From the Editors

This is the final issue of *The Victorian Naturalist* for 2007. We hope you have enjoyed the range of subject matter provided over the year, including the special issue highlighting the invertebrates, a group of organisms that has received far less attention than other animals, and the special issue that focused on invasive species. From the diversity of papers we are working on currently, the 2008 issues also should provide enjoyable reading.

Thank you from the Editors

*The Victorian Naturalist* would not be successful without the enormous amount of time and effort given voluntarily by a large number of people who work behind the scenes.

One of the most important editorial tasks is to have papers refereed. The Editors would like to say thank you to the following people who refereed manuscripts published during 2007:

Graeme Ambrose
Kevin Bonham
David Cheal
Nick Clemann
John Coventry
Ian Endersby
Ross Field
Maria Gibson
Luke Kelly
Richard Loyn
Ian Lunt

Lindy Macraaid
Richard Marchant
Tom May
Matthew McArthur
Ron Miller
Sharon Morley
Tim New
Dale Nimmo
Damon Oliver
John Pickett
Alistair Richardson

Melody Serena
Megan Short
Ken Simpson
Ron van der Waal
Yolanda van Heezik
Anneke Veenstra-Quah
Ken Walker
Rob Wallis
Neville Walsh
Jan West

The *Victorian Naturalist* publishes articles for a wide and varied audience. We have a team of dedicated proofreaders who help with the readability and expression of our articles. Our thanks go to:

Andrea Ballinger
Ken Bell
Arthur Carew
Chantal Carrigan
Leon Costermans
Ian Endersby
Linden Gillbank

Maria Gibson
Ken Green
Pat Grey
Murray Haby
Jamie Harris
Virgil Hubregtse
Michael McBain

Helen McNally
David Meagher
Anne Morton
Geoffrey Paterson
Gary Presland
Lyndsey Vivian

Sincere thanks to our book reviewers for 2007 who provided interesting and insightful comments on a wide range of books and other materials:

Nick Clemann
Helen Cohn
Leon Costermans
Ian Endersby
Maria Gibson

Linden Gillbank
Merilyn Grey
Ian Mansergh
Richard Marchant
Peter Marriott

Anne Morton
Gary Presland
Kevin Rule
Rebecca Steer

As always we particularly thank our authors, who provide us with excellent material for publication.

On the production side, thank you to:
Ken Bell, who prepares the annual index,
Helen McNally for printing the mailing labels,
Dorothy Mahler for administrative assistance, and
Printers, BPA Print Group, especially Tom Markovski.
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Intense fires promote uncommon post-fire ephemerals in Currawang Acacia doratoxylon dry scrubs of Little River Gorge, East Gippsland

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Abstract

Acacia scrubs are an unusual vegetation community in the Upper Snowy River region of Victoria and New South Wales, occurring as sharply-delineated patches amongst eucalypt forest on steep, rocky, north to west facing slopes. They can be dominated by a range of Acacia species, but understoreys of Acacia scrubs are generally reported as sparse and species poor, and little is known of their ecology. Extensive wildfires in 2003 provided an opportunity to compare the effects of mild and intense fires on plant species composition and vigour in Acacia scrub communities of the Little River Gorge in eastern Victoria. Acacia scrubs at this site were dominated by Acacia doratoxylon, not previously described as a dominant in Acacia scrubs in Victoria. Consistent with earlier observations, understoreys in unburnt scrubs were usually sparse. Light burns led to minimal change in understorey abundance, and sporadic establishment of a range of species that were uncommon in the understorey of unburnt sites. By contrast, burns that were intense enough to kill the Acacia overstorey stimulated dense establishment and profuse growth of species that were rare or absent in the understorey of unburnt plots, leading to a dramatic increase in native shrub richness and understorey abundance. Processes leading to these understorey changes are likely to involve both effects of fire on seed dormancy, and release from intense competition for resources after overstorey death. Infrequent, intense fires have previously been recognised as important for stimulating recruitment of overstorey species and thus the perpetuation of Acacia scrubs in far south-eastern Australia. This study indicated that a diverse range of understorey species are also dependent on intense fires in these communities, where they appear to behave as post-fire ephemerals. Further, many of these species are listed as rare or vulnerable in Victoria, and thus the appropriate fire management of Acacia scrubs is of significant conservation interest. (The Victorian Naturalist 124 (6), 2007, 320-331)

Introduction

Dry sclerophyll forests or ‘scrubs’ dominated by Acacia species form an anomalous vegetation community in the Snowy River region of eastern Victoria. They occur as sharply-delineated patches on steep, rocky north and west facing slopes within a matrix of eucalypt-dominated vegetation. Together with related scrubs of south-eastern NSW, these scrubs form the only class of vegetation east of the Great Dividing Range in which Acacia is the dominant tree (Keith 2004). They are not closely related to any other classes of vegetation in the region, although they share some floristic similarities with rocky outcrops in the adjacent sclerophyll forests (Keith 2004). In eastern Victoria, they are known as rocky outcrop scrubs (EVC 27, Woodgate et al. 1994; previously rocky-outcrop open scrubland community of Forbes et al. 1982).

Various Acacia species (A. binervia, A. blayana, A. doratoxylon, A. falciformis, A. kettlewelliae and A. silvestris) have been recorded as dominants in different scrub patches (Costin 1954, Clayton-Greene and Wimbush 1988, Keith and Bedward 1999). In the Snowy River region, Clayton-Greene and Wimbush (1988) found Acacia silvestris was dominant in most stands. The understorey of Acacia scrubs is usually reported as sparse, with scattered shrubs and minimal ground cover, but a dense shrub layer, particularly of Philotheca trachyphylla (sometimes without the Acacia overstorey) can also occur (Forbes et al. 1982, Clayton-Greene and Wimbush 1988, Keith 2004). Keith (2004) describes the community as typically species-poor, with only about a dozen species per 0.1 hectare.

Little is known about the ecology of dry Acacia scrubs (Clayton-Greene and Wimbush 1988). The even-aged nature of mature Acacia stands indicates that intense fires are important for their regeneration.
In these conditions, mature trees are killed and germination and growth of seedlings is stimulated (Clayton-Greene and Wimbush 1988). However, there is little documentation of effects of fire on other species in these communities, and patterns in species composition relating to other environmental factors are poorly understood.

Extensive wildfires in 2003 provided an opportunity to study the effects of fire on dry Acacia scrub communities on Lower Devonian volcanics of the Little River Gorge in East Gippsland, Victoria. We undertook stratified floristic surveys to assess short-term impacts of mild and intense fire on understorey composition and vigour, and to establish benchmarks for monitoring vegetation response to fires over a longer time frame. Surveys were also relevant to management of habitat of the Brush-tailed Rock Wallaby Petrogale penicillata (JE Gray 1825), as the Little River Gorge area provides the last remaining refuge for this species in Victoria.

The Study Area
The Little River, upstream of its junction with the Snowy River in East Gippsland, forms Victoria’s deepest gorge. The area is highly dissected, with steep slopes and deep valleys ranging in elevation from 200 to 1000 m A.S.L., and occupies a rain shadow with an average of around 600 mm rainfall per annum. Soils are derived from Lower Devonian volcanics (rhyodacites), and contrast with the coarse grained granodiorites and Upper Ordovician sediments (siltstones, schists, slates, shales and claystones) occurring immediately to the north and east (Clayton-Green and Wimbush 1988).

Typical vegetation of the local region is grassy woodland dominated by White Box Eucalyptus albens, grading to other eucalypt forests and woodlands at higher altitudes and on poorer soils. Dry Acacia scrubs occur as scattered patches associated with steep rocky valleys and slopes amongst these vegetation types, both on rhyodacites and sediments, but rarely on granodiorites (Clayton-Greene and Wimbush 1988).

Large areas of the Little River valley were burnt in the extensive Bogong Complex wildfires during January 2003. Fire intensity varied depending on aspect, fuel loads and weather conditions, leading to a mosaic of unburnt, lightly burnt and intensely burnt areas across the gorge.

Methods
Sampling
Floristic sampling focused on two areas of known Petrogale penicillata habitat on the northern slopes of Little River (37° 06’ S, 148° 20’ E) and Farm Creek (a tributary of Little River, 37° 07’ S, 148° 20’ E). Vegetation was dominated by tall Acacia scrub on dry slopes and spurs, with E. albens woodlands on locally cooler (eastern) aspects, and shrubland dominated by P. trachyphylla on exposed rocky outcrops. Some intergrading occurred among these communities, especially at Farm Creek.

Sampling was undertaken in November 2003 to January 2005, and was confined to vegetation with a prominent Acacia overstorey. Quadrats were 10 x 10 m, and permanently marked to allow long-term monitoring. Although the study was undertaken almost two years after the Bogong Complex fires, a range of fire intensities was easily distinguishable:

- Sites with deep, non-charred, ground-layer litter and occasional live shrubs with sparse to abundant twig-lichens (Usnea sp.), were classed as unburnt.
- Sites with visible charcoal and partially burnt twigs, fire-scars on trees and larger shrubs, no twig-lichens, and <20% kill of the Acacia canopy were classed as lightly burnt.
- Sites with >80% kill of the overstorey Acacia trees were classed as intensely burnt.

At each site we aimed to sample four replicates each of unburnt, lightly burnt and intensely burnt Acacia scrub. However, no unburnt sites were found at Little River, so the final sampling design comprised four unburnt plots (Farm Creek only), eight lightly burnt plots and eight intensely burnt plots (both sites).

Plots were placed so as to sample the range of topographic classes present at each site (NE to NW slopes, drainage lines and rocky spurs). Within each topographic class, we sought to place plots of each fire intensity class within close proximity, leading to paired (lightly-burnt and intensely-burnt) plots at Little River, and sets of three
Floristic monitoring

Percentage foliage projective cover was visually estimated for all higher plant and fern species and for bare ground, litter and rock cover. Species that were present at <1% visual cover were allocated a nominal cover of 0.5%. This may have led to over-estimates of total cover, as species were often present at very low cover. A range of other variables (richness and cumulative cover for native and shrub cover including and excluding P. trachyphylla, forb cover, grass cover and exotic cover) were calculated from primary data.

Data analysis

Richness and cover estimates were analysed in GenStat (2003), using general linear regression to perform analysis of variance of the unbalanced 8 block (pair or triplet) x 3 fire intensity design. It was assumed that effects of fire intensity were consistent across sites (i.e. that there was no site x fire intensity interaction), and that fire intensity and pre-fire vegetation composition were not significantly confounded. For each variable showing a significant overall effect, treatment means adjusted for block effects were calculated and compared using post-hoc tests (Fisher’s Protected Least Significant Differences, Steel and Torrie 1981).

Ordination was used to explore patterns in understory composition. Two ordinations were performed and compared, one using presence-absence floristic data and one using quantitative floristic data. For each analysis, floristic data (excluding tree species) were used to produce a distance matrix using the Bray-Curtis coefficient of dissimilarity (Faith et al. 1987). Non-metric multidimensional scaling (nMDS) analyses were performed on the distance matrices using the software package DECODA (Minchin 1989), and results were transferred to PC-ORD (McCune and Mefford 1999) for plotting and visual analysis. Analyses were performed in one to five dimensions using 10 random starts and global nMDS. Considerable stress reduction from the two to the three dimensional solutions, compared with minimal improvement in higher dimensions, led to selection of the three-dimensional solution for further exploration. Stress values of the selected solutions were 0.11 for the presence-absence and 0.10 for the quantitative analysis.

Correlations of environmental attributes with the distribution of sites on the final ordinations were examined by plotting each directly onto the ordination and, where appropriate, by calculating vectors of maximum correlation (Rmax) using the vector-fitting procedure of DECODA. Monte-Carlo tests, using 1000 random permutations of the data, were used to estimate the significance of each vector correlation. For the purposes of vector correlations, topographic class was treated as a sequence from gully to slope to rocky spur, and aspect a sequence from north-west to north-east. Where appropriate, vectors were used to order sites and species into two way tables indicating species contributing to relevant trends.

Results

Acacia scrubs of the study area were dominated by Currawang A. doratoxylon, which formed small trees to 20 m on lower slopes, and became smaller (to 3 m) on upper slopes and rocky spurs. A. silvestris was occasional at Little River, and became dominant on the rockiest sites at Farm Creek. Other overstorey trees included patches of E. albans, emergent Eucalyptus saxatilis at Little River and mallee-form Eucalyptus smithii at Farm Creek, and occasional Allocasuarina verticillata at Farm Creek. On very rocky sites P. trachyphylla replaced A. doratoxylon as the dominant, though usually with scattered emergent acacias. The understory of the Acacia scrubs was generally sparse beneath the intact canopy (e.g. Fig. 1a).

A total of 64 native plant species was recorded across the 20 plots (39 at Little River and 54 at Farm Creek), including seven grass, one sedge, 30 forb, 17 shrub and sub shrub, two vine and seven tree species. A high proportion (20%) of these species are classified as rare or vulnerable in Victoria (Department of Sustainability and Environment 2005). Only six exotic species were recorded, all of which were
herbaceous. Native species richness per 10 x 10 m plot ranged from 3 to 22 species, and exotic richness from 0 to 4. Total (cumulative) native cover was highly variable (range 6-71%), while exotic species cover was consistently very low (<2%). Understorey composition ranged from grass to shrub dominated and was generally different from surrounding grassy woodlands and dry forests.

Unburnt plots had a dense litter layer of *Acacia* phyllodes and twigs, with small amounts of bare soil and variable amounts of outcropping rock. Lightly burnt plots had approximately half the litter cover of unburnt plots (comprising litter accumulated since the fire and/or incomplete combustion of the pre-fire litter layer), and significantly more bare soil. On intensely burnt plots, the litter layer was largely removed by the fire and had not been replaced owing to canopy death. Bare soil levels of intensely burnt plots were similar to lightly burnt plots (Table 1).

Understorey cover at two years post-fire was significantly and dramatically influenced by fire intensity. Unburnt and lightly burnt plots generally had a sparse understorey of scattered shrubs and grass tussocks, with the exception of one unburnt plot located on a rocky spur and with a very dense cover (70%) of the shrub *Philotheca trachyphylla* (Fig 1a and b). Understorey cover increased to an average of 35% on intensely burnt plots (Fig. 1c), an increase of over 400% (excluding the anomalous *P. trachyphylla* plot, Table 1). Increases in cover due to intense burns were significant for the native shrub, grass and forb components of the understorey, but there were no significant effects on weed cover. Native shrub richness also increased on intensely burnt plots (Table 1).

Despite considerable variation in understorey composition between differing sets or pairs of plots, fire intensity correlated significantly with the nMDS ordinations (Figs. 2a, b; Table 2). On the presence-absence ordination, the correlation was relatively weak ($R_{max} = 0.65$). Unburnt plots were usually separated from burnt plots, but lightly burnt and intensely burnt plots were poorly distinguished from each other (Fig. 2a). On the quantitative ordination,
Table 1. Adjusted means for understorey and ground cover characteristics of Acacia doroatylon scrub two years after burning at different fire intensities. Means with different superscripts are significantly different from each other (P<0.05).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unburnt</th>
<th>Lightly Burnt</th>
<th>Intensely Burnt</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare soil</td>
<td>6.0a</td>
<td>27.9b</td>
<td>24.1b</td>
<td>0.01</td>
</tr>
<tr>
<td>Exposed rock</td>
<td>36.0a</td>
<td>37.9a</td>
<td>26.6a</td>
<td>ns</td>
</tr>
<tr>
<td>Litter</td>
<td>49.3a</td>
<td>27.4b</td>
<td>7.6c</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Native richness</td>
<td>11.4a</td>
<td>12.5a</td>
<td>15.34a</td>
<td>ns</td>
</tr>
<tr>
<td>Native cover (%)</td>
<td>25.4a</td>
<td>8.3b</td>
<td>35.5a</td>
<td>0.021</td>
</tr>
<tr>
<td>Native cover (%) excl. Philotheca</td>
<td>8.1a</td>
<td>7.7a</td>
<td>34.7b</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shrub richness</td>
<td>2.2a</td>
<td>3.3a</td>
<td>4.9b</td>
<td>0.006</td>
</tr>
<tr>
<td>Shrub cover (%)</td>
<td>21.8a</td>
<td>1.4a</td>
<td>18.6a</td>
<td>ns</td>
</tr>
<tr>
<td>Shrub cover (%) excl. Philotheca</td>
<td>4.5a</td>
<td>0.9a</td>
<td>17.9b</td>
<td>0.003</td>
</tr>
<tr>
<td>Grass richness</td>
<td>1.8a</td>
<td>1.4a</td>
<td>1.6a</td>
<td>ns</td>
</tr>
<tr>
<td>Grass cover (%)</td>
<td>-0.1a</td>
<td>2.0a</td>
<td>10.1b</td>
<td>0.002</td>
</tr>
<tr>
<td>Forb richness</td>
<td>2.6a</td>
<td>7.9a</td>
<td>9.9a</td>
<td>ns</td>
</tr>
<tr>
<td>Forb cover (%)</td>
<td>4.9a</td>
<td>7.3b</td>
<td>ns</td>
<td>0.006</td>
</tr>
<tr>
<td>Weed richness</td>
<td>0.4a</td>
<td>0.6a</td>
<td>1.4a</td>
<td>ns</td>
</tr>
<tr>
<td>Weed cover (%)</td>
<td>0.3a</td>
<td>0.7a</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

*Negative value due to adjustment; actual mean 1.9

Table 2. Vector correlations (R_max) of plot characteristics with ordinations using presence-absence and abundance data. P indicates significance of correlations.

<table>
<thead>
<tr>
<th>Plot characteristics</th>
<th>Presence/Absence R_max</th>
<th>P</th>
<th>Abundance R_max</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire intensity</td>
<td>0.65</td>
<td>0.031</td>
<td>0.87</td>
<td>0.000</td>
</tr>
<tr>
<td>Topography</td>
<td>0.74</td>
<td>0.002</td>
<td>0.69</td>
<td>0.019</td>
</tr>
<tr>
<td>Site</td>
<td>0.62</td>
<td>0.064</td>
<td>0.66</td>
<td>0.021</td>
</tr>
<tr>
<td>Aspect</td>
<td>0.23</td>
<td>0.823</td>
<td>0.15</td>
<td>0.930</td>
</tr>
</tbody>
</table>

Fig. 2. nMDS ordination results for (a) presence-absence data showing relationships with burning intensity. Axes showing most distinct differences are presented.
Fig. 2. cnd. nMDS ordination results for (b) abundance data (axes 1 versus axes 2 and axes 2 versus axes 3, showing relationships with burning intensity..
Research Report

R_{max} increased to 0.87 and intensely burnt plots were distinctly separated from all others (Fig. 2b). This suggests that abundance of species played an important role in distinguishing lightly burnt from intensely burnt plots, consistent with analyses of cover estimates.

Differences in floristic composition related to fire intensity are indicated in Table 3. A number of species, such as Platsace lanceolata, E. albans, Oxalis perennans, Galium liratum and Dichondra repens showed no detectable relationship. Few understorey species were clearly more prominent in unburnt or lightly burnt plots, but it is possible that P. trachyphylla and Dianella revoluta were disadvantaged by intense fires. As well, the overstorey species Allocasuarina verticillata and A. doratoxyylon were less frequent or abundant in intensely burnt plots owing to canopy death, consistent with our sampling strategy.

A distinct suite of species were absent from the understorey of unburnt plots, sparse or sporadic in lightly burnt plots, and frequent or abundant in intensely burnt plots (Table 3). These included the shrubs Dodonea rhombifolia, Muehlenbeckia decina, Cypanthera albicans (absent from Farm Creek), Solanum linearfolium, and the forbs Nicotiana suaveolens and Sigsbeckia australiensis. A number of other species occurred occasionally or infrequently in unburnt plots, but increased markedly in frequency or abundance with increasing fire intensity, e.g. Notodanthonia longifolia, Einaida hastata, Solanum prinophyllum and Lepidium pseudolasmanicum. Cynoglossum australe and Senecio hispidulus increased in burnt plots but with no clear effects of fire intensity.

Ordinations using either presence-absence or abundance data also correlated significantly with topography (Table 2), with all five samples from rocky spurs distinguished from other topographic classes (slopes and drainage lines). A range of species (e.g. Goodenia macmillanii, Lepidosperma laterale, Nicotiana suaveolens, Arthropodium milleflorum, Dichondra repens, Cheilanthes sieberi and Sigsbeckia australiensis) was absent from plots on rocky spurs, while Isotoma axillaris, A. silvestris and Philotheca trachyphylla were most frequent in plots on rocky spurs (Table 4). There was little effect of aspect within these topographic classes, probably reflecting the limited range of aspects occupied by Acacia scrubs (NE to NW, Table 2).

There was also some distinction in understorey composition between the two sites (significant on quantitative ordination only, Table 2). This separation could be attributed to the absence from the Little River plots of species such as Gonocarpus elatus (present at Little River, but not in the plots), Cheilanthes sieberi and Ozothumnus thyrsoides, and absence from the Farm Creek plots of Cynoglossum australe, Parietaria debilis and Cypanthera albicans, as well as a greater frequency of species such as Dodonea rhombifolia, Senecio hispidulus and Nicotiana suaveolens at Little River.

Discussion

Acacia doratoxylon has not previously been described as dominant in Acacia scrubs in Victoria, but A. doratoxyylon scrubs are noted from the adjoining Byadbo wilderness of NSW (Keith 2004). Clayton-Greene and Wimbush (1988) sampled a range of Acacia scrubs in the Upper Snowy region, and found A. silvestris was dominant in nine of 11 stands. However, they did not sample scrubs on rhydodacites owing to poor accessibility. Further surveys to elucidate the extent, status and environmental determinants of A. doratoxyylon scrubs in Victoria would thus be of value.

The structure and floristic composition of A. doratoxyylon compared with other Acacia scrubs is also of interest. In our study area, A. doratoxyylon formed low forests to tall shrublands with open understorey, but did not form dense, impenetrable thickets as commonly reported for A. silvestris scrubs (Clayton-Greene and Wimbush 1988). A high proportion of the component plant species recorded in this study are listed as rare or vulnerable in Victoria (Department of Sustainability and Environment 2005), but it is not known whether these species are typical of other types of Acacia scrub. We also noted relatively sparse and slow-growing regeneration of A. doratoxyylon (e.g. live cover values in intensely burnt plots were usually <1%, with seedlings mostly less than
Table 3. Two way table indicating the influence of fire intensity (U=unburnt, L=lightly burnt, I=intensely burnt) on understorey composition in 20 Acacia scrub samples at Little River Gorge and Farm Creek. Sites were ordered using the vector of maximum correlation for fire intensity for the quantitative nMDS ordination, and species were ordered according to their weighted average locations along this vector. Percent abundance is represented by the following classes: 1, <1%; 2, 1-2%; 3, 3-5%; 4, 6-10%; 5, 11-15%; 6, 16-25%; 7, 26-50%; 8, 51-75%; 9, 76-100%. All species that were recorded from 3 or more plots are included. Note that tree species (bold text) were not included in ordination analyses; low tree abundance on intensely burnt plots is due to canopy death.

<table>
<thead>
<tr>
<th>Fire intensity</th>
<th>L</th>
<th>U</th>
<th>U</th>
<th>U</th>
<th>L</th>
<th>L</th>
<th>U</th>
<th>U</th>
<th>U</th>
<th>L</th>
<th>L</th>
<th>L</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Philotheca trachyphylla</strong></td>
<td>-</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td><strong>Allocasuarina verruculata</strong></td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Acacia silvestris</strong></td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td><strong>Acacia doratoxylon</strong></td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>9</td>
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<td>8</td>
<td>8</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Dianella revoluta s.l.</strong></td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Lepidosperma laterale</strong></td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td><strong>Clematis microphylla</strong></td>
<td>1</td>
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</table>

0.5 m), compared with dense and robust regeneration in nearby *A. silvestris* scrubs (post-fire live cover to 50%, with many seedlings to 2 m in height, pers. obs.).

**Effects of fire on vegetation structure and floristics**

Consistent with earlier reports, the understorey of the *Acacia* scrubs of this study was sparse beneath the intact canopy (e.g. Fig. 1a), or dominated by dense *Philotheca trachyphylla* in rocky situations (Forbes et al. 1982, Clayton-Greene and Wimbush 1988, Keith and Bedward 1999). Richness ranged from 3-19 species (average 12) in unburnt plots: higher than reported by Keith (2004) for *Acacia* scrubs in NSW.

Surveys indicated that light burns led to minimal change in total understorey abundance, and sporadic establishment of a range of species that were rare or absent in the understoreys of burnt sites. By contrast, burns that were intense enough to kill the *Acacia* overstorey stimulated dense
establishment and robust growth of species absent from understoreys of unburnt plots, leading to a significant increase in native shrub richness and understorey abundance. As well, intense burns promoted lush growth of the grass *Notodanthonia longifolia* and forbs such as *Einadia hastata*.

Processes leading to these understorey changes are likely to involve both direct effects of fire on seed dormancy and germination, and release from intense competition for light, soil moisture and/or soil nutrients after overstorey death. As well, a flush of soil nutrients may have occurred with the breakdown of root systems of dead *Acacias* (Fisher and Binkley 2000).

The importance of the overstorey for suppressing understorey species is further evident from field observations, where sharp boundaries between dense and sparse understorey are coincident with boundaries between killed and live canopy respectively (e.g. Fig. 3).

Infrequent, intense fires have previously been recognized as important for stimulating recruitment of overstorey species and thus the perpetuation of *Acacia* scrubs in far south-eastern Australia (Clayton-Greene...
This study indicated that a range of understorey species are also dependent on intense fires in these communities, where they occur mostly as post-fire ephemerals (sensu Gill 1993, becoming abundant only after intense fires, and existing as scattered individuals and/or a dormant seed bank for long periods). Many of these species in Little River Gorge are vulnerable, rare or disjunct in Victoria (Table 5), and thus the appropriate fire management of Acacia scrubs is of significant conservation interest.

While the dramatic effects of canopy burns on understorey composition and vigour were readily evident in the field, a caveat must be placed on conclusions of this study. Because monitoring plots were established after the fire, some confounding of understorey composition with fire intensity may have occurred due to the influence of pre-fire vegetation on fire behaviour. For example, observations before the fire (R Martin, pers. comm.) suggest that some areas had high cover of dry grass thatch, and these may have been more flammable than other areas. Consequently, it is possible that pre-fire vegetation in intensely burnt areas was naturally somewhat denser than in unburnt areas. Nevertheless, observations of the vegetation before the fire (R Martin, pers. comm.) confirm that many species that flourished after the fire (e.g. Cyphanthera albicans, Muehlenbeckia diclinia, Dodonaea rhombifolia) were uncommon to very rare in the understorey before the fire, and that other species were common but less robust and abundant than after the fire (e.g. Goodenia macmillanii).

Implications for fire management
Some preliminary conclusions regarding appropriate fire regimes for managing Acacia scrubs and Petrogale penicillata habitat in Little River Gorge might be drawn based on conditions at two years post-fire. In particular, the strong differentiation of intensely-burnt plots from unburnt and lightly-burnt plots suggests that only intense, canopy-killing fires are suitable for releasing many fire-recruiting species from the seed-bank, and for promoting vigorous understorey growth in A. doratoxylon scrubs. By contrast, controlled, low-intensity fires as usually applied in management burns may not be sufficient to kill the canopy and hence promote significant recruitment and growth of understorey species.

Fig. 3. Sharp boundaries in understorey abundance relating to canopy death were typical across burnt areas at Little River and Farm Creek. All of the area in this image was burnt during the 2003 fire. However, canopy on the left was killed, corresponding with lush understorey growth, while canopy on the right was largely intact and understorey remains sparse.
Table 5. Fire responses of rare, vulnerable or disjunct species at Little River and/or Farm Creek.

<table>
<thead>
<tr>
<th>Species</th>
<th>Distribution in Victoria (Walsh and Entwisle 1994-1999)</th>
<th>DSE* (2005) classification</th>
<th>Notes (including fire response observed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acacia doratoxyylon</em> Currawang</td>
<td>Common and widespread in semi-arid NSW, disjunct outlier in eastern Victoria</td>
<td>Rare</td>
<td>Killed by intense fire, which stimulates germination of new generation</td>
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<tr>
<td><em>Cyphanthera albicans</em> subsp. albicans</td>
<td>Rare in Victoria where known only from a few localities in the upper Snowy River area</td>
<td>Rare</td>
<td>Post-fire ephemeral*</td>
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<tr>
<td>Hoary Rayflower</td>
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<tr>
<td><em>Dodonaea rhombifolia</em> Broad-leaf Hop-Bush</td>
<td>Disjunct in eastern Victoria viz. Pine Mountain and Snowy and Combienbar River</td>
<td>Rare</td>
<td>Post-fire ephemeral*</td>
</tr>
<tr>
<td><em>Eucalyptus saxatilis</em> Suggan Buggan Mallee</td>
<td>Known from few localities, viz. Stradbroke Chasm, Mt Wheeler and Little River Gorge.</td>
<td>Vulnerable</td>
<td>No seedlings seen. Vigorous post-fire resprouting, but frequent tree and/or resprout death due to post-fire drought. Enhanced by fire</td>
</tr>
<tr>
<td><em>Goodenia macmillanii</em> Pinnate Goodenia</td>
<td>Rare endemic in Victoria, known only from rocky slopes in rainshadowed valleys of the Macalister, Snowy and Deddick Rivers.</td>
<td>Vulnerable</td>
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<tr>
<td><em>Haloragodendron baenerteni</em> Shrubby Raspwort</td>
<td>In Victoria confined to far east between Suggan Buggan, Mt Tingaringy and Snowy River Gorge, on rocky spurs.</td>
<td>Rare</td>
<td>Not seen during this study but previously recorded from Little River <em>Acacia</em> scrubs</td>
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<tr>
<td><em>Muehlenbeckia dictyna</em> subsp. l</td>
<td>Known only from upper Snowy River area and near Licola.</td>
<td>Rare</td>
<td>Post-fire ephemeral*</td>
</tr>
<tr>
<td><em>Nicotiana suaveolens</em> Austral Tobacco</td>
<td>Widespread in drier inland, with disjunct occurrences in Snowy River and East Gippsland areas.</td>
<td>Rare</td>
<td>Post-fire ephemeral*</td>
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<tr>
<td><em>Pomaderris eterocephala</em> Woolly-head Pomaderris</td>
<td>Endemic in Victoria, scattered on shallow rocky soils east from near Barnsdale.</td>
<td>Rare</td>
<td>Recorded in only 2 plots (lightly and intensely burnt)</td>
</tr>
<tr>
<td><em>Scleranthus diander</em> Tufted Knawel</td>
<td>Mostly in stony soils of montane grassland and open woodlands above 500m.</td>
<td>Rare</td>
<td>Recorded in only 2 plots (unburnt and lightly burnt)</td>
</tr>
<tr>
<td><em>Senna aciphylla</em> Sprawling Cassia</td>
<td>In Victoria confined to the east, usually on rocky slopes in woodland scrubs.</td>
<td>Rare</td>
<td>Recorded in only 1 plot (unburnt)</td>
</tr>
<tr>
<td><em>Solanum linearifolium</em> Mountain Kangaroo-apple</td>
<td>In Victoria, apparently restricted to montane forests between Omeo and Mt Tingaringy, often appearing following disturbance or bushfire.</td>
<td>Rare</td>
<td>Post-fire ephemeral*</td>
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<tr>
<td><em>Teucrium thieleanum.</em></td>
<td>New species of <em>Teucrium</em> found at Farm Creek and Little River. (see Conn 2006)</td>
<td>Unknown</td>
<td>Occasional occurrences in burnt areas, flourishing after the fire. Not recorded in permanent plots.</td>
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</tbody>
</table>

*Department of Sustainability and Environment

*i.e. abundance in understorey in relation to fire: rare in unburnt plots, sporadic in lightly burnt plots, frequent or abundant in intensely burnt plots; longevity unknown*
While intense fires are likely to be critical for conservation of Acacia scrubs, ecologically appropriate fire return times are probably relatively high. Appropriate fire frequencies for maintaining plant species diversity and natural processes in the A. doratoxylon communities will involve a balance between a sufficient fire-free period for successful maturation of Acacia stands, and rare, hot (canopy-killing) fires to promote post-fire ephemerals and replenish their seed banks before soil seed stores senesce. A greater understanding of the longevity of such seed stores, and of the Acacia overstory, is needed to indicate the optimal frequency of intense fires.

Further studies are needed to evaluate the net benefit or disadvantage of intense fires for P. penicillata. An initial disadvantage might be expected during the immediate burn and post-burn period, but in the medium-term the wider richness and abundance of plant species present could provide better feed and cover for foraging animals. It is likely that fire return times appropriate for maintaining Acacia scrubs would be too long for intense burns to provide a practical management option for enhancing feed and cover availability over the long term. Thus if availability of feed and/or cover is shown to be an important limit to P. penicillata populations, alternative options would need to be considered, including suppression of the Acacia overstory in small patches or augmentation of feed and cover through other means.

Acknowledgements

This study was initiated and supported by the Department of Sustainability and Environment, Victoria. We thank Lucy Clausen for assistance with field work and Raz Martin for information on conditions before and during the fires. Terry Koen (NSW Department of Natural Resources) provided statistical advice.

Note


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Received 18 May 2006; accepted 12 July 2007
Contributions

A probable case of twins in the Short-beaked Echidna
_Tachyglossus aculeatus_ (Tachyglossidae: Monotremata), with
observations on suckling of young after their
emergence from the nursery burrow

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Abstract

The finding of the nursery burrow of a Short-beaked Echidna close to the house of the two senior authors allowed close observation and monitoring of breeding behaviour. Two young emerged from the nursery burrow eight days apart. Individual colour-marking of the mother and both young allowed their movements and behaviour to be monitored over subsequent months. Data are presented on post-emergence suckling of both young, which continued for 60 days after emergence, and included one instance when both were suckled simultaneously. Information is also presented on the movements, survival, and selection of shelter-sites by the juveniles. The two juveniles are likely to be twins, though they are not identical twins. These observations provide the first record of a female echidna successfully raising more than one young in a single breeding season, and the first records of parental care of young echidnas after they have vacated the nursery burrow. (_The Victorian Naturalist_ 124 (6), 2007, 332-340)

Introduction

The Short-beaked Echidna _Tachyglossus aculeatus_, along with the Platypus _Ornithorhynchus anatis_ and New Guinea Long-beaked Echidnas _Zaglossus_ spp, comprise the egg-laying mammals (Subclass Prototheria, Order Monotremata). Echidnas differ from all other mammals by laying an egg directly into a pouch on their abdomen where it is incubated and the young hatch. (Platypuses have no pouch and lay their two eggs directly into a nest in the nursery burrow). The hatchling, which resembles a new-born marsupial in its state of development, develops in the pouch until it is capable of being left in a burrow while the mother forages. Young echidnas feed by sucking milk from one of two areolae located inside the pouch — there are no teats. Observations of the frequency of a mother’s visits to the nursery burrow indicate that suckling occurs at intervals of several days (Griffiths 1978, Augee and Gooden 1993). However, the milk is rich in fats (Griffiths 1978) and a young can imbibe up to 40% of its body weight in a single feeding session lasting up to one hour (Rismiller 1999).

The Short-beaked Echidna is the most widespread of Australia’s native mammals but, until recently, comparatively little was known of its biology and ecology (Griffiths 1978; Augee and Gooden 1993; Rismiller 1999; Augee et al. 2006). In south-eastern Australia, courtship and mating occurs from roughly mid-June to the end of July. Gestation takes 23 days, incubation of the egg in the pouch 9-11 days, and the young remains in the pouch for a further 45-55 days (Rismiller and McKelevy 2000). The young is then deposited in a nursery burrow, the entrance of which is plugged with soil after each visit. Here it remains for 115-170 days until emergence. Thus the period from conception to emergence is 6.5-8.5 months. Females rarely breed annually (Augee et al. 2006) and in a study on Kangaroo Island, South Australia, observation of tagged individuals indicated that females bred on average only once every 4-6 years (Rismiller and McKelevy 2000), a very low rate of reproduction.

There are very few records of more than a single egg being laid by the Short-beaked Echidna. Griffiths (1978, page 245) lists one instance of two eggs being found in a pouch and another of two pouch young. Augee and Gooden (1993, page 31) state that ‘twins are known to occur rarely’ without giving further details. Augee et al. (2006, page 82) state that ‘usually only one egg is impregnated at a time, it is rare to
find a female carrying two young in her pouch.' Further, there appear to be no documented cases of female Short-beaked Echidnas raising to independence more than one young per breeding season. Here we describe observations of an individually recognisable female Short-beaked Echidna that was suckling two young that had emerged from the same nursery burrow eight days apart. We also provide the first documented observations of maternal suckling of young long after their emergence from the nursery burrow, and movement patterns and behaviour of the young until they increased their home ranges and could be found only intermittently.

Methods

Description of study area
The observations occurred in and around the garden of FP and JM at the Bend of Islands, a 400 ha area of high conservation-value bushland, located adjacent to the Yarra River, 33 km north-east of Melbourne. The area is zoned Special Use – Environmental Living under the Shire of Nillumbik Planning Scheme. This zoning prohibits the keeping of dogs, cats or other domestic or farm animals, restricts the planting of non-indigenous plants to a contained kitchen garden area near each house and prohibits the removal of native vegetation without a permit. The house is located on the Round the Bend Conservation Cooperative, a 128 ha property owned by 32 shareholders each with a 0.15 ha house site strategically located to minimise impact.

The vegetation is Box-Ironbark woodland with an understorey of native herbs, grasses and sparse shrubs. The dominant eucalypt species are Red Ironbark Eucalyptus sideroxylon, Long-leaf Box E. goniocalyx and Red Stringybark E. macrorhyncha. The house is surrounded by a verandah and by brick paving extending to a terraced-fill garden to the west and a terrace-cut garden to the east. A fenced transpiration bed/kitchen garden, garage, woodshed, garden shed and water tanks are located to the north of the house. There are no fences in the area and the nearest houses are 70 m to the north and 70 m to the east. The nursery burrow was 4 m north-west of the house at the end of a terraced garden bed.

The bush area adjacent to the house has the ground fuel reduced for fire protection. This is carried out sensitively on a five year cycle of patch raking or cool burning, so that in any year only 20% of the area is fuel reduced. Fallen timber, that is not fine fuel, is retained. All plants are indigenous except in the kitchen garden and some potted plants and ferns under the verandah.

Echidnas are not considered uncommon in the area. They are seen frequently in the summer when they come to drink and bathe in the garden ponds, particularly on very hot days.

Identification of individuals

The mother and four other adults that visited during the observation period were identified by detailed analysis of digital photos of the spines in their tails. The mother had a broken spine on the lower right side which facilitated her identification (Fig. 1), but the variation in shape, size and colouring of the individual tail spines made identification of each echidna quite feasible. The two juveniles were easy to identify due to differing size, spine density and colour of spines and fur (Fig. 2).

We initially marked the juveniles with paint on opposite sides of their tails. Later, small rings were made from the plastic insulation on electrical wire and three of these were glued to spines on the back, different sides and colours being selected for each individual (Fig. 2). The juveniles, the mother and one adult, of similar size and colour to the mother, were marked in this way.

Recording

To facilitate recording and communication each echidna was given a reference. The juveniles were B1 and B2, mother was M and other visiting adults were A1 to A4.

Initially, after the burrow had been noticed, photos were taken of the back-filled surface at the entry each time it changed, to record the occurrence of visits by the mother. When B1 was found being suckled outside the burrow, photo and video clip records were taken and movements were monitored fairly casually over the next week. When B2 was found being suckled outside the burrow, eight days after B1, photo and video clip records were also taken. The significance of multiple young was then established and movements and behaviour were monitored more closely by FP and JM.
Contributions

Fig. 1. *M* suckling B1 at its emergence from the nursery burrow, 30 December 2005. Note *M*'s diagnostic broken tail spine.

Monitoring generally involved periodically checking the location and activity of the juveniles. The frequency of observations depended on the activity levels of the echidnas, and our time availability. Typically we would go out about every hour or so and find B1 and B2 if possible, recording location and activity and always keeping an eye out for M or other adults. The difficulty of finding the juveniles increased as they developed and became more mobile, far-ranging, and adept at hiding. Recording comprehensive daily route information generally became impractical after the first four or five weeks.

Detection in the bush was much harder than in the immediate house surrounds. The best detection method developed for the bush was to remain motionless for at least five minutes and listen for movement of the ground litter. If no result, then move 20 m or so and start again. Temperature was recorded by a thermometer on the north wall of the house, under a 2.5 m wide verandah. Observations continued until the juveniles dispersed from the vicinity of the house in February. Intermittent observations were recorded until late March.

The following records were kept:
- **Record Summary Sheet** – A tabulated record of visits by M or other adults and, when possible, the overnight shelter location, duration of activity period for the day, distance travelled for the day and the night shelter for each of B1 and B2, and notes on temperature, if 33°C or higher, and any notable activities.
- **Daily Routes Plan** – A separate A4 plan of the house and surrounds was used each day to record the location and time of each echidna whenever seen. The daily route was then plotted for B1, B2 and M or other adults, if sufficient data had been collected.
- **Detailed Notes** – A detailed account of significant events, if any, was kept in daily diary format.
- **Digital photos and video clips** were taken with a Canon Powershot S1-1S x10 optical zoom camera. The photo number, date and time were automatically recorded.

### Minimal Interference
Our aim was to minimize interference to the echidnas, to enable observation of natural, unaffected behaviour. The echidnas were not handled except to attach the
marking rings. The juveniles were left to their own devices except that bowls of water were put out on days of extreme heat and an old door was used to provide shelter from sun or rain in two extreme circumstances.

Results

Chronological summary of observations

The nursery burrow was first found in early November 2005. Photographic records of changes to the earthen plug at the burrow entrance indicate a visitation frequency of 4-5 days. At least two visits to the burrow by the mother took place in the evening. Opening of the burrow entrance took up to one hour. While suckling was taking place a distinctive ‘snuffley heavy breathing’ could be heard from within the burrow. This sound was later heard at observed suckling events outside the burrow.

On 30 December 2005, B1 was found being suckled by M immediately outside the closed burrow entrance at around midday. B1 remained outside the burrow entrance all afternoon and was in the same location the following morning. Because of high temperatures (up to 42°C) an old wooden door was positioned above B1’s usual resting site to provide shade on 31 December. As far as could be seen, B1 remained within 4 m of the burrow for the next week, making only short excursions in the adjacent garden and excavating three small shelter sites.

On 7 January 2006, B2 was found suckling from M next to the nursery burrow at 1300 hrs. B1 was about 4 m away in a small excavated shelter at the base of a sleeper wall. The main entry to the burrow had not been excavated (the surface was identical in photos taken on 5 January and later on 7 January). B2 had emerged from the nursery burrow via a small opening in the upper surface at the south end of the burrow (Fig. 3). This opening had not been noticed previously; however, a subsequent blowup of a photo taken on 5 January indicates that the opening may have been partially open at that time. There had been disturbance at the opening surface subsequent to 5 January, and when investigated on 7 January, it was found to provide narrow but clear access to the burrow. The opening could accommodate a juvenile the size of B2 but not an adult. M had been observed to walk over this opening at 1200 hrs when approaching the burrow. M left the area at 1430 hrs and B2 moved about until settling in an excavated shelter that B1 had previously made. B1 and B2 remained in their separate shelters over the following three days, gradually enlarging them.

On 11 January, following overnight rain, B1 was found in its shelter on its back in about 25 mm of water, cold and shivering.

Fig. 2. The two juveniles showing the variation in size, fur colour and the colour and density of spines. Left: B1 with red plastic markers. Right: B2 with green/yellow markers, 22 February 2006.
The shelter was drained, dry mulch provided and the old door was placed on the terrace level above to protect the shelter. That afternoon B1 moved about considerably, making three determined efforts to climb a 0.4 m high section of sleeper wall before finally succeeding and entering the shelter occupied by B2 (initially excavated by B1 between 2 and 5 January). They both stayed together in this shelter for the following three nights.

Each morning they ventured out together to bask in the morning sun (see front cover), then moved off independently, travelling further each day. B2 returned to the same shelter each night, whereas B1 used a different shelter site every night, including one night beneath tussocks (Silvertop Wallaby-grass Jovceea pallida and Small Grass-tree Xanthorrhoea minor ssp lutea).

On the night of 18 January, B1 and B2 shared a new shelter site under the old door. At 1000 h on 19 January 2006, M was found at the shared shelter site suckling both juveniles simultaneously, 20 and 13 days respectively after B1 and B2 had emerged from the nursery burrow. M was standing tall on her front legs, with her forefeet turned outwards, her back arched, and her head between her front legs, possibly for added support. B1 was lying on its right side perpendicular to M’s right side, with its head between M’s front and rear right legs and well under M’s body to access the areola. B2 was in a similar position on M’s left side. Both B1 and B2 were making the rhythmic movements and sounds associated with suckling. This was the first sighting of M since B2 had emerged on 7 January.

B2 spent most of the following 10 nights in the garden shed, while B1 continued to use a different shelter site each night. On 23 January, M was observed systematically checking the shelter locations used by B1 and B2 on her previous visits. She then proceeded very deliberately to the garden shed, as if following a scent trail, and suckled B2 but not B1, although it was foraging within 3 m of the shed entrance. Subsequent observations of suckling are listed in Table 1.

From early February 2006, both juveniles moved increasing distances from the garden. Between 15 and 20 February, B1 was seen only once – 60 m from the house – and B2 was seen on only five of 13 days between 17 February and 2 March. B1 then returned and stayed in the vicinity of the garden between 21 and 28 February when it was suckled twice (Table 1). B2 spent long periods (24-48 hr) inactive in a shelter on 7 March, 12-13 March and 17-18 March, suggestive of having been suckled just prior to these times. The last sightings of the echidnas prior to the 2006 winter and the first sightings in spring are summarised in Table 2.

Subsequently, neighbours reported several independent sightings of B1 and B2 at a location 1200 m west of the house. Most visits near the house occurred on hot days and included a drink and swim in the ground level ‘bird pond’.

**Observations of suckling after emergence from the nursery burrow**

Suckling after emergence was observed on 10 occasions (Table 1). Four of these involved B1 alone, 5 B2 alone, and B1 and

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**Fig. 3.** The nursery burrow after excavation of the roof and loose material, 29 March 2006.
Table 1. Summary of observations of suckling by the two juvenile echidnas B1 and B2 after emergence from the nursery burrow. d = days.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time of day</th>
<th>Juvenile</th>
<th>Subsequent activity of juvenile</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Dec 2005</td>
<td>1200</td>
<td>B1 on first emergence</td>
<td>Stayed outside nursery burrow for 3 d</td>
</tr>
<tr>
<td>7 Jan 2006</td>
<td>1300</td>
<td>B2 on first emergence</td>
<td>Stayed close to nursery burrow for 5 d</td>
</tr>
<tr>
<td>19 Jan 2006</td>
<td>1000</td>
<td>B1 and B2</td>
<td>Low level of activity for next few d</td>
</tr>
<tr>
<td>23 Jan 2006</td>
<td>1200</td>
<td>B2</td>
<td>Probably inactive for next 2 d</td>
</tr>
<tr>
<td>30 Jan 2006</td>
<td>1500</td>
<td>B1</td>
<td>Low activity level for next few d</td>
</tr>
<tr>
<td>7 Feb 2006</td>
<td>1842</td>
<td>B2</td>
<td>Low activity level for next 2-3 d</td>
</tr>
<tr>
<td>17 Feb 2006</td>
<td>1340</td>
<td>B2</td>
<td>Little activity for next 2 d</td>
</tr>
<tr>
<td>21 Feb 2006</td>
<td>1412</td>
<td>B1</td>
<td>Probably inactive for next 1.5 d</td>
</tr>
<tr>
<td>28 Feb 2006</td>
<td>1145</td>
<td>B1</td>
<td>Travelled 50 m then probably low activity for 2 d</td>
</tr>
<tr>
<td>3 March 2006</td>
<td>1336</td>
<td>B2</td>
<td>Travelled 100 m then probably low activity for 4 d</td>
</tr>
</tbody>
</table>

Table 2. Dates of last sightings before winter 2006 and first sightings the following spring for the marked echidnas.

<table>
<thead>
<tr>
<th>Echidna</th>
<th>Last sighting before winter</th>
<th>First sighting after winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>31 March, 400 m w of house</td>
<td>19 August, first echidna seen near house</td>
</tr>
<tr>
<td>B1</td>
<td>19 March, near house</td>
<td>18 September, 60 m sw of house</td>
</tr>
<tr>
<td>B2</td>
<td>23 March, near house</td>
<td>19 September, near house</td>
</tr>
<tr>
<td>A4</td>
<td>21 March, last adult seen near house</td>
<td></td>
</tr>
</tbody>
</table>

B2 were fed simultaneously on one occasion. On one visit M fed neither young, and once she was seen leaving the area, so it is not known whether she fed either juvenile. The sequence of observed feeding events, showing the interval (in days), and the juvenile concerned, was: B1-8-B2-12-B1&B2-4-B2-7-B1-8-B2-7-?-3-B2-4-B1-7-B1-3-B2. For B1, the intervals between observed suckling events were 20, 11, 22 and 7 days; for B2 12, 4, 15, 10 and 14 days (Table 1). The period from burrow emergence to the last observed suckling was 60 days for B1 and 55 days for B2.

Suckling Behaviour

M would sometimes spend a long time foraging in the bush around the house before, apparently, actively seeking out a juvenile to feed. For example, on 21 February M browsed for 2½ hours, including bathing twice, before feeding B1. However, once started, her search for the juvenile was focused – M would systematically check locations where B1 and B2 had been on previous visits and then proceed very purposefully as if she was following a scent trail.

On approach, the juvenile would usually freeze and M would prod it with her snout until it seemed to smell the milk and move to start to feed. Normally, the young suckled for about 20 minutes from one side before switching to the other side, presumably to access the other areola (Fig. 4). When feeding, the mother demonstrated a strong maternal instinct and tenderness towards the juvenile. After feeding was finished, M would typically rest for about 15 minutes and then move off and almost immediately commence foraging as she went. After feeding, the juvenile was sometimes active; on other occasions it would move to a shelter and rest for up to two days.

Visits by Other Adults

At least four adults (apart from M) visited the garden during the observation period. A4 was identified on 6 visits, A3 on 1, A2 on 1 and A1 on 2. There were also 4 adult visits where no photos were taken and identification was not possible. The only interaction observed between these adults and the juveniles was when B1 sniffed around one of the unidentified adults for about 15 minutes while the adult remained motionless. B1 then moved off.

Comparison of the juveniles

The juveniles were certainly not identical twins. B2 had blacker fur and more numerous, longer spines that were whitish with dark tips. B1 was smaller, had browner fur and less dense, shorter spines that were...
Contributions

buff with dark brown tips (Fig. 2). B1’s colouring was similar to M’s. When B1 left the burrow on 30 December 2005 it was significantly less developed than B2 was when it left the burrow on 7 January 2006.

Both juveniles grew significantly over the period from emergence to dispersal. At emergence B1 was approximately 40% of the length of M and B2 was slightly bigger. At dispersal B1 and B2 were both approximately 65% of the length of M. When first seen after winter, in September 2006, B1 and B2 appeared to be a similar size to when they were last seen in March, indicating that no significant growth occurred over the winter hibernation period.

Activities of the juveniles
The juveniles appeared to instinctively start digging and foraging from the day they left the burrow. They were capable climbers and actively curious. Their activities were highly unpredictable and apparently spontaneous. For example, B2 spent several days digging a shelter to a depth of 550 mm; it then left and did not re-use it.

They were often inactive until late in the morning, emerging from the overnight shelter at around 1130 h EST (daylight saving). The first activity was usually a sun-bath for 10 to 15 minutes (front cover). The period of active foraging, often interspersed with a sleep under some cover, varied from 0 to 8 hours per day. It was not unusual for them to remain in their overnight shelter all day. B2 remained in its shelter for more than 48 hours on at least two occasions.

The selection of overnight shelter seemed at times to be entirely random, yet at other times a location was used repeatedly over consecutive nights and sometimes re-used at another time. A wide variety of locations were used, ranging from a clump of grass in the bush to being hidden under equipment in the garden shed. On several occasions, existing holes in the ground, made by other animals, were used. At other times they excavated their own hole under a log or other cover. On 16 March, B2 was foraging when heavy rain began falling. It moved directly to a tree, 8 m

Fig. 4. M suckling B2 on 17 February 2006, 41 days after emergence from the nursery burrow.
away, which was hollow at ground level, and buried itself in the litter within the trunk where it was quite dry. It stayed there for the next 40 hours.

On one occasion, as B1 was walking along the top of a 1 m high sleeper retaining wall, it appeared to be using the crural spur near its hindfoot to stabilise itself while peering down the wall face.

**Interaction of the juveniles**
B1 and B2 were quite independent of each other. When they were together their relationship could be described as passive tolerance. There was little evidence of interactive play so typical of many baby mammals. This was surprising, given their active, inquisitive characters, but reinforces our knowledge of the solitary nature of the echidna. Similar passive tolerance has been observed between adults on occasions when they have simultaneously used the garden pond.

**Nursery Burrow**
The burrow was located behind a 460 mm high sleeper wall that retained the upper level of a 3-level terraced garden. M entered by digging under the sleeper wall from the 2nd level. The gravel surface above the burrow was level with the top of the sleepers and formed a hard crust. However, there were a number of small cave-ins where holes formed in the surface. On 18 December 2005 a juvenile echidna could be seen below a surface opening. A sheet of chipboard was placed over the opening. The covering had to be extended a number of times as new cave-ins occurred. By 28 December the covering had been upgraded to an area of 1 m by 1.5 m, with a steel plate covering another small cave-in through which a juvenile was seen on 23 December 2005. The upper exit was later formed at the 50 mm gap between this plate and the top of the sleeper wall. These observations indicate that the upper exit was constructed from inside the burrow.

The burrow was excavated and measured on 28 March 2006 after the juveniles had dispersed (Fig. 3). The burrow consisted of a main curved chamber, 1.5 m long by 300-800 mm wide. The effective clear height was 200 mm from the underside of the roof to the surface of the loose material on the floor. The depth of this loose material varied from 0 to 160 mm and was easily removed with a gloved hand to expose the base of the excavation. There were several side pockets with higher base levels that were perhaps used as rest chambers. The exit at the south end was accessed by a tunnel 120 mm wide by 90 mm high leading to a large shallow area where the surface had collapsed under the cover plates.

Given the activity levels of the juveniles immediately after their emergence, it is likely that they would have been actively digging in the burrow, perhaps explaining the surface cave-ins, loose material on the floor and the eventual construction of the upper exit used by B2.

No post-emergence use of the burrow was observed except that B2 spent a short time at the upper exit one very hot day when it appeared to be suffering from the heat. After the steel cover plate was slid to the east to enlarge the gap from the top of the adjacent sleeper, B2 only partially entered the exit, although there was clear access into the burrow where it would have been cool.

**Discussion**

**Possibility of Adoption**
Although we have no reason to believe otherwise, we were unable to prove that the two juveniles were siblings – DNA primers were not available to allow identification of parents in the Short-beaked Echidna (D. Middleton, Healesville Sanctuary, and P. Rismiller pers comm.). Therefore we cannot discount the possibility that one of the babies was adopted by the mother, perhaps after having been dislodged from the pouch of another female, or being found in a nearby nursery burrow. Cases of adoption of pouch young are known to occur in marsupials, including macropods and bandicoots (Gemmel 1988) but would seem unlikely in a solitary animal such as the Short-beaked Echidna. Regardless, our observations represent the first record of a female Short-beaked Echidna raising more than one young per breeding season.

**Patterns in suckling within the burrow**
The frequency of M’s visits to the burrow (every four to five days), as estimated from observed changes in the soil plug at the burrow entrance, are consistent with published data on suckling rates of between 3 and 6 days (Griffiths 1989; Rismiller and McKelvey 2000), despite the fact that she was presumably suckling two rather than
one young. Whether this delayed development of the young is not clear but it does not seem to have had a major effect as their stages of development at emergence fall within the documented range and both survived their first year outside the burrow, suggesting that their nourishment was adequate.

Patterns in suckling after burrow exit
These observations represent the first documentation of continuing maternal care in the Short-beaked Echidna after the young has left the nursery burrow. All other authors state that the young is abandoned by the mother once it has been suckled immediately after first emergence (Griffiths 1989, Augee and Gooden 1993, Rismiller 1999, Augee et al. 2006). However, our observations indicate that suckling can continue for up to 60 days after the young leaves the nursery burrow.

There was no obvious pattern in the length of intervals between the observed feeding events, which ranged from 4 to 22 days, but they were considerably longer than the four to five day intervals recorded during the nursery burrow stage. It is almost certain that other feeding events occurred unobserved – M could move quickly and was amazingly cryptic. It would be reasonable to assume a detection rate in the order of 50%.

Inclement weather
As echidnas have a normal body temperature of 33° C and do not sweat or pant, they are vulnerable to heat stress (Augee et al. 2006). The juveniles seemed to cope well on hot days. B1 was initially suckled outside the burrow in 39° C heat. For the rest of that day and the following day, when ambient temperature reached 42° C, B1 remained outside the burrow almost completely buried in the surface soil. A door was placed to provide shade for B1.

B2 seemed to be heat stressed on 26 January 2006. It was 39° C late in the afternoon when B2 partially entered the upper exit of the nursery burrow. Fortunately a cool change arrived. We placed water bowls near B1 and B2 on very hot days. They drank some water but B1 wanted to climb into the bowl and B2 typically tipped its bowl over. On at least one occasion both B1 and B2 were found cold and wet after selecting inadequate shelter sites during rainy weather. However, as they developed, they seemed to learn to find dry shelters during rain, as observed on 16 March.

Activity periods
B1 and B2 were active for much of the day, except for early morning. They seemed to wait until the sun was high and then often sunned themselves, sometimes on a paved surface before beginning to forage. Although nocturnal monitoring was limited to searching on only a few nights, we formed the impression that B1 and B2 were mostly stationary at night. B1 was found in a different shelter in the morning on two occasions and we do not know the timing of these movements – they could have occurred at or just after dusk, after we had assumed it had settled for the night, or at any other time before our first morning check.

The opportunity to monitor the echidnas so close to the house is testament to the success of the local planning provisions that prohibit domestic pets and aim to maintain and advance the environmental integrity of the area.

Acknowledgements
We thank Peggy Rismiller for her advice and encouragement during the observation period.

Note
Detailed records of our observations, including photos and videos of most suckling events, and a geometric plan and section of the nursery burrow can be made available upon request.

References

Received 8 March 2007; accepted 9 August 2007
A new name in the terrestrial orchid genus *Pterostylis* R.Br. (Orchidaceae) for Victoria, Australia

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Abstract

Introduction
In a recent publication (Backhouse 2007), I proposed several new combinations for species of terrestrial orchids originally described in *Arachnorchis* (Jones 2006a) (= *Caladenia*; Hopper and Brown 2004a) and *Bunochilus* (Jones 2006b) (= *Pterostylis*; Hopper and Brown 2004b) in 2006. After publication of the new combinations, it was pointed out to me that one – *Pterostylis montana* (D.L. Jones) G.N. Backh. – was in fact a homonym (a taxonomic name identical to one previously applied to a different species) and therefore illegitimate, as *Pterostylis montana* Hatch had already been named and described from New Zealand (Hatch 1949). A new name is therefore required to accommodate *Bunochilus montanus* D.L. Jones within *Pterostylis* R.Br. as *Bunochilus* is not recognised as a distinct genus by the National Herbarium of Victoria (Walsh and Stajsic 2007), the central source of plant nomenclature for the State.

New name
*Pterostylis jonesii* G.N. Backh., *nom. nov.*

The new epithet honours David L Jones, recently retired from the CSIRO Centre for Plant Biodiversity Research, Canberra, and leading authority in the taxonomy of Australian orchids, who originally described this species as *Bunochilus montanus*.

Acknowledgements
I am grateful to Dr Peter Weston, National Herbarium of New South Wales, for pointing out the error in the proposed new combination for *Bunochilus montanus* and for suggesting the alternative name of *Pterostylis jonesii*; and to Peter Weston and Neville Walsh, National Herbarium of Victoria, for comments on the paper.

References

Received 26 July 2007; accepted 20 September 2007
Australian Natural History Medallion 2007

Jeanette Covacevich AM, PSM

The winner of the 2007 Australian Natural History Medallion is Jeanette Covacevich, who was responsible for the Queensland Museum’s herpetological collection for 35 years. By actively promoting the expansion of the reptile and frog collections (increasing it from about 7,000 to approximately 60,000 specimens), she played a major role in recognising and documenting the state’s biodiversity. Her research focused largely on the taxonomy and zoogeography of Australo-Papuan reptiles, particularly rainforest, heath and desert faunas. However, Jeanette’s research interests extend beyond herpetology. Among her publications are papers on Aboriginal history, medicine (envenomation), mammals and palm trees.

After completing a BA in English, Geography and Zoology at the University of Queensland in 1966, she progressed through the positions of Museum Cadet, Assistant Curator and Curator (Reptiles). Her MSc was awarded in 1977 for an Environment Studies thesis titled ‘Visitors to the Queensland Museum: a survey of attitudes to the museum and its visitors’. In 1978 Jeanette became Senior Curator (Reptiles,) and then Senior Curator (Vertebrates) in 1992.

Through an ‘open access’ policy to the collections in her care, Jeanette has contributed to the work of others by providing specimens for use in their projects – revising the systematics and taxonomy of Australia’s reptiles; analysing aspects of reptile ecology based on gut and gonad examination; publication of natural history and identification guides; tracking the history of the introduction and spread of chytrid fungus to Australia; and creating DNA profiles to inhibit wildlife smuggling.

Jeanette Covacevich has named 30 new reptile species, including one fossil from Riversleigh, and was instrumental in the rediscovery of the Western Taipan Oxyuranus microlepidotus (the world’s most venomous terrestrial snake). An earthworm, several spider species, a frog, and a gecko have been named to recognise her contributions.

A long association with the medical profession, through acting as an expert consultant to hospitals in the area of snake envenomation, has helped to save lives through the provision of specialist zoological knowledge. Jeanette has lectured on these topics to the Queensland Ambulance Service, St John Ambulance Australia, at many medical conferences, and to medical students of the University of Queensland.

A number of organisations have recognised Jeanette’s contributions: in 1991 she received the St John Priory Vote of Thanks for voluntary teaching regarding snakes and snakebite. Her highest recognition came in 1995, when she became a Member of the Order of Australia (AM), in the General Division. The citation was for service to science, particularly in the fields of herpetology and conservation. In 2002 she received the Queensland Museum Medal for promoting the reputation of the museum at both local and national levels, and in the following year was awarded the Public Service Medal (PSM). The Queensland Naturalists’ Club awarded Jeanette its Queensland Natural History Award in 2003 for her research on taxonomy of reptiles, maintenance of significant biological collections, collaboration with other scientists and voluntary teaching work on behalf of community groups.

She has played a key role in documenting the range and status of many endangered, rare, or threatened vertebrates, and has been a champion for conservation of bioregions such as the Brigalow Belt, the Wet Tropics and North Stradbroke Island.

Numerous societies have benefited from Jeanette’s committee roles: Australian Society of Herpetologists (President 1988-90); Royal Society of Queensland (Secretary 1974-79 and President 1993-96); Stradbroke Island Management Organisation (Secretary 1978-84) and Marks Hirschfield Medical Museum, University of Queensland (2001 – 2002).
In addition to these positions, Jeanette has served on the Scientific Advisory Committee, Environmental Protection Agency; Scientific and Clinical Immersions Sub-Committee, DPI Animal Ethics Committee, and Australian Medical Association Medical Ethics Committee, Queensland. She has been an active member of the Queensland Naturalists’ Club and Rainforest Conservation Society of Queensland.

In a publication record commencing in 1971, Jeanette Covacevich has produced 102 scientific papers as sole, senior or joint author. In addition, there have been eight books as author or editor, nine book chapters, numerous popular articles, films and a website.

Since her retirement, Jeanette has intensified her voluntary activities, including the collection of road-kill vertebrates of value for the Museum collection; assistance at the Cooktown Botanic Gardens and the Cooktown and District Historical Society; field trips with other naturalists with interests as diverse as orchids for illustration and photographing the local populations of Bennet’s Tree Kangaroo; lectures to community groups; and the editing and review of scientific manuscripts.

The nomination for the Medallion was made by the Queensland Naturalists’ Club and was accompanied by letters of support from members of the Queensland Museum, Environmental Protection Agency, Nature’s Powerhouse-Cooktown Botanical Gardens, and the Royal Society of Queensland.

Ian Endersby
56 Looker Road
Montmorency, Victoria 3094

Jeanette Covacevich (R) receives the 2007 Australian Natural History Medallion from Dr Jane Melville. Photo by Joan Broadberry.
EUCLID Eucalypts of Australia

by Centre for Plant Biodiversity Research

ISBN 064309335. RRP $120.00

EUCLID is incredibly easy to use, making it ideal for beginners to eucalypt identification as well as for those more experienced. A short ten minute tutorial explains how to use the program and is invaluable for the novice, but those familiar with Lucid keys may find the tutorial helpful to make best use of the key.

The home page allows one to choose to:
1. learn about eucalypts,
2. identify a eucalypt,
3. browse species information or
4. find out a little more about EUCLID.

In ‘learning about eucalypts’ there is a short introduction, which explains that EUCLID includes the long standing genus Angophora and the more recently described Corymbia. It is followed by brief notes on the evolution and distribution of eucalypts and on the identification of eucalypts. In the latter section, the importance of being able to recognise whether a tree is cultivated or occurs in a particular area naturally is explained. If it is cultivated, identification cannot use ‘geographic region’ as a character state when using EUCLID in trying to key out a species. The section on ‘inspection of species’ is more substantial and provides important information on many eucalypt features, providing essential understanding that will aid identification. ‘A brief history of Eucalyptus, Angophora and Corymbia’ provides understanding of the underlying systematics, and shows the importance of including these genera in EUCLID Eucalypts of Australia. This section is followed by a discussion of the evolutionary relationships of eucalypts and hybridisation.

Clicking on ‘identify a eucalypt’ opens to a window with four smaller windows labelled with ‘characters available’, ‘character states chosen’, ‘taxa remaining’ or ‘taxa discarded’. The ‘characters available’ window provides a list of 120 characters that can be selected to describe the specimen being identified. Each character has one or more states. Double clicking on the state of choice will make it appear in the character states chosen window. EUCLID then filters out any taxa that do not have this characteristic and moves them from the ‘taxa remaining’ to the ‘taxa discarded’ window. As successively more and more character states are chosen, only one taxon (occasionally two) eventually will be left in the ‘taxa remaining’ window. Presuming no mistake has been made in character states chosen, the last remaining taxon is the species being identified. To determine whether this is correct, the specimen should be compared to its description, which can be accessed by clicking on the
information icon for that species. Also provided for each species are a brief nomenclatural history and images of the whole plant as well as close-ups of significant characteristics. A link is provided enabling one to jump to a netsearch should one wish to find out more about the species.

The photographs are of excellent quality. There are over 9000 images, with more than 2200 new images not included in the second edition. There are a total of 894 taxa, 204 more than occurred in the second edition. Also new to the third edition is inclusion of the flowering times, type photographs for many eucalypt names and comparative notes for discrimination of species in many large eucalypt groups.

Clicking on ‘browse species information’ opens to a list of all species included in EUCLID. Clicking on any species brings up its related fact sheet with descriptions, images and nomenclatural history. This is useful if the user already knows the identity of the specimen and wants further information on it, or believes he or she knows the specimen’s identity but would like to double check. A useful component of this section is the inclusion of ‘miscellaneous’ names, such as synonyms that are no longer in use. Thus, if a species has undergone a name change, which is highly likely considering the number of relatively recent taxonomic reviews of the eucalypts, one could use an older name that one is familiar with to gain information on the species and, conveniently, catch up with the name change at the same time.

‘Finding out a little more about EUCLID’ provides such things as contact details of those involved in developing EUCLID, but appropriate links allow one to jump to the other sections of the system.

The back cover of the DVD states ‘EUCLID is the definitive electronic identification and information system now covering all 894 eucalypts of Australia in one publication’. It definitely is! This amount of information would be cumbersome indeed in book form. EUCLID is easy to navigate even if you have rarely used a computer, and the helpful information icons and conveniently linked glossary allows identification of specimens even if one’s botanical skills are almost non-existent. EUCLID is a must-buy for any botanist, ecologist, forester, land manager, educator, conservationist and student interested in eucalypts. At $120.00 it is expensive but well worth it.

Maria Gibson
Plant Ecology Research Unit
School of Life and Environmental Sciences
Deakin University, 221 Burwood Highway
Burwood, Victoria 3125

Australian Natural History Medallion Trust Fund

Donations were gratefully received during 2007 from the following:

Andrew Isles $1000 Mrs Phyllis Western $10
Mr John Poppins $20 Mr John Mitchell $50
Burnie Field Naturalist Club Inc $20 Dr Gary Presland $20
The Royal Society of Victoria Inc $200 The Field Naturalists Club of Victoria $200

If you would like to contribute to this fund, which supports the Australian Natural History Medallion, donations should be sent to: The Treasurer, Field Naturalists Club of Victoria, Locked Bag 3, PO Blackburn, Victoria 3130. Cheques should be made payable to the ‘Australian Natural History Medallion Trust Fund’.

The medallion is awarded annually to a person who is considered to have made the most significant contribution to the understanding of Australian natural history in the last ten years.
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Authors may submit material in the form of research reports, contributions, naturalist notes, letters to the editor and book reviews. A Research Report is a succinct and original scientific paper written in the traditional format including abstract, introduction, methods, results and discussion. A Contribution may consist of reports, comments, observations, survey results, bibliographies or other material relating to natural history. The scope of a contribution is broad and little defined to encourage material on a wide range of topics and in a range of styles. This allows inclusion of material that makes a contribution to our knowledge of natural history but for which the traditional format of scientific papers is not appropriate. Research reports and contributions will be refereed by external referees. Naturalist Notes are generally short, personal accounts of observations made in the field by anyone with an interest in natural history. These may also include reports on excursions and talks, where appropriate, or comment on matters relating to natural history. Letters to the Editor must be no longer than 500 words. Book Reviews are usually commissioned, but the editors also welcome enquiries from potential reviewers.

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References are cited chronologically in the text by author and date. All references in the text must be listed at the end of the paper in alphabetical order. All entries in this list must correspond to references in the text.

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The following abbreviations should be used in the manuscript (with italics where indicated): et al.; pers. obs.; unpubl. data; and pers. comm. which are cited in the text as (RG Brown 1994 pers. comm. 3 May). Use ‘subsp.’ for subspecies.

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In all papers, first reference to a species should use both the common name and binomial. This journal uses capitalised common names for species, followed by the binomial in italics without brackets, e.g. Kangaroo Grass *Themeda triandra*. However, where many species are mentioned, a list (an appendix at the end), with both common and binominal names, may be preferred. Lists must be in taxonomic order using the order in which they appear in the references recommended below.

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Web address:
http://www.vicnet.net.au/~fncv/vicnat.htm

Vol. 123 (6) 2006 347
The Victorian Naturalist
is published six times per year by the
The Field Naturalists Club of Victoria Inc.
Registered Office: FNCV, 1 Gardenia Street, Blackburn, Victoria 3130, Australia.
Postal Address: FNCV, Locked Bag 3, Blackburn, Victoria 3130, Australia.
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www.vicnet.net.au/~fncv

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