The response of the frog *Crinia signifera* to different silvicultural practices in southern Tasmania, Australia

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Abstract

We investigated the activity patterns of the frog Crinia signifera *in commercial production forests of Tasmania, Australia, subjected to two different silvicultural practices, namely the standard clearfell/burn/sow (CBS) logging practice but with retention of understorey islands, and 10% dispersed overstorey retention. Unlogged forest was sampled as a control. Pre-logging and post-logging sampling were undertaken over a period of nine years using pitfall traps. Our findings indicate that* C. signifera *is tolerant to disturbance with equivalent capture rates in the unlogged control compared to the two silvicultural treatments. Capture rates were significantly higher in all treatments in the post-logging period compared to the pre-logging period, including the unlogged control, and these differences were attributed to temporal environmental differences independent of forest harvesting. None of the tested silvicultural practices consistently favours habitat use by* C. signifera.

Keywords: Crinia signifera, *frog, logging, silviculture*

Introduction

Information relating to the response of amphibians to anthropogenic alterations in habitat, especially relating to the impacts of forest harvesting, is limited in Australia (Hazell, 2003). Internationally, however, similar limitations are less apparent. In their review of the North American literature, deMaynadier & Hunter (1995) found that the impact of recent clearcut forest harvesting tended to be negative for amphibians (and especially for salamanders), with a median amphibian abundance 3.5-fold greater in controls than in clearcut coupes. However, this response was highly variable because of differences in forest type, spatial and temporal environmental variability, species-specific differences, and a high variation in abundance estimates typical of many amphibian populations. The long-term effects of logging were found to be even more variable, and it was suggested that the presence of microhabitat features (rather than forest age per se) might be a more important determinant of the abundance of a species. Microhabitat features such as coarse woody debris, litter depth, understorey vegetation, canopy closure, moisture, light, temperature and pH have all been shown to influence the abundance of different amphibian species (deMaynadier and Hunter, 1995).

When compared to traditional harvesting techniques, alternative silvicultural practices may retain many microhabitat features, thus potentially moderating the impacts of traditional harvesting practices upon amphibian populations. However, despite the fact that alternative silvicultural practices are often recommended in management guidelines, their impact on amphibians remains unstudied (deMaynadier and Hunter, 1995).

In this paper we investigated the effect of two different alternative silvicultural practices on the activity of the frog *Crinia signifera*, to shed some light on the implications of habitat modification for this abundant ground-dwelling species.

Methodology

Study species

Crinia signifera is widely distributed throughout Tasmania and south-eastern mainland Australia, and is found in a wide range of habitats (Robinson, 1996). Breeding occurs in both permanent and ephemeral sites, and in Tasmania is limited to standing water (Littlejohn, 2003). In the southern forests of Tasmania, breeding occurs predominantly between early spring (August) and mid-summer (December), and any autumn breeding seems dependent on sufficient rainfall (Lauck, 2005). Metamorphosis occurs predominantly in January and February (Lauck, 2005).

Study area

The study area is located at the Warra Long-Term Ecological Research (LTER) site within the southern production forests of Tasmania. The site (43^{0}3′S; 146^{0}39′E) is approximately 60 km south of Hobart and has an elevation range of 37-1260 m (Brown *et al.*, 2001). The aims of research at the Warra LTER site are to develop an understanding of ecological processes in the wet *Eucalyptus obliqua* forests of Tasmania, and to demonstrate and develop sustainable forest management practices. For more information see the website <http://www.warra.com>

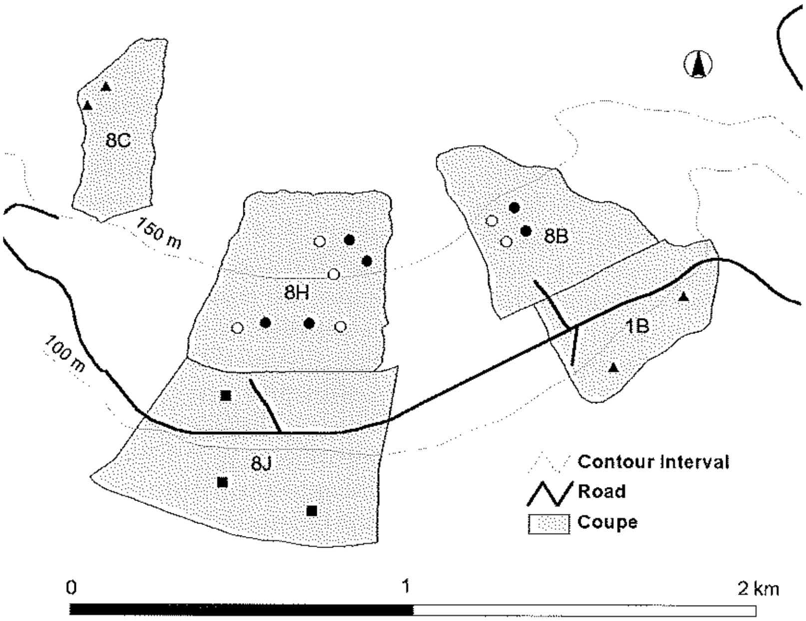

Figure 1. Map showing location of coupes of different silvicultural treatment, and sampling sites within coupes. Squares = sample sites in control coupe (8J), triangles = sample sites in "10% dispersed retention" coupes (1B and 8C) , filled circles = sample sites in felled areas of "CBS with understorey islands" coupes (8B and 8H), empty circles = sample sites at understorey island locations within "CBS with understorey islands" coupes (8B and 8H). Sites are allocated to one of three elevation categories: top (>150 m), middle (100–150 m) and bottom (<100 m).

Table 1. Silvicultural treatments in coupes. Data summarised from Bashford et al. *(2001) and Hickey* et al. *(2001).*

Coupe	Silvicultural treatment	Area (ha)	Sample site type	Number of sample sites	Burn intensity	Seed source
8J	control	35.0		3	none	none
1B	10% dispersed retention	15.7		2	low	natural seed fall
8C	10% dispersed retention	11.1		2	low	natural seed fall
8B	CBS with understorey islands	17.7	felled understorey island	2 2	high low	sowing none
8H	CBS with understorey islands	26.0	felled understorey island	4 4	high low	sowing none

Standard logging practice in Tasmanian wet sclerophyll and mixed forests has historically consisted of clearfelling, burning and aerial sowing with eucalypt seeds (CBS) in preparation for a planned rotation of 90 years (Hickey and Neyland, 2000). A Silvicultural Systems Trial has been established at the Warra LTER site to investigate alternative silvicultural practices (Hickey *et al.*, 2001). One investigative sub-component of this trial is to measure the response of invertebrates to alternative silvicultural practices (Bashford *et al.*, 2001). The specimens of *C. signifera* counted in this study were opportunistically obtained as by-catch from wet pitfall-traps used in the invertebrate study.

Between 1997 and 2005, pre-logging sampling and two phases of post-logging sampling were completed in five coupes at the Warra Silvicultural Systems Trial. These coupes comprised an unlogged control plus two different coupe-level experimental treatments, "10% dispersed retention" and "CBS with understorey islands", with two replicates of each of these experimental treatments. The locations of each coupe, and sampling sites within the coupes, are presented in Figure 1. The silvicultural practices and sampling intensity used in each coupe are presented in Table 1.

The unreplicated control treatment (coupe 8J, 3 sample sites within the coupe) was an area that remained both unlogged and unburnt throughout the study period. In the "10% dispersed retention" silvicultural treatment (coupes 1B and 8C, 2 sample sites in each coupe), 10% of the pre-harvest eucalypt basal area was retained but remaining overstorey and understorey was cleared. The two coupes managed according to the "CBS with understorey islands" silvicultural treatment (coupes 8B and 8H, 4 and 8 sample sites in these coupes respectively) were harvested using standard logging practices (CBS) but retaining a number of understorey islands of dimensions 40 m x 20 m. The "CBS with understorey islands" coupes were sampled both in cleared areas and in retained islands (2 sample sites in each type of area in 8B, and 4 sample sites in each type of area in 8H). For further details regarding these silvicultural treatments see Hickey *et al.* (2001).

Variation in topography over the whole study area meant that sample sites located at the top of the slope (towards the north) were well drained whereas sample sites located lower on the slope (towards the south) were swampy and wet. This variation had the potential to confound the effect of silvicultural treatments. Individual sample sites within coupes were thus categorised according to their location on the slope (see Figure 1), as either upper (elevation > 150 m, 6 sites), mid (150 m > elevation > 100 m, 9 sites) or lower (elevation < 100 m, 4 sites).

Each of the 19 sample sites consisted of a 50-m transect of 10 pitfall traps. Pitfall traps were arranged in pairs each separated by 1-2 m, and consisted of a 15-cm-long stormwater pipe set vertically into an augered hole in the soil. A 425-mL plastic cup (diameter = 9 cm) containing 100 mL of either 33 % ethylene glycol (Castrol RadiCool©) or 100% ethylene glycol (Castrol) was set inside each pipe (Bashford *et al.*, 2001).

The timing and duration of sampling in each coupe are shown in Figure 2. Pitfall traps were continuously open during sampling periods, with samples removed from the traps at monthly intervals. Three sampling phases were defined for each of the four harvested coupes, a pre-logging phase and two post-logging phases. Coupes were sampled for as long as logistically possible in the pre-logging phase. After logging and burning, pitfall traps were relocated at the same positions on the transects at each sample site, and samples collected in two post-logging phases. The first phase of post-logging sampling commenced as soon as feasible after burning, and continued for 12 months. The second phase of post-logging sampling commenced in October 2002 for coupe 1B and in September 2005 for the remainder of coupes.

Two sampling phases were defined for the unharvested, control coupe 8J, one covering a similar period to the pre-logging phase of the harvested coupes, and another covering a similar period to the second post-logging phase of the harvested coupes. Control coupe data from these periods were analysed along with harvested coupe data from the comparable phases.

Statistical analysis

Statistical analysis was undertaken using SPSS™ 10.0 for Windows and α was set at 0.05. Sampling effort (the length of logging phases, and the number of sites sampled) was unequal in different coupes/treatments, so captures were converted to capture rates (captures per 100 trap days) in order to enable comparisons.

It was not possible to randomly allocate treatments with respect to elevation. To ensure that elevation did not confound the effect of silvicultural treatment or site type within treatment, the Kruskal-Wallis test was used with categorical data to investigate any differences in capture rate with slope category.

Differences in capture rates with silvicultural treatment (or site type within the "CBS with understorey islands" treatment), and with logging phase, were tested using repeated-measures analysis of variance (ANOVA), with silvicultural treatment (or site type within treatment) the between-subjects factor, and logging phase the within-subjects factor defined at three

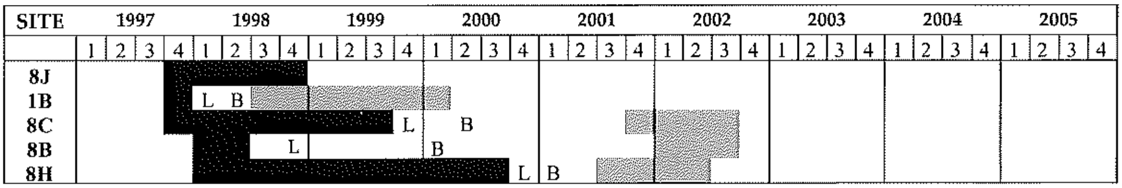

Figure 2. Timing and duration of sampling periods in coupes (L = logging, B = burning, black bars = pre-logging sampling phase [or equivalent in control coupe 8J], dark grey bars = first post-logging sample phase, light grey bars = second post-logging sample phase (or equivalent in control coupe 8J).

levels (pre-logging phase, first post-logging phase and second post-logging phase). The variance-covariance matrix of the dependent variables could not be assumed to be circular in form for the repeated-measures ANOVA on the total data-set (Mauchly's test of sphericity, $\chi^2 = 3.217$, $P = 0.200$), so the F-test degrees of freedom were adjusted by the value of epsilon using the conservative lower-bound test.

Trapping in the second post-logging sampling phase was only undertaken during the seasons when *C. signifera* is most active (spring and summer, Lauck *et al.*, 2005). To ensure that such restricted sampling did not bias comparisons between logging phases, the ANOVA was undertaken separately either using all data, or only summer/spring data from all logging phases.

The control treatment was not replicated, and there were only two replicates of each silvicultural treatment (or site type within treatment), so we were unable to test whether capture rates changed as a result of logging independent of other unrelated environmental conditions. Further, since coupes were not harvested on the same date, pre-logging and post-logging sampling did not coincide across the set of 5 silvicultural treatments, and logging phase was confounded with time-dependent parameters such as seasonal and inter-annual variation in climate variables.

Results

A total of 403 frogs were captured over a total 226,850 trap days. All were *C. signifera*. This equates to an average capture rate across all sample sites of 0.18 frogs per 100 trap days (or 0.18 frogs per 10 days of trapping at each sampling site, as there were 10 traps per site). The capture rates per 100 trap days for each silvicultural treatment (and for the two site types within the "CBS with understorey islands" treatment), over the pre-logging and both post-logging periods, are shown in Figure 3.

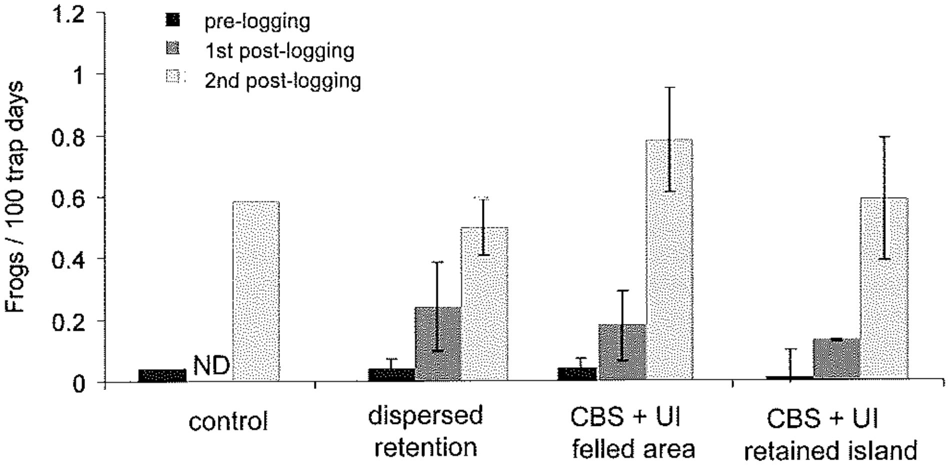

Figure 3. Mean (± SE, n = 2) number of frogs captured per 100 trap days in different phases of sampling for different silvicultural treatments (or sample site types within "CBS with understorey islands" treatment). Black bars = pre-logging (or equivalent time period in control coupe 8J), dark grey bars = first post-logging sample phase, light grey bars = second post-logging sample phase (or equivalent time period in control coupe 8J). "CBS +UI - felled area" = felled area within "CBS with understorey islands" treatment, "CBS +UI - retained island" = retained understorey area within "CBS with understorey islands" treatment . See Table 1 for further explanation. Control site was unreplicated. ND, not determined.

Mean capture rates in harvested coupes in the post-logging phases were higher than in the pre-logging phase (Figure 3). However, capture rates in the single control coupe showed similar trends over time (Figure 3), so it cannot be concluded that the differences between logging phases in the harvested coupes are a response to the forest harvesting.

Capture rates did not differ when sites were analysed according to their three topographical categories (upper, mid and lower slope) (Kruskal-Wallis test, $\chi^2 = 2.414$, $P = 0.299$). This justified pooling within silvicultural treatment (or site type within treatment) the data from various sample sites. The findings also did not differ when all data were analysed, or when the more limited spring/summer data-set was analysed. Results from the full data-set are therefore presented. Results for each silvicultural treatment are averaged over the coupes, sample site types, and length of sampling periods for that treatment, resulting in two-fold replication of each silvicultural treatment and no replication of the control treatment.

Mean capture rates (± SE) increased from 0.16 ± 0.032 captures per 100 trap days in the pre-logging phase ($n = 5$), to 1.82 ± 0.614 captures per 100 trap days in the first phase of post-logging sampling ($n = 4$, control not sampled), and to 6.21 ± 0.912 captures per 100 trap days in the second phase of post-logging sampling ($n = 5$). Mean capture rates thus increased significantly with logging phase (repeated measures ANOVA, $F_{1,3} = 19.056$, $P = 0.022$) but logging phase was confounded with time. Mean capture rates did not differ with silvicultural treatment (or site type within the "CBS with understorey islands" treatment) ($F_{2,3} = 0.863$, $P = 0.506$), and the interaction between logging phase and silvicultural treatment (or site type within the "CBS with understorey islands" treatment) was not statistically significant ($F_{2,3} = 0.627$, $P = 0.592$).

Discussion

The post-metamorphic stages of *C. signifera* are common in disturbed habitats (Margules et al., 1995; pers. comm. F. Lemckert cited in Kavanagh and Webb, 1998), but the reported effects of anthropogenic forest disturbance on the abundance of *C. signifera* are variable. Kavanagh and Webb (1998) reported low abundances of *C. signifera* in the unlogged forests of southern NSW, and higher relative capture rates both immediately after and eight years after logging; however, their study suffers limitations relating to a lack of replication, thus limiting statistical interpretation. Lemckert (1999), on the other hand, found that the abundance of *C. signifera* in the commercial forests of northern NSW decreased with increasing distance from the nearest forest reserve greater than 1000 ha in size, and decreased with increasing rainfall. This apparent response to rainfall may actually be related to an increase in the abundance of ponds that are constructed in greater numbers in drier forests (pers. comm. F. Lemckert). The abundance of *C. signifera* was, however, not significantly affected by logging disturbance (Lemckert, 1999). Margules et al. (1995) found that the abundance of *C. signifera* decreased in eucalypt forest fragments for four summers after the surrounding area had been cleared to establish pine plantations, but increased again in the two subsequent years.

Mean capture rates in our study were higher in both post-logging phases than the pre-logging period, but the differences are unlikely to be due to the effect of harvesting because capture rates in the single control site also increased similarly over the 1997-2005 time period. Instead, differences in environmental conditions over time independent of logging (rainfall or temperature, for example) may have resulted in the sites becoming increasingly conducive to amphibian activity over this period.

It is also possible that silvicultural practices may be indirectly responsible for increased capture rates in the post-logging period across the entire study area. Installation of fire management ponds is often undertaken as part of the logging process, in order to protect regenerating forests from fire damage. These ponds are opportunistically used by *C. signifera* as breeding sites (Lauck, 2005), and it is therefore possible that increased breeding site abundance could have resulted in a general increase in mobile *C. signifera* populations across the entire research area (Littlejohn and Martin, 1974; Taylor, 1991) irrespective of logging treatment on individual coupes.

There were no differences in capture rates between silvicultural treatments (or sample site types within the "CBS with understorey islands" treatment). The data thus do not indicate that any particular harvesting practice tested consistently favours habitat use by *C. signifera*. Microhabitats known to affect the abundance of some amphibian species, such as litter depth, understorey vegetation, canopy closure, moisture, light and temperature, are likely to have varied between sites as a result of the different harvesting techniques, but their magnitude must not have been sufficient to modify the activity levels of *C. signifera*. *Crinia signifera* seems tolerant to habitat disturbance from forest harvesting, and the silvicultural treatments tested in this study do not present any clear advantage with respect to the management of this specific amphibian species.

These data begin to redress the lack of information in Australia on the response of amphibians to alternative silvicultural practices (deMaynadier and Hunter, 1995) and to habitat modification (Hazell, 2003). Without such data, amphibians may be excluded from land-management planning completely, or prescriptions may be based on inappropriate assumptions of how species respond to landscape change (Goldingay et al., 1996; Hazell, 2003). The highly variable, species-specific responses to logging by amphibians (deMaynadier and Hunter, 1995; Lemckert, 1999) mean that the data presented here should not be extrapolated to other amphibian species that have different life history traits to *C. signifera*. Rather, research that investigates species-specific responses to logging is required in Australia, at least until our understanding of species groups with similar life history traits is adequate to warrant extrapolation.

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References

Bashford, R., Taylor, R., Driessen, M., Doran, N. and Richardson, A. (2001). Research on invertebrate assemblages at the Warra LTER Site. *Tasforests* 13: 109-118.

Brown, M.J., Elliott, H.J. and Hickey, J.E. (2001). An overview of the Warra long-term ecological research site. *Tasforests* 13: 1-8.

deMaynadier, P.G. and Hunter, M.L. (1995). The relationship between forest management and amphibian ecology: a review of the North American literature. *Environmental Review* 3: 230-261.

Goldingay, R., Daly, G. and Lemckert, F. (1996). Assessing the impacts of logging on reptiles and frogs in the montane forests of southern New South Wales. *Wildlife Research* 23: 495-510.

Hazell, D. (2003). Frog ecology in modified Australian landscapes: a review. *Wildlife Research* 30: 193-205.

Hickey, J.E. and Neyland, M.G. (2000). Testing silvicultural options for mixed forest). *Sustainable Management of Indigenous Forest, Proceedings of a symposium at the Southern Connection Congress III.* Wickliffe Press Ltd, Lincoln University, Christchurch, pp. 65-73.

Hickey, J.E., Neyland, M.G. and Bassett, O.D. (2001). Rationale and design for the Warra silvicultural systems trial in wet *Eucalyptus obliqua* forests in Tasmania. *Tasforests* 13: 155-182.

Kavanagh, R.P. and Webb, G.A. (1998). Effects of variable-intensity logging on mammals, reptiles and amphibians at Waratah Creek, southeastern New South Wales. *Pacific Conservation Biology* 4: 326-347.

Lauck, B. (2005). Life-history studies and the impact of recent forest harvesting on two frog species, *Crinia signifera* and *Litoria ewingii*. *Tasforests* 16: 83-94.

Lauck, B., Swain, R. and Bashford, R. (2005). Seasonal activity patterns of the frog, *Crinia signifera* (Anura: myobatracidae), in Southern Tasmania, Australia. *Papers and Proceedings of the Royal Society of Tasmania* 139: 29-32.

Lemckert, F. (1999). Impacts of selective logging on frogs in a forested area of northern New South Wales. *Biological Conservation* 89: 321-328.

Littlejohn, M.J. (2003). *Frogs of Tasmania*. Fauna of Tasmania handbook no. 6. University of Tasmania, Hobart.

Littlejohn, M.J. and Martin, A.A. (1974). The amphibia of Tasmania. In: *Biogeography and ecology in Tasmania*. (ed. W.D. Williams), pp. 251-289. Dr. W. Junk, The Hague.

Margules, C.R., Davies, K.F., Meyers, J.A. and Milkovits, G.A. (1995). The response of some selected arthropods and the frog *Crinia signifera* to habitat fragmentation. In: *Conserving Biodiversity: threats and solutions*. (ed. R.A. Bradstock *et al.*). pp. 94-103. Surrey Beatty & Sons.

Robinson, M. (1996). *A field guide to frogs of Australia*. Reed Books, Port Melbourne.

Taylor, R.J. (1991). Fauna conservation in production forests in Tasmania, Forestry Commission Tasmania, Hobart.