Wetland Connectivity in the Urban Environment
The Role of the Residential Garden

Caitlin Jane Bartholomaeus
Bachelor of Science
(Biological Sciences and Environmental Science)

Murdoch University
School of Environmental Science
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Declaration

This thesis is an account of my own research and has not been previously published or submitted at any tertiary institution, except for where acknowledgement has been made in the text.

Caitlin Jane Bartholomaeus

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Abstract

Urbanisation is the result of the increasing density of human population and the movement of populations to urban centres. It isolates populations of wetland species by removing and fragmenting habitat. Isolation can be damaging to wetland species such as frogs and turtles that rely on terrestrial vegetation for habitat and to assist in their movements between wetlands. This fragmentation may also be damaging to meta-population networks that existed within the natural environment. It is suspected that the residential gardens that have replaced native areas may be able to provide an alternative habitat source for these wetlands species.

The study site contained 236 residences within the City of Melville. Gardens in this area were assessed for the habitat they provided for local wetland species. To supplement this, residents completed a survey (45% response rate) with questions regarding gardening choices and attitudes and wetland species that they had seen in their gardens.

Turtles were found to be moving through one main section of the urban environment, which was the shortest and most accessible route between the wetlands. No relationship between any type of garden habitat and turtle presence was identified.

Frogs exhibited an inverse distance relationship with wetlands. This is contrary to findings in native areas, possibly due to impediments to movement present in the residential area. The probability of frog presence increased with the percentage cover of shrubs below 0.5m. It is highly likely that other ground cover types influence the presence of frogs, as many species of frogs utilise terrestrial habitat during the non-breeding season, but due to low occurrence of some types of ground cover these were not found to be significantly related to frog presence. Subdivision may be leading to an increase in paving and decrease of garden size. This will result in the loss of potential habitat for wetland species in the area.

Participants in the survey generally had a positive attitude towards the environment. This could be used to encourage and offer incentives for residents to increase the vegetated land cover within their gardens. The findings of this study can be used to inform residents and the local councils how their choices can impact on connectivity in the urban environment.
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Chapter 1 Introduction

1.1 Introduction

Urbanisation is increasing all over the world. Urbanisation is the result of the increasing density of human population and the movement of people to urban centres (Hamer and McDonnell 2008). This has led to an increase in the size and distribution of the urban environment (Amezaga et al. 2002). Nations such as Australia hold an increasing proportion of their population within their cities. In 2000, Australia had a population of approximately 19 million and it is predicted that by 2050 the population will be close to 28 million. On top of this increase in population it is predicted that the current 87.2% of the population in urban areas will increase to 93.8% by 2050 (United Nations 2008). This is an increase of over 9 million people who will be living in urban areas.

Wetlands perform highly important ecosystem functions and provide habitat for a multitude of species. Even small wetlands are of crucial importance for maintaining biodiversity (Semlitsch and Bodie 1998). In addition, wetlands provide a number of services both for humans and native species. Urbanisation, however, often occurs at the expense of natural bush land which provides habitat for many native species. Urbanisation is the main cause for the isolation of wetlands which leads to wetlands being located in pockets of remnant vegetation (De Meester et al. 2002).

Fringing vegetation and the terrestrial zone surrounding wetlands is important for wetland species because it acts as a buffer as well as providing food, shelter and breeding sites (Boulton and Brock 1999). In urban areas, wetlands often have a majority of their fringing vegetation and surrounding terrestrial zone removed. Semlitsch and Bodie (2003) identified that amphibians and reptiles can require a buffer zone around the core habitat of a wetland to be up to 399m wide. This includes a 30-60m aquatic buffer zone, a 142-289m core habitat buffer and an additional 50m buffer to prevent edge effects. In many urbanised areas, however, there is no longer an opportunity to put these buffers in place.

Wetlands tend to be managed as islands in a sea of suburbia. Prior to urbanisation, however, wetlands were connected by native vegetation. Many wetland species have their life cycles associated with more than one wetland (Roe and Georges 2007). Also some species are comprised of metapopulations which are groups of local populations linked by the movement of individuals (Hanski and Gilpin 1991). The connection by natural vegetation between wetlands allows for the movement of wetland species and abiotic flows. As Australian cities become more populated urban areas continue to spread and natural vegetation is replaced by houses and gardens. It is known some wetlands species (such as frogs) visit these residential gardens. This project explored whether
residential gardens assisted movement and provided support to wetland species similar to that which would be provided by native bushland.

1.2 Literature Review

1.2.1 People and the Urban Ecosystem

The urban ecosystem is an extremely diverse area which contains houses, parks, roads and possibly remnant native vegetation. It is usually an area where built residences or infrastructure cover a substantial part of the landscape. In many metropolitan areas the fastest growing zone is the suburban zone (Pickett et al. 2001). Increasingly, ecologists are realising that there are few ecosystems which have not been influenced in some way by humans and that the study of urban ecology is becoming ever more vital (Niemela et al. 2009; Pickett et al. 2001).

The process of urbanisation can cause changes in ecological, chemical and physical conditions in areas of urban development. Additionally, urbanisation will often remove or fragment habitat and isolate populations of plants and animals. This can be especially damaging to some amphibian species which live in a metapopulation network (Hamer and McDonnell 2008; Parris 2006). Urbanisation has caused a decrease in the area that wetlands cover and in wetland vegetation, leading to a decline in a number of wetland species, including amphibians (Hamer and McDonnell 2008). Apart from fragmentation and isolation of habitat, humans have also caused ecological challenges for wetland species including introduced competitors, predators and changes in community composition (Goddard et al. 2009).

Humans have caused many remarkable changes to the natural ecosystems around them over many years, but more often than not, humans are not included in ecological paradigms. Some argue that humans need to be incorporated into all urban ecology studies because of the interactions between them and their environment (Alberti et al. 2003). Humans are the cause of urbanisation and therefore the root of most problems in the urban environment. In residential areas, however, it may be possible to find a way to make humans part of the solution.

Recent research has indicated the possibility that private gardens have the ability to enhance the urban environment and provide habitat for organisms if additional native vegetation is added to them (Sperling and Lortie 2010). Residential gardens make up the majority of the green space in residential areas; however, these areas are often ignored and their potential as a major resource overlooked (Gaston et al. 2005). A first step in the process of enhancing urban gardens to provide habitat is to identify what attributes residential gardens currently provide.
A question that must be raised is why do people put what they do into their gardens? In Australian back yards this has changed over time. Originally the back garden was utilised for storage, food production and the outhouse. Over time this has changed and now back gardens are more utilised as a garden for recreation not utility (Seddon 1997). It has been suggested that the management of residential gardens can be contagious. Zmyslony and Gagnon (1998) found that this occurs especially in the case of front gardens. They suggest that residents are strongly influenced by the design of gardens that they see in their neighbours’ yards. This leads to a mimicry effect through different neighbourhoods. This knowledge could be used to improve the habitat resource in residential areas.

In this study, residents were asked to complete a survey to inform us of their gardening practices and the presence of frogs or turtles on their property. It is believed that this is a novel approach to collecting presence/absence data for wetland species in an urban area. The value of taking this approach is that the residents are capable of providing time-integrated data for their residence. This substantially reduces the amount of time that would normally be required to conduct this kind of research in the urban environment.

1.2.2 Connectivity and Meta-populations: Why is connectivity important?
Connectivity (or landscape permeability) is considered to be a property of the landscape which can assist or hinder the movement of organisms. It is a dynamic process that is usually quantified by the extent of biotic flow (movement of organisms) or abiotic flow (movement of water, nutrients, minerals) within the landscape. Most definitions of connectivity identify that the landscape may encourage or hinder the movement of organisms (Crooks and Sanjayan 2006; Moilanen and Hanski 2006). In addition, the connectivity of a landscape is species specific. This is due to the complexity/variety of environments and the differing requirements of individual species. The urban environment can create barriers to the movement of some species but not for others (Soule et al. 2006).

Connectivity is species specific and is an outcome based on the dispersal behaviour, mode of movement of the organism and how the landscape assists or hinders these (Lindenmayer and Burgman 2005; Taylor et al. 1993). Connectivity is important for a number of reasons; it allows individuals access to new habitats with potentially greater food supply and access to new mates. On a population level, connectivity is important because it provides the possibility of exchange of genetic material between potentially isolated populations (Crooks and Sanjayan 2006).

One term that is often mentioned together with connectivity is metapopulation. A metapopulation is “a set of local populations which interact via individuals moving between local populations” (Hanski and Gilpin 1991). Movement of any species can fall into a number of different categories. For example, day to day movements are usually undertaken within a home range and involve behaviour
such as foraging. Dispersal between habitats is another kind of movement. This usually occurs when a juvenile animal leaves its natal territory and moves to a new suitable habitat patch. Stopping this kind of movement can adversely affect the genetic diversity of the population and the species (Lindenmayer and Fischer 2006; Lindenmayer and Burgman 2005).

Metapopulations are important because a metapopulation supports more individuals than can be supported in a single patch of habitat, thus metapopulations are less likely to become extinct. Metapopulations exist in patches of suitable habitat separated in a matrix of unsuitable habitat. Some of their populations are often at risk of extinction without some dispersal between patches (Lindenmayer and Fischer 2006).

Movement of species can occur via overland travel or through vectors. A vector refers to a dispersal mechanism by which an organism or its propagules may spread. There are many different vectors such as wind, water, soil, fire and animals (Cousens et al. 2008). To identify the target organisms for this research, wetlands species were grouped into flora, invertebrates (specifically insects), frogs, turtles and water birds. The main modes of movement utilised by these groups were then assessed through the literature (Appendix One). The groups whose movements were most likely to be directly impacted by urbanisation were chosen as the target groups for this research.

1.2.3 Wetlands species guilds and the probable effect of the urban environment on their movement

Whilst connectivity is species specific, it is important to look at a range of species when assessing connectivity of an area (Taylor et al. 2006). Wetland species were grouped into the following guilds: flora, insects, frogs and turtles, and water birds. Individual species within these groups tend to have similar modes of movement or dispersal. Currently, the potential distance travelled and the vectors that each individual wetland species use cannot be identified due to gaps in the literature. A literature review was conducted to investigate the vectors utilised by each guild (see Appendix One) and a summary of the findings is shown below (Table 1.1). Three guilds were identified as particularly reliant on the environment between the wetlands in the study site. These were frogs, turtles and waterbirds with young. Frogs and turtles are particularly at risk as even when they fully mature they must still travel overland. Overland travel in an urban environment could drastically change or even prevent these groups’ movements. The movement of frogs and turtles and the potential impacts of the urban environment on these species are explored below.
Table 1.1: Summary of literature review into vectors utilised for movement and the impact of the urban environment on them.

<table>
<thead>
<tr>
<th>Species Guild</th>
<th>Dispersal Vector</th>
<th>Need to travel between Wetlands</th>
<th>Reason for travel/ no travel</th>
<th>Potential for the Urban environment to interfere with movement</th>
<th>Ability of the urban landscape to prevent connectivity?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flora</td>
<td>Wind and Water (Raven et al. 2005; Grime 2001; Neff and Baldwin 2005)</td>
<td>No</td>
<td>Can usually complete their lifecycle within one wetland.</td>
<td>The alteration of water movement between wetlands or birds being prevented access to wetland.</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Birds (Figuerola and Green 2002; Clausen et al. 2002)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insects</td>
<td>Active flight (Kovats et al. 1996; Liehne 1991)</td>
<td>No</td>
<td>Can usually complete their lifecycle within one wetland.</td>
<td>The alteration of water movement between wetlands.</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Water flow (Munoz 2010; De Meester et al. 2002)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Birds (Charalambidou and Santamaria 2002)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frogs and Turtles</td>
<td>Overland travel</td>
<td>Yes</td>
<td>To maintain sustainable population. To gain access to suitable habitat for breeding and additional resources.</td>
<td>Yes, road linked to a decrease in frog movements and death in turtles. Increased predation from introduced animals, even domestic animals.</td>
<td>High</td>
</tr>
<tr>
<td>Birds</td>
<td>Overland travel (Rodewald and Shustack 2008)</td>
<td>Yes</td>
<td>For access to available food and habitat</td>
<td>Yes, species that travel between wetlands with young can be severely affected.</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Flight (Dzus and Clark 1998; Stafford and Pearse 2007)</td>
<td></td>
<td>For migration access to suitable habitat</td>
<td>Removal of wetlands or decreases in fringing vegetation may adversely affect some species.</td>
<td>Low</td>
</tr>
</tbody>
</table>
**Turtles**

In Perth, there are two species of turtles: the Western Swamp Tortoise (*Pseudemydura umbrina*) and the Oblong Tortoise (*Chelodina oblonga*). *P. umbrina* was at one stage thought to be extinct; however it was rediscovered and now exists in three reserves and is currently listed as critically endangered (Threatened Species Scientific Committee 2004). These tortoises have no fixed home range and it is believed before the fragmentation of wetlands occurred, there was movement between wetlands. In the reserves they have been known to travel up to 600m from their wetland (Burbidge and Kuchling 1994).

*Chelodina oblonga* can often be found in permanent and seasonal wetlands and has a widespread distribution throughout the Perth area. *Chelodina oblonga* populations are found in both of the wetlands in the study site (City of Melville 2004a, 2004b). *Chelodina oblonga* is long-lived with a delayed maturity. Due to this, any impact that urbanisation has on this species may not become apparent for many years or even decades (Guyot and Kuchling 1998).

The main movements noted in *C. oblonga* are the movement of females to find suitable habitat for egg-laying, which can be up to 500m from the wetland. Mating occurs within the wetland but to lay eggs the female leaves the wetland in search of sandy soil in which to bury her eggs (Burbidge 1967). The use of gardens as nesting sites has been known to occur, especially if the urban properties are on higher ground (Giles 2001; Guyot and Kuchling 1998). *Chelodina oblonga*, whilst mostly aquatic, will leave wetlands not only to nest but also to disperse. Dispersal and migration occur when the turtles seek new habitats, most likely in an attempt to access new resources of food. This will often occur in less mature turtles (Giles 2001; Roe et al. 2009). Evidence suggests that *C. oblonga* losses will increase during terrestrial movements. These losses may be caused by traffic on roads or predation by ravens or foxes.

Roe et al. (2009) demonstrated that wetland complexes need to be conserved as a whole for turtles. This is due to the high migration rates between wetlands found in some species. Unfortunately, migration between wetlands may no longer be possible for wetlands within urban areas, including this study area. It has been shown that there are a proportion of turtles killed on roads (Giles 2001). This is of concern if nesting occurs in residential gardens, as the hatchling *C. oblonga* will have to cross roads to gain access to another wetland (Guyot and Kuchling 1998). This may mean that urban areas have a detrimental impact on both their numbers (i.e. decreased ability to get to new food sources) and on their genetics (i.e. isolation of small populations leading to inbreeding).
Frogs

There are many different species of frogs found within Perth and limited research has been conducted on their movements within the metropolitan area. Within the frogs of Perth, species are specialised for different habitats and life histories. For example, tree frogs have adaptations for climbing whilst others like the Turtle frog (*Myobatrachus gouldii*) crawl along the ground and burrow (Tyler and Doughty 2009). Bamford (1992) conducted a survey for *M. gouldii*, *Heleioporus eyeri* and *Limnodynastes dorsalis* by setting up capture sites at increasing intervals away from a wetland. It was found that there was no correlation between the capture rate of the species and the distance of trapping site (which were up to 2.5km from the wetland). This is similar to the findings of Lemckert (2004) whose summary of all research into frog movements found that the distance moved to new terrestrial habitats could vary from 385m to 1810m. This information supports a number of facts; the first is that there is a large variation between distances travelled for different species; the second is that many species of frogs are capable of moving large distances. Such ability could allow them to traverse the urban environment between the two wetlands in this study if the urban area was not a hindrance to dispersal.

Whilst limited, specific information is available for Western Australian frog species. It is known that some frog species do not live in wetlands all year around (Tyler and Doughty 2009). Terrestrial non-breeding habitat can contain essential resources of food and habitat. This habitat can occur bordering wetlands or hundreds of metres away, depending on the species of frog (Hamer and McDonnell 2008; Rittenhouse and Semlitsch 2007). This means that it is of vital importance that there is adequate terrestrial habitat available to frogs not only for foraging and habitat but also to allow the movement of frogs between wetlands (Simon et al. 2009; Rubbo and Kiesecker 2005).

Within urban areas frogs occur as meta-populations as they tend to live in isolated habitat patches. The size of these habitat patches also determine the species richness of frogs (Parris 2006). Increasing isolation is a problem to frogs, as an increase in isolation results not only in a decrease in migration and new genetic material brought in by migrants but also a decrease in the species richness of the area (Hamer and McDonnell 2008).

One barrier that is believed to greatly affect frog meta-populations is the isolation of their habitat by roads. The movement of breeding frogs and dispersal of young into new habitat can be dramatically decreased by mortality on roads (Parris 2006; Hamer and McDonnell 2008). Farhig et al. (1995) showed that density of frogs is significantly affected by traffic mortality. Additionally the road size and traffic load is also believed to influence frog mortality. This variation in traffic density and road size and its affects on frogs has not yet been fully explored but is of vital importance. More research into this area could allow the rating of roads in terms of traffic density and their potential to affect frog movement.
Other barriers to the movement and the dispersal of frogs through the urban environment are introduced predators. These predators may be aquatic ones that prey on eggs laid in ponds. These are often exotic fish such as *Gambusia holbrooki* and *Cyprinus carpio* which feed on frog eggs and tadpoles. These introduced species are capable of eradicating entire tadpole populations very quickly. This prevents the colonisation of home-owned ponds by frog populations and potentially decreases the possibility of dispersal of young within a metapopulation (Anstis 2002; Hamer and McDonnell 2008). Other introduced predators may be land-bound such as cats and foxes (Calver et al. 2007).

This study will focus specifically on connectivity for frogs and turtles due to their need to cross the urban environments to reach alternative habitats and their requirement to traverse the landscape individually on the ground (as opposed to other wetland species where movement may be facilitated by a number of vectors - Table 1.1).

There are a number of different ways in which connectivity can be assessed. The first is landscape pattern and patch metrics. These look at the characteristics of the patches in terms of provision of habitat within a potentially hostile matrix (Taylor et al. 2006). This type of assessment addresses land use type and its impact on the structural connectivity between wetlands. Secondly, distance analysis which uses the shortest distance between sources or places of interest, however, the shortest path may not always be the best (Fagan and Calabrese 2006). Thirdly is cost-distance analysis which looks at the matrix and the cost to the individual to travel through this area (Fagan and Calabrese 2006).

### 1.3 Research Questions

Urbanisation has greatly depleted and in most cases completely removed native bushland. The overarching question of this research is what attributes of the urban environment assist or hinder connectivity of wetlands? This question can be broken down further into more specific research questions:

- Are wetland species found in the urban environment?
- Do residential gardens provide habitat for wetlands species?
- What barriers to connectivity are present in the urban environment?
- How is connectivity between wetlands influenced by a resident’s gardening choices?

The value of the residential area as habitat and to promote connectivity will be assessed by garden condition assessment, surveys of residents and aerial mapping. This will identify landscape patterns over the study area and in each garden, investigate the role of distance in connectivity and ideally identify the path of least resistance similar to that provided by cost-distance analysis.
Chapter 2 Methods

2.1 Site Description

Due to human ethics requirements the specific location of this research cannot be named. The site chosen for this study was an urbanised area between two natural wetlands in the City of Melville, Perth, Western Australia. The first of these two wetlands, Wetland A, is a wetland within the Beeliar Regional Park. It is enclosed by three roads. Wetland A has been modified over the years to include an island, which was created as a sanctuary for roosting and nesting waterfowl. The depth of Wetland A varies seasonally and was artificially maintained in the 70’s and 80’s by water pumped in from a subterranean bore. Currently maximum depth can vary between 2m to 6m (City of Melville 2004a).

The second wetland, Wetland B, is also a wetland in the Beeliar Regional Park. Wetland B is bounded by a highway and two residential roads. Similarly to Wetland A, Wetland B also had its water level maintained in summer by the Council in the past (City of Melville 2004b). Both these wetlands provide habitat for existing populations of frogs (MacIntyre Unpublished Data) *C. oblonga* (Giles 2001) and numerous water bird species (City of Melville 2004a, 2004b).

The distance (as the crow flies) between the two natural wetlands is 510m and this is where the study site is located. Between these two wetlands are 236 residences including houses on full blocks (approx. 800m²), subdivided blocks and units (Figure 2.1).

The area is well established and some of the older residents have lived here for over 50 years. It is believed that much of the area was cleared of mature trees in the 1880’s. The Bateman holding as it was originally known, was subdivided in 1928 by the State Housing Commission. Residential development continued in this area well into the 1960’s and 70’s with the final subdivision completed in 1972 (City of Melville 2004a, 2004b).

As this was a fairly heterogenous residential area, all roads fit a similar traffic usage pattern. Traffic on these roads would be comparatively similar when compared to main roads or freeways for example. The affect of roads and the road avoidance behaviours of Western Australian frogs, turtles and water birds would be required to address this issue. Given that specific information is not available about road impacts on species pertinent to this research and that all the roads in the study site were very similar, the impacts of roads was not explored in this study.
The composition of the urban environment varies. Three approaches were used to identify what support the urban environment provides for local wetland species moving through the area. The three approaches utilised were garden condition assessment, surveys of residents and aerial mapping.
2.2 Garden condition assessment

Residential blocks may vary greatly; therefore it is possible that some gardens within these properties may provide all requirements for reproduction and living for frogs and turtles whilst others will not. This affects the overall ability of a residential areas ability to support movement and life. A garden condition assessment was completed for all the front gardens in the study area that could be observed from the footpath/verge and the back gardens to which we had permission to enter. The following factors were assessed:

- % cover leaf litter
- % cover of shrubs less than 0.5m in height
- % cover of shrubs greater than 0.5m in height
- % cover tall grass/overgrown lawn
- % cover of short lawn
- % area of swimming pool
- % area paving
- % area of sand or gravel
- Number of trees above 1.5m
- Presence of pond/boggy area or other water source (that was not a pool)
- If the yard was enclosed by a fence and if there were any gaps in this fence to allow passage by wetland wildlife.

Each of the above factors may contribute to a garden’s suitability to support or hinder wildlife transit or life support. Individually they may not be significant. What was important was the relative assistance or hindrance of garden condition to wetland connectivity. To best assess this a rating system was adapted from Mathieu et al. (2007). In this case this approach was adapted with the idea that as garden density increases so does the probable ability of a garden to support life and movement of wetland species (Table 2.1). The garden ratings were modified to take into account the potential presence of breeding habitat within the residential gardens. This rating procedure did not occur until all garden data had been collected; so as to decrease bias in the rating system.
Table 2.1: Rating scheme for garden assessments and aerial assessments.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description of rating</th>
<th>Identifiers of rating - Garden Assessments</th>
<th>Identifiers of rating – Aerial Assessment, Quoted from (Mathieu et al. 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>Land use provides all requirements for reproduction and living.</td>
<td>1.1 Provides habitat necessary for reproduction for frogs that specifically breed using ponds</td>
<td>“Mature and dense gardens with more than 70% of area comprising trees and shrubs” Possible water source such as a pond (this excludes pools)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2 Provides habitat necessary for reproduction for frogs that burrow and lay eggs in boggy areas</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.3 Sandy soil (Burbidge 1967)</td>
<td></td>
</tr>
<tr>
<td>Two</td>
<td>Land use provides requirements for life (food, suitable habitat for life) and growth (after metamorphosis).</td>
<td>Diverse habitat (multiple storeys) ground cover, shrubs. Leaf litter on the ground for species to hide under.</td>
<td>“Open garden with a mixture of vegetation structure elements (tree group, shrub hedge, and lawn), more than 30% and less than 70% of area comprising trees and shrubs” For the purposes of this study a mixture of vegetation structure elements can include a % of sand or dirt.</td>
</tr>
<tr>
<td>Three</td>
<td>Land use has habitat that allows for movement through the area</td>
<td>Gardens that are dominated by lawn, and have little structural diversity.</td>
<td>“Garden dominated by lawn and less than 30% of area comprising of trees and shrubs” Again for the purposes of this rating sand/dirt will be included with lawn.</td>
</tr>
<tr>
<td>Four</td>
<td>Land use allows for movement but at high risk to the individual</td>
<td>70% or more of the garden area paved and/or taken up by a pool.</td>
<td>Garden dominated by paving with less than 40% lawn</td>
</tr>
<tr>
<td>Five</td>
<td>Could allow movement but is extremely risky and will most likely result in death.</td>
<td>This rating would be reserved for areas where death is highly likely such as roads. This rating was not given to any gardens but is still in place to indicate the full spectrum of types of habitats.</td>
<td></td>
</tr>
</tbody>
</table>

Rating One was assessed using three parameters (1.1-1.3, Table 2.1) to take into account the different habitat requirements for reproduction for different species. As long the required reproductive habitat was available for section 1.1 or 1.2 the garden was given a rating one. For the turtles, rating 1.3 was given for the provision of habitat for nesting rather than total reproduction like the frogs. This was due to the fact that females will mate in the wetland before moving out to lay eggs (Giles 2001). Currently more information about selection of burrowing sites by turtles is required therefore gardens were not given a rating of one if they only contained sandy soil.
Rating Two was given to gardens that provided similar habitat support as rating one, but without the breeding habitat. An example of this is a diverse habitat with ground cover, shrubs, trees, with leaf litter and possible open sand/soil areas. If this location had a pond or a boggy area it would receive a rating of one, however, if it did not contain a pond or a boggy area it would receive a rating of two.

Rating Three was given to gardens dominated by grass/lawn (e.g. typical grass and palm tree garden) as traversing this area was considered risky due to absence of vegetation to hide beneath (to avoid predators and/or the desiccation from the sun).

Rating Four reflected gardens which contained mainly paving, did not provide a moist shelter (refuge) from predators and was likely to lead to death via desiccation e.g. as the paving heated up during the day (Child et al. 2009).

Rating Five was reserved for areas where there was considerable risk of death for frogs and turtles if they were to traverse it, e.g. a roadway where fauna could be killed by cars. It was considered highly unlikely that this rating would be given to a garden.

Additionally the presence of fences with no obvious gaps was included. These fences represent a barrier and whilst they do not affect the habitat that they enclose they could potentially restrict the movement of the frogs and turtles into the garden.

Environmental data collection (back and front garden assessment) was limited by restricted access to back and front gardens. Ideally during garden condition assessment the presence of any wetland species in all gardens should have been explored. However, due to the limited access to gardens this was not possible and a different approach was taken. The residents of the study area were asked to complete a survey (Appendix Two) asking questions about gardening choices and wetland species seen. This gave valuable time-integrated data for the presence and absence of frogs, turtles and waterbirds with young. This was considered more likely to indicate the presence of wetland species than a count of wetland species observed in the five minute garden assessment (time limited as the garden assessment needed to be completed while the owner/occupier was present for ethical reasons).
2.3 Residents survey

An occupant from each residence was contacted via door-knocking or by a postal drop. Regardless of whether they wished to participate in the backyard assessment, they were asked to complete a survey. Within this survey were questions relating to demographics, current gardening practices, attitudes towards gardens and their use to assist native fauna, and observation of wetland species in their garden. The resident’s responses regarding having seen/heard frogs and turtles in their garden were valuable as this time-integrated data could be compared to the rating given to the resident’s garden. This would show if garden composition and attitudes influences the presence or absence of wetland fauna in a particular garden.

2.3.1 Procedure for garden data collection and surveys

An initial letter drop was performed with a flyer informing potential participants that there would be a researcher door-knocking in the area over the next month. Potential participants (residents) were subsequently contacted through a door knock of the study area. Every property was door-knocked on a number of days (weekdays and weekends). Depending on the response one of the following four procedures followed:

1. If a resident was interested and willing to participate fully and allow access to the garden then they were asked to sign a consent form and the sampling was conducted immediately while the resident completed the survey.

2. If residents did not wish to allow access to the garden but were willing to complete the survey, they were given the option of completing the survey while the researchers waited. Alternatively, they were asked to leave their completed survey under the door mat on a nominated day or were supplied with a reply paid envelope and thanked for their time.

3. If a resident did not wish to participate they were thanked for their time and the researchers left.

4. If there was no answer at the property, the researcher returned at another date to attempt to contact the resident. Up to four attempts to contact the resident in person occurred. If the final attempt failed an information letter, survey and reply paid envelope with a note asking the resident to contact the researcher by phone or email if they wished to make a time for garden sampling to take place was posted to them.

A map was created with a unique numbering system which allowed the property (and its rating) to be correlated to the completed survey. For each round of door-knocking it was indicated on the map which residents were home and which had participated (or declined a request to participate). If the property had a pond and the resident had provided their consent, an aquatic invertebrate sweep was
completed on the pond. This involved a one minute sweep with a net (aperture 190x150mm, 200-250 micron mesh). Any captured invertebrates were stored in ethanol and later identified in the laboratory.

2.4 Aerial survey

Landscape uses were identified from the City of Melville’s online mapping system (2006) including residential blocks, roads and public lawns/open space. To support the garden assessments the photo mapping tool from Nearmaps (2010) was used to collected the following information:

- Area of block
- Area of house
- Area of driveway
- Area of other paving
- Area of swimming pool
- Area of lawn, sand or dirt (potential green space)
- Area of mature and dense garden (containing trees and shrubs)

Nearmap (2010) was used in this instance because it provided the most recent satellite photos of the area, which were taken in May 2010. Once the above data were collected for each individual block, the block received a rating. Similarly to the garden ratings these aerial ratings of gardens and public lawns/open space were adapted from Mathieu et al. (2007). The intention of collecting these aerial ratings was to supplement the garden assessments in cases where access to gardens was not possible.

A number of changes were made to the above aerial methods. Since condition assessment was completed for all front gardens (that could be seen from the verge), it was decided that collection of this data aerially would not be required for front gardens. The aerial data fields were only intended to supplement the condition assessment data which was far more detailed. Therefore this aerial data was only needed for back gardens. From this aerial data each back garden was given a rating (Table 2.1)

Additionally, the block area and house area were removed from data collection. City of Melville’s online mapping system (2006) included block area but not verge area. Calculation of verge area was not possible on the mapping system and assessment by another method would have introduced an inappropriate level of error. Therefore these areas were omitted from the study.
In light of the responses to the surveys, it was decided that the distance from each residence to the closest wetland (as the crow flies) was required. Using Nearmap (2010), this distance was calculated from the closest edge of the block to the nearest edge of the wetland.

This method of utilising aerial photographs did not allow the identification of water sources (such as ponds) within residential back gardens. However, this lack of information was supplemented by the surveys which asked residents to indicate whether they had a garden pond or not. From these responses, the distance from the residences of all respondents to the closest residence with a pond was calculated. These distances were all taken from the closest edge of each block.

Both aerial ratings and garden ratings (from section 2.1) were compiled onto a map which allowed the identification of the path of least resistance for the movement of frogs and turtles through the area. There is some uncertainty regarding the accuracy of this type of system for residential blocks as each block potentially contains a number of land uses. The quality of the aerial maps may also affect this procedure. As can be seen from Table 2.1 the aerial ratings and garden ratings were given on the same scale where a lower rating (e.g. rating one) provided more habitat than a higher rating (e.g. rating four). Since the same scale was used a statistical comparison between garden ratings and the aerial ratings occurred. This was to ensure that the aerial ratings were not in error. The aerial and garden ratings were then inserted into a final map to show connectivity of the overall area.

2.4.1 Drains

For each wetland, the number of storm water drains entering it and the approximate area of its catchment were identified; as it was considered possible that frogs could utilise these stormwater drains. Mazerolle (2005) documented frogs utilising open drainage ditches for movement. Wetland B has five stormwater outlets servicing the residential catchment as well as the main highway. Wetland B’s catchment is 19 hectares in size (City of Melville 2004b). Wetland A has seven storm water drains leading into it from surrounding residential areas. It has a catchment of 12 hectares (City of Melville 2004a). Unfortunately there was no information available regarding the possible connection of these two wetlands via the stormwater drainage systems. Given the size of each catchment, however, it is unlikely that these two wetlands are connected in this way.
2.5 Data Analysis

The responses to the survey were analysed by comparing the demographics to the 2006 ABS census data for the City of Melville. This is to ensure the respondents were not overrepresented by one particular demographic group. Mean and standard error were calculated for responses to yes/no questions with 1=yes and 0=no. Mean and standard error were also calculated for the attitude and judgement questions based on the Likert scale (4=strongly agree, 3=agree, 2=disagree and 1=strongly disagree).

An independent sample t-test assuming unequal variance was run between the front garden ratings of the house completed surveys and the front garden ratings of the houses that did not complete surveys. This was to show that the garden ratings of those people who completed surveys were representative of the whole area.

Binary logistic regressions (SPSS 17.0) were run to compare the presence/absence of frogs (or turtles) to the front garden ratings, the distance from wetland, distance from pond as well as each environmental factor individually.

Responses from participants regarding the presence of frogs and turtles were mapped. The study area was broken into five longitudinal sections at approximately 100m intervals from the edge of Wetland B. The presence/absence of frogs and turtles in each section was compared using chi-square statistic. An additional chi-square statistic was run to compare the garden ratings given for the western and eastern sides of the study site.

A cluster analysis using PRIMER 6 was conducted on the entire environmental data set for front gardens to support the ratings.

The ratings of the front gardens and barriers were mapped, along with the back garden data that was collected. Using the aerial ratings and the back garden ratings (from the garden assessment) a paired t-test was run to see if the aerial ratings were significantly different from the back garden data that was collected. Some houses could not be rated aerially due to obstructions such as shade sails etc. The aerial ratings were input on the same map as the front garden ratings to indicate the overall connectivity through the residential area.
Chapter 3 Results

3.1 Wetland species in the urban environment

Of the 236 residential homes in the study area, 107 surveys were completed by the residents (Figure 3.1). The respondents answered a range of questions (Appendix Two) and were asked to indicate whether they had seen frogs or turtles in their garden.

The respondents also completed an array of demographic questions to ensure that they were a representative sample of residents in the City of Melville.

3.1.1 Data Validity

It is important for the validity of the results that the survey sample was not biased. The demographics of the respondents in this survey were similar to 2006 Census data for the City of Melville (Table 3.1). The only digressions were that the sample was slightly overrepresented by females, people who had completed Bachelor and Postgraduate studies and the age groups of 36-45 and 55+. The responses to the survey were not skewed by a non-representative sample of the population in the study area. The average time that respondents had lived in the area was 12.9 years ±1.4 years. This demographic data is displayed graphically in Appendix Three.

Figure 3.1: Map showing the study site and the residences that completed surveys
Table 3.1: Demographic characteristics of sample and ABS Melville (Australian Bureau of Statistics 2006).

<table>
<thead>
<tr>
<th>Demographic Characteristic</th>
<th>Category</th>
<th>% Sample</th>
<th>%ABS Melville (Australian Bureau of Statistics 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>18-25</td>
<td>4.85</td>
<td>15.32</td>
</tr>
<tr>
<td></td>
<td>26-35</td>
<td>12.62</td>
<td>12.92</td>
</tr>
<tr>
<td></td>
<td>36-45</td>
<td>25.24</td>
<td>17.54</td>
</tr>
<tr>
<td></td>
<td>46-55</td>
<td>12.62</td>
<td>19.94</td>
</tr>
<tr>
<td></td>
<td>55+</td>
<td>44.66</td>
<td>34.29</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>34.02</td>
<td>47.57</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>65.98</td>
<td>52.43</td>
</tr>
<tr>
<td>Home Ownership</td>
<td>Rent</td>
<td>29.81</td>
<td>21.66</td>
</tr>
<tr>
<td></td>
<td>Own</td>
<td>70.19</td>
<td>78.34</td>
</tr>
<tr>
<td>Highest Education level</td>
<td>Year 10</td>
<td>10.53</td>
<td>13.28</td>
</tr>
<tr>
<td></td>
<td>Year 12</td>
<td>14.74</td>
<td>38.39</td>
</tr>
<tr>
<td></td>
<td>TAFE</td>
<td>24.21</td>
<td>23.90</td>
</tr>
<tr>
<td></td>
<td>Bachelor</td>
<td>35.79</td>
<td>20.47</td>
</tr>
<tr>
<td></td>
<td>Postgraduate</td>
<td>14.74</td>
<td>3.96</td>
</tr>
<tr>
<td>Mean # people per residence</td>
<td>Mean=2.85±0.21</td>
<td>Mean=2.6</td>
<td></td>
</tr>
</tbody>
</table>

3.1.2 Frog and turtle presence in the study area

On average respondents were likely to report seeing frogs in their garden over the last twelve months (0.72±0.044), while respondents were less likely to report hearing a frog in their garden (0.59±0.048) (Figure 3.2). A mean score closer to 1 indicates an increased likelihood of a ‘yes’ response while a mean score closer to 0 indicates a ‘no’ response is more common (Table 3.2). Only 26.16% of respondents indicated that they had a pond on their property with a very small number having seen tadpoles in their pond (0.043±0.0435) and a minority reporting that fish were kept in their pond (0.30 ±0.098). On average participants had not seen a turtle in their garden (0.43±0.049), although this mean is close to the midpoint (Figure 3.2).

If respondents had seen a frog in the last twelve months they were asked to indicate how many frogs had been seen in that period. The percentage of respondents that saw 1, 2 or 3 frogs was 21.05%, 19.74% and 23.68% respectively while a smaller proportion of respondents saw 4 (11.84%) or five frogs (6.58%) and 17.11% reported seeing more than 6 frogs in the one year (Figure 3.3).
Figure 3.2: Mean response to an array of yes/no questions regarding frogs, turtles and ponds (where 1=Yes, 0=No).

Figure 3.3: Number of frogs seen by residents in the last year (n=76)
There was a mixture of participants who saw frogs, turtles or both in their gardens (Figure 3.4). Frogs appeared evenly spread throughout the study area and to have no relationship to distance to wetland. Figure 3.5, however, illustrates that respondents who saw frogs were, on average, closer to the wetlands.

Figure 3.5: Box plots for the presence/absence of frogs and turtles and the distance from the closest wetland
The box plot (Figure 3.5) illustrates that there is a relationship between the presence/absence of frogs and the distance to the closest wetland. This is statistically significant (sig. 0.010, $R^2=0.179$) and there was an inverse distance relationship between wetlands and the presence of frogs (sig. 0.010, B value=-0.008). This means as the distance from the wetland increases probability of frog presence decreases. This binary logistic regression has an excellent goodness of fit (Hosmer and Lemeshow test sig. 0.255).

There was also a significant relationship between turtles’ presence and their distance to the wetland (Figure 3.5) with the probability of turtles present decreasing with increasing distance from the wetlands (sig. 0.002, $R^2=0.195$, B-value=-0.009, goodness of fit of 0.594).

Binary logistic regressions were also run on the presence/absence of the wetland species and the distance to closest pond, however, there was no significant relationship (Table 3.2).

**Table 3.2: Statistical results for the binary logistic regression run for the presence/absence of frogs or turtles and distance factors (significant results are highlighted below)**

<table>
<thead>
<tr>
<th>Distance Factor</th>
<th>Nagelkerke $R^2$</th>
<th>Hosmer and Lemeshow test for goodness of fit significance</th>
<th>B-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to closest pond-frogs</td>
<td>0.108</td>
<td>0.417</td>
<td>-0.003</td>
<td>0.745</td>
</tr>
<tr>
<td>Distance to closest pond-turtle</td>
<td>0.170</td>
<td>0.290</td>
<td>-0.010</td>
<td>0.173</td>
</tr>
<tr>
<td>Distance to closest wetland-frogs</td>
<td>0.179</td>
<td>0.255</td>
<td>-0.008</td>
<td>0.010</td>
</tr>
<tr>
<td>Distance to closest wetland-turtle</td>
<td>0.195</td>
<td>0.594</td>
<td>-0.009</td>
<td>0.002</td>
</tr>
</tbody>
</table>
The study area was separated into five sections A through E. The majority of turtles were seen in section C or B (Figure 3.6). It was hypothesised that turtles travelled mainly through section C due the road in this section directly connecting the wetlands. This appeared to be supported by mapping the presence of turtles (that had been seen in the last five years) in the study area (Figure 3.7).

A chi-square test was used to compare these five sections. There is a significant difference between each section (Pearson’s Chi² (4) = 26.495, p<0.001). The z-scores for section C and E and the presence of turtles was 2.2 (p<0.05) and 2.2 (p<0.05) respectively and both were significant. This means the association between turtle presence is driven by section C and the association between turtle absence is driven by section E.

The distance between wetlands (as the crow flies) was taken through the middle of each section (Table 3.3). Section C which was identified to be the section that contained a distinctly higher number of turtles present than other sections is also the section with the shortest distance between the two wetlands. Of the respondents who saw a turtle (n=44), 14 indicated that they had picked up a turtle and returned it to one of the wetlands, even though this was not specifically asked on the survey.

Table 3.3: Euclidian distance between wetlands through each section

<table>
<thead>
<tr>
<th>Section</th>
<th>Distance (m) between wetlands through section</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>612</td>
</tr>
<tr>
<td>B</td>
<td>502</td>
</tr>
<tr>
<td>C</td>
<td>474</td>
</tr>
<tr>
<td>D</td>
<td>532</td>
</tr>
<tr>
<td>E</td>
<td>580</td>
</tr>
</tbody>
</table>

The presence of frogs is almost randomly distributed through the study area (Figure 3.8). A chi-square test did not show a significant difference between the presence of frogs and the sections (Pearson Chi² (4) =3.793, p>0.435). Therefore there was no relationship between the sections and the presence of frogs in this study area.
Figure 3.7: Map of study area indicating which residence saw turtles in their gardens in the last five years

Figure 3.8: Map of study area indicating which residence saw frogs in their gardens in the last year
3.2 Habitat provided by residential gardens

The majority of the front gardens (n=200) in the study area were assessed for percentage cover of different types of ground cover (Figure 3.9) as this is an important component of species habitat. Well kept lawn and paving make up a major portion of these gardens (38.5±2.0%, 37.5±1.7% respectively). The next largest area of cover in the gardens is leaf litter at an average of 6.9±0.8%.

3.2.1 Garden Ratings

To provide a synthesis of attributes of garden habitat, a rating system was developed where One=reproductive habitat to Four=habitat that allows movement but at high risk (see section 2.1). To assess the reliability of this rating scheme a cluster analysis (Figure 3.10) was undertaken on all of the environmental factors shown below (Figure 3.9), which were used to calculate the rating. If taken at a Euclidian distance of 50, clusters separate well into the ratings two, three and four.

![Figure 3.9: Mean percentage cover in front gardens in the study area](image)

Rating one was scattered throughout the cluster diagram because the factor used to rate gardens at one was not percentage cover but specific reproductive habitat, and therefore did not fit well into in this cluster analysis. Cluster analysis separates sampled gardens into groups based on similarity. This can be used to indicate how accurate and logical the rating system is. For rating four the rating system utilised was 95.9% accurate, for rating three the accuracy was 96.7%. Rating two was grouped into two clusters, due to the unique nature of these gardens, and the accuracy was 66.7% (Figure 3.10). A number of gardens rated two were grouped with rating four, as they had no grass on their property. While this decreased the accuracy of rating two, this is an artefact of the analysis. As rating two took into account the cover of leaf litter and shrubs. Separation as to whether or not grass is present does not compromise the value of the rating, which was based on a synthesis of factors.
Cluster analysis of environmental data collected from garden assessments

Group average

Resemblance: D1 Euclidean distance

Ratings
- 1
- 2
- 3
- 4

Figure 3.10: Cluster diagram of environmental data collected from garden assessments and their associated ratings.
Garden assessment data was collected for majority of the front gardens and some back gardens in the study area (n=227) (Figure 3.11). Just under half of these residents completed a survey (n=107). To ensure that respondent’s gardens were representative of the entire study area, the garden ratings for respondents and non-respondents were compared (Figure 3.12). A two sample t-test (assuming unequal variances) was performed between garden ratings for respondents and non-respondents. There was no significant difference between the ratings (p-value=0.358), therefore the null hypothesis that there is no difference between the two samples was accepted. This confirms that the presence/absence data for frogs and turtles provided by the residents contains a representative sample of all garden types in the area. Only front garden data was used for the following analyses because the sample size for back gardens was too low and using both rating types would have led to the doubling of presence/absence data.
There was no significant relationship between the presence of frogs and the front garden ratings (Figure 3.13) when tested using binary logistic regression ($0.700$, $R^2=0.002$, Table 3.4. However, there were not equal samples of each garden rating; in fact there were only four samples for rating one whilst there were 41 samples for rating three (Figure 3.14). It is highly likely that this has skewed the data for this particular analysis, thus the faith in this statistical test is low.
Due to the skewing of the ratings the environmental data was separated into their individual percentage covers (Table 3.4). The presence or absence of frogs was then assessed against each of these categories separately using binary logistic regressions.

Table 3.4: Statistical results for logistic regressions run for presence/absence of frogs and environmental factors, significant factors are highlighted.

<table>
<thead>
<tr>
<th>Environmental Factor</th>
<th>Nagelkerke $R^2$</th>
<th>Hosmer and Lemeshow test for goodness of fit significance</th>
<th>B-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating</td>
<td>0.002</td>
<td>0.750</td>
<td>-0.101</td>
<td>0.700</td>
</tr>
<tr>
<td>% cover leaf litter</td>
<td>0.098</td>
<td>0.725</td>
<td>-0.019</td>
<td>0.335</td>
</tr>
<tr>
<td>% cover shrubs below 0.5m</td>
<td>0.179</td>
<td>0.255</td>
<td>0.103</td>
<td>0.033</td>
</tr>
<tr>
<td>% cover shrubs above 0.5m</td>
<td>0.098</td>
<td>0.724</td>
<td>-0.005</td>
<td>0.893</td>
</tr>
<tr>
<td>% cover long grass</td>
<td>0.098</td>
<td>0.724</td>
<td>0.019</td>
<td>0.856</td>
</tr>
<tr>
<td>% cover lawn</td>
<td>0.066</td>
<td>0.801</td>
<td>-0.021</td>
<td>0.150</td>
</tr>
<tr>
<td>% cover pavement</td>
<td>0.066</td>
<td>0.801</td>
<td>-0.023</td>
<td>0.120</td>
</tr>
<tr>
<td>% cover sand/gravel</td>
<td>0.066</td>
<td>0.801</td>
<td>-0.050</td>
<td>0.060</td>
</tr>
</tbody>
</table>

There a statistically significant relationship (0.033, $R^2=0.179$) between the presence of shrubs below 0.5m and frog presence (Table 3.4). Whilst the means were the same there were a greater proportion of gardens with a high percentage cover of shrubs below 0.5m where frogs were present (Figure 3.15). As the percentage cover of shrubs below 0.5m increased there was an increasing probability that frogs were present (B=0.103). The other environmental factors tested included percentage cover of leaf litter, shrubs above 0.5m, well kept lawn, long grass, paving, and sand. None of these was significantly related to the presence/absence of frogs in the study area (Table 3.4).

![Figure 3.15: Box plot for the presence/absence of frogs and the percentage cover of shrubs below 0.5m](image-url)
Similarly to frogs, binary logistic regressions were run on the presence of turtles and the respondent’s garden rating. A difference between the garden rating of blocks that saw turtles and those that did not was suspected (Figure 3.16) but was found to not be significant (sig.=0.983, $R^2=0.00$, B-value=0.005).

Similarly to the frogs there was a disparity between the number of samples for each garden rating (Figure 3.17). Again this may have skewed the data thus causing a non-significant result for the binary logistic regression between turtle’s presence and garden rating.
As with the frog data, binary logistic regressions were run for the turtle presence/absence comparing it to each environmental factor separately. The other environmental factors tested included percentage cover of leaf litter, shrubs below 0.5m, shrubs above 0.5m, well kept lawn, long grass, paving, and sand. None of these factors were significantly related to the presence absence of frogs in the study area (Table 3.5).

It is likely that the data skewing has been caused by the census style technique utilised to collect data. It is possible that the lack of rating one and two gardens may be masking important environmental factors, which are not present in large enough numbers here to be picked up by the binary logistic regression.
3.3 Residents gardening choices and wetland connectivity attitudes

In addition to identifying the content of urban gardens from an ecological connectivity perspective, it was necessary to gain an understanding of residents gardening choices in order to inform policy and provide education for effective management of urban wetland connectivity (see section 1.2). When asked how much time was spent in their garden each week, the majority (81.13%) of respondents spent less than 5 hours, 16.98% spent between 5-10 hours and only 2% of respondents spent more than 10 hours in their garden each week (Figure 3.18).

Residents were also asked to identify all of the factors that contribute to their choice of a plant for the garden. The most common reasons for plant choice were colour (37.4%) and aesthetic (35.5%), followed by ‘other’ (32.7%) and garden design (27.1%) (Figure 3.19). The most common reasons given when the ‘other’ category was selected were the use of water wise plants, durable plants or food producing plants.

![Figure 3.18: Percentage response of participants when asked how long they spend in their garden each week](image1)

![Figure 3.19: Percentage response for the reasons for plant choice](image2)
The majority of respondents (73.83%) did not have a pond or wet area on their property (mean 0.231±0.042) (Figure 3.20). Just under half of the respondents (54.2%) reported that they did not use pesticides (mean 0.43±0.049). The majority of respondents use fallen leaves or other materials to mulch their garden (mean 0.717±0.043), and just under half of the respondents (mean 0.446±0.049) reported leaving dead wood on the ground in their garden (Figure 3.20).

![Figure 3.20: Mean response and standard error for gardening practice questions, where 0=no and 1=yes](image)

The majority of respondents indicated that their garden was *not* designed to be a habitat resource (mean 0.253±0.045) (Figure 3.21). Interestingly, this item had a very high non-response rate (14.95%), which may suggest that participants were unsure or did not understand the question.

A majority of respondents indicated that they usually take note of wildlife observed in garden (mean 0.808±0.038); while just over half of the respondents (57.01%) agreed that they had a mix of wildlife living in their garden (mean 0.598±0.049).

Just over half of the respondents indicated they kept their pets inside (mean 0.573±0.057). This data appeared unreliable however, as a number of residents that marked ‘yes’ they did keep their pets inside at night had already indicated they did not have a pet earlier in the questionnaire. This was adjusted accordingly, by removing these ambiguous responses before calculating the mean.

The majority of respondents indicated they had removed a known weed from their garden (0.733±0.044), and almost the entire pool of participants (93.46%) indicated that they were not part of a community based environmental group or project (mean 0.029±0.016).
3.3.1 Gardening and environmental perceptions and attitudes

Responses to perception and attitude scales were based on the Likert scale where the scale ranges from 4 (Strongly agree) through to 1 (Strongly disagree). The mean score of 2.55±0.08 for the statement ‘I love gardening’ with a very small standard deviation indicates the sample is equally divided between participants agreeing and disagreeing with this statement (Figure 3.22). The mean score of 2.92±0.06 was returned when asked if the environment in their area was healthy, indicating that majority of respondents agreed with this statement. Respondents indicated that they believed that having a pond in their garden would help native wetland species (2.88±0.07) but would also attract mosquitoes (2.92±0.07).
Figure 3.22: Distribution of responses for perception questions and Likert scale means (where 4= Strongly agree, 1=Strongly disagree)

The majority of respondents agreed that their garden was a valuable habitat resource (2.82±0.06). There was a mixed response to the statement ‘The time I spend in my garden it important to me’ the mean response was positive (2.78±0.08), however, there was a substantial proportion of respondents who disagreed with this statement (Figure 3.23). The majority of respondents strongly believe that wetlands provide important habitat for our native species (mean response 3.64±0.05). The mean score of 2.71±0.07 for the statement ‘I am able to manage my garden to provide habitat for local species’ indicates the sample is almost equally divided between agreeing and disagreeing with this statement. A majority of respondents agreed that their gardening choices do make a difference to biodiversity (2.92±0.06).

Figure 3.23: Distribution of responses for attitudes towards gardens, and wetlands with Likert scale means (where 4= Strongly agree, 1=Strongly disagree)
3.4 Barriers in the urban environment

The ratings from the garden assessments were compiled onto a map (Figure 3.24). The study area was separated into a western section and an eastern section. Interestingly, the western areas contained no more than five subdivided blocks compared to the eastern portion in which majority of the blocks were subdivided.

![Figure 3.24: Map showing the garden ratings given to front/back gardens during garden assessment and the division of the site into west and east](image)

There was a greater number of gardens given a rating of four in the eastern section (Figure 3.25). A chi-square test was run comparing the west and east sections and the frequency of each rating type within them. There was a significant difference between the west and east sections of the study area ($\chi^2(3) = 12.907, p<0.005$). This may be due to the large amount of subdivision here in comparison to the western section. There was however no statistically significant difference between the numbers of frogs and turtles in the western section compared to the eastern section.
Figure 3.25: Frequency of each rating for the western and eastern areas of the study site.
3.5 Aerial ratings

A range of data regarding ground cover in back gardens was collected using aerial photography. This data was then used to rate the back gardens in the study site. Using the aerial ratings and the garden ratings (from the garden condition assessment) a paired t-test was run to see if the aerial ratings were significantly different from the back garden data that was physically assessed. There was no significant difference between the aerial and garden condition assessment ratings (p-value = 0.336).

There were a number of issues with the aerial ratings, as some houses could not be rated aerially due to obstructions such as shade sails or extended patios. Additionally 24% of the back gardens for which aerial data was collected could not be rated as the aerial rating scheme did not take gardens with equal proportions of grass, dense garden and paving into account. By attempting to alter the rating scheme to include these gardens it adversely affected the other ratings that had already been given. This created unreliability in the rating scheme therefore they were removed from the study.

The aerial ratings were put into a map along with the garden condition assessment ratings (Figure 3.26). The final aim of this study was to identify the path of least resistance for wetland species travelling between the wetlands in the study area. This was not possible, since there was no relationship between rating and presence/absence of frogs (or turtles); there was no mechanism by which a path of least resistance could be identified. It would appear for turtles however, which appeared unaffected by substrate that the line of least resistance was the shortest distance between wetlands (Figure 3.6).
Chapter 4 Discussion

4.1 Are wetland species found in the urban environment?

The potential for data collected in this research to be biased by utilising presence/absence information provided from residents in the area, rather than collecting this information in an ecological survey has been explored in detail. It is considered that the bias for this data is minimal, and this is discussed further in section 4.5.

4.1.1 Frogs

Frogs were present within the study site. Interestingly, while the majority of respondents *saw* a frog in their garden over the last year (0.72±0.044, where 1=yes, 2=no), fewer were likely to *hear* a frog in their garden (0.59±0.048). This response was surprising as during the door-knocking frog calls could be heard from the front gardens of residents who lived adjacent to the wetlands. It is possible that residents who live adjacent to the wetland and are therefore continually exposed to frog calls may stop noticing the sound as it becomes part of the ‘normal’ or ‘everyday’ noise of the area (Dahlberg and Dahlberg 2003).

Another possible explanation is that the community as a whole may not be able to recognise particular frog calls. The extremely high non-response rate (43.5%) to the question asking participants, who had heard a frog in their garden to describe the frog call, supports this supposition. It also raises an important question regarding the awareness of frog presence and sounds in the local community, highlighting that further research is required into community perception of frog sounds and accuracy of reporting.

An interesting result from this study is that as the distance from the wetland increases, the probability of seeing a frog decreases. This is surprising as Bamford (1992) showed for the Western Australian frog species *Myobatrachus gouldii*, *Heleioporus eyeri* and *Limnodynastes dorsalis* (*H. eyeri* and *L. dorsalis* are known occupants of Wetland A and Wetland B, Appendix Four) that there is no correlation between distance from wetland and frog species captured. The main difference between Bamford’s study and this one is that his study was based in non urban areas some of which were fire affected. In contrast, this research was conducted in the urban environment.

In this study no sample site was more than 350m from a wetland, however, an inverse distance relationship was still identified between frogs and wetlands. If this study identified this relationship over a distance of 350m in an urban area while Bamford (1992) could not show this relationship in a native area over 2.5km, this suggests a strong limit on frog movement within urban areas.
Unfortunately, there is a lack of research in this area for Western Australian frog species. It could be argued that some species that were not included in the research by Bamford (1992) are normally influenced by distance from wetland. This, however, is unlikely to be true. While the information collected in this study is not available at species level, it has been shown that generally species of the genus *Litoria* have a home range of 843m$^2$ (Lemckert 2004). This home range, if similar for *L. moorei* and *L. adelaidensis*, would indicate that the entire study site would be well within their home range. Thus it is unlikely that the members of the genus *Litoria* are usually influenced by the distance from wetlands in natural areas.

There is no information regarding home ranges or the distances that the *Crinia glauerti* (a known occupant of Wetlands A and B, Appendix Four) is known to travel. If presence data had been collected for each species it would be possible to see whether the impact of the urban environment is the same for all of these species. It would also identify if one particular species of frog is over-represented in the study area. This is an area that could be investigated in future research.

There may be a relationship between the presence of fish and absence of tadpoles in residents’ ponds, as it has been shown that fish such as *Gambusia holbrooki* can detrimentally affect the populations of tadpoles (Hamer et al. 2002). From this study however, a relationship between tadpole absence and fish presence is unlikely given that 69.5% of residents with ponds did not have fish and only 4.3% indicated that they had seen tadpoles. There are a number of reasons for this. It is possible that the residents did not see them because of the low visibility of many tadpoles in ponds and the high presence of species that breed in boggy areas surrounding wet areas instead of in ponds (Tyler and Doughty 2009; Anstis 2002). Since their eggs are not laid in the pond, the presence of fish will not necessarily be detrimental to the frogs young.
4.1.2 Turtles

Turtles (C. oblonga) are also present within the study site. As with frogs, there was a significant relationship between distance from wetland and C. oblonga sightings. This was not unexpected because for C. longicollis (which is found in the eastern states) the probability of movement between wetlands decreases with increasing distance between wetlands (Roe et al. 2009), which is not dissimilar to the findings of this study.

Interestingly there was a pattern in the area of the sample site where C. oblonga were most commonly sighted (Figure 3.7). It was found that a significant proportion of C. oblonga were found within section C when compared to the other areas. Interestingly, section C encompasses the shortest distance between the two wetlands. Importantly the most direct route; a road that links the two wetlands is through section C. Unfortunately it was not possible to identify whether turtles are travelling this way because it was the shortest route or because it was the easiest route. It is suspected, however, to be a mixture of both of these factors. To confirm this further research is required.

Whilst there is still limited research into the types of movements made by C. oblonga it is suspected that individuals were seen in section C for two reasons. The first reason for movement is the migration between the wetlands for access to new food sources. The second reason for movement is females searching for suitable nesting sites (Burbidge 1967; Giles 2001). One resident who lived within section C indicated that she had a turtle nest in her front garden even though she was over 150m away from the edge of Wetland B. This evidence supports the fact that turtles are moving in this area for nesting.

Interestingly, 14 of the 44 respondents indicated that they had seen a turtle moving through their garden and had returned it to the wetland. While this was not a specific question in the survey, this information was often given in the comments section of the survey. It would be interesting to conduct further research into this phenomenon of humans acting as vectors for the C. oblonga. It is suspected that if residents were asked specifically if they had assisted turtle movement the response rate would be higher than 14 out of 44. It is possible that this assisted movement by humans may be beneficial, preventing injury from travelling through the urban environment or providing the additional connectivity that would have been otherwise lost. It is also possible that this human-facilitated movement may be detrimental to their breeding cycle as it is unknown whether nesting female turtles will make another attempt at laying if they are interfered with (Giles pers com. 2010).
4.2 Do residential garden provide habitat for wetland species?

The ratings were designed to be an overall habitat indicator for each garden. There was, however, no significant relationship between the front garden ratings and the presence/absence of frogs (or turtles). This was surprising given that the garden ratings were based on a literature review which looked at the habitat requirements of frogs and turtles.

The ratings were collected in a census style to identify the available habitat resource in the study area. This led to a dataset that was skewed towards ratings three and four as few high quality habitat gardens existed in the study area. Further research is required to verify these ratings as indicators of habitat value or predictors of frog or turtle usage. A set number of garden samples of each rating could be collected with accompanying surveys and frog/turtle presence/absence data, and analysed using binary logistic regression.

An alternative reason why the ratings may not have worked is because they did not classify gardens into discrete types. Using a cluster diagram created from the environmental data the consistency of the ratings was assessed (Figure 3.10). Gardens with rating three and four were consistently grouped together, however, gardens with rating two were not. Some of the gardens that were given a rating two did not have grass; because of this the cluster analysis grouped these gardens with the rating four gardens. This is because the cluster analysis did not include a weighting of the relative importance of each type of habitat cover for the wetland species. Even though these outlier rating two gardens have no grass, they had a substantial amount of leaf litter and shrubs which meant that these gardens potentially provided important habitat to wetland species. To rectify this issue the analysis could be run again with long grass and shrubs weighted as more important. Even though rating two had a low accuracy, the ratings are still valid because the issues with the ratings are a statistical issue caused by the skewing of the data.

It was identified that percentage cover of shrubs below 0.5m was positively related to the presence of frogs. There was no significant relationship (positive or negative) with any other type of cover. This was surprising as it was expected that similar relationships between frogs and long grass or leaf litter would be found (Bamford 1992). It is known that frogs do use terrestrial habitat during non-breeding seasons (Rittenhouse and Semlitsch 2007; Rubbo and Kiesecker 2005; Simon et al. 2009). It is highly unlikely that they only utilise areas with shrubs below 0.5m. What is more likely is that the skewing of the data means that this association, which is most likely the strongest, is the one that was picked up. Possibly other types of ground cover frogs may be associated with (either positively or negatively) had an insufficient sample size to provide a significant relationship. In future research, frog preference for these kinds of vegetation cover could be explored in more depth and with a more extensive dataset.
The relationships between turtle presence/absence and ground cover were tested. There were no significant types of cover for turtles. This may be due to the data collection style. Participants were asked if they had seen a turtle in their garden. In addition they were asked what it was doing. The main response if a turtle was seen was the turtle is “travelling through garden to wetland”. It may be that the data will not show what habitat is being utilised by the turtles because some are seen travelling through the area, whilst others (females) are seeking habitat specifically for nesting. Due to the mixed use of this area it is not possible to separate these two very different types of behaviour. This may have had a confounding affect on the data. As currently there is limited knowledge regarding habitat utilisation of *C. oblonga* when it is not nesting. Therefore further research is required into the terrestrial habitat preferences and movements of *C. oblonga*.

If further information was to become available regarding *C. oblonga*’s habitat preferences it may be possible to encourage residents to make changes to their garden to assist these turtles. The urban environment does not have to inhibit movement of turtles; in fact vegetated drainage lines can provide safe passage for turtles moving in the urban environment. A similar result has also been found for frogs (Rees et al. 2009; Mazerolle 2005). Realistically these kinds of vegetated drainage lines are unlikely to be placed in existing urban areas. However, it could be a design option for new housing developments. Knowing where turtles are moving in the urban environment can allow the local councils, even in built up areas, to find options to ensure that turtles moving along these areas are sheltered from some of the dangers of the urban environment.

What do these results mean for connectivity for these species within the urban environment? Frogs are definitely associated with shrubs below 0.5m and it is likely that they are associated with other types of ground cover as well. For turtles, connectivity between wetlands has been confirmed by locals who have observed turtles migrating between the wetlands. There were no positive associations between any ground cover type and turtle presence. However, there is a level of uncertainty in the data as to the relative value of different types of environmental cover. It is highly likely that garden condition is an important aspect for wetland connectivity for frogs and turtles and the reason it has not been shown in this study is because it is an artefact of the sampling technique as outlined above. Therefore residents gardening choices are still an important consideration in wetland connectivity.
4.3 How is connectivity between wetlands influenced by residents gardening choices?

Even though only a weak relationship between garden condition and the presence of wetland species has been identified in this study, it is important to know residents’ gardening choices and the potential impact they may have on wetland species.

Residents gardening preferences are influenced by social and cultural factors (Kurz and Baudains 2010). Gardening choices may be influenced by a range of factors including home ownership, time they spend in the garden and its importance to them and membership in a local environmental group.

People tend to have a strong attachment to their home if they own it and the garden is often considered an extension of the home which gives the owner the responsibility to create and maintain it (Gross and Lane 2007). A majority of the respondents (68.22%) own their own homes; this is of importance as some participants living in rented properties commented that if they owned their home they would be willing to make changes to attract native species. The fact that such a large proportion of residents own their own home in this area means that they have the ability to change their garden if they so desire, whereas tenants of a rental property do not necessarily have this option.

The respondents also have a long period of residency in the area (average 12.9±1.4 years). Since on average participants have lived in the area for a long period of time it is likely that their garden composition reflects them and their demographics (such as age and income), (Kendal et al. 2010), rather than that of the previous occupants. Furthermore, it could be argued that the likelihood of a garden being well established and containing larger or more fully grown plants is greater in an area where residents have been living for a longer period of time. This may have an impact of how the gardens are used by local fauna. Habitat resources that have been present for a long period of time may have become part of animals home ranges. However this resource could be removed by subdivision or new roads (Trombulak and Frissell 2000).

The time that residents spent in their garden could directly influence whether they had seen any wetland species. A majority of the residents (81.1%) spend less than 5 hours work/leisure time in their garden a week. On average, however, respondents were likely to report seeing a frog in their garden. Even though respondents indicated that they did not spend much time in their garden over a week they did indicate that (on average) they viewed the time they spend in their garden positively. A majority of participants indicated that they took note of the wildlife seen in their garden. There
was, however, a mixed response to the ‘I love gardening’ question and almost the entire pool of participants were not involved in a community based environmental group or project.

These responses help characterise the respondents as people who, whilst they do not spend much time in their garden, tend to enjoy the time they spend in their garden and take note of wildlife they see. The respondents were evenly split between loving gardening or not loving gardening. Only three respondents were members of a community based environmental group or project. These factors may influence the gardening practices and attitudes of the respondents.

The choices of residents and their attitude towards the environment and their local wetlands could strongly influence wetland connectivity in the study area. The fact that colour (37.4%) and aesthetics (35.5%) were the main reasons for plant choice is not surprising, as it is highly unlikely that a participant would put something that that they think is ugly into their garden. People appear to be adopting the use of water wise and durable plant species. Since a number of water-wise plants are native species it would an added incentive to inform residents that using these would not only save water but provide habitat for local wetland species (especially if they in the 0-0.5m range) (Windust 2003).

Just over half of the respondents indicated that they do not use pesticides in their gardens. This is interesting and very important, because this will benefit frogs and turtles within the area. Pesticides have been attributed to declines in populations of frogs in the Eastern States by adversely affecting tadpole viability. Additionally pesticides can affect adult frogs as well; however the effects are less severe (Broomhall 2004; Davidson et al. 2001; Hamer et al. 2004; Mann and Bidwell 1999). The fact that the majority of respondents are not using pesticides shows that we are well on the way to encouraging the reduction of pesticide use within the survey area.

Participants were asked about their perceptions regarding ponds. The majority agreed that having a pond would help native wetland species but were concerned that ponds would attract mosquitoes. Even though majority of respondents agreed that having a pond would help native species only 26.2% of respondents have one. This could be promising if we could encourage neighbours to follow the lead of these residents as it is known that people tend to make changes to their gardens to conform with others around them (Zmyslony and Gagnon 1998). The perception that ponds attract mosquitoes, however, could be a deterrent. Other deterrents could include concerns for young children’s safety (as one participant indicated) as well as too much maintenance required. With the correct construction, maintenance and certain native fish, ponds can provide good habitat for wetland species with little or no mosquito infestation. This needs to be communicated more clearly to residents in the area.
Majority of respondents’ gardening choices include leaving fallen leaves to mulch gardens and not leaving dead wood lying around their garden. In an urban environment which is lacking in substantial amounts of water it is good to see that people are mulching their garden to retain moisture. Fallen leaves and mulch are also important for frogs for protection (Bamford 1992). Dead wood is important because it provides a hiding spot for native species (Lindenmayer and Burgman 2005) however, on average participants are removing dead wood from their garden. Possible reasons for this include the safety hazard, potential termite infestation or the fact that fallen branches do not fit within the gardener’s aesthetics (Baldwin et al. 2008).

A majority of participants remove weeds from their gardens. As particular weeds were not named, however, it could be possible that some people are removing what they perceive as weeds but are actually self sown native species. Doody et al. (2010) found that native plants were dispersing into residential gardens but were usually removed by residents who were interested in native gardening but lacked knowledge of native plants or by residents who felt that seedlings were out of place. Whilst the likelihood of self sown natives in Western Australia is low it would be interesting to conduct further research into the behaviours of Australian residents towards weeds.

Pets (especially cats) are considered to be predators of many native species (Barratt 1998; Calver et al. 2007). Just over half of respondents indicated that they kept their pets inside at night time. A few respondents indicated that they had chickens, birds and rabbits which they did not keep inside during the night. It is unlikely that these pets are of concern to frogs or turtles moving through the area. As previously mentioned there were some concerns about the reliability of the responses for this question. Whilst it is encouraging that half the respondents keep their pets inside at night-time a follow-up survey would be required to clarify the response to this question.

Majority of residents agreed that their garden is a valuable habitat resource. The question “my garden is designed to be a habitat resource”, however, had a non-response rate of 14.95%. The non-response rate may have been caused by the fact that nowhere within the survey was the term “habitat resource” defined. It is believed that this term caused confusion for some of the respondents. It would be beneficial to re-ask this question after defining habitat resource.

A minority of respondents designed their garden as a habitat resource, this may be linked to the mixed response to the question asking residents if they are able to manage their garden to provide habitat for local species. This shows that some residents feel that they can manage their garden to provide habitat for local species but choose not to whereas some residents do not have the ability or knowledge to do so.
These responses are at odds with the fact that the respondents agreed that their choices they made in their garden did make a difference to biodiversity and that their garden was a valuable habitat resource. This shows that whilst respondents agree that their gardens are important for local species they have not necessarily done anything to improve their gardens for these species. The respondents agreed that the environment in their area was healthy. Furthermore, the majority of the respondents strongly agreed that wetlands provide important habitat for native species. Even though this pool of participants is not biased by being members of an environmental group they still all have an extremely positive attitude towards their local environment. We should use this knowledge to encourage native gardening with specific focus for wetland species. From this we could greatly improve the urban residential garden resource.

Wetland connectivity can be supported by the residents of this study site. This is through their gardening choices such as their plant choices (native water wise vegetation), reduced pesticide usage and positive views of ponds. In addition, by using the positive attitudes and perceptions that respondents have towards the local area’s biodiversity and wetlands it may be possible to encourage residents to garden with a specific focus on wetland species. If incentives were available to allow for the planting of native shrubs and enough people participated it could increase the connectivity in the area.
4.4 Barriers in the urban environment

Fences immediately come to mind when barriers are mentioned. Unfortunately due to the data collection method it was not possible to identify all the fences in the back gardens that act as barriers. It is recommended that further research into the ability of the back garden fence to prevent connectivity is explored. However, a novel approach to solving the fence issue might be to encourage residents to drill holes to allow wildlife passage through them.

It was unknown whether the stormwater drainage system links the two wetlands outlined in section 2.4.1. If it does, this potentially could provide a safer route of travel for frogs and turtles. While it is known that roads impact on the movement of these wetland species (Trombulak and Frissell 2000; Jaeger et al. 2005) further research in the study area needs to be carried out on roads before the impact of these on the local wetlands species is understood.

Subdivision of residential blocks removes space covered by garden and replaces it with house and pavement. This decrease in block size leads to a decrease in garden size or the absence of a garden, as house size tends to remain the same. Subdivision may be influencing the garden structure leading to an increase of ratings three and four in the study area. The increase in these ratings indicates that there is an increase in the percentage cover of pavement. Even though no link between the ratings and wetland species could be established (and there was no identifiable effect of subdivision on frogs and turtle presence) this subdivision is still likely to be detrimental to connectivity in the study area. An increase in barriers such as fences and walls naturally follows from subdivision, as a single block is divided into two and people often put up screens for privacy when in close proximity to their neighbour. The impacts of subdivision on wetland species currently require more research.

Ways to offset the impacts of subdivision include conservation subdivision design. Conservation subdivision design clusters housing units to allow the preservation of ecological features, decreases the impact of stormwater on natural systems and minimises hard surfaces to decrease runoff and need for stormwater drains (Bowman and Thompson 2009).

Whilst this is not an option for residential areas that have already been built, the subdivision design ladder contains principles that can be applied in existing areas. Some design features that could be applied include vegetated traffic islands (or verge areas), reduction of the widths and lengths of paths, roads and driveways, open spaces connected (e.g. public parks) and clustering of subdivision lots (Bowman and Thompson 2009). These kinds of approaches along with encouraging residents to plant shrubs (particularly those below 0.5m) could offset the impact of subdivision.

There was no relationship between wetland species presence and the ratings; due to this the path of least resistance could not be identified. This lack of relationship may be an artefact of data collection.
4.5 Potential bias and limitations

The potential for data collected in this research to be biased by utilising presence/absence information provided from residents in the area, rather than collecting this information in an ecological survey is explored below. It is considered that the bias for this data is minimal.

There are a number of reasons why the risk of such bias is considered low for this research. The door-to-door knocking census method ensured that survey response was not reliant purely on participant motivation, so that not only residents sympathetic to wetlands but also those who might otherwise not respond were captured in the data set. This also addressed the related potential bias that residents who had specifically tailored their gardens for native species could be more likely to participate (Neuman 1999). The respondents were quite evenly spread through the area. There was no obvious bias operating on participant involvement (Figure 2.1). This is further supported by the results of a t-test which showed that the front gardens of respondents and non-respondents were not significantly different (p-value=0.358).

Another potential bias that can result from for door-knocking is the increased likelihood of participants being elderly, unemployed or inactive people who tend to stay at home (Encyclopedia of epidemiologic methods 2000). This risk was addressed by door-knocking multiple times at different times of day and on weekends. While the demographic information collected does indicate a large proportion of over 55’s in the sample (42.99%) this only varies by 5% from the ABS 2006 census data for the local government area.

Additional data indicating there was no significant respondent bias are the chi-square tests run for the five sections of the study area for frogs and turtles (see Figure 3.7 and Figure 3.8). If there was respondent bias we would expect the same result for both frogs and turtle (random reporting linked to participant desire to ‘please’ the researcher) (Brace 2004). The chi-square tests, however, showed that there was a relationship between the section and presence of turtles, whereas, for frogs and sections there was no relationship. Therefore any respondent bias can be assumed to be minimal for this set of data.

The utilisation of residents as a time-integrated data set is of great value because it provided a view of the region over a year thus decreasing the amount of time required to do such a study. There is, however, a limitation caused by using this method. Frog presence was collected for frogs as a whole rather than for individual species. As a result it is not possible to comment on the effect of urbanisation for frog species, thus findings can only be applied generally. Whilst this is not ideal, more detailed data collection to the species level was beyond the scope of this study.
Furthermore, this study appears (to our knowledge) to be the first foray into using urban residents survey responses to provide ecological data for the presence/absence of frogs. Future research will need to explore the best methods and scale of reporting error for utilising residents ‘non-expert’ monitoring to identify specific species presence/absence. Whilst there were a number of factors that could have potentially biased this study it is considered that the bias will be minimal.

### 4.6 Future research and recommendations

Future research is required in a number of areas. These are explained below in order of priority.

Significant research is required into the specific habitat requirements for all Western Australian frogs and the turtle *C. oblonga*, as currently there is insufficient specific information regarding habitat and life history. This restricts in-depth studies on the effects of the urban environment on frog populations and *C. oblonga*.

The role that humans play as vectors for the movement of turtles through the study site and potentially through other urban areas also requires further research. It may be possible to find a way for residents near wetlands to assist the movements of turtles so that they are less vulnerable to the impacts of roads and predators. For example, residents assisting the movement of turtles across roads to prevent road kill.

Turtles are more destination driven, with majority of turtles found in a line of shortest distance and most direct route between wetlands, whereas, frogs are spread throughout the area and were not clustered in specific regions of the study site. This indicates that frogs are influenced both by distance and habitat considerations. Further research is required into the influence of garden habitat and subdivision on the presence/absence of frogs and turtles.

Respondents in this study indicated positive attitudes towards the environment, however this is not always reflected in their gardening choices. A number of participants indicated that they would like to make their gardens more native species friendly but did not have the time, money or ability to do so. It is recommended that the residents are offered educational material and an incentive from the council to change their gardens to habitat gardens. If the council could provide information to the residents regarding companies that provide these services or organisations that assist with providing information about doing this, this problem could be overcome. If a number of residents change their gardens to habitat gardens it may encourage others in the area to do the same.

From the results of this study it is recommended that residents interested in habitat gardening are guided and encouraged to increase ground cover such as leaf litter and shrubs. Additionally providing residents with information regarding ponds and their appropriate construction and care would be of great value. There is also a need to encourage local councils to take the initiative to plant shrubs on
the verges around the suburban area as this would be highly beneficial for frogs moving through the environment.

Chapter 5 Conclusions

Wetland species are present within the urban environment and it has been shown that some types of habitat provided by residential gardens may assist them. Resident’s gardening practises also have the ability to assist the movement of these species.

Both frogs and turtles were present in the study site and had an inverse distance relationship with wetlands in the urban environment. This would not be the case for frogs, however, if they were in a natural environment (Bamford 1992) indicating the urban environment does hinder the movement of frogs. Residential gardens with shrubs below 0.5m were more likely to increase the presence of frogs than those residences without this cover.

Turtles were moving through the urban environment; specifically through section C which is the shortest distance between the wetlands. This section also provides a direct path as a road connects the two wetlands. Residents indicated they assisted turtles with their movements between wetlands and over roads. This may be of great value to turtles (e.g. preventing their death on roads) or it could be detrimental (e.g. preventing turtles from laying their eggs). The impact of this is currently unknown.

Subdivision is creating a shift toward greater paving cover in gardens. This is likely to be detrimental to connectivity in the study area. Residential gardens do provide habitat for frogs and turtles. While a positive association between the ‘higher’ ratings and the presence/absence of these wetlands species could not be shown, this was probably being masked by the small number of high value habitat gardens. It is still unknown what effect fences have on the movement of frogs and turtles. This is one area in particular that needs further research.

Respondents in the study area have a generally positive attitude towards wetlands and the environment, however, this is not always reflected in their gardening choices. Encouraging residents to put in habitat gardens would assist wetland connectivity.
Table 5.1: Overview of the attributes of the urban environment identified in the study area that assist or hinder wetland connectivity

<table>
<thead>
<tr>
<th>Assists connectivity</th>
<th>Hinders connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shorter distance</strong> between wetlands.</td>
<td><strong>Greater distance</strong> between wetlands.</td>
</tr>
<tr>
<td><strong>Beneficial ground cover</strong></td>
<td><strong>Unknown factors</strong> leading to the inverse distance relationship for frogs.</td>
</tr>
<tr>
<td>• Shrubs below 0.5m</td>
<td></td>
</tr>
<tr>
<td>• Leaf litter</td>
<td></td>
</tr>
<tr>
<td>• Mulching (more research required)</td>
<td></td>
</tr>
<tr>
<td>• Potentially long grass</td>
<td></td>
</tr>
<tr>
<td><strong>Humans assisting the movement of turtles</strong></td>
<td><strong>Roads</strong> (Eigenbrod et al. 2008).</td>
</tr>
<tr>
<td><strong>Accessible travel paths</strong></td>
<td><strong>Fences</strong> (level of hindrance unknown this area requires more research).</td>
</tr>
<tr>
<td>Such as the road along section C for turtles</td>
<td></td>
</tr>
<tr>
<td><strong>Limited pesticide usage</strong></td>
<td><strong>Domestic pets</strong> (requires more research).</td>
</tr>
<tr>
<td><strong>Resident’s perceptions</strong> that ponds and local wetlands are important for wetland species.</td>
<td><strong>Subdivision</strong> (potentially, further research required).</td>
</tr>
</tbody>
</table>

The overall findings (Table 5.1) can be used as education tools, to indicate to the public what they are doing to hinder connectivity and how they can assist connectivity in their local area. Additionally this can be used to develop management guidelines that could be used to inform managers of current urban developments about how they can limit the hindrance to connectivity within their area. It will also provide useful guidelines for existing councils who want to improve connectivity in their area.

Ideally, the path of least resistance between wetlands that might promote wetland connectivity would have been identified but due to the sampling regime this is not possible for frogs. From this study, however, we have been able to identify benefits and shortcomings of the residential landscape for wetland fauna and that turtles move along the shortest, most direct path between the two wetlands.
Reference List


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MacIntyre, E. Unpublished Data.


**Personal Communication**

Dr Jacqueline Giles, October 2010
Appendix One

Wetland Connectivity: The role of vectors in dispersal in the urban environment

Urbanisation has been increasing within modern society for many years. Even nations such as Australia hold an increasing proportion of their population within their cities. This has lead to an increase in the size and distribution of the urban environment (Amezaga et al. 2002). This review will define the urban environment as the urban sprawl most often associated as suburbia. This increase in suburban areas may not bode well for wetlands. These inland waters have often been likened to island habitats. These ‘island’ habitats are small isolated pockets of remnant vegetation and water within which some wetlands species may be able to live (De Meester et al. 2002).

Currently these wetlands are islands in a sea of suburbia; due to this these wetlands are often managed as isolated sites. This type of management may be detrimental to some of the species that utilise these wetlands. Many species rely on wetlands for parts of their life cycle and some may be able to survive and maintain a sustainable population within one wetland. However, it has been shown that some species need to move between wetlands to sustain their population or to access resources such as mates or specific habitat required for breeding. Species that need to move between wetlands are called meta-populations (Lookingbill et al. 2010; Amezaga et al. 2002; Taylor et al. 1993).

Meta-populations are “a set of local populations which interact via individuals moving between local populations” (Lindenmayer and Burgman 2005 p441). These species live within isolated patches of suitable habitat that interact with each other through migration. To qualify as a meta-population the species must be restricted to patches surrounded by unsuitable habitat. This unsuitable habitat must not be so hostile that it prevents all migration, but enough so that it does not qualify as habitat as well. These patches may be at risk of extinction and there must be dispersal and colonisations between patches (Hanski 1999; Lindenmayer and Burgman 2005). The movement of species between these habitat patches is termed connectivity.

Connectivity is considered to be a property of the entire landscape. Usually it is quantified by the extent of movement of organisms within the landscape. Most definitions of connectivity explain that the landscape itself may encourage or hinder the movement of organisms (Crooks and Sanjayan 2006; Moilanen and Hanski 2006). Movement of species can occur via overland travel or through vectors. In this review a vector refers to a dispersal vector by which an organism or its propagules may spread. There are many different vectors such as wind, water, soil, fire and animals (Cousens et al. 2008). These vectors may be capable of connecting isolated habitats. Connectivity is species specific thus it is hard to assess connectivity for every single species within an environment (Taylor et al. 2006).

Recently there has been a greater focus on connectivity through the urban environment. There has been significant research into connectivity for terrestrial species, but there has been less focus on wetland and aquatic species. Connectivity within the urban landscape could be vitally important because some species exist as meta-populations. Connectivity and the ease of movement between these patches directly influences the viability of these meta-populations (Rudd et al. 2002). Therefore it is possible that the urban environment may detrimentally impact these species.

As mentioned previously connectivity is species specific. But it is important to look at a range of species when assessing connectivity (Taylor et al. 2006). For this review species have been grouped into the following guilds, flora, insects, frogs and turtles, and birds. These groupings (into guilds) have been created for a number of reasons; the first is that they all tend to have similar modes of movement or dispersal. Secondly identifying vectors used and the distance that every single wetland species travels would be extremely difficult as there are gaps in the literature. This review will focus on wetlands species guilds, the dispersal vectors that they utilise and how these dispersal mechanisms influence movement through the urban environment.
Flora

Plants are a vital component of a wetland ecosystem. They not only form the base of the food web but assist in other vital functions such as providing a complex structure to the wetland which forms micro and macro habitats. These types of habitats assist in meeting the needs of invertebrates, fish, frogs, turtles and birds (Boulton and Brock 1999).

Despite the isolation of aquatic wetland plants, they are cosmopolitan and have greater distribution than terrestrial plants. This is often considered as evidence for constant dispersal of aquatic plants, however, other elements such as consistent aquatic environments, selection for taxa that are stress tolerant, phenotypic plasticity, local dispersal of asexual propagules and long distance dispersal of sexual propagules also play a major role in this widespread distribution (Santamaria 2002). The dispersal of seeds affects both genetic diversity and the distribution of species (Santamaria and Klaassen 2002).

Wind and water dispersal

Many plants have strategies that assist in the dispersal of their propagules. Plants that utilise wind dispersal may often have fruit or seeds that have the ability to be caught up in the wind. Some have modified seeds such as dust seeds or winged seeds. The spread of these seeds, however, is limited to fairly close areas as long distance dispersal by this method only common in a few species (Raven et al. 2005; Grime 2001).

The quantity of seeds found in waterways for dispersal can be greater than the amount trapped by the wind (Neff and Baldwin (2005). This can be an advantage to aquatic flora found in floodplains and marshes that can be connected by floods or overflow. Whereas other wetlands may not have any water connection at all, like the study site (Boulton and Brock 1999). In urban areas the water regime may be significantly altered preventing dispersal by this method. It is highly unlikely that the two wetlands in the study site will ever be connected by water flow

Animal vector dispersal

Birds are an important vector for the movement of plant propagules between wetlands. Seeds of aquatic plants can be carried by bird in two ways. Externally (epizoochory or ectozoochory) which usually involves the carriage of propagules on feet, bills or in feathers. Alternatively the propagules can be carried within in the digestive tract (endozoochory). Certain seeds require passage through the gut a bird to trigger germination. This makes endozoochory a very important process (Figuerola and Green 2002; Charalambidou and Santamaria 2002).

Each of these different transport types has different limits. Endozoochory is usually highlighted as the type of transport that allows long distance movements however; these are purely incidental events. As migration events are not synchronised with reproductive events in the plants, most propagules can not be transported during birds breeding migration. If the anatidae (swans, ducks) were to be carrying these propagules internally they will empty their gut contents within 300km of departure point, thus limiting the distance that these propagules can be dispersed. Unlike endozoochory, however, epizoochory is in synchronicity with the moult migration and the reproductive events in many aquatic plants (Clausen et al. 2002). Epizoochory is restricted by the habitat to which the birds move as the new habitat may be too dissimilar to the original habitat to survive. Within the urban environment it could be argued that some of the anatidae at the very least would be able transport seeds via endozoochory and epizoochory between wetlands. Within this small scale it increases the chance of survival of the propagules as there will be similar climatic conditions.

Due to the cosmopolitan nature of many aquatic plants and the fact that this study area has no record of water connection between the two wetlands it is possible that urban environment is not directly impacting the dispersal of these propagules of aquatic plant propagules.
Insects

Insects are an amazingly diverse group of organisms which utilise numerous methods of dispersal. Insects that are associated with wetlands tend to have at least part of their lifecycle in aquatic form. These aquatic organisms often have to rely on either active flight or passive dispersal (De Meester et al. 2002).

Active Flight

There are many different insects that fly under their own power; these can be generically grouped into mosquitoes, midges, dragonflies, damselflies and caddisflies. The distances that each of these groups can generally cover will determine if the urban environment has a role in the connectivity of wetlands for each species. It is important to note that all of these insects have an aquatic larval stage therefore water will be always be a requirement for breeding (Liehne 1991; Theischinger and Hawking 2006; Kovats et al. 1996).

Many species of mosquitoes (subfamily Culicinae) will opportunistically breed in any standing water around the suburban home. They are also capable of travelling great distances, usual dispersal range from the breeding site ranges from 5km to 10km (Liehne 1991). Another family within the insects which also has a large dispersal capability are the caddisflies (Trichoptera). Their range of travel is 650m to 1845m, which whilst significantly less than mosquitoes is still fairly substantial (Kovats et al. 1996). These two groups can usually travel in excess of 1km. However, they do require a water source within this distance that is suitable for breeding. Therefore in the cases of Culicinae and Trichoptera it is unlikely that the urban environment has a significant negative impact on these groups at population level. This is because they are capable of moving between wetlands if the urban environment does not provide suitable habitat or if they require additional habitats for other parts of their lifecycle.

Dragonflies and damselflies (order Odonata) on the other hand have a tendency to not move more than 500m maximum from their wetland of origin (Theischinger and Hawking 2006). The particular study site chosen has a distance of 510m between the wetlands, thus it is possible that movement between the wetlands within the study site may occur.

Midges have the most limited range, the species Rhopalomyia californica will only travel approximately 1.7m in its lifetime (Briggs and Latto 2000). This suggests that midges rely on other forms of dispersal during the aquatic stage of their life cycle and that they are capable of completing their entire lifecycle within one wetland. Thus connectivity is not essential for the successful completion of the midge lifecycle.

Passive Dispersal

Some invertebrates are capable of dispersing passively by the use of resting propagules. Cladocerans, copepods, anisotracans, rotifers and bryozoans are usually capable undergoing diapause during particular stages of their life cycles. This diapause allows for the production of resting propagules (also known as resting eggs) which are resistant to hostile environmental conditions. These propagules accumulate in the sediments not dissimilar to plant seed banks. These propagules may undergo dispersal or to start growing after extreme environmental conditions (Amezaga et al. 2002; De Meester et al. 2002; Munoz 2010).

Waterbirds have been indicated as one significant vector in the passive dispersal of the resting propagules of these invertebrates. These birds can disperse propagules through epizoochory or endozoochory. Endozoochory allows for the transport of propagules hundreds of kilometres (Charalambidou and Santamaria 2002; Figuerola and Green 2002; Green et al. 2002; Santamaria and Klaassen 2002).
Dispersal can also occur for water bodies connected by temporal or permanent water flows. This allows not only the spread of resting propagules but living individuals as well (De Meester et al. 2002). Dispersal through water flow can occur on flood plains, marshes or via drainage, however as previously mentioned there is no water connection between the two wetlands in the study site. Dispersal could also occur on land bound vectors such as mammals, however, at this stage there is very limited research regarding the dispersal of aquatic invertebrates by mammals.

One question raised consistently in the literature is the genetic importance of dispersal in these invertebrates. As this migration a passive product of the diapause life cycle and the creation of propagules. However, this dispersal ability coupled with the ability to colonise newly created ponds or wet areas is a significant advantage (De Meester et al. 2002). Until recently was assumed that there was little genetic speciation between geographic areas. Now it is thought that geographic speciation can occur over wide geographic ranges (Munoz 2010). Therefore these passively dispersed organisms disperse so easily that wetlands within the same region can have homogenous genetic structures. Additionally connectivity via birds is not prevented by the urban environment. There may be some impact by humans on connectivity via water but this does not seem to be a problem given the limited genetic speciation at local scale.

**Frogs and Turtles**

Unlike flora and insects frogs and turtles rarely rely on vectors. Thus frogs and turtles may need to move between suitable habitats via overland travel. This introduces the possibility of a whole suite of barriers within the urban environment.

**Turtles**

In Perth there are two species of turtles the Western Swamp Tortoise (Pseudemydura umbrina) and the Oblong Tortoise (Chelodina oblonga). P. umbrina was at one stage thought to be extinct; however, it was rediscovered and now exists in three reserves. It is currently listed as endangered under ANZECC (1991). These tortoises have no fixed home range and it is believed before the fragmentation of wetlands occurred there was movement between wetlands. As in the reserves they have been known to travel up to 600m from their wetland (Burbidge and Kuchling 1994).

The C. oblonga can often be found in permanent and seasonal wetlands, they have a widespread distribution throughout the Perth area. The main movements noted in this species are the movement of females to find suitable habitat for egg-laying, the distance travelled can be up to 500m from the wetland. Use of gardens as nesting sites can occur, especially if the properties are on higher ground (Giles 2001). Similarly to the P. umbrina the C. oblonga whilst mostly aquatic will leave wetlands not only to nest but sometimes to disperse. Dispersal and migration occur when the turtles seek new habitats, most likely in an attempt to access new resources of food, this will often occur in less mature turtles (Giles 2001; Roe et al. 2009). This means that urbanisation between wetland chains could be a significant barrier to the movement of turtles.

Roe et al. (2009) demonstrated that wetland complexes need to be conserved as a whole for turtles. This is due to the high migration rates between wetlands found in some species. Unfortunately migration between wetlands may no longer possible for wetlands within the urban areas. It has been shown that there is a proportion of turtle killed on roads (Giles 2001). This may mean that urban areas have a detrimental impact on both their numbers (i.e. decreased ability to get to new food sources) and on their genetics (i.e. isolation of small populations leading to inbreeding).
Frogs

There are many different species of frogs (anurans) found within Perth, limited research has been conducted of their movements within the metropolitan area. Within the anurans of Perth some species are specialised for different functions e.g. the tree frogs have adaptations for climbing whilst others like the Myobatrachus gouldii crawl along the ground and burrow. Bamford (1992) conducted a survey for M.gouldii, Heleiopourus eyeri and Limnodynastes dorsalis by setting up capture sites at increasing intervals away from a wetland. It was found that there was no correlation between the capture rate of the species and the distance of trapping site (which were up to 2500m from the wetland). This correlates with Lemckert (2004) whose summary of all research into anuran movements found that mean home range could vary from 6.3m2 to 5099m2 and more importantly the distance moved to new terrestrial habitats could vary from 385 to 1810m. This information supports a number of facts; the first is that there is a large variation in distance travelled between different species; the second is that many species of frogs are capable of moving large distances. Such ability would allow them to travel through the urban environment.

Parris (2006) found that within urban areas anurans do act as meta-populations. These meta-populations increase with species richness the larger the habitat area is but decrease in species richness the more isolated the habitat is. Increasing isolation is one problem to anurans as an increase in isolation means a decrease in migration to the area, decreases in the new genetic material brought in by migrants. Increasing isolation in the urban area is due to an increase in barriers that limit anuran movement.

One barrier that is believed to greatly affect anuran meta-populations is the habitat isolation of their habitat by roads. The movement of breeding anurans and dispersal of young into new habitat can be dramatically decreased by mortality on roads (Parris 2006; Hamer and McDonnell 2008). Farhig et al. (1995) showed that density of anurans is significantly affected by traffic mortality. Additionally the road size and traffic load is also believed to influence anuran mortality. This variation in traffic density and road size and its effects on anurans has not yet been fully explored. This information is vitally important because more research into this area could allow the rating of roads in terms of traffic density and their potential to effect anuran movement.

Other barriers to the movement and the dispersal of anurans through the urban environment are introduced predators. These predators may be aquatic ones that predate on eggs laid in ponds. These are often exotic fish such as Gambusia holbrooki and Cyprinus carpio which feed on anuran eggs and tadpoles. These introduced species are capable of eradicating entire tadpole populations very quickly. This prevents the colonisation of these home-owned ponds by frog populations; this potentially decreases the possibility of dispersal of young within the meta-population (Anstis 2002; Hamer and McDonnell 2008). Anurans do exist as meta-populations, however, with increasing urbanization it is highly likely that connectivity is being reduced and anurans are being prevented from travelling between suitable habitats.
Water Birds

As has been shown through this literature review water birds are of importance for the dispersal of many aquatic organisms, however, when acting as vector and carrying organisms internally they are capable of transporting these organisms’ extreme distances. Within a local scale, however, we will explore whether connectivity of wetlands for birds will affected by the urban environment. The two main methods of travel for water birds are flight and overland travel.

Flight

Majority of birds are capable of flight and in fact all water birds found within Australia’s wetlands systems can fly. Increasing urbanisation has lead to a loss in suitable habitats for not only local birds but migratory birds as well. The loss of habitat can lead to exceeding the carrying capacity of remaining wetlands during migration stopovers and this can lead to an increase mortality (Amezaga et al. 2002).

Urban areas may only have limited affect on water birds, it has been shown that there is often no correlation between the survival of males, females and nests and the amount of urbanisation within the landscape (Rodewald and Shustack 2008). It is suggested that if the habitat does not satisfy the birds needs then they can go to other wetlands instead. Therefore whilst the urbanisation may impact birds breeding and feeding habitat, it may not necessarily impact the connectivity of wetlands for them. Unfortunately there is little research on the effect the urban environment on wetland connectivity for waterbirds at this stage.

Overland travel

There is limited information in the literature covering the overland travel of most water bird species. Thus this section will focus on the overland travel of the Mallard (Anus platyrhynchos) as an example. This is because like many water birds that breed in Australia it has broods that travel ‘overland’ (on foot) for the first few months after hatching. Mallards utilizes a number of wetlands within the brood-rearing period (Dzus and Clark 1997) whilst this may not be the case with all water birds that breed within Australia it does give insight into the issues associated with overland travel.

The mallard has a tendency to prefer to seasonal wetlands and emergent vegetation, this forces the parent Mallards and the ducklings to move overland to gain access to better source of food or shelter (Dzus and Clark 1997; Stafford and Pearse 2007). The dangers for overland movement are high for ducklings but urban environments increase the risk even more due to extra predators and roads. The older the duckling is the more reduced the chance of death during overland travel is (Krapu et al. 2006). Loss of multiple broods within a species could potentially have catastrophic effect on populations of water birds. Therefore connectivity within the urban environment may play a significant role in the population structure of water bird species that travel overland with their broods.
## Summary

Below is Table One which provides a summary of the information presented in this literature review in terms of species guild, vectors, need to travel between wetlands, how the urban environment can interfere with movement of guilds between wetlands and a rating of the ability of the urban landscape to prevent connectivity.

Table One: Summary of species guilds and their dispersal vector. This also summarises from literature review the need for travel and whether the urban environment will interfere with this movement.

<table>
<thead>
<tr>
<th>Species Guild</th>
<th>Dispersal vector</th>
<th>Need to travel between wetlands?</th>
<th>Why do/don’t they need to travel?</th>
<th>Potential for the urban environment to interfere with movement</th>
<th>Rating of the ability of the urban landscape to prevent connectivity?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flora</td>
<td>Wind and water</td>
<td>No</td>
<td>Can usually complete their lifecycle within one wetland.</td>
<td>The alteration of water movement between wetlands or birds being prevented access to wetland</td>
<td>Medium</td>
</tr>
<tr>
<td>Birds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Insects</td>
<td>Active flight</td>
<td>No</td>
<td>Can usually complete their lifecycle within one wetland.</td>
<td>The alteration of water movement between wetlands.</td>
<td>Low</td>
</tr>
<tr>
<td>Water flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Medium</td>
</tr>
<tr>
<td>Birds</td>
<td></td>
<td></td>
<td>Also minimal genetic differences between other local wetlands</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Frogs and Turtles</td>
<td>Overland travel</td>
<td>Yes</td>
<td>To maintain sustainable population. To gain access to suitable habitat for breeding and extra resources.</td>
<td>Yes, roads linked to decrease in anuran movements. Increased predation from introduced domestic species.</td>
<td>High</td>
</tr>
<tr>
<td>Birds</td>
<td>Overland travel</td>
<td>Yes</td>
<td>For extra habitat and food</td>
<td>Yes, species that travel between wetlands with young can be impacted.</td>
<td>High</td>
</tr>
<tr>
<td>Flight</td>
<td></td>
<td></td>
<td>For migration, suitable habitat</td>
<td>No, removal of wetlands or a decrease in the surrounding habitat may adversely affect some species.</td>
<td>Low</td>
</tr>
</tbody>
</table>
Conclusion

The urban environment can influence connectivity for some species guilds which are using specific vectors. As indicated by figure one overland travel is the most likely to be adversely impacted by the urban environment. Factors not discussed within this review could also affect connectivity. For example the guilds of frogs and turtles, and birds may have specific requirement for movement such as close wet patches such as ponds or dense shrub cover. There is limited literature in this field and thus it requires more exploration.

Overall overland travel appears to be the most at risk from the urban landscape and this should be explored fully.

Reference List


Appendix Two

**Demographic details:** Please circle the appropriate category or answer in the provided space

<table>
<thead>
<tr>
<th>Age</th>
<th>18-25</th>
<th>26-35</th>
<th>36-45</th>
<th>46-55</th>
<th>over 55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Male</td>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>&lt;$15,000</td>
<td>$15,000- $30,000</td>
<td>$30,000- $45,000</td>
<td>$45,000- $60,000</td>
<td>&gt;$60,000</td>
</tr>
<tr>
<td>Education qualification</td>
<td>Year 10</td>
<td>Year 12</td>
<td>TAFE certificate</td>
<td>Bachelor Degree</td>
<td>Postgraduate (Masters, PhD)</td>
</tr>
</tbody>
</table>

Do you rent or own the house you are currently living in? Rent  Own
How many years have you lived in this house for? ____________________________
How long do you think you will continue to live here? ____________________________
What pets do you have? ______________________________________________________
How many people live in your household? ____________________________

**Please write your answer in the space provided, or circle the appropriate category**

1a. Who makes decisions about or is responsible for your garden? ____________________________

1b. How much work/leisure time do you spend in the garden each week?
0-1 hours 1-5 hours 5-10 hours 10-15 hours 15-20 hours >20 hours

1c. What helps you choose a particular plant for your garden? (Circle all that apply)
- colour
- low cost
- available
- garden design
- aesthetic
- Gift
- habitat
- other (please list)

1d. Do you have plants flowering all year round in your garden? Yes  No

1e. Do you have a garden pond or wet area in your garden? Yes  No

1f. Do you use pesticides in your garden? Yes  No

If yes, what types of pesticides do you use? ____________________________

1f. What changes would you be willing to make to potentially increase the amount of wetland wildlife visiting your garden? (select all that apply)
- Add native wetland plants to existing garden
- Plant a large area with natives
- Put a water source (pond or boggy spot) into the garden
- Not interested in making any changes

Other (please list) ____________________________
Please select yes or no for the following questions. Leave blank if not applicable.

2a) My garden is designed to be a habitat resource  
   Yes  
   No

2b) Do you use fallen leaves or other material to mulch your garden?  
   Yes  
   No

2c) Do you leave dead wood lying on the ground around your garden?  
   Yes  
   No

2d) Do you usually take note of wildlife observed in your garden?  
   Yes  
   No

(mental note, written records, photos)

2e) Do you have a mix of wildlife living in your garden?  
   Yes  
   No

2f) Do you keep domestic animals (if you own any) inside at night?  
   Yes  
   No

2g) Have you removed any known weed from your garden?  
   Yes  
   No

2h) Are you involved in a community based environmental group/project?  
   Yes  
   No

Please mark the box that most closely represents how you feel about each statement.
There is no right or wrong answer.

<table>
<thead>
<tr>
<th>3a) My own garden is a valuable habitat resource</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3b) I love gardening</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3c) The time I spend in my garden is very important to me</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3d) The environment in my area is healthy</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3e) Wetlands provide important habitat for native species</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3f) Our gardening choices are not important as long as we conserve wetlands in the area.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3g) Gardens are really mini-conservation reserves for natural flora and fauna</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3h) I would like my garden to be a habitat resource for local native species</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3i) I am able to manage my garden to provide habitat for local species</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3j) I am likely to discuss biodiversity with others in my local community</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3k) I am likely to join or participate in a local community group working towards conserving the natural habitat in their area</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3l) The choices I make in my garden make a difference to biodiversity</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3m) Having a pond in my garden would help native wetland species</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3n) Having a pond in my garden attracts mosquitoes</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

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4a) Have you seen any frogs in your garden over the last twelve months?  
   Yes  No

   If yes, how many frogs have you seen? 1  2  3  4  5  6+

   How many different types of frogs have you seen? 1  2  3  4+

   Whereabouts within your garden have you seen frogs? ____________________________

   How often do you see the frogs? ____________________________

4b) Have you heard any frogs in your garden in the last twelve months?  
   Yes  No

   If yes, can you describe the frog call? ____________________________

   In which month did you hear this? ____________________________

4c) Have you ever seen tadpoles in your pond?  Yes  No

4d) Do you keep fish in your pond?  Yes  No

   If yes, what types of fish are they? ____________________________

4e) Have you ever seen a turtle in your garden?  Yes  No

   If yes, where did you see it and what was it doing? ____________________________

   When did you see this? ____________________________
4f) Please tick all of the following boxes that apply:

i. I have:
   - [ ] Seen this bird in my garden
   - [ ] Seen this bird in my local area with chicks
   - [ ] Seen this bird in my garden with chicks

ii. I have:
   - [ ] Seen this bird in my garden
   - [ ] Seen this bird in my local area with chicks
   - [ ] Seen this bird in my garden with chicks

iii. I have:
   - [ ] Seen this bird in my garden
   - [ ] Seen this bird in my local area with chicks
   - [ ] Seen this bird in my garden with chicks

iv. I have:
   - [ ] Seen this bird in my garden
   - [ ] Seen this bird in my local area with chicks
   - [ ] Seen this bird in my garden with chicks

v. I have:
   - [ ] Seen this bird in my garden
   - [ ] Seen this bird in my local area with chicks
   - [ ] Seen this bird in my garden with chicks

Do you have any further comments you would like to make?__________________________________________

__________________________________________

Thank you for participating in this survey

Garden Zone  1 [ ]  2 [ ]  3 [ ]  4 [ ]  5 [ ]  not assessed [ ]
Survey Number______
Appendix Four

Frog species found in Wetland A and B

The table below indicates the species present at Wetland A and B, in 2010. Species located through audio sampling and spotlighting. Data part of unpublished honours thesis. Courtesy of Erica MacIntyre 2010

<table>
<thead>
<tr>
<th>Wetland A</th>
<th>Wetland B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heleiporus eyrei</td>
<td>Heleiporus eyrei</td>
</tr>
<tr>
<td>Limnodynastes dorsalis</td>
<td>Limnodynastes dorsalis</td>
</tr>
<tr>
<td>Crinia glauerti</td>
<td>Crinia glauerti</td>
</tr>
<tr>
<td>Litoria adelaidensis</td>
<td>Litoria adelaidensis</td>
</tr>
<tr>
<td>Litoria moorei</td>
<td>Litoria moorei</td>
</tr>
</tbody>
</table>