A novel course for South Creek Catchment

This thesis is written in the form of a journal article from Landscape and Urban Planning.

Declaration

I wish to acknowledge the following assistance in the research detailed in this report:

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All other research described in this report is my own work.

Elisha Duxbury

Department of Biological Sciences

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ABSTRACT

The traditional goal of restoration ecology to return ecosystems to their historical conditions is increasingly unfeasible due to high levels of disturbance and ongoing threatening processes such as climate change. A new approach to restoration, termed 'renewal ecology,' has been proposed, recognising the need to harmonise biodiversity with human infrastructure, for the benefit of both. This project uses the renewal ecology framework to examine how a degraded ecological riparian community could be transformed into a novel community with high human amenity and biodiversity values.

Five sites along creeks in Western Sydney were surveyed to provide benchmark data for the proposed restoration. Measurements at each location included vegetation characteristics and bird diversity as an indicator of biodiversity value and habitat quality of each site. Surveys were also distributed to the Western Sydney community to investigate the attitudes to, and preferences of, local residents to green space.

This project thus had three complementary objectives. First, the data collected on the composition of the vegetation communities will inform restoration and management practices for the degraded riparian sites. Second, the relationship of bird diversity to habitat structure will indicate the suitability of native and novel vegetation communities as habitat along riparian corridors. Third, linking the outcomes from the ecological studies with the landscape preferences of Western Sydney residents will inform the design of recreational spaces that will not only benefit biodiversity but also have high value to the local community.

1. Introduction

Over half of the global population is now living in cities (UN, 2018). The year 2014 marked a turning point where more than 50% of the human population became urban compared to non-urban, and that percentage is projected to increase to 68% by 2050 (UN, 2014). Urban growth has resulted in humans having a greater impact on the world's ecosystems than ever before (Johnson et al., 2017). Significant alterations to abiotic conditions in ecosystems, affected by forces such as climate change, industrial pollution, and eutrophication and salinity increases in soils and water, have led to

irreversible changes to the world's biomes (Hobbs et al., 2011; Johnson et al., 2017). Land clearing for agriculture and infrastructure has led to drastic declines in biodiversity and extinction caused by habitat loss (Steffen et al., 2007).

Riparian zones are among the world's most altered ecosystems (Pittock et al., 2015). Nutrient rich river floodplains have provided the potential for prosperous agriculture since before the development of the first urban societies, leading to long-term landscape modifications (Macklin & Lewin, 2015). As sites of concentrated human activity, riparian ecosystems experience a wide range of intense anthropogenic pressures (Pittock et al., 2015). Impervious surface cover in urban catchments alters the hydrology and geomorphology of streams leading to increased runoff from urbanised surfaces and industrial discharges resulting in increased loading of nutrients, metals, pesticides, and other contaminants to streams (Paul & Meyer, 2001). The consequences of these changes are consistent declines in the richness of algal, invertebrate, and fish communities in urban waterways (Paul & Meyer, 2001). Considered biodiversity hotspots, riparian ecosystems are typically comprised of taxa that are taxonomically or functionally distinctive from surrounding habitats (Pittock et al., 2015). Habitat clearing along waterways to make way for human infrastructure transforms large tracts of continuous ecosystems into smaller fragments of remnant habitat (Grimm et al., 2008), resulting in communities, which are more biotically homogeneous and often dominated by exotic species (McKinney, 2006).

1.1 South Creek Catchment in Western Sydney

South Creek Catchment in Western Sydney is one of the most heavily degraded catchments in Australia (Hawkesbury-Nepean CMA, 2007). The catchment has suffered from high pollution loads, increased impervious surfaces because of urbanisation, and long-term clearing of vegetation (Boon, 2017). Establishment of several sewage treatment plants along its course has had a devastating effect on the water quality of the catchment, with one study finding heavy metal contamination in South Creek with concentrations up to 800 times higher than background levels (Thoms & Thiel, 1995). The region's population has grown rapidly since the 1950s (Simmons & Scott, 2006) with the past ten years having had particularly high rates and intensification of urban growth (ABS, 2016), resulting in extensive land clearing (Tozer et al., 2015). The population of Western Sydney west of the Liverpool and Blacktown local government areas (LGSs) is projected to grow from 1,070,000 in 2016 to accommodate over 450,000 new people by 2036 (ABS, 2016), with major growth hubs on South Creek and its main tributary Eastern Creek (GSC, 2017). Despite the extensive land clearing that has already occurred in Western Sydney (Tozer et al., 2015), land

releases are underway for the development of new housing and infrastructure to accommodate additional residents (Department of Planning & Environment, 2017).

Areas of remnant vegetation in Western Sydney are small, heavily fragmented, and often in poor condition (Benson & Howell, 2002; Tozer, 2003; Tozer et al., 2015). Most of the ecological communities occurring in this region are listed as endangered under both federal and state conservation legislation (NSW Scientific Committee, 1998a, 1998b, 1999, 2000a, 2000b, 2000c, 2002a, 2002b, 2002c, 2007, 2009). The reduction in the historical range of the dominant ecological community, Cumberland Plain Woodland, is estimated to be 92-94% (Tozer et al., 2015). The contemporary clearing rate of Cumberland Plain Woodland is approximately half the historical average, but there is evidence that this rate will double as a consequence of ongoing urbanisation and government policy of biodiversity offsets that allows 'double dipping' and using bushland in existing reserves as offsets(CCN, 2018; Tozer et al., 2015). Further clearing will likely lead to a loss in floristic diversity and habitat (Tozer, 2003).

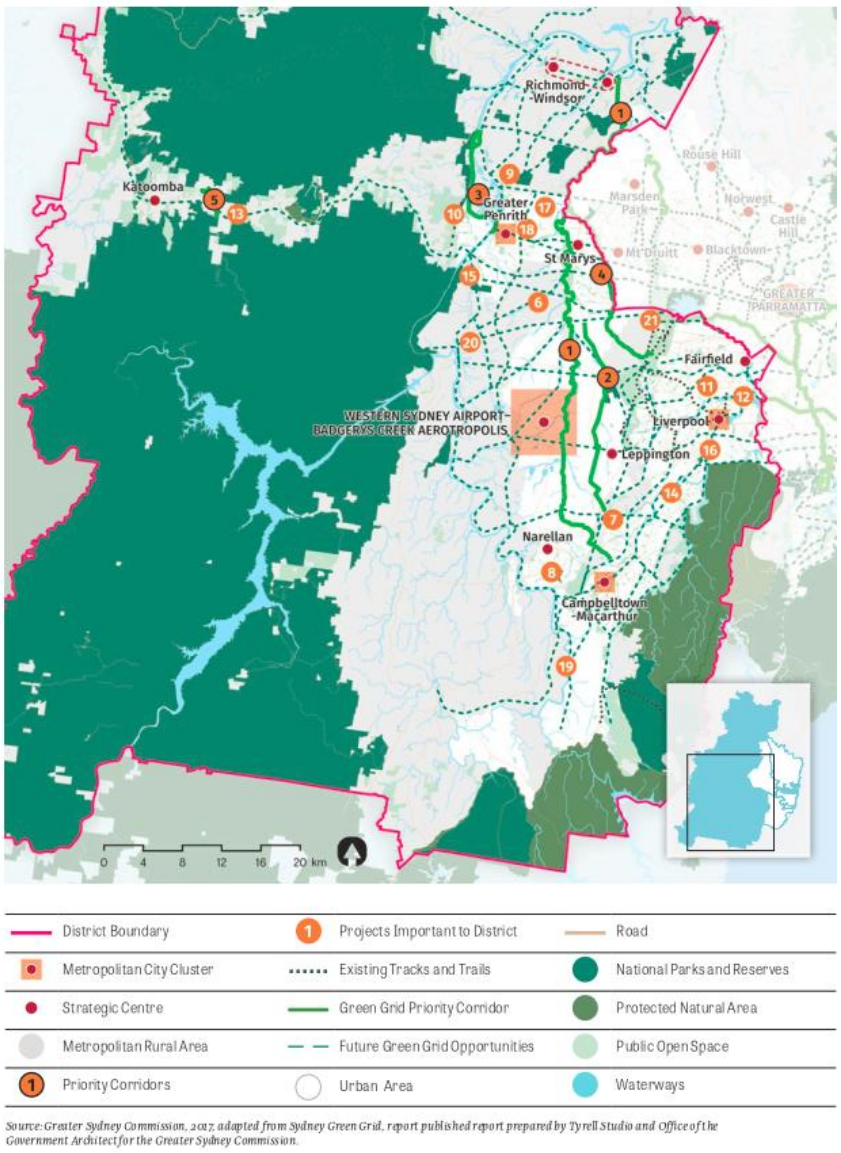
The ranges of many mammal and bird species have been severely reduced in Western Sydney due to fragmentation (Jones et al., 1997; Keast, 1995; Van Dyck & Strahan, 2008). Certain iconic species are only found in larger connected remnants, such as wombats, echidnas, and the common wallaroo (Jones et al., 1997). Only a few mammal species are abundant in smaller bushland fragments in Western Sydney, such as the eastern grey kangaroo, common brushtail possum, grey-headed flying fox, and a few microchiropteran bat species (Jones et al., 1997). Bird species were relatively common until the 1950's compared to present-day, but have significantly declined since the 1970s (Keast, 1995). Aggressive native species, such as the noisy miner, now often outcompete smaller woodland birds in small, disturbed bushland fragments (Dow, 1977; Maron et al., 2011).

Remaining bushland fragments are often very degraded because of disturbance and damage by trampling from off trail bushwalking and horse riding, illegal recreational vehicle use, dumping, and invasion of exotic plant species (Benson & Howell, 2002; Tozer et al., 2015). Plant communities of the Cumberland Plain are particularly vulnerable to weed invasion because of their understory of native grasses, which are susceptible to being outcompeted by aggressive invasive grass species, relatively fertile soils, and past agricultural uses (Hill et al., 2005; Tozer, 2003). Weeds such as African love grass, African olive, and bridal creeper have established widely and displace native plants (Cuneo & Leishman, 2006; Hill et al., 2005). Additionally, Western Sydney is disproportionately affected by climate change compared to more coastal metropolitan areas. Significantly greater increases in hot days and severe fire weather are projected for the region by 2079 than for coastal Sydney, and in the South West, rainfall is expected to increase less than the North West or coast (Adapt NSW, accessed 11/2018).

1.2 Future of South Creek Catchment

Despite the many threats to the natural environment in Western Sydney, biodiversity outcomes are beginning to be integrated into urban planning for the region (GSC, 2017). The Greater Sydney Commission has drafted plans for urban development to accommodate Western Sydney's growing population. The Draft Western City District Plan includes an objective to incorporate natural landscape features into the urban environment (GSC, 2017). Sustainability Planning Priorities are proposed for the region, aiming to deliver habitat, promote an urban tree canopy for climate change adaptation, and create parks and open space for people (GSC, 2017). Under this plan, South and Eastern Creeks will be rehabilitated to serve as habitat corridors that also provide ecosystem services including nutrient capture, urban cooling, and walking and cycling trails (Figure 1; GSC, 2017). These corridors will connect to a larger *Greater Sydney Green Grid*, which is to provide regional connections that link open space, waterways and bushland (Figure 1; GSC, 2017). These plans provide an opportunity to design a biodiversity-friendly cityscape that could complement traditional restoration, which to date, has been ineffective at improving the conditions of riparian communities in South Creek Catchment (Hawkesbury-Nepean CMA, 2007).

Restoration efforts often attempt to return ecosystems to some perceived natural or historic state (Hobbs et al., 2009). The term 'natural' itself is problematic because the local Aboriginal people, the Dharug, managed the landscape prior to the arrival of Europeans through practices such as burning, digging topsoils to aerate and enrich soils, aiding the germination of seeds, and the manual transfer of rhizomes of useful plants (Benson & Redpath, 1997). Further alteration of Western Sydney's ecosystems occurred soon after the arrival of the First Fleet through the imposition of agriculture and vegetation clearing, so the pre-European conditions for many are largely unknown (Benson & Howell, 2002). Furthermore, modifications of the catchment's geomorphic structure, water quality, and riparian ecosystems have been so extensive that efforts to restore them to perceived past conditions are likely to be futile (Hawkesbury-Nepean CMA, 2007).



Source: Greater Sydney Commission, 2017, adapted from Sydney Green Grid, report published report prepared by Tyrell Studio and Office of the Government Architect for the Greater Sydney Commission.

Figure 1: Map of the Western City District, including proposed Green Grid Priority Corridors and regions of urban growth (GSC, 2017).

The short comings of historical targets have been recognised by restoration ecologists in a debate about the adequacy of existing conservation methods (Bowman et al., 2017). A new approach for conservation termed 'renewal ecology' has been proposed, recognising the need to harmonise biodiversity with human infrastructure, for the benefit of both (Bowman et al., 2017). This approach acknowledges that all natural systems have been effected by human-induced global change and that conscious ecosystem design and management is now necessary (Bowman et al., 2017). South Creek Catchment provides an opportunity to apply the renewal ecology concept to a case study of an extremely degraded riparian ecosystem, which is facing increasing human pressures.

This study aims to integrate the preferences of local residents with benchmark ecological data to inform the future design of riparian ecosystems in South Creek Catchment. An online survey was undertaken to capture the community's attitudes towards the use and management of riparian ecosystems, and preferences for particular vegetation types. Ecological surveying was conducted to collect benchmark data of habitat value of riparian communities. Vegetation characteristics were recorded, including the diversity of native and exotic species, ratio of exotic species to native species, and structure, to inform restoration practices. Bird species richness at the same sites was surveyed. Birds are a useful indicator of habitat value because they are ubiquitous, easy to survey, and extensive literature exists describing their responses to habitat characteristics. Ecological and community survey results were then used to develop a set of recommendations to inform the design of recreational green spaces to maximise their value for both biodiversity and the local community.

2. Methods

2.1 Characteristics and history of South Creek Catchment

2.1.1 Geography

South Creek Catchment covers an area of around 620 km^2 and falls entirely within the Cumberland Plains region in Western Sydney (EPA, 2005). It is the largest sub-catchment of the Hawkesbury-Nepean Catchment, which provides most of the drinking water for the Greater Sydney region (Boon, 2017). Though parts of the Hawkesbury River are estuarine, South Creek and its tributaries are entirely freshwater (Boon, 2017). The catchment extends the length of Western Sydney, with South Creek beginning 4 km north-east of Narellan and 7 km west of Minto in the south-west (Boon, 2017). It then flows for 70 km until it joins the main stem of the Hawkesbury at Windsor (Boon, 2017). South Creek's flow path is generally north, and it is joined by 17 smaller tributaries, including Badgerys Creek, Kemps Creek, Ropes Creek, and Eastern Creek (Boon, 2017). The creek's major tributary is Eastern Creek, which joins South Creek at Riverstone (Boon, 2017). The catchment extends across portions of seven Local Government Areas (LGAs) in Western Sydney: Liverpool, Penrith, Blacktown, Camden, Fairfield, Hawkesbury, and Campbelltown (Rae, 2007).

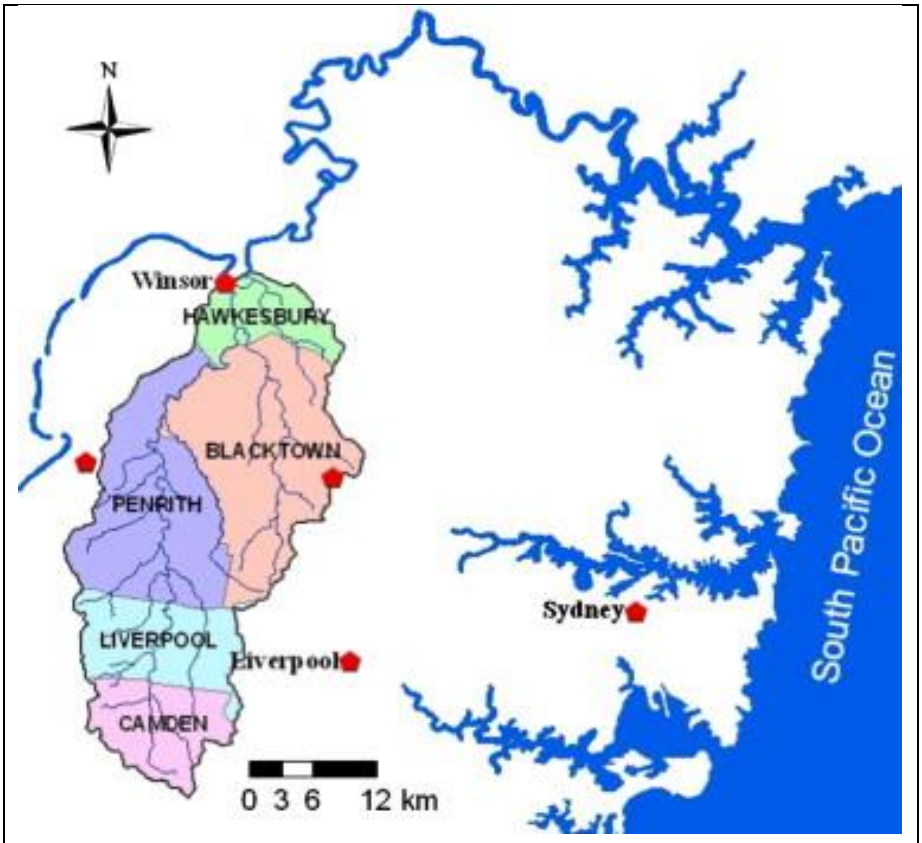


Figure 2: Location of South Creek Catchment in Greater Sydney and LGAs within the catchment area (Nawarathna et al., 2010).

2.1.2 Climate

Western Sydney has more extreme temperature highs and lows than the rest of the Sydney Metropolitan Region (Adapt NSW, 2014). Mean maximum temperatures for the region range from 28-30^{o}C during summer and mean minimum temperatures during winter are between 8-10^{o}C (Adapt NSW, 2014). Average annual rainfall in South Creek catchment is less than 800mm (Rae, 2007).

Temperatures in Western Sydney are up to 6-10^{o}C higher than in the east during extreme weather events (Adapt NSW, 2014). Western Sydney currently experiences 10-20 days per year with temperatures that exceed 35^{o}C, and average maximum and minimum temperatures are projected to increase by up to 2.5^{o}C over the next 60 years (Adapt NSW, 2014). This is expected to increase by an additional 10-20 days by 2079, increasing the region's bushfire risk (Adapt NSW, 2014).

2.1.3 Geology

The Cumberland Plain is covered by Wianamatta Group soils, the youngest soil group in the Sydney Basin (Bannerman & Hazelton, 1990; Macgregor, 1985). These soils formed in the mid-Triassic 238-235 million years ago and extend over the central business district out to Penrith in the West, Picton in the south, and Windsor in the north, as well as capping parts of plateau ridges that radiate out of Sydney (Macgregor, 1985). Wianamatta Group soils are composed of three strata – older Ashfield Shale and the younger Bringelly Shale, which sandwich a very thin layer of sandstone (Minchinbury Sandstone) (Macgregor, 1985). Bringelly Shale occurs across the Cumberland Plain (Macgregor, 1985). These soils are relatively fertile compared to the very nutrient poor sandstone soils that occur in other parts of the Sydney region and led to Western Sydney being primarily used for agriculture from the late 18th century until the mid-20th century (Haworth, 2003).

2.1.4 Vegetation

The dominant vegetation community along the waterways of the South Creek Catchment is classified as Alluvial Woodland (Tozer, 2003). Previously classified as Sydney Coastal River-flat Eucalypt Forest, the community was subdivided by Tozer in 2003 into three separate vegetation-types, Alluvial Woodland, Riparian Woodland, and Riparian forest. Alluvial Woodland remains recognised as a sub-community of River-flat Eucalypt Forest by the NSW Scientific Committee (2005). Vegetation of this type corresponds to draining Wianamatta shale-derived soils and is most often dominated by cabbage gum (*Eucalyptus amplifolia*) and forest red gum (*E. tereticornis*), with *Angophora floribunda* occurring less frequently (Tozer, 2003). The shrub layer is sparse and dominated by *Bursaria spinosa*, and often has a dense groundcover layer dominated by *Oplismens aemulus*, *Microleana stipoides*, *Entolasia marginata*, and *Echinopogon ovatus* (Tozer, 2003).

2.1.5 Aboriginal history and fire

South Creek is known by local Aboriginal people as Wianamatta, meaning ‘mother place’ (Brook, 1999). The land near South Creek was occupied by the Gomerigal-Tongarra band belonging to the Dharug language group (Brook, 1999). Traditionally Ropes and South Creek would have provided the Dharug people with a source of fresh water, fish, shellfish, and aquatic plants used for a variety of purposes (Brook, 1999).

Aboriginal people in the Sydney area used fire in a variety of ways such as for flushing out food animals for hunting and regenerating desirable food plants (Boon, 2017). Ecological evidence suggests that Aboriginal burning resulted in substantial changes in the geographic range and demographic structure of many vegetation types in Australia (Gammage, 2012). There is some evidence that fire was used in south-eastern Australia to stimulate reed growth, to create open water for some species of fish, and to facilitate travel (Bowman, 1998).

The understory of the Cumberland Plain was probably burnt frequently with a mosaic of low-intensity fires (Benson & Redpath, 1997). Studies in Lane Cove catchment suggest vegetation on fertile shale soils was probably burnt every 1-5 years, which could also be the case for the rest of the Cumberland Plain (Boon, 2017). Intentional fires on Cumberland Plain were probably more frequent than on sandstone because grassy woodlands hold more game (Recher et al., 1993). However, within six years of the initial arrival of Europeans in Australia in 1788, settlers cleared timber from land they intended to cultivate and for a certain distance around that land as a precaution against fires (Kohen, 1993; Rosen, 1995).

2.1.6 European settlement history

European settlement on the land around South Creek Catchment began not long after the arrival of the first fleet (Stapleton & Stapleton, 1983). By 1794 land around South Creek was taken up as farmers began to colonise the upper Hawkesbury and its tributaries (Fletcher, 1976; Stapleton & Stapleton, 1983). The Rev. Samuel Marsden established the historic Mamre farm, now Mamre homestead, at Orchard Hills on South Creek in 1799, where he began experiments on hemp, flax, and wool production on 238 acres of land (White & Murray, 1988). In 1800 William Paterson was appointed Lieutenant Governor and granted 137 new parcels which nearly filled in almost all of the remaining ‘unoccupied’ areas of land between Richmond and Windsor, down South Creek and along the Hawkesbury River (Fletcher, 1976).

Scheyville National Park to the northeast of South Creek Catchment is the largest remaining fragment of Cumberland Plain vegetation (DECCW, 2011). For nearly 100 years, starting in the early 1800s, farmers grazed their animals freely on the land, which is now the National Park (Stubbs & Stubbs, 1983). From WWII onwards, Scheyville was used for a variety of purposes including police and military training, education, as a demonstration farm, and a migrant holding centre, until it was placed under the care of National Parks in 1996 (NPWS, 2003; Stubbs & Stubbs, 1983).

2.1.7 Condition of the catchment

There are anecdotal reports that the water in South Creek remained clear until around the mid 20th century (Riley, 2000). South Creek Catchment has suffered from rapid environmental decline, beginning in the period of rapid urbanisation in the 1950s (Boon, 2017). From 1950 onwards, the region experienced rapid population increase because of the post-World War II baby boom and migration from Europe (Simmons & Scott, 2006). During this time the first sewage treatment plants were established at St Marys and Quakers Hill (Simmons & Scott, 2006). During the 1960s South Creek was used as a convenient site for the disposal of agricultural and sewage wastes with algal blooms being recorded regularly (Simmons & Scott, 2006). The catchment receives discharge from Sydney Water's St. Marys, Riverstone, and Quakers Hill sewage treatment plants; council operated plants at McGraths Hill and South Windsor; and from 20 other licenced discharges, including abattoirs, dairies, golf courses, and small farms (Boon, 2017).

Efforts have been made to improve the water quality of the catchment (Vlaming & Maheshwari, 2009; NSW Government, 2006; SWC, 2006). Most notably, the sewage treatment plant at St Marys was upgraded between 2006 and 2009 (NSW Government, 2006). But despite efforts of non-government organisations, communities, and individuals, the creek remains in a depauperate condition, with high concentrations of nutrients and heavy metals (Boon, 2017). Concerns remain about the effects of sewage treatment plants on the water quality, particularly the effects of detergents and pharmaceuticals on aquatic ecosystem, which are not removed by the current sewage treatment system (Needham, 2006).

2.1.8 Endangered ecological communities

River-flat Eucalypt Forest, including Alluvial Woodland, is listed by an endangered ecological community by the NSW Scientific Committee (2005). It is estimated that less than one fifth of its original extent remains (Tindall et al., 2004). Large areas that formerly supported this community have been cleared for agricultural land and remaining stands are severely fragmented and under continuing threat from urban development, pollution from urban and agricultural runoff, weed invasion, and rubbish dumping (Benson and Howell, 1990; Boulton et al., 2014). The NSW Scientific Committee has commented that River-flat Eucalypt Forest on the Coastal Floodplains of the Sydney Basin is likely to become extinct unless circumstances and factors threatening its survival or evolutionary development cease (2005).

2.2 Study sites

Five creek reserve sites were selected for sampling plant species richness and bird diversity. Four sites are within South Creek Catchment, and a fifth is located at Scheyville National Park on Long Neck Creek, north of the catchment (Figure 3). Each site is on public land used for recreation and all include a bushland fragment. Three sites, Whalan Reserve, Shaw Park, and Samuel Marsden Reserve, are managed by local government, in either Blacktown or Penrith LGA. The fourth site in the catchment, Western Sydney Parklands at Richmond Road, is managed by Western Sydney Parklands trust and is in Blacktown LGA. Blacktown and Penrith are two of the largest local government areas in South Creek Catchment. All sites have a history of agricultural use (Boon, 2017; Stubbs & Stubbs, 1983) and are areas where rapid population growth and urbanisation are occurring (GSC, 2017).

A fifth site outside South Creek Catchment in Scheyville National Park was used as a reference site. While is often assumed that reference sites will provide baseline data for historical conditions (Hobbs et al., 2011), it is acknowledged that Scheyville National Park cannot provide these data because it was mostly cleared for agriculture before being coming under the management of National Parks and Wildlife Service who facilitated revegetation and the regrowth of native vegetation at the park (NPWS, 2003; Stubbs & Stubbs, 1983). However, remnant bushland in South Creek Catchment is very degraded and offers an unrealistic benchmark for restoration. So, Scheyville provides the best possible site comparison in the region.

2.3 Ecological surveys

2.3.1 Plant biodiversity

Species richness of the ground cover was measured within 1m x 1m quadrats placed along transects orthogonal to banks at 1-2m, 2-3m, 5-6m, 10-11m, 20-21m, and 30-31m. Sites were divided into quarters and two transects were placed on either side of each creek at each site (4 in total per site) at randomly selected points. All species within each quadrat were identified and recorded. Percentage cover of native and exotic plants within each quadrat was also estimated.

Tree and shrub diversity and vegetation characteristics were recorded along two 1 km transects placed on each side of each creek, except at Samuel Reserve where two 1 km transects were surveyed along the western side of the creek due to accessibility issues. Measurements were taken at eight randomly selected points along each transect (16 total for each trees and shrubs) for tree and shrub species, density, and tree diameter at breast height (DBH) 1.5m from the ground. The point

quarter method was used for surveying such that an ‘x’ shape was placed over each point and the distances from the centre point to the closest trees and shrubs within each quarter were measured. The average distance of trees and shrubs from the centre point was calculated to estimate vegetation density.

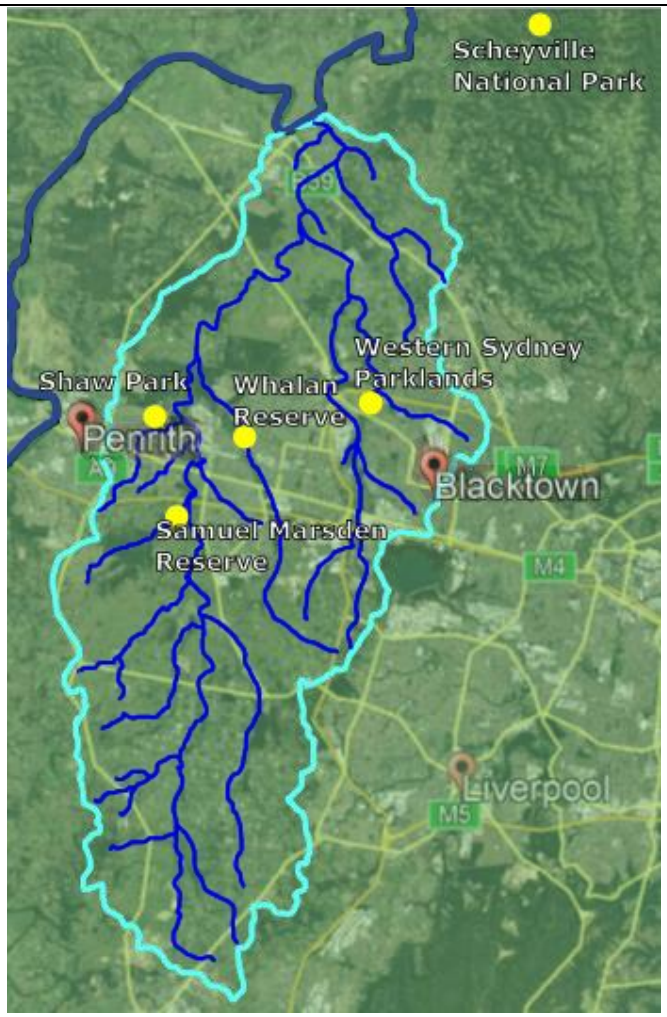


Figure 3: Location of field sites relative to South Creek Catchment. Sites are indicated by yellow circles.

2.3.2 Bird diversity

Bird surveys were conducted over two months in August-September 2018. Observations were made over a 3-4 hour period from first light on fine days that were not windy or rainy. At each site, two transects 1 km in length were surveyed along each side of the creek, except at Samuel Marsden Reserve where two 1 km transects was surveyed along the western side of the creek. Bird species were recorded at 16 randomly selected points along the transects within 30 m of the creek bank, such that 8 points were located on each side of each creek. Each transect was surveyed on foot, with

10 minutes spent at each sampling point. Birds that were observed using a habitat were recorded and those that were flying above the canopy were excluded.

All birds that could be seen or heard were recorded. Identifications and estimates of abundance were made with the assistance of volunteers from the Blue Mountains Bird Observers Club. Each point count was recorded using a RODE SmartLav microphone and Rec Forge Lite Android audio app. Bird calls that could not be identified immediately in the field were identified later using recorded audio. After identification, each bird species was assigned to a foraging guild using published information (Mac Nally, 1994).

2.4 Community perceptions

A questionnaire was created using the online platform SurveyMonkey and distributed to residents over 18 years of the South Creek Catchment area using boosted Facebook posts. The questionnaire included both quantitative and qualitative questions, as well as demographic questions including age, gender, whether they live with children, and the language spoken at home. Responses from the questionnaire were compared to census data for the catchment area to determine the representativeness of the sample. Respondents were asked how frequently they visit parks and how important they believe it is for creek reserves to have native vegetation and provide habitat for native animals. Free format comments about the natural environment in Western Sydney and use of creek reserves were also invited (Appendix).

Participants were also asked to rank the attractiveness of photos representing different vegetation types with two photos used for each type. Preferences for ‘natural’ and novel vegetation-types were compared by including representative photos of each vegetation-type in the questionnaire. Novel vegetation-types are those in which species exist in new combinations and relative abundances that have not previously occurred (Hobbs et al. 2006). Whalan Reserve in Blacktown was selected as a site to represent novel vegetation. The riparian zone of this site is dominated by *Casuarina glauca* with the understory and ground cover dominated by exotic species. Long Neck Creek in Scheyville National Park was used to represent the ‘natural’ vegetation-type, and had a eucalyptus canopy and a ground layer and mid-story comprised of native species. To quantify the influence of landscape complexity on responses, ten by ten grids were placed over each photo and the number of grid cells containing trees, shrubs, and ground cover was counted (Tveit, 2009).

2.5 Statistical analyses

All analyses were carried out using R version 3.5.1. Non-metric multidimensional scale modelling (nMDS) was used to visualise the differences in plant and bird communities between sites and permutational analyses of variance (PERMANOVA) were carried out using the adonis function in the vegan package to test significance of differences (Oksanen et al., 2018). Similarity of percentage (SIMPER) analysis was used to determine which species contributed most to dissimilarities between sites. Native and exotic ground cover was transformed by adding 0.1 to each percentage and creating a ratio of native to exotic ground cover, which was then log10 transformed. Log10 ratios of percentage ground cover were used to compare sites using two-way ANOVAs with site and distance from creek bank as factors.

Regression analysis was used to investigate the relationship between overall bird diversity and the plant characteristics tree and shrub density, ratio of native to exotic ground cover species, and DBH using average data for each 1km transect at each site. Bird diversity within each feeding guild was also compared with the same vegetation characteristics by regression analyses.

The differences between habitat preference scores in the community questionnaire were compared using t-tests. T-tests were also used to determine differences in vegetation complexity between photos, and to compare differences between ‘yes’ and ‘no’ responses to questions about the importance of biodiversity and habitat in the catchment area. Regression analysis was used to investigate the relationship between vegetation complexity and image preference.

3. Results

3.1 Community perceptions

3.1.1 Demographics

The local government areas in South Creek Catchment have a total combined population of 1,235,987 (ABS, 2016). Women make up 50.57 % of the catchment population and men 49.43% (Table 4). Blacktown is the most populous LGA in South Creek Catchment with 336, 962 residents (Table 1). The next most populous LGAs, Liverpool and Fairfield, have populations of 204, 326 and 198, 817 residents, respectively. The least populated local government area is Hawkesbury, which has 64, 592 residents (Table 1).

English is the predominant language spoken in the catchment (75%). The most commonly spoken languages other than English are Arabic (6%), Vietnamese (6%), and Hindi (3%) (Table 2). Languages other than English are more commonly spoken in some LGA's than others. In Hawkesbury 3% of the residents spoke a language other than English, and in Fairfield 63% of the residents spoke a language other than English (Table 2).

Table 1: Population of each catchment LGA compared to survey respondents (ABS, 2016)**.**

	Blacktown	**Liverpool**	**Fairfield**	**Penrith**	**Campbelltown**	**Camden**	**Hawkesbury**
Total population	336,962	204,326	198,817	196,066	157,006	78,218	64,592
Percentage catchment population	27%	17%	16%	16%	13%	6%	5%
Percentage survey respondents	16%	24%	1%	22%	14%	6%	23%

Table 2: Percentage of speakers of different languages in the local government areas of South Creek Catchment. The bottom two rows show the percentages for top non-English languages spoken in the catchment overall (ABS, 2016**)**.

	Blacktown	**Liverpool**	**Fairfield**	**Penrith**	**Campbelltown**	**Camden**	**Hawkesbury**
% only English	76%	62%	37%	94%	84%	94%	97%
% other than English	24%	38%	63%	6%	16%	6%	3%
Top languages	**Arabic**	**Vietnamese**	**Hindi**	**Tagalog**	**Punjabi**	**Assyrian Neo-Aramaic**	**Spanish**
Catchment %	6%	6%	3%	2%	1%	1%	1%

The median age bracket in South Creek Catchment is 30-34 years old. Residents of these ages make up 11% of the population. This is slightly younger than the median age of the Greater Sydney region, which is 36. The next largest age brackets are 25-29 years old (10%) and 35-39 years old (10%) (Table 3).

Table 3: Proportion of different age groups in South Creek Catchment (ABS, 2016).							
Age bracket	**20-24 years**	**25-29 years**	**30-34 years**	**35-39 years**	**40-44 years**	**45-49 years**	**50-54 years**
Percentage	10%	10%	11%	10%	10%	9%	9%
Age bracket	**55-59 years**	**60-64 years**	**65-69 years**	**70-74 years**	**75-79 years**	**80-84 years**	**85 years and over**
Percentage	8%	7%	6%	4%	3%	2%	2%

Women and English speakers were over represented among survey respondents (Table 4). A total of 102 people responded to the online survey and 95% of respondents spoke only English at home compared to 75% of catchment residents (Table 4). Only four respondents identified that they spoke a language other than English at home. Those languages were Hindi, Tagalog, Mandarin, and French. Women made up 63% of respondents compared to 51% of catchment residents (Table 4).

The local government areas Fairfield and Blacktown were under-represented in the survey (Table 1). Penrith, Liverpool, and Hawkesbury were over-represented. The age group with the most respondents was 35 to 44 years old (25%), followed by 25 to 34 (24%) and 45 to 54 (22%). This corresponds to the ages reported in the census (Table 4). The median age bracket is 30-34 years old followed by 25-29 years old. More people identified that they live with children under the age of 18 (51%) than not (47%).

Most survey respondents were long-term residents of South Creek Catchment who visit creek reserves on a semi-regular basis. The largest group of respondents had lived in the catchment area for more than 20 years (42%), followed by those that had lived in the catchment area for 10 to 20 years (19%). Most respondents visited creek reserves less than once per month (49%), followed by those who never visited creek reserves (21%) and those visited them monthly (21%). Fewer respondents visited on a weekly basis (9%) and only one respondent reported visiting creek reserves daily (1%).

Table 4: Demographic characteristics of survey respondents compared with the population average within the Local Government Areas in South Creek Catchment.		
Demographic characteristic	*Survey respondents*	*Average for seven Local Government Areas (ABS, 2016)*
Female	63%	51%
Spoke only English at home	95%	75%
Age bracket (median)	35-44	30-34

3.1.2 Residents' perceptions of local greenspace

Respondents to the online survey thought that having local greenspaces is valuable to their communities.

> "Open space is valuable for our local community and promotes improved mental and physical health. It is also a unique opportunity for residents to engage with the local environment."

> "If protected they are natural remnants and a haven for flora and fauna. Bushland and water are a peaceful combination that resonates with all humans and adds to quality of life."

> "It's an opportunity to be around nature in an otherwise urban area I don't like when creek reserves are only just grass."

> "These environmental assets create an environment for everyone to enjoy. Most people like trees, water and all the natural live life that it creates. (Fauna)"

Walking was by far the most popular activity at creek reserves, with 64 out of 87 responses reporting that they enjoy going for walks. Playgrounds or play equipment was mentioned in 17 out of 87 responses and bike riding 14 out of 87. Some respondents reported activities that relied on the presence of fauna, such as fishing (10 out of 87) and bird watching (6 out of 87).

> "Walking and helping locals engage in voluntary conservation projects. This include weed control, planting, collecting feral animal evidence and recording, bird watching and recording."

> "Werrington lake we visit every week. The kids like the playground and workout equipment and as a family we enjoy walking and riding bikes."

> "I have spent the past 30 years walking, fishing and filming the wildlife on the entire South Creek Catchment."

"When younger, my children enjoyed the sporting and play equipment. I enjoy nature walks with easy access."

"Walking, resting on bench to enjoy view. Would like to have somewhere to ride my horse."

"Walking, bird watching, appreciating nature. observing the changing landscape in all its facets."

"We like playground equipment, especially if adults can use it as well. Areas for walking and riding bikes."

"I like the paths you can walk or ride your bike on although some need to be upgraded and widened. And I like seeing the wildlife and the playground for the kids are great and workout area at Werrington lake is great…"

"I like the shady vegetation, the walking tracks, the bbqs, the small bridges, the ability to explore, the sound of water."

"…I work at the children's centre nearby and we go for walks through the park with the children."

"I like the atmosphere created in a natural environment with water, the kids enjoy watching ducks and eels, fish etc…"

However, respondents were mostly unsure whether they would use an online platform where they could share their experiences of visiting creek reserves (38%), compared to those who said they would (34%) or would not (27%) use the platform.

Residents recognised and appreciated the benefits greenspaces provide. Specific ecosystem services, such as "urban cooling", "improved mental and physical health", and "air filtration" by trees were reported in their responses. Others mentioned they enjoyed observing local flora and fauna during their visits, such as birds, kangaroos, goannas, and eels, and appreciated the habitat creek reserves provide.

"I value the green space, animal habitat, cooling benefits to surrounding areas, and air filtration of tree plantings..."

"Like: The abundance of native wildlife in some of the reserves, e.g. Kangaroos and Emus in Wianamatta Regional Park, and Goannas in Western Sydney Parklands."

"Trees that attract native birds."

"I like that they are habitat for birdlife."

"…they are a good place to find a variety of birds."

"I like the fact that we have lots of bird life at the Werrington Lake area..."

They valued having high quality greenspaces in their areas and reported disliking the small size of creek reserves, weeds, rubbish, pollution, and lack of management by local government.

> "…I don't like that the reserves aren't bigger."
>
> "Creek corridors and the vegetation areas are not managed (except sometimes by some volunteers). These works do not ensure that areas being managed for conservation are protected. Some bush regeneration sites are simply trashed by the government authority with no recourse."
>
> "Sometimes I don't like having to travel the distance to go to a creek reserve."
>
> "I do not like the turbidity and pollution in the water. I like the vegetation but not the weeds."
>
> "I don't like feeling uneasy with young kids at the water's edge and uncertainty about water toxicity."
>
> "…I find that rubbish is a common problem."
>
> "They are often quite polluted from general rubbish."
>
> "Dislikes: The amount of invasive weeds present, and rubbish in some areas."
>
> "I don't like the rubbish. Needs to be more bins. Would like to see a small basketball court, tennis/soccer wall etc (like what's been done at Jamison park)."

Respondents were highly concerned about the extent and rate of environmental degradation and land clearing in the catchment area because of urban development.

> "I have personally witnessed the destruction of the South Creek environment over decades due to Western Sydney councils ignoring their duty of care to the land in an absolute criminal way. The last 5 years have been the worst with irreversible damage done to this floodplain by poor development practices and landfill."
>
> "This catchment must be protected from the ongoing overdevelopments generated by the government's Greater Sydney Commission plan. The catchment needs greater connectivity enforced protections otherwise it too will die a death by a 1000 cuts."
>
> "Our natural environment is being systematically destroyed by over development especially the Cumberland Plain Woodland which has been classified as an endangered ecological community and yet development is able to rip it to pieces."
>
> "It's simply not good enough. Degraded, ill-kept, there's a lot we know now and seem to completely disregard in terms of rehabilitation of natural spaces. And we know that natural spaces improve the

health and lives of those who engage with them. Failure on the scale we see in SW Sydney could almost be described as environmental classism/racism. And also, once our natives of gone, there's no shopping centre where we can just pick up refills."

"Cumberland Plains Woodland and Shale Sandstone Transition Forest are rapidly diminishing and little is held in public ownership. Accelerated development currently underway will be its death knell. Bio-banking is a rort under the guise of preservation."

"It is not long ago that South Creek was generally pristine and platypus were inhabitants. Pollution due to development, poor management practices, erosion, deforestation and agricultural run-off all have contributed to its demise."

Respondents recognised the pressure on the local ecosystems caused by population increase and its effects on the catchment.

"It's undervalued and needs a significant amount of money invested to protect what is left into the future. The new residents and the growing population are not sufficiently informed or connected to nature and as a result we're at risk of having a hugely apathetic population and poorly maintained natural environments."

"It is vitally important that creek reserves include as much native Cumberland Plain bush-land as possible, as this community is being absolutely decimated. This decimation of native woodland is wreaking havoc for local ecosystems, but perhaps even worse for local communities. People wonder why the temperature in far western Sydney was reaching close to 50 degrees last summer. The answer (apart from climate change) is the vast amount of tree clearing which turns this area into a concrete jungle which succumbs to the urban heat effect."

Concern was expressed about lax legislation and lack of enforcement, and the impact on the natural environment.

"Water pollution from residential construction is unmanaged. Construction such as road works are managed under an EPA license. Residential construction is not managed by the EPA or with a license. I don't feel council do enough inspections and enforce penalties on residential works. They can have very limited erosion and sediment measures and cause pollution in our catchments in Western Sydney."

"More needs to be done to ensure connectivity between reserves. More care needs to be taken in restoring and maintaining the bushland. The natural environment is under immense pressure.

Critically endangered communities are still being destroyed. We are losing our biodiversity. The laws are an absolute joke."

"Recently I went for a walk through Nurragingy Reserve. Illegal works had been carried out. I believe it's the Western Sydney Parklands Trust. They have cleared vegetation all the way up to the creek. The trust never put the bushland as their top priority. Wianamatta Regional Park should have been a nature reserve. It's destroyed by roads. Feral animal control also needs to be carried out. The deer, rabbits, foxes are in big numbers. More funding is needed."

"They need funding, upgrading and maintenance. Also, there is ownership issues. I've heard half of the creeks will not be managed by local council but will stay in private ownership which is crazy! We need leadership from state or federal government!"

The extent of environmental degradation discouraged some respondents from wanting to stay in Sydney.

"As Western Sydney undergoes the remarkable and painful transformation from rural to city there are increasingly few places to escape and enjoy nature in quiet."

"As residential lots get smaller it is invaluable for reserves to be committed to large-scale native trees. I am concerned about urban heat sinks and believe a multi-faceted approach to cooling is needed but reserves that protect our rivers and provide woodland buffer need to be a component. I value my local reserves and losing them would diminish quality of life for my young family and discourage us from remaining in Sydney, especially taking into account the documented impacts of air pollution and the asthma rates of SW Sydney."

"There's a lot of potential and I love the focus on native flora and fauna. The rivers aren't very clean, however. There has been too much loss of natural environment in favour of property development and this saddens me and causes the city to lose appeal. (In my area of Liverpool)."

Some respondents suggested ways they thought the catchment could be better managed.

"The natural environment is being destroyed almost everywhere I look, especially around where I live in SW Sydney. The birds and animals are being displaced at alarming rates and we are seeing more and more roadkill. Please do whatever you can to reverse this destruction. We need wide corridors all the way through this creek area! I would wish for it to continue on through a little further to the Botanic Gardens just for the sake of creating a proper wildlife corridor, as the birds and animals need it."

"Needs a big, big push to keep the developers away from it. Also - about 200m out from every waterway around towns and beaches should be public property with road or track access. That means no private ownership of the last 200m from any waterway."

3.1.3 Residents' preferences for vegetation-type and management

Survey respondents thought that creek reserves should be vegetated with Australian native plants and provide habitat for native animals (Figures 4, 5, & 6). Eighty eight percent thought that creeks should be vegetated with trees and bushes (Figure 4), and 86% thought that reserves should be vegetated with Australian native plants (Figure 5). Ninety seven percent thought that creek reserves should provide habitat for native animals (Figure 6). Photos of the 'native' vegetation-type with a eucalyptus canopy and native ground cover and understory were preferred to the novel community with a casuarina canopy and exotic shrub layer and ground cover ($t= -5.73$, $p << 0.01$) (Table 5). Photos of the native vegetation type were significantly more complex than the novel type ($t= 2.30$, $p=0.02$). However, there was no significant correlation between image preference and vegetation complexity ($F= 8.0$, $p=0.11$).

Table 5: Survey photos and percentage respondents who preferred each photo.

	
Photo 1. 30%	Photo 2. 70%
	
Photo 1. 58%	Photo 2: 42%

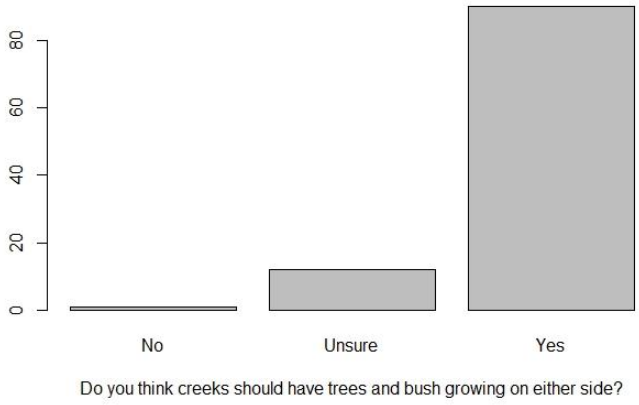


Figure 4: Percentage of respondents who thought that creek reserves should have riparian vegetation.

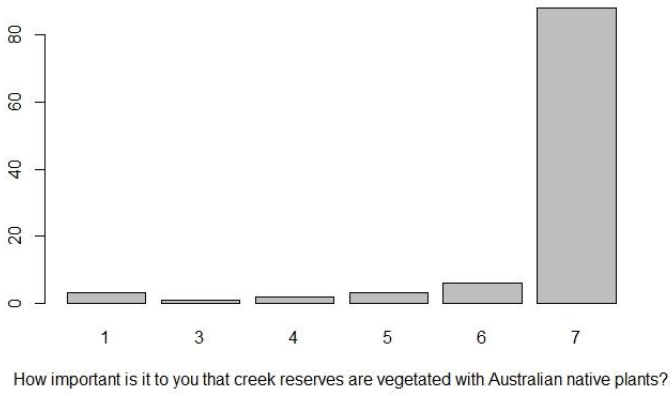


Figure 5: Percentage of respondents who thought that riparian areas should be vegetated with native species.

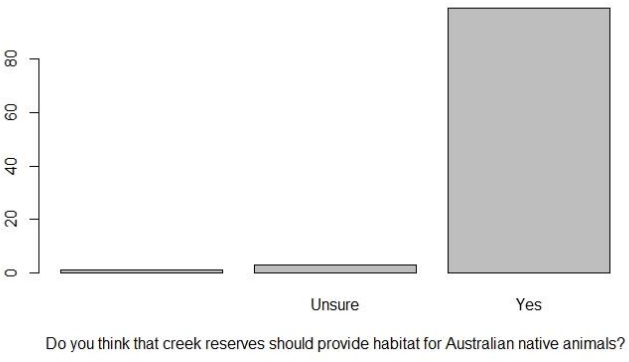


Figure 6: Percentage of respondents who thought that creek reserves should provide habitat for native fauna.

3.2 Plant diversity

Ground cover communities did not differ between sites, however there were differences for the extent of native and exotic ground cover (Figures 7 & 8; Table 6). There were weak relationships between ground cover species richness (p=0.001, R^2 = 0.081) (Figure 7), species richness of exotic species (p=0.001, R^2=0.13), and richness of native species (p=002, R^2 = 0.12) and site. The ratio of percentage cover of natives to exotic species was significantly different between sites (F=18.5, p<<0.01). The ratio of the percentage of native to exotic ground cover at Scheyville National Park was significantly higher than all other sites, where the percentage cover of native species was 65.9% (Figure 8; Table 6). Shaw park had the next highest percentage cover of native species (43.5%) and had a ratio of percentage cover significantly higher than all sites other than Scheyville National Park and Samuel Marsden Reserve (Figure 8; Table 6).

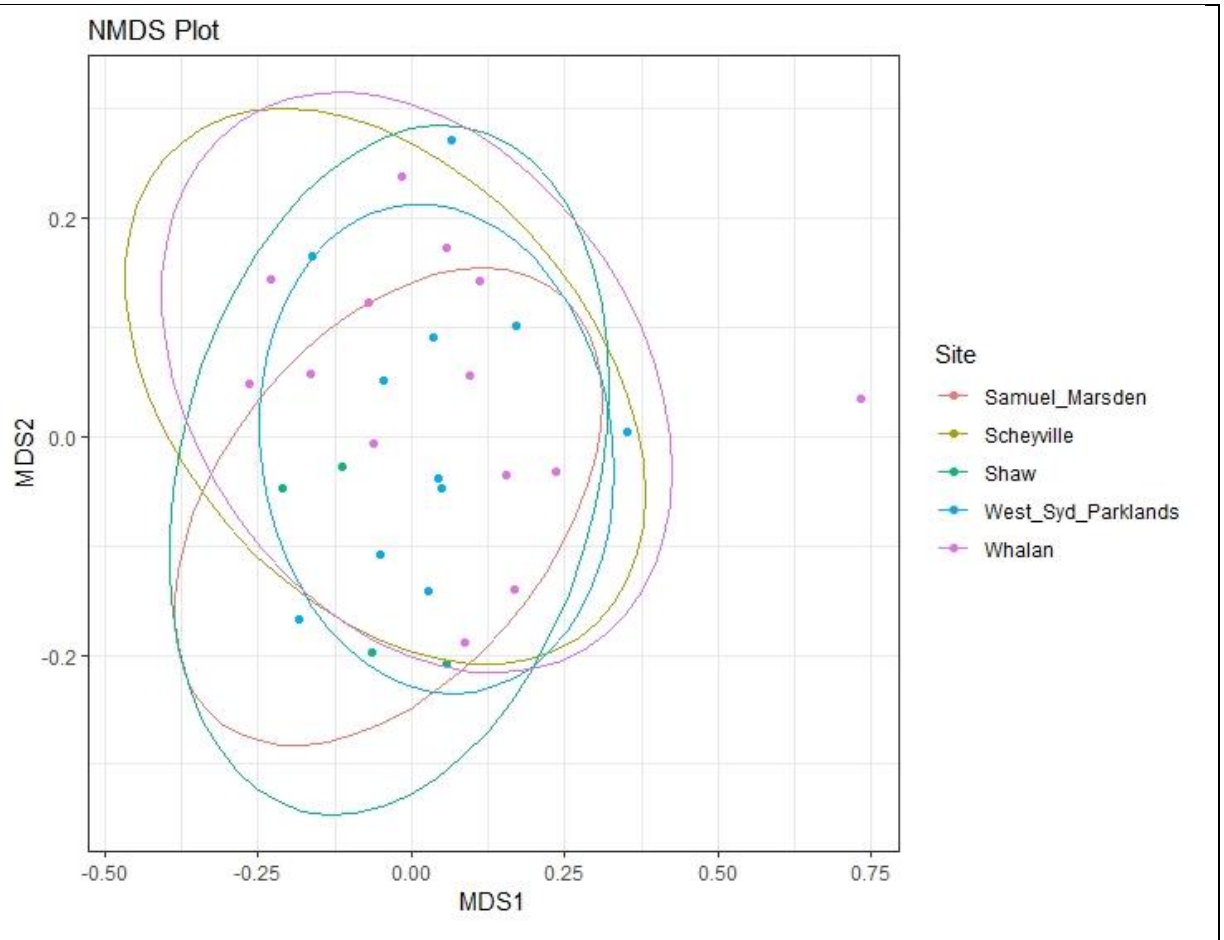


Figure 7: NMDS plot of ground cover species richness for field sites.

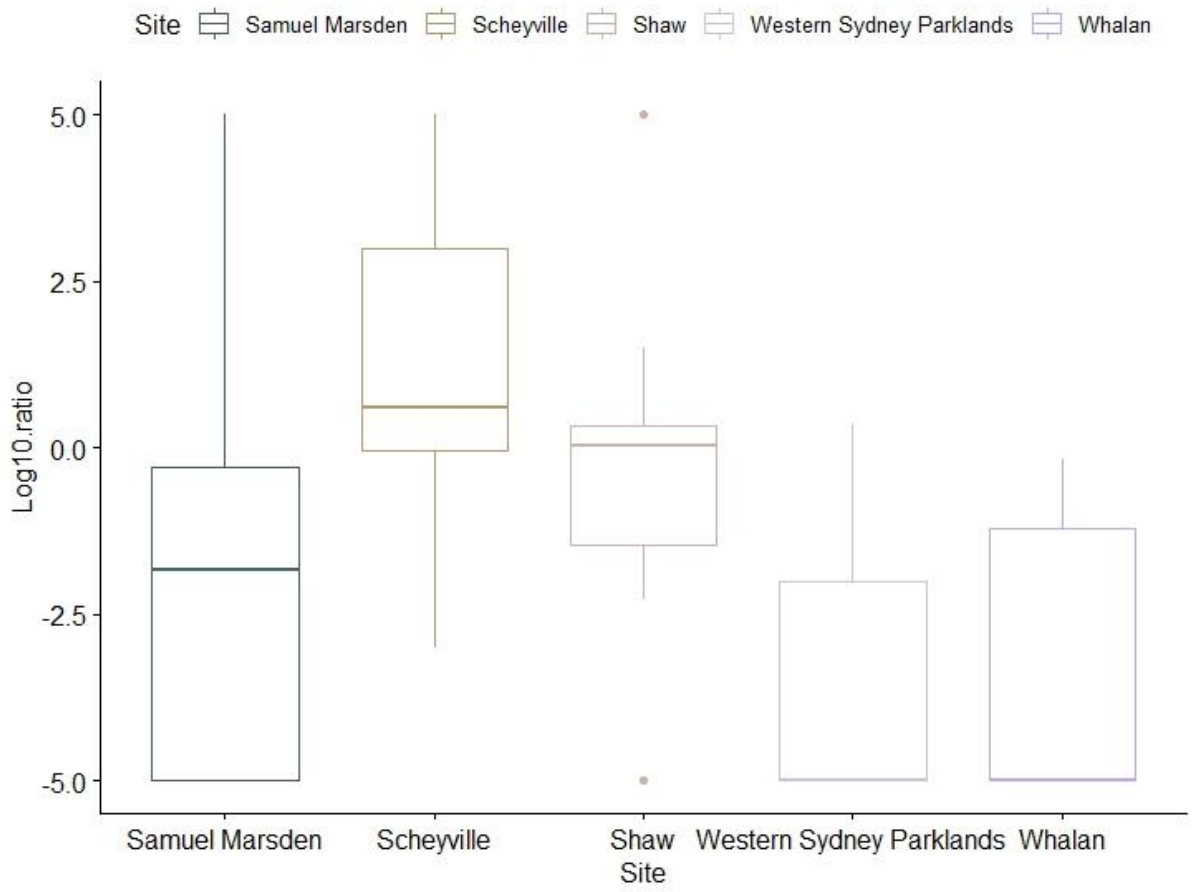


Figure 8: Differences in log10 transformed ratio percentage native to exotic ground cover between sites.

Table 6: Tukey HSD results for site differences between ratio of native to exotic ground cover.

Sites	*p values*
Scheyville-Samuel Marsden	>> 0.01
Shaw-Samuel Marsden	0.17
Western Sydney Parklands-Samuel Marsden	0.15
Whalan-Samuel Marsden	0.30
Shaw-Scheyville	0.06
Western Sydney Parklands-Scheyville	>> 0.01
Whalan-Scheyville	>> 0.01
Western Sydney Parklands-Shaw	0.0001
Whalan-Shaw	0.0005
Whalan-Western Sydney Parklands	0.99

One native shrub species influenced the most dissimilarity between sites (Table 8). *Bursaria spinosa* accounted for the most dissimilarity between Scheyville National Park and other sites. Shrub assemblages at Scheyville National Park differed from Samuel Marsden Reserve and Western Sydney Parklands (R^2=0.42, p=0.001) (Figure 9), and had the lowest diversity and species richness (Table 7). Whalan Reserve and Samuel Marsden Reserve supported different assemblages (Figure 9). Samuel Marsden Reserve and Shaw Park had the highest shrub diversity (Table 8).

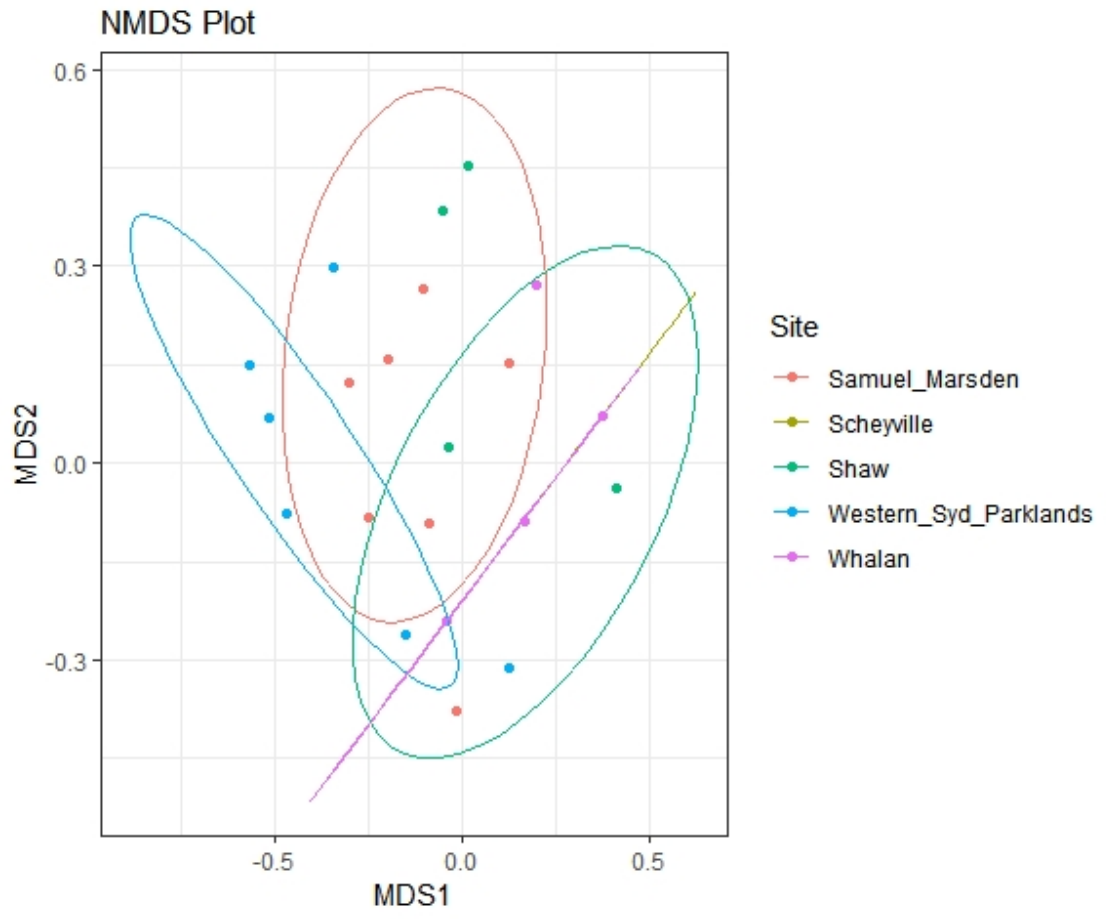


Figure 9: NMDS plot showing differences in shrub assemblages between sites.

Table 7: Simpson diversity and species richness of shrub assemblages at field sites.

	Samuel Marsden	**Scheyville NP**	**Shaw Park**	**Western Sydney Parklands**	**Whalan Reserve**
Simpson diversity	0.77	0.25	0.69	0.57	0.50
Number of species	7	2	9	7	4

Table 8: SIMPER results showing percentage contribution to dissimilarity between sites of different shrub species, with top contributors indicated in blue and exotic species indicated with an *.			
	Samuel Marsden Reserve – Whalan Reserve	**Scheyville NP – Western Sydney Parklands**	**Scheyville NP – Samuel Marsden Reserve**
Bursaria spinosa	**20.2**	**44.9**	**42.6**
Olea europaea*	**19.1**	0	**18.6**
Ligustrum lucidum*	17.1	1.7	**16.9**
Ligustrum sinense*	**31.9**	**9.4**	10.9
Cestrum parqui*	8.2	**31.7**	7.6
Solanum pseudocapsicum*	2.6	5.3	2.5
Indigofera australis	0.87	0	0.85
Rubus fruticosus*		2.5	
Dodonaea viscosa	0	0.83	0
Solanum linnaeanum*	0	0.83	0

Two eucalypts were main canopy species at dissimilar field sites (Table 10). Scheyville National Park and Samuel Marsden Reserve supported different assemblages (R^2 = 0.27, p=0.001) (Figure10). Each supported different dominant tree species, *Eucalyptus moluccana* and *Eucalyptus amplifolia* (Table 10). Tree species diversity was highest at Shaw Park and Whalan Reserve (Table 9). Other influential tree species were *Angophora floribunda*, *Acacia parramattensis*, and *Casuarina glauc*a (Table 10).

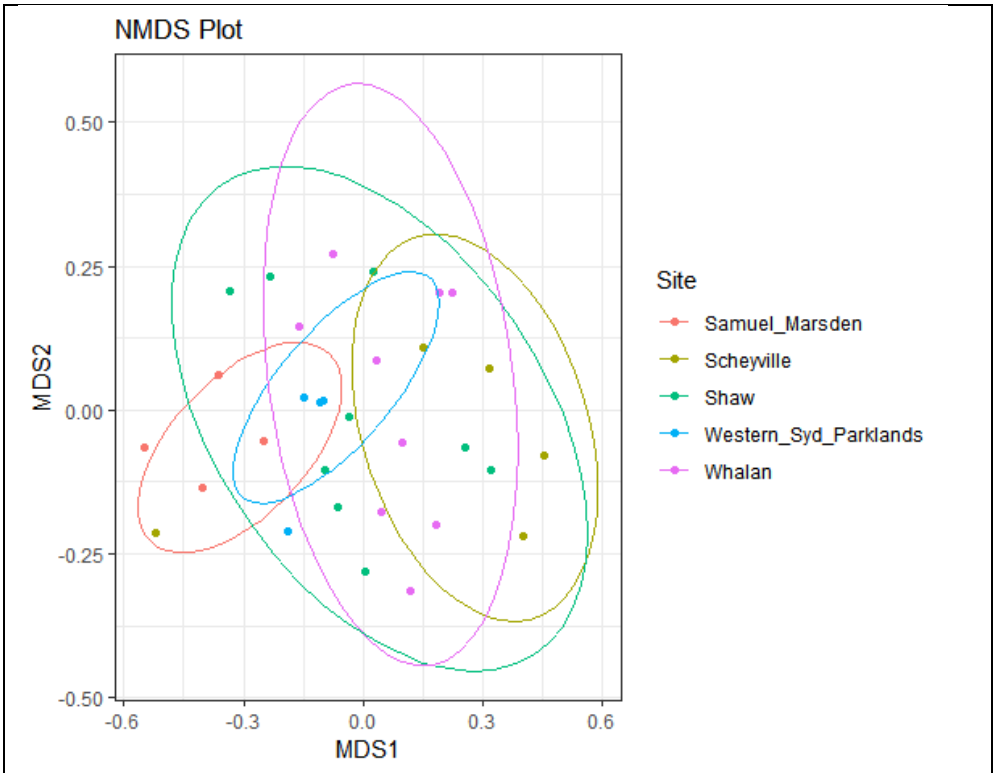


Figure 10: Differences between tree assemblages at field sites displayed in an nMDS plot.

Table 9: Tree species richness and Simpson diversity at field sites.

	Samuel Marsden Reserve	**Scheyville NP**	**Shaw Park**	**Western Sydney Parklands**	**Whalan Reserve**
Simpson diversity	0.61	0.74	0.80	0.67	0.77
Number of species	5	9	10	9	7

Table 10: SIMPER results for tree assemblages showing top contributors to dissimilarity in blue. Both native and exotic trees were included in the analysis, but all contributors to dissimilarity were native species.

	Eucalyptus amplifolia	*Eucalyptus moluccana*	*Casuarina glauca*	*Acacia parramattensis*	*Angophora floribunda*
Scheyville NP – Samuel Marsden Reserve	**23.1**	**18.0**	13.9	12.7	9.9

3.3. Bird diversity

Two bird species, bell miners and noisy miners, drove the most dissimilarity between sites (Table 12). Three out of five sites supported distinct bird assemblages ($R^2 = 0.44$, p=0.001) (Figure 11). Shaw Park, a small, highly modified site, supported assemblages different to all others (Figure 11). Whalan Reserve and Scheyville National Park supported different assemblages than each other. Bell miners contributed to the most dissimilarity between Scheyville National Park and Whalan Reserve (Figure 11; Table 12). Dissimilarity between Shaw Park and other sites was driven by noisy miners (Table 12). These birds are notoriously aggressive and exclude other birds from their territory (Dow, 1977).

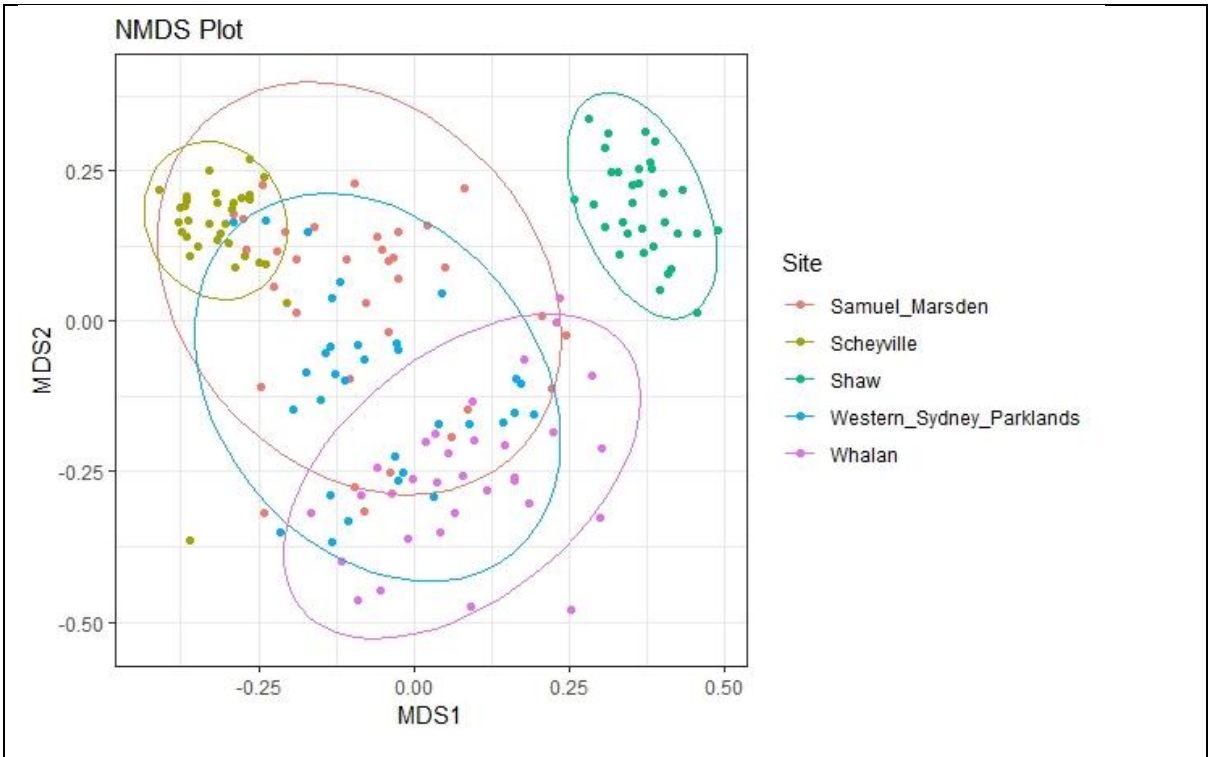


Figure 11: NDMS plot displaying differences in bird assemblages between field sites.

Table 11: Simpson diversity and species richness for bird assemblages at field sites.					
	Samuel Marsden	**Scheyville NP**	**Shaw Park**	**Western Sydney Parklands**	**Whalan Reserved**
Diversity	0.68	0.23	0.82	0.86	0.92
Number of species	45	58	28	43	42

Table 12: Contribution to dissimilarity between sites of different bird species from SIMPER analysis. Percentages coloured blue indicate top contributors.					
	Shaw Park-Whalan Reserve	**Shaw Park – Western Sydney Parklands**	**Shaw Park – Samuel Marsden Reserve**	**Scheyville NP-Shaw Park**	**Scheyville NP-Whalan Reserve**
Noisy miner	**17.6**	**11.0**	**10.1**	**4.88**	0.83
Bell miner	0.28	**17.9**	**35.0**	**71.6**	**73.5**
Yellow thornbill	**10.2**	5.95	0.45	0.32	**2.78**
Superb fairy-wren	**6.58**	**9.17**	**5.52**	**2.36**	**2.55**
Yellow faced honeyeater	6.48	6.76	5.31	0.59	1.59
Rainbow lorikeet	5.91	3.98	3.70	1.24	1.01

Grey butcher bird	5.27	3.39	3.45	1.47	0.31
Spotted pardalote	4.14	2.67	4.51	1.82	1.52
Silvereye	4.08	6.73	2.64	1.07	1.80
King parrot	3.96	2.58	3.05	1.01	0.01
Magpie	3.70	2.49	2.30	0.91	0.48
Red browed finch	2.73	2.45	0	0.10	0.80
Grey fantail	1.82	3.47	1.69	0.20	0.63
Eastern whip bird	0	0.33	0.45	2.23	2.28
Variegated fairy-wren	0.36	2.73	0	0.35	0.44

Bird diversity was lowest at Scheyville National Park (Table 11 & 13). Scheyville had the highest number of species, so its low diversity was due to the extremely high abundance of bell miners present at that site because Simpson diversity considers both species diversity and relative abundance of individuals (Table 11).

Habitat characteristics had only minor influences on bird diversity or feeding guilds. No significant correlation was found between overall bird diversity and habitat characteristics. Aquatic bird diversity was negatively correlated with tree density (R^2= 0.50, F=9.9, p=0.01). Canopy insectivore diversity was negatively correlated with the ratio of native to exotic ground cover (R^2= 0.42, F=7.5, p=0.03). Nectarivore diversity was negatively correlated with DBH (R^2=0.38, F=6.5, p=0.03). Nectarivore/ insectivore diversity was negatively correlated with the ratio of native to exotic ground cover (R^2=0.39, F=6.8, p=0.03).

Table 13: Simpson diversity of each feeding guild at different field sites.

	Samuel Marsden	**Scheyville NP**	**Shaw Park**	**Western Sydney Parklands**	**Whalan Reserve**
Shrub insectivore	0	0.32	1	0	0

Nectarivore/ insectivore	0.40	0.20	0.03	0.59	0.46
Omnivore	0.64	0.61	0.66	0.38	0.71
Insectivore	0	0.35	1	0	0
Ground insectivore	0.63	0.62	0.47	0.54	0.72
Ground granivore	0.82	0.73	0.73	0.47	0.66
Frugivore	1	0	0	1	1
Carnivore	0	0.44	0	0	0
Nectarivore	0.29	0.39	0.36	0.35	0.42
Canopy insectivore	0.28	0.10	0.61	0.57	0.62
Canopy granivore	0.35	0.38	0	0.50	0
Aerial insectivore	0	0	1	0.24	0
Aquatic	0.62	1	0.48	0.22	0

4. Discussion

This study has combined benchmark data from ecological and community surveys to inform restoration targets for a degraded riparian ecosystem. South Creek Catchment in Western Sydney has undergone extensive modification leading to the disturbance and fragmentation of habitats (Boon, 2017). Current and future urban growth in the region will continue to place pressure on this natural environment, making appropriate planning necessary for population changes that provide both human amenity and limits further environmental deterioration (Tozer et al., 2015). Here, the renewal ecology framework was used to integrate the preferences of the local community for greenspace features and ecological data to inform the design of riparian ecosystems that could provide recreational infrastructure for residents, support biodiversity, and provide valuable habitat.

Overall, the ecological surveys indicated that riparian ecosystems had both habitat value and were appreciated by the local community, despite their present state of degradation. South Creek Catchment residents who responded to the survey indicated a strong preference for vegetation with a eucalyptus canopy with native vegetation in the shrub layer and ground cover over a novel

ecosystem with a casuarina canopy and exotic shrub layer and ground cover. Respondents also indicated a desire for the provision of healthy riparian vegetation to provide habitat for Australian native flora and fauna. The five surveyed sites in South Creek Catchment and at Scheyville National Park were found to have relatively few differences in terms of their shrub and tree communities, though some sites had a higher proportion of native groundcover species. While few differences were found to suggest that bird communities were strongly associated with vegetation structure, two aggressive bird species were found to dominate certain sites and their presence was associated with reduced community diversity.

4.1 Attitudes of local residents to the environment of South Creek

Having high quality local green spaces was important to survey respondents who recognised that these spaces provide a variety of ecosystem services, including "urban cooling", "improved mental and physical health", and "air filtration" by trees. Threats to the environmental condition of creek reserves were also identified, including water pollution and turbidity, weed invasion, and rubbish. Land clearing for urban development and inadequate management of bushland reserves were identified as the main culprits leading to environmental degradation in Western Sydney. There was general discontent among respondents about diminishing environmental conditions, and concern about what Western Sydney will look like in the future. Most notably, two respondents indicated that they would consider moving away from their local area if the conditions of the natural environment continue to deteriorate.

Survey respondents valued the remaining creek reserves in South Creek Catchment and used them for a variety of recreational purposes. Walking was the most frequently mentioned activity undertaken in creek reserves (64 out of 87 responses), with bicycling and use of playground equipment also common. Paths for walking and cycling are already features of the Draft Western City District Plan and are expected to be integrated into green space design (GSC, 2017). However, while provision of amenities for young people is recognised as a priority in the District Plans, inclusion of play equipment is not specified in their greenspace designs (GSC, 2017). Residents in Western Sydney are younger on average than the rest of the Greater Sydney region (ABS, 2016), and young people are projected to make up a substantial proportion of the new residents (GSC, 2017). Children are a key driver of preferences for urban public landscapes (Burgess et al., 1988), and these responses indicate that residents value amenities specific to that age group.

In addition to using built features, some respondents undertook activities that directly involved flora and fauna such as bird watching, photography, and fishing. Certain respondents mentioned iconic

species such as goannas, kangaroos, or emus, that they associated with the character of their local landscapes. The ability to undertake these activities relies on the particular features of ecosystems, such as habitat for species of interest.

The local community in the South Creek Catchment area indicated strong preferences for riparian vegetation and thought that creek lines should be vegetated with Australian native plants, providing habitat for native animals. These priorities were also reflected in their responses to the image preference questions. Vegetation with a eucalyptus canopy and higher proportion of native plants, were more frequently selected than images of vegetation with a casuarina or exotic canopy and understory. While vegetation complexity often influences preferences for certain landscapes (Harris et al., 2018; Ode et al., 2009), respondents in the present study did not indicate a preference for more complex vegetation.

There are a number of caveats that may affect the interpretation of the survey results. Firstly, people who choose to do online surveys may have a pre-existing interest in the topic, such as an affinity for their locality (Marcus et al., 2007). The largest proportion of respondents had lived in South Creek Catchment for over 10 years. Attachment to their local area and observing drastic changes in Western Sydney could have driven them to respond and report discontent about degradation of the natural environment in the survey (Hidalgo & Hernandez, 2001; Lewicka, 2011). This is significant because many of the future residents who are predicted to move to Western Sydney will be new to the region. Secondly, the researcher's public Facebook page and professional networks were used to advertise the survey, so it was likely exposed to a higher proportion of people who are interested in the environment and who would have flora and fauna identification skills. Lastly, certain areas of the catchment were either over or underrepresented in the responses, which was probably partly due to their representation in the researcher's social and professional networks. Demographics vary between local government areas, particularly for language spoken at home and ancestry (ABS, 2016). This could have skewed responses because there is evidence that different cultures perceive and use green spaces differently (Buijs et al., 2009; Kaplan & Talbot, 1988; Ordóñez-Barona, 2017).

Cultural backgrounds in Western Sydney are also likely to be more diverse than those captured in this survey. Over one third of Western Sydney's population speaks a language other than English (ABS, 2016). The survey was only distributed in English, thus potentially excluded or under-represented non-English speakers.

4.2 Environment

4.2.1 Vegetation

Only minor differences were found for both tree and shrub assemblages between sites, with a few native species driving dissimilarities. Two endemic eucalyptus species were dominant canopy species at sites that were distinct. Cabbage gum (*Eucalyptus amplifolia*) was the main species at Samuel Marsden Reserve, and grey box (*Eucalyptus moluccana*) was the primary species at Scheyville National Park. The native shrub *Bursaria spinosa* was in high abundance at Scheyville National Park. This species is known to outcompete other shrubs, creating dense thickets in landscapes with low-frequency fire regimes (Watson & Morris, 2006). While fire management is undertaken in the park, the area of Scheyville where the surveys were undertaken is burned less frequently than recommended (NPWS, 2016).

Ground cover species richness was not significantly different between sites, although Scheyville National Park and Shaw Park had higher percentage cover of native species than the other sites. As the largest fragment of Cumberland Plain vegetation in Western Sydney, the interior of Scheyville is further from edges and less susceptible to disturbance and the edge effect than other sites (DECCW, 2011). All sites other than Scheyville are managed by local government, so the greater proportion of ground cover at that site could also be due to differences in fire management practices. Scheyville has a management policy that schedules ecological and hazard reduction burns for the National Park (NPWS, 2016), whereas regular burning is not undertaken in smaller urban fragments because of concerns about their proximity to residential areas and infrastructure (pers obvs.).

Shaw Park is located across the road from a high school and is subject to frequent arson attempts (pers obvs.). It is possible that these acts of arson have reduced the cover of exotic species and contributed to regrowth of native ground cover, leading to the higher species richness at this site. However, the effects of arson should not be interpreted as wholly beneficial as they are essentially unregulated, and if occurring too frequently, could lead to a decrease in diversity in the long-term (Watson & Morris, 2006).

4.2.2 Bird diversity

Birds were surveyed to indicate habitat quality of riparian ecosystems in South Creek Catchment. Although most of the sites were fairly degraded, they nonetheless supported bird species richness and a diversity of guilds. Overall, few weak correlations were found between bird diversity and habitat characteristics. This is contrary to past studies that found vegetation structure is more

strongly correlated with composition of bird communities (Chase & Walsh, 2006; Stagoll et al., 2012; Threlfall et al., 2016). This could be for two reasons. Firstly, the statistical power of the linear regression analysis in this study was low because data were analysed at the site level. Secondly, there were few differences in the vegetation characteristics, such as shrub and tree density and DBH, between sites. It is likely that interactions between bird species, and to a lesser extent other features such as fragment size and connectivity, had a larger effect on bird community composition in this study.

Two bird species, bell miners (*Manorina melanophrys*) and noisy miners (*Manorina melanocephala*), drove dissimilarity in the composition of bird communities between the five sites. Both species are aggressive native honeyeaters and are linked to key threatening processes recognised by the NSW Scientific Committee (2008, 2013). Noisy miners are very common in both fragmented urban landscapes and uncleared woodland (Dow, 1977). They live in large colonies and cooperate to defend their territory from other species (Dow, 1977). Birds of other species that enter the colony territory are met with aggressive behavior and physical attacks, and through this behavior, the miners are able to exclude almost all passerine birds of similar or smaller size (Dow, 1977). The effect of noisy miner presence on other birds is substantially greater than the effects of other threats such as habitat modification and reduces overall bird species richness and abundance (Maron et al., 2011). In smaller woodland fragments, they are able to completely exclude smaller birds (Dow, 1977; Maron et al., 2011).

Bell miners are also colony forming and territorial. Their presence is linked to the spread of a soil borne disease (*Phytothphora spp.*) which causes eucalypt dieback (Stone, 2005). Dieback is a process in which the trees enter a cycle of defoliation and regrowth, leading to mortality if conditions persist (Bird et al., 1974). Sap sucking psyllids (*Glycaspis spp.*) are over abundant at sites where bell miner-associated dieback is present (Stone, 2005). These insects produce a sugary shield called a lerp that protects them from small predators (Clark, 1964). Psyllids and their lerps are a rich food source for small insectivores and nectarivores and form a substantial portion of their diet (Woinarski et al., 1989). Bell miners feed on psyllids and their lerps, and it is possible that they may also farm them, perhaps by preferentially feeding on the lerps rather than consuming the insect (Haythorpe & Macdonald, 2010). However, evidence for this relationship is inconclusive and bell miners could simply be more abundant at sites with higher psyllid numbers (Silver & Carnegie, 2017). Like noisy miners, bell miners aggressively exclude other species of birds from their territories (Clarke and Schedvin, 1999). Lack of predation allows psyllid populations to increase, putting trees under pressure and causing canopy damage (Stone, 2005).

Both bell miners and noisy miners are associated with particular habitat structures (Maron et al., 2008; Silver & Carnegie, 2017). Grey box was the dominant canopy species at Scheyville National Park and is affected by bell miner associated dieback (NSW Scientific Committee, 2008). Bird diversity was lowest at this site despite it being the 'reference' site and having the highest bird species richness, most likely because of the very high numbers of bell miners present. Dense understory vegetation, such as *B. spinosa* thickets at Scheyville, provides bell miners with superior nesting sites that results in low mortality of bell miner nestlings (Stone et al., 2008; Silver & Carnegie, 2017). Invasion of exotic woody shrubs and disturbance of the canopy have also been implicated as the causes of understory conditions that lead to bell miner over-abundance (Lambert et al., 2016). Noisy miners prefer habitats with sparse understories and scattered trees, and habitat edges (Parsons et al., 2006; Maron et al., 2011). Consequently, they have benefited from landscape clearing and fragmentation, and now dominate many small (<20ha) bushland fragments in eastern Australia (Dow, 1977; Maron, 2008; Maron et al., 2011). Shaw Park was the smallest site in this study, and had a high edge to interior ratio, providing excellent habitat for noisy miners and likely leading to its low species richness.

4.3 Future of Western Sydney

The urban landscape of Western Sydney is undergoing drastic changes (GSC, 2017; Tozer et al., 2015). Population in the region is growing rapidly, leading to a shift from agricultural land-use to medium- and high-density housing (GSC, 2017). In addition, Western Sydney is the hottest and driest region in the Sydney Basin, so will be disproportionally affected by high temperatures under future climate scenarios (Adapt NSW, 2014).

Greenspace is typically solely planned around recreational amenities despite increasing demands for a range of ecosystem functions, services, and benefits (Boulton et al., 2018). Urban green space is not adequately protected under current NSW biodiversity legislation, which protects ecosystems similar to historical conditions, leaving ecosystems considered degraded vulnerable to being cleared for offsetting (EDO, 2014). This raises environmental justice issues regarding peoples' rights to access natural spaces and the benefits they provide, particularly in Western Sydney, which is a low socioeconomic area (Wolch et al., 2014). Concern is growing that people are becoming increasingly disconnected from wild spaces, undergoing an extinction of experience with nature associated with urbanisation and sedentary lifestyles (Pyle, 1978).

This study found that the local community in Western Sydney values their local green space, despite its degraded state, and would like it to provide ecosystem services. The Draft Western City District Plan's design for the Western Sydney green grid and South and Eastern Creeks corridors provide opportunities for the results of this study to be used to design diverse riparian ecosystems that are valued by the local community.

4.4 Recommendations for management

This paper gives the following recommendations for designing, protecting, and managing riparian ecosystems in South Creek Catchment to maximise human amenity while enhancing biodiversity and ecosystem services.

1.) Encourage the growth of native ground cover

2.) Create a structurally complex shrub layer that provides habitat for diverse bird species, and limits bell and noisy miner abundance

3.) Use eucalyptus species to create a canopy

Residents valued Australian native flora so management techniques that encourage native species are suggested to be used in the catchment area, and a eucalyptus-dominated canopy to be planted or maintained in preference to a casuarina-dominated canopy. Understories in creek reserves in the catchment area could be managed to enhance their structural complexity to create habitat that would not be dominated by noisy and bell miners, allowing for a diverse range of bird species and increasing the overall bird diversity at sites.

A variety of management tools could be employed to achieve these ecosystem goals. Fire is an important management tool in Australian landscapes and can affect the generation of Cumberland Plain species from seed banks (Hill and French, 2003) and decrease the number of herbaceous and woody weed species (Watson & Morris, 2006). A moderate regime of burns 1-2 times per decade is suggested for increasing diversity in Cumberland Plain Woodland, with intervals that vary between 4-12 years (Watson & Morris, 2006). However, it should be investigated whether this fire regime can be applied to riparian zones because there has been insufficient investigation into the optimal burning pattern and frequency for alluvial woodland, the community surveyed in this study (Benson & Redpath, 1997). At sites where native flora diversity is very low, ground layer diversity could be increased using reconstruction techniques, such a sowing native seeds, in combination with weed removal and fire (Gibson-Roy et al., 2010).

Additional practices need to be considered for weed control for certain urban and peri-urban sites. Many bushland remnants in Western Sydney are managed by local councils with no-burn policies because of concerns about using fire close to residential areas (City of Blacktown, pers. coms.). In these cases, where the invasion of exotic species is confined to a small area, they can be regulated through manual weeding and the application of herbicides to individual plants after cutting or scraping stems (SERA, 2017). Where invasion of exotic species is extensive or the plants themselves difficult to handle (for example blackberry), brush cutters can be used to clear weeds and they can be suppressed by splatter spraying the cut plants with herbicide (SERA, 2017) Use of these practices could create an ecosystem rich with native species that have aesthetic value for the local community and a structurally complex understory that supports diverse bird communities.

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Appendix

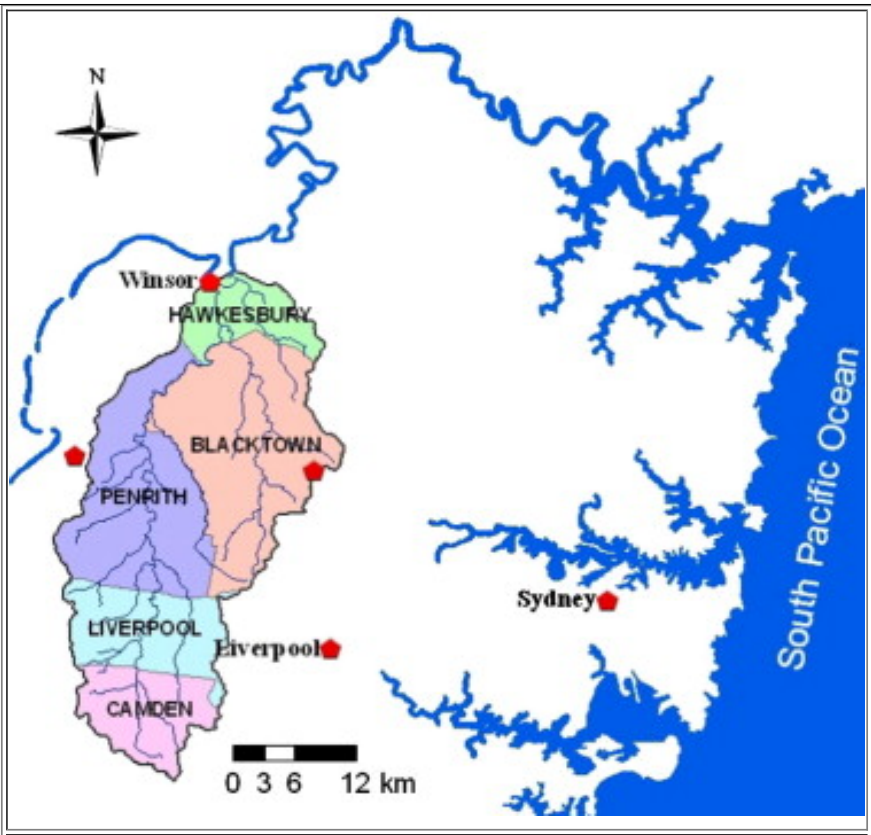
How do you want your local green spaces managed? A path to better parks in South Creek Catchment

Department of Biological Sciences
Faculty of
MACQUARIE UNIVERSITY NSW 2109

Phone: +61 (0)470 742 283
Email: elisha.duxbury@students.mq.edu.au

Participant Information and Consent Form

You are invited to participate in a study on reserves along creeks (creek reserves) in South Creek Catchment in Western Sydney. The population within the catchment area is expected to grow by up to 500,000 people over the next 30 years. New green infrastructure is being planned to accommodate this growth. South Creek is to be revegetated so that it can serve as an important habitat corridor for native animals and provide recreational amenities for the community. We want to hear your say on how you would like to see in these creek reserves managed. This questionnaire will take approximately 10 minutes to complete.



Map of South Creek Catchment and its position in Western Sydney. (Davidson et al. 2013).

Left: Section of South Creek running through Orchard Hills near the M4 motorway. **Top:** Baseball field at Samuel Marsden Reserve near South Creek. Sports fields are an example of recreational amenities found at creek reserves.

The study is being conducted by Elisha Duxbury (Mob: 0470 742 283, Email: elisha.duxbury@students.mq.edu.au) to meet the requirements of a Masters of Research under the supervision of Professor Lesley Hughes (Ph: 9850 8195, Email: lesley.hughes@mq.edu.au) of the Department of Biological Sciences.

If you decide to take part, you will be asked to rank the attractiveness of photographs of vegetation and answer questions your use of creek reserves. The survey also contains questions about your demographics. Answering any these questions is entirely optional. These questions are being asked because previous research suggests that demographic factors correlate with preferences for vegetation types and green space use. You will also be asked for your comments on the natural environment in South Creek Catchment and Western Sydney. If you consent your comments may be used in publications and presentations.

All information or personal details gathered in the course of the study are confidential, except as required by law. No individual will be identified in any publication of the results. All answers will be kept confidential and will only be shared between the lead researcher and co-investigator. All data will be stored for five years. A summary of the results of the data can be made available to you on request by contacting the co-investigator. The results from this study will be used to inform future research on green space in Western Sydney.

Participation in this study is entirely voluntary. If you decide to participate, you are free to withdraw at any time without having to give a reason and without consequence.

The ethical aspects of this study have been approved by the Macquarie University Human Research Ethics Committee. If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Director, Research Ethics & Integrity (telephone (02) 9850 7854; email ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

* 1. You have read and understand the information above, and any questions I have asked have been answered to my satisfaction. I agree to participate in this research, knowing that I can withdraw from further participation in the research at any time without consequence.

ELECTRONIC CONSENT: Please select your choice below.

Clicking on the "agree" button below indicates that:

- you have ready the above information
- you voluntarily agree to participate
- you are at least 18 years of age

If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button.

- ◯ Agree to participate
- ◯ Decline to participate

2. What is your age?

- ◯ Under 18
- ◯ 18 to 24
- ◯ 25 to 34
- ◯ 35 to 44
- ◯ 45 to 54
- ◯ 55 to 64
- ◯ 65 or over

3. What is your gender?

- ◯ Male
- ◯ Female
- ◯ Prefer not to answer

Other (please specify if you would like to)

4. What language do you mainly speak at home?

- ◯ English
- ◯ Arabic
- ◯ Punjabi
- ◯ Hindi
- ◯ Tagalog
- ◯ Serbian
- ◯ Gujarati
- ◯ Spanish
- ◯ Vietnamese
- ◯ Mandarin
- ◯ Prefer not to answer
- ◯ Another language (please specify)

5. Do you live with any children or teenagers under the age of 18?

- ◯ Yes
- ◯ No
- ◯ Prefer not to answer

6. How long have you lived in the South Creek Catchment area?

- ◯ Less than a year.
- ◯ 1 to 5 years
- ◯ 6 to 10 years
- ◯ 10 to 20 years
- ◯ More than 20 years
- ◯ Unsure
- ◯ I do not live in the South Creek Catchment area
- ◯ Prefer not to answer

7. In which local government area do you reside?

Map of the local government areas in South Creek Catchment (Source: Gavin Beveridge, CRC IF 2007).

- ◯ Blacktown
- ◯ Liverpool
- ◯ Penrith
- ◯ Camden
- ◯ Campbelltown
- ◯ Fairfield
- ◯ Hawkesbury
- ◯ I do not live in the South Creek Catchment area
- ◯ Unsure
- ◯ Prefer not to answer

8. How often over the past year have you visited creek reserves in South Creek Cat

	Creek Reserves in South Creek Catchment
1	Wianamatta Regional Park, Ropes Crossing, Blacktown LGA
2	Tregear Reserve, Tregear, Blacktown LGA
3	Whalan Reserve, Whalan, Blacktown LGA
4	Werrington Lakes Reserve, Werrington, Penrith LGA
5	Shaw Park, Cambridge Park, Penrith LGA
6	Western Sydney Parklands, Dean Park, Blacktown LGA
7	Narrangingy Reserve, Doonside, Blacktown LGA
8	Samuel Marsden Reserve, Orchard Hills, Penrith LGA
9	Kemps Creek Nature Reserve, Cecil Park, Liverpool LGA

- ◯ Daily
- ◯ About weekly
- ◯ About monthly
- ◯ Less frequently
- ◯ Never

9. What do you like about creek reserves? What don't you like?

10. Are there particular activities you like to participate in at creek reserve (for example using playground equipment, bike riding, walking, sports, etc.)? Which ones?

11. Would you use an online platform where you could share your experiences of visiting creek reserves?

- ◯ Yes
- ◯ No
- ◯ Unsure

Why?

12. Do you think creeks should have trees and bush growing on either side?

- ◯ Yes
- ◯ No
- ◯ Unsure

Why?

13. How important is it to you that creek reserves are vegetated with Australian native plants?

	1	2	3	4	5	6	7
Please indicate on a scale of 1 to 7, with 1 meaning not important at all and 7 meaning very important.	◯	◯	◯	◯	◯	◯	◯

14. Do you think that creek reserves should provide habitat for Australian native animals?

- ◯ Yes
- ◯ No
- ◯ Unsure

Why?

15. Which vegetation do you prefer? Please select a photo.

16. Which vegetation do you prefer? Please select a photo.

17. Please share with us any comments you may have about the natural environment in Western Sydney.

18. Please share any comments you may have about creek reserves in South Creek Catchment.

19. I consent to quotations from my answers to be used in presentations and publications. Your quotations will be shared anonymously.

- ◯ Yes
- ◯ No

Fw: Ethics Projsect 5201800402 Hughes - Final Approval

Duxbury Elisha (HDR)

Tue 5/03/2019 5:22 PM

To: MRes Examination <exam.mres@mq.edu.au>;

Cc: Lesley Hughes <lesley.hughes@mq.edu.au>;

Hi Helen,

Please see the letter below for my human ethics approval.

Warm regards,
Elisha

From: Faculty of Science Research Office <sci.ethics@mq.edu.au>
Sent: Tuesday, 3 July 2018 11:19 AM
To: Lesley Hughes; Duxbury Elisha (HDR)
Cc: fse.ethics; Katherine Shevelev; Cathi Humphrey-Hood
Subject: Ethics Projsect 5201800402 Hughes - Final Approval

Dear Prof Hughes

RE: Ethics project entitled: "Renewing South Creek Catchment"

Ref number: 5201800402

The Faculty of Science and Engineering Human Research Ethics Sub-Committee has reviewed your application and granted final approval, effective 3/07/2018. You may now commence your research.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:

http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Prof Lesley Hughes
Elisha Duxbury

NB. STUDENTS: IT IS YOUR RESPONSIBILITY TO KEEP A COPY OF THIS APPROVAL EMAIL TO SUBMIT WITH YOUR THESIS.

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research

(2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports.

Progress Report 1 Due: 3/07/2019
Progress Report 2 Due: 3/07/2020
Progress Report 3 Due: 3/07/2021
Progress Report 4 Due: 3/07/2022
Final Report Due: 3/07/2023

NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:
http://www.mq.edu.au/policy/

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have final approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of Final Approval to an external organisation as evidence that you have Final Approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of final ethics approval.

Yours sincerely,
Human Research Ethics Sub-Committee
Faculty of Science and Engineering
Macquarie University
NSW 2109

MACQUARIE University

ANIMAL RESEARCH AUTHORITY (ARA)

AEC Reference No.: 2018/022 **Date of Expiry:** 25 October 2018

Full Approval Duration: *01 August 2018 to 25 October 2018*

This ARA remains in force until the Date of Expiry (unless suspended, cancelled or surrendered) **and will only be renewed upon receipt of a satisfactory Progress Report before expiry (see Approval email for submission details).**

Principal Investigator:
Professor Lesley Hughes
Department of Biological Sciences
Macquarie University NSW 2109
lesley.hughes@mq.edu.au
Mobile: 0415 527 275

Associate Investigator:
Elisha Duxbury 0423 416 028

In case of emergency, please contact:
the Principal Investigator / Associate Investigator named above
or **Animal Welfare Officer** - 9850 7758 / 0439 497 383

The above-named are authorised by MACQUARIE UNIVERSITY ANIMAL ETHICS COMMITTEE to conduct the following research:

Title of the project: **A novel course for South Creek Catchment**

Purpose: **7 - Research: Environmental Study**

Aims: **To investigate the current biodiversity and habitat value of creek reserves in the catchment of South Creek.**

Procedure category: **1 - Observation Involving Minor Interference**

All procedures must be performed as per the AEC-approved protocol, unless stated otherwise by the AEC and/or AWO.

Maximum numbers approved (for the Full Approval Duration):

Species	Strain	Age/Sex/Weight	Total	Supplier/Source
20 - Bird Native Wild 17 - Bird Exotic Wild	Any present at time of Observation	Any	Observation	Wildlife in situ
		TOTAL	Observation	

Location of research:

Location	Address
Schoeville National Park	Schoeville Road, Schoeville NSW
Whalan Reserve	Ellsworth Drive, Whalan NSW
Shaw Park	Herbert Street, Cambridge Park NSW
Samuel Marsden Reserve	Orchard Hills NSW
Western Sydney Parklands	Richmond Road, Dean Park NSW

Amendments approved by the AEC since initial approval: N/A

Conditions of Approval: N/A

Being animal research carried out in accordance with the Code of Practice for a recognised research purpose and in connection with animals (other than exempt animals) that have been obtained from the holder of an animal suppliers license.

Associate Professor Nathan Hart (Chair, Animal Ethics Committee) **Approval Date:** 19 July 2018

Adapted from Form C (issued under part IV of the Animal Research Act, 1985)