

Reptilia, Murray catchment, New South Wales, south-eastern Australia

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ABSTRACT: Two large-scale, long-term biodiversity monitoring programs examining vertebrate responses to habitat fragmentation and landscape change in agricultural landscapes are taking place in the Murray Catchment Management Area of New South Wales, south-eastern Australia. Field surveys involve counting reptiles under a range of management conditions and across a broad range of vegetation types in two bioregions, the South-western Slopes of New South Wales and the Riverina. We list reptiles recorded during surveys conducted between 2002 and 2009. We include additional species recorded between 1997 and 2009 from a conservation reserve. Thirty-nine species from nine families were recorded. The list will be useful for workers interested in reptile zoogeographical distributions and habitat associations as well as those interested in the biodiversity value of remnant vegetation and tree plantings in fragmented agricultural landscapes.

INTRODUCTION

Habitat loss and fragmentation is the leading cause of biodiversity loss worldwide (Fahrig 2003). Agricultural development has made a major contribution to this process (Lindenmayer and Fisher 2006), to such an extent that in many parts of the world formerly intact landscapes now consist of a mosaic of varying sized patches of remnant vegetation embedded within a matrix of crops and pasture (Hobbs and Yates 2000). Indeed, agricultural activities now take place in over 35% of the global land surface (Ramankutty and Foley 1999). This figure is predicted to increase as further changes in vegetation cover are driven by global pressure to provide food, water and shelter to an increasing population (Foley *et al.* 2005). Herein lies a challenge to effectively manage trade-offs between maintaining biological diversity and ecosystem function and meeting immediate human needs (Fisher *et al.* 2006). Large-scale, long-term monitoring programs and empirical studies are required to better understand and, in turn, better predict the impacts of habitat loss and fragmentation on biodiversity world wide (Wiens 1999).

To this end, we established two long-term monitoring programs in the Murray catchment of southern New South Wales, south-eastern Australia. The 'Restoration Study' involved a nested 'natural experiment' to examine the interactive effects of tree plantings and native vegetation on biodiversity (Cunningham *et al.* 2007; 2008) whereas, the 'Biodiversity Baseline Monitoring Project' was designed to examine biodiversity responses to landscape change facilitated by government financial incentive schemes. Currently, more than three quarters of the Murray catchment is dedicated to agricultural activities, including irrigation, dry land cropping and livestock production. For more than 160 years remnant vegetation in the catchment has been subjected to threatening process such as isolation, habitat loss, changes in plant species' composition, weed invasion, altered fire regimes and dry land salinity (Yates and Hobbs 1997). Due to the prolonged history of human

disturbance in the region, local extinction of species is expected to occur. One of the main objectives of our long-term monitoring programs is to provide baseline data on biodiversity in agricultural landscapes. In this paper, we provide a list of reptiles recorded between 2002 and 2009 as part of the Restoration Study and Biodiversity Baseline Monitoring Project. For comparison, we include additional species recorded between 1997 and 2009 on a flora and fauna conservation reserve in the Murray catchment.

MATERIALS AND METHODS

Study area

The study was undertaken in agricultural landscapes and travelling stock reserves within southern New South Wales, south-eastern Australia (Figure 1) and specifically within the South-western Slopes (SWS) and Riverina bioregions of the Murray catchment (Figure 2). The midpoint of the study area had the co-ordinates 35°21' S, 145°42' E. The study region supports a range of vegetation types (*sensu* Keith 1999), of which seven were selected across both studies. In the SWS, the following vegetation classes were included: (1) URDSF - upper riverina dry sclerophyll forest dominated by *Eucalyptus macrorhyncha*, *E. goniocalyx*, *E. blakelyi*; (2) WSGW - western slopes grassy woodland dominated by *E. albens*, *E. blakelyi* and *E. melliodora*; (3) FTW - floodplain transition woodland dominated by *E. microcarpa*, *Callitris glaucophylla* and *E. melliodora*, and (4) IRF - inland riverine forest dominated by *E. camaldulensis*. In addition, we surveyed native tree plantings (TP) and granite outcrops (GO), either supporting WSGW or URDSF vegetation or completely devoid of native vegetation. In the Riverina, the following additional vegetation classes were included: (1) RSW - riverine sandhill woodland dominated by *C. glaucophylla*, *C. gracilis* and *E. melliodora*; (2) IFW - inland floodplain woodland dominated by *E. largiflorens*; and (3) RPW - riverina plain woodland dominated by *Acacia pendula*. In addition, old man saltbush *Atriplex numelleria* plantings

(SP) were surveyed. Thus, ten environmental categories were included in the study.

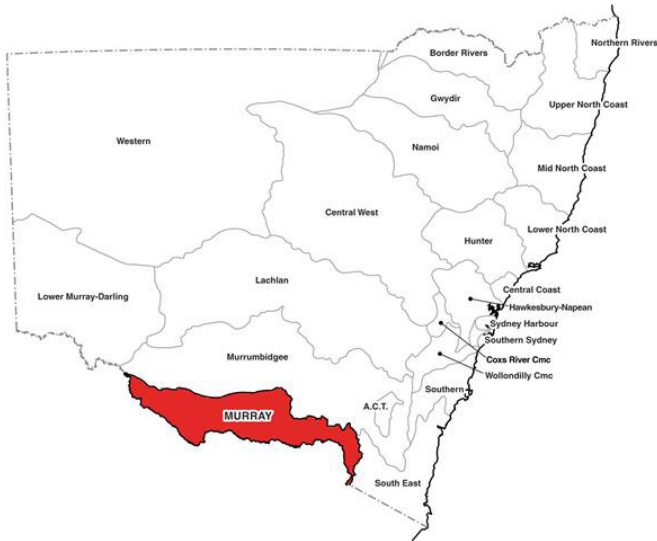


FIGURE 1. Location of the Murray Catchment Management Area, New South Wales, south-eastern Australia.

Survey design

The study region contained 251 sites. In the SWS this included 114 remnants (64 eucalypt remnants, 27 vegetated granite outcrops and 17 cleared granite outcrops on farms and six travelling stock reserves) and 28 tree plantings. In the Riverina this included 105 eucalypt / acacia remnants and six saltbush plantings. In the SWS remnant eucalypt and planting sites were selected based on two cross-classifying factors: (1) the amount of native tree plantings and (2) the amount of remnant native vegetation within a relatively homogenous landscape area covering 10,000 ha (Cunningham *et al.* 2007). Between one and three granite outcrops were selected within these landscapes where possible (Michael *et al.* 2008). In addition, approximately 35 100 x 100 m (1 ha) surveys were conducted on Nail Can Hill Flora and Fauna Reserve located in Albury (Michael 2004; Michael 2007). The vegetation and geology of the reserve is diverse and consists mostly of WSGW and URDSF vegetation types, and mica schist, granite gneiss and other granitoid rock types.

In the Riverina sites were selected based on vegetation and management type. We classified the management of remnants as follows: (1) Biodiversity sites - a site that had been managed primarily for biodiversity conservation for a minimum of three years. These sites are fenced, with or without enhancement plantings and / or strategically grazed to reduce annual weeds and promote native grass regeneration. (2) Production site - a site managed primarily for agricultural production purposes. (3) Conversion site - a site recently converted from a production area to a conservation area; and (4) travelling stock reserves - areas subject to seasonal grazing.

Reptile surveys

With the exception of granite outcrops and the Nail Can Hill Flora and Fauna Reserve, we established a permanent 200 m transect at each of the remnant and planting sites. At each site, we actively searched for reptiles by inspecting exfoliating bark, fallen timber, surface rocks, leaf litter and artificially placed cover objects (roof tiles, stacks of corrugated iron, recycled railway sleepers in the Riverina and fence palings in the SWS) within a 1 ha search area (200 m x 50 m). Along each transect two arrays of cover objects were placed 100 m apart. Each array consisted of four roof tiles (32 cm x 42 cm), two sheets of corrugated iron (1 m x 1m) stacked on top of each other and four sleepers (1.2 m long).

For the granite outcrop sites, reptiles were actively sought behind bark, within rock crevices, and beneath fallen timber, surface rocks and leaf litter within a 4 ha search area (200 m x 200 m). Field ecologists from The Australian National University completed each survey (DM, MC, RMD, CM and LM). In the Riverina, sites were surveyed during October 2008 and August 2009. In the SWS, remnants and planting sites were surveyed during August 2003 and November 2002, 2003, 2005 and 2008. Granite outcrops were surveyed between October 2006 and February 2007, and surveys on Nail Can Hill Flora and Fauna Reserve were conducted annually between 1997 and 2009 by DM for comparison. All surveys were conducted between 09:00h - 16:00h on clear days with minimal wind. Surveys were conducted under the Department of Environment and Climate Change scientific license number S12604.



FIGURE 2. Major towns and bioregions of the Murray Catchment Management Area, New South Wales, south-eastern Australia.

RESULTS AND DISCUSSION

Table 1 contains a list of reptiles recorded during field surveys between 2002 and 2009, as well as incidental species recorded between 1997 and 2009 on Nail Can Hill Flora and Fauna Reserve. We recorded 41 species from nine families. Thirty one species were recorded in sites associated with the two monitoring programs (21 species were recorded in both bioregions) and an additional 10 species were recorded from the conservation reserve (Michael 2004). This total represents 72% of species known to occur in the study area (Michael and Lindenmayer 2010). Species that were absent and known to occur in the Riverina bioregion include the Dark-spined Blind Snake *Ramphotyphlops bicolor* (Gray, 1845), Prong-snouted Blind Snake *Ramphotyphlops bituberculatus* (Peters, 1963), Common Death Adder *Acanthophis antarcticus* (Shaw and Nodder, 1802) and Bandy Bandy *Vermicella annulata* (Gray, 1841). Species known to occur in the SWS that were absent include the Blackish Blind Snake *Ramphotyphlops nigrescens* (Gray, 1845). The remaining undetected species have limited distributions in the Murray catchment and are only known from a few populations that are restricted to predominantly mallee vegetation in the far western part of the region (Michael and Lindenmayer 2010).

Significant findings from the SWS Restoration Study and granite outcrop study have been reported in detail elsewhere (Cunningham *et al.* 2007; 2008; Lindenmayer *et al.* 2007; Michael and Lindenmayer 2008; Michael *et al.* 2008). For example, although tree plantings may provide habitat for some taxa, they may not effectively offset the negative effects of native vegetation clearing for all species, especially those reliant on old-growth woodland or rocky environments. Some general findings to date include:

A) Differences in species richness and assemblage structure among broad vegetation types are due to a range of factors, including phylogeographic (Caughley and Gall 1985), evolutionary and land use histories as well as species-specific habitat preferences (Lemkert 1998). For example, 15 species were detected in only one of the two bioregions.

B) Small remnants of native vegetation in agricultural

landscapes collectively support a diverse range of reptiles. However, some species, especially those associated with leaf-litter and friable soils (*e.g.*, blind snakes), are rarely encountered (particularly if using the survey methods employed in this study) and may be under threat of local extinction. This emphasises the importance of maintaining large areas of remnant vegetation such as travelling stock reserves and flora and fauna conservation reserves, which have the potential to support species that are no longer found in agricultural landscapes.

C) Some species associated with native grasslands, such as the Southern Rainbow Skink *Carlia tetradactyla* (O'Shaughnessy, 1879) and Olive Legless Lizard *Delma inornata* (Kluge, 1974), were more abundant in tree plantings than remnant vegetation types. This is due to grazing exclusion and the accumulation of leaf litter and tussock-forming grass species which provide suitable cover and foraging resources. Evidence of reptiles using tree plantings may provide some insight into certain species' ability to persist in agricultural areas and colonise restored habitat.

D) In the South-western Slopes, granite outcrops provide habitat for many species, some of which, such as the Inland Carpet Python *Morelia spilota metcalfei* (Lacepede, 1804), are predominantly restricted to this habitat. Vegetation management on granite outcrops is required to maintain suitable conditions, particularly in terms of species' thermal requirements.

The list in Table 1 should be of broad interest to natural resource managers responsible for the Murray catchment management area, as well as those interested in studying biodiversity in fragmented agricultural landscapes. Field surveys of reptiles in the Murray catchment are on-going and major re-counts will recommence in coming years as new tree plantings are established and mature in the SWS, and selected remnants in the Riverina are excluded from stock, enhanced with understorey species and allowed to recover with the assistance of Federal and State government-supported financial incentive delivery schemes targeting threatened ecological vegetation communities.

TABLE 1. Reptile species detected in the South-western Slopes and Riverina bioregions of the Murray catchment of New South Wales, south-eastern Australia, classified by vegetation type, planting type and outcrop. Abbreviations follow environmental categories described in the text. Codes are: (-) = absent, S = sparse (detected at < 5 % of sites), R = rare (detected at 5 - 25 % of sites), U = uncommon (detected at 26 - 50 % of sites), C = common (detected at 51 - 75 % of sites) and A = abundant (detected at > 75 % of sites), # = only detected on Nail Can Hill Flora and Fauna Reserve, 1 = detected only in the Riverina, 2 = detected only in the South-western Slopes. Nomenclature follows Wilson and Swan (2008), except *Cryptoblepharus pannosus* = *carnabyi*, after Horner (2007) and *Lerista timida* = *muelleri*, after Hutchinson (2008).

COMMON NAME	SCIENTIFIC NAME	URDSF	WGSW	FTW	IRF	RSW	IFW	RPW	TP	SP	OC
		NUMBER OF SITES									
		33	52	32	5	29	26	24	28	6	17
AGAMIDAE											
Jacky Lizard #	<i>Amphibolurus muricatus</i>	-	S	-	-	-	-	-	-	-	-
Nobbi Dragon #	<i>Amphibolurus nobbi</i>	-	U	-	-	-	-	-	-	-	-
Eastern Bearded Dragon	<i>Pogona barbata</i>	S	R	-	-	S	-	-	-	-	-
CHELIDAE											
Snake-necked Turtle	<i>Chelodina longicollis</i>	-	S	-	-	S	-	-	-	-	-
Murray Turtle #	<i>Emydura macquarii</i>	-	S	-	-	-	-	-	-	-	-

TABLE 1. CONTINUED.

COMMON NAME	SCIENTIFIC NAME	URDSF	WSGW	FTW	IRF	RSW	IFW	RPW	TP	SP	OC
ELAPIDAE											
Yellow-faced Whip Snake #	<i>Demansia psammophis</i>	-	S	-	-	-	-	-	-	-	-
Eastern Tiger Snake #	<i>Notechis scutatus</i>	-	S	-	-	-	-	-	-	-	-
Dwyer's Snake	<i>Parasuta dwyeri</i>	R	-	R	-	S	-	-	-	-	-
Red-bellied Black Snake #	<i>Pseudechis porphyriacus</i>	-	S	-	-	-	-	-	-	-	-
Eastern Brown Snake	<i>Pseudonaja textilis</i>	R	-	-	-	-	-	S	R	-	R
Curl Snake ¹	<i>Suta suta</i>	-	-	-	-	-	R	R	-	U	-
GEKKONIDAE											
Southern Marbled Gecko	<i>Christinus marmoratus</i>	U	C	U	A	S	R	S	R	-	R
Eastern Stone Gecko	<i>Diplodactylus vittatus</i>	R	-	S	-	S	-	S	-	-	R
Tessellated Gecko ¹	<i>Diplodactylus tessellatus</i>	-	-	-	-	-	R	U	-	C	-
Tree Dtella ¹	<i>Gehyra variegata</i>	-	-	-	-	S	-	-	-	-	-
Southern Spiny-tailed Gecko ¹	<i>Strophurus intermedius</i>	-	-	-	-	R	-	R	-	-	-
PYGOPODIDAE											
Pink-tailed Worm Lizard ²	<i>Aprasia parapulchella</i>	-	R	-	-	-	-	-	S	-	-
Olive Legless Lizard	<i>Delma inornata</i>	S	R	-	-	S	-	S	U	-	S
Burton's Legless Lizard #	<i>Lialis burtonis</i>	-	S	-	-	-	-	-	-	-	-
Eastern Hooded Scaly-foot ¹	<i>Pygopus schraderi</i>	-	-	-	-	S	-	S	-	-	-
PYTHONIDAE											
Inland Carpet Python ²	<i>Morelia spilota metcalfei</i>	S	-	-	-	-	-	-	-	-	R
SCINCIDAE											
Southern Rainbow Skink ²	<i>Carlia tetradactyla</i>	U	C	S	U	-	-	-	C	-	R
Ragged Snake-eyed Skink	<i>Cryptoblepharus pannosus</i>	U	U	C	U	C	A	U	R	-	U
Spotted-back Skink ¹	<i>Ctenotus orientalis</i>	-	-	-	-	S	S	-	-	-	-
Large Striped Skink	<i>Ctenotus robustus</i>	S	R	S	-	S	R	-	R	C	C
Copper-tailed Skink #	<i>Ctenotus taeniolatus</i>	-	S	-	-	-	-	-	-	-	-
Cunningham's Skink ²	<i>Egernia cunninghami</i>	-	-	-	-	-	-	-	-	-	S
Tree Crevice Skink ²	<i>Egernia striolata</i>	R	R	-	-	-	-	-	S	-	A
Yellow-bellied Water Skink #	<i>Eulamprus heatwolei</i>	-	S	-	-	-	-	-	-	-	-
Three-toed Skink ²	<i>Hemiergis decresiensis</i>	S	R	-	-	-	-	-	R	-	-
Garden Skink #	<i>Lampropholis guichenoti</i>	S	S	-	-	-	-	-	-	-	-
Bougainville's Skink ²	<i>Lerista bougainvillii</i>	R	-	-	-	-	-	-	S	-	S
Wood-mulch Slider ¹	<i>Lerista timida</i>	-	-	-	-	U	R	R	S	R	-
Grey's Skink	<i>Menetia greyii</i>	-	R	R	-	R	R	U	-	U	-
Saltbush Skink ¹	<i>Morethia adelaidensis</i>	-	-	-	-	-	S	R	-	R	-
Boulenger's Skink	<i>Morethia boulengeri</i>	C	C	A	A	A	A	A	U	U	U
Shingleback ¹	<i>Tiliqua rugosa</i>	-	-	-	-	S	-	U	-	-	-
Common Blue-tongue	<i>Tiliqua scincoides</i>	-	S	-	-	-	S	S	S	-	-
TYPHLOPIDAE											
Woodland Blind Snake ²	<i>Ramphotyphlops proximus</i>	-	S	-	-	-	-	-	-	-	S
VARANIDAE											
Sand Goanna ¹	<i>Varanus gouldii</i>	-	-	-	-	S	-	-	-	-	-
Lace Monitor	<i>Varanus varius</i>	S	R	R	-	-	S	-	-	-	-
TOTAL NUMBER OF SPECIES		13	25	9	4	17	12	15	12	6	12

ACKNOWLEDGMENTS: We acknowledge the work carried out by Sachiko Okada, Scott Lucas and Geoff Kay in assisting with field work associated with these studies. These monitoring programs are made possible by the support provided by Land and Water Australia, the Australian Research Council and the Murray Catchment Management Authority of New South Wales. Clive Hilliker kindly produced the maps.

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RECEIVED: October 2009

LAST REVISED: January 2011

ACCEPTED: January 2011

PUBLISHED ONLINE: January 2011

EDITORIAL RESPONSIBILITY: Henrique Caldeira Costa