Non-breeding habitat requirements of the giant burrowing frog, *Heleioporus australiacus* (Anura: Myobatrachidae) in south-eastern Australia

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ABSTRACT

Non-breeding habitats are an important, yet poorly understood component of the habitat requirements of most frog species. As a result, non-breeding habitats may be poorly protected and their loss may be the proximate cause of decline for some species. The giant burrowing frog is a threatened frog species in south-eastern Australia. To understand its non-breeding habitat requirements, we measured the habitat attributes associated with non-breeding records of this frog from a number of sites in southern New South Wales and compared these with a series of sites where the species has not been detected. The giant burrowing frog records were typically associated with dry forest and little vegetative ground cover and we suggest that this may be related to the ability of the species to burrow at a site. Suitable habitat areas appear to be widespread across south-eastern NSW and Victoria, and the difficulty in detecting the species appears to be the best explanation for the lack of records from many areas.

Key words: amphibian, conservation management; non-breeding habitat, *Heleioporus australiacus*.

Introduction

Amphibians have complex life cycles which often result in differential habitat requirements in the breeding and non-breeding areas. Most research on amphibian habitat requirements has focussed on breeding ponds or streams (Hamer *et al.* 2002; Parris 2002; Gillespie *et al.* 2004), with very little research relating to non-breeding habitat requirements (e.g. Lamoureux and Madison 1999; Regosin *et al.* 2003). This has probably occurred because many amphibians, and the majority of anurans, are more readily observed in breeding areas due to their vocalisations (anurans) or because they congregate in large numbers. The result of this bias is that the conservation management of amphibians is commonly based on breeding habitats and little attention is given to impacts on non-breeding habitats (although see Semlitsch and Bodie 2003).

The giant burrowing frog *Heleioporus australiacus* (Shaw and Nodder) is a large, threatened frog species in south-eastern Australia. Records of the species extend from Singleton, NSW in the north through to 120 kilometres east of Melbourne, Victoria in the south (Penman *et al.* 2004). There is a disjunction in the records of this species between Jervis Bay and Narooma, which separates the northern and southern populations (Penman *et al.* 2005). The species is listed as vulnerable under Australian Commonwealth legislation under the *Environmental Protection and Biodiversity Conservation Act* 1999 and in New South Wales under the *Threatened Species Conservation Act* 1995 and as threatened in Victoria under the *Flora and Fauna Guarantee Act* 1988. These listings are based on the paucity of records for this frog, and the poor understanding of the ecology of this species. Such rarity may indicate a species with specialised habitat requirements and hence a species predisposed to declines from habitat disturbance (e.g. de la Pena *et al.* 2003; Krauss *et al.* 2003).

This species is known to utilise distinct breeding and non-breeding habitats (Lemckert and Brassil 2003) but little has been published about the non-breeding habitat requirements (Penman *et al.* 2004). The species appears to be restricted to naturally vegetated areas. In the southern populations, the species has been recorded from a range of forest types (Littlejohn and Martin 1967; Webb 1987; Gillespie 1990; Lemckert *et al.* 1998), whereas in northern populations the species appears to be prevalent in heath communities (Mahony 1993; Daly 1996). No specific analysis of habitat requirements has been undertaken, with published data usually limited to describing the habitat conditions for a small number of observations in a restricted geographic area (eg Harrison 1922; Gillespie 1990; Daly 1996). Such information provides little understanding of the true habitat requirements of *H. australiacus* and consequently, little confidence in protecting this species successfully.

One significant management problem is that *H. australiacus* is known to be very difficult to detect even in areas where it is known to occur (Gillespie 1990; Kavanagh and Webb 1998; Lemckert *et al.* 1998). As a result it is not possible to confidently identify areas where *H. australiacus* is actually absent and hence all naturally vegetated areas within the species' range are considered potential habitat (Penman *et al.* 2004). If we can identify features of the habitat that can accurately predict the presence or absence of *H. australiacus*, conservation resources and survey effort can be better directed to improve our understanding of the distribution of *H. australiacus* and its long-term conservation prospects.

This study examines the non-breeding habitat requirements of *H. australiacus* in the southern populations by comparing the habitat at known non-breeding sites where it has been recorded with the habitat at a series of random sites. This allows us to describe the common features of known sites and produce a habitat model for *H. australiacus* in the region.

Methods

The study was conducted in south-eastern NSW from Narooma through to the Victorian border (Figure 1). In this study we collated all the non-breeding records for *H. australiacus* from the NSW Department of Environment and Conservation wildlife atlas, Forests NSW wildlife survey data and recent survey sites. Non-breeding records

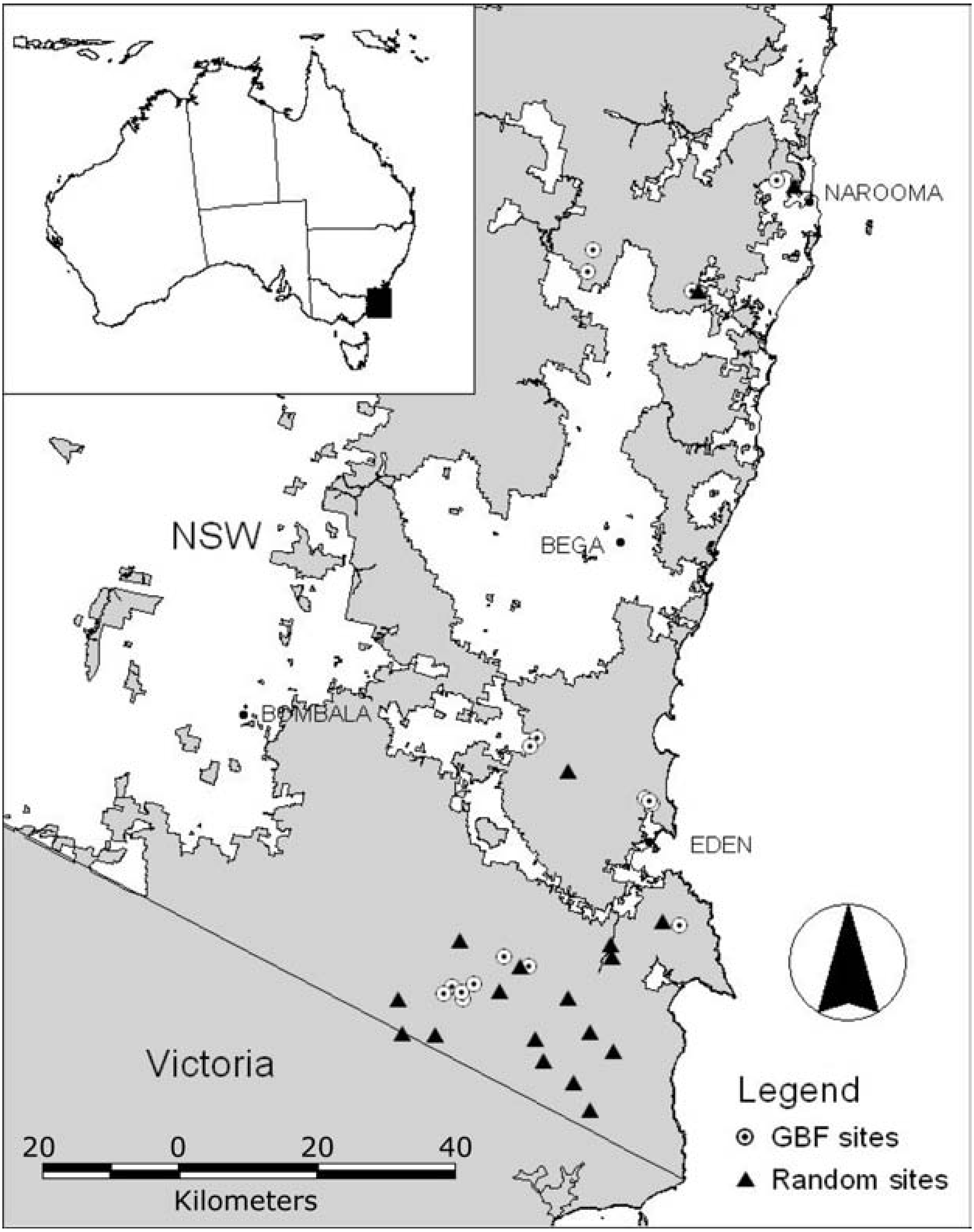

Figure 1. Sites at which Giant Burrowing Frogs were recorded and random sites used in the analysis. Shaded area indicates forest environments.

are those which do not fall within 50 m of a stream or pool (Penman 2005). All records used in the study were either made by the authors or were verified by the authors. We only used records obtained since 1995 because the habitat at sites where the species was recorded more than ten years old may have undergone significant changes as a result of natural vegetation succession or forest disturbance. For the same reasons, we removed two sites from the dataset where logging had occurred since the species was detected. Where a record occurred within one kilometre of another record, the newest record was retained and the other(s) excluded to prevent pseudo-replication. This distance was considered sufficient to distinguish between sub-populations, if not populations (Penman *et al.* 2005).

A total of 17 known sites and 19 pseudo-absence sites were used in the analysis (Figure 1). The sites used in this study were derived from nocturnal road transects (15/17) and pitfall traps (2/17). Radio-tracking studies have indicated that individuals in the non-breeding habitat usually occupy the habitat at the capture point (Lemckert and Brassil 2003). The pseudo-absence sites were random sites generated using a random point generator (Jenness 2004) within forest areas where surveys had been conducted by the authors and *H. australiacus* had not been detected. It must be noted that these presence sites have all been derived from observations of adult *H. australiacus* and there is some question as to whether juvenile frogs may have different habitat requirements and responses. We consider this unlikely, however, as juvenile frogs have been observed to exhibit similar behaviours and occupy similar habitats to adult *H. australiacus* (Penman 2005).

Habitat features were recorded at each site for a 10m radius around the location of the record point. For road records, the area considered was a minimum of 15 m off the road. The side of the road used was determined randomly by a coin toss. The physical environment was measured in terms of slope (degrees), aspect relative to north (degrees), aspect of the catchment relative to north (degrees), soil pH, soil type and topographic position. Vegetation height and cover was recorded for each of the four main strata (ground, shrub, understorey and canopy). This allowed for the calculation of a structural complexity score for the habitat (Catling and Burt 1995). The number of trees and the diameter at breast height (dbh) of each tree was recorded. Horizontal vegetation structure was measured at three levels – 0-20, 40-60 and 80-100 cm. Floral species diversity was recorded for the entire site and then calculated separately for each strata. The proportion of ground covered by vegetation, leaves and woody debris and the proportion of the ground that was bare was assessed. The number of stumps and the average height of fire scars were taken as measures of historical disturbance. The distance to the coast was calculated using ArcView GIS (ESRI, USA). Elevation and the stream order (Strahler 1952) of the nearest stream were derived from a 25 m digital elevation model (DEM) of the study area (Southern CRA DEM version 2, NSW National Parks and Wildlife Service, 04/05/99).

All analyses were conducted on SAS version 8.2 (SAS Institute Incorporated, USA). Generalized linear models (GLMs) were used to build the habitat model. A correlation matrix was calculated for all factors and those with correlations greater than 0.8 were identified. Models were then built by adding and removing variables to determine the set of factors that built the model with the best statistical fit. Akaike's Information Criteria (AIC) was used to determine the set of factors which created the model with the best fit. AIC assesses the model fit by comparing how close fitted values are to the true values, while accounting for the number of parameters included in the model (Agresti 2002). Correlated factors were tested singularly and together, and tests were made to ensure multicollinearity did not occur following the methods of Chattergee *et al.* (2000). Model fit was assessed using the area under the curve (AUC) value from the receiver operating characteristic curve (ROC curve) (Woodward 1999). The ROC curve represents the relationship between the sensitivity and the false positive fraction (1-specificity) of the model over a range of threshold values. A good model maximises the sensitivity for low values of the false positive fraction (Woodward 1999). Thuiller *et al.* (2003) use the traditional academic point system (Swets 1988) as a rough guide for classifying the accuracy of the model. Models with AUC values under 0.70 are considered poor, values of 0.70-0.80 are rated as fair, 0.80-0.90 are rated as good and those over 0.90 are rated as excellent.

Results

A summary of the habitat characteristics recorded for *H. australiacus* and the random sites is presented in Table 1 and a summary of the soil conditions is presented in

Table 1. Summary of environmental variables measured at each site for a) Giant Burrowing Frog sites and b) random sites.
a) Giant Burrowing Frog site data

Factor	Mean ± S.E	Minimum	Maximum
Slope (degrees)	11.000±1.461	3.000	25.000
Aspect to north (degrees)	67.600±13.220	5.000	164.000
Catchment aspect relative to north (degrees)	90.333±16.184	25.000	180.000
pH	4.679±0.186	4.000	6.000
Number of stumps	1.067±0.345	0.000	3.000
Number of trees	15.067±5.186	3.000	84.000
Average DBH trees	377.208±51.232	106.786	781.250
Canopy species diversity	2.067±0.182	1.000	3.000
Understorey species diversity	2.083±0.260	1.000	3.000

Factor	Mean ± S.E	Minimum	Maximum
Shrub species diversity	4.867±0.810	1.000	13.000
Ground species diversity	7.867±0.850	3.000	14.000
Total site floral diversity	14.333±1.085	9.000	21.000
Canopy cover (%)	45.333±3.065	30.000	70.000
Understorey cover (%)	20.000±3.780	0.000	50.000
Shrub cover (%)	35.667±5.539	10.000	80.000
Ground cover (%)	38.667±5.356	10.000	80.000
Habitat complexity	5.600±0.273	4.000	7.000
Canopy height (metres)	33.333±1.162	30.000	40.000
Understorey height (metres)	11.750±1.081	5.000	15.000
Shrub height (metres)	2.700±0.175	1.500	4.000
Ground cover height (metres)	0.440±0.027	0.200	.500
% ground vegetation	21.333±4.322	5.000	70.000
% ground leaf	58.333±5.087	20.000	85.000
% ground log	12.333±1.750	5.000	30.000
% ground bare	2.333±0.9600	0.000	10.000
% ground rock	5.333±3.362	0.000	50.000
Horizontal vege. density (0-20 cm) (%)	49.350±7.558	7.500	96.250
Horizontal vege. density (40-60 cm) (%)	18.467±4.192	1.250	63.250
Horizontal vege. density (80-100 cm) (%)	12.083±4.208	0.000	61.250
Elevation (metres)	300.267±37.594	99.000	616.000
Distance to coastline (kilometers)	17.607±2.736	2.131	27.925
Topographic position	3.647±0.256	2.000	6.000
Stream order	1.235±0.136	1.000	3.000

b) Random site data

Factor	Mean ± S.E	Minimum	Maximum
Slope (degrees)	7.737±0.794	2.000	14.000
Aspect to north (degrees)	84.053±10.437	17.000	180.000
Catchment aspect relative to north (degrees)	97.105±12.644	0.000	180.000
pH	4.632±0.145	4.000	6.000
Number of stumps	1.105±0.222	0.000	3.000
Number of trees	19.579±4.736	3.000	98.000
Average DBH trees	263.987±31.584	55.908	667.333
Canopy species diversity	2.158±0.201	1.000	4.000
Understorey species diversity	2.059±0.267	1.000	5.000
Shrub species diversity	5.211±0.346	2.000	8.000
Ground species diversity	7.421±0.654	3.000	12.000
Total site floral diversity	13.947±0.817	8.000	24.000
Canopy cover (%)	40.789±5.052	10.000	80.000
Understorey cover (%)	26.842±5.357	0.000	70.000
Shrub cover (%)	32.368±4.970	10.000	80.000
Ground cover (%)	58.158±6.459	20.000	100.000
Habitat complexity	7.526±0.262	6.000	10.000
Canopy height (metres)	32.632±1.595	20.000	45.000
Understorey height (metres)	13.353±1.314	6.000	25.000
Shrub height (metres)	2.026±0.168	1.000	3.000
Ground cover height (metres)	0.421±0.024	0.200	0.500
% ground vegetation	42.895±5.912	10.000	95.000

Factor	Mean ± S.E	Minimum	Maximum
% ground leaf	42.895±6.341	0.000	85.000
% ground log	7.105±1.252	0.000	20.000
% ground bare	3.947±2.124	0.000	30.000
% ground rock	3.158±3.074	0.000	60.000
Horizontal vege. density (0-20 cm) (%)	61.316±7.209	5.000	100.000
Horizontal vege. density (40-60 cm) (%)	32.171±6.477	3.750	100.000
Horizontal vege. density (80-100 cm) (%)	19.145±5.462	0.000	100.000
Elevation (metres)	203.947±33.503	47.000	523.000
Distance to coastline (kilometers)	15.502±1.799	0.592	30.445
Topographic position	3.632±0.260	2.000	6.000
Steam order	2.000±0.393	1.000	6.000

Table 2. All of the sites within the study area are dry open forest with an average canopy cover of 45% but not exceeding 70%. The species is found in the catchments of smaller streams with the majority of sites being in catchments of 1st or 2nd order streams. There is limited vegetation cover at the ground level as seen by the measures of the percentage of ground covered by vegetation and average horizontal vegetation density at 0-20 and 40-60 cm. The species has been recorded from a range of soil types in similar proportions to the random sites. No habitat sites were from clay loam sites or loamy clay sites, however these were only represented by one site each in the random sites. Records of the species have been derived from the full range of topographic positions (lower slope, mid slope, upper slope, saddle and ridge). When converted to an ordinal scale, the topographic position of the records were found to be normally distributed (Kolmogrov Smirnov p=0.445, Figure 2).

Table 2: Soil types at habitat and random sites

Soil type	Habitat Site	Random Site
Sand	2 sites	1 sites
Sandy Clay Loam	10 sites	10 sites
Sandy Loam	5 sites	6 sites
Clay Loam	0 sites	1 sites
Loamy Clay	0 sites	1 sites

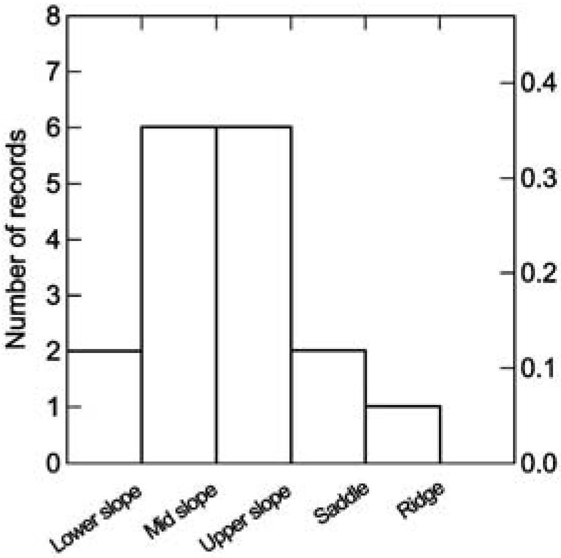

Figure 2: Topographic position of records

Table 3: Final non-breeding habitat model for the Giant Burrowing Frog

Parameter	DF	Estimate	Standard Error	P value
Intercept	1	2.7397	1.8163	0.1315
Ground cover	1	-0.0467	0.0196	0.0170
Shrub height	1	1.9288	0.7550	0.0106

The probability of *H. australiacus* occurring at a site increases as the percentage of cover provided by ground vegetation decreases and the height of the shrub layer increases. The final habitat model is presented in Table 3. Vegetation cover at the ground level ranges from 20 to 70% with the majority of sites between 25 and 50% coverage. Shrub heights for the majority of the sites were between 2.5 and 3 metres. The AIC value from the ROC curve for the final model was 0.872, which means the model is classified as having a good fit (Swets 1988).

Discussion

This study presents the most extensive information available on the non-breeding habitat requirements of *H. australiacus* in south-eastern NSW. The records from this study are consistent with historical records of the species in the region (Webb 1991; Lemckert *et al.* 1998; Kavanagh and Webb 1998), although they differ from observations in the northern populations (Mahony 1993; Daly 1996). Northern populations are commonly found in heath woodlands however this habitat type is uncommon in south-east forests. In the study area there is approximately 551,500 hectares of native vegetation of which only approximately 7000 hectares is classed as heath (Keith and Bedward 1999). These areas have not been surveyed for *H. australiacus* due to restricted access. The northern and southern populations may occupy different vegetation communities (Penman *et al.* 2004). However, it is possible that structural characteristics of the community (e.g. vegetative cover) or physical characteristics of the environment (e.g. soil type) are determining the species distribution rather than the vegetation itself. A description of sites used by *H. australiacus* in Victoria (Gillespie 1990) indicates it is is present in a much wider range of forest types than in NSW. A number of these records however are associated with breeding, i.e. tadpole or calling records. Only eight records appear to be of non-breeding frogs and seven of these eight were from dry schlerophyll forests, with one from a damp forest. It appears therefore that the species is occupying quite similar non-breeding habitats in Victoria and south-eastern NSW.

Our analysis indicates that the preferential non-breeding habitat is dry forest with relatively little vegetative ground cover. Areas with lower levels of vegetative ground cover (i.e. vegetation less than 0.5 m in height) may offer more favourable burrowing opportunities for individuals of this species. Behavioural studies of a burrowing frog species in North America (*Scaphiopus holbrookii holbrookii*) demonstrated an inability or unwillingness to burrow in soil covered by vegetation (Jansen *et al.* 2001). *Heleioporus australiacus* is a large frog (approximately 60-100 mm; Penman *et al.* 2004) with relatively short legs (Cogger 2000) and therefore, dense ground vegetation may restrict movement and feeding opportunities. So, while increased ground cover may provide better camouflage and shelter from predators, movement and foraging opportunities may be restricted sufficiently for the *H. australiacus* to avoid these areas.

The habitat described for the giant burrowing frog appears to be widespread throughout the south-east of NSW and Victoria (e.g. Keith and Bedward 1999), however there is only a small number records of the frog from this region and few current populations of the species are known (Penman *et al.* 2005). It is possible that the known sites actually represent the true extent of the species within the region and that this species really is rare and restricted in this part of its range. While it must be acknowledged that the low number of records would have restricted the predictive power of statistical analysis, and may therefore limit our ability to determine a more prescriptive habitat model, important environmental attributes not considered in the analysis may influence the species' distribution. One of these may be the distribution of suitable breeding sites and not features of the non-breeding habitat. Breeding records of the giant burrowing frog have been derived primarily from first and second order streams (Littlejohn and Martin 1967; Gillespie 1990; Mahony 1993). Using a 25 m DEM across the Eden region, approximately 337,000 drainage lines have been mapped (Penman *unpublished data*). Of these approximately 169,000 are classed as first order and 79,000 are classed as second order streams. Within the region, there are many streams that are similar to those known to be used by *H. australiacus.* It therefore seems unlikely that only a small number of streams provide suitable breeding habitat for *H. australiacus* and therefore limit the distribution of this species across the landscape. It may be the matrix of breeding, non-breeding and transition habitat areas that is determining the distribution of this species. However, there are currently insufficient records for such an analysis.

It is possible that this species is more widespread than our current knowledge indicates. Detecting *H. australiacus* is difficult even in areas where it is known to occur. Therefore it is possible that many populations have not yet been located. The most commonly used technique for detecting the species is nocturnal road transects (Penman *et al.* 2004) and this is usually only effective with experienced survey staff. Furthermore, roads in forest areas are usually constructed on ridge lines to minimize the disturbance to watercourses (Penman *et al.* 2004). Since this species occupies areas that include the lower slopes through to the ridge line, large areas of potential habitat and large portions of populations cannot be surveyed using nocturnal road transects. It is important, therefore, to develop alternative sampling techniques that improve our ability to detect the species.

It is impossible to assess the potential impact of forest disturbances on *H. australiacus* based on these results. The direct measures of disturbance chosen, i.e. fire scars and number of stumps, were not significant in the final model. Shrub height was included in the final model and this may be a measure of the time since disturbance. Other authors have suggested that the species may prefer older forests (Kavanagh and Webb 1998; Lemckert *et al.* 1998), however the result in these studies may simply reflect a survey bias. Many of the sites (9/17) used in our analysis were also located during pre-logging surveys for this species. This could incorporate some bias because sites subject to future logging in commercial forests are usually older than other forest areas.

A comprehensive analysis of habitat attributes at all known sites across the species' range is likely to improve our understanding of the species habitat requirements and distribution. It would also indicate if the habitat requirements differ between the northern and southern populations.

Acknowledgements

This study has been funded by an Australian Postgraduate Industry Award supported by Forests NSW, NSW National Parks and Wildlife Service and the University of Newcastle. We thank Mike Crowley for assistance in locating the Narooma sites and Kelly Rowley for assistance in collecting the site data for these sites. Hal Cogger, Will Osborne, Traecey Brassil, Alison Towerton and two anonymous referees provided useful comments on earlier drafts of this manuscript.

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