

The vertebrate fauna of Currawananna State Forest and adjacent agricultural and aquatic habitats in the New South Wales South Western slopes bioregion

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ABSTRACT

The New South Wales South Western Slopes bioregion has been significantly altered by agricultural development and is likely to experience additional significant impacts as a result of anthropogenic climate change. A simple inventory survey of the vertebrate fauna of Currawananna State Forest, a small woodland remnant on the Murrumbidgee River in the south of the bioregion, over the period 2002-2010 identified 172 vertebrate fauna species. This included three species of national conservation concern (the Trout Cod *Maccullochella macquariensis*, Murray Cod *Maccullochella peelii* and Superb Parrot *Polytelis swainsonii*) and another 16 species (5 fishes, 8 birds and 3 mammals) of state-level concern, as well as diverse frog, reptile, woodland and wetland bird and microchiropteran bat assemblages. This study demonstrates that even small remnants play an important role in supporting biodiversity in agricultural landscapes.

Key words: temperate woodland, lowland river, mammals, birds, reptiles, amphibians, freshwater fishes, threatened species, remnant habitat, agricultural wildlife.

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Introduction

The New South Wales (NSW) South Western Slopes bioregion (Thackway and Creswell 1995) forms part of Australia's wheat-sheep belt, the agricultural heartland of modern Australia and one of the most extensively modified areas on the continent. European exploration of the bioregion in the early 19th century was quickly followed by squatters and settlers. By the late 20th century (within 170 years of the explorers) 80% of the bioregion's original temperate woodland and forest had been cleared and 55% of the bioregion was devoted to intensive agricultural or pastoral production (State of the Environment Advisory Council 1996). Most of the remaining native vegetation occurs as small fragmented remnants, generally on poorer soils, and has a high proportion of weed species and an altered structure due to grazing by domestic stock (Benson 2008; Watson 2011). Soil erosion and salinity are now landscape-scale problems (Benson 2008).

Aquatic ecosystems in the bioregion have also been severely degraded. River regulation and extraction of water for irrigation have substantially reduced river flows and the frequency of replenishment of floodplain billabongs and wetlands (Thomson 1992; Briggs and Thornton 1999). Loss of riparian vegetation and in-stream woody debris, spread of exotic species, insecticide and fertilizer run-off from agriculture, increased sedimentation and overfishing have also had significant adverse effects (NSW Fisheries Scientific Committee 2001; Gilligan 2005; Lintermans 2009).

The impact of the rapid and severe landscape changes on the bioregion's native vertebrate fauna has been significant. Several species have become regionally extinct, including the Australian Bustard *Ardeotis australis* and Bilby *Macrotis lagotis* (Blakers *et al.* 1984; Ashby *et al.* 1990). Many other species are declining and/or dependent on the remaining remnants of the original vegetation.

A suite of declining woodland birds includes the Emu *Dromaius novaehollandiae*, Superb Parrot *Polytelis swainsonii*, Hooded Robin *Melanodryas cucullata*, Southern Whiteface *Aphelocephala leucopsis* and Crested Shrike-tit *Falcunculus frontatus* (Reid 1999; Traill and Duncan 2000). Declining species from other vertebrate taxa include the Freshwater Catfish *Tandanus tandanus*, Inland Carpet Python *Morelia spilota metcalfei* and Squirrel Glider *Petaurus norfolcensis* (Shine 1994; Claridge and van der Ree 2004; Lintermans 2009). New wildlife assemblages are developing in the agricultural matrix, comprising a mix of disturbance-tolerant native woodland and forest species, native species of naturally open habitats and introduced species.

Field surveys to document the distribution and status of fauna are valuable but can be costly and time-consuming. Regional-scale surveys can give a good broad overview but, with minimal survey effort per site, can be expected to underestimate the species richness of individual sites and therefore can only provide limited information on biodiversity richness at the local scale (Murphy and Murphy 2006). The need to collate information on the current status of the fauna of the NSW South Western Slopes has been made even more urgent by the prediction that the southern part of the bioregion is likely to experience significant climate change impacts by the mid 21st century (DECCW 2010). This paper reports on a simple field study of the vertebrate fauna of Currawananna State Forest (SF), a small woodland/forest remnant near Wagga Wagga in the southern part of the bioregion. Species of conservation concern are identified, the value of the different broad habitats present is discussed and seasonal and longer term variation in the fauna is noted, including the likely impact of anthropogenic climate change. This study provides an example of the significant value of even small woodland remnants in agricultural landscapes.

Methods

Study area

Currawananna SF (35°01'S 147°03'E) is located on the north bank of the Murrumbidgee River in *Wiradjuri* Aboriginal Country, approximately 25 km west of Wagga Wagga in the lower slopes sub-region (Morgan and Terrey 1992) and the

lowland section of the Murrumbidgee catchment (Gilligan 2005). The climate is temperate with hot, dry summers and cool, moist winters and an annual rainfall of about 570 mm, peaking in late autumn to early spring (BOM 2011). The state forest is only 286 ha in area, with an elevation range of 165-190 m AHD. The study area (Fig. 1) comprised the state forest, the adjacent stretch of river to the south and a

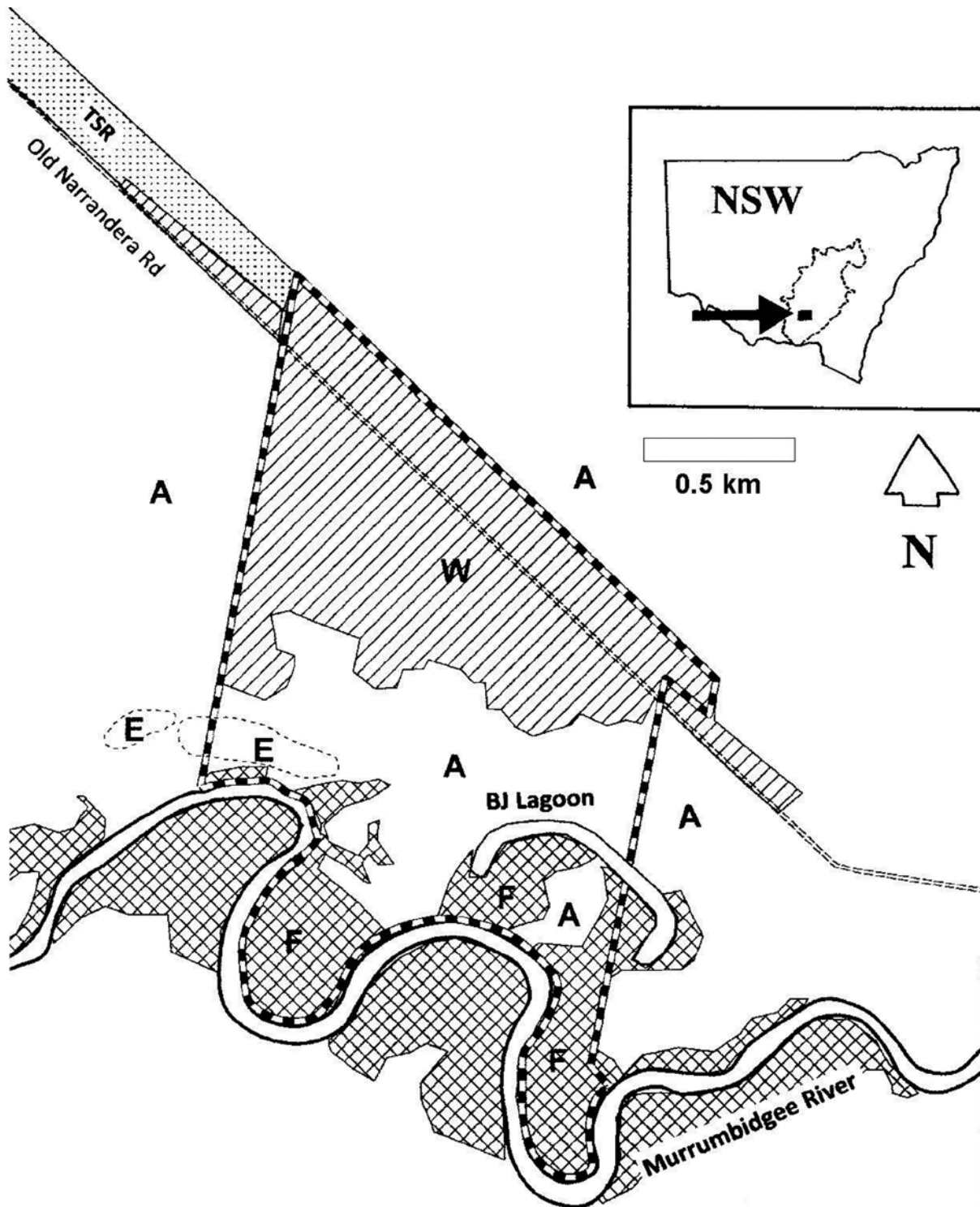


Figure 1. Location of Currawananna State Forest in the southern part of the NSW South Western Slopes bioregion. Broad terrestrial habitats within the study area are mapped: F = Riverine open forest on alluvial floodplain soil; W = cypress-eucalypt woodland on sandy soil; A = agricultural habitat areas. Additional features shown are the Murrumbidgee River and Berry Jerry (B) Lagoon, ephemeral wetland areas (E) within agricultural habitat, the Travelling Stock Route (TSR) along Old Narrandera Road and the state forest boundary (dashed line).

500 m wide band of the surrounding farmland to the east, west and north. Four broad habitats were identified:

1. Riverine open forest (Fig. 2) dominated by River Red Gum *Eucalyptus camaldulensis* with some River Oak *Casuarina cunninghamiana* occupies about 65 ha on alluvial floodplain soils in the south of the area. Very large red gums with numerous hollows were common. Domestic cattle *Bos taurus* periodically grazed this area.
2. Cypress-eucalypt woodland (Fig. 3) occupies about 130 ha on a low sandy rise in the north of the area and is dominated by White Cypress Pine *Callitris glaucophylla* with Yellow Box *Eucalyptus melliodora*, Blakely's Red Gum *E. blakelyi* and Inland Grey Box *E. microcarpa* also present. No domestic stock or recent indications of stock were seen in this area over the duration of the study.
3. Agricultural habitat (Fig. 4) (about 380 ha) is associated with stock grazing and cropping and comprises cleared fields with scattered single trees, small farm dams and remnant vegetation on roadsides. A shallow ephemeral wetland (Fig. 5) about 5 ha in extent was present in low lying fields in the south-west of the area in July and September 2010 following extensive local rain.
4. Aquatic habitat (Fig. 6) is provided by the main channel of the Murrumbidgee River (4.4 km of river frontage in the study area) and also Berry Jerry Lagoon, a 1 km long billabong which contained water in October 2002, April/June 2006 and July/September 2010 but was dry on other visits.



Figure 2. Riverine open forest habitat in Currawananna SF. Photo, M.J. Murphy



Figure 3. Cypress-eucalypt woodland habitat in Currawananna SF. Photo, M.J. Murphy



Figure 4. Agricultural habitat adjacent to Currawananna SF. Photo, M.J. Murphy



Figure 5. Ephemeral wetland in low-lying fields at Currawananna during *La Nina* conditions in 2010. Photo, M.J. Murphy



Figure 6. Murrumbidgee River adjacent to Currawananna SF, showing abundant in-stream large woody debris. Photo, M.J. Murphy

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Currawananna SF No. 186 was dedicated in February 1915 and is managed for economic and environmental values in accordance with the NSW *Forestry Act* 1916. An assessment of the forest by the NSW Forestry Commission in the 1960s concluded that “this forest is rather unique in that it carries excellent stands of both cypress pine and red gum growing only 20 chains (400 m) apart” (Anon. 1966). Timber supply has been the primary management objective over the last century. The riverine open forest was last logged in 2004 and the cypress-eucalypt woodland not since the 1950s, although harvesting is proposed there in the near future (S. Campbell Forests NSW pers. comm. August 2012). Sections of the forest were also leased under occupation permits for stock grazing and, in the central treeless area, wheat cropping (Anon. 1966). A principal concern of foresters in the mid 20th century was to ensure regenerating cypress pines were protected from overgrazing (McCallum 1955; Anon. 1966) and to this effect cypress-eucalypt woodland areas were fenced and grazing permits periodically closed. Additional management actions with biodiversity benefits include harvesting prescriptions requiring habitat tree retention (Forestry Commission of NSW 1986) and regulation of firewood collection through a permit system. Although less than ideal for biodiversity conservation, past management has enabled the survival of woodland and riverine open forest remnants with significant habitat values in a local landscape dominated by agriculture. Current issues include the high proportion of exotic weeds (48% of total flora taxa) (Burrows 1999) and impacts associated with uncontrolled recreational activities.

Survey methods

Records of vertebrate fauna species found in the study area were collated from 13 visits to the Wagga Wagga area between October 2002 and September 2010. A total of 32 days and 16 nights were spent in the study area, with time spread equally between spring (September–November), summer (December–February), autumn (March–May) and winter (June–August) (Appendix 1). The survey was based on opportunistic observation or remote detection only, with no animal trapping done. Survey methods comprised the following:

1. Random meander walks through the different terrestrial habitats by day to detect diurnally active species by sight or call and locate inactive species under cover.
2. Noting indirect signs such as tracks, scats, sloughed skins and remains during random meander walks.
3. Checking roads for animals killed by traffic.
4. Searching at night for nocturnal species by torchlight either from a car or on foot. This included random meanders through the different terrestrial habitats looking and listening for animals and also riverside observation of fishes.
5. 27 mammalian predator scats collected in the study area were analysed by scat specialist Barbara Triggs.

6. Microchiropteran bat calls were recorded in the first four hours after sunset at three sites (2 in riverine forest and 1 in cypress-eucalypt woodland) for about 30 - 60 minutes per site on a warm, calm night in December 2008, using a hand-held ultrasonic detector (Anabat: Titley Electronics). Expert analysis of recorded calls was provided by bat specialist Glenn Hoye.
7. Information concerning fishes in the stretch of river adjacent to Currawananna SF was collated from conversations with 10 recreational anglers in the study area in 2007–2008.

Birds were recorded every visit, with an attempt made to list all species present and assess relative abundance on each visit. Other taxa were only surveyed on limited occasions or noted opportunistically. The results of the field study were supplemented with records from the Atlas of NSW Wildlife (NSW Office of Environment and Heritage data supply 12 August 2010). Taxonomic nomenclature in this paper follows McDowall (1996) for fishes, Anstis (2007) for frogs, Wilson and Swan (2010) for reptiles, Christidis and Boles (2008) for birds and Van Dyck and Strahan (2008) for mammals.

Results

In total, 171 vertebrate species were recorded in the Currawananna study area: 28 mammals (13 families), 114 birds (44 families), 13 reptiles (seven families), seven frogs (two families) and nine fishes (seven families). Eight mammals, two birds and two fishes are introduced taxa. Diurnal observation and searching identified the most species (predominantly birds), followed by ultrasonic bat detection, nocturnal searching and discussion with anglers. Identification of indirect signs contributed two additional species to the species tally and checking roads for dead animals another one species. Predator scat analysis identified seven mammals as prey items but did not add to the overall species tally. The minimum suite of survey methods required to detect all 171 species was therefore six of the seven methods employed. Records of one additional species within the study area were obtained from the Atlas of NSW Wildlife: the Platypus *Ornithorhynchus anatinus*. The most recent Platypus records dated from 2006. A complete list of the 172 vertebrate species known from the study area is provided in Appendix 2, together with information on habitat usage, method of detection and status in the study area.

Table 1 lists 19 species from the study area which have been identified as being of current state, national or global conservation concern. All 19 species (seven fishes, nine birds and three mammals) are of state-level concern under the NSW *Fisheries Management Act* 1994 (FM Act) or NSW *Threatened Species Conservation Act* 1995 (TSC Act) (current to August 2012). Threatened fishes are listed under the FM Act while threatened frogs, reptiles, birds and mammals are listed under the TSC Act. Categories for listing

Table I. Summary of threatened species, population and ecological community records from Currawananna study.

Conservation status: IUCN = IUCN (2012) Red List status (only shown for near-threatened status or above), EPBC Act = Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999, FM Act = NSW *Fisheries Management Act* 1994; TSC Act = NSW *Threatened Species Conservation Act* 1995, EEC = endangered ecological community. Status current to August 2012.

Species	Conservation status	Summary of observations
Freshwater Catfish <i>Tandanus tandanus</i>	FM Act: endangered population & part of EEC	Reported as having been caught in the river adjacent to Currawananna SF by 10% of fishermen, most recently in the late 1980s. Possibly locally extinct.
Murray Cod <i>Maccullochella peelii</i>	IUCN: critically endangered EPBC Act: vulnerable FM Act: part of EEC	Reported as having been recently caught in the river adjacent to Currawananna SF by 100% of fishermen.
Trout Cod <i>Maccullochella macquariensis</i>	IUCN: endangered EPBC Act: endangered FM Act: endangered species & part of EEC	Reported as having been recently caught in the river adjacent to Currawananna SF by 70% of fishermen.
Silver Perch <i>Bidyanus bidyanus</i>	IUCN: vulnerable FM Act: vulnerable species & part of EEC	Reported as having been recently caught in the river adjacent to Currawananna SF by 40% of fishermen.
Additional native fish species of the Lower Murray aquatic EEC	FM Act: part of EEC	Australian Smelt <i>Retropinna semoni</i> frequently seen by torchlight along river margin. River Blackfish <i>Gadopsis marmoratus</i> reported as having been recently caught in the river adjacent to Currawananna SF by 20% of fishermen and also observed once by torchlight. Golden Perch <i>Macquaria ambigua</i> reported as having been recently caught in the river adjacent to Currawananna SF by 70% of fishermen.
Square-tailed Kite <i>Lophoictinia isura</i>	TSC Act: vulnerable	Very rare visitor. Single bird flying back and forth low over canopy of River Red Gum forest in October 2008.
Little Eagle <i>Hieraaetus morphnoides</i>	TSC Act: vulnerable	Rare visitor. Single birds flying over River Red Gum forest in July 2003 and September 2010.
Superb Parrot <i>Polytelis swainsonii</i>	EPBC Act: vulnerable TSC Act: vulnerable	Regular visitor spring-summer (over 20 records) with single winter record. Usually seen flying low over River Red Gum forest, cypress-eucalypt woodland or farmland. Additional sightings include pair perched at potential nest site in large River Red Gum (in October), single male feeding on ground in River Red Gum forest, group of 8 birds in cypress pine in cypress-eucalypt woodland and 1 female dead on roadside in farmland.
Brown Treecreeper <i>Climacteris picumnus</i>	TSC Act: vulnerable	Common resident in River Red Gum forest, foraging on tree trunks and major branches, on fallen timber and on ground. Recorded every visit. Average of 10.8 birds seen/heard per ½ hr of random meander transect through River Red Gum forest (based on 5 transects in September 2010).
Speckled Warbler <i>Chthonicola sagittata</i>	TSC Act: vulnerable	Rare resident in cypress-eucalypt woodland. Thirteen records: all associated with stands of cypress pines: Maximum count 2 pairs.
Flame Robin <i>Petroica phoenicea</i>	IUCN: near-threatened TSC Act: vulnerable	Uncommon winter seasonal visitor. Single or in loose groups of up to 10 birds on ground and low perches in cypress-eucalypt woodland and River Red Gum forest in July 2009 and July 2010.
Grey-crowned Babbler <i>Pomatostomus temporalis</i>	TSC Act: vulnerable	Rare visitor to cypress-eucalypt woodland. Group of 4 birds feeding on ground in loose mixed flock with Apostlebirds and White-winged Choughs on edge of woodland in March 2008. Group of 5 birds in cypress pines in October 2008.
Varied Sittella <i>Daphoenositta chrysoptera</i>	TSC Act: vulnerable	Uncommon resident in cypress-eucalypt woodland. Small groups of 2-6 birds foraging on branches of eucalypt trees in December 2004, March 2008, January 2010 and September 2010.

Species	Conservation status	Summary of observations
Diamond Firetail <i>Stagonopleura guttata</i>	TSC Act: vulnerable	Rare resident. Two birds feeding on ground in River Red Gum forest in July 2009. Three birds in cypress pines in cypress-eucalypt woodland in January 2010. Single bird on ground in cypress-eucalypt woodland in September 2010.
Squirrel Glider <i>Petaurus norfolcensis</i>	TSC Act: vulnerable species & endangered population	Very rare resident. Single animal in River Red Gum forest in December 2008. Seen at midnight, gliding to base of River Red Gum then climbing tree and chewing at bark.
Yellow-bellied Sheathtail Bat <i>Saccolaimus flaviventris</i>	TSC Act: vulnerable	'Possible' identification in River Red Gum forest in December 2008, based on Anabat call analysis.
Large-footed Fishing Bat <i>Myotis macropus</i>	TSC Act: vulnerable	'Confident' identifications in River Red Gum forest and cypress-eucalypt woodland in December 2008, based on Anabat call analysis.

under both acts are 'critically endangered' (extreme risk) species and ecological communities, 'endangered' (high risk) species, populations and ecological communities, 'vulnerable' (lower risk) species and ecological communities and 'presumed extinct' species. There is uncertainty whether the Brown Treecreeper *Climacteris picumnus* form present in the study area was the threatened eastern subspecies *C. picumnus victoriae* or the unlisted inland and nominate subspecies *C. picumnus picumnus*, as the Wagga Wagga area lies within the zone of intergradation between the two (Schodde and Mason 1999). Three species (two fishes and one bird) are identified as being of national-level concern under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (current to August 2012). Four species (three fishes and one bird) are listed as being of global concern on the *IUCN Red List* (IUCN 2012). An additional 17 bird species from the study area have been identified as declining woodland birds of regional conservation concern in Australian temperate woodlands (Reid 1999; Traill and Duncan 2000) (Table 2).

Table 2. Non-TSC Act listed species from the Currawananna study area identified as declining woodland birds by Reid (1999) and/or Traill and Duncan (2000).

Whistling Kite <i>Haliastur sphenurus</i>
Painted Button-quail <i>Turnix varia</i>
Peaceful Dove <i>Geopelia striata</i>
Chestnut-rumped Thornbill <i>Acanthiza uropygialis</i>
Southern Whiteface <i>Aphelocephala leucopsis</i>
Crimson Chat <i>Epthianura tricolor</i>
Red-capped Robin <i>Petroica goodenovii</i>
Eastern Yellow Robin <i>Eopsaltria australis</i>
White-browed Babbler <i>Pomatostomus superciliosus</i>
Crested Shrike-tit <i>Falcunculus frontatus</i>
Rufous Whistler <i>Pachycephala rufiventris</i>
Restless Flycatcher <i>Myiagra inquieta</i>
White-browed Woodswallow <i>Artamus superciliosus</i>
Dusky Woodswallow <i>Artamus cyanopterus</i>
Apostlebird <i>Struthidea cinerea</i>
Double-barred Finch <i>Taeniopygia bichenovii</i>
White-backed Swallow <i>Cheramoeca leucosternus</i>

Figure 7 and Appendix 3 summarise information on the number of species from each fauna group recorded in each broad habitat. Cypress-eucalypt woodland had the greatest number of species recorded (59% of total), including the most reptiles and birds. Riverine forest had 52% of total species including the most mammals. Frogs were recorded as most diverse in woodland and in farm dams and wetlands in farmland. The bird communities of riverine forest and cypress-eucalypt woodland differed: out of 88 bird species recorded in forest/woodland, only 43 were found in both habitats. Over a third (38%) of total species was recorded using agricultural habitats, including two frogs and 10 birds not recorded elsewhere. The river and billabong supported 20% of total species, primarily fishes and water birds as well as other aquatic species such as the Murray Turtle *Emydura macquarii* and Water Rat *Hydromys chrysogaster*.

The cumulative species curve for birds (Fig. 8) shows a steady rise in number of species over the duration of the study, with 6% of species first recorded on the final visit. The continued recording of new bird species in later visits was in large part due to the appearance of ephemeral wetland habitat at the penultimate visit. Nine of the 13

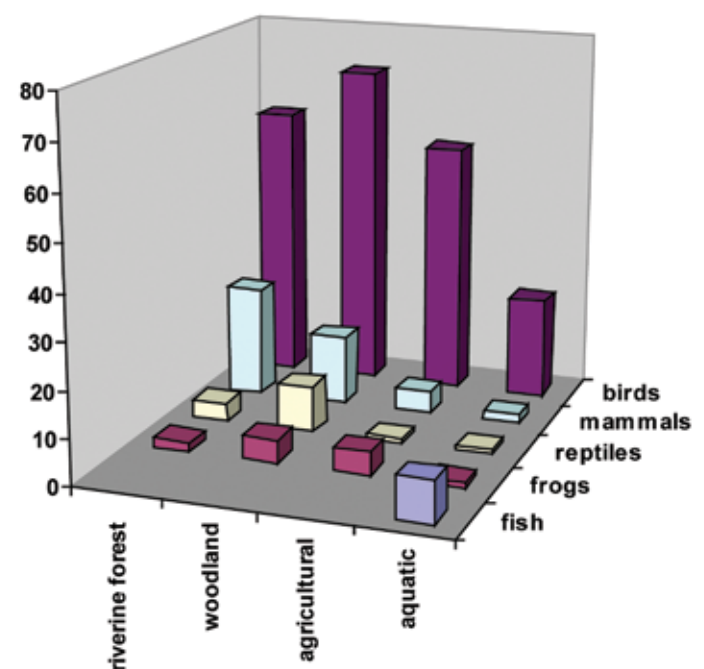


Figure 7. Number of species recorded in each habitat.

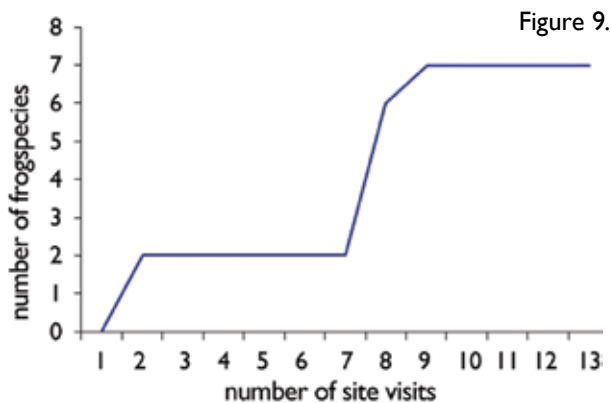
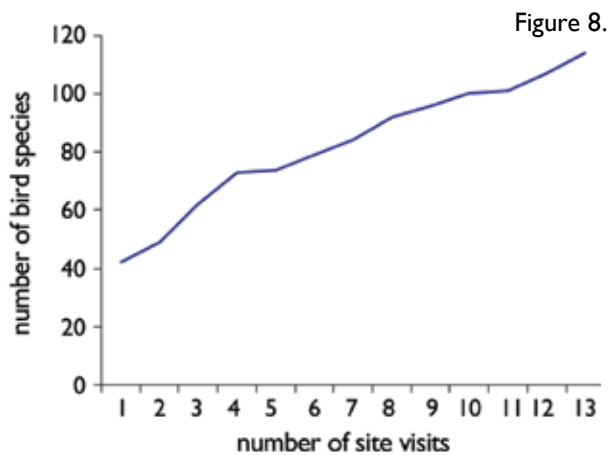
species added in the last two visits were wetland species. The highest proportion of total bird species recorded in one visit was 66% (September 2010). Information on seasonal variation in the detection of bird species is included in Appendix 2. Ninety two species were recorded in spring, 66 in summer, 75 in autumn and 78 in winter.

Other taxonomic groups slowly accumulated new species over the course of the study with the exception of frogs and microchiropteran bats. Frogs (Fig. 9) showed a spike in detection of new species when visits in October and December 2008 coincided with suitable conditions for breeding. Survey of microchiropteran bats was limited to a single night of sampling.

Discussion

Bioregional context

The fauna of the Currawananna area reflects the location of the NSW South Western Slopes bioregion in a transitional zone between the Eyrean (western) and Bassian (south-eastern) faunal divisions (Kikkawa and Pearce 1969; Schodde 1979; Caughley and Gall 1985). Eyrean species recorded include the Wrinkled Toadlet *Uperoleia rugosa*, Sand Goanna *Varanus gouldii*, Crimson Chat *Epthianura tricolor*, Southern Whiteface *Aphelocephala leucopsis* and Inland Broad-nosed Bat *Scotorepens balstoni*. Bassian species include the Red-bellied Black Snake *Pseudechis porphyriacus*, Superb Fairy-wren *Malurus cyaneus*, Eastern Yellow Robin *Eopsaltria australis*, Dusky Woodswallow *Artamus cyanopterus* and Swamp Wallaby *Wallabia bicolor*.



Figures 8 & 9. Species accumulation curves for birds (8) and frogs (9).

Caughley and Gall (1985) considered that the central area of the NSW South Western Slopes was more of a gap than an overlap between Eyrean and Bassian herpetofauna assemblages. They reported that the central South Western Slopes was depauperate compared to the western and eastern parts of the region, noting an average species richness of 3.3 frogs and 8.8 reptiles per forest block and a lingering memory of “hours of fruitless searching” in this area. Murphy and Murphy (2006) noted that low abundance could be mistaken for low diversity and suggested that substantial survey effort was needed to detect the full range of species present in forest remnants in this area. Extended observations at Currawananna over an eight year period and a range of weather conditions identified seven frog and 13 reptile species, a comparatively high diversity of herpetofauna.

Species of conservation significance

A relatively high number of species of conservation significance was recorded during the survey, given the small size of the study area, including species of global, national, state and regional concern. This highlights both the importance of small habitat remnants in supporting these species as well as the dire overall condition of the bioregion, in that such a large proportion of the vertebrate fauna is considered to be at risk.

The Trout Cod *Maccullochella macquariensis* was the species of highest conservation concern recorded in this study. The persistence of this species in the Murrumbidgee catchment now depends on a stocking program initiated in 1988, with the last recorded wild-bred individual dating from 1976 (Gilligan 2005). The Murray Cod *Maccullochella peelii* is currently relatively common and widespread in the Murrumbidgee catchment, supported by a stocking program since 1988 (Gilligan 2005), and was the most frequently reported fish species in this study. The Freshwater Catfish was formerly common in the Murrumbidgee River downstream of Wagga Wagga (Lake 1971) but is now either very scarce or locally extinct in the Murrumbidgee catchment (Gilligan 2005). The only record from the present study dated from the late 1980s. The Silver Perch *Bidyanus bidyanus* declined in the Murrumbidgee River in the early 1960s and is now at extremely low abundance, despite a substantial stocking program since 1981 (Gilligan 2005). The regular reporting of this species by anglers at Currawananna could be due to repeated misidentification or may indicate that this stretch of river supports a significant population. Further investigation of the occurrence of this species at Currawananna is warranted. All seven native fish species recorded in this study are part of an endangered ecological community which includes the entire Murrumbidgee catchment downstream of Burrinjuck dam (NSW Fisheries Scientific Committee 2001). The severely degraded status of the catchment's fish community is illustrated by the estimate that the introduced Carp *Cyprinus carpio* comprises 87% of the total fish biomass in the catchment (Gilligan 2005).

The Superb Parrot inhabits riverine forest and eucalypt-pine woodland, nesting in tree hollows close to water and foraging in nearby woodland remnants (Forshaw and Cooper 1981; Webster and Ahern 1992, Baker-Gabb 2011). The species was regularly observed in this study during spring-summer and once in winter, and possibly nests in the study area. The Currawananna study area is within the internationally-listed *South-west Slopes of NSW Important Bird Area*, identified as containing the largest known population of the Superb Parrot (Dutson *et al.* 2009). There is some evidence that the species' decline may have halted (Garnett *et al.* 2011).

Three diurnal raptors recorded in this study are of conservation concern. The Square-tailed Kite *Lophoictinia isura* occurs in very low densities in eucalypt forest and woodland where it is a specialist predator of nesting passerines (Debus and Czechura 1989). The single record in this study was a bird flying back and forth low over the canopy of riverine open forest in spring, probably searching for nesting birds. The Little Eagle *Hieraetus morphnoides* is found in open forest to open woodland and feeds primarily on lagomorphs, birds and reptiles (Cupper and Cupper 1981; Debus and Ley 2009). The Whistling Kite *Haliastur sphenurus* is found in open forest and woodland, particularly near water, scavenging carrion and preying on small mammals, birds, reptiles, fishes and insects (Cupper and Cupper 1981; Fuentes *et al.* 2005). The Little Eagle was only seen twice while the Whistling Kite was one of the most frequently observed raptors. The study area would only comprise a small part of the territory of individuals of these three species.

The Currawananna area is a valuable refuge for declining woodland passerines, with six species of state-level conservation concern and another 14 species of regional concern recorded there. However, some species such as the Speckled Warbler *Chthonicola sagittata* and possibly the Varied Sittella *Daphoenositta chrysoptera* may only exist there as small isolated populations in the process of declining to local extinction through extinction debt. Others such as the Grey-crowned Babbler *Pomatostomus temporalis* and Flame Robin *Petroica phoenicea* are better able to move through the surrounding agricultural matrix, while the Brown Treecreeper *Climacteris picumnus* probably maintains connectivity along the Murrumbidgee River. Four species possibly lost from the nearby Murrumbidgee Valley National Park (NP) (formerly Berry Jerry SF) between the 1970s and 1990s, the Speckled Warbler, Eastern Yellow Robin, White-browed Babbler *Pomatostomus superciliosus* and Diamond Firetail *Stagonopleura guttata* (Murphy 2007), all survive at Currawananna, predominantly in the ungrazed cypress-eucalypt woodland. The absence of Noisy Miners *Manorina melanocephala* from Currawananna may also be a factor in the diversity of woodland passerines there (Grey *et al.* 1998; Ford 2011).

The Squirrel Glider, recorded only once in this study, is widely but sparsely distributed in woodland and open forest remnants in the NSW South Western Slopes bioregion (Claridge and van der Ree 2004). The species has been recorded nearby in Murrumbidgee Valley NP

(Berry Jerry section) in riverine forest (Murphy 2007). The Squirrel Glider probably depends on connectivity along the Murrumbidgee River corridor to maintain a viable population in the Currawananna study area.

A very minimal survey effort identified a remarkably rich microchiropteran bat fauna of 13 species. The documented occurrence of the Large-footed Fishing Bat *Myotis macropus* is particularly noteworthy. This species, which typically feeds over streams and ponds, is primarily found within 100 km of the coast (Churchill 2008), but also occurs very sparsely further inland along the Murray and Murrumbidgee rivers (Gall 1982; Law and Anderson 1999).

A notable absence from this study was the Southern Bell Frog *Litoria raniformis*, which was recorded in identical habitat 3 km south in Murrumbidgee Valley NP (Berry Jerry section) in the late 1970s (Caughley and Gall 1985). This was the last record of the species from the Wagga Wagga area (Murphy 1997). The Southern Bell Frog was formerly widespread throughout the NSW South Western Slopes, particularly along the Murrumbidgee and Murray rivers, but has since suffered a substantial westward range contraction and is now thought to be extinct in the bioregion (Wassens 2008).

Natural habitat values

Past land management practices in Currawananna SF have enabled the survival of high value forest and woodland remnants in the study area, in a broader landscape dominated by agriculture. The importance of cypress pine woodlands for biodiversity conservation has long been underestimated (Thompson and Eldridge 2005). Cypress-eucalypt woodland in the study area supported diverse frog, reptile, bird and microchiropteran bat faunas. Twenty one threatened or declining bird species were observed in the cypress-eucalypt woodland, nine of which were only recorded in this community. The Speckled Warbler, for example, was closely associated with cypress pine, favouring dense stands of cypress. Other bird species only recorded in the cypress-eucalypt woodland included the Painted Button-quail *Turnix varius*, Varied Sittella, Southern Whiteface and Eastern Yellow Robin. The diversity of reptiles found in this small remnant is also noteworthy, as reptile assemblages in Australia's wheat-sheep belt bioregions are following the same extinction vortex as woodland birds (Driscoll 2004; Brown *et al.* 2008). The number of frog species found in cypress-eucalypt woodland and adjacent farm dams in this study was greater than that reported from an extensive survey of 26 Murrumbidgee floodplain wetlands spread along almost 600 km of the river between Gundagai and Hay (Jansen and Healey 2003), and probably in part reflects the absence of stock grazing in this remnant.

The abundance of large hollow-bearing trees in the riverine open forest is of high value for a range of hollow-dependent vertebrate fauna species including owls, parrots, possums, gliders and microchiropteran bats. Threatened hollow-dependent fauna from the study area include the Superb Parrot, Brown Treecreeper, Squirrel Glider and the Yellow-bellied Sheath-tail-bat *Saccolaimus*

flaviventris (Gibbons and Lindenmeyer 2002). The riparian forest also has an important role in maintaining instream habitat complexity, including providing a source of large woody debris (Koehn 1993; Faragher and Harris 1994). The abundant snags in the river at Currawananna provide valuable instream habitat for many native fish species (Lintermans 2009), as well being used as resting or basking sites by a range of other fauna such as turtles and water birds.

Berry Jerry Lagoon provides valuable complementary aquatic habitat to that available in the main river channel. The intermittent drying and re-flooding of billabongs is a stimulus for macrophyte and invertebrate productivity and enhances nutrient cycling, making them particularly valuable areas for aquatic vertebrate fauna (Maher and Carpenter 1984; Briggs and Maher 1985; Scholz *et al.* 2002). The billabong dried out twice during the course of this study. Aquatic species recorded in the billabong but not the river included the Australasian Grebe *Tachybaptus novaehollandiae*, Yellow-billed Spoonbill *Platalea flavipes*, Black-fronted Dotterel *Eseyornis melanops* and Water Rat.

The small area of riverine forest at Currawananna forms part of a chain of similar remnants along the Murrumbidgee River (Fig. 1). This connectivity is vital to the continued survival of many riverine forest fauna species in the study area. The Brown Treecreeper, for example, is unable to maintain viable populations in small, isolated habitat areas (Barrett *et al.* 1994; Cooper *et al.* 2002; Ford *et al.* 2009). Riverine forests provide the best opportunities for recreating linkages across regional landscapes in the eastern Australian sheep-wheat belt (Reid 1999), and the protection and enhancement of the riverine forest remnants along the Murrumbidgee River would protect a significant regional wildlife corridor (Murphy 2007). A 200 m wide Travelling Stock Route (Fig. 1) with cypress-eucalypt open woodland provides a degree of connectivity linking the small area of cypress-eucalypt woodland at Currawananna to larger cypress-eucalypt remnants 9 km north-west (the 244 ha Kockibitoo SF) and 15 km north-west (the 3176 ha Matong SF). The narrowness (and hence significant edge effects) and more open vegetation structure of this corridor would restrict the variety of woodland species able to use it, but it is the best available habitat linkage for cypress-eucalypt woodland fauna in the highly developed agricultural matrix of the local landscape. Linear remnants in any condition are better than none at all (Driscoll 2004).

Agricultural habitats

Over a third of all species in this study were found in agricultural habitats. Some were species of naturally open habitats such as the Crested Pigeon *Ocyphaps lophotes*, Black-shouldered Kite *Elanus axillaris* and Brown Songlark *Cincloramphus cruralis*, and others were waterbirds taking advantage of the ephemeral wetland, such as the Plumed Whistling Duck *Dendrocygna eytoni*, Black Swan *Cygnus atratus* and Purple Swamphen *Porphyrio porphyrio*. The majority of species, however, were woodland fauna, ranging from those relatively tolerant of clearing and fragmentation to others still dependent on woodland remnants. From one perspective, habitat features in

the surrounding farmland help support populations of a range of forest/woodland species at Currawananna and from another, the forest and woodland remnants at Currawananna enable a more diverse farmland wildlife community to exist in the local area.

The development of agricultural landscapes in Australia has been very rapid, occurring over less than 200 years compared to over 6000 years in Europe, and the original fauna is still reacting to the sudden and severe landscape modifications. The decline or disappearance of disturbance-sensitive woodland and forest species, the adaptation of disturbance-tolerant woodland and forest species to new habitats, the range expansion of open country species and the establishment of introduced species are all part of a process which will in time result in characteristic wildlife communities in Australian agricultural landscapes. Large areas of Australia are now dominated by agriculture, and there is value in documenting the current state of development of these new agricultural wildlife communities for future reference. We also have some capacity to guide the direction of this development, with implications for the delivery of ecosystem services in agricultural regions. Research in Europe has demonstrated that landscape heterogeneity is critical for agricultural wildlife (Krebs *et al.* 1999; Benton *et al.* 2003; Smith *et al.* 2004; De Laet and Summers-Smith 2007). Research in Australian agriculture-dominated systems has demonstrated a similar relationship, highlighting the contribution of woodland features apart from the larger remnants (Cunningham *et al.* 2008; Haslem and Bennett 2008; Attwood *et al.* 2009; Hanspach *et al.* 2012). Retaining and protecting remnant forest and woodland areas of all sizes as part of the agricultural landscape in Australia will encourage the continued survival of a range of woodland and forest fauna as part of species-rich agricultural wildlife communities. The alternative is a homogenous agricultural landscape where eventually even galahs are scarce.

Three introduced species recorded in this study, the House Sparrow *Passer domesticus*, English Starling *Sturnus vulgaris* and European Brown Hare *Lepus europaeus*, are of conservation concern in their natural range (Smith *et al.* 2005; Robinson *et al.* 2006; De Laet and Summers-Smith 2007; Dandapat *et al.* 2010). Although currently only considered as pest species here, Australia may eventually have a contributing role to play in the global conservation of these species in agricultural habitats if their conservation status within their natural range continues to deteriorate. The need to consider the possible conservation value of wild *ex situ* (i.e. feral) populations is likely to become increasingly common as the global species extinction crisis progresses, raising complex biodiversity management challenges (Wodzicki and Flux 1971; Pell and Tidemann 1997; Bradshaw *et al.* 2006).

Value of this study

Remnant vegetation areas in agricultural regions tend to occur on less-productive soils; the leftover bits rejected as being unsuitable for agriculture (Margules and Pressey 2000; Watson 2011). Examples from the NSW South Western Slopes bioregion include The Rock Nature

Reserve (NR), Ulandra NR, Goobang NP, Weddin Mountains NP and Conimbla NP – valuable reserves but not typical of much of the bioregion. Currawananna SF, located on alluvial floodplain soils and adjacent sandy soils, is of particular value because it is more representative of the original vegetation of the great proportion of the bioregion now devoted to agriculture.

Fauna surveys cost time and money (Garden *et al.* 2007) and researchers seldom have the opportunity to study one area over an extended period. Much work, such as that done for environmental impact assessment and planning purposes, is done within a narrow timeframe and seldom reaches the published literature. Studies such as the present one are valuable complements to broader bioregional-scale studies, providing insight into biodiversity richness at the local scale.

Survey limitations

The field study reported here was of limited scope with respect to the survey effort for fishes, frogs, reptiles and mammals. No trapping was done, such as use of concertina-type fish traps, pitfall traps, aquatic drum traps, Elliott traps, cage traps or harp traps, and the effort expended on ultrasonic detection was minimal. Notwithstanding, this study has provided an extensive inventory of the vertebrate fauna. However, it is probable that some additional species would be added by further survey effort including use of trap-based methods. For example, small benthic fish species such as carp-gudgeons *Hypseleotris* species would be more likely to be detected by fish traps than through discussion with anglers (which was biased towards species catchable by line fishing). Many of the species recorded in the study (31% of reptiles, 11% of fishes and 14% of both frogs and mammals) were represented by single records, suggesting that further species may have gone undetected. Other species known from the Wagga Wagga local area which could potentially be recorded at Currawananna with further survey effort include the Broad-palmed Frog *Litoria latopalmata* (Healey *et al.* 1997), Snake-necked Turtle *Chelodina longicollis*, Common Dwarf Skink *Menetia greyii*, Shingleback Lizard *Tiliqua rugosa* and Eastern Brown Snake *Pseudonaja textilis* (Annable 1995; Sass 2003) and Lesser Long-eared Bat *Nyctophilus geoffroyi* (Atlas of NSW Wildlife).

Birds were regularly recorded over the duration of the study and it is considered that most resident and regular seasonally visiting bird species at Currawananna were detected. However, 10% of bird species recorded were represented by single records and there is potential for additional species, particularly nomadic/irregular visitors or very rare species, to be added by further survey effort. Additional woodland/forest species known from the Wagga Wagga local area include the threatened Little Lorikeet *Glossopsitta pusilla*, Barking Owl *Ninox connivens*, Scarlet Robin *Petroica boodang* and Gilbert's Whistler *Pachycephala inornata* and the declining woodland birds Brown Quail *Coturnix ypsilophora*, Jacky Winter *Microeca fascians* and Masked Woodswallow *Artamus personatus* (Murphy 1999; Murphy 2007; Parker *et al.* 2007). Additional species known from agricultural habitats within 5km of

Currawananna include the Black-winged Stilt *Himantopus himantopus*, Cockatiel *Nymphicus hollandicus*, Eastern Barn Owl *Tyto javanica*, Blue-faced Honeyeater *Entomyzon cyanotis* and Common Blackbird *Turdus merula* (Atlas of NSW Wildlife; Murphy pers. obs.).

Seasonal and climatic factors

Seasonal variation in the bird fauna at Currawananna was evident. Winter seasonal visitors included the Red Wattlebird *Anthochaera carunculata*, Flame Robin, Golden Whistler *Pachycephala pectoralis* and Pied Currawong *Strepera graculina*. Spring/summer visitors included the Sacred Kingfisher *Todiramphus sanctus*, White-winged Triller *Lalage sueurii*, Australian Reed-Warbler *Acrocephalus australis* and Brown Songlark. Unusual records included the Rufous Fantail *Rhipidura rufifrons*, a species typically found in mesic forests of the coast and ranges. The single bird seen in April 2007 was probably in transit during autumn migration north from Victoria (Morris *et al.* 1981).

Most of the study period coincided with drought but *La Nina* conditions in 2010 made that year the third wettest on record for NSW and the wettest in over 50 years (BOM 2011). The Wagga Wagga area experienced 180% of the average annual rainfall (BOM 2011). Berry Jerry lagoon filled from the river for the first time since 2006 and an ephemeral wetland formed in low-lying fields for the first time during the study period. Nine water bird species were only recorded in the study area in 2010, including the locally uncommon Plumed Whistling Duck and Chestnut Teal *Anas castanea*. The diversity of wetland avifauna using the study area would have been substantially underestimated if the survey had finished after seven rather than eight years.

Frog activity at Currawananna was generally low, with only two species recorded in the seven visits prior to October 2008: the Plains Froglet *Crinia parinsignifera* and Spotted Marsh Frog *Limnodynastes tasmaniensis*. The visit in October 2008 was the first to coincide with noteworthy rain and another four species were detected at that time, including the burrowing species Giant Banjo Frog *Limnodynastes interioris* and Common Spadefoot Toad *Neobatrachus sudelli*. Frog surveys can easily miss burrowing species and under-estimate species diversity unless visits coincide with favourable weather conditions (Fletcher 1892; Murphy 1997).

The Currawananna study area is within a region of NSW predicted to experience severe anthropogenic climate change impacts over coming decades (DECCW 2010). By 2050 the climate is virtually certain to be hotter (average daily maximum temperatures 1.5-3.0°C higher in all seasons), the rainfall pattern is likely to shift from winter to summer dominance, total annual rainfall is likely to decline, droughts are likely to become more severe and substantial declines in stream flows are likely (DECCW 2010). These climate changes are virtually certain to have major impacts on natural ecosystems in the region, with those worst affected including floodplain communities, wetlands and smaller woodland communities (DECCW 2010). All of these communities occur at Currawananna.

Vertebrate fauna species at Currawananna likely to be adversely affected include those reliant on river flows and temporary water bodies, seasonal migrants and disturbance-sensitive species with fragmented populations restricted to woodland and forest remnants. Site-based

species inventory studies can provide useful information for understanding the local details of large-scale changes. The information documented here can assist assessment of regional impacts of climate change on vertebrate fauna over the next 40 years.

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APPENDIX I

Appendix I. Field survey dates for Currawananna study.

Spring	Summer	Autumn	Winter
1 & 3 Oct 2002 (2 days)	29-30 Dec 2004 (2 days, 1 night)	18-20 Apr 2006 (3 days, 2 nights)	10-11 Jul 2003 (1 day, 1 night)
3-5 Oct 2008 (3 days, 2 nights)	27-29 Dec 2008 (3 days, 1 night)	15-16 Apr 2007 (2 days, 1 night)	4 Jul 2006 (1 day)
28-30 Sept 2010 (3 days, 2 nights)	19-21 Jan 2010 (3 days, 2 nights)	22-24 Mar 2008 (3 days, 1 night)	10-12 Jul 2009 (3 days, 1 night)
			16-18 Jul 2010 (3 days, 2 nights)
8 days & 4 nights	8 days & 4 nights	8 days & 4 nights	8 days & 4 nights

Appendix 2. Vertebrate fauna recorded from Currawananna study area.

Habitat: A = aquatic (river or billabong), C = cleared farmland, F = riverine open forest, W = cypress-eucalypt woodland.

Method of detection: A = active search, C = call recognition, F = reported by anglers, I = indirect sign (scat, slough, tracks or remains), O = diurnal observation, P = recorded as prey in dog/fox scat, R = dead on road, S = spotlighting, U = ultrasonic recording by Anabat, W = record from Atlas of NSW Wildlife.

Local status: Fishes: presented as percentage of anglers reporting species + C = commonly observed and R = rare (single record) by torchlight. Amphibians, reptiles and mammals (excluding bats): presented as number of visits when species recorded (maximum 13 but note that these groups were not regularly surveyed on every visit) and maximum abundance recorded on one visit. C = common (6+ animals), U = uncommon (3-5), R = rare (1-2). Birds: presented as number of visits per season when species recorded (maximum 3) and average abundance when recorded. (Note in order to standardize the number of visits to 3 per season the short visits in July 2003 and July 2006 were pooled.) Abundance: A = abundant (frequently recorded in large numbers), C = common (frequently recorded in small numbers), U = uncommon (infrequently recorded, 3+ birds), R = rare (1-2 birds only recorded). Microchiropteran bats: presented as number of sites where species recorded by Anabat (maximum 3) + R = recorded rarely (once) by day under loose bark on River Red Gum and C = audible call commonly heard at night. * introduced species,¹ either *C. australis* or *C. pannosus*,² unable to identify below genus level.

Family	Species	Common name	Habitat	Method	Local status
Fishes					
Retropinnidae	<i>Retropinna semoni</i>	Australian Smelt	A	S	C
Plotosidae	<i>Tandanus tandanus</i>	Freshwater Catfish	A	F	10%
Cyprinidae	<i>Cyprinus carpio</i>	Carp*	A	F	70%
Percichthyidae	<i>Macquaria ambigua</i>	Golden Perch	A	F	70%
	<i>Maccullochella peelii</i>	Murray Cod	A	F	100%
	<i>Maccullochella macquariensis</i>	Trout Cod	A	F	70%
Terapontidae	<i>Bidyanus bidyanus</i>	Silver Perch	A	F	40%
Percidae	<i>Perca fluviatilis</i>	Redfin Perch*	A	F	30%
Gadopsidae	<i>Gadopsis marmoratus</i>	River Blackfish	A	FS	20% + R
Amphibians					
Hylidae	<i>Litoria peronii</i>	Peron's Tree Frog	C	C	2U
Myobatrachidae	<i>Crinia parinsignifera</i>	Plains Froglet	CFW	ACS	6C
	<i>Limnodynastes fletcheri</i>	Barking Marsh Frog	C	C	1U
	<i>Limnodynastes interioris</i>	Giant Banjo Frog	W	S	1R
	<i>Limnodynastes tasmaniensis</i>	Spotted Marsh Frog	AFCW	ACS	5U
	<i>Neobatrachus sudelli</i>	Common Spadefoot Toad	CW	CS	2C
	<i>Uperoleia rugosa</i>	Wrinkled Toadlet	W	CS	1U
Reptiles					
Cheluidae	<i>Emydura macquarii</i>	Macquarie Turtle	A	IO	2R
Gekkonidae	<i>Christinus marmoratus</i>	Marbled Gecko	FW	A	7C
Scincidae	<i>Cryptoblepharus</i> sp. ¹	Snake-eyed Skink species	W	AO	2R
	<i>Lerista timida</i>	Three-toed Lerista	W	A	6R
	<i>Morethia boulengeri</i>	Boulenger's Skink	FW	AO	7C
	<i>Tiliqua scincoides</i>	Common Blue-tongue	W	I	1R
Agamidae	<i>Pogona barbata</i>	Common Bearded Dragon	CW	OR	2R
Varanidae	<i>Varanus gouldii</i>	Sand Goanna	W	IR	1U
Typhlopidae	<i>Ramphotyphlops bituberculatus</i>	Prong-snouted Blind Snake	W	RS	1U
Elapidae	<i>Demansia psammophis</i>	Yellow-faced Whip Snake	F	I	1R
	<i>Parasuta dwyeri</i>	Dwyer's Snake	W	AI	2R
	<i>Pseudechis porphyriacus</i>	Red-bellied Black Snake	F	R	1R

Family	Species	Common name	Habitat	Method	Local status			
					spring	summer	autumn	winter
	<i>Vermicella annulata</i>	Eastern Bandy-bandy	W	S		IR		
Birds								
Anatidae	<i>Dendrocygna eytoni</i>	Plumed Whistling-Duck	C	O	IU	-	-	-
	<i>Cygnus atratus</i>	Black Swan	C	O	IR	-	-	IR
	<i>Tadorna tadornoides</i>	Australian Shelduck	AC	O	2R	-	IR	2R
	<i>Chenonetta jubata</i>	Australian Wood Duck	ACF	O	3C	3U	3C	3C
	<i>Anas rhynchotis</i>	Australasian Shoveler	AC	O	IU	-	-	IU
	<i>Anas gracilis</i>	Grey Teal	ACFW	O	3U	IR	2U	3U
	<i>Anas castanea</i>	Chestnut Teal	AC	O	IR	-	-	IR
	<i>Anas superciliosa</i>	Pacific Black Duck	AC	O	3U	3U	3U	3U
	<i>Aythya australis</i>	Hardhead	AC	O	-	-	-	IR
Podicipedidae	<i>Tachybaptus novaehollandiae</i>	Australasian Grebe	AC	O	2R	IR	-	IU
Columbidae	<i>Phaps chalcoptera</i>	Common Bronzewing	FW	O	IR	3R	3U	-
	<i>Ocyphaps lophotes</i>	Crested Pigeon	FCW	CO	3U	3U	3U	3U
	<i>Geopelia cuneata</i>	Diamond Dove	F	O	-	-	IR	-
	<i>Geopelia striata</i>	Peaceful Dove	FW	CO	3U	3U	3U	2R
Podargidae	<i>Podargus strigoides</i>	Tawny Frogmouth	F	S	-	-	IR	IR
Anhingidae	<i>Anhinga novaehollandiae</i>	Australasian Darter	A	O	IR	-	-	2R
Phalacrocoracidae	<i>Microcarbo melanoleucos</i>	Little Pied Cormorant	AC	O	2R	IR	2R	3R
	<i>Phalacrocorax carbo</i>	Great Cormorant	A	O	-	-	IC	-
Pelecanidae	<i>Pelecanus conspicillatus</i>	Australian Pelican	A	O	IU	-	IC	-
Ardeidae	<i>Ardea pacifica</i>	White-necked Heron	CF	O	IU	-	-	-
	<i>Egretta novaehollandiae</i>	White-faced Heron	AC	O	IR	-	IR	IU
Threskiornithidae	<i>Threskiornis molucca</i>	Australian White Ibis	C	O	IR	-	-	-
	<i>Threskiornis spinicollis</i>	Straw-necked Ibis	ACF	O	3U	-	IR	IR
	<i>Platalea flavipes</i>	Yellow-billed Spoonbill	A	O	IR	IR	IU	-
Accipitridae	<i>Elanus axillaris</i>	Black-shouldered Kite	CW	O	IR	-	IR	2R
	<i>Lophoictinia isura</i>	Square-tailed Kite	F	O	IR	-	-	-
	<i>Haliastur sphenurus</i>	Whistling Kite	FCW	CO	2R	2R	2R	2R
	<i>Milvus migrans</i>	Black Kite	F	O	-	IR	-	-
	<i>Accipiter fasciatus</i>	Brown Goshawk	FW	O	IR	-	-	-
	<i>Aquila audax</i>	Wedge-tailed Eagle	CW	O	-	-	IR	IR
	<i>Hieraaetus morphnoides</i>	Little Eagle	F	O	IR	-	-	IR
Falconidae	<i>Falco cenchroides</i>	Nankeen Kestrel	FC	O	2U	IR	2R	IR
	<i>Falco berigora</i>	Brown Falcon	CW	O	2R	-	-	IR
	<i>Falco longipennis</i>	Australian Hobby	C	O	IR	-	-	IR
Rallidae	<i>Porphyrio porphyrio</i>	Purple Swamphen	C	CO	IR	-	-	-
	<i>Gallinula tenebrosa</i>	Dusky Moorhen	A	CO	2R	-	2R	2R
	<i>Fulica atra</i>	Eurasian Coot	C	O	IC	-	-	-
Charadriidae	<i>Elseyornis melanops</i>	Black-fronted Dotterel	A	O	-	-	IU	IR
	<i>Vanellus miles</i>	Masked Lapwing	AC	CO	3U	-	3U	3U
Turnicidae	<i>Turnix varius</i>	Painted Button-quail	W	O	-	-	IR	-
Cacatuidae	<i>Eolophus roseicapilla</i>	Galah	FCW	CO	3A	3A	3C	3A
	<i>Cacatua tenuirostris</i>	Long-billed Corella	CF	CO	2R	-	2R	IR
	<i>Cacatua sanguinea</i>	Little Corella	CFW	O	IU	2U	IU	3U

Family	Species	Common name	Habitat	Method	Local status			
	<i>Cacatua galerita</i>	Sulphur-crested Cockatoo	CFW	CO	3A	3A	3A	3A
Psittacidae	<i>Polytelis swainsonii</i>	Superb Parrot	FCW	COR	3U	IR	-	IR
	<i>Platycercus elegans</i>	Crimson (Yellow) Rosella	FCW	CO	3U	3U	3U	3U
	<i>Platycercus eximius</i>	Eastern Rosella	F	CO	2U	3U	3U	3U
	<i>Psephotus haematonotus</i>	Red-rumped Parrot	CFW	CO	3C	3C	3U	3C
Cuculidae	<i>Chalcites basalis</i>	Horsfield's Bronze-Cuckoo	W	CO	IR	-	-	-
Strigidae	<i>Ninox novaeseelandiae</i>	Southern Boobook	FCW	CS	2U	3U	3U	1U
Halcyonidae	<i>Dacelo noveaguineae</i>	Laughing Kookaburra	FCW	O	3U	3U	3U	3U
	<i>Todiramphus sanctus</i>	Sacred Kingfisher	FCW	CO	2C	3U	IR	-
Meropidae	<i>Merops ornatus</i>	Rainbow Bee-eater	FW	CO	IR	2U	-	-
Coraciidae	<i>Eurystomus orientalis</i>	Dollarbird	FW	CO	1U	3U	-	-
Climacteridae	<i>Climacteris picumnus</i>	Brown Treecreeper	F	CO	3C	3C	3C	3C
Maluridae	<i>Malurus cyaneus</i>	Superb Fairy-wren	F	CO	3C	3C	3C	3C
Acanthizidae	<i>Chthonicola sagittata</i>	Speckled Warbler	W	O	2R	2R	2R	2R
	<i>Smicromis brevirostris</i>	Weebill	FW	CO	IR	1U	IR	1U
	<i>Gerygone fusca</i>	Western Gerygone	FW	CO	3U	2U	1U	1U
	<i>Acanthiza nana</i>	Yellow Thornbill	W	CO	3U	2U	2U	3U
	<i>Acanthiza chrysorhoa</i>	Yellow-rumped Thornbill	FCW	CO	2U	3U	3C	3C
	<i>Acanthiza uropygialis</i>	Chestnut-rumped Thornbill	W	O	2R	IR	1U	1U
	<i>Acanthiza apicalis</i>	Inland Thornbill	W	O	2R	IR	IR	2R
	<i>Aphelocephala leucopsis</i>	Southern Whiteface	W	O	IR	2R	1U	2R
Pardalotidae	<i>Pardalotus punctatus</i>	Spotted Pardalote	FW	CO	2R	-	IR	2R
	<i>Pardalotus striatus</i>	Striated Pardalote	FW	CO	2U	3U	2R	IR
Meliphagidae	<i>Lichenostomus penicillatus</i>	White-plumed Honeyeater	FW	CO	3C	3C	3C	3C
	<i>Anthochaera carunculata</i>	Red Wattlebird	CW	CO	-	-	-	1U
	<i>Epthianura tricolor</i>	Crimson Chat	W	O	IR	-	-	-
	<i>Melithreptus brevirostris</i>	Brown-headed Honeyeater	W	CO	2U	2R	IR	2R
	<i>Philemon citreogularis</i>	Little Friarbird	FW	CO	2R	1U	IR	-
Pomatostomidae	<i>Pomatostomus temporalis</i>	Grey-crowned Babbler	W	CO	IR	-	IR	-
	<i>Pomatostomus superciliosus</i>	White-browed Babbler	W	CO	3U	2U	3U	3U
Neosittidae	<i>Daphoenositta chrysoptera</i>	Varied Sittella	W	O	IR	2R	IC	-
Campephagidae	<i>Coracina novaehollandiae</i>	Black-faced Cuckoo-shrike	FCW	CO	3U	3U	3U	1U
	<i>Lalage sueurii</i>	White-winged Triller	W	O	2R	-	-	-
Pachycephalidae	<i>Falcunculus frontatus</i>	Crested Shrike-tit	F	O	IR	IR	-	2R
	<i>Pachycephala pectoralis</i>	Golden Whistler	F	O	-	-	-	1U
	<i>Pachycephala rufiventris</i>	Rufous Whistler	FW	CO	3C	3U	2U	2U
	<i>Colluricincla harmonica</i>	Grey Shrike-thrush	FCW	CO	3U	3U	3U	3C
Artamidae	<i>Artamus leucorhynchus</i>	White-breasted Woodswallow	F	O	-	IR	-	-
	<i>Artamus superciliosus</i>	White-browed Woodswallow	FCW	O	-	2U	-	-
	<i>Artamus cyanopterus</i>	Dusky Woodswallow	FW	O	2R	-	IR	2U
	<i>Cracticus torquatus</i>	Grey Butcherbird	W	CO	-	-	2R	-
	<i>Cracticus nigrogularis</i>	Pied Butcherbird	CW	CO	2R	3R	IR	IR
	<i>Cracticus tibicen</i>	Australian Magpie	FCW	CO	3C	3C	3C	3C
	<i>Strepera graculina</i>	Pied Currawong	FCW	CO	-	-	2R	3U
Rhipiduridae	<i>Rhipidura rufifrons</i>	Rufous Fantail	W	O	-	-	IR	-
	<i>Rhipidura albiscapa</i>	Grey Fantail	FW	CO	3U	3R	3U	3U

Family	Species	Common name	Habitat	Method	Local status		
	<i>Rhipidura leucophrys</i>	Willie Wagtail	FCW	CO	2C	3U	3U 3C
Corvidae	<i>Corvus coronoides</i>	Australian Raven	FCW	CO	2U	2U	2U 3U
	<i>Corvus mellori</i>	Little Raven	CW	CO	1U	1R	2U 1R
Monarchidae	<i>Myiagra rubecula</i>	Leaden Flycatcher	W	CO	1U	-	- -
	<i>Myiagra inquieta</i>	Restless Flycatcher	F	CO	-	-	- 2R
	<i>Grallina cyanoleuca</i>	Magpie-lark	AFCW	CO	3U	3U	3U 3U
Corcoracidae	<i>Corcorax melanorhamphos</i>	White-winged Chough	FW	CO	3C	3C	3C 3C
	<i>Struthidea cinerea</i>	Apostlebird	CW	CO	3U	2U	3U 3U
Petroicidae	<i>Petroica goodenovii</i>	Red-capped Robin	CW	COR	3C	3C	3U 3C
	<i>Petroica phoenicea</i>	Flame Robin	FW	O	-	-	- 2U
	<i>Eopsaltria australis</i>	Eastern Yellow Robin	W	CO	3U	3U	2U 3R
Acrocephalidae	<i>Acrocephalus australis</i>	Australian Reed-Warbler	A	CO	1R	2R	- -
Megaluridae	<i>Cindoramphus mathewsi</i>	Rufous Songlark	FW	CO	2U	2U	- -
	<i>Cindoramphus cruralis</i>	Brown Songlark	C	C	1R	1R	- -
Timaliidae	<i>Zosterops lateralis</i>	Silvereye	W	CO	2R	-	1R 2R
Hirundinidae	<i>Cheramoeca leucosterna</i>	White-backed Swallow	CW	O	-	-	1R -
	<i>Hirundo neoxena</i>	Welcome Swallow	AFCW	O	3U	1R	3U 3U
	<i>Petrochelidon ariel</i>	Fairy Martin	FW	O	3R	2R	- -
	<i>Petrochelidon nigricans</i>	Tree Martin	AFW	O	2U	3U	2U 1C
Sturnidae	<i>Sturnus vulgaris</i>	Common Starling*	C	CO	2R	-	- 1U
Estrilidae	<i>Taeniopygia guttata</i>	Zebra Finch	W	O	-	-	1R -
	<i>Taeniopygia bichenovii</i>	Double-barred Finch	FW	CO	1U	2R	2U 2U
	<i>Stagonopleura guttata</i>	Diamond Firetail	FW	O	1R	1R	- 1R
Passeridae	<i>Passer domesticus</i>	House Sparrow*	C	O	-	1U	- -
Motacillidae	<i>Anthus novaeseelandiae</i>	Australasian Pipit	C	O	-	1R	- -
Mammals							
Ornithorhynchidae	<i>Ornithorhynchus anatinus</i>	Platypus	A	W	-	-	-
Tachyglossidae	<i>Tachyglossus aculeatus</i>	Short-beaked Echidna	F	O	-	-	1R
Petauridae	<i>Petaurus norfolcensis</i>	Squirrel Glider	F	S	-	-	1R
Pseudocheiridae	<i>Pseudocheirus peregrinus</i>	Common Ringtail Possum	F	PS	-	-	6R
Phalangeridae	<i>Trichosurus vulpecula</i>	Common Brushtail Possum	F	PS	-	-	10C
Macropodidae	<i>Macropus giganteus</i>	Eastern Grey Kangaroo	FCW	IOPS	-	-	13C
	<i>Wallabia bicolor</i>	Swamp Wallaby	FW	OPRS	-	-	9U
Emballonuridae	<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheath-tail Bat	F	U	-	-	1
Vespertilionidae	<i>Chalinolobus gouldii</i>	Gould's Wattled Bat	FW	U	-	-	3
	<i>Chalinolobus morio</i>	Chocolate Wattled Bat	FW	U	-	-	3
	<i>Myotis macropus</i>	Large-footed Fishing Bat	FW	U	-	-	2
	<i>Nyctophilus sp.²</i>	Long-eared Bat species	F	U	-	-	2
	<i>Nyctophilus gouldi</i>	Gould's Long-eared Bat	F	A	-	-	R
	<i>Scotorepens balstoni</i>	Inland Broad-nosed Bat	FW	U	-	-	3
	<i>Vespadelus darlingtoni</i>	Large Forest Bat	FW	U	-	-	3
	<i>Vespadelus regulus</i>	Southern Forest Bat	F	U	-	-	2
	<i>Vespadelus vulturinus</i>	Little Forest Bat	FW	U	-	-	3
Molossidae	<i>Mormopterus sp. 2</i>	Eastern Freetail Bat	F	U	-	-	2
	<i>Mormopterus sp. 3</i>	Inland Freetail Bat	FW	U	-	-	3
	<i>Mormopterus sp. 4 (long penis form)</i>	Southern Freetail Bat	FW	U	-	-	3

APPENDIX 2

Family	Species	Common name	Habitat	Method	Local status
	<i>Tadarida australis</i>	White-striped Mastiff Bat	F	CU	2 + C
Muridae	<i>Hydromys chrysogaster</i>	Water Rat	A	S	1U
	<i>Mus domesticus</i>	House Mouse*	FW	AIPS	3U
Leporidae	<i>Lepus europaeus</i>	European Brown Hare*	W	IO	12U
	<i>Oryctolagus cuniculus</i>	European Rabbit*	FC	IOPS	10U
Canidae	<i>Canis domesticus</i>	Domestic Dog*	FW	IO	4R
	<i>Vulpes vulpes</i>	Red Fox*	FCW	IO	5R
Felidae	<i>Felis catus</i>	Feral Cat*	W	O	1R
Bovidae	<i>Bos taurus</i>	Domestic Cow*	FC	IO	6C
	<i>Ovis aries</i>	Domestic Sheep*	C	OP	9C

APPENDIX 3

Appendix 3. Number of species from each fauna group recorded in each broad habitat at Currawananna.

Habitat type	Fishes	Frogs	Reptiles	Birds	Mammals	Total (all taxa)
Riverine forest	-	2	4	60	24	90
Cypress-eucalypt woodland	-	5	10	71	15	101
Agricultural	-	5	1	55	5	66
Aquatic	9	1	1	22	2	35
Total (all habitats)	9	7	13	114	29	172

APPENDIX 4



The Giant Banjo Frog *Limnodynastes interioris* (photographed at Currawananna) is a burrowing frog typically only seen following substantial rain.

Photo, M.J. Murphy.



The Eastern Bandy-bandy *Vermicella annulata* (photographed at Currawananna), a specialist predator of blind snakes, was part of a suite of reptile species found in cypress-eucalypt woodland.

Photo, M.J. Murphy.

APPENDIX 4



The Sulphur-crested Cockatoo *Cacatua galerita* & Little Corella *Cacatua sanguinea* (photographed at Currawananna) were both vocal and prominent members of Currawananna's bird fauna. The corella has extended its range as a result of agriculture.

Photo, M.J. Murphy.



The threatened Brown Treecreeper *Climacteris picumnus* (photographed at Currawananna) was common in riverine open forest in the study area but probably relies on connectivity along the Murrumbidgee River to maintain a viable population.

Photo, M.J. Murphy.



The Red-capped Robin *Petroica goodenovii* (female photographed at Currawananna), a declining species in Australia's temperate woodlands, was part of a suite of woodland birds found in cypress-eucalypt woodland but not riverine open forest.

Photo, M.J. Murphy.



The Common Brush-tailed Possum *Trichosurus vulpecula* (photographed at Currawananna) is a hollow-dependent species and was commonly seen at night in riverine open forest.

Photo, M.J. Murphy.

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The Swamp Wallaby *Wallabia bicolor* (photographed at Currawananna) survives in agricultural regions in small forest and woodland remnants. Photo, M.J. Murphy.



The Water Rat *Hydromys chrysogaster* (photographed at Wollundry Lagoon, Wagga Wagga) utilised temporary aquatic habitat in Berry Jerry Lagoon, where it was observed at night catching and eating yabbies *Cherax destructor*. Photo, M.J. Murphy.