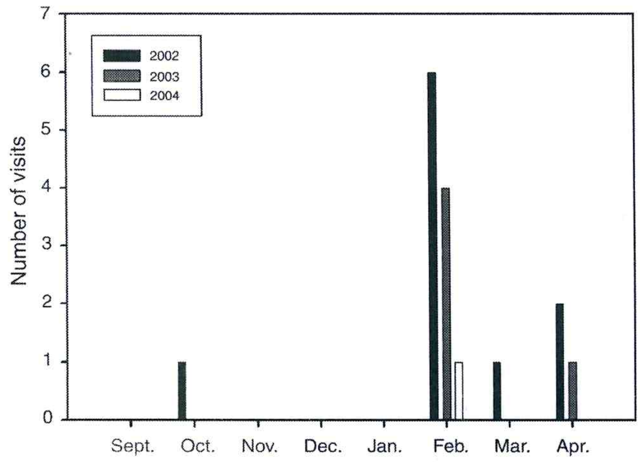

Fig. 2. The number of individual frogs visiting the breeding sites by month throughout the entire study period.

when breeding were 1–17 m from the breeding site with an average distance of 9.2 m ($n = 13$).

Non-breeding activity

All tracked individuals used a limited number of burrows located within a discrete forest area during their non-breeding activities, which we refer to hereafter as their 'activity area'. The burrows used by this species were not structured burrows and could rarely be recognised from the surface. On each visit to a burrow an individual frog must dig through the soil surface. The Loop wand allowed the location of the burrow to be determined to within 2 cm and therefore repeated use of a burrow could be determined precisely.

Bootstrapping with a MCP indicated that the size of individual activity areas stabilised after ~110 records; datasets of this size were available for only 14 frogs (8 males, 6 females). Therefore, we compared the activity of frogs for which more than 110 records were available to that of frogs for which 30–110 records were available (mean 56 records; 5 males, 5 females, 1 subadult). We refer to these frogs as having a stable activity area and an expanding activity area respectively. There was no significant difference in the size of the non-breeding activity areas between the sexes for both frogs with stable activity areas ($t = -1.67$, d.f. = 11, $P = 0.12$) and those with expanding activity areas ($t = -0.56$, d.f. = 8, $P = 0.59$) and so we combined the data for the sexes for further analyses. Mean activity areas for frogs with stable estimates for activity areas were 498.1 ± 79.1 m^2 compared with 200.2 ± 39.1 m^2 for those frogs with expanding activity areas (as determined by bootstrapping analysis).

Figure 1 demonstrates the locations of activity areas for three different clusters of frogs at the study site, using the MCPs generated for each individual to demarcate their non-breeding activity areas. Each cluster is separated by a minimum of 100 m and therefore is presented separately. Of particular note is that there is no evidence of overlap between any of the activity areas generated at any of the three locations, regardless of sex.

We used a simulation technique to determine whether the non-overlapping home ranges could occur randomly for two clusters of frogs observed in the study. For Area 1, only 9 of the 100 attempts exhibited exclusive activity areas for all frogs and in Area 2 this was reduced to 3 (Table 1). There is thus an overall probability of 0.0027 (0.09×0.03) that the activity areas in both Area 1 and Area 2 are exclusive for all frogs considered. It is therefore unlikely that the observed exclusivity of activity areas occurred by chance alone.

Seven frogs (5 males, 2 females) were radio-tracked for more than one season. One male established a new activity area 500 m from his original area. The remaining six animals used several home burrows between years and portions of the same activity area for two (4 males, 1 female) or three (1 female) consecutive seasons (see Fig. 3 for two examples).

All recorded activity areas had central points located 20–250 m from the breeding streams (Fig. 4). Although activity areas for each sex were found across all distances from the streams, those of males were significantly closer (mean 99 m) than for females (mean 143 m) ($F = 4.78$, d.f. = 1,27, $P = 0.038$). The distance from the central point of the activity area to the breeding site was not related to the body size (snout–vent length) for males

Table 1. Number of overlapping home ranges in 100 random placements of activity areas

No. of frogs with exclusive ranges	Area 1	Area 2
All	9	3
3	24	12
2	30	28
1	25	40
0	12	17

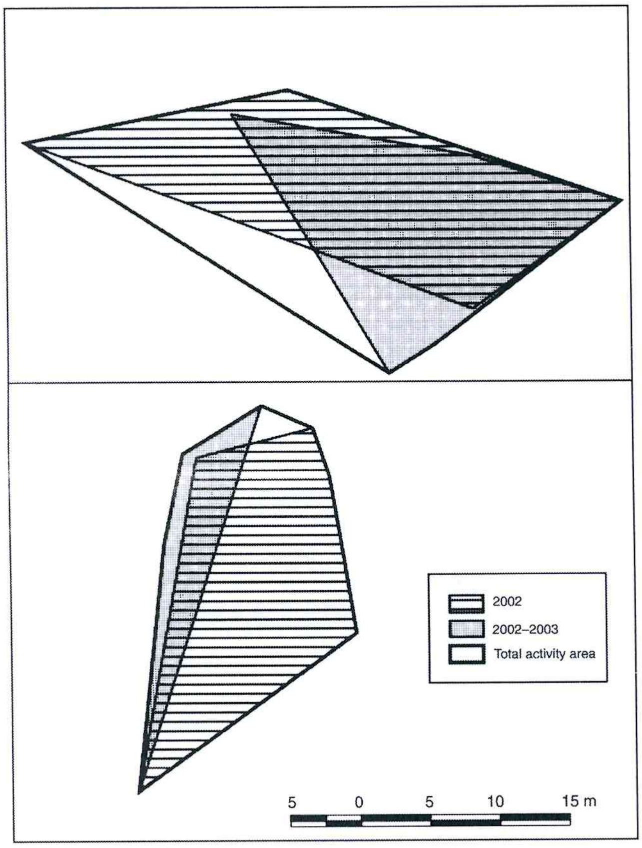

Fig. 3. Seasonal variation in yearly activity areas for two frogs for which data are available.

(F = 0.246, d.f. = 1,7, P = 0.638), females (F = 0.625, d.f. = 1,5, P = 0.474) or both sexes combined (F = 0.060, d.f. = 1,13, P = 0.810).

Burrowing

Individuals in the non-breeding area primarily sheltered diurnally by burrowing into the soil (1791 records for males, 98.2%; 1279 records for females, 99.1%). We also recorded frogs sitting on the substrate on 32 occasions, partially burrowed in leaf litter 12 times and twice perched within the foliage of grass trees (*Xanthorrhoea australis*) ~0.4 m above the soil surface. The

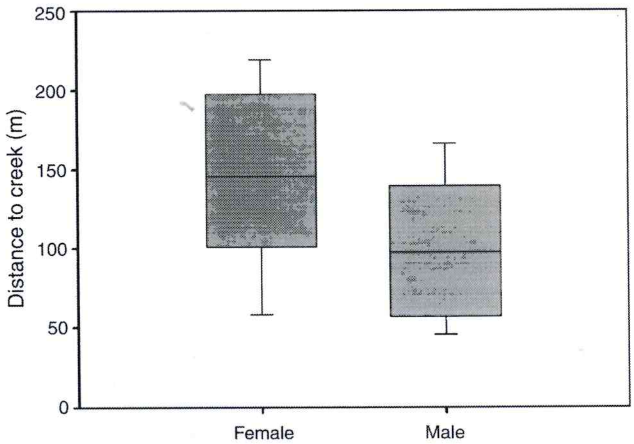

Fig. 4. Average distance of male and female activity areas from known breeding sites.

choice of diurnal shelter sites did not differ by sex ($\chi^2 = 4.96$, d.f. = 2, $P = 0.084$).

Each frog occupied single-use burrows and multiple-use burrows (which we term home burrows). We defined a home burrow as a site that was used on two or more separate occasions for periods longer than one night. Males used 3 to 12 (mean 6.78) burrows in each area, whereas females used 3–24 (mean 8.72) burrows. Males used 1–7 home burrows (mean 3.5) and females used 1–14 (mean 4.2). With the data corrected for the number of records per frog, there was no significant difference between the sexes for the number of burrows used (t = 2.06, d.f. = 23, P = 0.78) or the number of home burrows (t = 2.07, d.f. = 23, P = 0.53).

Across all visits, the number of days spent in a home burrow during a single visit ranged from 1 to 156 for males with a mean of 13.2 ± 1.7 (mean ± s.e.) days and from 1 to 95 days with a mean of 11.2 ± 1.3 (mean ± s.e.) for females. Two frogs (1 male, 1 female) used the same burrow for a period of three months and were observed to be active during this period. The time between the reuse of a burrow ranged from 2 to 379 days for males (mean 34.62 ± 4.59 days) and 2 to 335 days (mean 36.1 ± 5.2 days) for females. The mean distance between home burrows was 7.63 ± 0.91 m (mean ± s.e.) and the maximum 40 m. The greatest distance travelled between home burrows on any one night was 40 m.

Non-breeding habitat characteristics

There were no significant differences between the habitat features of the burrows occupied by males and females. Points at which the species burrowed had low levels of coverage by ground vegetation with the square metre surrounding the site having a mean of 7.84 ± 1.01% ground cover. Bare ground or leaf litter (both of which are suitable for frogs to burrow in) constituted a mean of 79.78 ± 1.34% of the ground coverage, with the remainder being either woody debris (10.74 ± 1.00%) or rocks (1.64 ± 0.60%). Litter depth above the burrow was a mean of 2.76 ± 0.15 cm. Records of the frogs were from 15 m through to 240 m from a breeding site, representing the lower slope through to the ridgeline.

The final habitat model, developed using a forward continuation ratio model, is presented in Table 2. Model fit was considered good, with an AUC value of 0.802. There were no detectable differences in any of the habitat characteristics of single-use ($n = 131$) and multiple-use burrows ($n = 98$). A quadratic relationship between the location of frog sites and the distance to the breeding site was found ($P < 0.001$). This relationship suggests that two clusters of frog locations exist in the dataset: one ~60–80 m from the breeding site and another ~150 m from the breeding site. Frogs selected sites with more understorey cover ($P = 0.0009$) than was recorded at the random sites. If a frog was found at a site, the probability of the individual sitting on the surface increased as the proportion of 'burrowable' ground (i.e. leaf litter + bare ground) decreased ($P = 0.0003$).

Mortality

No mortality was recorded from the implanting procedure and all frogs appeared healthy (i.e. no wounds and maintaining body condition) when observed throughout the study. Five radio-tracked frogs were preyed upon during the course of the study: four due to red-bellied black snakes (*Pseudechis porphyriacus*) and one by a kookaburra (*Dacelo novaeguineae*). Predation of a further two frogs not implanted with radio-transmitters was recorded during the study period (Penman and Lemckert 2007).

Discussion

In this study, 33 individual *H. australiacus* were radio-tracked for extended periods and over successive seasons. This unique dataset has provided us with an improved understanding of this species' habitat use and behaviour, particularly in the non-breeding habitats. Broadly, forest habitats used in this study are consistent with the reports from the other south-east New South Wales sites (Lemckert *et al.* 1998; Lemckert and Brassil 2003; Penman *et al.* 2005*a*), Victoria (Gillespie 1990) and from the north of its range (Mahony 1993; Daly 1996). Data from this study has enabled us to develop recommendations about the most appropriate approaches for the management of this species.

Habitat use

Heleioporus australiacus spends at least 97% of its time in the non-breeding habitat. To our knowledge, this is longer than has been demonstrated for other amphibian species. This may reflect that most detailed research has either focussed on breeding behaviour (e.g. Fukuyama *et al.* 1988; Lemckert and Brassil 2000) or on post-breeding migrations (e.g. Lamoureux and Madison 1999; Richter *et al.* 2001) rather than the non-breeding habitat use itself. Some other frog species use forest areas only during primarily wet periods. For example, Bulger *et al.* (2003) found that *Rana aurora draytonii* used terrestrial sites for short periods (median of 4–6 days) only after summer rains or during the winter wet season. Other burrowing frog species have been found to spend extended periods of the year in non-breeding activity areas (e.g. Pearson 1955; Pilliod *et al.* 2002). The ability to burrow to obtain shelter seems the most likely reason for *H. australiacus* to occupy dry forest areas away from breeding sites throughout the year rather than just during wetter times.

Activity areas estimated for *H. australiacus* were similar between the sexes and were within the ranges reported for other species. In a review, Lemckert (2004) found a mean home range of 1773 m^2 (range 6.3–5099 m^2) for anurans based on 18 studies. In this study, we estimated the activity area for *H. australiacus* as 498.1 ± 79.1 m^2. However, this considered only sheltering ranges in the non-breeding habitat and the estimates would have been significantly higher if we included nocturnal movements and breeding migrations.

The non-breeding activity areas appear to be based strongly around a series of home burrow sites that are used repeatedly and are well known to the individual. Individuals are able to home directly to these sites, even after many months of non-use and in the absence of a structured burrow. This indicates that these home burrow sites must have features that are highly preferred by individuals, but what factors drive this selection are not yet clear. Sites for the activity areas appear to be selected mainly on the basis of increased shade from the shrub and understorey layers. Increased shading over a burrow site would reduce the range of temperatures experienced, resulting in a reduction in the rate of moisture loss from the soil hence from burrowed individuals. Notably, records of frogs remaining on the surface were associated with wet conditions, suggesting that they did not need

Table 2. Results from the continuation ratio model examining habitat associations for random surface, single use and home burrow sites

Parameter	Estimate	s.e.	Wald χ^2	$P > \chi^2$
Level 0 – Random				
Intercept Level 0	–9.37030	1.92000	23.8174	<0.0001
Distance to creek	0.10340	0.02390	18.6859	<0.0001
Distance to creek^2	–0.00027	0.00007	13.5625	0.0002
Understorey cover	–0.01960	0.00720	7.3902	0.0066
Shrub cover	–0.01440	0.00775	3.4555	0.063
Level 1 – Surface				
Intercept Level 1	8.69190	2.00140	18.8609	<0.0001
Percentage of ground 'burrowable'	–0.02000	0.00767	6.7830	0.0092
Level 2 – Single-use burrows				
Intercept Level 2	9.66050	1.92470	25.1937	<0.0001

to burrow to avoid desiccation. Alternatively burrowing may have been avoided at this time owing to reduced oxygen availability in the saturated soils.

Homing behaviour to sites has been observed in other frog species, with animals returning to breeding ponds (e.g. Gill 1979), over-wintering burrows (e.g. Kelleher and Tester 1969) and structured shelter sites (e.g. Seebacher and Alford 1999). However, such specific site fidelity after long periods of absence has not been reported. Pearson (1955) studied the behaviour of spadefoot toads (*Scaphiopus holbrooki holbrooki*) and found animals using 2–5 structured burrows in the non-breeding area, indicating that other burrowing frog species may have similar habits. How they find these burrows again so specifically is uncertain, although chemical cues are likely.

The finding that the activity areas of individual *H. australiacus* do not appear to overlap with those of conspecifics was unexpected. There may possibly be some overlap of activity at times that frogs were not observed, but we never located a frog sheltering within the known activity area of another individual and individuals were never observed to cross into an activity area during periods of nocturnal activity (>30 observations), adding weight to the belief that they do not share activity areas. The fact that individual activity areas never overlap suggests an active avoidance or exclusion from activity areas by individuals and so they are exhibiting non-breeding territoriality. Many anurans are well known to be strongly territorial during times of reproduction, but there is little evidence of non-breeding territoriality. Mathis *et al.* (1995) reviewed territoriality in anurans and urodeles and concluded that anurans regularly undertake territorial defence of breeding sites, but rarely show any evidence of aggressive behaviour during non-breeding periods. Pearson (1955) observed some spatial and temporal separation of *S. h. holbrooki* in the non-breeding environment, which may have been a result of territoriality, but he had no specific evidence to confirm this. There are no obvious reasons why more anurans would not exhibit non-breeding territoriality if there was a resource that was limited and worth defending. However, we do not yet know what resources would be limited for these species, and further investigation is required. In particular, the abundance of prey within forests occupied by *H. australiacus* should be assessed to determine whether they could form the limiting resource that is being defended.

Implications for conservation

The patterns of habitat use and behaviour of *H. australiacus* creates challenges for the conservation of this species where multiple-use of forests is the desired outcome. This species occupies activity areas of ~500 m^2 in dry forest areas, with only rare movement into the breeding sites. They burrow in relatively shallow unstructured burrows that support the notion that fire and commercial timber harvesting are considered the main threats for this species (Penman *et al.* 2004, 2005*b*, 2006*c*).

Prescriptions have been developed for this species that incorporate either stream-side buffer zones or broad-scale exclusion areas in which fire and logging are excluded, depending on the region in which the frog is found (e.g. Anon. 1999). In the central coast region of New South Wales, stream buffer zones of 30 m are established around all drainage lines within 200 m of a known locality for the species. Along the south coast a disturbance exclusion zone with a 500-m radius (78 ha) is established around the record. In far southern New South Wales a 200-ha exclusion zone is established around any record site for this frog within which no logging is allowed and there are restrictions placed on conducting prescribed burns. Within Victoria, where individuals are detected on smaller streams or away from streams a 50-ha disturbance exclusion zone is established. For records on larger streams a linear buffer of 100 m is established around the stream for 1 km upstream and downstream of the record.

The results of this study indicate that implementing stream-side buffer zones can probably not be applied effectively if both timber production and species conservation are the management aims. Males are more likely to be found closer to the breeding site than females and so narrower buffer zones will protect a disproportionate number of males relative to females, leading to a decline in the size of the population of breeding females and almost certain serious reductions in overall population size and genetic diversity. A larger 300-m buffer zone, as suggested by Semlitsch and Bodie (2003), will very likely protect most of a *H. australiacus* population and so be effective for conservation, but would not be practical if timber production was to continue. In areas occupied by *H. australiacus*, more than 95% of a catchment falls within 300 m of a potential breeding site, therefore for all intents and purposes 300-m buffer zones would function essentially as complete exclusion zones.

The use of buffer zones around known locations of this frog also has its limitations. Individual burrowing frogs have average non-breeding activity areas of ~0.05 ha. A 200-ha exclusion zone is therefore ~4000 times larger than an individuals' activity area and covers a significantly larger area than is used by the populations in this study. Where point records have occurred scattered over forests, large areas have been removed from forestry operations and most of this will have no significance to the species being protected.

A more suitable approach to managing this species, where timber production is also required, is the specific reservation of several known populations rather than attempts to buffer key habitat features within these areas. Specific reservation zones should be based on biologically meaningful areas that encompass several known breeding sites as well as the associated non-breeding habitat areas and not just an exclusion zone of a predetermined area, therefore the size of the zone needed to be protected will vary between areas. For most populations needing reservation, this would mean that additional surveys are required to adequately design the protection zones as this information is not currently available. The remaining populations would be protected with standard prescriptions designed to protect water quality and stream-side habitat, but recognising that most individuals will be subject to disturbances. The use of such an approach weighs up the desire of society to have a timber resource whilst trying to maintain the long-term conservation of these populations.

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References

Ananth, C. V., and Kleinbaum, D. G. (1997). Regression models for ordinal responses, a review of methods and applications. *International Journal of Epidemiology* **26**, 1323–1333. doi: 10.1093/ije/26.6.1323

Anon. (1999). 'Integrated Forestry Operations Approval Package: Eden Region.' (Resource and Conservation Division, Department of Urban Affairs and Planning: Sydney.)

Bamford, M. J. (1992). The impact of fire and increasing time after fire upon *Heleioporus eyrei, Limnodynastes dorsalis* and *Myobatrachus gouldii* (Anura, Leptodactylidae) in banksia woodland near Perth, Western Australia. *Wildlife Research* **19**, 169–178. doi: 10.1071/WR9920169

Bulger, J. B., Scott, N. J., and Seymour, R. B. (2003). Terrestrial activity and conservation of adult California red-legged frogs *Rana aurora draytonii* in coastal forests and grasslands. *Biological Conservation* **110**, 85–95. doi: 10.1016/S0006-3207(02)00179-9

Daly, G. (1996). Observations of the eastern owl frog *Heleioporus australiacus* (Anura, Myobatrachidae) in southern New South Wales. *Herpetofauna* **26**, 33–42.

Dodd, C. K. (1996). Use of terrestrial habitats by amphibians in the sandhill uplands of north-central Florida. *Alytes* **14**, 42–52.

Fukuyama, K., Kusano, T., and Nakane, M. (1988). A radio-tracking study of the behaviour of females of the frog *Buergeria beurgeria* (Rhacophoridae, Amphibia) in a breeding stream in Japan. *Japanese Journal of Herpetology* **12**, 102–107.

Gill, D. E. (1979). Density dependence and homing behavior in adult red-spotted newts *Notophthalmus viridenscens* (Raffinesque). *Ecology* **60**, 800–813. doi: 10.2307/1936616

Gillespie, G. R. (1990). Distribution, habitat and conservation status of the giant burrowing frog (*Heleioporus australiacus*) in Victoria. *Victorian Naturalist* **5**, 144–153.

Guisan, A., and Harrell, F. E. (2000). Ordinal response regression models in ecology. *Journal of Vegetation Science* **11**, 617–626. doi: 10.2307/3236568

Hooge, P. N., and Eichenlaub, B. (1997). Animal Movement Extension to Arcview version 1.1. Alaska Science Center – Biological Science Office, US Geological Survey, Anchorage, AK, USA.

Jansen, K. P., Summers, A. P., and Delis, P. R. (2001). Spadefoot toads (*Scaphiopus holbrookii holbrookii*) in an urban landscape, effects of non-natural substrates on burrowing in adults and juveniles. *Journal of Herpetology* **35**, 141–145. doi: 10.2307/1566038

Keith, D. A., and Bedward, M. (1999). Native vegetation of the South East Forests region, Eden, New South Wales. *Cunninghamia* **6**, 1–218.

Kelleher, K. E., and Tester, J. R. (1969). Homing and survival in the Manitoba toad, *Bufo hemiophyrys*, in Minnesota. *Ecology* **50**, 1040–1048. doi: 10.2307/1936895

Lamoureux, V. S., and Madison, D. M. (1999). Overwintering habitats of radio-implanted green frogs, *Rana clamitans*. *Journal of Herpetology* **33**, 430–435. doi: 10.2307/1565639

Lemckert, F. L. (2004). Variations in anuran movements and habitat use, implications for conservation. *Applied Herpetology* **1**, 165–182. doi: 10.1163/157075403323012179

Lemckert, F., and Brassil, T. (2000). Movements and habitat use of the endangered giant barred river frog (*Mixophyes iteratus*) and the implications for its conservation in timber production forests. *Biological Conservation* **96**, 177–184. doi: 10.1016/S0006-3207(00)00066-5

Lemckert, F. L., and Brassil, T. D. (2003). Movements and habitat use of the endangered giant burrowing frog, *Heleioporus australiacus*, and its conservation in forestry areas. *Amphibia-Reptilia* **24**, 207–211. doi: 10.1163/156853803322390453

Lemckert, F. L., Brassil, T., and McCray, K. (1998). Recent records of the giant burrowing frog (*Heleioporus australiacus*) from the far south coast of NSW. *Herpetofauna* **28**, 32–39.

Liang, K. Y., and Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. *Biometrika* **73**, 13–22. doi: 10.1093/biomet/73.1.13

Littlejohn, M., and Martin, A. A. (1967). The rediscovery of *Heleioporus australiacus* in eastern Victoria. *Proceedings of the Royal Society of Victoria* **80**, 31–35.

Lunney, D., Curtin, A. L., Ayers, D., Cogger, H. G., Dickman, C. R., Maitz, W., Law, B., and Fisher, D. (2000). The threatened and non-threatened native vertebrate fauna of New South Wales: status and ecological attributes. National Parks and Wildlife Service, Sydney.

Mahony, M. J. (1993). The status of frogs in the Watagan Mountains area the Central Coast of New South Wales. In 'Herpetology in Australia: A Diverse Discipline'. (Eds D. Lunney and D. Ayers.) pp. 257–264. (Royal Zoological Society of NSW: Sydney.)

Mathis, A., Jaeger, R. G., Keen, W. H., Ducey, P. K., Walls, S. C., and Buchanan, B. W. (1995). Aggression and terrtoriality by salamanders and a comparison with the territorial behaviour of frogs. In 'Amphibian Biology: Vol. 2. Social Behaviour'. (Eds H. Heatwole and B. K. Sullivan.) pp. 633–676. (Surrey Beatty: Sydney.)

Pearson, P. G. (1955). Population ecology of the spadefoot toad, *Scaphiopus h. holbrooki* (Harlan). *Ecological Monographs* **25**, 233–267. doi: 10.2307/1943283

Penman, T., Lemckert, F., and Mahony, M. (2004). Two hundred and ten years of looking for the giant burrowing frog. *Australian Zoologist* **32**, 597–604.

Penman, T. D. (2005). Applied conservation biology of a threatened forest dependent frog, *Heleioporus australiacus*. Ph.D. Thesis, Univeristy of Newcastle.

Penman, T. D., Lemckert, F. L., Slade, C. J., and Mahony, M. J. (2005*a*). Non-breeding habitat requirements of the giant burrowing frog (Anura: Myobatrachidae) in south-eastern NSW. *Australian Zoologist* **33**, 258–264.

Penman, T. D., Mahony, M. J., and Lemckert, F. L. (2005*b*). Soil disturbance in integrated logging operations and the potential impacts on a fossorial Australian frog. *Applied Herpetology* **2**, 415–424. doi: 10.1163/157075405774483111

Penman, T. D., and Lemckert, F. L. (2007). *Heleioporus australiacus* predation. *Herpetological Review* **38**, 185–186.

Penman, T. D., Lemckert, F. L., Slade, C. P., and Mahony, M. J. (2006*a*). Description of breeding sites of the giant burrowing frog *Heleioporous australiacus*. *Herpetofauna* **36**, 102–105.

Penman, T. D., Lemckert, F. L., and Mahony, M. J. (2006*b*). Meteorological effects on the activity of the giant burrowing frog, *Heleioporus australiacus*, in south-eastern Australia. *Wildlife Research* **33**, 35–40. doi: 10.1071/WR04081

Penman, T., Lemckert, F., and Mahony, M. (2006*c*). Impact of fire on a forest dependent burrowing frog. *Pacific Conservation Biology* **12**, 78–83.

Pilliod, D. S., Peterson, C. R., and Ritson, P. I. (2002). Seasonal migration of Columbia spotted frogs (*Rana luteiventris*) among complementary resources in a high mountain basin. *Canadian Journal of Zoology* **80**, 1849–1862. doi: 10.1139/z02-175

Richter, S. C., Young, J. E., Siegel, R. A., and Johnson, G. N. (2001). Postbreeding movements of the dark gopher frog, *Rana sevosa* Goin and Netting, implications for conservation and management. *Journal of Herpetology* **35**, 316–321. doi: 10.2307/1566123

Rosenthal, R., and Rosnow, R. L. (1985). 'Contrast Analysis: Focused Comparisons in the Analysis of Variance.' (Cambridge University Press: Sydney.)

Schabetsberger, R., Jehle, R., Maletzky, A., Pesta, J., and Sztatecsny, M. (2004). Delineation of terrestrial reserves for amphibians: post-breeding migrations of Italian crested newts (*Triturus c. carnifex*) at high altitude. *Biological Conservation* **117**, 95–104. doi: 10.1016/S0006-3207(03)00268-4

Schwarzkopf, L., and Alford, R. A. (2002). Nomadic movement in tropical toads. *Oikos* **96**, 492–506. doi: 10.1034/j.1600-0706.2002.960311.x

Seebacher, F., and Alford, R. A. (1999). Movement and microhabitat use of a terrestrial amphibian (*Bufo marinus*) on a tropical island, seasonal variation and environmental correlates. *Journal of Herpetology* **33**, 208–214. doi: 10.2307/1565716

Semlitsch, R. D., and Bodie, J. R. (2003). Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology* **17**, 1219–1228. doi: 10.1046/j.1523-1739.2003.02177.x

Sokal, R. R., and Rohlf, F. J. (1995). 'Biometry.' 3rd edn. (W.H Freeman & Co.: New York.)

Swets, K. A. (1988). Measuring the accuracy of diagnostic systems. *Science* **240**, 1285–1293. doi: 10.1126/science.3287615

Thuiller, W., Araujo, M. B., and Lavorel, S. (2003). Generalized models vs. classification tree analysis, predicting spatial distributions of plant species at different scales. *Journal of Vegetation Science* **14**, 669–680. doi: 10.1658/1100-9233(2003)014[0669:GMVCTA]2.0.CO;2

Tyler, M. (1997). 'The Action Plan for Australian Frogs.' (Wildlife Australia: Canberra.)

Webb, G. A. (1991). A survey of the reptiles and amphibians of Bondi State Forest and surrounding area, near Bombala, New South Wales. *Australian Zoologist* **27**, 14–19.

Woodward, M. (1999). 'Epidemiology. Study Design and Data Analysis.' (Chapman & Hall: London.)

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Observations of Giant Burrowing Frogs *Heleioporus australiacus* (Limnodynastidae) in the Mitchell River catchment, East Gippsland, Victoria

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Abstract
Within Victoria, limited records of the threatened Giant Burrowing Frog have been obtained in recent decades. This paper describes 16 records of calling Giant Burrowing Frogs from four tributaries of the Mitchell River system in the Mount Alfred State Forest and Mitchell River National Park, Victoria. Stream condition was a major determinant of calling activity, with calling detected only in pools with no or slow flow, within first, second and fourth order streams, often with sandstone bases. Calling was not always closely associated with rainfall, and occurred across most seasons. (*The Victorian Naturalist* **132** (5) 2015, 128–133)

Keywords: amphibian, breeding habitat, calling behaviour, *Heleioporus australaicus*

Introduction

The threatened Giant Burrowing Frog *Heleioporus australiacus* (Fig. 1) is a large, cryptic amphibian from south-eastern Australia (Gillespie 1990; Penman *et al.* 2004). Its known range extends from east of Walhalla in Victoria along the Great Dividing Range to Newcastle in NSW, where it has been recorded from various forested habitat types (Gillespie 1990; Penman *et al.* 2004). Despite this wide distribution, limited records exist towards the southern extent of its range in Victoria where it is now considered Critically Endangered compared to a national listing of Vulnerable (DSE 2013). It is so rarely encountered that until recently information on the species' ecology barely extended beyond a limited number of incidental observations (Gillespie 1990; Daly 1996; Penman *et al.* 2004) and a description and sonagram of the call (Littlejohn and Martin 1967). Recent studies on radio-tagged individuals in south-eastern New South Wales investigated important ecological aspects, including spatial ecology, burrowing locations, habitat requirements and meteorological influences on movement (e.g. Lemckert and Brassil 2003; Penman *et al.* 2005a, 2006b, 2008), but there is little information on breeding sites and calling behaviour (Gillespie 1990; Daly 1996; Penman *et al.* 2006c). Anstis (2013) provides an account and illustrations of the life history and larval development of the species in the Sydney area.

The present paper details observations of Giant Burrowing Frogs calling from streams in the Mitchell River catchment in East Gippsland, Victoria.

Methods

Study area

The study area primarily included the Stony Creek catchment (a tributary of the Mitchell River) within the Mount Alfred State Forest and lower Mitchell River National Park, East Gippsland, Victoria. The area is located approximately 220 km east of Melbourne and 20 km north-west of Bairnsdale. Elevation is largely between 50 and 300 m. The vegetation is dominated by Lowland Forest on the ridges and upper slopes, typically with Lowland Herb-rich Forest in the gullies. Dominant overstorey species include *Eucalyptus globoidea, E. cypellocarpa, E. polyanthemos* and *E. consideniana*, and dominant understorey species include *Pomaderris aspera, Acacia dealbata, A. mearnsii, Cassinia* spp., *Gahnia radula, Goodenia ovata, Kunzea* sp., *Lepidosperma* spp., *Lomandra longifolia, Pteridium esculentum* and *Stypandra glauca.*

Surveys

Between 2003 and 2008 two observations of calling Giant Burrowing Frogs were obtained incidentally during nocturnal surveys targeting large forest owls. Between April 2011 and

Fig. 1. A male Giant Burrowing Frog in a typical calling posture and location.

May 2014, 17 periodic targeted surveys for Giant Burrowing Frogs were conducted throughout the Mount Alfred State Forest and Mitchell River National Park, primarily after rainfall (>5 mm) and when it was expected that ephemeral streams would contain water. All surveys were nocturnal and involved either walking along streams listening for calls (usually 200–700 m), or 10 minute listening surveys near roads close to streams. Most surveys were conducted <3 h after dark. When a Giant Burrowing Frog was heard, attempts were usually made to observe the individual and obtain site coordinates using a GPS unit. The site was revisited during daylight hours to measure the water body (maximum width and depth), and record surrounding vegetation. At three sites where calling had been noted, an automated audio recording device (Song Meter SM2+, Wildlife Acoustics, Massachusetts, USA), was deployed in an attempt to record calling behaviour for 3 h after sunset. When repeat visits detected an individual within close proximity to a recent previous detection (within 15 m), it was considered to be the same individual, even if occupying a different nearby pool or stretch of creek.

Meteorological data were obtained from a weather station at Glenaladale (Site no. 58270) (Bureau of Meteorology) located approximately 5 to 10 km from the study area. Average annual rainfall for the years 2002–2013 was 696 mm (± 127 mm).

Results

Sixteen records of calling Giant Burrowing Frogs were obtained from four separate streams. The probable total number of individual males was nine, with repeat observations of several individuals suspected (Table 1). One female was observed incidentally. It should be noted that searches for egg-masses and tadpoles were not conducted during surveys; however, Giant Burrowing Frog tadpoles were conspicuous throughout the creek at Site B over a nine month period from the initial surveys undertaken in Autumn 2011 until early Summer the same year (searches along the creek itself beyond this date were not undertaken).

Table 1. Calling sites of male Giant Burrowing Frogs.

Site ID	Stream order	Stream/ pool width	Max. pool depth (<2 m from frog)	No. of distinct calling sites	No. of individual frogs	Dominant plant species within 30 m
A	4	~10 m	?	?	2	*Eucalyptus tereticornis, E. globoidea, Brachychiton populneus, Dodonaea viscosa, Kunzea* sp., *Cassinia sp.*
B	2	2–3 m	5–40 cm	6	4	*E. cypellocarpa, E. globoidea, E. polyanthemos, Pomaderris aspera, Elaeocarpus reticulatus, Hakea eriantha, Acacia dealbata, A. mearnsii, Cassinia sp., Bursaria spinosa, Lomandra longifolia, Lepidosperma sp., Gahnia radula, Olearia lirata, Pteridium esculentum, Goodenia ovata.*
C	2	~3 m	50 cm	1	1	*E. cypellocarpa, E. globoidea, E. polyanthemos, Pomaderris aspera, H. eriantha, Kunzea* sp., *Acacia pycnantha, L. longifolia, Cassinia sp., Gahnia radula, Goodenia ovata.*
D	1	0.8 m	30–70 cm	2	2	*E. globoidea, E. cypellocarpa, E. consideniana, A. dealbata, Kunzea* sp., *Gahnia radula, Stypandra glauca, Cassinia sp., Pteridium esculentum.*

Site descriptions

Calling was heard from first, second and fourth order streams (Table 1). All calling sites were within pools in streams with no, or very limited, flow (Fig. 2). The width of streams/pools occupied by calling males ranged from 0.8 m to ~10 m, with pool depth ranging from <5.0 to 70.0 cm (Table 1). The second and fourth order streams where Giant Burrowing Frogs were present have a sandstone base (Fig. 2a).

Calling locations

Giant Burrowing Frogs were observed in their calling position on 14 occasions (Table 2). While calling, all individuals were partially submerged in water (Fig. 1), usually either in shallow water or perched on a prominent rock or log in a deeper pool. One frog was floating while calling. Individuals suspected of being observed more than once occupied different calling locations, sometimes in neighbouring pools.

Influence of weather and stream condition

The role of rainfall in stimulating calling varied. Most detections followed recent rainfall (< 7 days: a product of survey bias), but the two incidental records were obtained 13 and 15 days since rainfall of >5 mm (Table 3). Temperature and humidity were not recorded during these two calling events (in February and August), but at other calling times air temperature ranged from 10.1 to 17.5°C, with 65 to 97% relative humidity. Wind strength was mostly calm during surveys (<10 km/h), but three detections occurred with light breeze (10–20 km/h). Although numerous surveys were undertaken when creeks were flowing moderately, all calling events were at times of no or slow creek flow.

Table 2. Calling locations of male Giant Burrowing Frogs.

Description of calling site	No of observations
Edge of stream/pool in small depression or recess and well hidden/ sheltered	3
Edge of stream/pool in a relatively exposed location	6
Standing on a prominent rock in stream/pool	3
Standing on a log in log-debris in a stream/pool	1
Floating while calling	1

Fig. 2. Calling sites of Giant Burrowing Frogs in the Mount Alfred State Forest. (a) Site B, second order stream; (b) Site D, first order stream.

Calling behaviour

Frequency

Song Meters, programed to operate continuously for three hours after sunset (at three sites), recorded Giant Burrowing Frogs calling on four consecutive nights at one site. These data indicated that calling could be almost continuous, commencing an unknown time prior to sunset and usually averaging 18–19 (range 16–21) calls per minute for virtually the entire recording. This calling rate appeared similar to those of other Giant Burrowing Frogs heard (unless they were disturbed), and is consistent with rates reported by Littlejohn and Martin (1967).

Disturbance

The response of calling individuals to disturbance varied. In some cases observer presence and torchlight caused cessation of calling for several minutes, even at considerable distance (e.g. sometimes >20 m away); calling often recommenced at a slow rate and low volume. Calling could also be disturbed by vehicles passing nearby. Conversely, some individuals seemed relatively oblivious to disturbance, continuing to call when approached and observed by torchlight.

Calling season and weather influence on detectability

Calling was recorded during five separate months of the year, extending over late Winter, Spring, late Summer and Autumn (Table 3). Rather than reflecting optimal calling periods, these detections were more likely an artefact of local conditions and survey bias, but they do suggest that calling can occur throughout much of the year if conditions are suitable.

Under optimal conditions (no wind) and when frogs were calling from exposed locations, calls could be heard up to 300 m away. However, in less favourable circumstances, calls could be difficult to detect at a distances less than 30 m.

Table 3. The influence of rainfall events on the calling of Giant Burrowing Frogs. A rainfall event is the accumulated rainfall over consecutive rain days (<4 days), calculated from the last rain day. #Song Meters did not detect calling again after this date, *includes an observation of a female close to two calling males on 17/3/12.

Site	Detection date/period	Stream order	No. individuals	Days since last rainfall >5 mm	>10 mm	>30 mm	Rainfall in previous six months (ml) and percent of long-term average
A	13/2/2003	4	2	13	68	75	133 (38%)
B	30/8/2007	2	2	15	15	15	503 (144%)
B	10–11, 16–17/4/2011	2	3	0–1	0–1	18	384 (110%)
C	11/4/2011	2	1	0	0	18	384 (110%)
B	30/9/2011	2	1	0	0	0	279 (80%)
D	11–17/3/2012#	1	3*	1–7	1–7	1–7	609 (174%)

Discussion

Calling and breeding sites of the Giant Burrowing Frog were similar to those described previously; primarily pools with minimal flow from first and second-order streams (Gillespie 1990; Daly 1996; Penman *et al.* 2006c). Of interest was the detection within the fourth order stream; such streams usually have strong flow and therefore do not provide suitable breeding habitat. But this observation was made in an exceptionally dry period when the stream comprised only a series of pools. In contrast, the upper section of a highly ephemeral first order stream also provided suitable conditions. This record followed heavy rainfall (~170 mm), and the calling site was at virtually the highest location that could temporarily hold water (a flooded burrow of a Common Wombat *Vombatus ursinus*: Fig. 2b). Interestingly, the pools dried completely within six weeks, and remained dry for the following 15 months.

These examples demonstrate that Giant Burrowing Frogs are capable of using a diverse range of sites to attempt breeding, but breeding opportunities can be highly variable and often limited temporally, being influenced by factors including rainfall (and other meteorological effects), hydrology, geology and stream order. This is especially applicable to first, third and fourth order streams because they often provide either fast-flowing water or no water. This highlights the importance of streams with sandstone bases that can hold water in pools for long periods, especially some second order streams, allowing increased breeding opportunities and successful tadpole development (e.g. Daly 1996; Penman *et al.* 2006c). In the Sydney Basin larval life-span extends over 3 to 11 months (Anstis 2013).

Although weather conditions and recent rainfall can stimulate calling (Daly 1996; Penman *et al.* 2006c), the incidental detections of calling 13 and 15 days following rainfall of >5 mm indicate that recent rainfall is not essential for calling to occur. Instead, stream condition/flow appeared critical for stimulating calling. However, despite considerable monitoring during seemingly conducive conditions (appropriate season, limited or no stream flow, temperature >10.0°C, limited wind, recent rainfall >5mm) at sites where Giant Burrowing Frogs had previously recently been active, the detection of calling was rare. Calling activity sometimes differed dramatically between consecutive nights, with frogs calling consistently one night and seemingly being inactive the next, despite apparently similar and suitable climatic conditions. The factors that stimulate calling behaviour and breeding require detailed investigation.

Conservation

Few records of Giant Burrowing Frogs have been obtained in recent decades in Victoria, and the population reported here is currently the only known extant population in the state (Victorian Biodiversity Atlas; Nick Clemann, Graeme Gillespie pers. comm.). Its status has recently been elevated to Critically Endangered in Victoria (DSE 2013). The Mount Alfred State Forest is of particularly high conservation value for the Giant Burrowing Frog, and it is of serious concern, therefore, that potential threats, notably clear-fell logging and frequent prescribed fires (Penman *et al.* 2005b, 2006a), are regularly undertaken throughout the area. Although the impacts of these practices on the Giant Burrowing frog are poorly understood, implementing additional protective measures throughout the region to conserve important habitat should be a priority. Undertaking studies on the species in the area is a crucial step in helping to inform such future management actions.

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References

Anstis M (2013) *Tadpoles and frogs of Australia*. (New Holland: Sydney)

Daly G (1996) Observations of the Eastern Owl Frog (*Heleioporus australiacus*) in southern New South Wales. *Herpetofauna* **26**, 33–42.

DSE (2013) Advisory list of threatened vertebrate fauna in Victoria. (Department of Sustainability and Environment: Melbourne)

Gillespie GR (1990) Distribution, habitat and conservation status of the Giant Burrowing Frog (*Heleioporus australiacus*) (Myobatrachidae) (Shaw) in Victoria. *The Victorian Naturalist* **107**, 144–53.

Lemckert FL and Brassil T (2003) Movements and habitat use of the Giant Burrowing Frog (*Heleioporus australiacus*). *Amphibia-Reptilia* **24**, 207–211.

Littlejohn M and Martin AA (1967) The rediscovery of *Heleioporus australiacus* (Shaw) [Anura: Leptodactylidae] in eastern Victoria. *Proceedings of the Royal Society of Victoria* **80**, 31–36.

Penman TD, Lemckert FL and Mahony MJ (2004) Two hundred and ten years looking for the Giant Burrowing Frog. *Australian Zoologist* **32**, 597–604.

Penman TD, Lemckert FL, Slade C and Mahony MJ (2005a) Non-breeding habitat requirements of the giant burrowing frog (*Heleioporus australiacus*) (Anura: Myobatrachidae) in south-eastern Australia. *Australian Zoologist* **33**, 251–257.

Penman TD, Mahony MJ and Lemckert FL (2005b) Soil disturbance in integrated logging operations and the potential impacts on a fossorial Australian frog. *Applied Herpetology* **2**, 415–424.

Penman TD, Lemckert FL and Mahony MJ (2006a) A preliminary investigation into the potential impacts of fire on a forest dependent burrowing frog species. *Pacific Conservation Biology* **12**, 78–83.

Penman TD, Lemckert FL and Mahony MJ (2006b) Meteorological effects on the activity of the Giant Burrowing Frog (*Heleioporus australiacus*) in south-eastern New South Wales. *Wildlife Research* **33**, 35–40.

Penman TD, Lemckert FL, Slade C and Mahony MJ (2006c) Description of breeding sites of the Giant Burrowing Frog (*Heleioporus australiacus*) in south-eastern NSW. *Herpetofauna* **36**, 102–105.

Penman TD, Lemckert FL and Mahony MJ (2008) Spatial ecology of the Giant Burrowing Frog (*Heleioporus australiacus*): implications for conservation prescriptions. *Australian Journal of Zoology* **56**, 179–186.

Victorian Biodiversity Atlas (2013) Giant Burrowing Frog *Heleioporus australiacus*. Department of Environment and Primary Industries, www.depi.vic.gov.au/environment-and-wildlife/biodiversity/victorian-biodiversity-atlas. Accessed July 2013.

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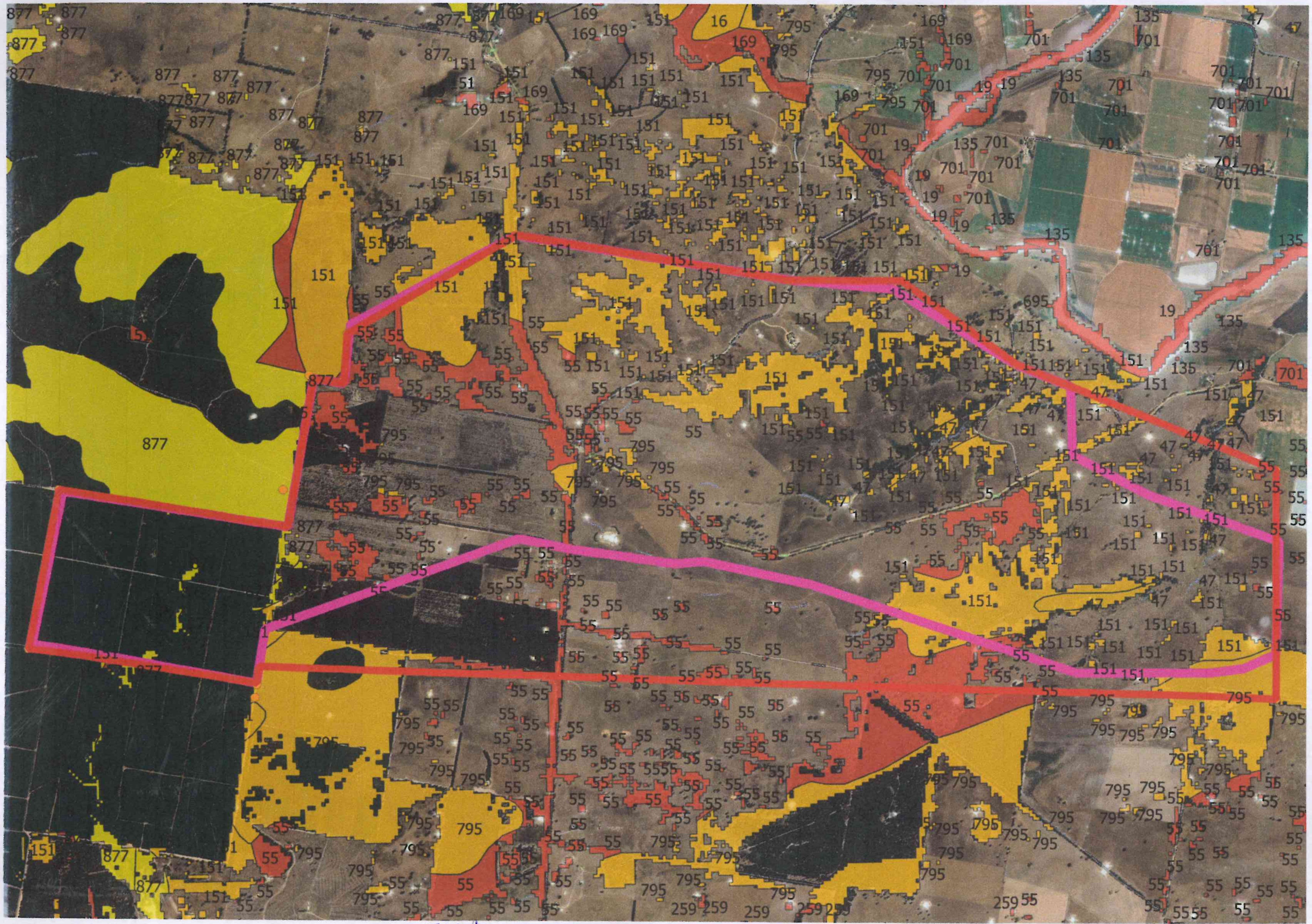
Eighty-nine Years Ago

FROGS IN A FERNERY

Nearly a dozen frogs are at home in my shade-house, and earn their lodging as enemies of slugs and 'slaters', caterpillars, and other pests among the ferns. Several of my pets are Golden Bell-frogs, *Hyla aurea*, one of the handsomest of all known species: others are Common Brown Tree-frogs, *H. ewingii*. The latter are the most confiding; but three of the green and golden frogs, domiciled in the fernery about a year ago, are so tame now that they rarely attempt to jump when touched or taken in the hand. Recent arrivals are wary: The early inhabitants have favourite spots, where they rest during the daytime—their hunting is done after dark. A hanging basket is the 'habitat' of one Brown Tree-frog. It is seen there every day, with green fronds all about it. *H. aurea* is said to include small frogs in its dietary, but, so far, none of the examples in my shade-house has eaten a diminutive neighbour. Tree-frogs especially make interesting pets, and some of the Australian species are dainty and beautiful. —C. BARRETT

From *The Victorian Naturalist* **XLII**, p. 234, January 8, 1926



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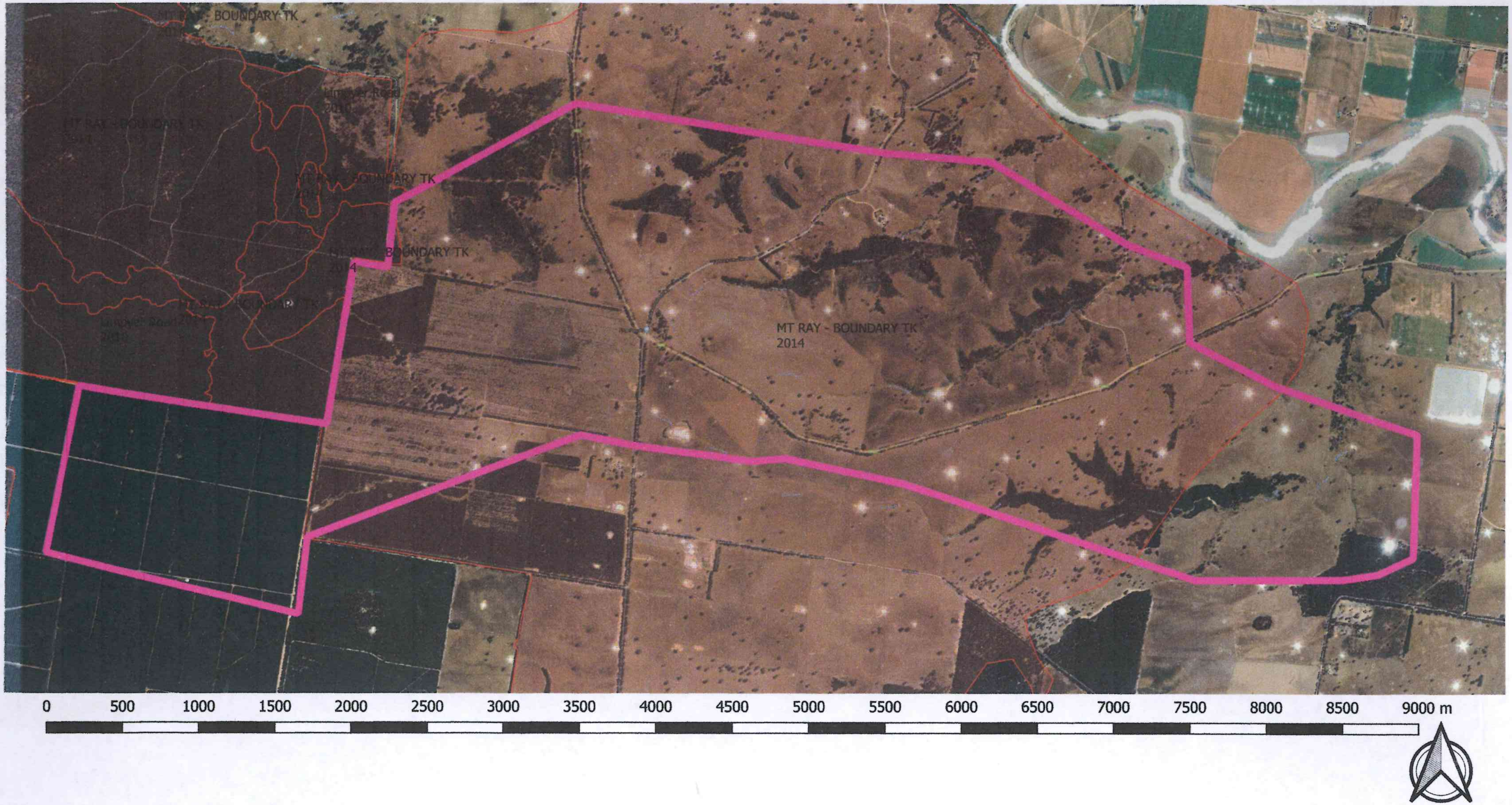
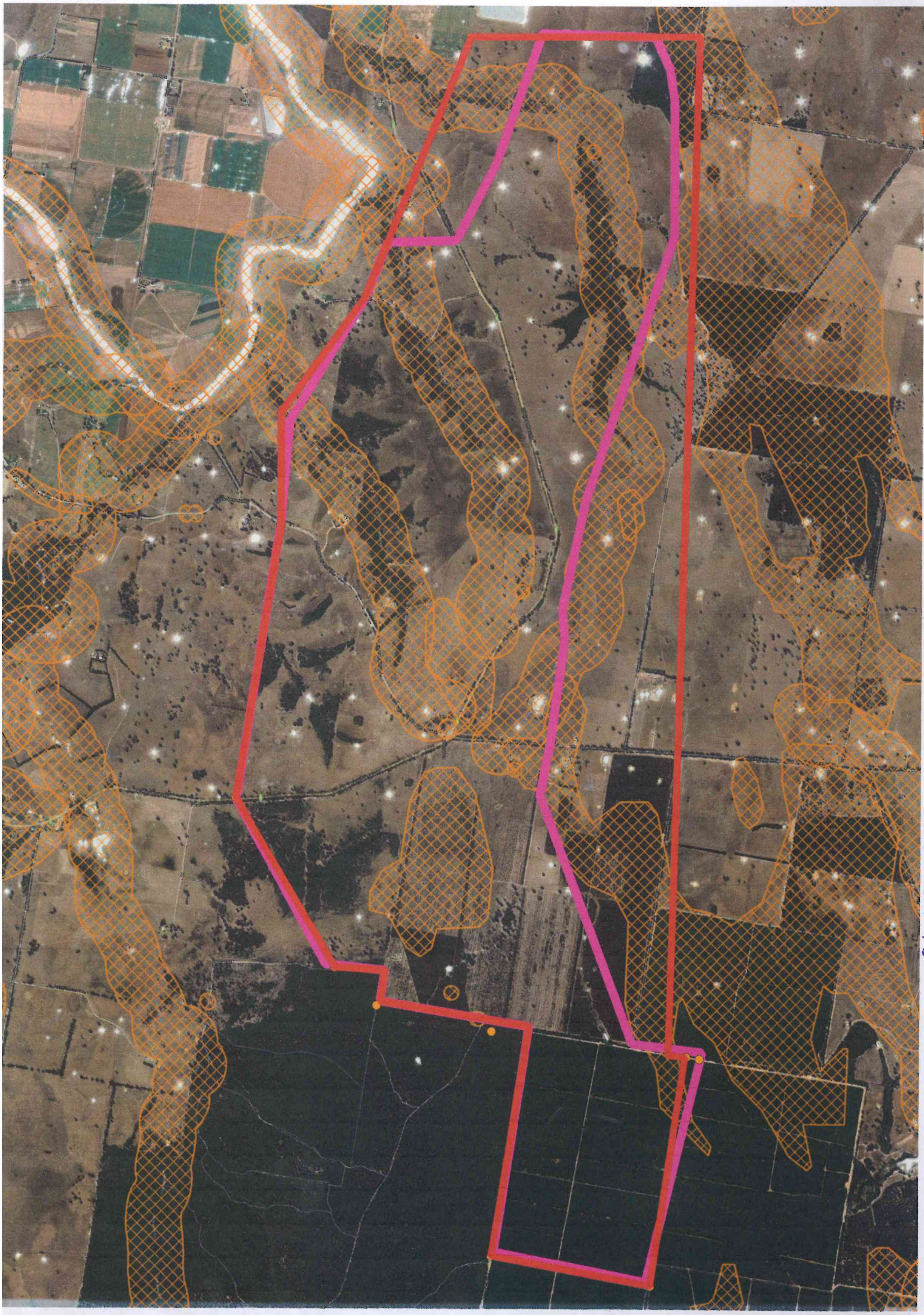


Proposed Fingerboards Project Proposed Project Area Original

FIRE_HISTORY_LASTBURNT East Gippsland 2014

Google Satellite Hybrid



CULTURAL HERITAGE OVELAY