**Report to the Natural Resources Commission's investigation into "Active and Adaptive Management of white cypress pine management in the Brigalow and Nandewar State Conservation Areas".**

# Reptile assemblages and refugia use in the Cypress Forests of the North-west slopes of NSW

Nobbi Dragon basking on old log (photo D. Paull, Pilliga East Forest)

**Modified from Date and Paull (2000). Fauna survey of the cypress/ironbark forests of north-west New South Wales. (Report to the State Forests of NSW, Dubbo.)**

# Contents

## 1. Introduction

This study was undertaken in 1993 and 1994 to inform a series of harvesting management plans being prepared by the then Forestry Commission of NSW. Fauna surveys were undertaken at 40 sites across state forests in the Dubbo, Pilliga, Gilgandra, Gunnedah and Inverell Management Areas in 1993 and then repeated in 1994 (Forestry Commission 1980-1989).

As part of this baseline assessment, targeted surveys were undertaken for reptiles, which included habitat searches, nocturnal searches and road transects. The same effort was applied to each site of the 120 search areas (3 transects per site).

Habitat features, disturbance history and vegetation communities were recorded at each of the search areas, as were the habitat details at each location reptiles where detected. Species and abundance of each species were also recorded. The distribution of species and changes to species diversity, abundance and composition was analyzed by use of a three-dimensional ordination (multi-dimensional scaling – PATN Belbin 1987) firstly of the distribution of species across search areas and then these reptile assemblages against microhabitat, floristic, structural and disturbance characteristics of the fauna survey transects (including time since logging) to identify significant habitat associations.

Micro habitat preferences from search data were also categorized and analysed for patterns of reptile use, mainly diversity and abundance. Functional aspects of reptile use were incorporated into the microhabitat categories that were assigned to each reptile upon capture or detection (eg., closeness to old log or tree, living or dead tree etc). Each category is also characterised by differing levels of nutrient turnover and microclimatic conditions, though these were not quantified. Various authors (Adams 1985; Heatwole and Taylor 1987; Pianka 1988) have identified microhabitat guilds while investigating the ecology of reptile communities. Each guild showed distinctive species composition, diversity and abundance characteristics.

These type of analyses, when considered together, help to describe reptile community responses to various disturbance factors as functional units. Some management implications for cypress logging is also discussed.

## 2. Reptile Diversity and Abundance in north-west cypress forests

Sixty-three species of reptile were recorded during the surveys (Appendix 1). These are described, including a measure of the relative abundance (number of individuals) of each species, the ecological habit of each and their regional distribution. In addition, a roadkill of one species, *Morelia spilota* was collected at Rocky Glen in 1993 by Dean Metcalfe and was also examined by DCP. 59 species of reptile were recorded at the 40 sites during 1993 and 47 species during 1994. Of the 1993 species, eight were detected opportunistically away from transects, including seven snakes. In 1994, two species of snake were detected opportunistically. Seventeen species seen in 1993 were not recorded in 1994, but five species were added.

For six species, our sightings include records which appear to extend their known geographic range, based on records of the Australian Museum. These include, for *Ctenotus allotropis* an extension to the east from individuals found in Leard State forest. *Ctenotus eurydice* records represent an extension of the known range to the west. To our knowledge this species has not been recorded from the Nandewar Range before. The *Furina dunmalli* record from Bebo State forest represents a significant extension to the south of its known range and the first recorded sighting in NSW. *Ramphotyphlops ligatus* specimens were collected in areas of Pilliga East State forest, to the east of its previously known range. Detections of two arboreal snake species in the Sandgate/Tallegar

State forests, represent western extensions to their known ranges. They are the Pale-headed Snake, *Hoplocephalus bitorquatus* and the Eastern Children's Python, *Liasis maculosus.* At the time of the surveys, the taxonomic position of the *Lophognathus* dragon detected in the study area as not clear (Ellis and Higgins 1993), though is now known as *Amphibolorus byrnei.*

In 1993 pit-trapping was used at all transects but resulted in a relatively low capture rate when compared to the active search method (no. of individuals=45:1353; no. of species=3:63) and was not used in 1994. Though species richness and frequency of capture were high throughout the study area, about half the species of the reptile were seldom encountered (less than five times over the two years of field surveys, Appendix 1).

## 3. Distribution of Assemblages

Using a pattern analysis of (PATN, Belbin 1987) the distribution of reptiles among the transects for the two years' data is shown below (Table 1; Appendix 2). The 240 transects of the fauna survey formed seven groups based on similarity of species composition and richness of reptile assemblage within groups. Only the more common species occurring on greater than 5% of transects within the group are represented in the table.

**Table 1. Reptile Assemblages at Seven Grouped Transects.** Ecological habit: A=arboreal, B=burrowing, T=terrestrial, O=opportunistic.

| **Species** | **1** | **2** | **3** | **5** | **6** | **7** |
|---|---|---|---|---|---|---|
| *D. intermedius* | | | A | | | |
| *D. williamsi* | A | A | A | | A | |
| *G. dubia* | A | A | A | A | A | |
| *O. lesueurii* | | A | | | | |
| *O. monolis* | A | A | A | ; | A | |
| *O. tryoni* | | A | | | | |
| *V. varius* | A/T | A/T | | A/T | | |
| *C. tetradactyla* | | | | A/T | | |
| *C. carnabyi* | A | A | A | A | A | |
| *C. virgatus* | | A | | A | | |
| *E. modesta* | A/T | A/T | | | | |
| *D. vittatus* | T | T | T | | T | T |
| *U. sphyrurus* | | | | T | | |
| *D. plebeia* | T | | | | | |
| *A. nobbi* | T | T | T | T | T | |
| *L. gilberti* | | T | T | | | T |
| *P. barbata* | T | T | T | T | | |
| *C. allotropis* | T | T | T | | T | |
| *C. eurydice* | | T | | T | | |
| *C. robustus* | T | | | T | | |
| *L. foliorum* | T | T | | T | T | |
| *D. psammophis* | T | | | | | |
| *S. spectabilis* | T | | | | | |
| *A. leuckartii* | B | B | | B | B | |
| *L. bougainvillii* | B | B | | | | |
| *L. muelleri* | B | B | B | B | B | B |
| *L. punctatovittata* | B | B | B | B | | |
| *F. diadema* | | | B | | | |
| *G. varigata* | O | O | O | O | | |
| *H. binoei* | O | O | O | O | O | O |
| *E. striolata* | O | O | O | | O | O |
| *M. boulengeri* | O | O | O | O | O | O |
| | **24** | **24** | **18** | **17** | **13** | **6** |

In terms of species richness; low richness assemblages had a low number of species but sometimes high abundances and species most tolerant of human disturbance; moderate richness had a low-mod. abundance, with a mod.-high number of species; and high richness assemblages had a low-high overall abundance, but with a high number of species. Four species (*Heteronotia binoei, Morethia boulengeri, Gehyra variegata, Egernia striolata*) are identified as being opportunistic ('O', cf. Table 1) due to their high frequencies of sighting, their wide habitat and microhabitat selection preferences and their tolerance for the most highly disturbed areas. These species are also known as "fugitive" which describes their ability to colonise readily and to adapt to disturbed conditions (ecologically vagile, Cogger and Heatwole 1984). In the absence of other reptiles, they are good indicators of disturbance levels, particularly logging, grazing and fire regimes (see Sections below for more detail).

These assemblages showed some differentiation geographically. Pilliga, Narrabri, Gunnedah and Inverell forests were characterised by moderate and high species rich assemblages whereas the west Pilliga and Monkey Scrub districts were generally characterised by assemblages of moderate richness. Low richness sites were scattered through the study area. The Nandewar foothill forests (Inverell) were characterised by a relatively rich reptile fauna, containing unique arboreal and saxicolous species. High diversities of terrestrial and arboreal species were found to be associated with rich reptile communities. Group 4 was eliminated as it was a slightly less diverse subset of Group 1 from the Gunnedah and Narrabri Forests and containing the same species composition. The final assemblages are given below:

Group 1: high richness (Pilliga, Narrabri & Gunnedah forests);
Group 2: high richness (Inverell forests)
Group 3: moderate richness (western Pilliga/Monkey Scrub)
Group 5: moderate richness + rocky sites (Dubbo, Gilgandra & Inverell)
Group 6: moderate to low richness (all areas);
Group 7: low richness-no arboreals (all areas).

## 4. Microhabitat Selection

Reptile species diversity and abundance patterns within habitats are largely determined by the availability of microhabitat refugia and food sources. The availability of these resources in turn are shaped by structural and functional habitat components, such as fallen logs, groundcover, moisture and thermal gradients. These are also known as microhabitat and microclimate components. Reptile refugia can be readily identified as most reptiles encountered during the field surveys were sedentary with small home-ranges and low dispersal abilities. Most are probably sensitive to the disturbance of their shelter and food resources. Exceptions may be more vagile species such as large snakes and goannas whose critical habitat components are not always readily identified. During the survey an attempt was made to identify the microhabitat components which were most important for reptile species richness. Such associations can be overlooked when comparing general habitat structure and floristic attributes between transects.

Pattern analysis of the microhabitat data collected during routine habitat appraisals at each of the transects (eg. strata cover, canopy height, rocks etc) identified 9 groups of reptiles (Appendix 3). Groups 1 to 4 were primarily composed of terrestrial species. Group 1 included small skinks and geckoes which inhabit litter and larger ground debris and sometimes bare soil or rock, whereas Group 2 included legless lizards and small snakes which are mainly found under larger ground debris associated with logs. Group 3 included some rare, some common and some ubiquitous, opportunistic species that were found in litter and other debris, vegetation and man-made structures. Group 4 contained the largest reptiles encountered in the study, including large skinks, dragons, snakes and goannas, which were encountered across the spectrum of microhabitats. Group 5 included species associated exclusively with rock. Groups 6 and 7 were arboreal species, Group 6 being the rarer species found exclusively in live or dead trees and Group 7 those found primarily in trees but also in litter and logs on the ground. Group 8 were species caught in traps only and Group 9 were species encountered once only opportunistically on roads.

This analysis shows that reptile microhabitat selection tends to separate according to whether the species is mainly terrestrial, arboreal, saxicolous, etc. Using this information and the site data obtained from the reptile habitat searches undertaken across the study area, twelve microhabitat types were identified for assessment qualitatively. Each "guild" is composed of a unique suite of species composition, diversity and abundance (biomass) characteristics (Table 2).

Three broad types of reptile microhabitat were identified within the exploited forests of the study area (Table 2). A terrestrial type containing 7 microhabitat guilds and dominated by terrestrial species; an arboreal type with two arboreal habitat components; and a "transition" type of refuge for both terrestrial and arboreal species. Three of these were identified, two man-made: wood-dumps and cut stumps, and a third: in or on old hollow logs. Few natural stumps were detected during the study,

**Table 2. Microhabitat guilds of reptiles in study area.** * 1994-95 data only due to small differences in data collection method between years ** specialist species found only in this microhabitat category.

| | **Microhabitat** | **Degree man-made** | **Abundance *** | **Species diversity** | **Specialists *** |
|---|---|---|---|---|---|
| Terrestrial | 1.Reeds, near water | Low | 9 | 5 | 4 |
| | 2.Open ground | low-high | 93 | 10 | 3 |
| | 3.Grass/branch/shrub | low-high | 22 | 9 | - |
| | 4.Isolated woody debris | low-high | 112 | 12 | - |
| | 5.Small log | mod-high | 224 | 16 | 2 |
| | 6.Rocky terrain | Low | 71 | 16 | 3 |
| | 7.Woody debris, litter, near old logs; tree-bases | low-mod. | 322 | 28 | 6 |
| Transitional | 8.On/in log | low-mod. | 98 | 16 | - |
| | 9.Wood-dump | High | 91 | 14 | - |
| | 10.Stumps | High | 86 | 9 | - |
| Arboreal | 11.Stags | mod.-high | 186 | 13 | 2 |
| | 12.Mature trees | Low | 63 | 14 | 4 |

### a. Terrestrial habitats

The most important microhabitat, in terms of reptile diversity (n=28), abundance levels (biomass, n=322) and number of specialists (n=6) was ground woody debris (bark and wood) and leaf litter closely associated (closer than 2 m) with large, old logs and tree-bases. These microhabitats have high levels of moisture retention, nutrient cycling, invertebrate richness and wide temperature gradients, ideal for food and thermoregulatory patterns necessary for reptiles. This guild is closely associated with the hollow log transition guild but is a reptile assemblage found at ground-level or below, near or under an old log or at the base of old trees. Most rare and specialist terrestrial and fossorial (burrowing) species were found within this guild (Table 2). The most species-rich examples of this guild are also around old, hollow naturally fallen logs and senescent trees, mostly eucalypts, with high levels of litter accumulation at the base. In highly disturbed forests, naturally fallen logs and senescent trees often offer the major refugia for less common terrestrial species even when such formations are scarce compared with timber on the ground that has resulted from harvesting and silvicultural (thinning) practices.

In contrast, woody debris in the "open" (usually isolated wood fragments or pieces of bark) were selected by 12 species at a low level of biomass than the debris found associated with logs etc. None of the litter specialists were found in this microhabitat. This may reflect the lack of surface area for cover in these situations, compared to the more extensive and complex microhabitat provided by logs and tree bases.

Two other important microhabitat supporting more than 15 species of terrestrial and fossorial species were associated with small logs and rocky microhabitats. The former had a significantly lower richness than the large log guild, and it is largely affected by human disturbance. Most components from this category are recently cut cypress tree-heads and logs, having lower levels of microhabitat complexity (less bark dehission, hollow formation, litter and debris accumulation than is associated with the natural log guild). The reptiles found here were a range of terrestrial species, but fewer specialist species and usually dominated by opportunistic and more common terrestrial species. Rocky microhabitats also were important for specialist saxicolous and fossorial species which prefer the microclimatic and refugia conditions created by rock outcrops. Some rare species (*Underwoodisaurus sphyrurus* and *Ctenotus eurydice*) are found mainly in this guild.

The microhabitat category of grass/branches/shrubs included areas affected by silvicultural treatment, often with thinnings on the ground or branch remains from logging operations. This type pf habitat recorded just 9 species of reptile, recorded infrequently (22 times out of 1,377 records). The species in this habitat are the more mobile, active and larger skinks and snakes, with some small species, like the common *Morethia boulengeri.* Thin branches and isolated shrub cover provide some temporary refuge, though do not have conditions that are suitable as resting refuge sites.

Two abundant terrestrial species, *Morethia boulengeri* and *H. binoei* were commonly encountered during the survey in a wide variety of microhabitats and disturbance conditions, typical of species termed opportunistic or "fugitive", but preferring ground debris and timber as refugia. These species often dominated the reptile communities found in logged or managed habitats and were sometimes the only terrestrial species present. However, whereas the *M. boulengeri* is quick to colonise disturbed and recently burned areas, *H. binoei* probably owes its abundance in State forest areas to fire management practices in commercial areas which promote fire exclusion and suppression. *H. binoei* dominates terrestrial reptile communities in such areas and it was the most frequently encountered reptile in the study area. Our results also support the contention that it is a fire-sensitive species, adversely affected by high fire frequencies (Braithwaite, 1987).

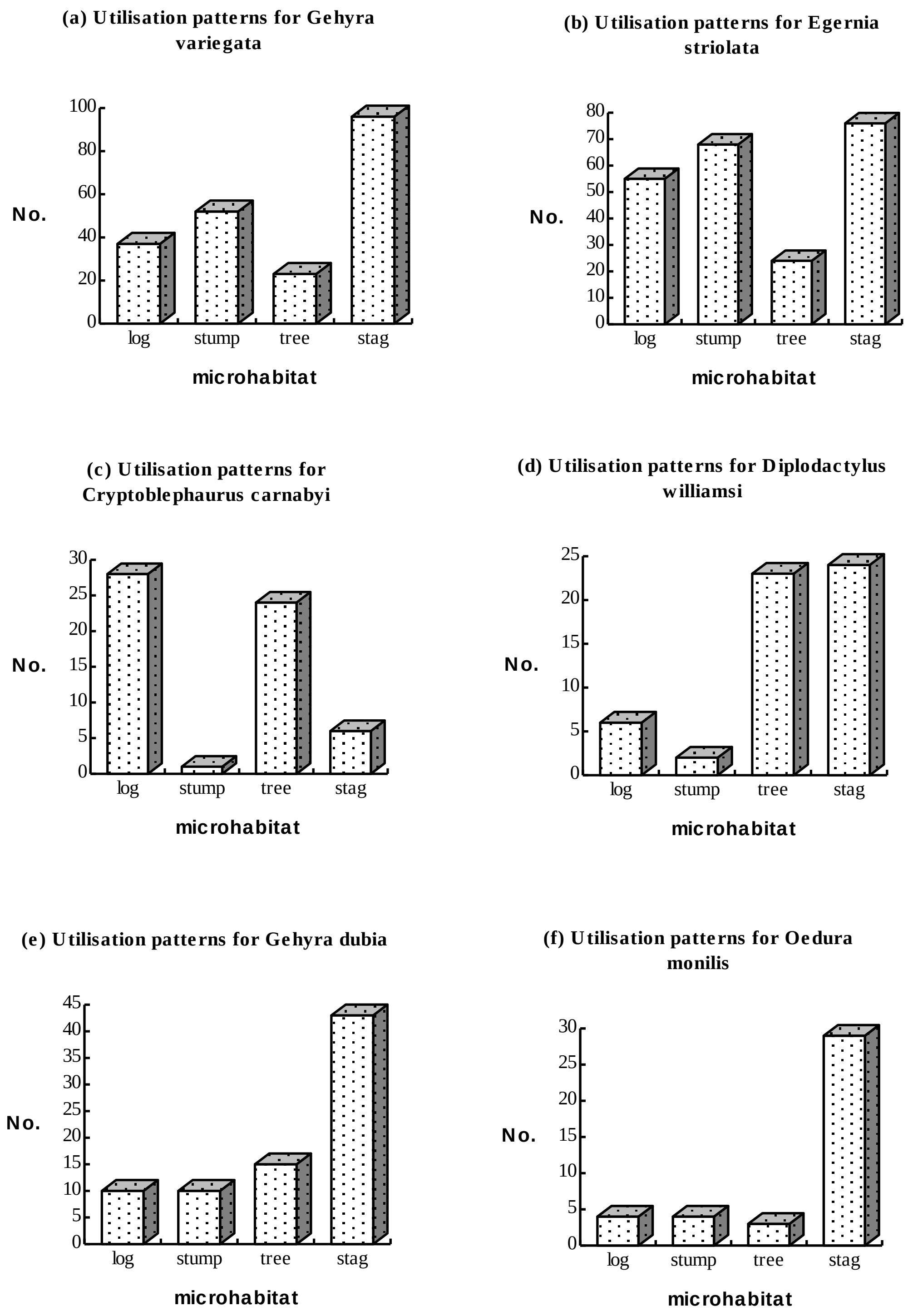
**b. Arboreal habitats**

As far as tree species selection by arboreal reptiles is concerned, White Cypress Pine *C. glaucophylla* was the most frequently used tree species (N=155), compared with ironbarks (N=65) and red gums (N=49). Boxes and *A. leuhmannii* also supported small numbers of geckoes and skinks. This to some extent relative may reflect existing tree densities which in turn, may reflect the silvicultural management regime of the search areas.

As a result of ringbarking, culling, thinning and logging throughout the high commercial value compartments of the survey area, mature and naturally senescent eucalypt and cypress trees are reduced in numbers in proportion to the high numbers of dead standing trees (stags), and this appears to have influenced the abundances of arboreal fauna such that twice as many reptiles were detected on dead trees as compared with large living mature trees (289:138). Such human activities may favour small arboreal species, which are often found under suitable bark dehission usually associated with small or culled trees.

By examining several arboreal species from this disturbed reptile community, we found that the use of culled sub-mature stems is restricted to opportunistic species (*Gehyra variegata* and *Egernia striolata*). These two species are the most tolerant human disturbance, sometime thriving in areas logged for cypress pine and often dominating species poor communities as long as tsumps and stems with bark dehission are present (Bustard 1969c; 1970). Dead tree specialists (*Oedura monilis* and *Gehyra dubia*) did not select culled cypress stems, but rather lightning struck trees, accounting for their relative scarcity during the study. This habit is supported by the observations of Bustard (1969d, 1971) who described them generally uncommon.

**Figure 1. Arboreal reptile microhabitat Selection patterns.**



Species preferring mature trees and fallen logs (*Diplodactylus williamsi, Cryptoblephaurus carnabyi*) occurred at low to moderate frequencies, preferring red gums and box species as well as cypress pine. Another Spiny-tailed Gecko, *D. intermedius*, was only detected on mature cypress pine, *C. glaucophylla.*

Whereas stags yielded higher reptile frequencies, mature trees yielded a slightly higher species richness, including hollow-dependent arboreal snakes which were not detected on stags. This may be due to inappropriate microclimatic and nutrient conditions of stags for large arboreal reptiles, as well as a lack of appropriate hollow development in ring-barked stags compared with living trees. Most culled trees were killed before hollow development was advanced, accounting for low levels of hollow development in silviculturally treated compartments.

Both species of python encountered in this study require hollow bearing trees, *Liasis maculosus* was observed to emerge from a small hollow on a mature box tree, *E. populnea* while *Morelia spilota* is known to use a range of tree, rocky and hollow log roosting sites (Slip and Shine 1988). *Hoplocephalus bitorquatus* is also known to utilise hollows, trunk cracks and bark dehission on trunks as refuge areas. *H. bitorquatus* was recorded under the bark on mature *E. crebra* and *E. chlorocoda* stems during the study, and is also known to inhabit mature *Callitris glaucophylla* (Bustard, 1968b).

Pale headed Snake (Photo by Phil Spark, Pilliga East State Forest)

## 5. Habitat and Disturbance Associations

A three-dimensional ordination (multi-dimensional scaling) of floristic, structural and disturbance characteristics of the fauna survey transects was used to identify significant habitat associations with reptile assemblages. Because the structural and disturbance variables tended to be more important in separating groups of transects, a further 3D ordination of floristic data only was used to identify significant associations of floristic variables with reptile assemblages. Floristic variables which had a correlation of $P<0.1$ with either the floristics ordination were identified. as significant predictors of reptile assemblage/habitat associations, whereas significant structural and disturbance variables were identified if they had a correlation of $P<0.1$ with the structural and disturbance ordination (Table 3). Paired comparisons were not performed statisitically. The group differences presented in the table were determined by visual inspection of the group means.

Logging history was assessed by recording time since logging, with recent (<20 years), old

(50-70 years) or very old (>70 years or non-existent).

For plants, some reptile assemblages were significantly associated with several species, particularly the presence of Buloke (*A. leuhmannii*) which was positively correlated species-rich reptile assemblages in the Pilliga but not with reptile groups in the Inverell, Gunnedah and Dubbo areas, reflecting the geographic distribution of this species and forest with large amounts of bull oak regrowth in the white cypress forests. Conversely, reptile assemblages from the Pilliga area were associated with low frequencies of Silver-leafed Ironbark (*E. melanophloia*) whereas those from the Dubbo, Gunnedah and Inverell areas were associated with moderate to high frequencies of this species. The frequency of Wilga (*G. parviflora*) was related to reptile species richness with low frequencies of Wilga associated with high species richness regardless of geographic location and high frequencies of Wilga associated with low to moderate species richness.

**Table 3. Results of the ordination of floristics, structural and disturbance data for the fauna survey transects.** Significant relationships (P<0.1) are shown with an asterisk. Correlation co-efficients listed in bold type indicate important variables in the ordinations and ordinate loadings listed in bold type indicate the ordinate to which a variable contributes most. For each important variable the Kruskal-Wallis test indicates whether there are significant differences among the groups of transects as identified by their reptile assemblage. Transect groups as characterized by reptile assemblage in Figure 5.4 are: 1 = high richness (Pilliga); 2 = high richness (Inverell); 3 = moderate richness (western Pilliga/ western Dubbo); 5 = moderate richness rocky sites (mainly Inverell and eastern Dubbo); 6 = moderate to low richness (all areas); 7 = low richness-no arboreals (all areas).

| **Variable** | **Florist.,Structural,Disturb.** | | | | **Floristics only** | | | | **Transect Group Differences** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **r** | **Ord 1** | **Ord 2** | **Ord 3** | **r** | **Ord 1** | **Ord 2** | **Ord 3** | **K-W** | **p** | **Group Differences** |
| *Acacia sp.* | 0.27 | 0.06 | **0.82** | 0.57 | **0.63** | **-0.98** | 0.10 | 0.18 | 10.37 | 0.11 | - |
| **A. leuhmannii* | 0.34 | 0.65 | 0.67 | 0.36 | **0.48** | 0.13 | **0.97** | -0.20 | 17.57 | 0.01 | 6<2, 5,7<1<3 |
| *A. floribunda* | 0.26 | **-0.83** | 0.23 | 0.51 | **0.47** | 0.02 | -0.27 | **0.96** | 5.71 | 0.46 | - |
| *Aristida sp.* | 0.18 | -0.02 | -0.18 | **-0.98** | **0.45** | **0.83** | -0.24 | -0.49 | 7.53 | 0.27 | - |
| *E. blakelyi* | 0.23 | **-0.67** | 0.46 | 0.59 | **0.68** | 0.43 | 0.11 | **0.90** | 5.83 | 0.44 | - |
| *E. crebra* | **0.46** | 0.52 | **0.86** | 0.01 | **0.78** | -0.10 | **0.99** | -0.09 | 10.51 | 0.10 | - |
| **E. melanophloia* | 0.28 | -0.43 | **-0.85** | -0.29 | **0.53** | 0.10 | **0.99** | -0.09 | 12.45 | 0.05 | 3<6<1,5,7<2 |
| **G. parviflora* | 0.24 | 0.07 | **-0.98** | -0.16 | **0.41** | -0.17 | **-0.77** | -0.61 | 11.28 | 0.08 | 1,2, 6<3,5,7 |
| *GRASS | 0.35 | -0.58 | 0.34 | **0.74** | | | | | 13.93 | 0.03 | 7<2,3<5,6<1 |
| *Small eucalypt size | **0.90** | **-0.74** | 0.35 | 0.57 | | | | | 25.02 | 0.0003 | 6<2,5,7<3<1 |
| *% Bare Ground or Litter | **0.64** | 0.32 | 0.77 | 0.55 | | | | | 15.96 | 0.01 | 2,5,7<6<1<3 |
| *Aspect | **0.87** | -0.61 | -0.02 | **-0.79** | | | | | 24.48 | 0.0004 | 3<1,7<2,5<6 |
| *Slope | **0.71** | -0.41 | -0.19 | **-0.89** | | | | | 27.73 | 0.0001 | 3<1<7<5<6<2 |
| *Last WCP logging | **0.74** | -0.06 | **-0.77** | 0.64 | | | | | 16.54 | 0.01 | 5,6<1,7<2,3 |
| *Last IBK logging | **0.68** | 0.29 | **0.96** | -0.02 | | | | | 14.51 | 0.02 | 5,6,7<2<1,3 |

Species-rich reptile assemblage of the Pilliga preferred a high frequency of grass as a structural element, with the lowest richness sites having less grass, perhaps reflecting dense understorey.

The strongest associations with the reptile assemblages were disturbance and structural factors, including tree size, slope and aspect. Transects with large eucalypts (>60 cm dbh) and a range of eucalypt sizes were associated with high reptile species richness across the study area, whereas those with small eucalypts (<60 cm dbh) or a limited range of tree sizes were associated with low or moderate species richness. High species richness was also associated with high percentages of bare ground or (more probably) litter (>50%, i.e., low % vegetation cover), whereas low to moderate species richness was associated with low percentages of bare ground or litter (<50%, i.e., high % vegetation cover). High species richness was associated with north and east-facing gentle slopes and low to moderate richness with south-east facing slopes of >5$^{o}$.

With respect to time since last logging event, reptile responses were different in how they responded to cypress and ironbark operations. Assemblages of both higher and low reptile species richness in the Pilliga was associated with one logging event of White Cypress Pine (usually older, since 1965), while moderate richness assemblages in the Pilliga were associated with very low levels of cypress logging. For ironbark operations, (which were being phased out at the time of the study) rich reptile assemblages were correlated with the oldest ironbark logging events, while low and moderate richness sites were found in areas that have experienced the most recent ironbark logging.

## 6. Conclusion – implications for management.

A number of key points which are relevant for the management of cypress forests:

1. Reptile diversity and abundance is affected geography, habitat and disturbance.

2. The importance of natural cycles of tree formation and decay for the diversity of arboreal and terrestrial reptile communities in the study area.

3. The most diverse reptile assemblages are found in the forest of the Pilliga, Narrabari, Gunnedah and Inverell Management Areas and were found to be most strongly correlated with:

- A mixture of terrestrial and arboreal species
- Presence of woody debris associated with old logs and mature tree bases
- Presence of dead standing trees
- Presence of White Cypress Pine and Bull Oak
- Presence of large trees
- Presence of grass
- Old cypress pine logging operations

Low diversity areas for reptiles were found to have the following features:

- Lacking arboreal species
- Absence of old logs or mature trees
- Large numbers of small stems
- Lack of grass
- Old cypress pine logging operations

4. Rocky areas were also good for reptile diversity because of several specialist species these habitats support.

5. Cypress logging (removal of sawlogs) can be beneficial for reptiles over timescales of 40-50 years, promoting the richest reptile assemblages, though also promotes the poorest assemblages. Clearly, time since cypress logging itself is not affecting reptile diversity, but more likely, the type and intensity of previous management. Poor assemblages may reflect conditions of stands that have been subject to long and repeated timber usage and associated silvicultural treatments and stand improvement methods. Many areas logged for ironbark

were also logged for cypress pine and to a large extent these to operations over-lap spatially leading to sites which may have several cypress and ironbark logging events.

6. What is important for reptile diversity is the retention of old growth forest habitats. Old logs, mature and dead trees and the microhabitats they promote appear to be the most important. The analysis showed that areas of recent logging can support moderately rich reptile communities as long as there are the retention of these elements. Logging residues, unwanted parts of trees, wood dumps, stumps, provide habitat for some reptiles, though these habitats do not support the diversity associated old logs with developed woody debris and litter accumulation and some specialists are lost, particularly burrowing lizards (eg. *Delma plebeia*) and snakes (eg. *Simoselaps australis*), and some terrestrial species (eg. *Lerista bougainvillii*).

7. Very few ‘old grey” cypress pine ere encountered during the field surveys, but mature pines (>40 years old) can provide refuge for arboreal species, as long as there is bark dehission and trunk cracking. It appears that reptile populations can be kept healthy with cypress logging operations which are low intensity (1 logging cycle every 40 -50 years) and with minimal ground disturbance such that old growth elements are retained. The recruitment of these old growth elements is also important and should be reflected in harvesting prescriptions with specified base retention levels for all tree age classes.

## References


Adams, J. (1985) The definition and interpretation of guild structure in ecological communities. J. Animal Ecol. 54: 43-59.

Belbin, L. (1987) PATN Pattern Analysis Package, Technical Reference. Division of Wildlife and Ecology, CSIRO, Canberra.

Braithwaite, R.W. (1987) Effects of fire regimes on lizards in the wet-dry tropics of Australia. J. Trop. Ecol. 3: 265-275.

Bustard, H.R. (1968b) The reptiles of Merriwindi State Forest, Pilliga West, northern New South Wales. Herpetologica 24: 131-140.

Bustard, H.R. (1969c) Population ecology of the gekkonid lizard (*Gehyra variegata* Dumeril and Bibron) in exploited forests in northern New South Wales. J. of Animal Ecol. 38: 35-51.

Bustard, H.R. (1969d) The ecology of the Australian geckos *Diplodactylus williamsi* and *Gehyra australis* in northern New South Wales. Proc. Kon. Ned. Akad. Wet. 72: 451-477.

Bustard, H.R. (1970) A population study of the scincid lizard *Egernia striolata* in northern New South Wales. Proc. Kon. Ned. Akad. Wet. 73: 186-213.

Bustard, H.R. (1971) A population study of the Eyed gecko, *Oedura ocellata* Boulenger, in northern New South Wales, Australia. Copeia 1971: 658-669.

Cogger, H.G. (1992) Reptiles and Amphibians of Australia. Reed Books, Chatswood.

Cogger, H.G. and Heatwole, H. (1981) The Australian reptiles: origins, biogeography, distribution patterns and island evolution. Pp. 1331-1373 in A. Keast (ed.) Ecological biogeography of Australia. Dr. W. Junk, The Hague.

Ellis, M. and Higgins, D. (1993) The occurrence of Gilbert's Dragon *Lophognathus gilberti* in the Paroo Drainge Basin, Western New South Wales. In D. Lunney and K. Ayers (eds) Herpetology of Australia: A Diverse Discipline. Royal Zoological Society of NSW, Mosman.

Forestry Commission of N.S.W. (1980) Management Plan for Inverell Management Area. Forestry Commission of N.S.W., Sydney.

Forestry Commission of N.S.W. (1984) Management Plan for Gilgandra Management Area. Forestry Commission of N.S.W., Sydney.

Forestry Commission of N.S.W. (1985) Management Plan for Gunnedah Management Area. Forestry Commission of N.S.W., Sydney.

Forestry Commission of N.S.W. (1986) Management Plan for Pilliga Management Area. Forestry Commission of N.S.W., Sydney.

Forestry Commission of N.S.W. (1988) Management Plan for Dubbo Management Area. Forestry Commission of N.S.W., Sydney.

Heatwole, H. and J. Taylor (1987) Ecology of Reptiles. Surrey Beatty, Chipping Norton.

Pianka, E. R. (1988). Evolutionary Ecology, 4th edn. Harper Collin, New York.

Slip, D.J. and Shine, R. (1988) Habitat use, movements and activity patterns of free-ranging diamond pythons, *Morelia spilota spilota* (Serpentes: Boidae): a radiotelemetric study. Aust. Wildl. Res. 15: 515-531.

APPENDIX 1

**Reptile diversity, distribution and abundance.** Nomenclature follows Cogger (1995). Frequency includes all captured individuals. Conservation Status is included for species listed on Schedule 2 of the TSC Act (1995) as V=Vulnerable; and also for species of concern (C) as identified by Cogger *et al.* (1993). Ecological habit codes are: T=terrestrial, B=burrowing or fossorial, A=arboreal, W=confined to standing water. Distribution codes refer to detections during this study of the species in State Forests districts of the study area: P=Pilliga, D=Dubbo, I=Inverell, N=Nyngan, and G=Gunnedah.

| | SPECIES NAME | COMMON NAME | Frequency | Status | Habit | Distrib |
|---|---|---|---|---|---|---|
| 1 | *Chelodina longicollis* | Snake-necked tortoise | 1 | | W | I |
| 2 | *Amphibolurus muricatus* | Jacky Lizard | 2 | | T | DN |
| 3 | *Amphibolurus nobbi* | Nobby Lizard | 113 | | T | DPING |
| 4 | *Lophognathus (gilberti?)* | Plains Lashtail | 26 | | T | PIN |
| 5 | *Physignathus lesueurii* | Eastern Water Dragon | 8 | | W | I |
| 6 | *Pogona barbata* | Bearded Dragon | 38 | | T | DPING |
| 7 | *Tympanocryptus lineata* | Lined Earless Dragon | 1 | | T | I |
| 8 | *Varanus varius* | Lace Monitor | 53 | | AT | DPING |
| 9 | *Varanus gouldii* | Gould's or Sand Monitor | 11 | | T | DPIN |
| 10 | *Diplodactylus intermedius* | Eastern Spiny-tailed Gecko | 5 | | A | N |
| 11 | *Diplodactylus vittatus* | Wood/Stone Gecko | 46 | | T | DPING |
| 12 | *Diplodactylus williamsi* | Spiny-tailed Gecko | 51 | | | PI |
| 13 | *Gehyra dubia* | Dtella | 93 | | A | DPIN |
| 14 | *Gehyra variegata* | Tree Dtella | 241 | | A | DPGN |
| 15 | *Heteronotia binoei* | Bynoe's Gecko | 632 | | T | DPING |
| 16 | *Oedura lesueurii* | Lesueur's Velvet Gecko | 4 | | T | I |
| 17 | *Oedura monilis* | Ocellated Velvet Gecko | 40 | | A | DPIN |
| 18 | *Oedura robusta* | Robust Velvet Gecko | 1 | | A | D |
| 19 | *Oedura tryoni* | Southern Spotted Velvet Gecko | 16 | | A | I |
| 20 | *Underwoodisaurus milii* | Barking Thick-tailed Gecko | 2 | | T | IG |
| 21 | *Underwoodisaurus sphyrurus* | Border Thick-tailed Gecko | 2 | V | T | I |
| 22 | *Delma plebeia* | Leaden Delma | 7 | | B | PIG |
| 23 | *Delma tincta* | Excitable Delma | 2 | | B | PG |
| 24 | *Lialis burtonis* | Burton's Snake-lizard | 5 | | B | DP |
| 25 | *Pygopus lepidopodus* | Common Scaly-foot | 3 | | T | DPI |
| 26 | *Anomalopus leuckartii* | Two-clawed Worm Skink | 43 | | B | PIG |
| 27 | *Carlia tetradactyla* | Southern Rainbow Skink | 2 | | T | D |
| 28 | *Carlia vivax* | Tussock Rainbow Skink | 1 | | T | I |
| 29 | *Cryptoblepharus carnabyi* | Spiny-palmed Tree Skink | 86 | | A | DPING |
| 30 | *Cryptoblepharus virgatus* | Cream-striped Tree Skink | 11 | | A | PI |
| 31 | *Ctenotus allotropis* | Ctenotus Skink | 18 | | T | DPIN |
| 32 | *Ctenotus eurydice* | Ctenotus Skink | 6 | C | T | I |
| 33 | *Ctenotus robustus* | Robust Ctenotus | 22 | | T | DPING |
| 34 | *Ctenotus taeniolatus* | Copper-tailed Ctenotus | 3 | | T | P |
| 35 | *Egernia modesta* | Eastern ranges Rock Skink | 37 | | AT | I |
| 36 | *Egernia striolata* | Tree Skink | 270 | | A | DPING |
| 37 | *Egernia whitii* | White's Rock Skink | 1 | | T | P |
| 38 | *Eremiascincus richardsonii* | Broad-banded Sand Swimmer | 1 | | T | I |
| 39 | *Eulamprus quoyii* | Eastern Water Skink | 1 | | TW | D |
| 40 | *Lerista bouganvillii* | South-eastern Slider | 30 | | B | DPIG |
| 41 | *Lerista muelleri* | Wood Mulch Slider | 70 | | B | DPING |

| | | | | | | |
|---|---|---|---|---|---|---|
| 42 | *Lerista puntatovittata* | Eastern Robust Slider | 36 | | B | DPNG |
| 43 | *Lygisaurus foliorum* | Litter Skink | 31 | | T | DPIG |
| 44 | *Menetia greyii* | Dwarf Skink | 2 | | T | PI |
| 45 | *Morethia boulengeri* | South-eastern Morethia | 562 | | T | DPING |
| 46 | *Tiliqua scincoides* | Eastern Blue-tongued Lizard | 1 | | T | D |
| 47 | *Trachydosaurus rugosus* | Shingle-back Lizard | 4 | | T | DN |
| 48 | *Ramphotyphlops bituberculatus* | Burrowing Snake | 2 | | B | DP |
| 49 | *Ramphotyphlops ligatus* | Burrowing Snake | 9 | | B | PIG |
| 50 | *Liasis maculosus* | Eastern Children's Python | 1 | C | A | N |
| 51 | *Morelia spilota* | Carpet Python | 1 | C | AT | P |
| 52 | *Demansia psammophis* | Yellow-faced Whip Snake | 10 | | T | DPING |
| 53 | *Denisonia divisi* | De Vis' Banded Snake | 1 | | T | N |
| 54 | *Furina diadema* | Red-naped Snake | 9 | | B | DPIN |
| 55 | *Furina dunmalli* | Dunmall's Snake | 1 | V | T | I |
| 56 | *Hoplocephalus bitorquatus* | Pale-headed Snake | 2 | V | A | NP |
| 57 | *Pseudechis australis* | Mulga or King Brown Snake | 1 | | T | P |
| 58 | *Pseudechis guttatus* | Spotted Black Snake | 3 | | W | P |
| 59 | *Pseudechis porphyriacus* | Red-bellied Black Snake | 5 | | W | DI |
| 60 | *Pseudonaja nuchalis* | Western Brown Snake | 1 | | T | I |
| 61 | *Pseudonaja textilis* | Eastern Brown Snake | 10 | | T | DPI |
| 62 | *Simoselaps australis* | Coral Snake | 3 | | B | PI |
| 63 | *Suta spectabilis* | Hooded Snake | 9 | | T | PI |
| 64 | *Suta suta* | Myall or Curl Snake | 1 | | T | P |
| | ***Total*** | | 2601 | | | |

**Appendix 2.**

**Two-way classification of reptile assemblages and transects. See Appendix B for decoding of species name abbreviations.**

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         atcsdpcpc|ccocdmptueoprcvdtdplfshlvdlel|pspvr|alcgddoeghm|aelcou|gg|cep
         mrtupg-lv|rartdgslmrtparvtsptbdabggipwb|ssbal|-mc-vwmsvbb|lmfels|ec|tql
         uuatsuvei|yloeireiiiromoaicleoiuiionuhu|epari|nuadiiotaio|eoouep|ha|eue
         rgesatisr|plbnveunlcyrpbrniexuastlutnir|uerag|oerutlnrrnu|udlrsh|yt|top
         ionumtvug|touoiydelhophuicnbtgdtoblectt|dcbna|blnbtliiiol|ceiyuy|re|ryi
         csitmaaea|stsssieaianhssutceiaerredrtio|otast|blaiailoeee|ksoder|sn|aid
         auoaotxrt|prtpiictiriyptsaoilnmaqrimain|natpu|iebatailgin|atriru|pa|dio
                  |                             |     |           |      |  |
                  |                             |     |           |      |  |   ?
1-a               |                             |     | **  *  ***|      |  |
5-f               | *                           |     |**** ** ***|      |  |
40d               | *                           |     | *      ***|      |  |
42e   G           |                             |     | *      ***|      |  |
39a   R           |                         **  | *   | ***    ***|      |  |
4-a   O     *     |                          *  | *   |    *  ****|      |  |
23d   U     *     |              *           *  |     |  * *  ****|      |  |
17d   P     *     |                             |     |* *    ****|      |  |
22e               |                             |     |* *   *****|      |  |
19e   1           |                             |     |* *    *** |      |  |
39b       *       |              *              |     |  *     ***|      |  |
39d               |              *              |     |  **   ****|      |  |
21f               |                   *         |     |       ****|      |  |
45e               |              *              |     |*      ****|      |  |
41d               |              *              |     |        ***|      |  |
6-a               |      *                      |     |* *    * **|      |  |
45d               |             ** *            |     |*      ****|      |  |
6-d               |             *            *  |     |*     *****|      |  |
9-e               |                             |     |*      ****|      |  |
16a               |                             |     |* *      **|      |  | *
20e               |                   *         |  *  |*        **|      |  |
13e               |                             |     |*       ***|      |  |
17e               | *                           |     |*       ***|      |  |
42f               |                          *  |     |**      ***|      |  |
45f               |                    *        |     |**      ***|  *   |  |
17c               |                             |     | **      **|      |  |
11e               |                             |     |         **|      |  |
20d               |             ***             |     |  ***    **|      |  |
27d               |              *              |     |         **| *  * |  |
18f               |                   *         |     |  **  * ***|*     |  |
31f               |             **  ***         |  *  |         **|      |  |
28e              *|                             |     |   *     **|**    |  |
30f              *|                             |     |         **|***   |  |
1-b               |                             |     |   *    ***|      |  |
22d               |             *               |     |   **  ****|      |  |
9-f               |             *   *           |     |    *******|      |  |
10e               |             *               |     |    *** ***|      |  |
1-c               |                          *  |     |     *  ***|      |  |
5-e               |                             |     |    **  ***|      |  |
2-e               |                          *  |     |        ***|      |  |
7-d          *    |                             |     |  *     ***|      |  |
2-b               |                     *       |     |   * ** * *|      |  |
         ---------+-----------------------------+-----+-----------+------+--+---
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4-c               |                             |     |    *    **|      |  |
40a               |                             |     |         **|      |  |
18d               |              *              |     |  *    * **|      |  |
21d               |                             |     |       * **|*     |  |
9-d               |                             |     |      *****|      |  |
41e   G           |                             |     |       * **|      |  |
26e   R           |                             |     |    ** * **|      |  |
34f   O           |             *     *         |     |       * **|      |  |
10c   U           |                           **|     |*        **|* *   |  |
24b   P           |          *                  |     |       * * |*     |* |
26f               |          *                  |     |    *  * **|* **  |  |
16b   2           |                             |     |**       * |      |  |
21c               |                   *         |     |  *      * |      |  |
40e               |              *              |     |        ** |      |  |
23a               |                          *  |     |         * |  *   |  |
24c               |              *              |     |*  *   * **| *    |  |
24f               |          *        *         |  *  |*  **    **|**    |  |
27b               |                             |     |*        * |*** * |  |
28a               |                       *  *  |     | * *   * **|**    |  |
27c          *    |                             |     |         * | **** |  |
28b              *|                             |   * |       * **| **   |  |
30b               |         **                  |     | * * *   * |      |  |
30c               |          *                  |     | * *     * | **   |  |
27a               |          *   *              |     |           | **   |  |
28d               |              *        **    |  *  |   *     **| *    |  |
28f              *|                          *  |     |   *   * **| **   |  |
30e               |                             |     | * *     * | **   |  |
         ---------+-----------------------------+-----+-----------+------+--+---
2-a               |                    *        |     |   * * *** |      |  |
7-b              *|                             |  ** |  *    *** |      |  |
7-f               |                          *  |     |     * ****|      |  |
38d   G           |                             |     |  *    ****|      |  |
2-c   R           |                          *  | *   |    * **** |      |  |
4-f   O           | *                           |     |        ** |      |  |
7-e   U           | *                        *  |     |  *    ****|      |  |
5-c   P           |                             |     |* *********|      |  |
7-a               |                             |     |*    ******|      |  |
7-c   3           |*                            |   * |  * ** ****|      |  |
2-f               |                             |     |  * *******|      |  |
8-c               |                    *     *  |     | *   *** **|      |  |  *
43d               |                             |     |**    * ***|      |  |
39e               |                             |     | ***    ***|      |  |
39f      *        |              *              |     |        ***|      |  |
38a               |                       * *   |     |       ****|      |  |
38c               |                         ** *|     |       ****|      |  |
38e               |    *                     *  |     |       ****|      |  |
38f               |                       *     |     | ***   ****|      |  |
5-b               |                       *     |  ** |     *** **|      |  |
13b               |                    *        |     |*   *  * **|      |  |
4-d               |                             |     |         **|      |  |
9-b               |                             |   * |    **   **|      |  |
11c               |                             |     |    ** * **|      |  |
17a               |                             |     |**   * * **|  *   |  |
12e               |                             |     |**** *   **|      |  |
         ---------+-----------------------------+-----+-----------+------+--+---
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4-b               |                             |     |   **  ****|      |* |
13f               | *                           |     |**  *  ****|      |  |
6-f               |                             |     |***********|      |  |  *
6-b   G           |                       *     |  *  |*   *  * **|      |  |
24e   R           |          *                  |  *  |*   *  * **|      |  |
23f   O           |                             |  *  |**  *  ** *|      |  |
13c   U           |                             | *  *|    *  * **|      |  |
32e   P           |                             |     |       * **|  *   |  |
13d               |                             |     |    *  * **|      |  |
23c   4           |       *      *              |     | *     * **|  *   |  |
17f               |                             | *   |**   * * **|      |  |
41f       *       |                             |     | *     * **|      |  |
5-d               |              *              | *   |**    *****|      |  |
5-a               |              *              |**** |***  *   **|      |  |
12d               |                  *          |     |**   *   **|      |  |
13a               |                             |     |*    * * **|      |  |
11d               |                             |     |*      * **|      |  |
31c               |                             |     |*      *  *|      |  |
26c              *|            * *              |     |*      * **|*     |  |
32d              *|             **              |     |*      * **|      |  |
11b               |                             |     |   *   * **|      |  |
19d               |              *              |     |   *   * **|      |  |
24d               |              *              |     |*  *   * **|      |  |
33d               |                   *         |     |*  *   * **|      |  |
20f               |                   *         |     |  **   * **|*     |  |
21e               |                   *         |     |       * **|*     |  |
33f        * *    |                   *         |     |*      * **|*     |  |
18b               |                   *         |     |       * **|      |  |
19c               |                             |     |  *    *  *|      |  |
19b               |                   *         |     |* **   *  *|      |  |
28c              *|                       *     |     |   *   * * | *    |  |
8-e               |                             |     |     *** * |      |  |
44e               |                          *  |     | *  *  ** *|      |  |
44f               |                          *  |     |       ** *|      |  |
24a               |          *                  |     |*      * * |*     |  |
26d               |          *                  |     |*      * **|*     |  |
33c        *      |                 *           |     |*      * * |*     |  |
26a               |              *              |     |       *   |* *   |  |
26b               |          * *                |     |*   ** * * |*     |  |
6-c               |                             |     |*    * *  *|      |  |
31d               |                             |     |       *  *|*     |  |
9-c               |                             |   * |    *  * **|      |  |
31a               |                        *    |     |    *  *  *|      |  |
21b               |              *              |     |       *   |      |  |
34d               |             *               |     |       *   |      |  |
4-e               |                             |  *  |      ** **|      |  |
23e               |             *               |  *  |       ****|      |  |
6-e               |             *               |     |  *   **** |      |  |
18e               |                             |     |*       ***|*     |  |
31e               |                   *         |     |       ****|*     |  |
11a               |                             |     |   * * ** *|      |  |
44c               |                             |     |       ** *|      |  |
40f               |                             |     |     * ** *|      |  |
22c               |                       *     |     |        *  |      |  |
41b      **       |                             |     |        * *|      |  |
19a               |                             |     |  ***  *  *|      |  |
19f               |                   *         |  *  |  **   *  *|*     |  |
20a               |     *                       |     |   *   *  *|      |  |
33a               |                 * *         |     |   *   * **|      |  |
34b               |                             |     | *     *  *|      |  |
34e               |                             |     | *     *  *|      |  |
20c               |                   **  *     |     |       *   |      |  |
32c               |                          *  |     |       * * |  *   |  |
32f               |                             |     |       * **|      |  |
         ---------+-----------------------------+-----+-----------+------+--+---
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10b               | *                           |     |* * **   * |      |  |
12f               |**           *               |     | *** *     |      |  |
17b               | *                           |  * *| **  * * * |      |  |
11f   G           |                             |     | ***   * * |      |  |
34a   R           |        *                 *  |     | *     *   |      |  |
22f   O           | *            *           *  |     | ** * ** **|      |  |
43a   U           |                             |     | *    *   *|      |  |
12b   P           |                             |     |     *     |      |  |
23b               |                          *  |     |           |      |  |
30a   5        ***|                             |     |*          |      |  |
2-d               |                             |     |           |      |  |
40c               | **                          |     |           |      |  |
43b               | *                           |     |          *|      |  |
21a               |                             |     |           |*     |  |
36b               |                             |     |           |*     |**|
25c               |                 *           |     | * *       |*     |  |
45c               |                             |     | *         |      |  |
12a               |                             |     |**   *   * |      |  |
12c               |                             |     |**   *     |      |  |
16d               |                             |     |*          |      |  |
16c               |                             |     |*         *|      |  |
33e               |                             |     |*      * * |      |  |
14d          **   |                             |     |* *       *|      |  |
22a               |                    **       |     | *     *  *|  *   |  |
32a              *|             *         *     |     |*      * **|  *   |  |
27e               |                             |     |*        **|  *   |  |
36d               | *                 *         |     |          *|  *   |  |
40b               |                             |     |      *  * |      |  |
8-f               |                             |     |      ** * |      |  |
42c               |                          *  |     |      *  * |  *   |  |
8-d               |                             |     |         * |      |  |
10f               |                             |     |         * |      |  |
         ---------+-----------------------------+-----+-----------+------+--+---
8-a               |                             |     |*        **|      |  |
16e               |                             |     |         **|      |  |
14c               |             *      *        |     |         **|      |  |
45a   G           |                             |     |         **|      |  |
9-a   R           |             *               |   * |      *  **|      |  |
33b   O           |             *               |     |*        **|      |  |
36a   U           |                             |     |          *|  *   |  |
43c   P           |                             |     |          *|      |  |
14f               |                          *  |     |  *       *|      |  |
36c   6           |                             |     |   *      *|* *   |  |
36f               |                             | *   |   *     **|* *   |  |
42a               |                             |  *  |          *|      |  |**
42d               |                             |  *  |          *|      |  |***
25a             * |                 *           |     |*  *      *|     *|  |
25e               |                             |     | * *      *|      |  |
36e               |                             |     |   *      *|      |  |
25b               |     *                       |     |*  *     * |*  *  |  |
25f               |                             |     |** *     **|   *  |  |
25d               |                             |     |*  *     **|*  *  |  |
27f               |                             |     |         **|** ***|  |
10a               |             *               |     |*        **|      |  |
10d               |             **              |     |         **|      |  |
14b               |                    *        |     |  *      **|      |  |
41c          *    |                             |     |         **|      |  |
18a               |              *              |     |  **      *|      |  |
16f               |                             |     | **       *|      |  |
14e               |                             |     |  * *    **|      |  |
41a               |             **             *|     |        * *|      |  |
30d             * |          **                 |     |**        *|      |  |
38b               |                      **     |     |  **    ***|      |  |
39c               |                         **  |     |  **    ***|      |  |
1-d               | *                           |     |  **    * *|      |  |
1-e               |                             |     |       ** *|      |  |
14a               |                             |     |          *|      |  |
44a               |                             |     |          *|      |  |
44b               |                             |     |          *|      |  |
44d               |                             |     |          *|      |  |
         ---------+-----------------------------+-----+-----------+------+--+---
8-b               |                             |  * *| *  *  *  *|      |  |
34c               |                             |     |       *  *|      |  |
45b               |                             |     |         **|      |  |
22b   G    *      |                       *     |     | *     *  *|      |  |
18c   R           |                   *        *|     |    *  *  *|*     |  |
20b   O           |                   *         |     |   *      *|      |  |
```

```
31b   U           |   *          *              |  *  |       *  *|      |  |
42b   P           |                             |     |       *  *|      |  |
1-f        **     |                        *    |     |       ** *|      |  |
32b   7           |             *   *  *  *     |     |         **|  *   |  |
43e          *    |                             |     | *  *    **|      |  |
43f               |                    *        |     | *  * *  **|      |  |
```

APPENDIX 3

**Two-way classification of reptile species by microhabitat (**see Table 2 for abbreviations of species names and microhabitat codes).

```
            BIOiIRSCIH|ILUU|GITOILLW|nUUUUUUUU|DFUUuUoTUU
            ULRsRDhKRS|GSMW|RLRLDIID|eOBBRBBLL|TCBBbBtKBB
             G    rEE |   T|  P E T |aW U GT U|  FU-D IOO
                  uWW |   B|      B |r  L RB W|  CLaT TLT
                  b   |    |      L |L        |   Or    K
                      |    |      G |G        |   Lb
                      |    |        |         |
                      |    |        |         |
                      |    |        |         |
   aleucka     *      |   *|  *     | * ******|
G  lpuncta    **      |    |  *    *|   ******|
R  lmuelle   * *      |  * | **  *  | ********|
O  lbougai     *      |    | **     |** **** *|
U  anobbii    *  * * *|    |******  |* ** * **| * *  *
P  dvittat   *        |    |***     |** *** **| *  *   *
   lfolior    *       |    |*** *** |*   *** *|
1  emodest    *       |    |*       |    *  **|   * *  **
   lgilber   *   *    |    |*  *    |     * **|   *
            ----------+----+--------+---------+----------
   dplebei            |    | *      |     * **|
G  sspecta            |    |       *|  *  * **|
R  fdiadem     *      |    |        |     *  *|   *
O  rligatu     *      |    |        |     *  *|
U  lburton     *      |*   |        |        *|
P  saustra       *    |    |        |     *  *|
2  trugosa       *    |    |        |     *  *|
            ----------+----+--------+---------+----------
   callotr            |    |***     |**   **  |
G  crobust            |  * |*  **   | *   * * |
R  ctetrad            |    | *    * | *       |
O  dpsammo            |*   |*   *  *|* * *    |
U  paustra            |    |       *|         |
P  plepido            |    |*    *  |         |
   umillii            |    |*       |         |
3  ssuta              |    |        |*        |
   usphyru            |    |        |*       *|
   hbinoei  ****      |  **|**** ***|*********|****** **
   mboulen            |****|********|*********| *****  **
            ----------+----+--------+---------+----------
   cvirgat    *       |    |   *    |      *  | * * *** *
G  plesuer    *  * *  |    |*       |         |      ** *
R  lmaculo            |    |        |         |         *
O  dtincta            |    |        |   *     |
U  equoyii      *     |    |   *    |         |
P  pbarbat   *   **   |    |*  *    |*        | **   **
   vvarius       *    |    |*       |         |      ** *
4  tscinco       *    |    |        |         |
   vgouldi    *  *    |    |*       |         |
   pguttat         ** |    |        |         |
   pporphy       * ** |    |        |         |
            ----------+----+--------+---------+----------
   ceurydi            |    |        |    *    |
G  ctaenio            |    |        |    **   |
5  oleseur    *       |    |        |    *    |
            ----------+----+--------+---------+----------
   dinterm            |    |        |         |*  **  *
G  otryoni    *       |    |        |    *    |*  ***  *
R  ewhitii    *       |    |*       |         |*   *
P  orobust            |    |        |         |*   *
6  hbitorq            |    |        |         |    *  *
            ----------+----+--------+---------+----------
```

```
   ccarnab  *         |    |****   *| *    ***|* ********
G  dwillia            |    |***     |         |****** ***
R  gdubia   * *       |    |        |    *    |**********
P  omonili            |    |        |         |****** **
   estriol  **        |    |* **   *| *   ****|**********
7  gvarieg  *         |    |     * *|**     **|**********
            ----------+----+--------+---------+----------
   amurica            |    |  *     |       * |
G  ddevisi            |    |        |       * |
R  cvivax             |    |  *     |         |
P  erichar            |    |  *     |         |
8  mgreyii            |    |  *     |         |
            ----------+----+--------+---------+----------
   clongic       *    |    |        |         |
G  fdunmal       *    |    |        |         |
R  pnuchal       *    |    |        |         |
P  rbitubu       *    |    |        |         |
   tlineat       *    |    |        |         |
9  ptextil       *    |    |        |         |
```