Understanding the decline of an urban turtle species: the critical role of combining ecological and social research

Caitlin Jane Bartholomaeus

B.Sc. (Honours)

This thesis is presented for the degree of Doctor of Philosophy of Murdoch University

2015
The research in this thesis was conducted under Murdoch University Animal Ethics permit RW2453/11, Human Ethics permit 2012/080 and Department of Parks and Wildlife, Western Australia Licences SF008999, SF008399 and SW015843.
Declaration

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

....................................
Caitlin Jane Bartholomaeus
2015
Abstract

Wildlife populations in urban environments face increasingly diverse pressures. Varying environmental conditions and human behaviours influence the persistence of populations. This study investigates the advantages and limitations of using ecological, social research and citizen science concurrently to develop a holistic understanding of declining populations of the freshwater turtle *Chelodina colliei* in the urban environment of Perth, Western Australia.

Ecological methods assessed population size and demographics using mark-recapture over three trap seasons and environmental conditions in five natural and seven anthropogenic wetlands, and their upland environments. Less than 27 *C. colliei* individuals were captured in 80% of wetlands; the combined function of depauperate populations, human impacts on turtle behaviour and trapping efficacy. Environmental conditions significantly differed between natural and anthropogenic wetlands, with reduced resource provision leading to a significantly smaller population size, particularly of juveniles, females and older sexually mature turtles in anthropogenic wetlands. However, the heterogeneity of wetlands confounded identification of ecological drivers of turtle demography.

Social research, using a survey of local residents (n=1842, response rate 21.2%), found that people around wetlands had positive attitudes towards *C. colliei* and wetlands, but their knowledge regarding *C. colliei* was poor, increasing the likelihood of negative interactions. Citizen science and community data identified that human/*C. colliei* encounters were with adult and female turtles and occurred within 500m of a wetland. Citizen science/community data and ecological research concurred that *C. colliei* movements reflected seasonal temperature and rainfall patterns.

The benefits of a multi-disciplinary approach to urban ecological research and the value of concurrently using citizen science and social research to understand the effect of human-wildlife interactions in urban areas was demonstrated. When populations are at the brink of extinction, insufficient data and prohibitive cost (time/money) may constrain ecological research. Citizen science, social research and community data can offset this by increasing availability of both temporal and spatial data, providing greater breadth of understanding and a more complete picture of wildlife populations in urban environments.
This thesis is dedicated to the memory of my grandparents
    Mary, Andrew, Dulcie and John.
Acknowledgements

First and foremost I would like to thank my supervisors Jane Chambers and Catherine Baudains for their support and encouragement throughout my PhD candidature. Your belief in and enthusiasm for my research was infectious and your feedback throughout my candidature has helped to shape my critical thinking, writing and research skills.

I would also like to thank a range of people who provided me with specific technical, methodological or data collection assistance along the way. Firstly, to Mirela Tulbure for her assistance in both the initial stages of this study and with the GIS components for this research. Secondly, to both Belinda Robson and Ed Chester for all the assistance they have given me including allowing us to work together for the macroinvertebrate section of this thesis. Thirdly, to Shino Hamada for taking the time to teach me the basics of turtle trapping and handling procedures during her research. Fourth, to Murray in the workshop who never complained despite how many batches of turtle trap frames he had to weld together for me. Fifth, to Geoff Syme for providing me with additional information regarding his published attitudinal scales. And last, but not least, thank you to Mark Gerlach for his extensive assistance with the terrestrial vegetation sampling.

I would like to acknowledge both the financial and in kind support that I received from the City of Cockburn. I would also like to acknowledge (in no particular order) ClimateWatch, Turtle Watch, Native Arc, the Turtle Oblonga Rescue and Rehabilitation Network (TORRN) and WildCare for working with me and providing data for the citizen science portion of this study. These groups willingness to share data was integral to this thesis and I am extremely grateful for all their help.

This thesis would not have been possible without my field work volunteers, Scott Strachan, Peter O’Toole, Gaia McNeil, Rebecca Baumgartner, Karina Preston, Kate Hutcheon, Fiona Bartholomaeus and Heather Bartholomaeus, who have my deepest gratitude for slogging through wetlands with me and for keeping me company while I convinced people to fill out my survey. A special thanks to my parents Roslyn and Michael who helped me more in the field than everyone else combined, I am more than confident that you both now know far more about Chelodina colliei than you ever expected.

Special thanks also go to Kate Hutcheon for being there for me whenever I needed help, encouragement, advice or just someone to take my mind off work— you are the best. To Scott Strachan, Peter O’Toole, Gaia McNeil, Wendy Vance, Joanna Pearce, and Brooke Shields thank you for your support and encouragement through my PhD journey.

Finally, but by no means least, thank you to my family for believing in me and for your encouragement, I am so lucky to have you all.
# Table of Contents

**Declaration** ......................................................................................................................... iii

**Abstract** ................................................................................................................................. v

**Acknowledgements** .............................................................................................................. vii

**Table of Contents** ................................................................................................................ ix

**List of Figures** ...................................................................................................................... xiii

**List of Tables** ......................................................................................................................... xix

**Chapter One - General Introduction** .................................................................................. 1

  - Freshwater turtles in the urban environment ...................................................................... 7
  - The study species, *Chelodina colliei* .................................................................................. 9
  - Distribution ............................................................................................................................ 9
  - Biology and ecology ............................................................................................................. 9
  - Populations ........................................................................................................................... 11
  - Taxonomy ............................................................................................................................. 12
  - Thesis aims and structure ................................................................................................. 13

**Chapter Two - Study sites and environmental conditions** .................................................. 15

  - Introduction .......................................................................................................................... 15
  - Methods ............................................................................................................................... 17
    - Site selection .................................................................................................................... 17
    - Site descriptions ............................................................................................................... 18
  - Water quality methods ........................................................................................................ 22
  - Water quality analysis .......................................................................................................... 22
  - Macroinvertebrate diversity ............................................................................................... 23
  - Habitat ................................................................................................................................. 23
  - Vegetation surveys ............................................................................................................... 25
  - Results .................................................................................................................................. 26
  - Water quality – measurements during trapping ................................................................. 26
Hypothesis Three ........................................................................................................... 135
Turtle Knowledge ............................................................................................................. 135
Hypothesis four .................................................................................................................. 136

Chapter Six - General Discussion .................................................................................... 139
Population .......................................................................................................................... 139
Habitat ............................................................................................................................... 146
Human/Species Interaction ............................................................................................... 148
Movement and behaviour (of wildlife) .............................................................................. 152
Building a holistic understanding of urban wildlife ....................................................... 155
Recommendations for management and future research ................................................. 156
The outcome of combining ecological and social research in determining a holistic view of C. colliei in the urban environment ......................................................... 159
Conclusion ........................................................................................................................ 161

References ....................................................................................................................... 163

Appendix One: Social Survey Instrument ....................................................................... 178
Social Survey Questions ................................................................................................. 178
Section One ....................................................................................................................... 178
Section Two ...................................................................................................................... 178
Section Three .................................................................................................................. 179
Section Four ..................................................................................................................... 180
Section Five ..................................................................................................................... 180
Section Six ......................................................................................................................... 181
Section Seven .................................................................................................................. 181

Appendix Two: Example of map provided to participants ................................................. 182
List of Figures

Figure 1.1: “Gardens as socio-ecological constructs. A conceptual framework showing the key ecological and socio-economic components impacting on private gardens at multiple spatial scales. We identify a nested hierarchy in garden management that spans three scales: (a) the individual garden or household; (b) the neighbourhood or garden ‘patch’; and (c) the city or landscape scale. In reality, many of the ecological and socio-economic factors can act at more than one scale along this continuum (e.g. vegetation structure or social status) and interactions exist between scales to illustrate feedbacks within the garden ecosystem (black arrows). Ecological factors influence socio-economic factors through the provision of ecosystem services and economic and health benefits (red arrows). Socio-economic factors influence ecological conditions via human decision-making and subsequent management (blue arrows). Research and management is necessary at multiple scales to maximise the utility of private gardens for native biodiversity conservation.” (Goddard et al. 2010, p94) Image reprinted with permission.

Figure 1.2: An example of a natural wetland, Booragoon Lake, one of the study sites.

Figure 1.3: An example of an anthropogenic wetland, Juett Park, one of the study sites.


Figure 2.2: Map of the south of Perth, Western Australia indicating locations of study wetlands.

Figure 2.3: Process of vegetation classification of RapidEye Orthorecified imagery. Urban area and the closest road to the wetland were masked along with the water. Land cover was then classified into Open sand and dirt (yellow), Trees and Sedges (dark green), Grass (green) and shrubs (aqua).
Figure 2.4: The mean pH of water in natural wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines...

Figure 2.5: The mean pH of water in anthropogenic wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines...

Figure 2.6: The mean conductivity of water in natural wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines...

Figure 2.7: The mean conductivity of water in anthropogenic wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines...

Figure 2.8: The mean temperature of water in natural wetlands in the morning (am) and afternoon (pm) over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error...

Figure 2.9: The mean temperature of water in anthropogenic wetlands in the morning (am) and afternoon (pm) over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error...

Figure 2.10: The mean DO (%) of water in natural wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines...

Figure 2.11: The mean DO (%) of water in anthropogenic wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines...
Figure 2.12: The mean turbidity (NTU) of water in natural wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines.

Figure 2.13: The mean turbidity (NTU) of water in anthropogenic wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error.

Figure 2.14: Mean pH from the twelve wetlands sampled in Spring 2013. Error bars are standard error.

Figure 2.15: Mean dissolved oxygen (%) collected at twelve wetlands in Spring 2013. Error bars are standard error. Black line indicates ANZECC trigger value for DO (%).

Figure 2.16: Mean conductivity (mS/cm) collected at twelve wetlands in Spring 2013. Error bars are standard error. Black line indicates ANZECC upper trigger value for Conductivity (mS/cm).

Figure 2.17: Mean TP (µg.P/L) value for twelve wetlands sampled in Spring 2013. Error bars are standard error. Black line indicates the ANZECC guideline trigger value for TP.

Figure 2.18: Mean TN (µg.N/L) for twelve wetlands sampled in Spring 2013. Error bars are standard error. Black line indicates the ANZECC trigger value for TN.

Figure 2.19: Mean value of Chl a (µg/L) present in twelve wetlands sampled in Spring 2013. Error bars are standard error. Black line indicates the trigger value for Chl a from the ANZECC guidelines.

Figure 2.20: Total number of macro-invertebrate taxa found at each wetland in Spring 2011.

Figure 2.21: Mean number of macro-invertebrate taxa found in anthropogenic and natural wetlands in Spring 2011. Error bars are standard error.

Figure 2.22: NMDS ordination plot of presence/absence composition of macro-invertebrate taxa at each wetland.
Figure 2.23: The percentage composition for each wetland for the four main taxa eaten by *C. colliei* (Diptera, Odonates, Ostracods and Cladocerans), the three of the most common taxa and other macro-invertebrates. ..........................................................37

Figure 2.24: Mean abundance of macro-invertebrate individuals collected at each wetland. Error bars are standard error. ..........................................................37

Figure 2.25: Total area of shrubs, trees and sedges, sand and grass surrounding each wetland from classification of Orthorectified RapidEye imagery (21st January 2012) of study wetlands ..........................................................38

Figure 2.26: Mean number of native and exotic aquatic vegetation species present in each wetland during Spring 2013. ..........................................................39

Figure 2.27: Mean percentage of cover of aquatic vegetation during Spring 2013. Error bars are standard error ..........................................................39

Figure 2.28: Mean percentage of (a) canopy cover, (b) understory cover, and (c) groundcover for wetland study sites during Spring 2013. Green underline indicates Natural wetlands and orange underline indicates anthropogenic wetlands. Error bars are standard error ..........................................................41

Figure 3.1: Carapace length distributions of *C. colliei* in natural and anthropogenic wetlands. Dashed lines indicate size of sexual maturity for males (13cm) and females (16cm) respectively ..........................................................54

Figure 3.2: Distribution of carapace length of turtles by wetland. Dashed lines indicate size of sexual maturity for males (13cm) and females (16cm) respectively ..........................................................55

Figure 3.3: Sex of turtles present in natural and anthropogenic wetlands. ...............59

Figure 4.1: Distribution of *C. colliei* carapace lengths recorded by TORRN ............78

Figure 4.2: ClimateWatch data, number of turtles seen stratified by turtle age classes and whether they were seen on land or water (n=168). .................80

Figure 4.3: Distance turtle was observed from water’s edge. Data from ClimateWatch and Social surveys (Chapter Five) ..........................................................81

Figure 4.4: Number of turtles logged each month on ClimateWatch stratified by age class and location of sighting ..........................................................82
Figure 4.5: Number of turtles received by TORRN each month by age class. .......................................................................................................................... 82

Figure 4.6: Graph of all data points (ClimateWatch, Native ARC, TORRN and Wildcare) stratified by month and year. Bars on the right-hand side of the graph indicate the duration of data collection for each data source. ............... 84

Figure 4.7: The reported behaviour of observed turtles from ClimateWatch .......... 85

Figure 5.1: "The interaction among physical, ecological, engineering, social, and management variables and drivers in the new Tempe Town Lake, Arizona" Caption and image source Grimm et al. (2000) p578 reprinted with permission................................................................. 98

Figure 5.2: Map showing the locations of survey sites adjacent to wetlands and survey sites not adjacent to wetlands (minimum 500m from the closest open water)........................................................................................... 107

Figure 5.3: Mean responses (and standard error) to attitudinal subscales grouped by respondents residence location (near to wetland or far from wetland)............................................................................................... 114

Figure 5.4: Mean responses (and standard error) to attitudinal subscales responses group by whether respondent had or had not seen a turtle in their local area. .......................................................................................... 116

Figure 5.5: Overview of all associations tested for Hypothesis One and Two, two way arrows indicate a significant relationship. Grey boxes indicate attitudinal sub-scales and their effect size from Mann-Whitney tests. White boxes indicate categorical data and strength of association from Chi-Square tests........................................................................... 118

Figure 5.6: Histogram of grouped responses to hypothetical situations one and two (H1, H2). Each group of responses is coded to indicate whether the interaction was classed as positive (green), negative (red) or not enough information known to assess (orange). ............................................. 120

Figure 5.7: Histogram of grouped responses to hypothetical situation three (H3). Each group of responses is coded to indicate whether the interaction was classed as positive (green), negative (red) or not enough information known to assess (orange). ..................................................... 121
Figure 5.8: Histogram of grouped responses to hypothetical situation four (H4). Each group of responses is coded to indicate whether the interaction was classed as positive (green), negative (red) or not enough information known to assess (orange).................................................................121

Figure 5.9: Histogram of grouped responses to hypothetical situation five (H5). Each group of responses is coded to indicate whether the interaction was classed as positive (green), negative (red) or not enough information known to assess (orange).................................................................122

Figure 5.10: Histogram of knowledge scores (out of 9) for respondents who answered all questions.................................................................126

Figure 5.11: Histogram of nesting knowledge scores (out of a possible 6) calculated from responses to knowledge questions 2, 6, 7, 9, 10 and 11 in social survey.................................................................126

Figure 6.1: Model of research findings and how different factors in the urban environment may influence C. colliei populations.................................................160
List of Tables

Table 2.1: Site descriptions of study wetlands for this project ........................................ 18
Table 2.2: Land cover classifications used and their relevance to *C. colliei* life in urban environments .......................................................................................................................... 25
Table 2.3: Summary of water parameters collected for this study. Table indicates if parameters were outside ANZECC guidelines and if results significantly differed between natural and anthropogenic wetlands ........................................ 34
Table 2.4: Wetlands and their dominant aquatic taxa and their vegetation functional groups (Boulton et al 2014). Key:  ₪Emergent, ⌂Submerged, ₪Floating, ⎟Terrestrial, ⓢAlage and * indicates exotic species. ........................................ 40
Table 3.1: Number of turtles captured at each wetland and the number of recaptures over the course of three trapping seasons ....................................................... 53
Table 3.2: The ratio of male to female turtles captured from each study site in Perth, populations statistically significantly dominated by females are indicated in green. ......................................................................................................................... 56
Table 3.3: Summary of all *C. colliei* research conducted where number of turtle captured or sex ratio data was collected. ................................................................. 58
Table 3.4: *Chelodina colliei* population size estimates, standard error and 95% confidence interval ......................................................................................................................... 60
Table 4.1: Data sources, types, date range and number of records for citizen science and community data provided by ClimateWatch, Wildcare, TORRN, Native Arc and the social survey ........................................................................... 73
Table 4.2: Sex and age class of *C. colliei* recorded by TORRN .................................. 79
Table 4.3: Reason for incident report and rescue of *C. colliei* by TORRN .......... 86
Table 4.4: Reasons for *C. colliei* admission to Native ARC ........................................ 86
Table 4.5: Percentage of calls to Wildcare hotline regarding key items ............... 87
Table 4.6: Type of injury that *C. colliei* turtle had upon arrival to Native ARC .......................................................................................................................... 88
Table 4.7: Outcome of *C. colliei* rehabilitation by Native ARC ............................ 89
Table 4.8: The outcomes of the C. colliei turtles rescued and/or rehabilitated by TORRN

Table 5.1: Location types and number of surveys delivered

Table 5.2: Demographic characteristics of the returned surveys and the ABS data for the City of Cockburn (Australian Bureau of Statistics 2011b)

Table 5.3: Demographic characteristics of the returned surveys and the ABS data for the City of Melville (Australian Bureau of Statistics 2011c)

Table 5.4: Mann-Whitney test indicates a significant relationship between whether the respondent lived near or far to a wetland and the attitudinal subscales of Ownership, Participation, Security and Wildlife.

Table 5.5: Mann-Whitney test indicates a significant relationship between having seen a turtle or not seen a turtle and all of the attitudinal sub-scales

Table 5.6: Percentage of turtle sightings and resultant interactions by respondents living near and far from a wetland.

Table 5.7: Potential number of turtles that have been interacted with in each local council extrapolated using human population size in each local government area and data collected from social survey.

Table 5.8: Turtle knowledge questions, correct answers and percentage of respondents that answered correctly and incorrectly.

Table 5.9: Kruskal-Wallis tests for association between respondents overall and nesting knowledge and the action the respondent would take for each hypothetical situation.

Table 5.10: Results of tests for association between knowledge scores and outcome of the respondent’s hypothetical action (positive, negative or unknown impact)

Table 6.1: The key advantages and limitations of using Ecological Research, Citizen Science/Community Data and Social Reasearch to investigate urban wildlife populations
Chapter One - General Introduction

The urban environment is a strange place, comprised of mixtures of environmental variables not found in nature (Hobbs et al. 2006). Large scale landscape change resulting from urban development can particularly effect native wildlife, whose habitat is modified in a myriad of ways in both space and time (Alberti et al. 2003, DeStefano and DeGraaf 2003). Some species adapt and flourish despite these changes (e.g. raccoons (Prange et al. 2003)), some experience reduced local populations but are able to persist, whilst others are severely affected leading to local extinction (e.g. native bird species (Blair and Johnson 2008)). So what enables persistence of populations in spite of a changing urban environment?

To address this intriguing question we must ask what factors are critical in determining population persistence in urban areas? Is it maintenance of habitat and resources within the environment; tolerance or adaptive capacity of the native species; direct interaction with the species engineer of this new environment (humans); or is it a combination of these? To investigate and answer these questions a combination of methods from across disciplines may be required to encompass both the ecological and social complexities of urban wildlife populations. This thesis takes the first steps towards investigating these questions and examines the value of using a combination of ecological and social research to examine population demography and the life of freshwater turtles, who share the urban environment with humans.

Urban ecology can examine ecology within cities and the ecology of cities (Pickett et al. 2001). Urban ecology in the context of this thesis refers to the former, particularly with the affect that the physical structure of urban environment has on native wildlife. Urban environments differ from natural systems in many ways including, but not limited to; reduction in vegetation coverage (Ramalho and Hobbs 2012), slightly higher soil and air temperatures (see Kuttler (2008) and Arnfield (2003) for more detail), differences in hydrological flows (Konrad and Booth 2005) and increased presence of nutrients and other ions within waterways (Paul and Meyer 2001). These vary both between and within urban environments due to their inherent heterogeneity (Alberti et al. 2003, Cadenasso et al. 2007). Urban ecology can help us understand how these variations between habitats may affect the long-term persistence of wildlife populations.
The importance of patch dynamics (remnant habitat mosaicked amongst urbanised land) for wildlife is a common focus for urban ecology research (Pickett et al. 2001, Pickett et al. 2011). Remnant patches provide safe harbour for wildlife displaced by development although they may lack some resources required for long-term population survival (Battin 2004, Hamer and McDonnell 2008). These deficiencies can force wildlife to move around the urban environment to meet their needs. Where wildlife corridors (corridors of suitable habitat) exist they may allow individuals to disperse and access additional suitable habitats (Ignatieva et al. 2011). Urban habitats, such as residential gardens for example, may also be able to perform this function by acting as stepping-stones for movement between hospitable areas (Soulé 1991, Baum et al. 2004). In fact, gardens may be considered patches of suitable habitat for some species, as garden structure and size can influence both species presence and community composition (Baker and Harris 2007). Therefore, urban habitats created or modified by humans have the potential to support urban wildlife populations in contrast to the well documented negative impacts of urbanisation.

Human resource use alters the environment in a myriad of ways and is driven by a complex network of socio-economic and policy factors (Ostrom 2009, McGinnis and Ostrom 2014). There are particular facets of urban ecology which consider how the humans who inhabit and dominate the urban environment influence its structure (Pickett et al. 2011). Alongside the creation of the built environment, human occupants drive the future design and management of an urban environment through their attitudes and behaviour (Grimm et al. 2000). An example of this is residential gardens, the structure and composition of which is determined by different socio-economic factors at different scales (Figure 1.1). At a neighbourhood scale particular gardening styles are social norms, influencing both the extent and configuration of neighbourhood gardens as well as individual’s attitudes (Zmyslony and Gagnon 1998, Goddard et al. 2010). At an individual garden scale, personal attitudes and beliefs along with socio-economic status can influence the features of gardens and abiotic factors (Goddard et al. 2010). As patches of natural areas become ever more diminished it is likely that human created environments (such as gardens, parks and created wetlands) will hold more value for native species. Therefore, understanding individual attitudes, behaviours and choices made both in a garden and the urban environment at large is imperative to understanding how native wildlife are affected by humans (van Heezik et al. 2013).
Figure 1.1: “Gardens as socio-ecological constructs. A conceptual framework showing the key ecological and socio-economic components impacting on private gardens at multiple spatial scales. We identify a nested hierarchy in garden management that spans three scales: (a) the individual garden or household; (b) the neighbourhood or garden ‘patch’; and (c) the city or landscape scale. In reality, many of the ecological and socio-economic factors can act at more than one scale along this continuum (e.g. vegetation structure or social status) and interactions exist between scales to illustrate feedbacks within the garden ecosystem (black arrows). Ecological factors influence socio-economic factors through the provision of ecosystem services and economic and health benefits (red arrows). Socio-economic factors influence ecological conditions via human decision-making and subsequent management (blue arrows). Research and management is necessary at multiple scales to maximise the utility of private gardens for native biodiversity conservation.” (Goddard et al. 2010, p94) Image reprinted with permission.
Human influences are an important consideration when conducting ecological wildlife studies in the urban environment. Humans control the habitat within which wildlife reside and humans can also directly interact with wildlife in the environment. These human-wildlife interactions are most often considered from a human-wildlife conflict perspective (Madden 2004). Conflict can result from a) perceived or actual damage to property, b) dangers created by or resulting from the presence of wildlife, or c) conflict between humans regarding how mitigation of wildlife damages or dangers should be handled (Madden 2004); for example raccoons entering a roof through a chimney causing both nuisance, damage and perceived risk of disease or parasite transmission (Prange et al. 2003). These types of conflicts can be mitigated in many ways including limiting access to anthropogenic food sources or modification of the urban environment.

However, there are many interactions between wildlife and humans in the environment that do not fall into the conflict category. Dowle and Deane (2009) and FitzGibbon and Jones (2006) investigated the attitudes and knowledge of local residents to bandicoots, some of which were digging up grass in gardens. Despite this “nuisance” behaviour most residents did not view the native bandicoot as a problem and were positive about bandicoot’s presence in their local vicinity. While these interactions are not considered as conflict, they may still have a positive or negative impact on the wildlife involved. Positive effects of human-wildlife interactions may include assisting the geographic spread and expansion of some species populations in urban environment through the provision of food, shelter and protection (DeStefano and DeGraaf 2003). Negative effects may include modification of normal diet, injury and translocation to unsuitable habitat (DeStefano and DeGraaf 2003). Such interactions can be unintentional (e.g. resulting from the structure of the urban environment) or intentional (e.g. specific human choices; such as modification of garden contents changing available habitat resources (Fuller et al. 2008)). It is important to consider the nature and frequency of these non-conflict human-wildlife interactions because in order to understand the life of wildlife in the urban environment we need to understand how people interact with them.
Unfortunately, when wildlife ecology is conducted in the urban environment more often than not, consideration of humans is overlooked. Research in the urban environment tends to focus on landscape ecology, animal behaviour, conservation, population ecology and wildlife management using methods designed for the natural environment (Magle et al. 2012). Little of this research considers how human interactions and behaviour may directly affect or influence wildlife populations or in fact the validity of traditional research techniques and data in these environments. This is a significant gap in many studies conducted in the urban area. Urban ecology indicates that humans play a key role in the urban environment (Grimm et al. 2000, Alberti et al. 2003) and yet, this is generally not the case.

It is vital that all ecological projects conducted in the urban environment consider the human variable, without which a complete picture of the urban ecosystem being examined is impossible. Excluding the human variable has the potential to confound results and lead to inaccurate conclusions (e.g. correlation does not equal causation (Aldrich 1995)). If possible effects of human-wildlife interactions are not ruled out how can we be certain that human behaviour is not a significant factor? For example, Rees et al. (2009) monitored the movements of urban freshwater turtles (Chelodina longicollis) in comparison to a control group in a national park and found that urban turtles covered significantly larger distances. They suggested that urban C. longicollis were making use of culverts to move between anthropogenic wetlands; but what if this was not the case and instead humans were encountering these turtles and moving them between wetlands? There is no way to know since the research (as with many other ecology projects (Magle et al. 2012)) did not indicate if human interaction with the study species was considered. Unless research explicitly states that due consideration has been given to human-wildlife interactions, the reader cannot assume it has been incorporated. Without this information there is no way to identify if human interactions have influenced the target species or community.

It is possible that data regarding human-wildlife interactions are not included because social research methodologies required to collect such data are not part of the typical suite of ecological research methods. Social research is necessary to investigate human’s attitudes, perceptions and interactions with wildlife. On the rare occasions when human attitudes and knowledge are assessed for ecological purposes (e.g. in the case of a bandicoot in Australia (FitzGibbon and Jones 2006, Dowle and Deane 2009)), a silo approach is taken, where information about humans and their interactions is
considered separately to any ecological information collected. To fully understand
human’s perception of and interaction with wildlife populations (and the impacts these
have) we must utilise a combination of social and ecological research methodology.
These methods need to be used concurrently to understand the complexities of life for
any urban wildlife population and to accurately investigate; the availability and
maintenance of resources in habitats, the population dynamics of the species, the direct
interactions with humans and the interplay between these factors.
Freshwater turtles in the urban environment

A significant impact of continuing urbanisation is the reduction in the number and quality of wetlands available for native species. Infilling or significant modification due to urban development detrimentally affects water quality, plant and animal communities (Horner 2000). Some species of frogs, fish and turtles are unable to leave these modified wetlands in search of more suitable habitats (unlike more mobile bird species) and therefore become isolated in patches of habitat within urban areas. It is unknown how well these patches can support populations in the long-term (Goddard et al. 2010). A complicating factor for many species of frogs and turtles is that they use the upland habitats surrounding wetlands for a range of functions including breeding and migration to ensure maintenance of meta-populations (Baldwin et al. 2004, Cushman 2006, Attum et al. 2008a). The changes resulting from urbanisation could therefore severely compromise a species survival.

Urban freshwater turtles have had to cope with the change from pristine native vegetation in their upland habitat to the built environment (Rees et al. 2009). The built environment presents two challenges to freshwater turtles: 1) infrastructure and impermeable surfaces and 2) roads around wetlands. Buildings around local wetlands are problematic for female freshwater turtles as they act as physical barriers preventing access to nesting sites (Eskew et al. 2010). They also hinder other life cycle movements such preventing hatchling turtles from accessing a wetland and disrupting typical migration movements of turtles, which in turn can affect the meta-populations (a population made up of smaller local populations that are linked through migration) (Pereira et al. 2011). Impermeable surfaces reduce the area available for nesting sites and preclude cover from predators. Roads have been linked to skewing of the sex-ratio of populations for freshwater turtles around the world (Steen and Gibbs 2004, Aresco 2005, Steen et al. 2006). The female turtle’s life cycle puts them at greater risk as they may need to cross roads to find nesting sites and as a result are more likely to fall prey to motor vehicle accidents (Giles 2001, Aresco 2005). Despite these issues urban populations of turtles still exist, although the extent of population change due to urbanisation of wetlands remains unquantified.
Urban environments are inherently heterogenic (Alberti et al. 2003, Cadenasso et al. 2007). This heterogeneity is also reflected in the urbanisation of wetlands, where some wetlands are more heavily affected by urbanisation than others. This thesis examines the two broad types of wetlands found in the urban environment: natural and anthropogenic wetlands. Natural wetlands, for the purpose of this thesis, are defined as systems that have not undergone significant structural modification and retain a large proportion of their fringing vegetation (Figure 1.2). Anthropogenic wetlands are defined as being either heavily modified or created wetlands with a minimal presence of natural fringing and terrestrial vegetation (Figure 1.3). Both these types of wetlands are known to be home to the freshwater turtle species investigated in this study, *Chelodina colliei*. This thesis explores the role of ecological and social research in understanding population dynamics of freshwater turtles in anthropogenic and natural wetlands within the urban environment.

Figure 1.2: An example of a natural wetland, Booragoon Lake, one of the study sites.

Figure 1.3: An example of an anthropogenic wetland, Juett Park, one of the study sites.
The study species, *Chelodina colliei*

“In the twelve months prior to October 1973, an area at the northern end of Lake Joondalup was gradually developed as a new housing estate.” “During the weekend of October 13/14 large numbers of Long-necked Tortoise, *Chelodina oblonga* (*now C. colliei*), were seen to leave the lake and make their way into the bush to lay their eggs.” “My husband and I policed them across the road and over the weekend only one was hit and killed by a car” (Nicholson 1975, pg42)

*Chelodina colliei* (the Long-Necked or Oblong turtle) has often captured the interest of the general public. Being the only native freshwater turtle species seen commonly in Perth, it is well known among residents who live near natural and anthropogenic wetlands. This section outlines what is known of *C. colliei* in Western Australia to provide background to this study.

**Distribution**

*Chelodina colliei* can be primarily found in wetlands in the South-West of Western Australia. The distribution of *C. colliei* is bounded by Hill River 170km north of Perth and the Fitzgerald River National Park about 240km east of Albany (Cann 1998). In the east they are found no further inland than approximately 200km from the coast. *Chelodina colliei* inhabit a range of systems from those which dry-out over summer to permanent systems to heavily modified anthropogenic wetlands. Perth has developed a significant expanse of urban sprawl within which *C. colliei* populations can be found. The wetlands studied in this thesis are all located in the southern region of Perth (See Chapter Two for full site descriptions).

**Biology and ecology**

*Chelodina colliei* has been recorded to grow up to 30cm in carapace length (carapace is the top shell), although there is speculation that it may be able to reach 40cm given favourable conditions (Cann 1998). Carapace length can be used as an estimation of sexual maturity and this study uses this approach. Males are considered sexually mature when they reach 13 to 14cm in carapace length, the minimum size for female sexual maturity has not been identified but females are sexually mature at 16 to 17cm in carapace length (Kuchling 1988, 1989).

*Chelodina colliei* communicates underwater and these calls may form some part of an advertisement display for reproduction (Giles *et al.* 2009). Breeding usually occurs
during winter and spring (Cann 1998) and female *C. colliei* leave the water to nest during late spring (September to November) and summer (December to January). They can produce one clutch during both of these seasons (Clay 1981). Preferred nesting sites tend to be open with soft sandy soil (Clay 1981). Total clutch size over these two nesting periods has the potential to be up to 45 eggs per individual (Kuchling 1988). The largest reported clutch size, however, is 25 eggs in one nest (Bush *et al.* 2010) and on average they lay 8 eggs in spring and 4 eggs in summer (Clay 1981).

In the past, *C. colliei* females have been seen leaving wetland en-masse for nesting, the cue for this movement being “seasonal rain-bearing low pressure systems, falling barometric pressure and an air temperature above 17°C” (Clay 1981 p27). It has been less common to see this en-masse nesting movement in recent years. *Chelodina collliei*’s nesting movement on to land is risky as it provides foxes and other predators with access to breeding females. The time taken for the nesting process (digging, laying and compacting) can take from 25 to 45 minutes. In addition, the turtle can spend over an hour searching for a suitable nesting site (Burbidge 1967, Clay 1981).

Incubation time of *C. colliei* eggs is approximately 200 to 230 days (Burbidge 1967). It is thought that turtles will hatch from their eggs but remain under ground until conditions are suitable for departure. Some suburban residents have reported digging up completely hatched and active young in their gardens (Survey respondent 1w78, 2012). The average carapace length of hatchling *C. colliei* is 29 to 33mm (Burbidge 1967). Hatchling turtles will emerge from the nest and move towards nearby wetlands. Similarly to the nesting movement, this movement to wetlands is high risk and predation of hatchlings in not uncommon (Spencer 2002).

 Hatchlings which survive the movement to the wetland are still vulnerable to birds such as Little Pied Cormorants (*Microcarbo melanoleucos*) (Bush *et al.* 2010). Whilst Gilgies (*Cherax quinquecarinatus*) do not predate upon hatchlings, other crayfish such as Marron (*Cherax tenuimanus*), Koonacs (*Cherax preissii*) and Yabbies (*Cherax destructor*) do act aggressively towards hatchlings (Bradsell *et al.* 2002) and may contribute to hatchling mortality.

*Chelodina colliei*, like many other Australian turtles, has adapted to cope with its habitat drying out over summer by aestivating, which is a state of torpor (Cann 1998). *Chelodina colliei* aestivates by burying itself in the substrate of the wetland and will remain in this position until the wetland refills. However, Burbidge (1967) has
suggested that the *C. colliei* can also choose to migrate to local rivers or other water bodies if the need arises.

*Chelodina colliei* once grown, is considered the apex predator underwater. It is a generalist feeder and an opportunistic carnivore. The diet of the urban *C. colliei* includes an array of aquatic invertebrates, which will change over the year due to seasonal changes in macroinvertebrate community structure (Tysoe 2005). This diet may be supplemented by small fish, carrion (Woldring 2001) and potentially small birds such as ducklings or coot (*Fulica atra*) young (Burbidge 1967).

**Populations**

Research has been conducted on a number of *C. colliei* populations over the last 40 years. Study sites have included Thompsons Lake (Clay 1981), Shenton Park and Perry Lakes (Guyot and Kuchling 1998), Claremont Lake and Shenton Park (Tysoe 2005), Blue Gum Lake, Booragoon Lake and Piney Lake (Giles *et al.* 2008), Black Swan Dam (McKeown 2010) and in Lake Joondalup and Yellagonga Regional Park (Hammond 2010, Chester 2012). An overview of this is presented in Chapter Three, Table 3.3. While all of this research is important, it remains disjointed and a large scale study of populations over the same period of time, in both anthropogenic and natural wetlands, has not been conducted.

It appears that *C. colliei* populations have not genetically diverged since urbanisation began. Hamada (2011) conducted genetic analysis and identified that no significant difference in genetic variation was found, which they suggest is because either there has been an acceptable gene flow to overcome genetic drift or the long generation time of *C. colliei* means that any genetic divergence is not yet visible. A third option, intimated by this study, is that gene flow has been maintained by human-mitigated movement of turtles.

As for population demography, the majority of the population studies conducted so far have only focussed on one or two wetlands at a time, with very little comparison between studies or over time. In addition, only three of the nine accessible studies have been published in the primary literature, which impedes ongoing research and more importantly has minimised our ability to identify the status of *C. colliei* in the urban environment. This has resulted in our current poor understanding of *C. colliei* numbers and distribution. Shenton Park is one wetland where multiple studies have been conducted over time (355 turtles captured in 1997/8 (Guyot and Kuchling 1998), 89
turtles captured in 2005 (Tysoe 2005) and 20 turtles captured in 2011 (Hamada 2011)). Despite an apparent decline in captures over time at Shenton Park, the trapping methods used and the trap effort differed between projects, as each project had a different focus (populations, diet and genetics respectively). Therefore, while it is suspected that urbanisation is negatively affecting *C. colliei* populations, there is no evidence to support or disprove this. If *C. colliei* populations are to continue into the future we need to ensure that they are managed properly by the relevant authorities. However, we cannot manage these urban populations appropriately if we do not know what state they are in. This thesis provides the largest scale assessment of *C. colliei* populations to date.

**Taxonomy**

In this thesis you may note that almost all references used regarding *C. colliei* and its biology use the name *C. oblonga* instead. There has been some taxonomic confusion regarding *C. colliei*, *C. rugosa* and *C. oblonga*. For over 45 years the South-Western species that this study was conducted upon (*C. colliei*) was known as *C. oblonga*. At the same time, *Chelodina rugosa* was the name used to refer to the Snake-Necked turtle species found in the Northern Territory.

Gray (1856) in the late 1800’s described the South Western species of long necked turtle as *Chelodina colliei* and indicated that it was a separate species to the one found in the north. The holotype of the Northern Snake-Necked turtle was called *Chelodina oblonga* (Kuchling 2010, Kennett *et al.* 2014). Later both the Northern and South-Western long necked turtle’s species were considered (erroneously) as one taxa under the name *C. oblonga* due to a change in geographic boundaries. When this was noticed, Goode (1967) split the Northern and South-Western forms restricting the name *C. oblonga* to the South Western species and giving the Northern species an alternative name (which went through a further taxonomic name change to arrive at *C. rugosa*). The use of *C. oblonga* (South-Western species) and *C. rugosa* (Northern species) has been used consistently for the last 46 years (Kennett *et al.* 2014).

As a result of an ICZN ruling in 2013 in relation to *C. rugosa* and its holotype which was named *C. oblonga*, *C. rugosa* should now be referred to as *C. oblonga*. As the South-Western Long-necked turtle has been clearly defined as a separate species and can no longer be referred to as *C. oblonga*, the name *Chelodina colliei* for the South-Western species as described by Gray (1856) is therefore now in use (Georges and Thomson 2010, Kuchling 2010, Kennett *et al.* 2014).
Thesis aims and structure

The over-arching aim of this thesis is to examine the value and role of ecological and social research in understanding freshwater turtle populations in an urban environment. To do this, each of the following chapters investigates different aspects of *C. colliei*’s life in the urban environment using ecological research, citizen science and social research.

Chapter Two describes the wetland environment at each study site and investigates the difference between the natural and anthropogenic wetlands study sites. The hypothesis for this chapter is; “*Environmental conditions vary between natural and anthropogenic wetlands*” The discussion of this chapter will consider the environmental conditions of the study sites and discuss the likelihood and degree to which they that are likely to influence populations.

Chapter Three examines how (direct) human modification of wetlands affects *C. colliei* populations, using ecological methods. There are two hypotheses for chapter three: “*Population structure of C. colliei in natural wetlands will differ from anthropogenic wetlands*”; and, “*Differences in environmental conditions between wetlands results in differences in population structure.*”

Chapter Four uses citizen science and community data sources to investigate the following questions: 1. *What is the demography of turtles observed in the urban environment?* 2. *Where are turtles observed in the urban environment?* 3. *When are turtles observed in the urban environment?* 4. *What are turtles observed doing in the urban environment?* 5. *What are the outcomes of turtle rescues in the urban environment?* The overarching question for this chapter is, what value does community data and citizen science add to our overall understanding in comparison to the information provided by ecological research?

Chapter Five uses social methodology to consider the human component of the urban environment. This chapter has two overarching aims, the first is to identify the attitudes of urban residents towards wetlands and wildlife, because this can influence how we (humans) structure and manage the human environment. This has two related hypotheses; “*People who live adjacent to wetlands have a more positive attitude towards wetlands and turtles*”; and, “*People who have had an interaction with a turtle have a more positive attitude towards turtles and wetlands*.” The second overarching
aim of chapter five asks, in what ways do humans interact with turtles and what are the possible outcomes of these interactions? This also has two related hypotheses; “*People who have an interaction with a turtle are likely to have had a negative impact on the turtle*”; and, “*People with good knowledge about turtles are more likely to behave in a positive manner when they encounter a turtle*”.

Overall this thesis investigates the value and role of ecological research, citizen science and social research methodologies in investigating the ecology of the urban wildlife.
Chapter Two - Study sites and environmental conditions

Introduction

All living organisms have basic requirements that must be fulfilled for survival i.e. food, water and habitat, all of which are provided by the environment (Klemens 2000). Urbanisation, however, can modify or destroy natural habitats (including wetlands) by significantly changing land cover and biotic assemblages (Hamer and McDonnell 2008). Patches of remnant natural areas can provide resources such as food and habitat for endemic species (which may be restricted to these patches), however, these patches may not provide all the resources required for life (Semlitsch and Bodie 2003, Zang et al. 2011). The life of Chelodina colliei occurs primarily in wetlands although terrestrial environments play a key role. In Perth, C. colliei exists in habitats that range from natural through to anthropogenic, however, what environmental conditions do C. colliei live within? And how might differences between wetlands influence C. colliei populations? This chapter examines the differences in environmental conditions between wetlands close to their natural state and anthropogenic wetlands.

Wetlands that are not removed by urbanisation are isolated in a modified landscape often with natural linkages (associated fringing and upland terrestrial vegetation) removed or heavily modified (Gibbs 2000). Animal species diversity can be driven by factors such as structural diversity and heterogeneity of terrestrial vegetation (Tews et al. 2004). Fringing and upland terrestrial vegetation provide not only linkages or corridors but also provide and influence resources such as food, habitat and nesting sites for endemic wetland species (like C. colliei) (Semlitsch and Bodie 2003). Therefore, modifications to wetlands and surrounding terrestrial habitat alters resource provision and can reduce suitability of a habitat. For example the modification of upland habitat results in wetland condition parameters of vegetation, bank stability, and water quality deteriorating which has a documented adverse effect on amphibian diversity (Jansen and Healey 2003). The detrimental effect of removal of upland and terrestrial vegetation in a wetland’s catchment on water quality (Muscutt et al. 1993) can in turn directly affect the resources used by wetland fauna – for example potential food sources such as macroinvertebrates (McKinney 2008). It is likely that anthropogenic wetlands in Perth,
which generally lack fringing and upland habitat, are compromised in the resources they provide.

Wetlands support complex food chains, provide important habitat for wildlife and maintain rich biodiversity (Wang et al. 2008) but urbanisation can reduce this capacity. The effect of urbanisation varies between groups of animals for two key reasons. Firstly, different requirements for life, such as food and habitat allow some species to continue to live in the habitat while other species many no longer have their needs met. Secondly, the differential ability of species to move through the urban environment: amphibians, reptiles and invertebrates tend to have a low ability to disperse through urban environments (Lehtinen et al. 1999, Semlitsch and Bodie 2003); therefore they may be unable to leave a habitat that is not meeting their needs, or find another habitat which suits their needs (or die in attempt to find a new habitat). In contrast, birds have a higher dispersal ability leading to high bird abundance in urban wetlands, as they provide a refuge from urbanised land (McKinney et al. 2011).

This chapter will focus on the environmental variables that are likely to influence C. colliei populations in the two broad types of wetlands found within the urban environment, natural and anthropogenic wetlands. This chapter explores the hypothesis: “Environmental conditions vary between natural and anthropogenic wetlands”. In the absence of definitive research indicating the habitat requirements of C. colliei the discussion of this chapter will consider the likelihood and the degree to which these environmental conditions could constrain these populations.
Methods

Site selection

Perth is the largest city in Western Australia with a population of slightly over two million and has the fastest population growth rate of Australian capital cities from 2013-2014 (Australian Bureau of Statistics 2015). With an increasing population new housing developments are occurring around its outskirts. The Perth metropolitan area has a number of wetland chains that run through it. One such chain in the south of Perth is the Beeliar Wetlands.

Twelve urban wetlands in and adjacent to the Beeliar Wetland chain were chosen for this study, five of which were natural wetlands. Natural wetlands were chosen based on the presence of *C. colliei* and amount of remnant natural vegetation surrounding the wetland. Seven anthropogenic wetlands were chosen based on the presence of *C. colliei* (reported by either the Local Government Authority or residents). Anthropogenic wetlands were either heavily modified natural systems or created wetlands with a minimal presence of fringing or terrestrial vegetation. Seven anthropogenic sites were chosen rather than five because two sites were in close proximity to the other sample wetlands. The selected wetlands and site descriptions are listed in Table 2.1.
### Site descriptions

#### Table 2.1: Site descriptions of study wetlands for this project

<table>
<thead>
<tr>
<th>Wetland (Locations: Figure 2.2)</th>
<th>Photo (Figure 2.1)</th>
<th>Natural or Anthropogenic?</th>
<th>Does this wetland completely dry out during Summer?</th>
<th>Is the water level maintained?</th>
<th>Is the wetland plastic lined or concrete walled?</th>
<th>Number of storm drains</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booragoon Lake *</td>
<td>a</td>
<td>Natural</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>5</td>
<td>Booragoon Lake is a natural wetland which had the closest roads and residential area.</td>
</tr>
<tr>
<td>Piney Lake Natural</td>
<td>b</td>
<td>Natural</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>0</td>
<td>Piney Lake natural is located in the middle of a large remnant reserve, this reserve is surrounded by roads on two sides and parkland on the other two sides where Piney Lake Ornamental and Juett Park are located.</td>
</tr>
<tr>
<td>Piney Lake Ornamental Juett Park Frederick Baldwin</td>
<td>f</td>
<td>Anthropogenic</td>
<td>No</td>
<td>Yes</td>
<td>Lined and walled</td>
<td>0</td>
<td>Both these wetlands back onto the bushland where Piney Lake Natural is found. Both of these wetlands have fountains/aerators.</td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>Anthropogenic</td>
<td>No</td>
<td>Yes</td>
<td>Lined and walled</td>
<td>0</td>
<td>This system has a fountain/aerator.</td>
</tr>
<tr>
<td>Chelodina Wetland *</td>
<td>c</td>
<td>Natural</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>0</td>
<td>This natural wetland is located at the back of Murdoch University campus. It is used for teaching and research purposes.</td>
</tr>
<tr>
<td>South Lake</td>
<td>e</td>
<td>Natural</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>0</td>
<td>This natural wetland borders onto a new light industrial development and a 70km/hr highway. Over sampling Typha has overgrown much of what was open water area. North of Little Rush Lake and separated by a railway.</td>
</tr>
<tr>
<td>Little Rush Lake *</td>
<td>d</td>
<td>Natural</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>0</td>
<td>This natural wetland is located between South Lake (to the north-west) and Yangebup Lake (not studied – to the south east). It is separated from South Lake by a railway and from Yangebup by a road.</td>
</tr>
<tr>
<td>Lucken Reserve Berrigan Lake</td>
<td>i, j</td>
<td>Anthropogenic</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>2, 3</td>
<td>Heavily modified natural system.</td>
</tr>
<tr>
<td>Broadwater Gardens Harmony Lake</td>
<td>k, l</td>
<td>Anthropogenic</td>
<td>No</td>
<td>No</td>
<td>Lined and partially walled</td>
<td>1, 2</td>
<td>Heavily modified wetland with concrete base and lining.</td>
</tr>
</tbody>
</table>

* wetland is a coloured system
A survey of each wetland was conducted to identify what resources were available for *C. colliei* by identifying food available, habitat types and water quality attributes (pH, dissolved oxygen, turbidity, conductivity and temperature).

Figure 2.2: Map of the south of Perth, Western Australia indicating locations of study wetlands.
**Water quality methods**

Water quality measurements of pH, temperature, dissolved oxygen (DO), conductivity and turbidity were taken during the turtle trapping sessions of this study (see Chapter Three: Methods). As wetlands were very shallow (<1m), water samples were integrated across depth. With the exception of turbidity, measurements were taken each morning and afternoon as the traps were being checked for turtles. Turbidity samples were taken prior to traps being set at each wetland at the commencement of trapping to avoid the effect of water disturbance and measured using a Hach 2100p turbidity meter. Water temperature was also recorded due to the influence of water temperature on turtle captures (Chessman 1988b). As wetlands were trapped on a rotational basis, these measurements were not taken on the same day for each wetland.

**Simultaneous water quality measurements**

To allow direct comparison between wetlands, simultaneous water quality measurements were taken from all wetlands post-trapping in Spring 2013. Water quality measurements of pH, DO and conductivity were taken at five locations within each wetland. At three of these locations water samples were taken and analysed for total phosphorus (TP), total nitrogen (TN) and chlorophyll a concentrations.

**Water quality analysis**

All data was averaged for each wetland and analysed using independent t-tests or Mann-Whitney tests (in SPSS 21) to compare results between natural and anthropogenic wetlands.

The ANZECC guideline default trigger values for South Western Australia (ANZECC and ARMCANZ 2000) were used to indicate if the wetlands were habitable. Given that a few of the wetlands sampled were coloured (tannin-stained), the acceptable range used for pH was 4.5 to 8.5, as highly coloured wetlands typically have a more acidic pH (Wrigley et al. 1988) and *C. colliei* is known to occur in a number of highly coloured wetlands in Perth.
Macroinvertebrate diversity

During Spring in November 2011 each wetland was surveyed to identify the macro-invertebrate prey present. A minimum of three 15 second sweep samples were conducted at each wetland using a triangular net (250μm mesh). Samples were preserved in ethanol and macroinvertebrates were subsequently counted and identified to genus level (where possible).

Data was analysed using ordination MDS plot (PRIMER 6) to identify any difference in the composition of assemblages using presence/absence data. T-tests were used to compare number of taxa present in natural wetlands to anthropogenic wetlands. The existing research on *C. colliei* diet (Woldring 2001, Tysoe 2005) only provided analysis at order level (or higher in some cases) and no further information was available on *C. colliei*’s dietary preferences for particular genera. Therefore, data analysis for this study was also conducted at order level (or higher).

Habitat

A mixture of methods was used to examine the presence of vegetation and land cover. Terrestrial land cover area was assessed using classification of satellite imagery. This provided the total area of different land cover types around the wetlands. To gain a more detailed understanding of the vegetative composition of the habitat surrounding and within wetlands vegetation surveys were conducted.

*Area of vegetation- GIS*

Extent of fringing and terrestrial land cover between the water’s edge and the closest road, railway or significant fence line (in the case of Chelodina Wetland), were classified using a maximum likelihood classification (Figure 2.3). This was conducted using ENVI 4.7 on Orthorectified RapidEye imagery taken on the 21st January 2012. All wetlands were classified separately with the exception of 1) Piney Lake Natural, Piney Lake Ornamental and Juett Park, and, 2) Berrigan Lake and Broadwater Gardens. These wetlands and their upland habitats are not separated from each other by roads or railway; therefore, the fringing and terrestrial vegetation was classified as one large group rather than arbitrarily separating these clearly connected wetlands.
1. Orthorectified RapidEye Imagery

2. Urban area and water masked

3. Vegetation classified

Figure 2.3: Process of vegetation classification of RapidEye Orthorectified imagery. Urban area and the closest road to the wetland were masked along with the water. Land cover was then classified into Open sand and dirt (yellow), Trees and Sedges (dark green), Grass (green) and shrubs (aqua).

Four primary land cover groups were classified: 1. Open sand and dirt; 2. Trees and sedges; 3. Grass (lawn), and; 4. Shrubs. Tree canopy and sedges were classified as one group as the resolution of the imagery (1 pixel = 5m$^2$) was too coarse to identify most stands of sedges, which occurred in smaller patches. In addition, sedges were often obscured by tree canopy therefore it was most practical to assess these as one group. Open sand and dirt, Grass (lawn) and Shrubs class areas were likely also underestimated due to tree canopy cover. Table 2.2 provides an explanation into the importance of each of the land cover classifications for *C. colliei*. 
Table 2.2: Land cover classifications used and their relevance to C. colliei life in urban environments

<table>
<thead>
<tr>
<th>Land cover classification</th>
<th>Importance for C. colliei</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open sand and dirt</td>
<td>Needed for nesting, however large areas of sand may not provide enough little cover for moving C. colliei.</td>
</tr>
<tr>
<td>Tree canopy and sedges</td>
<td>Provide cover for moving C. colliei as well as providing additional benefits to the wetland itself.</td>
</tr>
<tr>
<td>Grass</td>
<td>Manicured grass is not an ideal surface for C. colliei as it may act as an obstruction to nesting and provides no cover for movement.</td>
</tr>
<tr>
<td>Shrubs</td>
<td>Provide cover for moving C. colliei as well as providing additional benefits to the wetland itself.</td>
</tr>
</tbody>
</table>

All classes were corroborated using GPS points (±10m) collected during the vegetation survey (described below) and visually confirmed from higher resolution aerial imagery.

**Vegetation surveys**

Vegetation surveys were conducted to provide more detailed information about vegetation around and within a wetland including aquatic vegetation, presence of exotic species and the structural complexity of the terrestrial vegetation.

**Aquatic plants**

An aquatic vegetation survey incorporating percentage cover, total number of species, number of native species, number of exotic species, vegetation condition and dominant taxa (greater than 10%) of emergent/floating angiosperms, submerged angiosperms and algae was conducted at each study site during Spring 2013, following the sampling design of (Keighery 1994). Results for natural wetlands and anthropogenic wetlands were compared using t-tests.

**Terrestrial plants**

Terrestrial vegetation was also surveyed at each study site during Spring 2013 measuring the same parameters as aquatic vegetation in the three structural layers of canopy, understory and ground cover. In addition, percentage of ground that was bare and soil type was recorded. Results for natural wetlands and anthropogenic wetlands were compared using t-tests.
Results

Water quality – measurements during trapping

$pH$

There was a significant difference between the pH at natural and anthropogenic wetlands ($t(290)=-12.60$, $p<0.005$). None of the anthropogenic wetlands contained acidic waters (Figure 2.5) and natural wetlands had a more variable pH between seasons (Figure 2.4). On average the pH of natural wetlands was $6.87\pm0.11$ (within ANZECC pH limits) compared to anthropogenic wetlands with a pH of $8.21\pm0.048$ (over ANZECC pH trigger in some locations for some trap sessions).

![Figure 2.4: The mean pH of water in natural wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines.](image1)

![Figure 2.5: The mean pH of water in anthropogenic wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines.](image2)
Conductivity

Conductivity was significantly different between natural and anthropogenic wetlands (t(285)=8.80, p <0.005) with natural wetlands having slightly higher conductivity (Figure 2.6, Figure 2.7). Booragoon Lake, South Lake and Broadwater gardens had at least one sample where the conductivity was over the 1500μS upper limit in the ANZECC freshwater guidelines and Booragoon Lake was consistently over the limit.

The range of conductivity within Spring 2012 (sampling session 2) was highly variable at Berrigan Lake (lower: 146μS, upper: 2500μS), Broadwater Gardens (lower: 550μS, upper: 2520μS), Piney Lake Ornamental (lower: 471μS, upper: 2270μS) and Juett Park (lower: 559μS, upper: 2350μS).

**Figure 2.6:** The mean conductivity of water in natural wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines.

**Figure 2.7:** The mean conductivity of water in anthropogenic wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines.
Temperature

Water temperature was cooler during session two as this session occurred during spring and the other two sessions occurred during summer (Figure 2.8 and Figure 2.9). There was no significant difference between water temperatures in natural and anthropogenic wetlands $t(289) = -0.919, p > 0.05$.

![Figure 2.8: The mean temperature of water in natural wetlands in the morning (am) and afternoon (pm) over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error.](image)

![Figure 2.9: The mean temperature of water in anthropogenic wetlands in the morning (am) and afternoon (pm) over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error.](image)
Dissolved oxygen

Anthropogenic wetlands had higher dissolved oxygen (DO) than natural wetlands (Figure 2.10 and Figure 2.11) with greater variance in each session. An independent values t-test not assuming equal variances (because the variances are not equal, F=0.003, p>0.05) indicated DO was significantly higher in anthropogenic wetlands t(273.52)= -10.555, p<0.005).

Figure 2.10: The mean DO (%) of water in natural wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines.

Figure 2.11: The mean DO (%) of water in anthropogenic wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines.
**Turbidity**

Turbidity was low in anthropogenic wetlands (< 3 NTU, Figure 2.13). Natural wetlands had a greater variation of turbidity with high values occurring at Booragoon and Piney Lake N during summer 2012 and summer 2013 (respectively) and South Lake during spring 2012. There was a statistically significant difference between natural and anthropogenic wetlands (U=147, z= -3.459, p<0.001), however no wetlands exceeded the ANZECC freshwater guidelines.

![Figure 2.12: The mean turbidity (NTU) of water in natural wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error. Black line indicates the upper trigger values from the ANZECC guidelines.](image1)

![Figure 2.13: The mean turbidity (NTU) of water in anthropogenic wetlands over three sampling sessions: 1 = Summer 2012, 2 = Spring 2012 and 3 = Summer 2013. Error bars are standard error.](image2)
Water quality – Spring 2013

Water quality collected on one day during Spring 2012 had statistically significant differences between natural and anthropogenic wetlands with anthropogenic wetlands having higher pH ($U=111.5, z=-4.626, p<0.005$, Figure 2.14) and dissolved oxygen ($U=738.5, z=5.341, p<0.005$, Figure 2.15) and natural wetlands having higher conductivity ($U=65, z=-5.366, p<0.005$, Figure 2.16). Both Booragoon Lake and Chelodina Wetland had values greater than the local ANZECC trigger value for conductivity, however Booragoon’s conductivity was twice many of the other wetlands. Harmony Lake was the only location where dissolved oxygen was greater than the trigger guideline (ANZECC 2000).

![Figure 2.14: Mean pH from the twelve wetlands sampled in Spring 2013. Error bars are standard error.](image)

![Figure 2.15: Mean dissolved oxygen (%) collected at twelve wetlands in Spring 2013. Error bars are standard error. Black line indicates ANZECC trigger value for DO (%).](image)
Nutrients in the water column, TP (Figure 2.17) and TN (Figure 2.18) were present in significantly higher concentration in natural wetlands (U=24.5, \(z=-4.270\), \(p<0.005\), and \(W_s=231\), \(z=-5.057\), \(p<0.005\), respectively). There was no significant difference between natural and anthropogenic wetlands for chlorophyll \(a\) (Chl \(a\)) (Figure 2.19). Four of the five natural wetlands had concentrations greater than the trigger values (ANZECC 2000) for both TP and TN, however, none of them exceeded the trigger value for Chl \(a\). All anthropogenic wetlands were within acceptable limits.
Figure 2.18: Mean TN (µg.N/L) for twelve wetlands sampled in Spring 2013. Error bars are standard error. Black line indicates the ANZECC trigger value for TN.

Figure 2.19: Mean value of Chl a (µg/L) present in twelve wetlands sampled in Spring 2013. Error bars are standard error. Black line indicates the trigger value for Chl a from the ANZECC guidelines.
Water quality summary

Table 2.3 presents a summary of the water quality data collected. Booragoon was the only wetland that consistently had a parameter significantly over the ANZECC (2000) trigger guidelines. Whilst there were differences between natural and anthropogenic wetlands water parameters, the majority of the variation occurred within acceptable environmental limits, suggesting they would not impair turtle function.

Table 2.3: Summary of water parameters collected for this study. Table indicates if parameters were outside ANZECC guidelines and if results significantly differed between natural and anthropogenic wetlands

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Water quality (during trapping)</th>
<th>Water quality (Spring)</th>
<th>Nutrients (Spring)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH (^1) DO (^1) Cond (^1) Turbidity (^1)</td>
<td>pH (^1) DO (^1) Cond (^1) Turbidity (^1)</td>
<td>TP (^1) TN (^1) Chl (a) (^2)</td>
</tr>
<tr>
<td>Natural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Booragoon</td>
<td>✓ ✓ ✔</td>
<td>✓ ✓ ✔</td>
<td>✓ ✔</td>
</tr>
<tr>
<td>Piney Lake Natural</td>
<td>✓ ✓ ✔</td>
<td>✓ ✔ ✔</td>
<td>✓ ✔</td>
</tr>
<tr>
<td>Chelodina Wetland</td>
<td>✓ ✓ ✔</td>
<td>✓ ✔ ✔</td>
<td>✓ ✔</td>
</tr>
<tr>
<td>South Lake</td>
<td>✓ ✓ ✔</td>
<td>✓ ✔ ✔</td>
<td>✓ ✔</td>
</tr>
<tr>
<td>Little Rush Lake</td>
<td>✓ ✓ ✔</td>
<td>✓ ✔ ✔</td>
<td>✓ ✔</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✔ ✔ ✔</td>
<td>✔ ✔</td>
</tr>
<tr>
<td>Anthropogenic</td>
<td></td>
<td>✔ ✔ ✔</td>
<td>✔ ✔</td>
</tr>
<tr>
<td>Piney Lake Ornamental</td>
<td>≈ ≈ ✔</td>
<td>≈ ✔ ✔</td>
<td>≈ ✔</td>
</tr>
<tr>
<td>Juett Park</td>
<td>≈ ≈ ✔</td>
<td>≈ ✔ ✔</td>
<td>≈ ✔</td>
</tr>
<tr>
<td>Frederick Baldwin</td>
<td>≈ ≈ ✔</td>
<td>≈ ✔ ✔</td>
<td>≈ ✔</td>
</tr>
<tr>
<td>Berrigan Lake</td>
<td>≈ ≈ ✔</td>
<td>≈ ✔ ✔</td>
<td>≈ ✔</td>
</tr>
<tr>
<td>Broadwater Gardens</td>
<td>≈ ≈ ✔</td>
<td>≈ ✔ ✔</td>
<td>≈ ✔</td>
</tr>
<tr>
<td>Lucken Reserve</td>
<td>≈ ≈ ✔</td>
<td>≈ ✔ ✔</td>
<td>≈ ✔</td>
</tr>
<tr>
<td>Harmony Lake</td>
<td>≈ ≈ ✔</td>
<td>≈ ✔ ✔</td>
<td>≈ ✔</td>
</tr>
</tbody>
</table>

\(^1\)= Anthropogenic and Natural wetland significantly differ for this measurement (p<0.005).

\(^2\)= Anthropogenic and Natural wetland do not significantly differ for this measurement (p>0.05).

Key for Water Quality: ✓ = Good/within ANZECC trigger values

≈ = Slightly over/under trigger values

*= Significantly outside of trigger values
Macro-invertebrate diversity

The number of different taxa found at each lake in a spot sample in Spring 2011 is presented in Figure 2.20. Juett Park had lowest number of taxa present and South Lake had the greatest. The number of taxa found in natural wetlands was slightly higher (Figure 2.21). However, an independent samples t-test indicates that this difference is not statistically significant (t(8.973)=1.041, p>0.05).

![Figure 2.20: Total number of macro-invertebrate taxa found at each wetland in Spring 2011.](Image 1)

![Figure 2.21: Mean number of macro-invertebrate taxa found in anthropogenic and natural wetlands in Spring 2011. Error bars are standard error.](Image 2)
An NMDS plot (Figure 2.22) of the presence/absence of macro-invertebrate taxa at each wetland indicated a slight difference between the compositions of invertebrate communities in natural wetlands compared to anthropogenic wetlands, however, there was no statistically significant difference (Global $R= 0.133$, $p = 0.134$).

The percentage composition of the four primary taxa (Diptera, Odonates, Ostracods and Cladocerans) which form the majority of *C. colliei*’s diet (based on Tysoe 2005) are presented in Figure 2.23, together with the three most common taxa in the study wetlands (Copepoda, Oligochaeta and Gastropoda). The percentage contribution of the four primary diet taxa was over 70% in four anthropogenic wetlands (Piney Lake Ornamental, Frederick Baldwin, Lakelands and Lucken Reserve) and one natural wetland (Booragoon Lake). There was clear difference in the percentage contribution of each taxa between all wetlands. One interesting difference between natural and anthropogenic sites is the lack of Copepods present in the anthropogenic sites.

While Little Rush and South Lakes have a low percentage composition of the four main taxa that is eaten by *C. colliei*, they both had a high abundance of macroinvertebrates overall. Anthropogenic wetlands had a lower macroinvertebrate abundance than natural wetlands ($t(40)=3.271$, $p<0.005$, Figure 2.24).

Correlation between each wetland’s macroinvertebrate abundance, number of taxa present and nutrients (i.e. TP and TN) was tested, as macroinvertebrate presence and abundance can be influenced by nutrients. There was a significant correlation between macroinvertebrate abundance and both TP ($\tau = 0.477$, $p<0.05$) and TN ($\tau = 0.491$, $p<0.05$). There was no significant correlation between number of taxa and TP and TN.
Figure 2.23: The percentage composition for each wetland for the four main taxa eaten by *C. colliei* (Diptera, Odonates, Ostracods and Cladocerans), the three of the most common taxa and other macro-invertebrates.

Figure 2.24: Mean abundance of macro-invertebrate individuals collected at each wetland. Error bars are standard error.
Habitat

**Land cover classification and areas**

The area of land between the water’s edge and the closest road/or railway was classified into four groups, Trees and Sedges, Shrubs, Grass, and open Sand (Figure 2.25). Natural wetlands were characterised as having a larger area of land surrounding the wetland, containing 10% or less grass in their classified area, and having over 73% of their area containing Trees, Sedges and Shrubs (Figure 2.25). Both South Lake and Little Rush Lake had significant areas of open Sand (more than 10ha).

Anthropogenic wetlands were characterised as having a very small area of land surrounding the wetland (less than 6ha), containing over 25% grass, less than 71% of Trees, Sedges and Shrubs and less than a hectare of open Sand. Berrigan and Broadwater Gardens, however, are a wetland complex as such they varied slightly with a larger upland habitat and almost 2ha of open Sand.

The other wetland complex of Piney Lake Natural, Piney Lake Ornamental and Juett Park displayed some unique characteristics, with large areas of Shrubs, Sedges and Trees (36ha and 16ha respectively) whilst also having the largest area of Grass of all the sites (17ha).

![Figure 2.25: Total area of shrubs, trees and sedges, sand and grass surrounding each wetland from classification of Orthorectified RapidEye imagery (21st January 2012) of study wetlands.](image-url)
**Aquatic vegetation**

Natural wetlands had a larger number of aquatic species present \((t(56)=6.954, p>0.005, \text{Figure } 2.26)\) and a greater percentage of total aquatic vegetation cover \((t(56)=3.155, p>0.005, \text{Figure } 2.27)\). Exotic aquatic species were found both in natural and anthropogenic systems but only in three wetlands (Booragoon Lake, Piney Lake Natural and Juett Park (Table 2.4)). Anthropogenic wetlands generally had less fewer aquatic species present and in cover and abundance.

![Figure 2.26: Mean number of native and exotic aquatic vegetation species present in each wetland during Spring 2013.](image)

![Figure 2.27: Mean percentage of cover of aquatic vegetation during Spring 2013. Error bars are standard error.](image)
Table 2.4: Wetlands and their dominant aquatic taxa and their vegetation functional groups (Boulton et al 2014). Key: \(^{E}\)Emergent, \(^{S}\)Submerged, \(^{F}\)Floating, \(^{T}\)Terrestrial, \(^{A}\)Alage and * indicates exotic species.

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Dominant taxa (&lt;10% cover)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booragoon</td>
<td>Couch grass <em>(Elytrigia repens)</em>(^{1})*</td>
</tr>
<tr>
<td>Piney Lake Natural</td>
<td><em>Juncus microcephalus</em>, <em>Centella cordifolia</em>(^{E}) and Charophyta(^{A})</td>
</tr>
<tr>
<td>Chelodina Wetland</td>
<td><em>Baumea articulata</em>, Charophyta(^{A})</td>
</tr>
<tr>
<td>South Lake</td>
<td><em>Lemna minor</em>(^{F}) and <em>Elatine gratioloides</em>(^{E})</td>
</tr>
<tr>
<td>Little Rush Lake</td>
<td><em>Lemna minor</em>(^{F}), <em>Elatine gratioloides</em>(^{E}) and <em>Persicaria decipiens</em>(^{E})</td>
</tr>
<tr>
<td>Piney Lake Ornamental</td>
<td>Charophyta(^{A})</td>
</tr>
<tr>
<td>Juett Park</td>
<td><em>Baumea sp</em>(^{E})</td>
</tr>
<tr>
<td>Frederick Baldwin</td>
<td>Charophyta(^{A})</td>
</tr>
<tr>
<td>Berrigan Lake</td>
<td><em>Najas marina</em>(^{E})</td>
</tr>
<tr>
<td>Broadwater Gardens</td>
<td>Charophyta(^{A})</td>
</tr>
<tr>
<td>Lucken Reserve</td>
<td><em>Typha</em>(^{E})*</td>
</tr>
<tr>
<td>Harmony Lake</td>
<td><em>Spirogyra</em>(^{A}) and Charophyta(^{A})</td>
</tr>
</tbody>
</table>

**Terrestrial vegetation**

Canopy cover was significantly different between natural and anthropogenic wetlands (tt(61.534)=3.336, p<0.005, Figure 2.28) with greater canopy cover present in natural wetlands, as was shown in the land cover classification. Understory cover (which could not be assessed using satellite imagery) was also significantly different between natural and anthropogenic wetlands (tt(57.977)=3.037, p<0.005, Figure 2.28) with significantly more understory vegetation cover present in natural wetlands. Ground cover was significantly higher in anthropogenic wetlands (tt(100.494)=3.217, p<0.005, Figure 2.28). The land cover classification showed that a significant proportion of ground cover present at anthropogenic wetlands was grass (Figure 2.25). Percentage bare ground cover did not significantly differ between natural and anthropogenic wetlands tt(112.606)=-2.319, p>0.05.

Natural wetlands had greater variation between sites, but generally had significantly more canopy and understory cover than anthropogenic wetlands. Anthropogenic wetlands all had similar characteristics with a canopy of less than 30%, tree height of less than 30m, understory almost absent (less than 10% cover) and a ground cover primarily of grass (greater than 50%).
Figure 2.28: Mean percentage of (a) canopy cover, (b) understory cover, and (c) groundcover for wetland study sites during Spring 2013. Green underline indicates Natural wetlands and orange underline indicates anthropogenic wetlands. Error bars are standard error.
Discussion

All environmental conditions (water quality, macro-invertebrate abundance, vegetation and land cover) significantly differ between natural and anthropogenic wetlands. The hypothesis “Environmental conditions differ between Natural wetlands and Anthropogenic wetlands” is clearly supported. This chapter provides a detailed insight into the variations both between and within the natural and anthropogenic wetland classifications and will now consider the influence that these environmental conditions on C. colliei and its populations. Subsequently, Chapter Three will examine C. colliei populations within these wetlands and how these resources have influenced these populations.

Water quality

As C. colliei live in the water, water quality should be an important habitat factor for the species, as it is the medium in which they live. The pH, DO, conductivity, total phosphorus (TP) and total nitrogen (TN) in natural and anthropogenic wetlands significantly differed from each other for both the samples taken simultaneously in Spring 2013 and during turtle trapping. Little information is available on C. colliei habitat requirements, however, it is reasonable to assume that water quality must be within certain parameters to be conducive to life. For the purposes of this study the ANZECC water quality guidelines (ANZECC and ARMCANZ 2000) provide a basis for identifying water quality suitable for C. colliei. Therefore, despite this significant difference, the majority of the values were within or just outside of ANZECC guidelines (with the exception of TP and TN) (ANZECC and ARMCANZ 2000) and it is therefore likely that for these water parameters, anthropogenic wetlands are as suitable as natural wetlands as habitat for C. colliei.

Chelodina colliei is adapted to wetlands periodically drying out and in response will bury themselves in the substrate of a wetland to aestivate (Cann 1998). Therefore, it is reasonable to assume that C. colliei are robust enough to cope with short periods of high conductivity, high nutrients, extreme pH ranges and low dissolved oxygen which occur as a wetland dries (Boulton et al. 2014). As drying is common in the context of Perth wetlands peaks and drops in water quality parameters as drying occurs may not significantly affect C. colliei. The following two examples highlight results in this study which likely resulted from drying. 1) The consistently high conductivity at Booragoon Lake is common among shallow wetlands that dry during summer in Perth (Davies et
al. 1993). 2) The high TP and TN at all natural wetlands which completely dry during summer (i.e. all except for Chelodina Wetland) is a common phenomenon amongst these types of wetlands. As most of the water quality data points that exceed ANZECC guideline ranges are typical for wetlands that dry it may be that *C. colliei* is equipped to handle these in the short to mid-term. However, due to the combination of a changing climate and groundwater level reductions (due to urban residents) many natural wetlands are staying dry for longer periods of time (Cargeeg *et al.* 1987, Sommer and Horwitz 2001) therefore further research exploring the long term effect of parameters outside of the ANZECC guideline range on *C. colliei* is recommended.

Water quality does not only affect *C. colliei* directly, its food sources are also influenced by water quality. Water quality and nutrients (along with habitat structure) are environmental factors which influence macroinvertebrate abundance and diversity (Wang *et al.* 2007). This study found that there is a greater abundance of macroinvertebrates in wetlands with higher levels of TP and TN, this means that there is more food available for *C. colliei* in these wetlands. However, if TP and TN levels are too high there is the potential for eutrophication to occur which can cause high turbidity, reduce dissolved oxygen and result in a loss of native species diversity (Boulton *et al.* 2014) which would affect both *C. colliei* and the available food sources (macroinvertebrates). Therefore the water quality of the habitat in which *Chelodina colliei* lives needs to be suitable for *C. colliei* as well its primary food sources and food web. While the water quality values in this study do not appear to be a cause for concern currently (as mentioned previously) regular and consistent monitoring of the study sites would advisable given the combination of the urban environment, climate change and groundwater level reduction.

**Macroinvertebrates**

*Chelodina colliei*’s diet is primarily composed of invertebrates such as Diptera larvae, Ostracods, Amphipods, Cladocerans, Acarina, Hemiptera, Copepods, Oodonates and Annelida (Tysoe 2005). This diet is seasonal and can vary between locations, likely due to different invertebrate complements at each wetland. There is some evidence that *C. colliei* eats small fish and carrion (Woldring 2001), and baby birds (Burbidge 1967). It is clear that *C. colliei* is a generalist feeder but invertebrates compose a substantial part of their diet. Therefore, this study has focussed specifically on aquatic invertebrates, the principle component of *C. colliei*’s diet (Tysoe 2005).
There was a significant difference in the abundance of macroinvertebrates collected from natural wetlands and anthropogenic wetlands. This may be of concern as the numbers of macroinvertebrates within the anthropogenic wetlands are quite low and may not be sufficient to maintain C. colliei population over time.

To determine if there is enough food available for the population in each wetland the number of turtles within the wetland must first be known. However, wetlands that provide more food sources for turtles allow for faster turtles growth and therefore have higher reproductive outputs (Brown et al. 1994). This could be very important for the maintenance of C. colliei populations, as if turtles are sexually mature sooner that means greater reproductive potential for the population.

There was no difference in the number of taxa identified between natural and anthropogenic wetlands, although there was a slight difference in composition. All the taxa identified by name in Figure 2.23 have been recorded in turtle stomach contents (Tysoe 2005), although some only occurred in very small numbers (e.g. Copepoda percentage contribution 0.38%±1.6%). The four primary diet taxa, however, did make up over 70% of the samples at Booragoon Lake, Piney Lake Ornamental, Frederick Baldwin, Lakelands and Lucken Reserve, therefore provision of key diet taxa is not limited specifically to anthropogenic or natural wetlands. In this case, composition of the invertebrate community might not be overly important, as C. colliei is a generalist feeder. Therefore any differences in the macroinvertebrate community composition between natural and anthropogenic wetlands are may not have significant impact on C colliei.

Macroinvertebrate abundance is more likely (potentially) to be the key limiting factor as it is the primary food source for C. colliei and the abundance was small in a number of anthropogenic wetlands. If food is limited it has the potential to affect the growth and development of juveniles as well as limit the number of C. colliei that the wetland has the capacity to carry. Greater competition for food may also affect the ability of C. colliei females to produce and lay eggs and for C. colliei to aestivate appropriately (although none of the anthropogenic wetlands dry to the degree where aestivation is necessary). Further research is needed to investigate the specific affects that limitation of food has on C. colliei individuals and populations.

In some anthropogenic wetlands it is suspected that the diet of C. colliei is supplemented by humans feeding turtles. The author observed this occurring twice at one of the study sites with turtles being fed bread and prawns. This feeding was
occurring on such a regular basis that anyone approached the edge of the wetland the turtles would swim up to them and “beg” for food. Supplemented feeding can alter the natural behaviour patterns of individuals and populations, it can assist endangered species but also has risks such as encouraging dependence and negative human interactions such as poaching (Orams 2002). This feeding changes turtle behaviour which in turn could influence the effectiveness of trapping (see Chapter 3) by either making turtles trap happy or reducing the chance of capturing turtles (as they are already well fed). While supplemented feeding has risks to a population could also assist populations where the abundance of food sources is low.

Vegetative habitat

Aquatic habitat

Aquatic habitat is vital for *C. colliei* as it spends majority of its life within the aquatic environment, therefore, the structure and composition of this environment is likely to have a strong influence of *C. colliei* populations. Natural wetlands had greater aquatic plant diversity and cover than anthropogenic wetlands. The microhabitats created by aquatic vegetation within a wetland provide different sets of environmental conditions, which can favour particular species.

The specific aquatic micro-habitats which *C. colliei* use is unknown, however, turtles in general use an array of vegetated micro-habitats within wetlands (Hartwig and Kiviat 2007). These habitats may be used for different functions such as basking sites, which *C. colliei* has been observed using or juveniles may use different habitat to adults. Aquatic vegetation may also be important as it provides cover from predation within the wetland which would be especially vital for younger individuals which are prey to animals such as birds or crayfish (such as *Cherax destructor* (Bradsell et al. 2002)).

While not supported by the data in this study, previous research has shown that aquatic vegetation can influence macroinvertebrate community colonisation, composition, richness and abundance (de Szalay and Resh 2000, Theel et al. 2008). As macroinvertebrates are *C. colliei*’s primary food source, presence of aquatic vegetation influencing available food sources is an important consideration as it is likely that *C. colliei* utilises aquatic vegetation for feeding as well as habitat (Hartwig and Kiviat 2007). The higher presence of aquatic vegetation in natural wetlands may also provide
cover which can assist juvenile and hatchling turtles in avoiding predators (Bradsell et al. 2002).

While we have a general understanding of the aquatic habitat required by *C. colliei*, currently a detailed assessment of wetland aquatic habitat provision for *C. colliei* is not possible. Given the proportion of its life that *C. colliei* spends within the aquatic habitat it is of concern that not more is known about its aquatic habitat requirements. Future research needs to consider the aquatic micro-habitat usage and needs of *C. colliei*. This information would allow managers to improve the habitat provided in anthropogenic wetlands where *C. colliei* reside, which in turn could assist populations in the future and allow better future management of *C. colliei* habitat.

**Upland habitat**

If a wetland provided acceptable water quality, an array of suitable micro-habitats and food, it is likely that an individual *C. colliei* would be sustained and possibly maintain a short-term population. However, if a population of *C. colliei* is to exist over a longer term, a wetland also needs to provide adequate environmental conditions for the maintenance of a breeding population. For reproduction and migration, *C. colliei* requires terrestrial habitat.

*Chelodina colliei*’s terrestrial habitat requirements are likely to be close to the original natural environment that surrounded wetlands: vegetation that is structurally complex; with a canopy, natural understory and sandy open soil (far enough away from the wetland to prevent inundation) suitable for nesting (Clay 1981). A structurally complex terrestrial environment would provide foliage cover to protect the nesting female (or migrating individual) from aerial predation, while an understory of vegetation may provide cover to nesting *C. colliei* and hatchlings from land based predators (Clay 1981). For reproductive purposes, turtles may be able to cope with a band of terrestrial vegetation wide enough and far enough from the wetland to prevent egg inundation and if vegetation is sufficiently dense to provide protection whilst laying eggs and for hatchlings returning to a wetland. If these terrestrial requirements are met it should be possible for a population to exist over the mid-long term.

Upland habitat that is well vegetated provides *C. colliei* with cover for movement on land. The loss or removal of upland habitat may affect *C. colliei* both on land (less cover for movement) and in the wetland. A buffer of upland habitat can prevent or reduce the effect of changes to the landscape (e.g. agriculture or urbanisation) on wetlands, which can assist some species in maintaining their abundance (Sterrett *et al.*
Anthropogenic wetlands in this study all had a parkland community surrounding them, characterised by low canopy, little to no understory and a ground cover of lawn or grass. The reduced structure of this vegetation (i.e. reduced understory and canopy) provides less cover for the movement of *C. colliei* on land. Anthropogenic wetlands had a significantly lower percentage of canopy cover, a smaller associated terrestrial area, a greater area of grass and very low or no areas of open sand (for nesting). Whereas natural wetlands in almost all cases did provide all these requirements. Therefore, natural wetlands do provide a suitable upland habitat while anthropogenic wetlands do not.

Piney Lake Natural, Piney Lake Ornamental and Juett Park area consisted of both parkland around the anthropogenic wetlands and an adjacent native bush area where Piney Lake Natural is located. This was the only location where there were roughly equivalent areas of grass, shrub, trees and sedges. This mix of anthropogenic habitat with natural habitat provides the turtles within the two anthropogenic wetlands (Piney Lake Ornamental and Juett Park) with areas for nesting and movement that they would not have had access to if they were completely surrounded by road like all the other systems in this study. Therefore Piney Lake Ornamental and Juett Park probably provide the best habitat for *C. colliei* as they are adjacent to natural bush land areas.

Booragoon Lake had the smallest associated terrestrial area (10.4ha) of all the natural wetlands assessed in this study. Booragoon had very little open sand area and bare ground available for nesting. This smaller area and lack of suitable nesting ground may be one reason why residents around this wetland report finding turtles attempting to lay eggs in their gardens (anecdotal report from social survey, see Chapter Five). Turtles utilising gardens as a nesting habitat is not uncommon around urban wetlands (Guyot and Kuchling 1998). These gardens provide open soil area that is easily accessible to *C. colliei* and most often within a suitable range. However, the lack of vegetative cover available for these nesting movements into the urban area may result in more predation upon nesting females.

The differences in upland habitat are another key factor that may affect the populations of *C. colliei*. Lack of vegetative cover around anthropogenic wetlands increase the risk to any turtle on land. This will particularly affect female *C. colliei* while they are moving to lay their eggs. Prior research has shown that urban wetlands surrounded by roads and residences tend to have a population skew towards males as many females are killed crossing the roads or from predation (Spencer and Thompson 2003, Steen and
Gibbs 2004, Spencer and Thompson 2005, Steen et al. 2006, Beaudry et al. 2008, Beaudry et al. 2010). It would be reasonable to expect a similar skew in the study wetlands (see Chapter Three).

The hypothesis “Environmental conditions differ between Natural wetlands and Anthropogenic wetlands” was supported, natural wetlands do provide environmental conditions more suitable for *C. colliei* than anthropogenic wetlands. From this, specifically, key environmental factors which may constrain *C. colliei* populations are to be macroinvertebrate abundance and upland habitat. Further research is required to identify more specific details about *C. colliei* habitat requirements including: aquatic microhabitat usage, preference for aquatic vegetation, macroinvertebrate diet (and size of diet) and the effect of long-term high values of conductivity and nutrients on turtles as individuals and at a population level. If natural wetlands do provide *C. colliei* with suitable environmental conditions it would be expected that *C. colliei* populations would be larger and have a better structure in natural wetlands. The following chapter investigates this further.
Chapter Three - *Chelodina colliei* populations

**Introduction**

Chelonians are unique reptiles which are thought to be able to live 20 to 30 years in the natural environment (Gibbons 1987). In comparison to short-lived species, Chelonians take a long time to become sexually mature. *Chelodina oblonga* (previously *Chelodina rugosa* (Kennett et al. 2014)) males mature at 3.9 years (16.5cm) and females mature at 6.5 years (21cm), while *Elseya dentate* males mature at 8.6 years (22cm) and females at 13.5 years (27.6cm) (Kennett 1996). This slow generation time means that freshwater turtle populations ability to cope with long-term disturbance is limited, as if mature individuals are lost from the population it can take many years for them to be replaced (Congdon *et al.* 1994). In addition, due to the long-lived nature of turtles, disturbance to a population may not be immediately obvious (Burke *et al.* 2000).

Human modification of the environment in urban areas can result in wetland components being lost or so heavily modified that their function is compromised or replaced by human control. The term ‘anthropogenic wetland’ is used to denote this different type of wetland. Generally these anthropogenic wetlands lack native fringing vegetation and are managed for human amenity before ecological needs. This is exemplified in Chapter Two which identified a lack of suitable upland habitat and macro-invertebrate abundance for *C. colliei*. Anthropogenic habitats increase the risk of harm to turtles but also modify their population structure and functioning as a population and meta-population. For example, deaths of nesting or migrating individuals have been attributed to roads, causing a high male sex skew in a number of turtle populations (Steen and Gibbs 2004, Steen *et al.* 2006). The loss of fringing habitat also increases risk of predation (Spencer and Thompson 2003). Unlike some aquatic species that complete their life cycle with a wetland, freshwater turtles require both wetland and upland habitats, and may be differentially and additively affected by human modifications to each (Burke *et al.* 2000).

Population structure examines the demography of the population, primarily with regards to sex distribution, age and size (Oxford Ecology Dictionary 2010). Knowledge of these factors and abundance is required to understand how a population is functioning, so that it can be conserved (Gibbs and Amato 2000). While species dependent (Bury 1979), by examining population structure it is possible to identify if urbanisation has adversely affected a population. From the literature, an ideal *C. colliei* population structure would
have a small proportion of juveniles (as freshwater turtles tend to have a low hatchling and juvenile survival rate (Gibbs and Amato 2000), equal sex ratios (Bury 1979) and a range of sexually mature age classes (Harless and Morlock 1979). Significant variation in population structure, such as skewed sex ratios (Aresco 2005) or lack of juveniles are linked to disturbances such as urbanisation. The first hypothesis for this chapter investigates this:

“Population structure of C. colliei in natural wetlands will differ from anthropogenic wetlands” (i.e. natural wetlands meet more of the ideal population characteristics).

Population structure can also be influenced by factors such as disease and predation or intra-specific competition. Disease and predation are two factors that can naturally control population sizes and the probability of survivorship from these factors can be dependent upon the age of the individual (Dempster 1975, Moss et al. 1982). Intra-specific competition is the competition between individuals for access to resources such as food, space, nesting sites and shelter (Dempster 1975). It follows that in a constrained environment large populations may have a greater struggle to access required resources. This study did not specifically investigate the influence of these factors on C. colliei populations.

Chapter Two identified that anthropogenic wetlands environmental conditions considerably differ from natural wetlands with upland habitat and food sources being conditions of importance C. colliei populations. Upland habitat and variation in turtle population structure have been linked to differences in wetland environmental variables, such as fringing vegetation, as well as habitat and landscape features such as upland vegetation cover surrounding wetlands (Marchand and Litvaitis 2004). Therefore, it is likely that the differences in resources provided in urban wetlands would also influence population structure of C.colliei. Modification of wetlands may lead to decline in the species richness or abundance of invertebrates and fish (Meyer and Paul 2001) and macro-invertebrate abundance is lower in anthropogenic wetlands. The provision of invertebrates is one of main resources provided by a wetland for species higher up the food chain. If these resources are not provided it can lead to a decline in vertebrate populations (Smallbone et al. 2011) In the case of C. colliei it is not known how population structure would change as a result of lack of food or other resources, as there is no existing research that illustrates this relationship. Hypothesis two investigates whether:
“Differences in environmental conditions between wetlands results in differences in population structure.”

**Method**

Mark-recapture was conducted at twelve wetlands (see Chapter Two: Site descriptions) where *C. colliei* was known to be present. To assess the population structure, baited modified funnel traps (Kuchling 2003) were placed at each wetland. Each morning and evening traps were checked for turtles and to minimise trap theft, interference and to comply with university animal ethics requirements.

Three trap seasons ran over summer (January to March) 2012, spring (October to November) 2012 and summer (January to March) 2013. Trapping was timed to avoid the colder parts of the year (May-September), as below certain temperatures trapping success for Chelonians is adversely affected (Chessman 1988a, Rowe and Moll 1991). This minimum temperature has not been identified for *C. colliei*. Trapping was also timed to capture turtles prior to the natural wetland drying out. Two wetlands (Little Rush Lake and South Lake) could not be sampled for the final half of the trap season in 2013 (two and a half days each) due to low water level.

The study was initially designed to comprise two trap seasons. Each season would contain five and a half days of trapping for each wetland, with rebaiting occurring on the third day. However, extreme trap shyness was identified at the conclusion of the first trapping season. To minimise the effect of trap shyness, modifications were made to the second season, and a third season was added to supplement the dataset. These modifications included; 1) splitting trapping for each season into two lots of two and a half days, 2) rotating trapping between wetlands so that there was approximately one month between the first set of days and the second and 3) rebaiting each day to maintain a more constant bait signal.

When captured, each turtle was weighed using electronic scales. The carapace length, width and depth, plastron length and extended tail length (from the base of the plastron to the tip of the tail) were measured using vernier calipers (Clay 1981, Giles *et al.* 2008). To identify re-captured individuals each turtle had a “v” shaped notches filed on the marginal scute/s following the standard *C. colliei* numbering system (Burbidge 1967). Sex was identified for all captured turtles except for eight individuals that were too small.
Much research conducted about *C. colliei* over the last forty years has only had the opportunity to collect data from two or three wetlands at a time. All available research (incorporating number of individuals captured, population estimated and sex ratios) was collated (Table 3.3) to allow a comparison of prior works conducted on *C. colliei*.

**Data analysis**

All analysis of turtle carapace length data was conducted using Mann-Whitney tests as the data was not normally distributed. Chi-Square tests were used to analyse sex ratios in anthropogenic and natural wetlands. Mark-recapture analysis using Program MARK was conducted for each wetland where recaptures occurred. CAPTURE analysis was performed to estimate population size. The appropriate function was used to suggest the most appropriate model for each wetland. Models used included Null, Chao, Zippin and Jackknife. This was only performed for Chelodina Wetland, Little Rush Lake, Piney Lake Natural, Piney Lake Ornamental and Juett Park as there were no recaptures at any of the other study sites. To identify if resources or environmental factors influenced population structure, Spearman correlation coefficient and multiple regression were used.
Results

Two hundred and sixty six turtles were captured over three trap seasons with a 9% recapture rate overall (Table 3.1). The majority of anthropogenic wetlands had very low capture numbers, despite trap effort being equal between all wetlands. Only Little Rush Lake, Chelodina Wetland, Piney Lakes (natural and ornamental) and Juett Park had recaptures.

Table 3.1: Number of turtles captured at each wetland and the number of recaptures over the course of three trapping seasons

<table>
<thead>
<tr>
<th>Wetland</th>
<th>N(^0) of Turtles Captured(^1) (Turtles recaptured)</th>
<th>Total(^2)</th>
<th>Percentage of turtles recaptured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Wetlands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Booragoon Lake</td>
<td>3 3 3</td>
<td>9</td>
<td>0%</td>
</tr>
<tr>
<td>Piney Lake Natural</td>
<td>16 (2) 1 (1) 0</td>
<td>20</td>
<td>18%</td>
</tr>
<tr>
<td>Chelodina Wetland</td>
<td>6 (1) 1 9 (1)</td>
<td>18</td>
<td>13%</td>
</tr>
<tr>
<td>Little Rush Lake</td>
<td>6 80 (2) 14</td>
<td>102</td>
<td>2%</td>
</tr>
<tr>
<td>South Lake</td>
<td>2 4 5</td>
<td>11</td>
<td>0%</td>
</tr>
<tr>
<td>Anthropogenic wetlands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piney Lake Ornamental</td>
<td>15 7 (1) 3</td>
<td>26</td>
<td>4%</td>
</tr>
<tr>
<td>Juett Park</td>
<td>31 (3) 10 (8) 2 (2)</td>
<td>56</td>
<td>30%</td>
</tr>
<tr>
<td>Frederick Baldwin</td>
<td>4 0 3</td>
<td>7</td>
<td>0%</td>
</tr>
<tr>
<td>Lucken Reserve</td>
<td>4 1 0</td>
<td>5</td>
<td>0%</td>
</tr>
<tr>
<td>Berrigan lake</td>
<td>1 0 0</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>Broadwater Gardens</td>
<td>1 0 1</td>
<td>2</td>
<td>0%</td>
</tr>
<tr>
<td>Harmony Lake</td>
<td>2 2 5</td>
<td>9</td>
<td>0%</td>
</tr>
</tbody>
</table>

\(^1\)Value excluding recapture  
\(^2\)Including recaptures  
Grand total: 266 9%
Hypothesis One

“Population structure of C. colliei in natural wetlands will differ from anthropogenic wetlands”.

Age class

As is usual with freshwater turtle populations, distribution of the carapace lengths of all turtles captured was non-normal (carapace length is used as an indicator for sexual maturity in C. colliei.). There was significant difference between the distributions of carapace lengths in natural wetlands compared to anthropogenic wetlands (Figure 3.1). This was supported by a Mann Whitney test (U=5856.5, z=-2.199, p<0.05).

The two key differences were: 1) more hatchling and juvenile turtles were present in natural wetlands and 2) there was a comparatively smaller number of sexually mature individuals (17cm+) in the anthropogenic wetlands compared to natural wetlands. In contrast, the numbers of turtles in the 10cm to 16cm range were relatively even between wetland types.

![Carapace Length Distributions](image)

Figure 3.1: Carapace length distributions of C. colliei in natural and anthropogenic wetlands. Dashed lines indicate size of sexual maturity for males (13cm) and females (16cm) respectively.
The average carapace length of *C. colliei* differed between wetlands (Figure 3.2). The natural wetlands, Booragoon Lake and South Lake had a large average carapace length of 26cm and 23cm respectively, indicative of an aged population and in addition no juvenile turtles were captured in these wetlands. Similarly, a previous study at Booragoon Lake (Giles *et al.* 2008 Table 3.3) also found little evidence of recruitment. The three other natural wetlands all had a distribution of turtles that included both juveniles and adults. The average carapace length for Chelodina Wetland and Piney Lake (natural) were both less than the length for male sexual maturity. In comparison to the previous study conducted at Piney Lake natural (Giles *et al.* 2008 Table 3.3) the population was far more skewed to juveniles (as a percentage of captures 64% in this study compared to 16% by Giles *et al.*) and had significantly less adult turtles overall (seven individuals in this study compared to 120 by Giles *et al.*) Four of the seven anthropogenic wetlands (Frederick Baldwin, Lucken Reserve, Berrigan Lake, and Broadwater Gardens) had no juveniles captured. Juett Park and Piney Lake ornamental were special, as they not only had juveniles present but had a larger abundance of turtles than the other anthropogenic sites (Table 3.1).

![Figure 3.2: Distribution of carapace length of turtles by wetland. Dashed lines indicate size of sexual maturity for males (13cm) and females (16cm) respectively.](image)

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Carapace Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booragoon Lake Natural</td>
<td></td>
</tr>
<tr>
<td>Chelodina Wetland</td>
<td></td>
</tr>
<tr>
<td>Little Rush Lake</td>
<td></td>
</tr>
<tr>
<td>South Lake</td>
<td></td>
</tr>
<tr>
<td>Piney Lake Ornamental</td>
<td></td>
</tr>
<tr>
<td>Juett Park</td>
<td></td>
</tr>
<tr>
<td>Frederick Baldwin</td>
<td></td>
</tr>
<tr>
<td>Lucken Reserve</td>
<td></td>
</tr>
<tr>
<td>Berrigan Lake</td>
<td></td>
</tr>
<tr>
<td>Broadwater Gardens</td>
<td></td>
</tr>
<tr>
<td>Harmony Lake</td>
<td></td>
</tr>
</tbody>
</table>

Natural Wetland

Anthropogenic Wetland
**Sex ratio**

The ratio of males to females was only skewed towards males at Piney Lake Ornamental, however, this ratio did not significantly differ from a 1:1 ratio (Table 3.2). Only Little Rush Lake and Juett Park had a sex ratio that statistically deviated from 1:1, and both of these were skewed towards females. All other wetlands had a sex ratio which did not statistically deviate from a 1:1 ratio (3) or the \( \chi^2 \) could not be run as the number of turtles captured was too low. Of the 14 previous wetlands where *C. colliei* was captured and the sex ratio or numbers of each sex were published (Table 3.3) two wetlands had a skew towards males, four had a skew towards females and eight did not significantly differ from a 1:1 ratio.

Table 3.2: The ratio of male to female turtles captured from each study site in Perth, populations statistically significantly dominated by females are indicated in green.

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>Wetland</th>
<th>Ratio of M:F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Wetlands</td>
<td>Booragoon Lake</td>
<td>1:3.5(^1)</td>
</tr>
<tr>
<td></td>
<td>Chelodina Wetland</td>
<td>1:1.29 (^{n.s.})</td>
</tr>
<tr>
<td></td>
<td>Little Rush Lake</td>
<td>1:4.21(^1)</td>
</tr>
<tr>
<td></td>
<td>South Lake</td>
<td>1:1.75 (^{n.s.})</td>
</tr>
<tr>
<td></td>
<td>Piney Lake Natural</td>
<td>1:3.5(^1)</td>
</tr>
<tr>
<td>Anthropogenic Wetlands</td>
<td>Piney Lake Ornamental</td>
<td>1:0.92 (^{n.s.})</td>
</tr>
<tr>
<td></td>
<td>Juett Park</td>
<td>1:2.07(^1)</td>
</tr>
<tr>
<td></td>
<td>Berrigan Lake</td>
<td>1:2(^1)</td>
</tr>
<tr>
<td></td>
<td>Broadway Gardens</td>
<td>1:1.(^1)</td>
</tr>
<tr>
<td></td>
<td>Frederick Baldwin</td>
<td>1:2.5(^1)</td>
</tr>
<tr>
<td></td>
<td>Harmony Lake</td>
<td>1:1.25(^1)</td>
</tr>
<tr>
<td></td>
<td>Lucken Reserve</td>
<td>1:4(^1)</td>
</tr>
</tbody>
</table>

\(^1\chi^2\) test significant p<0.05, \(^{n.s.}\)\(\chi^2\) test not significant p>0.05,
\(^{1}\chi^2\) test not run, sample size too small, \(^1\)Green indicates female dominated population
Table 3.3 provides a summary of all *C. colliei* research conducted in Western Australia where turtle data has been published. Piney Lakes Natural and Booragoon Lake were previously studied by Giles *et al.* (2008). A comparison of the number of *C. colliei* captured by Giles *et al.* (2008) and this study indicate a decline in numbers in Piney Lake Natural from 131 turtles captured in 2000/2001 to just 20 turtles captured in 2012/2013 (Table 3.3). The trap effort at Piney Lake Natural in this study was two-thirds of that in Giles *et al.* 2008, but the population difference is significantly greater than can be attributed to the smaller trap effort. At Booragoon Lake, *C. colliei* captures in this study (9 turtles) were also lower than Giles *et al.* 2008 (29 turtles in 2000/2001). Although due to low capture numbers at Booragoon Lake in Giles study, the number of *C. colliei* captures presented includes hand-captures. Interestingly, this study did not find a statistically significant skew towards females at Piney Lake Natural but there was a skew in 2000/2001 (Giles *et al.* 2008). Booragoon Lake's sex skew could not be statistically tested for 2012/2013 as the sample size was too small and in 2000/2001 there was no statistically significant sex skew.
Table 3.3: Summary of all *C. colliei* research conducted where number of turtle captured or sex ratio data was collected.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year of sampling</th>
<th>Lake/Wetland</th>
<th>Number of individuals captured</th>
<th>Population estimate</th>
<th>Sex Ratio M:F²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guyot and Kuchling, 1998</td>
<td>1997/1998</td>
<td>Perry Lakes (Two lakes)</td>
<td>1041</td>
<td>-</td>
<td>1:0.97n.s., 1:0.96n.s.</td>
</tr>
<tr>
<td>Tysoe 2005</td>
<td>2005</td>
<td>Shenton Park (Jualbup Lake)</td>
<td>89</td>
<td>-</td>
<td>1:0.48†</td>
</tr>
<tr>
<td>Tysoe 2005</td>
<td>2005</td>
<td>Claremont Lake</td>
<td>125</td>
<td>-</td>
<td>1:1.36ns.</td>
</tr>
<tr>
<td>Giles et al 2008</td>
<td>2000/2001</td>
<td>Blue Gum Lake (Natural)</td>
<td>446 (includes 12 hand captures)</td>
<td>1835 to 2040</td>
<td>1:3.88**</td>
</tr>
<tr>
<td>Giles et al 2008</td>
<td>2000/2001</td>
<td>Booragoon</td>
<td>29</td>
<td>247</td>
<td>1:0.53ns.</td>
</tr>
<tr>
<td>McKeown 2010</td>
<td>2010</td>
<td>Black Swan Dam (Natural)</td>
<td>66 (8 recapture)</td>
<td>136 ±36.5</td>
<td>1:1.47ns.</td>
</tr>
<tr>
<td>Phoenix Environmental Services 2011</td>
<td>2010</td>
<td>Bibra Lake</td>
<td>23</td>
<td>-</td>
<td>1:2.29ns.</td>
</tr>
<tr>
<td>Hamada 2011</td>
<td>2011</td>
<td>Shenton Park (Jualbup Lake)</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hamada 2011</td>
<td>2011</td>
<td>Kogolup</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hamada 2011</td>
<td>2011</td>
<td>Joondalup</td>
<td>28</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hamada 2011</td>
<td>2011</td>
<td>Mabel Talbot</td>
<td>19</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hamada 2011</td>
<td>2011</td>
<td>Blue Gum Lake</td>
<td>36 (all hand captured)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hamada 2011</td>
<td>2011</td>
<td>Yangebup</td>
<td>28</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hamada 2011</td>
<td>2011</td>
<td>Yanchep</td>
<td>16</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hamada 2011</td>
<td>2011</td>
<td>Black Swan</td>
<td>36</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Giles 2012</td>
<td>2011</td>
<td>Bibra Lake</td>
<td>85</td>
<td>-</td>
<td>1:1.93³</td>
</tr>
<tr>
<td>Dawes 2012</td>
<td>2012</td>
<td>Needonga Lake</td>
<td>15</td>
<td>-</td>
<td>1:0.15⁷</td>
</tr>
<tr>
<td>Dawes 2012</td>
<td>2012</td>
<td>Chittering Lake</td>
<td>10</td>
<td>-</td>
<td>1:0.43ns.</td>
</tr>
</tbody>
</table>

¹ not χ² tested as individuals captured on the land during nesting season, which in part explains the high number of females to males captured for this paper. All other papers captured turtles in water using traps or hand.

²Blue indicates male dominated population, green indicates female dominated population

*χ² test highly significant p<0.001, *χ² test significant p<0.05, n.s. χ² test not significant p>0.05
There was a statistically significant relationship between type of wetland (Natural/Anthropogenic) and sex of the turtle ($\chi^2(1)=5.652$, p>0.05). With a proportionally smaller number of female *C. colliei* present in anthropogenic wetlands (62.0%) compared to the number of females present in natural wetlands (76.6%) (Figure 3.3).
**Population estimates**

Turtles were only recaptured at two of seven anthropogenic wetlands (Juett Park, Piney Lake Ornamental) and three of five natural wetlands (Little Rush Lake, Chelodina Wetland and Piney Lake Natural). Population size estimates (Table 3.4) for these wetlands indicate that the two anthropogenic wetlands had larger populations than the natural wetlands (with the exception of Little Rush Lake). Little Rush Lake had the largest number of turtles captured (100 turtles) and the largest population estimated (1538±878.6), however, as a result of low recapture numbers (2%) the population estimation for Little Rush Lake has a very large standard error and confidence interval.

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Population Estimate</th>
<th>SE</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Wetlands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chelodina Wetland</td>
<td>68</td>
<td>42.6</td>
<td>29</td>
</tr>
<tr>
<td>Little Rush Lake</td>
<td>1538</td>
<td>878.6</td>
<td>578</td>
</tr>
<tr>
<td>Piney Lake Natural</td>
<td>17</td>
<td>0.05</td>
<td>17</td>
</tr>
<tr>
<td>Anthropogenic Wetlands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piney Lake Ornamental</td>
<td>120</td>
<td>25.1</td>
<td>83</td>
</tr>
<tr>
<td>Juett Park</td>
<td>85</td>
<td>14.5</td>
<td>65</td>
</tr>
</tbody>
</table>

**Outcome for Hypothesis One**

Anthropogenic wetlands had fewer females, juveniles, older adults (17cm+) and a lower overall abundance with two exceptions (Juett Park and Piney Lakes Ornamental). As a result, the majority of anthropogenic wetlands (Berrigan Lake, Broadwater Gardens, Frederick Baldwin Lake, Harmony Lake and Lucken Reserve) are less likely to be sustainable given that they are missing an important fraction of new recruits, the breeding population, as well as having very small abundance. In contrast, natural wetlands had more juveniles present, a slight skew towards females, a better range of adult age classes and higher abundance. This supports hypothesis one that natural wetlands *C. colliei* populations are more sustainable than anthropogenic wetlands.
Hypothesis Two

“Differences in environmental conditions between wetlands results in differences in population structure.”

Environmental conditions which significantly differed between natural and anthropogenic wetlands are described in Chapter Two and include pH, conductivity, dissolved oxygen (DO), leaf litter (%), aquatic vegetation cover (%), bare ground (%) and native aquatic species (n). These conditions along with the factors of wetland minimum and maximum extent (m²) (which reflect the drying of some of the wetlands studied) had both multiple regression and correlation analysis conducted on them to identify if they influenced turtle abundance, carapace size or proportion of females. There was no statistically significant relationship between any of the above environmental factors and turtle abundance, carapace size or proportion of females. The same analysis was also run on the variables of upland habitat (total terrestrial vegetation cover (%)) and macro-invertebrate abundance (n) identified from Chapter Two as likely key factors for influencing population structure. These also were not statistically significant. This lack of significance is partially due to the depauperate nature of turtle populations, small sample size, the heterogeneous nature of the wetland and the multitude of environmental factors influencing C. colliei in the urban environment. Post–hoc power analysis indicates that the correlation had a low power (0.2443) and that a sample size between 67 and 99 wetlands would have been more ideal for multiple regression analysis.

Hypothesis two is therefore not supported due to lack of turtle captures, the heterogeneous nature of the wetland environments and small sample size.
Discussion

Hypothesis Two

While vegetation coverage and other factors have in the past been shown to influence populations (Marchand and Litvaitis 2004). Abundance, proportion of female turtles and average carapace length could not be explained by the environmental conditions presented in Chapter Two and Hypothesis Two was not supported. There are two key factors which have caused this result.

Firstly, the small sample size of this study (n= 12 wetlands) would have played a role in the non-significant result. That said this is the largest study ever undertaken of *Chelodina colliei* across the Perth region. The cost in both time and money to sample 12 wetlands effectively was reasonably high with over 300 trap hours per wetland plus the time taken to conduct detailed surveys of vegetation, macroinvertebrates presence and the cost of equipment and analysis of water samples. For multiple regression analysis the suggested sample size of 67 to 99 wetlands is not practically viable due to both the reduction of wetlands within the Perth area and the prohibitive effort required to sample this number of wetlands. If more wetlands were sampled for turtles with less trap effort at each site and less fine detail collected about each wetland it would be possible to increase sample size, however, the loss of resolution itself may then affect any analysis completed. Also given the low populations of turtles in many of the anthropogenic wetlands, it may be that adding more study sites may not increase the numbers of turtles to a level where a meaningful statistical outcome can be gained.

Secondly, very small populations and high wetland heterogeneity would have played an important role in the non-significant result. There were so few turtles captured in many of the wetlands, that these insufficient numbers coupled with the heterogeneity of the wetlands studied resulted in the regression analysis being unable to identify key habitat factors of importance. Coupled with this is the possibility that different factors (or combinations thereof) drive abundance, proportion of female turtles and average carapace length in different wetlands. In addition, Chapter Four and Five explore human-turtle interactions, which vary between wetlands but also have the potential to influence population structures.

Wetland heterogeneity and turtle scarcity have the limited the capacity of data to show statistical relationships. When population numbers are low this limits our ability to assess the importance of habitat structure of the population. Clearly, an alternative
approach or research design is required to investigate the key resource factors of importance for *C. colliei* populations.

**Hypothesis One**

Hypothesis one, that population structure in natural wetlands will be more sustainable compared to anthropogenic wetlands, was supported. Fewer females, juveniles and older sexually mature turtles were present in anthropogenic wetlands along with a significantly smaller population size.

**Sex ratio**

Greater numbers of females were present in the natural wetlands compared to anthropogenic wetlands. This is not surprising as literature suggests that death on roads around urban wetlands result in a loss of females when they leave the wetland to nest and anthropogenic wetlands had closer proximity to roads (Steen and Gibbs 2004, Aresco 2005, Gibbs and Steen 2005, Steen *et al.* 2006). The same literature suggests that loss of females for these reasons results in a very strong sex skew towards males. However a male sex skew was not apparent in this study, with most populations not significantly differing from a 1:1 male to female ratio. Prior research found variable results in relation to the sex ratio of *C. colliei*, four found skews towards females, two found skews towards males and eight found populations that were almost equivalent (Table 3.3)(Clay 1981, Guyot and Kuchling 1998, Tysoe 2005, Giles *et al.* 2008, McKeown 2010, Phoenix Environmental Services 2011, Dawson 2012, Giles 2012). Therefore, this study’s findings align with previous *C. colliei* research, showing that sex ratio is often equivalent but on occasion will deviate from 1:1.

While female *C. colliei* are susceptible to harm in the urban environment due to their need to leave the wetland to nest (Eskew *et al.* 2010), there are four possibilities as to why *C. colliei* populations do not show a male sex skew. Firstly, Gibbs and Steen (2005) showed that the trend in male bias for turtles has increased linearly since 1930, which coincided with the expansion of the road network in the United States. Therefore it may be that similar *C. colliei* sex skews from roads are yet to become apparent given that roads and residential areas started to be built around the study wetlands between the late 1950’s to the early 1980’s (Western Australian Land Information Authority 2015b, a). Secondly, given that ten of the fourteen prior studies conducted on *C. colliei* (Table 3.3) occurred in urban areas there is no data available indicating what sex ratio should be expected for *C. colliei* populations prior to urbanisation or in completely natural
settings. Therefore, perhaps *C. colliei* populations should be naturally heavily female biased and the results of this study (and those prior) do show the decrease in females due to urbanisation. Thirdly, given the low numbers of turtles captured in anthropogenic wetlands it may be that sex skews were present but obscured by the low capture numbers, as the $\chi^2$ test to identify if sex significantly skews from 1:1 cannot be run if either sex has less than 5 individuals. Fourth, and probably the least likely, is that urban areas are having a net neutral effect on the population ratios where the pressure of the urban environment on females (roads) is equal to pressures that may only affect males.

**Age class**

 Anthropogenic wetlands generally had an absence (or only a few) juvenile turtles and also tended to have lower numbers of sexually mature individuals. The lack of juvenile turtles and the low number of sexually mature individuals suggest that the urban environment is having an impact on the survival of these populations. Two anthropogenic wetlands (Piney Lake Ornamental and Juett Park) had a very good age class distribution with presence of juvenile turtles, as well as sexually mature individuals. These age class distributions may be in part related to their close proximity to a natural wetland and bush land area, where Piney Lake Natural is located. As Piney Lake Natural had a population with far less sexually mature individuals perhaps migration between these wetlands is related to these well-distributed age classes. In eastern Australia, Roe *et al.* (2011) found that freshwater turtles (*Chelodina longicollis*) in modified suburban systems grew faster and had more individuals per age class compared to those found in natural wetlands (surrounded by suburban areas). However, this was not the case for *C. colliei*, there were more *C. colliei* individuals per adult age class in natural wetlands. If anthropogenic turtles did have a faster growth rate we would expect to see more sexually mature individuals in anthropogenic wetlands – which was not the case.

Natural wetlands had a better distribution of age classes; however, two natural wetlands (Booragoon Lake and South Lake) were also lacking numbers of immature individuals. This absence of juveniles and the presence of only larger individuals at Booragoon Lake is consistent with the findings of Giles *et al* (2008). It appears that little has changed in the distribution of age classes at Booragoon in the eleven years between studies.

The absence of juveniles and/or mature adults is likely due to the structure of both the wetland and its surrounds not meeting the needs of particular life stages. It may also be related to other factors such as invasive species. For example, the invasive Yabbie
(Cherax destructor) have been shown to be predacious upon hatchling C. colliei in certain situations (Bradsell et al. 2002). Yabbies were consistently present during trapping in four wetlands all of which were anthropogenic (Lucken Reserve, Berrigan Lake, Broadwater Gardens and Harmony Lake). Interestingly, of these wetlands only Harmony Lake had C. colliei juveniles present. Whether the absence of juvenile captures were directly related to the presence of large numbers of Yabbie, a lack of aquatic vegetation offering protection from predation or just an artefact of sampling cannot be determined from this study; but it may be one of many factors that have contributed to the low abundance of C. colliei in anthropogenic wetlands. Further research on yabbie/turtle interaction is required as this raises a number of questions including: 1) what density of yabbie is needed before an impact on C. colliei is observable, and 2) can or do aquatic microhabitats affect a hatchlings chance of being predated?

Abundance and population structure

Little Rush Lake, Juett Park, Piney Lake Ornamental, Piney Lake Natural and Chelodina Wetland had the largest abundances and the only recaptures. With the exception of Piney Lake Ornamental and Juett Park, all five other anthropogenic wetlands had less than ten turtles captured over three trap seasons thus suggesting that these systems were depauperate. The two other natural wetlands, South Lake and Booragoon Lake also had low abundance. The differences in abundance could be due to differences in resource provision, the effect of the terrestrial environment (urban areas) around the anthropogenic wetlands or, more likely, a mixture of these two.

The stark difference between the abundance of Little Rush Lake (100 turtles captured) and South Lake (9 turtles captured) is surprising. Both these natural systems are similar in many ways (including size, resources) and they are located next to each other (but separated by a railway). South Lake has a slightly larger area of terrestrial vegetation (see Chapter Two) and over the course of this study an initially small stand of Typha orientalis spread through the wetland. Rapid and dense growth of Typha is likely to have reduced the area of suitable habitat available to C. colliei. South Lake, unlike Little Rush Lake, also lacked juveniles with only larger sexually mature turtles captured. This suggests that recruitment was not occurring, yet there was suitable nesting habitat available. It is highly recommended that further research is conducted at South Lake to investigate why the population is so low in comparison to Little Rush Lake.
Both Juett Park and Piney Lake Ornamental had a large abundance of *C. colliei*, a distribution of age classes which included juveniles and sexually mature individuals, and Juett Park had a sex skew towards females. This sets these anthropogenic wetlands apart from all the others. Both of these anthropogenic wetlands back onto an area of native bushland. This area of native bushland is where the Piney Lake Natural system is located. There is no road between this area of bushland and these wetlands, just grass and a bicycle path. It is likely that the populations at these two locations are doing so well because *C. colliei* can move into an area (bushland) suitable for nesting without having to move through the urban environment, just over some grass. While the trapping found no evidence of movement between wetlands (as all turtles had individual marks), it is possible that these two anthropogenic wetlands make up a wetland complex with Piney Lake Natural and assist in the movement of turtles between these sites.

Only nine individuals were captured at Booragoon Lake, therefore population size was not able to be estimated. This is comparable to findings of Giles et al. (2008) which indicates that this wetland has had a small population for some time. Comparatively, it does not appear that the abundance of *C. colliei* has dropped significantly over the 11 years between trapping. Whereas Piney Lake Natural had a significantly smaller population size compared to that of 11 years ago. Even though the Piney Lake Natural population was found to have a high prevalence of juveniles suggesting recruitment, the decline in the population size is of concern. One potential reason for the significant difference between these samples over time is reduction in available aquatic habitat; observationally the area and depth of water in Piney Lake Natural has decreased over time, likely due to a reduction in ground water levels (Bekesi et al. 2009). It is also possible that some of the turtles from Piney Lake Natural have moved to the more permanent adjacent anthropogenic sites of Piney Lake Ornamental and Juett Park, although there is no way to confirm this. This raises interesting concept that connection between drying natural wetlands and permanent anthropogenic wetlands may be a way of sustaining turtles in a drying climate into the future. Alternatively, artificially maintaining water levels in natural wetlands would be of value but is probably not sustainable.

The low abundance in the other anthropogenic wetlands is also cause for concern, as these populations appear to be small and comprised of primarily sexually mature adults. The low capture rate, however, may have been influenced by a number of factors occurring in the urban environment. Firstly, unlike many studies where traps are
checked once daily or every 48 hours (Giles et al. 2008, Sterrett et al. 2011), due to animal ethics requirements traps were checked twice daily (approximately every 12 hours). This increased movement around traps has the potential to affect the numbers of turtles captured by scaring them away. Secondly, at some wetlands turtles may already be trap shy due to illegal crayfishing. On three occasions the researcher encountered people who indicated that they trapped for crayfish using opera house nets (which can capture $C. \text{colliei}$) of a night. One man indicated that he had occasionally captured turtles in these traps. Thirdly, this project had three instances of trap interference. On two of these three occasions traps were taken (Frederick Baldwin) or stolen (Lucken Reserve and Berrigan Lake) out of study wetlands. This again results in not only additional movement within the wetland waters but the potential for turtles to be poached from these locations. Fourth, on two occasions people were observed feeding turtles at Juett Park and the researcher has strong suspicions that this was also occurring at Piney Lake Ornamental. This could affect trapping by reducing the likelihood of turtles entering traps because they are being hand fed or increase the likelihood of turtle capture by reducing trap shyness because turtles are more used to human interaction. Further consideration of human behaviours and interactions around wetlands where ecological studies are taking place is needed so these effects can be more appropriately quantified.

Hypothesis one was supported as fewer females, juveniles and older sexually mature turtles were present in anthropogenic wetlands along with a significantly smaller population size. The low abundance of $C. \text{colliei}$ (despite human influencing factors) is cause for concern. These populations, especially in the anthropogenic areas, do not appear to have recruitment of new individuals occurring, which suggests they are at risk of dying out. Hypothesis two was not supported, likely due to the combination of depauperate populations and high heterogeneity between habitats, and, from either the drivers of populations differing between wetlands or the overabundance of variables in the urban environment being too great to detect change. While the environmental conditions that influence to $C. \text{colliei}$ populations could not be identified it is clear that anthropogenic wetlands provide different environmental conditions to natural wetlands (Chapter Two) and the population structure at these anthropogenic sites is clearly lacking. Consideration therefore needs to be given to how we can manage and monitor these populations in a situation where there is a partial information vacuum and when capturing turtles is difficult and time consuming.
Chapter Four - Community data and citizen science

Introduction

Wildlife research is time and resource intensive and the effectiveness of sampling is often influenced by factors beyond a researcher’s control. With limited numbers of wetlands within the urban environment, temporal data is needed to supplement the data collected from Chapter Three. Chapter Three identified that where anthropogenic wetlands were close to bushland populations were larger and have better structure. Therefore, there is also a need to consider *C. colliei* movements in the urban environment. This chapter will use citizen science and community data which provides longer-term data set and information about *C. colliei* movement in the urban environment.

The urban environment is a particularly difficult place to monitor wildlife due to adaptation of wildlife behaviour to cope with stresses caused by urbanisation (Ditchkoff *et al.* 2006) and human interactions (e.g. trap theft and interference, feeding of wildlife etc.). The fact that the urban environment is a space shared between humans and wildlife can, however, be used to our advantage. Government data, community data and citizen science projects provide the opportunity to capture long-term information about *C. colliei* in the urban environment that wildlife research is unable to achieve on its own. This chapter will interrogate citizen science and community data to determine what segment of the *C. colliei* population is using this urban environment, how they are using the environment and how humans and why human rescues and in interact with *C. colliei* through the following questions: What was the demography of turtles observed in the urban environment?

1) Where were turtles observed in the urban environment?
2) When were turtles observed in the urban environment?
3) What were turtles observed doing in the urban environment?
4) What are the outcomes of turtle rescues in the urban environment?

Using the answers to these questions the discussion will explore the overall question, “What value does community data and citizen science provide to ecological research?”

Citizen science is the term used to indicate projects that use community volunteers (citizen scientists) to contribute to the collection and/or analysis of data to assist...
professional research (Silvertown 2009). Examples of citizen science projects include ClimateWatch and Earthwatch. Another type of data which falls into a similar category to citizen science is community data. Community data is a database collated either by community groups, professional groups (e.g. NativeARC) or government departments (e.g. Wildcare) for purposes other than scientific enquiry. For clarity, this chapter refers to citizen scientists and those who assist the collection of data for community databases (public participants) as volunteers.

Using citizen scientists to collect data has become more common over recent years. It can be a useful tool which allows the collection of long-term or difficult-to-collect data (e.g. rare species such as the porcupine ray *Urogymnus asperrimus* (Chin 2014)). Citizen science, however, is not a new concept and has a long history dating back to 1900 in the USA (Silvertown 2009). This particular project is an annual Christmas bird count which has occurred every year since 1900 and has provided valuable long-term data resulting in over 200 peer-reviewed papers (National Audubon Society Inc 2014). Projects such as these are normally developed in collaboration between researchers and volunteers (citizen scientists) (Cooper et al. 2007).

Volunteers can be valuable to a project by providing extra human resources (Foster-Smith and Evans 2003) or providing computing power (Knispel et al. 2010, Fernández-Quiruelas et al. 2011) to assist in projects that would be too physically difficult or resource intensive for a small number of researchers to conduct. The level of involvement of the volunteers themselves may vary as citizen science collects a wide spectrum of data types. Some projects require high-levels of volunteer involvement such as directly assisting with field work e.g. surveying terrestrial invertebrates (Lovell et al. 2009), while other projects may be less intensive, requiring interested participants to log sightings of particular animals in specified locations e.g. wildlife in New York State (Kretser et al. 2008), coyotes in suburban New York (Weckel et al. 2010) and bird monitoring in Sweden (Snäll et al. 2011). The value and quality of data collected through citizen science projects is often viewed with scepticism, as the citizen scientists may not be professionally trained (Lovell et al. 2009). However, if projects are well designed, the tasks are realistic and effectively managed and volunteer level of experience is taken into consideration these projects can be immensely valuable (Foster-Smith and Evans 2003, Newman et al. 2003).

Incorporating citizen science can also help provide information that researchers would not otherwise be able to access. For example Lunney et al. (2000) used community
surveys to identify what native fauna was found on private properties. This type of information can assist in future management and planning efforts, and empowers the community to become informed and meaningfully involved in management and conservation. Engagement in citizen science can benefit participants, and this can motivate people to volunteer. Benefits include general care for the environment, place attachment, learning about the environment, contributing to the community, social interaction and personal development (Measham and Barnett 2008).

Other forms of data collection can also be considered as citizen science. For example, community based monitoring describes “a process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track and respond to issues of common community [environmental] concern” (Whitelaw et al. 2003 p.410, Conrad and Hilchey 2011). This community data, that is, a database collated by community groups or government departments is not often used to inform science. One notable exception is Shine and Koenig (2001) who showed that information provided by community programs that rescue urban wildlife have the potential to provide information about local distribution and abundance and the nature of interactions between people and wildlife. These community databases can be extremely useful, not only for noting interactions between people and wildlife but also by providing long-term insight, whereas, many citizen science projects (especially in Australia) have not been running for long enough (and may not be sustained for long enough) to provide long-term data.

This chapter specifically incorporates citizen science and community data that contains information about *C. colliei* in Perth. As *C. colliei* is the only long-necked native freshwater turtle found in the Perth urban area, there is little to no chance of misidentification. The freshwater turtle’s life cycle is comprised of basking, feeding, foraging, and mating (Cann 1998). This means that *C. colliei* will move around their environment to find suitable sites for particular components of their life cycle. These movements occur within the water; however, there are three movements that occur on land. These are nesting (Baldwin et al. 2004, Beaudry et al. 2010), migration (Grgurovic and Sievert 2005) and hatchling movement back to the wetland. These movements (in and out of water) can be influenced by urban development (BenDor et al. 2009). It is reasonable to expect that when turtles are on land in urban areas they are likely to be seen by humans. In Perth, there are a number of groups that collect data about native animals that are seen or require assistance in the urban environment.
Using both community and citizen science data this chapter identifies where and when *C. colliei* has been observed, the characteristics of the turtles seen, what the turtles were doing and what happens to them in the urban environment. From this we can examine our question, what value does community data and citizen science provide to ecological research? The data in this chapter was provided by the ClimateWatch, Wildcare hotline, the Turtle Oblonga Rescue and Rehabilitation Network (TORRN), Native Arc and used responses to Section Seven (Appendix One: Social Survey Instrument) of the social survey (as described in Chapter Five).
Data collection methodology

The data presented in this chapter was provided by various stakeholders and collected using a number of different methods. This is summarised in Table 4.1 and described in more detail below.

Table 4.1: Data sources, types, date range and number of records for citizen science and community data provided by ClimateWatch, Wildcare, TORRN, Native Arc and the social survey.

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Collection method</th>
<th>Area of collection</th>
<th>Date range of records</th>
<th>Number of records</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClimateWatch</td>
<td>Online platform. Public logs location and details of sighting.</td>
<td>Australia wide.</td>
<td>October 2010 to October 2013</td>
<td>227</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Only data from</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Western Australia</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presented.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildcare</td>
<td>Hotline for wildlife emergencies provided by Department of Parks and Wildlife.</td>
<td>Western Australia</td>
<td>January 2007 to January 2012</td>
<td>261</td>
</tr>
<tr>
<td>TORRN</td>
<td>Oblong turtle rescue and rehabilitation group</td>
<td>Perth</td>
<td>January 2012 to the 12th</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>December 2013</td>
<td></td>
</tr>
<tr>
<td>Native Arc</td>
<td>Wildlife rehabilitation group – responsible for the rehabilitation of all</td>
<td>Southern Perth</td>
<td>January 2008 to 19th November</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>native wildlife received.</td>
<td></td>
<td>November 2013</td>
<td></td>
</tr>
<tr>
<td>Social survey</td>
<td>Participants asked to indicate locations of turtle sightings in the past five</td>
<td>Study area (Figure</td>
<td>n/a</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>years on a map of their local area. See Chapter Five for detailed collection</td>
<td>5.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>method.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ClimateWatch

ClimateWatch is an online platform administered by the Earth Watch Institute (ClimateWatch 2012). This online platform allows the community to log sightings of many species of flora and fauna, including C. colliei. To log a wildlife sighting the participant must register with the website for data confirmation purposes (pers comm. Richard Weatherill 24th June 2011). To log the sighting the participant can (either on a computer or smart phone) indicate the location of the sighting by placing a pin on a satellite image (from Google maps). This allows the latitude and longitude of the sighting to be recorded. Participants are also invited to answer an array of questions (listed below), write down any observations they have made and upload a photo (ClimateWatch 2012). Additional questions about the C. colliei observation were developed in partnership with ClimateWatch specifically for this study. These supplementary questions went live on the website in September 2011, data collected prior to this date only contains responses to the questions asterisked (*) below.

- Date and time of sighting*
- How many turtles were there?*
- Behaviour
  - Basking
  - Feeding
  - Courting/mating
  - Hatching/ed eggs
  - Juveniles
  - Moving
  - Nesting
- What surface was the turtle initially seen on?
  - Grass
  - Road
  - Pavement
  - Water
  - On basking site
  - In shrubs
- Was the turtle’s shell
  - Longer than a can of soft drink (e.g. Coke or Solo)
  - Smaller than the top of a can of soft drink (e.g. Coke or Solo)
  - In between?
- Habitat*
- Additional comments*

The questions added to the ClimateWatch website were designed to provide more detailed information about the turtle sighting. The question about behaviour was to provide an idea of what the turtle was doing. It did not, however, have an exhaustive list of behaviours and relied on interpretation by the participant. Because indicating the location of sighting on the google map had a degree of error involved, a question
regarding the surface the turtle was seen on was asked to provide some fine scale information about where the turtles were seen on land.

ClimateWatch participants were also asked to indicate the size of the turtle’s shell in reference to a can of soft drink (a well-known object) to provide basic size information about the turtle observed. This allowed the grouping of observed turtles into age classes of: hatchlings or very young turtles (shell length less than the top of a soft drink can <6cm); adults (shell length greater than the length a soft drink can ≥13cm), and; juveniles (shell length between 6cm to 13cm). These age classes are slight generalisations (males are recorded to be sexually mature 13 to 14cm and females around 15 to 17cm (Kuchling 1988, 1989)), however, they do provide a simple and consistent way to age class turtles observed by a third party. This approach provides us with as much detail as possible without requiring a person to interact with the turtle they are observing. Because the participants are comparing the turtles shell to such a well-known object it also improves our confidence in the data provided.

The data was obtained from the ClimateWatch website for the period October 2010 to October 2013. There were 231 entries for *C. colliei* over this period. Four of these entries were removed; two because of sighting location irregularities (in the ocean) and two because no information other than GPS location was noted. For the 227 entries reported there were 366 observations of individual turtles. One observation of multiple turtles was treated as one record. Due to the website design, when multiple observations were entered at the same time the participant could only answer one set of the questions above regardless of the number of turtles seen.

**Location data- ClimateWatch and Social surveys**

The location of *C. colliei* sightings in the study area (see Chapter Two) was obtained from two sources: the ClimateWatch records and a social survey conducted during this study. Chapter Five describes the survey method in detail and as part of the survey participants were asked to mark the locations (on a map of their local area, Appendix Two: Example of map for participants) where they had observed *C. colliei* over the last five years. These locations were then entered into Google Earth and then the co-ordinates were transferred ArcMAP 10.1. The latitude and longitude of ClimateWatch observations were also imported into ArcMAP. The distance from each observation location from the closest wetland was calculated.

The distances from both ClimateWatch and the social surveys conducted were used to identify the median distance that *C. colliei* was seen from wetlands. A Mann-Whitney
test was also conducted to see if there was a difference in these results based upon collection method.

**Wildcare**

The Wildcare hotline is a 24-hour helpline, which provides assistance and advice for people who encounter wildlife. This hotline is answered by volunteers and is facilitated by the Western Australian Government Department of Parks and Wildlife. Each call has a number of details recorded including date, suburb, the species in question, general notes about the conversation, if there were any injuries and referrals to a vet or wildlife rescuer.

The helpline has been active since 2007 and the data provided is from January of 2007 to January of 2012. This data was analysed by extracting details of the calls from the general notes. Calls relating to injury, turtle eggs, moving/relocating turtle were extracted. Five records were removed from the data set as they related to keeping *C. colliei* as a pet and were not considered relevant to this research. The date for every observation made was also extracted to identify the peak times of year when *C. colliei* is observed.

**TORRN**

The Turtle Oblonga Rescue and Rehabilitation Network Inc. (TORRN) is a non-profit group dedicated to the rescue and rehabilitation of *C. colliei*. They also provide training for wildlife rehabilitators and community information. They were formed in response to the drying of Blue Gum Lake in early 2011 which resulted in over 100 turtles leaving the wetland (Pers comm. TORRN 23rd October 2011). TORRN operate a rescue call line for *C. colliei* and callers to Wildcare are often referred to TORRN. These two datasets did not overlap as TORRN data from 2012 onwards was used. TORRN has a standard incident report form that is used to record details of turtles found. This includes (but is not limited to) the incident details, size (carapace length) and weight, sex, age class, if eggs were laid, closest lake, postcode and outcome of incident. Also recorded are their admissions to/from some wildlife rehabilitation centres in Perth.

A total of 176 individual turtles are recorded in the TORRN database, of these either weight, carapace length or both were recorded for 107 individual turtles. The weight to carapace length ratio of the turtle was used as a proxy for health i.e. low weight to large size may be due to sickness or lack of food (Hamada 2011). This ratio was compared to the turtle data as presented in in Chapter Three. It should be noted that while this ratio is
the best way to compare these two cohorts for health, it has potential for error. This approach cannot differentiate between living and dead turtles nor does it provide detailed health information.

Native ARC

Native Arc is a volunteer, non-profit wildlife rehabilitation centre located in the City of Cockburn (Native ARC Inc 2014). Data provided by Native ARC included date of intake, location turtle was received from (sometimes just suburb), admission reason, injury classification (if applicable), outcome of admission (released, euthanasia etc.) and release location. A total of 121 *C. colliei* intakes were recorded from January 2008 to 19th November 2013.

Due to the large time period that the Native ARC data covered there were some inconsistencies in classification, where multiple terms were used to describe similar injuries (e.g. Shell fracture, carapace fracture, top shell fracture) or similar admission reasons (e.g. found wandering on road, displaced). Prior to analysis these were categorised into groups of similar injury types and admission reasons.

Combined observations

All data collected were collated and stratified by month and year. To identify any link between weather conditions and human observations of turtles a multiple regression using average monthly rainfall, mean monthly minimum temperature and mean monthly maximum temperature from the Perth weather station (BOM 2014) was conducted.
Results

What was the observed demography of turtles?

ClimateWatch and TORRN both provided detailed information about the turtles seen or received including size (age class or length), sex and weight. From the ClimateWatch data, 74% of the observations recorded the age class of the turtle. Overall, hatchlings, juveniles and adults made up 9.6%, 31.7% and 58.7% (respectively) of all ClimateWatch reported observations.

Of the 176 turtles recorded in the TORRN database, carapace length was recorded for 89 *C. colliei* individuals. TORRN primarily received very small individuals (hatchlings) and sexually mature individuals (turtles with a carapace of 15cm or greater) (Figure 4.1).

TORRN recorded both weight and carapace length for 79 individuals. A Mann-Whitney U test showed that the distribution of TORRN weight to carapace length ratio was the same as the ratios from turtles captured for this project (Chapter Three) ($U=8759$, $z=-1.269$, $p>0.05$).
Age class and sex was recorded for the majority of the turtles in the TORRN dataset (see Table 4.2). Adult female turtles and hatchlings were the most common types of turtles received by TORRN (at 36% and 18.3% respectively). However, because multiple hatchlings can emerge from one nest this may inflate the number of hatchlings received (i.e. all hatchlings rescued from one clutch). Most turtles received by TORRN were adults (66.3%) and often sex was not identified (42.3%). Nineteen of the 79 turtles recovered were gravid and four other turtles were missing eyes. A total of 64 eggs were also received by TORRN.

Table 4.2: Sex and age class of C. colliei recorded by TORRN

<table>
<thead>
<tr>
<th>Age Class</th>
<th>F</th>
<th>M</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>63</td>
<td>26</td>
<td>27</td>
<td>116 (66.3%)</td>
</tr>
<tr>
<td>J</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>13 (7.4%)</td>
</tr>
<tr>
<td>H</td>
<td>0</td>
<td>0</td>
<td>32</td>
<td>32 (18.3%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
<td>0</td>
<td>13</td>
<td>14 (8.0%)</td>
</tr>
<tr>
<td>Total</td>
<td>71 (40.6%)</td>
<td>30 (17.1%)</td>
<td>74 (42.3%)</td>
<td></td>
</tr>
</tbody>
</table>
Where were turtles observed?

From the ClimateWatch data, 78.0% of the observations identified the type of surface upon which the turtle was observed. Of these observations, turtles were most often observed in the water (52.0%) and less often seen on pavement (11.8%), roads (10.2%), grass (16.9%), logs (5.1%) and in shrubs (4.0%). Sightings on land (collapsed into one group of 42.9%) occurred almost as often as those in the water.

There was a significant association between turtle size and whether it was seen on land or water, $\chi^2(2)= 15.317$, $p<0.001$. Proportionally more hatchlings were seen on land compared to water (18.9% to 2.2% respectively) and fewer juveniles were seen on land compared to water (23% to 38.7% respectively, see Figure 4.2).

![Figure 4.2: ClimateWatch data, number of turtles seen stratified by turtle age classes and whether they were seen on land or water (n=168).](image)
Distance from wetlands - ClimateWatch and Surveys

In the ClimateWatch dataset, 61 observations fell within the study area. Of these, the distance that turtles were observed from wetland ranged from 0 to 495m. A total of 25 observations were of turtles in water in wetlands. Of the 36 sightings on land, turtles were seen at a median distance of 119m from the water’s edge.

There were 240 distance-from-wetland turtle observations collected from the social surveys (Chapter Five). These ranged from 0 to 416m from the wetland. A total of 56 turtle observations were of turtles in wetland waters. Of the 184 observations on land, turtles were seen at a median distance of 92m from the water’s edge.

An Independent Samples Mann-Whitney Test (U=3692, z=1.088, p=0.277) indicated that there is no significant difference between the distribution of distances from wetlands recorded in the ClimateWatch data and the social survey data. Most turtles were seen within 200m of a wetland, however, proportionally more turtles were observed in the 200 to 400m range from a wetland in the social survey (Figure 4.3).

![Figure 4.3: Distance turtle was observed from water’s edge. Data from ClimateWatch and Social surveys (Chapter Five)](image-url)
When were turtles observed? Seasonal movements.

Both ClimateWatch and TORRN provided data regarding the age class of turtle and when they were sighted or received. The data from both of these collection methods indicates a peak of hatchling sightings during August (Figure 4.4 and Figure 4.5), which aligns with normal hatching time. Observations of *C. colliei* occurred less during very hot months (December and January) and very cold months (June and July). Most adult turtles were seen on land during September and October (Figure 4.4).

![Figure 4.4: Number of turtles logged each month on ClimateWatch stratified by age class and location of sighting.](image1)

![Figure 4.5: Number of turtles received by TORRN each month by age class.](image2)
Combined observations

All the data presented in this results section were collated and stratified by month and year (Figure 4.6). The data shows that there was an increase in the observations of *C. colliei* in 2013. This increase is most significant in the second half of 2013 and relates primarily to TORRN incident reporting. It should be noted that TORRN increased the distribution of their contact details in 2013 and this may have affected the frequency of reporting incidents.

The data also indicates that the peak of turtle observations has moved to earlier in the year by a month (c.f. sightings from 2007 and 2008 to those in 2012 and 2013).

The multiple regression found that Rainfall (Beta= -0.537, p<0.005), minimum temperature (Beta= 1.989, p<0.005) and maximum temperature (Beta= -2.560, p<0.005) were all significant predictors of *C. colliei* observations. The overall model fit was $R^2=0.339$, which indicates that other factors (apart from weather conditions) may also influence human observations of turtles.
Figure 4.6: Graph of all data points (ClimateWatch, Native ARC, TORRN and Wildcare) stratified by month and year. Bars on the right-hand side of the graph indicate the duration of data collection for each data source.
What were turtles seen doing in the urban environment?

ClimateWatch invited participants to indicate the behaviour of the turtle(s) during their observations (Figure 4.7), 84.6% of participants responded to this question. The top three behaviours were basking (38.8%), feeding (32.1%) and migrating (18.4%). (Note that migrating category may also include nesting females).

![Bar chart showing observed turtle behaviour](image)

**Figure 4.7:** The reported behaviour of observed turtles from ClimateWatch
What are the outcomes of turtle rescues in the urban environment?

Wildcare, TORRN and Native ARC provided information indicating why *C. colliei* was observed and in the case of TORRN and Native ARC, what happened to the turtles subsequent to its rescue.

*Why was the turtle observed or rescued?*

Turtles found either wandering or displaced were the primary reason for contacting Native ARC (29.8%) or TORRN (38.2%). There may be a tendency for people to rescue turtles that don’t require assistance as 18.4% of Wildcare callers were told to return/relocate turtle found to a wetland.

Motor vehicle incidents were one common reason for observation and need for rehabilitation. These incidents made up 18.5% of TORRN rescues (Table 4.3), 19.8% of Native ARC intakes (Table 4.4) and 4.6% of the Wildcare hotline calls (Table 4.5). Injury or illness was another common reason for Wildcare calls (11.9%), Native ARC intakes (19%) and TORRN rescues (12.1%).

<table>
<thead>
<tr>
<th>Reason for report/rescue</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found at Beach/salt water</td>
<td>10</td>
<td>5.8%</td>
</tr>
<tr>
<td>Found in pool</td>
<td>5</td>
<td>2.9%</td>
</tr>
<tr>
<td>Laying Eggs</td>
<td>8</td>
<td>4.6%</td>
</tr>
<tr>
<td>Disturbed eggs</td>
<td>2</td>
<td>1.2%</td>
</tr>
<tr>
<td>Found in dangerous situation</td>
<td>2</td>
<td>1.2%</td>
</tr>
<tr>
<td>Found displaced/wandering</td>
<td>66</td>
<td>38.2%</td>
</tr>
<tr>
<td>Found on or near road/MVA</td>
<td>32</td>
<td>18.5%</td>
</tr>
<tr>
<td>Found sick or injured</td>
<td>21</td>
<td>12.1%</td>
</tr>
<tr>
<td>Malicious/suspicious injury or death</td>
<td>4</td>
<td>2.3%</td>
</tr>
<tr>
<td>Predation (Birds/Foxes/Dogs)</td>
<td>8</td>
<td>4.6%</td>
</tr>
<tr>
<td>Surrendered for re-wilding and release</td>
<td>6</td>
<td>3.5%</td>
</tr>
<tr>
<td>Found dead</td>
<td>9</td>
<td>5.2%</td>
</tr>
</tbody>
</table>
Table 4.4: Reasons for *C. colliei* admission to Native ARC

<table>
<thead>
<tr>
<th>Reason for admission</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury</td>
<td>23</td>
<td>19.0%</td>
</tr>
<tr>
<td>Injury/ lake dried up</td>
<td>7</td>
<td>5.8%</td>
</tr>
<tr>
<td>Disease</td>
<td>2</td>
<td>1.7%</td>
</tr>
<tr>
<td>MVA</td>
<td>24</td>
<td>9.8%</td>
</tr>
<tr>
<td>Attacked by Magpies</td>
<td>2</td>
<td>1.7%</td>
</tr>
<tr>
<td>Attacked by Ravens</td>
<td>3</td>
<td>2.5%</td>
</tr>
<tr>
<td>Fell in Pool</td>
<td>2</td>
<td>1.7%</td>
</tr>
<tr>
<td>Lake dried up</td>
<td>11</td>
<td>9.1%</td>
</tr>
<tr>
<td>Hatchling</td>
<td>7</td>
<td>5.8%</td>
</tr>
<tr>
<td>Displaced</td>
<td>36</td>
<td>29.8%</td>
</tr>
<tr>
<td>Not Recorded</td>
<td>4</td>
<td>3.3%</td>
</tr>
</tbody>
</table>

There were 266 calls to the Wildcare help line regarding *C. colliei*. These calls identify the primary reasons that people were concerned about *C. colliei* (Table 4.5). In 18.4% of the calls, the caller or call receiver mentioned returning the turtle to a wetland. Calls that were not placed in these categories tended to be general calls about encounters with no specific information recorded.

Table 4.5: Percentage of calls to Wildcare hotline regarding key items

<table>
<thead>
<tr>
<th>Calls relating to</th>
<th>Percentage of calls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injured/sick turtle</td>
<td>11.9%</td>
</tr>
<tr>
<td>Turtle laying eggs/ discovered turtle eggs</td>
<td>4.2%</td>
</tr>
<tr>
<td>Car incident</td>
<td>4.6%</td>
</tr>
<tr>
<td>Dead turtle</td>
<td>3.4%</td>
</tr>
<tr>
<td>Re-location occurred or advised.</td>
<td>18.4%</td>
</tr>
<tr>
<td>No notes taken apart from species and date</td>
<td>10.9%</td>
</tr>
</tbody>
</table>
**What injuries did the turtle have?**

Native ARC provided information regarding the type of injury that the turtle had at the time of admission. A large group (36.8%) were not injured but were displaced or a hatchling. The most common injuries were to the turtles shell with shell fracture (15.4%) or shell rot/fungal infection (13.7%). Fewer injuries occurred to the head, face or eyes (6.8%) and legs (6.0%), (Table 4.6).

### Table 4.6: Type of injury that C. colliei turtle had upon arrival to Native ARC

<table>
<thead>
<tr>
<th>Injury type</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Just displaced/Hatchling/DOA</td>
<td>47</td>
<td>36.8%</td>
</tr>
<tr>
<td>Head/Facial/Eye Injuries</td>
<td>8</td>
<td>6.8%</td>
</tr>
<tr>
<td>Leg Wounds or Injuries</td>
<td>7</td>
<td>6.0%</td>
</tr>
<tr>
<td>Major hole to undercarriage</td>
<td>1</td>
<td>0.9%</td>
</tr>
<tr>
<td>Multiple injuries/Wounds/Internal Bleeding</td>
<td>3</td>
<td>2.6%</td>
</tr>
<tr>
<td>Neck/Spine Injury or Illness</td>
<td>3</td>
<td>2.6%</td>
</tr>
<tr>
<td>No injury detected</td>
<td>2</td>
<td>1.7%</td>
</tr>
<tr>
<td>Not Recorded</td>
<td>12</td>
<td>10.3%</td>
</tr>
<tr>
<td>Shell fracture</td>
<td>18</td>
<td>15.4%</td>
</tr>
<tr>
<td>Shell fracture + Additional injury</td>
<td>4</td>
<td>3.4%</td>
</tr>
<tr>
<td>Shell Rot or Fungal Infection</td>
<td>16</td>
<td>13.7%</td>
</tr>
</tbody>
</table>
**What happened to the turtle?**

Native ARC and TORRN provided information regarding the outcome of rescued and rehabilitated turtles. The Native ARC outcomes (Table 4.7) and the TORRN outcomes (Table 4.8) were relatively similar in the percentages of turtles released (71.9% to 64.4% respectively) and the percentage that died or were dead on arrival (26.5% to 23% respectively).

For *C. colliei* received by Native ARC with most common injury (shell fracture, see Table 4.6) the survival rate was 38.9%. The second most common injury (shell rot or fungal infection) had a survival rate of 100%.

**Table 4.7: Outcome of C. colliei rehabilitation by Native ARC**

<table>
<thead>
<tr>
<th>Outcome of rescue/rehabilitation</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euthanised</td>
<td>21</td>
<td>17.4%</td>
</tr>
<tr>
<td>Died</td>
<td>3</td>
<td>2.5%</td>
</tr>
<tr>
<td>DOA</td>
<td>8</td>
<td>6.6%</td>
</tr>
<tr>
<td>Escaped</td>
<td>1</td>
<td>0.8%</td>
</tr>
<tr>
<td>Released</td>
<td>87</td>
<td>71.9%</td>
</tr>
<tr>
<td>Transferred</td>
<td>1</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

TORRN recorded two types of turtle release, where turtles are released back into their original habitat (28.2%), or were relocated (36.2%). Of the relocated turtles, 18 were returned to the wetlands closest to where they were found, all others were returned to an alternative suitable habitat.

**Table 4.8: The outcomes of the C. colliei turtles rescued and/or rehabilitated by TORRN**

<table>
<thead>
<tr>
<th>Outcome of rescue</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eggs - left in situ</td>
<td>2</td>
<td>1.1%</td>
</tr>
<tr>
<td>In Care</td>
<td>8</td>
<td>4.6%</td>
</tr>
<tr>
<td>Released after care – Original habitat</td>
<td>49</td>
<td>28.2%</td>
</tr>
<tr>
<td>Released after care - Relocation</td>
<td>63</td>
<td>36.2%</td>
</tr>
<tr>
<td>Euthanased</td>
<td>17</td>
<td>9.8%</td>
</tr>
<tr>
<td>Died</td>
<td>23</td>
<td>13.2%</td>
</tr>
<tr>
<td>Unknown</td>
<td>12</td>
<td>6.9%</td>
</tr>
</tbody>
</table>
Discussion

**What was the observed demography of turtles?**

*Chelodina colliei* females leave the wetland to lay their eggs and once the hatchlings emerge they will move to a wetland. This was reflected by the observational data. Adult and hatchling turtles were more likely to be seen on land around wetlands than juveniles but juveniles were more often observed in the water. Generally, females were the most common adult turtles observed. The citizen science data used to monitor *C. colliei* depicts typical movements that we would expect to see from *C. colliei* during different stages of its life cycle.

The observed demography of turtles should not be viewed as a replacement for traditional ecological sampling methods as it only reflects parts of the animal’s lifecycle. It may not be meaningful measure of population structure within a wetland. If further research was conducted to identify the proportion of sexually mature females that attempt nesting each year there is the potential for citizen science data to be used as a proxy measure for population health. For example, if there are a large number of sexually mature females present, there is greater likelihood that a large number of females will be observed on land. Turtle population surveys are time consuming, costly and require a level of expertise that may not be available to the managers of many wetlands. Citizen science data and its potential to be a proxy measure for population health could fill the gap allowing at least partial monitoring of a system where there would otherwise be none.

**Where were turtles observed?**

*Chelodina colliei* were generally seen between 0m and 200m (but up to 500m) from the water’s edge. It is likely that many of these observed turtles were seen during or after they had crossed a road as all of the anthropogenic and some of the natural wetland sites had roads within 100m of the water’s edge. Road crossing is risky to turtles, potentially resulting in death and sometimes a skew in population sex ratios. Nesting females are more likely to be killed on the road than sexually mature males (Aresco 2005, Steen *et al.* 2006). As TORRN received a large proportion of female turtles for rehabilitation this suggests that there is a greater risk for female turtle death in the urban environment.
It is not surprising that hatchlings were more often seen on land as they hatch, move overland and then enter the wetland. As many hatchlings were observed during this movement an opportunity may exist for human intervention to assist the life cycle of *C. colliei* by ensuring offspring safely arrive at a wetland. Given the concern about the status of *C. colliei* populations in the urban environment (see Chapter Three) this may assist these populations and their future growth. Importantly, it should be recommended that residents watch over hatchlings moving to wetlands rather than physically assisting them. 

*Chelodina colliei* spends most of its life in the water, yet the Climate Watch data show that on-land observations occurred almost as often as those in the water. Citizen science and community data provide an opportunity to monitor turtle movements on land, which would not usually be possible without a large-scale tracking project. As ecologists, limited opportunities exist to observe the movements of *C. colliei* on land and our capacity to do so is usually constrained by financial and logistical resources. By encouraging the communities surrounding wetlands to provide this data we can obtain more consistent information, over both the short and long-term. Given the financial and time cost of tracking wildlife, not only does community and citizen science data provides a cheaper alternative (especially for a species not listed as threatened), it also can cover greater areas over longer periods of time than most scientific programs would be able to do.

Identifying where turtles are most often seen in the urban environment also provides the opportunity to determine how to best manage the urban environment around wetlands. Targeting roads that turtles are commonly seen crossing with crossing signage or turtle underpasses, or contacting residents each year to inform them that turtles may come into their garden to nest are strategies that could be employed to better protect turtle populations.

**When were turtles observed?**

Observations of *C. colliei* can be partially predicted by the weather. Sightings occurred less frequently in late summer and the middle of winter. This may be a function of how people choose to use their wetlands (visiting less during the extremely hot and cold parts of the year). However, it could also be a function of the turtle’s biology, as *C. colliei* will aestivate during summer if the wetland is dry and turtles tend to be less active in winter due to the cold temperatures (Chessman 1988b).
The ClimateWatch, Native ARC, ToRRN and Wildcare data provide information that is consistent with our current understanding of *C. colliei* biology. This encouraging finding supports the use of these data types together with ecological research to build a picture of *C. colliei* in the urban environments and provides a strong case for using this type of data in the future. The fact that the data identified peaks of turtle activity during nesting and hatching seasons (Figure 4.6) suggests that there are enough people participating with ClimateWatch and contacting Wildcare and ToRRN to provide data sets of reasonable size and consistency.

The timing of the peak of human observations of *C. colliei* each year may indicate the timing and environmental impacts on turtle movements. The peak of calls in the second half of the year relates to the beginning of nesting season for females. This has the potential to be a positive and non-invasive way to identify when the nesting season begins each year. This information is highly valuable as the cue for nesting is climatic and related to a combination of temperature and barometric pressures changes (Clay 1981). Climate change is projected to result in hotter temperatures of 0.4–2.0°C by 2030 and more variable rainfall (Hughes 2003, Alexander and Arblaster 2009). It therefore may affect *C. colliei* nesting patterns as the effect of climate is already apparent in the data set. In 2009 and 2010 there was very low rainfall, which coincided with low observation rates of *C. colliei* (Figure 4.6).

All of the data sources presented showed observational peaks during the second half of the year when nesting occurs. Should a correlation be established between low *C. colliei* observation rates and change in climatic conditions over time, this data may provide the opportunity to monitor the long-term effects that a changing climate will have on the nesting of *C. colliei*. Most ecological projects cannot run long-term due to the cost and effort required for monitoring wildlife and that most tracking devices suitable for *C. colliei* would not have sufficient battery life for long-term (5 or more years) monitoring. This is one area that community and citizen science data can provide significant value to an ecological research project.

Climatic factors do not just affect when turtles lay their eggs. Evidence shows that climatic cues can be used by turtle hatchlings to indicate when it is time to emerge from nests, (Doody et al. 2001) although this may depend on species (Spencer and Janzen 2011). If used, this cue is vitally important as often it is timed to ensure best access to water bodies and food (Doody et al. 2001). Anecdotally, *C. colliei* hatchlings have been found sitting inside their nest chambers awaiting either an emergence cue or for all the
hatchlings to fully develop. Further investigation is needed to identify if the cue for *C. colliei* hatchling emergence is climate-based. If it is, emergence cues may change due to the changing climate and local climatic changes (i.e. temperature tends to be slightly warmer in cities (Bolund and Hunhammar 1999)). Changes to emergence cues may be a problem if emergence is triggered and habitat is not suitable for hatchlings. This may have a flow on effect upon the survival of hatchlings and affect the future of *C. colliei* populations.

**What were the outcomes for turtles reported and rescued in the urban environment?**

Community collected data can be valuable in two ways. Firstly it can identify here and when turtles are seen by humans; and secondly it can identify what happens to turtles when they are observed. Motor vehicle incidents, injury or illness and displaced or wandering turtles were the primary reasons for contacting Wildcare, Native ARC or ToRRN. It can be assumed that the majority of these observations occur on land as it is unlikely that people could regularly notice an ill or injured turtle while it was swimming in water.

Understanding the types of injuries that turtles are found with, combined with a better understanding of where people are seeing turtles, will allow delivery of targeted education about turtles moving on land to those who are more likely to see them (i.e. those who are commonly within 400m of wetland waters). Community data about the rescue and rehabilitation of *C. colliei* also provides us with a potential estimate of the death rate of turtles in particular areas. It may also be possible to estimate birth rate from hatchling sightings (although double counting may occur in this instance). Therefore, there is the potential for this information to be fed back into ecological research to assist in population metrics. This could better inform assumptions made in population modelling and therefore improve the accuracy of these models.

There is an overabundance of turtles being “rescued” when they do not actually require assistance. A large number of Wildcare callers were told to return/relocate turtles found to a wetland and almost thirty percent of Native ARC’s intakes were turtles with no injuries that were “displaced”. There are two key concerns about rescuing a turtle that doesn’t require rescuing. Firstly, if the turtle is female attempting to nest there is no literature available describing what affect disturbance will have on further nesting effort. Secondly, unwarranted stress is caused to the turtle from the handling, transport, captivity and may also expose turtles to illness (such as shell rot) (Hartup 1996).
The data received from Native ARC and ToRRN differs from the ClimateWatch and Wildcare data, because they rehabilitate turtles prior to release. ToRRN where possible, releases turtles back into the original habitat (28.2%), but in many cases they are relocated (36.2%). Native ARC similarly endeavours to return turtles to their original habitat. In the future it may become important to have good records of where turtles are relocated to maintain population genetics, as well as population structure. It will be important to ensure that locations used for relocation are not over populated, that they have suitable habitat for the entire life cycle and that they are not artificially sex-biased. As ToRRN has a high intake of mature females the effect of relocation on female *C. colliei* also requires investigation to identify if it has the potential to affect future reproductive success.

**What value does community data and citizen science provide to ecological research?**

Community data and citizen science provide increased scope and long-term data collection opportunities for research on freshwater turtles in urban areas. Citizen science provides a greater scope for assessing turtle movements on land in urban areas (depending on the research question). Locations of sightings provided from a citizen science source (e.g. ClimateWatch) may be more efficient (in both time and cost) than traditional radio tracking methods which often only track between 20 to 50 individuals (e.g. Bodie and Semlitsch 2000, Milam and Melvin 2001, Hartwig and Kiviat 2007, Attum *et al.* 2008b, Pittman and Dorcas 2009, Rees *et al.* 2009, Beaudry *et al.* 2010, Rasmussen and Litzgus 2010). Community data, while not as detailed or specific still provides simple information such as the date of sighting and size class can allow us to monitor the effect of a changing climate on basic turtle lifecycle features such as nesting and emergence from nests.

Community data and citizen science may also provide basic population information such as death rates and birth rates in urban areas. This type of information may be of use to research looking at population survival rates. Further research is required to identify if information on turtles observed moving on land around a wetland can inform population structure and identify areas of low populations in need of ecological research. Community and citizen science data cannot replace ecological methods but it can effectively provide a broader base of data than would otherwise be available.
Community data also identified two factors that may have directly affected the turtle populations as discussed in Chapter Three. The first is the large number of unwarranted turtle rescues, i.e. turtles that are healthy but have been redistributed in the environment which may have the capacity to skew the demography of populations or potentially overpopulate locations that rehabilitators perceive as “suitable”. Secondly, the need for effective monitoring and management of turtle relocations and accurate records needs to be available to researchers so that they can identify if turtles have been removed or added to the population during or between sampling sessions. The addition or removal of individuals during research has the potential to violate assumptions made by researchers and undermine results. Additionally, the impact of relocation (translocation) of *C. colliei* by humans has the potential to negatively affect wetland populations in the long term as incremental removal of adult individuals may reduce the populations capacity to recruit new individuals.

These databases are immensely valuable, they provide the opportunity to collect and maintain long-term urban turtle data sets, which would be expensive and difficult to maintain otherwise. The citizen science data set provided more specific location based details and could be focussed on a particular study area, however, there are clear limitations to these data sets, as they require active participation and engagement of community members. As a result these citizen science data sets may be difficult to maintain over time as participation waxes and wanes. Community database sets (Wildcare, Native ARC and ToRRN) provided far more general data regarding location of sighting and tend to focus more on injured or dis-located species, however, this data collection is passive as it does not require engagement of the community as these groups are providing a community service. Therefore these types of data collection are more likely to continue long-term.

The viability of using these data-sets long-term would be increased if there was greater consistency in the way that information was recorded and if it were held centrally. This would also assist data analysis, comparison and allow researchers greater ease of access to this type of information. These types for data do not only support research but can also act as a useful resource for managers requiring information more specific information about turtle presence and movements in the urban environment.

While citizen science and community data does not replace the need for traditional ecological research, it does have the potential to be used for long-term monitoring or
can provide a valuable source of supplementary and secondary data. For example, Chapter Three noted that there was some unquantified human interaction with the study species. These community-based data collection projects/groups identified both the rescue and movement of turtles by humans within the urban environment. If the citizen science and community data had not been considered any conclusions drawn from the ecological research would be incomplete and potentially result in faulty conclusions and management suggestions. Coupling ecological research with citizen science and community data provides a more holistic picture of what is occurring to turtles in the urban environment.
Chapter Five - The human component of *Chelodina colliei*’s environment

**Introduction**

Humans have a significant impact on the environment in which they live, yet human behaviour is rarely incorporated into ecological research in the urban landscape (Jacobson and McDuff 1998, Nilon *et al.* 2003). Humans can affect wildlife populations through both the management and changes they make to the environment around them, and through direct interaction with wildlife. Despite this, the published research focuses on the direct effect of the built environment (roads, habitat fragmentation etc.) on freshwater turtles (Giles 2001, Baldwin *et al.* 2004, Steen and Gibbs 2004, Beaudry *et al.* 2008) more often than the incidence, interaction and impact of human behaviour on turtles. While Chapter Four focuses on reported interactions between humans and turtles to fully understand *C. colliei*’s life in the urban context it is also necessary to consider how humans perceive urban wetlands, the direct interactions that humans may or will have with *C. colliei* and to consider what drives these interactions.

In order to explore the human component of the urban environment, it is necessary to examine social variables such as attitudes, values and behaviours. Attitudes (of communities and individuals) are a key component of environmental management as they can influence management and design decisions (Miller 2009, Cook *et al.* 2012). This is illustrated by the Grimm *et al.* (2000) conceptual model (Figure 5.1) where, in a local context, residents’ positive or negative attitudes towards existing management practices directly influence future management decisions. In turn, the management decisions made as a result of these attitudes affect the management and ultimately the structure of the urban environment.
Social variables such as residents attitudes affect land use and thus ecological patterns and processes within the urban environment (Grimm et al. 2000). Attitudes are the “overall degree of favourability” (Ajzen 2001 p29) that a person feels towards an issue, person or place. Attitudes are complex constructs which can be influenced by factors such as underlying environmental values (Barr and Gilg 2007), socio-economic and demographic variables, place of upbringing, place of residence (Swanwick 2009) and prior experiences or stimuli (Ajzen 2001). The first two hypotheses in this chapter explore the attitudes of residents towards wetlands and wildlife as these may influence the structure and management of the urban environment.

Community attitudes can influence management choices, and place of residence is one factor which can influence attitudes (Kurz and Baudains 2012). In addition it is reasonable to assume that people who live near wetlands are more likely encounter turtles. In order to understand interaction and impact of human behaviour on turtles in the urban environment, we need to assess if the proximity of place of residence to a wetland is related to attitudes. The first hypothesis for this chapter, “People who live adjacent to wetlands have a more positive attitude towards wetlands and turtles”, aims to explore this relationship.
Wildlife based tourism literature (Duffus and Dearden 1990, Reynolds and Braithwaite 2001) indicate that individuals’ attitudes are also influenced by experience of and interaction with wildlife in the environment. While the impact of experience in wildlife based tourism is well documented (Newsome et al. 2005), everyday wildlife experiences around a person’s home are less well researched. Local interactions may have greater impact on both the person and wildlife for a number of reasons: there is potential for a greater number of experiences when continually sharing the same environment; humans have more control over their physical environment in urban areas (i.e. gardens) than in nature reserves; interactions in urban environment are less likely to be supervised by experts; and there is likely to be an increased regularity of using natural environments in urban areas due to proximity. The second hypothesis for this chapter, “People who have had an interaction with a turtle have a more positive attitude towards turtles and wetlands” explores these possible links.

The examination of human behaviour in urban environments that contain patches of remnant habitat is needed, as it is reasonable to expect that there is a greater potential for interactions between humans and wildlife in these environments. Some types of direct human interaction with wildlife such as the effects of road kills on wildlife population demographics are well documented (Baldwin et al. 2004, Aresco 2005, Epps et al. 2007). Human wildlife conflict is another well researched interaction (Madden 2004). Normally such research is focussed on larger or nuisance animals (e.g. bears, wolves, and lions) with conflict resulting from, wildlife causing damages to crops or livestock; the perception of the wildlife as a threat to humans, or; conflict between humans in regards appropriate measures to deal with animal threats (Madden 2004, Whittaker et al. 2006, Kretser et al. 2009, Weckel et al. 2010). There is little research exploring human-wildlife interactions unrelated to road kill or human-wildlife conflict. One exception is a study that investigated interactions between humans and marmosets in a city park in Brazil. Leite et al. (2011) highlighted that these human-wildlife interactions were viewed positively by locals, and concern for the wellbeing of local wildlife has the potential to lead to feeding. While road-kills of *C. colliei* females is known to occur (Giles 2001), there are many other opportunities for potential human interactions with *C. colliei* including, females laying eggs in urban gardens, rescues by wildlife groups and feeding of turtles (Guyot and Kuchling 1998, Tysoe 2005).
Whilst community and wildlife care groups report turtles being rescued by (untrained) members of the public from roads or urban areas (TORRN 2014) the fate of the turtle after the rescue is not usually considered (see Chapter Four). In addition, how a person chooses to interact with wildlife might be a factor in determining the survival of the animal. For example, feeding of wildlife can have positive impacts as well as negative impacts (Rollinson et al. 2003). By identifying how people would choose to interact with a turtle in different situations, the impact of human interaction on *C. colliei* can be investigated. The third hypothesis, “People who have an interaction with a turtle are likely to have had a negative impact on the turtle”, explores this further.

It is likely that the person interacting with wildlife may not be equipped with the necessary knowledge to interact appropriately with wildlife. Human behaviour is complex and is influenced by a range of psychological constructs (Kollmuss and Agyeman 2002). A person’s environmental attitudes, knowledge and behaviour are all interconnected and knowledge *can* influence behaviour (Kaiser *et al.* 1999, Kaiser and Fuhrer 2003). While knowledge by itself is not a good predictor of environmental behaviour (because of its connection with attitudes), correct knowledge is required if correct behaviours are to be adopted (Kaiser and Fuhrer 2003). Knowledge about *C. colliei* may be a factor that affects human-turtle interactions. The fourth and final hypothesis, “People with good knowledge about turtles are more likely to behave in a positive manner when they encounter a turtle”, explores this.
Method

To examine resident’s attitudes towards wetlands, wildlife and turtles, and to explore human-turtle interactions, a social survey of residents who lived in proximity to urban wetlands was conducted. The survey instrument utilised was created specifically for the following hypotheses:

1) People who live adjacent to wetlands have a more positive attitude towards wetlands and turtles.

2) People who have had an interaction with a turtle have a more positive attitude towards turtles and wetlands.

3) People who have an interaction with a turtle are likely to have had a negative impact on the turtle.

4) People with good knowledge about turtles are more likely to behave in a positive manner when they encounter a turtle.

Survey design and contents

The social survey instrument developed to gather data from residents used both open-ended and multiple-choice questions (Appendix One). The survey instrument contained seven sections which were used to investigate: human demographics (Section One); wetland use (Section Two); attitudes and perceptions of wetlands (Section Three); knowledge of C. colliei life history (Section Four); attitudes and perceptions of wildlife and turtles (Section Five); turtle interactions – hypothetical behaviours (Section Six); and turtle sightings (Section Seven).

Sections Three and Five of the instrument contained a series of 5-point Likert scale items (statements with the five options: Strongly disagree, Disagree, Neutral, Agree, Strongly Agree). Responses to a series of Likert scale statements (items) are often combined to arrive at a score (or a series of scores) for the respondent. These scores are calculated as a mean of a group of selected items, which relate to the same topic (or construct). These groups of items, which relate to the same topic, are referred to as a subscale.

A subscale is tested for reliability using a Standard Cronbach Alpha test in which scores can range from 0 to 1. A Standard Cronbach Alpha of 0.7 to 0.8 is generally considered an acceptable score; markedly lower values usually indicate that a sub-scale is
unreliable due to internal inconsistencies (i.e. items in the subscale do not measure the same topic or construct) (Cortina 1993).

Each section of the survey is explained in further detail below. These are presented by the hypotheses they test.

**Hypothesis 1 and 2**

**Attitudes and perceptions of wildlife and turtles:** Section Five of the instrument measured respondent’s attitudes and perceptions towards wildlife and *C. colliei*. Section Five contained 19 items (WA1 to WA19, Appendix One) on a 5-point Likert Scale, taken from two published scales (Fulton *et al.* 1996, Dowle and Deane 2009). Items WA1 to WA8 were taken from Fulton *et al.* (1996). These items made up two subscales, “Residential Wildlife Experience” and “Wildlife Education”. Both of these subscales have previously been shown to be highly reliable with Standard Cronbach Alphas of 0.82 and 0.8 respectively.

Items WA9 to WA19 were adapted from Dowle and Deane (2009) to measure attitudes and perceptions towards turtles. Dowle and Deane (2009) examined attitudes towards bandicoots in an urban environment, the items which make up the two sub-scales of “intrinsic rights and values or bandicoots” and “awareness of threats to bandicoots survival” were changed to refer to turtles rather than bandicoots. Dowle and Deane (2009) did not indicate if a Chronbach Alpha test had been conducted for this scale.

**Attitudes and perceptions of urban wetlands:** Section Three of the instrument was designed to measure the respondent’s attitude toward and perceptions of, their local wetland. It consisted of 25 attitudinal items (A1 to A25, Appendix One) on a 5-point Likert scale. The 25 items form three subscales; Ownership (A1 to A9), Participation (A10 to A18) and Security (A19 to A25). These three subscales were chosen as they reflected major components of attitudes towards wetlands. The Ownership subscale relates to a person’s feelings of control over the wetland area, increased feeling of ownership can correlate to frequency of use. The Participation subscale relates to how involved a person feels in the maintenance and planning of their local wetland. The Security subscale relates to how safe and secure people feel around the wetland, how secure someone feels about a wetland can correlate with visitation (Syme *et al.* 2001). These subscales have shown to be reliable with a minimum Standardised Cronbach Alpha of 0.75 (Syme *et al.* 2001).
The remaining sections (One, Two, Four, Six and Seven) in the instrument were created specifically for the purposes of this study. These sections contained a mixture of true/false, multiple-choice and open-ended questions.

**Hypothesis 2 and 3**

**Turtle sightings:** In Section Seven respondents were asked if they had seen *C. colliei* in the “wild” in the previous five years. If they had, they were asked to write down any actions taken. Respondents were also asked to mark the location, year and month they saw the turtle on a map of the respondent’s local area and wetland/s provided (Appendix Two: Example of map for participants). This sighting data was previously discussed in Chapter Four.

**Hypothesis 3 and 4**

**Turtle interactions – hypothetical behaviours:** Section Six of the instrument contained five hypothetical situations (H1 to H5) with an open-ended response (a modified style of choice-modelling (Hanley *et al.* 2001)). These items were created to identify the likely impact respondents would have on *C. colliei* if they encountered one in the urban environment. As it was beyond the scope of this study to observe actual behaviours of people encountering turtles, this style of question provided the opportunity to gain an insight into the most likely ‘behaviour’ of respondents. Respondents were asked to write what they would do (if anything) in each situation. These situations included encountering *C. colliei* on a busy road, a road clear of traffic, and encountering nesting turtles, hatchling turtles and turtle movement. The response for each situation was categorised based on what the respondent indicated they would do. Each interaction category was then coded as having a potential positive, negative or unknown effect on *C. colliei*.

**Hypothesis 4**

**Knowledge of *C. colliei* life history:** The items in Section Four measured the level of resident’s knowledge about the behaviour and biology of *C. colliei*. The items in this section focused on people’s understanding of turtle behaviours out of water (when the respondents are most likely to interact with *C. colliei*). Items K1 to K9 had a True/False response and, K10 and K11 had a multiple-choice response. An overall knowledge score could then be calculated for each respondent.
Other information

Wetland Use: Section Two contained eight items focussed on how frequently the respondent used or visited wetlands and surrounding parkland/bushland area. Respondents were also asked to indicate the type of activities they generally undertook around wetlands and which site (if any) they most often visited. While this section does not directly contribute to the Hypotheses, the variable ‘wetland use’ was likely to be related to the other variables being investigated such as number of turtle sightings. Therefore this information was recorded in order to identify if this relationship existed.

Human demographics: Section One contained general demographic questions: sex; age; income; level of education and field of education; home ownership; how long they have lived in the area; the number of people who live in their residence; and what pets they own. This data was collected to compare against the Australian Bureau of Statistics 2011 census data to identify if the respondents were representative of the general population.

Sampling

Surveys were distributed on a “drop off and pick up” basis (Steele et al. 2001). Survey participants were recruited using door-to-door visits to each of the properties. One male or female over the age of 18 was recruited per residence. If after two visits to the property there had been no contact with the resident a copy of the survey and a reply paid envelope was left in the letter box. Survey participants recruited face to face were offered three ways to return the survey:

- Complete it immediately and hand it back to the researcher;
- Leave it under a door mat or other nominated location for pick up at an agreed upon time; or
- Return using a reply paid envelope.

The intention of providing the participant a variety of options to return the completed survey was to increase the likelihood of response. Reminder notes were placed in resident’s letterboxes approximately two weeks after the surveys were delivered to encourage any participants who had forgotten to submit their survey to do so. This is accepted practice, as outlined in Edwards et al. (2002).
Sites

The residential areas surrounding the twelve wetlands study sites (See Chapter Two) were used as the location for the social surveys. Because some of the twelve wetlands were located adjacent to each other and shared the same residential area, they were clustered into eight “groups” of wetlands for the purposes of the social survey. Three groups contained natural wetlands, four groups contained anthropogenic wetlands and one group contained a mixture of both natural and anthropogenic wetlands (Table 5.1). The closest 100 properties adjacent to the wetland(s) in each group were selected as a survey site, except for the mixed group where the closest 200 properties were selected for the survey site (as the mixed group contained three wetlands rather than one or two wetlands as in other groups).

Control sites, (not adjacent to a wetland), were also chosen. To minimise variation in demographics each control site was matched to a wetland-adjacent site in the same suburb. These control sites also contained 100 properties and were located as far as possible away from wetlands (minimum 500m). To account for the wetland-adjacent site which contained 200 properties (2w-Table 5.1) two control sites of 100 properties each (2a and 2b) were selected. The location and number of properties sampled at each site are shown in Figure 5.2 and Table 5.1.

The numbers of properties sampled were chosen based on an expected response rate of 25%. This was a reasonable expectation as personal delivery surveys have a higher response rate than most other methodologies (Perneger et al. 1993, Allred and Ross-Davis 2011).
Table 5.1: Location types and number of surveys delivered

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Anthropogenic or Natural</th>
<th>What land use is adjacent?</th>
<th>Number of properties delivered to</th>
<th>Map Location (Figure 5.2)</th>
<th>Corresponding non-adjacent survey sites (Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booragoon Lake</td>
<td>Natural</td>
<td>Residential</td>
<td>102</td>
<td>1w</td>
<td>1</td>
</tr>
<tr>
<td>Piney Natural</td>
<td>Natural</td>
<td>Residential</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Piney Ornamental</td>
<td>Anthropogenic</td>
<td>Residential</td>
<td>199</td>
<td>2w</td>
<td>107</td>
</tr>
<tr>
<td>Juett Park</td>
<td>Anthropogenic</td>
<td>Residential</td>
<td></td>
<td></td>
<td>2b, 103</td>
</tr>
<tr>
<td>Frederick Baldwin Lake</td>
<td>Anthropogenic</td>
<td>Residential</td>
<td>100</td>
<td>3w</td>
<td>3</td>
</tr>
<tr>
<td>Chelodina Wetland</td>
<td>Natural</td>
<td>University, STUDENT VILLAGE, Residential</td>
<td>30 University offices, 35 Student Village, 33 Residential</td>
<td>4wa, 4wb, 4wc</td>
<td>4</td>
</tr>
<tr>
<td>South Lake</td>
<td>Natural</td>
<td>Industrial Estate</td>
<td>30 Industry</td>
<td>5wa</td>
<td>5</td>
</tr>
<tr>
<td>Little Rush Lake</td>
<td>Natural</td>
<td>Residential</td>
<td>101 Residential</td>
<td>5wb</td>
<td>5</td>
</tr>
<tr>
<td>Broadwater Gardens</td>
<td>Anthropogenic</td>
<td>Residential</td>
<td>102</td>
<td>6w</td>
<td>6</td>
</tr>
<tr>
<td>Berrigan Lake</td>
<td>Anthropogenic</td>
<td>Residential</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Lucken Reserve</td>
<td>Anthropogenic</td>
<td>Residential</td>
<td>100</td>
<td>7w</td>
<td>7</td>
</tr>
<tr>
<td>Harmony Lake</td>
<td>Anthropogenic</td>
<td>Residential</td>
<td>100</td>
<td>8w</td>
<td>8</td>
</tr>
</tbody>
</table>


Figure 5.2: Map showing the locations of survey sites adjacent to wetlands and survey sites not adjacent to wetlands (minimum 500m from the closest open water).
Analysis

The statistical package PSAW Statistics 21 was used to analyse data. All attitudinal scales were tested for their reliability, the resulting Standardised Chronbach Alpha score was compared to that reported in the literature. Hypotheses were tested using Mann-Whitney, Kruskal-Wallis and Chi-Square tests as well as logistic regression. It is important to note that these results only indicate relationships and associations between factors; they do not indicate a one-way relationship. For example, if there is an association between the attitudes towards wildlife and having previously seen a turtle, it is not possible to identify whether having seen a turtle improves a person’s attitude towards wildlife or whether people with a positive attitude to wildlife seek out opportunities to see turtles.

Data collation for Turtle interactions – hypothetical behaviours questions

Hypothesis three and four used data collected from responses to hypothetical situation questions (H1 to H5). Each question asked if the participant would do anything (Yes/No) and if the response was yes they were asked to write down what they would do. All responses were examined and types of similar responses were identified and each response was categorised (e.g. stop / warn others / allow turtle to cross road). Each category was then coded as having a positive, negative or unknown impact on the turtle based upon current knowledge of *C. colliei* lifecycle and biology. For example, stopping the car / warning others / allowing the turtle to cross the road was coded as a positive interaction because the turtle was allowed to continue on its journey to lay its eggs (or migrate). Putting a turtle back in the wetland was classed as a negative interaction because this compounds the risk to the turtle. Moving through the urban environment is high risk due to predators and human actions when a turtle is picked up part way through this movement it means that this movement will need to be made again therefore exposing the turtle to additional risk. If they don’t, the population loses a potential source of recruitment and if they do, there is additional risk to the female which has already partially made this movement before. For H5, despite the potential for the person to be moving the turtle to where it was headed the interaction was still classed as a negative because of the potential damage (as mentioned above) for the times the turtle is returned to the wetland prior to it nesting.
**Results**

One thousand, eight hundred and forty-two surveys were hand delivered to each property and the response rate was 21.2% overall. The response rate for surveys conducted near wetlands was 23.3% and 18.8% at sites far from wetlands (controls). The results were first assessed to identify if the survey respondents were representative of the local population and if the attitudinal sub-scales were consistent.

**Data Validity: Demography of respondents**

To assess if the survey respondents were representative of the local population, the demographic data were compared to the Australian Bureau of Statistics (ABS) 2011 Census Local Government Area data for City of Cockburn and City of Melville.

**City of Cockburn**

(n= 163, Survey areas: 4, 5, 5wa, 5wb, 6, 6w, 7, 7w, 8, 8w).

All age categories were well represented although there was a slight under-representation of the 18-25 age bracket (Table 5.2). Female respondents were over-represented (65.9% of respondents compared to 50.7% in the local government area - (Australian Bureau of Statistics 2011b)). There were a greater proportion of higher income earners in the survey sample. There was an over-representation of respondents with a bachelor’s degree or postgraduate degree (although the general trend of data still matched the ABS data). There was also an over-representation of four person households and an under-representation of one person households. All other survey data was similar to the ABS data. The survey demographics were considered to be representative of the local area.
Table 5.2: Demographic characteristics of the returned surveys and the ABS data for the City of Cockburn (Australian Bureau of Statistics 2011b)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Category</th>
<th>ABS 2011 Cockburn</th>
<th>Cockburn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18-25</td>
<td>14.3%</td>
<td>11.7%</td>
</tr>
<tr>
<td></td>
<td>26-35</td>
<td>20.6%</td>
<td>23.9%</td>
</tr>
<tr>
<td></td>
<td>36-45</td>
<td>20.8%</td>
<td>20.9%</td>
</tr>
<tr>
<td></td>
<td>46-55</td>
<td>17.1%</td>
<td>16.6%</td>
</tr>
<tr>
<td></td>
<td>55+</td>
<td>27.2%</td>
<td>27.0%</td>
</tr>
<tr>
<td>Sex</td>
<td>Males</td>
<td>49.3%</td>
<td>34.1%</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>50.7%</td>
<td>65.9%</td>
</tr>
<tr>
<td>Income</td>
<td>&lt;$15,600</td>
<td>19.0%</td>
<td>15.3%</td>
</tr>
<tr>
<td></td>
<td>$15,600-$31,200</td>
<td>21.2%</td>
<td>19.4%</td>
</tr>
<tr>
<td></td>
<td>$31,200-$52,000</td>
<td>21.0%</td>
<td>18.1%</td>
</tr>
<tr>
<td></td>
<td>$52,000-$78,000</td>
<td>19.5%</td>
<td>25.0%</td>
</tr>
<tr>
<td></td>
<td>&gt;$78,000</td>
<td>19.3%</td>
<td>22.2%</td>
</tr>
<tr>
<td>Property ownership</td>
<td>Rent</td>
<td>24.3%</td>
<td>18.0%</td>
</tr>
<tr>
<td>Education</td>
<td>Own</td>
<td>75.7%</td>
<td>82.1%</td>
</tr>
<tr>
<td></td>
<td>Year 10</td>
<td>19.1%</td>
<td>16.9%</td>
</tr>
<tr>
<td></td>
<td>Year 12</td>
<td>24.2%</td>
<td>18.8%</td>
</tr>
<tr>
<td></td>
<td>TAFE</td>
<td>33.8%</td>
<td>27.9%</td>
</tr>
<tr>
<td></td>
<td>Bachelors</td>
<td>17.4%</td>
<td>29.2%</td>
</tr>
<tr>
<td>Number of people in residence</td>
<td>Postgrad 1</td>
<td>5.4%</td>
<td>7.1%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>33.1%</td>
<td>36.9%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>17.9%</td>
<td>17.2%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>18.6%</td>
<td>23.6%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7.3%</td>
<td>8.9%</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>2.1%</td>
<td>1.9%</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>8+</td>
<td>0.3%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

**City of Melville**

(n=204, Survey areas: 1, 1w, 2a, 2b, 2w, 3, 3w, 4wa, 4wb, 4wc)

The age bracket 26-35 was not well represented within the survey sample in the City of Melville, while there was an over-representation of the 55+ bracket (Table 5.3). Females were also slightly over-represented within the survey population. There were a slightly higher proportion of people who owned their own home in the survey sample compared to the ABS data for Melville (Australian Bureau of Statistics 2011c). As with the surveys from Cockburn, there was an over-representation of respondents with a
bachelor’s degree or post graduate degree. The survey sample was slightly skewed towards both the lowest tier of income and the highest tier of income.

There was again an under-representation of one-person households within the data. However, there was an overrepresentation of houses with four or more people (e.g. 3.2% of respondents lived in an eight or more person household compared to 0.1% in ABS data) which was due to the students responding from Murdoch student village, as majority of the housing contains six or more rooms. The survey demographics for City of Melville were considered to be representative of the local area.

Table 5.3: Demographic characteristics of the returned surveys and the ABS data for the City of Melville (Australian Bureau of Statistics 2011c)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Category</th>
<th>ABS 2011 Melville</th>
<th>Melville</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>18-25</td>
<td>15.2%</td>
<td>17.7%</td>
</tr>
<tr>
<td></td>
<td>26-35</td>
<td>14.0%</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td>36-45</td>
<td>16.9%</td>
<td>12.6%</td>
</tr>
<tr>
<td></td>
<td>46-55</td>
<td>18.9%</td>
<td>21.2%</td>
</tr>
<tr>
<td></td>
<td>55+</td>
<td>35.1%</td>
<td>43.9%</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>47.3%</td>
<td>43.2%</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>52.7%</td>
<td>56.8%</td>
</tr>
<tr>
<td></td>
<td>&lt;$15,600</td>
<td>18.4%</td>
<td>25.8%</td>
</tr>
<tr>
<td></td>
<td>$15,600-$31,200</td>
<td>21.3%</td>
<td>14.7%</td>
</tr>
<tr>
<td></td>
<td>$31,200-$52,000</td>
<td>18.2%</td>
<td>12.3%</td>
</tr>
<tr>
<td></td>
<td>$52,000-$78,000</td>
<td>16.8%</td>
<td>16.0%</td>
</tr>
<tr>
<td></td>
<td>&gt;$78,000</td>
<td>25.4%</td>
<td>31.3%</td>
</tr>
<tr>
<td>Property ownership</td>
<td>Rent</td>
<td>23.7%</td>
<td>17.5%</td>
</tr>
<tr>
<td></td>
<td>Own</td>
<td>76.3%</td>
<td>82.5%</td>
</tr>
<tr>
<td>Education</td>
<td>Year 10</td>
<td>12.6%</td>
<td>6.8%</td>
</tr>
<tr>
<td></td>
<td>Year 12</td>
<td>23.9%</td>
<td>15.2%</td>
</tr>
<tr>
<td></td>
<td>TAFE</td>
<td>26.1%</td>
<td>23.6%</td>
</tr>
<tr>
<td></td>
<td>Bachelors</td>
<td>27.2%</td>
<td>37.7%</td>
</tr>
<tr>
<td></td>
<td>Postgrad</td>
<td>10.3%</td>
<td>16.8%</td>
</tr>
<tr>
<td>Number of people in residence</td>
<td>1</td>
<td>23.8%</td>
<td>7.4%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>33.5%</td>
<td>37.6%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>16.1%</td>
<td>16.4%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>17.7%</td>
<td>22.8%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6.7%</td>
<td>7.9%</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1.7%</td>
<td>3.2%</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.3%</td>
<td>1.6%</td>
</tr>
<tr>
<td></td>
<td>8+</td>
<td>0.1%</td>
<td>3.2%</td>
</tr>
</tbody>
</table>

Overall the demographics of the respondents in the City of Melville and Cockburn were sufficiently similar to the ABS demographics to conclude that our survey respondents were a reasonably representative sample of their populations.
Data Validity: Sub-scale consistency

Section Three of the instrument contained three subscales, Ownership, Participation and Security. These subscales had a Standardised Chronbach Alpha of 0.791, 0.852 and 0.685 respectively. Participation and Ownership were well above the usual acceptable Standardised Chronbach Alpha of 0.7 while the Security scale was less internally consistent. Responses to Security subscale items A21 and A24 regarding lighting and the presence of teenagers around wetlands were varied and were likely to be a cause of the less than acceptable Standardised Chronbach Alpha score.

The response to item A24 “The wetland is well lit at night” (Appendix One: Section Two) was highly varied as the statement was worded in such a way that it did not take differing perceptions of wetlands or the type of wetland into account, confounding the result. A number of respondents who strongly disagreed with the statement pointed out that since their local wetland was a natural system they did not want nor expect it to be well lit at night. A better phrasing for this statement would have been “I am happy with the level of lighting around the wetland during the night”.

A respondent also indicated that item A21 with the statement “there are often teenagers around the wetland” implied that it is bad to have teenagers around wetlands. Perhaps some members of the community would feel that presence of adolescents as a threat whilst others would appreciate that this is part of a healthy lifestyle. This particular respondent commented that they were happy to see teens still interested in local natural areas. The ambiguity resulting from the statement can result in the sub-scale being less effective.

The Security subscale did not take into consideration the different ways aspects of urban wetlands could be perceived which has led to its ineffectiveness. Due to the composition of the survey it is not possible to estimate the effect that these underlying perceptions have had on the Security subscale. Despite the Security subscale’s lower consistency score it is still presented and discussed as because this sub-scale has previously been used and shown to be reliable (Syme et al. 2001). In addition, the score of 0.685 is not far from the traditionally accepted 0.7, the sample size is very large (>350), and the data from this subscale still offers some valuable insights.
Hypothesis One

“People who live adjacent to wetlands have a more positive attitude towards wetlands and turtles.”

Respondents living adjacent to wetlands had a significantly more positive attitude towards wetlands (sub-scales of ownership, participation and security) and wildlife, than respondents living far from wetlands (Table 5.4). The sub-scale participation displayed the greatest difference between those who lived near to wetlands and those who live far from wetlands (Figure 5.3).

Table 5.4: Mann-Whitney test indicates a significant relationship between whether the respondent lived near or far to a wetland and the attitudinal subscales of Ownership, Participation, Security and Wildlife.

<table>
<thead>
<tr>
<th>Sub-scale</th>
<th>Significant relationship</th>
<th>Details</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership</td>
<td>Y</td>
<td>U=15505, z=3.148, p=0.002</td>
<td>r= 0.17 Small</td>
</tr>
<tr>
<td>Participation</td>
<td>Y</td>
<td>U=18022, z=5.367, p=0.0005</td>
<td>r= 0.29 Medium</td>
</tr>
<tr>
<td>Security</td>
<td>Y</td>
<td>U=17793, z=4.478, p=0.0005</td>
<td>r=0.24 Small to Medium</td>
</tr>
<tr>
<td>Wildlife</td>
<td>Y</td>
<td>U=16778, z=2.796, p=0.005</td>
<td>r=0.15 Small</td>
</tr>
<tr>
<td>Turtle</td>
<td>N</td>
<td>U=16055, z=1.681, p=0.093</td>
<td></td>
</tr>
</tbody>
</table>
This data supports the hypothesis that residents living adjacent to wetlands have a more positive attitude towards the wetlands and wildlife in general.

A binary logistic regression assessed the combined effects between the **attitudinal** scales and living near or far from a wetland. The sub-scales of participation and security were significantly associated with living near a wetland ($\chi^2(5) = 35.212, p < 0.0005$), explained 15.8% (Nagelkerke $R^2$) of the variance and correctly classified 63.3% of cases.
Hypothesis Two

“People who have had an interaction with a turtle have a more positive attitude towards turtles and wetlands”.

To test this hypothesis the same scales of ownership, participation, security, wildlife and turtle were used as described in the previous section. Respondents who had seen a turtle in their local area had a significantly more positive attitude towards wetlands (sub-scales of ownership, participation and security), wildlife and turtles than those who had not seen a turtle (Table 5.5). This supports the hypothesis that people who have had an interaction with a turtle have a more positive attitude towards turtles and wetlands. Interestingly there is a greater difference in mean responses to the subscales for having seen a turtle (Figure 5.4) than there was for living adjacent to a wetland (Figure 5.3).

Table 5.5: Mann-Whitney test indicates a significant relationship between having seen a turtle or not seen a turtle and all of the attitudinal sub-scales

<table>
<thead>
<tr>
<th>Sub-scale</th>
<th>Significant relationship</th>
<th>Details</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership</td>
<td>Y</td>
<td>U=6852, z=-6.831, p=0.0005</td>
<td>r=-0.38 Medium to Large</td>
</tr>
<tr>
<td>Participation</td>
<td>Y</td>
<td>U=7752, z=-6.061, p=0.0005</td>
<td>r=-0.34 Medium</td>
</tr>
<tr>
<td>Security</td>
<td>Y</td>
<td>U=9585, z=-4.617, p=0.0005</td>
<td>r=-0.25 Small to Medium</td>
</tr>
<tr>
<td>Wildlife</td>
<td>Y</td>
<td>U=9051, z=-5.500, p=0.0005</td>
<td>r=-0.29 Medium</td>
</tr>
<tr>
<td>Turtle</td>
<td>Y</td>
<td>U=8062, z=-6.688, p=0.0005</td>
<td>r=-0.36 Medium to Large</td>
</tr>
</tbody>
</table>
A binary logistic regression assessed the combined effects between the attitudinal scales and having seen or not seen a turtle. The scale of attitudes towards turtles and the subscales of ownership and security were significantly associated with having previously seen a turtle ($\chi^2(5) = 60.134, p < .0005$), explained 26.3% (Nagelkerke $R^2$) variance and correctly classified 69.0% of cases.

Figure 5.4: Mean responses (and standard error) to attitudinal subscales responses group by whether respondent had or had not seen a turtle in their local area.
Wetland use: An additional factor influencing Hypothesis One and Two

In addition to recording whether the respondent lived adjacent or far from a wetland, and if they had seen a turtle, residents were also asked how frequently they visited the wetland (Appendix One, Section One, Item U1), “How often do you visit your local wetland? Once or more per week, Once every 2 weeks, Once per month, Once every 2 months, Once every 6 months, Once last year, Never”

Living near a wetland and the frequency of use of a wetland were significantly related \( \chi^2(6)=69.778, \ p=0.005 \), there was a strong association (Cramer’s V=0.440). The factors of having seen a turtle and frequency of wetland use were also significantly related \( \chi^2(6)=47.190, \ p=0.0005 \), there was a medium association (Cramer’s V=0.367). The factors of having seen a turtle and living near to a wetland were similarly significantly related \( \chi^2(1) =110.289, \ p=0.01 \), there was a low association (Cramer’s V=0.170). On the basis of the results it is reasonable to expect that people who live next to a wetland are more likely to visit a wetland regularly and therefore would be more likely to encounter a turtle. This expectation is supported by the three way relationship between having seen a turtle, how often the person visits the wetland and whether the person lives near to a wetland.

Figure 5.5 illustrates how these three factors relate to each other; turtle knowledge, and the attitudinal sub-scales (of ownership, participation, security, wildlife and turtles). All of the relationships indicated by arrows are statistically significant and the strength of these relationships is indicated by effect size or association (dependent on the type of test utilised). Potentially the relationship between wetland visitation frequency and having seen a turtle may be stronger than the relationship between living near wetland and having seen a turtle. The relationship between having seen a turtle and both attitudes and knowledge is demonstrably stronger than living close to a wetland (as shown by the larger effect size/association). Specifically the relationship between having seen a turtle and both ownership and attitudes towards turtles is far stronger than the living near to a wetland relationship.
In future studies, structural equation modelling could be utilised to further analyse these associations, however, for the purposes of this thesis this method is not necessary to test our hypotheses.

Figure 5.5: Overview of all associations tested for Hypothesis One and Two, two way arrows indicate a significant relationship. Grey boxes indicate attitudinal sub-scales and their effect size from Mann-Whitney tests. White boxes indicate categorical data and strength of association from Chi-Square tests.
Turtle interactions – hypothetical situations

Hypothesis three “People who have an interaction with a turtle are likely to have had a negative impact on the turtle” and Hypothesis four “People with good knowledge about turtles are more likely to behave in a positive manner when they encounter a turtle” were tested by analysing responses to the hypothetical questions outlined below.

H1: You are driving down a road and you see a turtle crossing the road heading away from the wetland. On the other side of the road are houses and the road is very busy with traffic.

H2: You are driving down a road and you see a turtle crossing the road heading away from the wetland. On the other side of the road are houses and there is no visible traffic.

H3: You see a turtle come into your garden and start digging in it.

H4: You see tiny baby turtles walking around on the ground. They are 100m from the wetland.

H5: It is summer and you see a turtle moving along a road in your area where there is very little traffic. You know that the closest wetland is more than 500m away.

Each participant was asked if they would do anything (Yes/No) and if yes they were asked to write what they would do. These open-ended responses were categorised into groups of responses and these were then coded as having a positive, negative or unknown impact on the turtle.
Items H1 and H2 only varied in the density of traffic described. For H1, 70.5% of respondents said that they would try to do something as opposed to 55.7% of respondents for H2. Of those who indicated they would try to do something there was little difference in what they would choose to do based upon whether there was or wasn’t traffic present, although less people (6.5%) indicated they would move a turtle in the direction it was heading if there was no traffic (Figure 5.6). People seeing a turtle cross the road are most likely to move it or shepherd it back to a wetland (H1 35.4% and H2 38.2%) or stop, warn others of the crossing and allow the turtle to cross (H1 24%, H2 27.7%). There was no more than a 2.8% variation for items H1 and H2 between the groups of positive interactions, negative interactions and outcome unknown.

Figure 5.6: Histogram of grouped responses to hypothetical situations one and two (H1, H2). Each group of responses is coded to indicate whether the interaction was classed as positive (green), negative (red) or not enough information known to assess (orange).
In response to H3, 48% of respondents would do something upon finding a turtle in their gardens. Most were likely either to remove it directly (33.0%) or to call an expert (or someone they view as an expert) to give them advice (37.4%, Figure 5.7).

In response to H4, 56.6% of respondents would do something to help hatchling turtles on land. Almost all respondents would interact with hatchlings in a positive manner (Figure 5.8).
For H5, 56.6% of respondents said that they would do something if they saw a turtle 500m from a wetland during summer. The majority of these respondents (67.5%) who would do something if they encountered the turtle indicated that they would return the turtle to the wetland (Figure 5.9).

![Figure 5.9: Histogram of grouped responses to hypothetical situation five (H5). Each group of responses is coded to indicate whether the interaction was classed as positive (green), negative (red) or not enough information known to assess (orange).](image-url)
Hypothesis Three

“People who have an interaction with a turtle are likely to have had a negative impact on the turtle”.

Of the respondents who had seen a turtle in the last 5 years, there was a difference between those who lived close to wetlands and those who live far from a wetland. Of the respondents who lived close to a wetland, 49.3% had seen a turtle and of these turtle sightings, 31% chose to interact with the turtle in some way. Of the respondents who live far from a wetland, 32.1% had seen a turtle and of these turtle sightings, 21.2% chose to interact with the turtle in some way (Table 5.6). Only one of these reported interactions involved a hatchling turtle.

Table 5.6: Percentage of turtle sightings and resultant interactions by respondents living near and far from a wetland.

<table>
<thead>
<tr>
<th></th>
<th>Respondent lives near a wetland</th>
<th>Respondent lives far from a wetland</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of respondents that <strong>had not</strong> seen a turtle (in the last 5 years)</td>
<td>50.7%</td>
<td>67.8%</td>
</tr>
<tr>
<td>% of respondents that <strong>had</strong> seen a turtle (in the last 5 years)</td>
<td>49.3%</td>
<td>32.1%</td>
</tr>
<tr>
<td>% of consequent interactions with observed turtles</td>
<td>31.0%</td>
<td>21.2%</td>
</tr>
</tbody>
</table>

Hypothesis three is not well supported by the data, the only significant relationship between having seen a turtle and the outcome of the interaction was the potential negative interactions with turtles encountered more than 500m away from a wetland during summer (Figure 5.9, H5 $\chi^2(2)=7.209$, p=0.027, Cramers V=0.193). Therefore having seen a turtle previously does not often affect the outcome of future turtle interactions. Living close to a wetland, however, means that people are more likely to see a turtle and to choose to interact with it (Table 5.6).
Estimating the number of turtle interactions in the urban environment

Given that more than 35% of potential interactions (with the exception of H4- Figure 5.8) are likely to have a negative outcome (see Figures 5.6, 5.7 and 5.9), it is necessary to consider the total number of turtle interactions in the study area. To identify the potential number of turtles seen and consequent interactions that may have occurred over the last five years, the “far from wetland” percentages of turtles seen and consequent interactions of the respondents (from Table 5.6) were used to extrapolate data for the human population within both local government areas. The “far from wetland” data was used as the basis for this extrapolation as it was more likely to be representative of the average turtle observation and interaction levels in each local government area (as most residents do not live adjacent to a wetland).

The results indicate a potential for over 6000 human-turtle interactions to occur in each council area over a five year period (Table 5.7). If the proportion of positive and negative interactions remains consistent beyond the study area (e.g. similar to Figures 5.6-5.9) then approximately 35% to 67% of interactions are likely to have a negative impact on the wellbeing of the turtle. This suggests that more than 2000 human-turtle interactions may have resulted in a negative outcome in each of these council areas over the last five years.

Table 5.7: Potential number of turtles that have been interacted with in each local council extrapolated using human population size in each local government area and data collected from social survey.

<table>
<thead>
<tr>
<th>Human population size (ABS 2011)</th>
<th>City of Cockburn</th>
<th>City of Melville</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of population likely to see a turtle–from survey data (Table 5.6)</td>
<td>88,662</td>
<td>95,027</td>
</tr>
<tr>
<td>Probable population that has seen a turtle</td>
<td>32.1%</td>
<td></td>
</tr>
<tr>
<td>Percentage of encounters that will result in an interaction – from survey data (Table 5.6)</td>
<td>28,461</td>
<td>30,504</td>
</tr>
<tr>
<td>Number of turtles interacted with in the last 5 years</td>
<td>6,034</td>
<td>6,467</td>
</tr>
</tbody>
</table>
Hypothesis Four

“People with good knowledge about turtles are more likely to behave in a positive manner when they encounter a turtle”.

Hypothesis Four was examined using the hypothetical interaction and the knowledge questions. The survey instrument contained eleven knowledge questions (items K1 to K11). Knowledge data was examined in two steps. Overall knowledge was examined using results from all the questions in Table 5.8. The results indicate that knowledge of respondents was generally poor with a mean score of 4.2±0.13 out of a potential 9 (Figure 5.10).

A sub set of knowledge questions (K2, K6, K7, K9, K10 and K11) focussing on knowledge of nesting habits and reproduction of *C. colliei* was also examined. The knowledge of respondents for this sub-set was poor with a mean of 2.17±0.09 out of a possible score of 6 (Figure 5.11).

Table 5.8: Turtle knowledge questions, correct answers and percentage of respondents that answered correctly and incorrectly.

<table>
<thead>
<tr>
<th>Question</th>
<th>Question type and answer</th>
<th>Correct (%)</th>
<th>Incorrect (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K2</td>
<td>Female oblong turtles require sandy soil for nesting.</td>
<td>True/False</td>
<td>30.1%</td>
</tr>
<tr>
<td>K3</td>
<td>Turtles don’t need vegetation around the edge of wetlands for protection.</td>
<td>True/False</td>
<td>53.5%</td>
</tr>
<tr>
<td>K4</td>
<td>Roadside curbs do not hinder turtle movement.</td>
<td>True/False</td>
<td>48.0%</td>
</tr>
<tr>
<td>K6</td>
<td>Nesting is when female turtles lay their eggs.</td>
<td>True/False</td>
<td>62.4%</td>
</tr>
<tr>
<td>K7</td>
<td>It is possible to see if a female turtle is carrying eggs by looking at it.</td>
<td>True/False</td>
<td>22.6%</td>
</tr>
<tr>
<td>K8</td>
<td>Oblong turtles can move fast enough to avoid traffic when crossing roads.</td>
<td>True/False</td>
<td>78.2%</td>
</tr>
<tr>
<td>K9</td>
<td>Female turtles can travel up to 500m from a wetland to lay their eggs.</td>
<td>True/False</td>
<td>37.2%</td>
</tr>
<tr>
<td>K10</td>
<td>In what season/s do you think turtles lay eggs?</td>
<td>Multiple-choice</td>
<td>53.9%</td>
</tr>
<tr>
<td>K11</td>
<td>How long does it take turtle eggs to hatch?</td>
<td>Multiple-choice</td>
<td>6.2%</td>
</tr>
</tbody>
</table>
Figure 5.10: Histogram of knowledge scores (out of 9) for respondents who answered all questions

Figure 5.11: Histogram of nesting knowledge scores (out of a possible 6) calculated from responses to knowledge questions 2, 6, 7, 9, 10 and 11 in social survey
Because the relationship between knowledge and behaviour is complex, Hypothesis Four was assessed using three sub-questions. These were: 1) Was the respondent’s choice to interact (or not) with a turtle associated with their level of turtle knowledge? 2) Was the way the respondent chose to interact with the turtle associated with their level of turtle knowledge? and 3) Was the projected outcome of the interaction (Positive, Negative, Unknown) associated with the respondents level of turtle knowledge? These sub-questions ensure that any association between knowledge and the hypothetical questions has been fully explored.

1. **Was the respondent’s choice to interact with a turtle associated with their turtle knowledge?**

This association was tested using binary logistic regression for each of the five hypothetical situations. The choice to interact with a turtle crossing a busy road (H1 -see Figure 5.6) was significantly associated with the respondents overall turtle knowledge ($\chi^2(6) = 9.355, p < 0.005$). The regression only explained 4.6% (Nagelkerke $R^2$) of the variance in response but did correctly classify 74.5% of the cases. This choice to interact with a turtle crossing a busy road was also significantly associated with nesting turtle knowledge ($\chi^2(4) = 10.440, p < 0.05$). The regression also only explained a low percentage of variance 3.8% (Nagelkerke $R^2$) but correctly classified 74.5% of the cases. No other hypothetical questions were significantly associated with knowledge. Therefore, knowledge can in some situations influence whether a respondent would choose to interact with a turtle.

2. **Was the way the respondent chose to interact with the turtle associated with their turtle knowledge?**

This association was tested using Kruskal-Wallis tests for association for each of the five hypothetical situations. There was a significant association between actions that the participants would take for H1 (turtle crossing busy road) and both their overall knowledge and nesting knowledge (Table 5.9). There was also a significant association between nesting knowledge and Hypothetical question 5 (turtle is observed 500m from wetlands during summer). Therefore in some situations (e.g. turtle crossing a busy road) knowledge can influence how a respondent would choose to interact with a turtle.
Table 5.9: Kruskal-Wallis tests for association between respondents overall and nesting knowledge and the action the respondent would take for each hypothetical situation.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Significant relationship</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1 – Overall Knowledge</td>
<td>Y</td>
<td>$H(7)=17.631$, $p=0.014$</td>
</tr>
<tr>
<td>H1 – Nesting Knowledge</td>
<td>Y</td>
<td>$H(7)=18.511$, $p=0.01$</td>
</tr>
<tr>
<td>H2 – Overall Knowledge</td>
<td>N</td>
<td>$H(7)=11.036$, $p=0.137$</td>
</tr>
<tr>
<td>H2 – Nesting Knowledge</td>
<td>N</td>
<td>$H(7)=7.449$, $p=0.384$</td>
</tr>
<tr>
<td>H3 – Overall Knowledge</td>
<td>N</td>
<td>$H(6)=9.736$, $p=0.136$</td>
</tr>
<tr>
<td>H3 – Nesting Knowledge</td>
<td>N</td>
<td>$H(6)=9.207$, $p=0.162$</td>
</tr>
<tr>
<td>H4 – Overall Knowledge</td>
<td>N</td>
<td>$H(3)=3.717$, $p=0.294$</td>
</tr>
<tr>
<td>H4 – Nesting Knowledge</td>
<td>N</td>
<td>$H(3)=5.647$, $p=0.130$</td>
</tr>
<tr>
<td>H5 – Overall Knowledge</td>
<td>N</td>
<td>$H(6)=9.974$, $p=0.126$</td>
</tr>
<tr>
<td>H5 – Nesting Knowledge</td>
<td>Y</td>
<td>$H(6)=12.948$, $p=0.044$</td>
</tr>
</tbody>
</table>
3. *Was the projected outcome of the interaction associated with the respondent's turtle knowledge?*

This association was tested using Kruskal-Wallis tests for association for each of the five hypothetical situations. There was no significant association found between overall knowledge (or nesting knowledge) and the projected outcome (positive, negative, unknown) of the respondents hypothetical actions on a turtle (Table 5.10).

**Table 5.10: Results of tests for association between knowledge scores and outcome of the respondent’s hypothetical action (positive, negative or unknown impact)**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Significant relationship</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1 – Overall Knowledge</td>
<td>N</td>
<td>H(2)=4.569, p=0.102</td>
</tr>
<tr>
<td>H1 – Nesting Knowledge</td>
<td>N</td>
<td>H(2)=2.093, p=0.351</td>
</tr>
<tr>
<td>H2 – Overall Knowledge</td>
<td>N</td>
<td>H(2)=3.647, p=0.161</td>
</tr>
<tr>
<td>H2 – Nesting Knowledge</td>
<td>N</td>
<td>H(2)=2.141, p=0.343</td>
</tr>
<tr>
<td>H3 – Overall Knowledge</td>
<td>N</td>
<td>H(2)=5.570, p=0.062</td>
</tr>
<tr>
<td>H3 – Nesting Knowledge</td>
<td>N</td>
<td>H(2)=3.251, p=0.197</td>
</tr>
<tr>
<td>H4 – Overall Knowledge</td>
<td>N</td>
<td>U=281, z=-0.08, p=0.933</td>
</tr>
<tr>
<td>H4 – Nesting Knowledge</td>
<td>N</td>
<td>U=232, z=-1.524, p=0.128</td>
</tr>
<tr>
<td>H5 – Overall Knowledge</td>
<td>N</td>
<td>H(2)=4.590, p=0.101</td>
</tr>
<tr>
<td>H5 – Nesting Knowledge</td>
<td>N</td>
<td>H(2)=4.958, p=0.84</td>
</tr>
</tbody>
</table>

The hypothesis “People with good knowledge about turtles are more likely to behave in a positive manner when they encounter a turtle” is not supported. However, in certain situations (such as perceived danger, e.g., a turtle crossing a busy road) knowledge does appear to play some role as it is associated with both; if a person will interact with the turtle *and* what they choose to do with the turtle.
Discussion

Respondents who lived close to a wetland were more likely to have positive attitudes towards wetlands and wildlife, similarly respondents who had an interaction with a turtle had a more positive attitude towards wetlands and wildlife. Of these it appears that having an interaction with a turtle and a person’s attitudes are more strongly related than living close to a wetland and a person’s attitudes. Additionally, having a prior interaction with a turtle does not influence future interactions with a turtle, and that a person’s turtle knowledge can influence their choice to interact (or not) with a turtle but does not influence how they would interact with the turtle.

Data validity

Prior to discussing the results for each hypothesis in more detail the survey’s representation of the general population and the reliability of the sub-scales will be considered.

Was the survey representative?

The sample populations in Cockburn and Melville were considered adequately representative of their populations, although there were a few minor differences which are considered in detail herein (Table 5.2 and Table 5.3). There was an over-representation of female respondents in the Cockburn area (Table 5.2), however it is not uncommon to find a higher response rate for women in social surveys (Mainieri et al. 1997, Chan 1998, Thomas et al. 2001, Martikainen et al. 2007). An over-representation of higher-income earners and people with degrees was recorded in both sample areas. This is possibly the result of sampling two areas of newer housing developments and the high cost of properties in these areas (Swinburne Institute for Social Research 2008).

There was also an under-representation of one-person households in both Cockburn and Melville. This may be due in part to the method of recruitment for the survey. When no-one answered the door at a property, a copy of the survey was left in their letter box. This more likely to occur at single occupant households, because the chance of someone being encountered at the residence is greater the larger the household. It has been shown that “drop off – pickup” surveys tend to have a higher response rate than surveys that are posted (Allred and Ross-Davis 2011). Therefore, lack of interaction with the person conducting the survey can lead to a decreased response rate. In addition, the zoning of the sample locations and the housing density are likely to also have had an effect. There
were fewer apartment blocks and duplex houses present in the areas sampled which were more likely to be single person households.

**Attitudinal Sub-scale consistency**

People’s perceptions, expectations and preferences can vary because of many factors. For example, perceptions of what wilderness is, varies between rural and urban residents (Lutz et al. 1999) and, some urban residents prefer heavily grazed woodlands as they appear to be a more park-like environment (Williams and Cary 2002). Therefore, it is possible that this difference in perception extends to wetlands and wildlife as presented within the survey instrument. All attitudinal sub-scales used in the survey were internally consistent except the Security subscale (see Data Validity: Sub-scale consistency). Items A21 and A24 were worded such that responses could be influenced by the respondent’s preconceptions or expectations of wetlands. The terminology wetland is so broad that some respondents may expect wetlands to be European style lakes and heavily manicured (park-like), while others might expect wetlands to be untouched natural areas. Whilst this subscale was still presented in this thesis, it is recommend that prior to the re-use of this sub-scale all items should be further validated to ensure the result is an accurate representation of feelings about security rather than being confounded by complex issues such as social perceptions and cultural expectations of wetlands.

**Hypothesis One**

The effect of distance from natural areas on human attitudes towards wildlife depends on the specific context. This study found that people who live close or adjacent to wetlands had a more positive attitude towards wetlands and wildlife, thus supporting Hypothesis One. Much of the relevant literature tends to focus on human-wildlife conflict, nuisance or on consumptive recreational interactions (Boyle and Samson 1985, Madden 2004). The results of this study suggest that those who live closer to wetlands are more accepting of the wildlife around them in the Western Australian context, or that there are other benefits to the person (health, lifestyle and wellbeing (Hartig et al. 1991)). This indicates that to drive community participation in the conservation of *C. colliei* a good starting target area would be those people who live close to wetlands and then expand outwards.

Environmental attitudes can vary between rural and urban areas, however, this is not consistently supported in the literature (Arcury and Christianson 1993, Berenguer et al.
The significant difference in attitudes between those who live near a wetland and those who lived far from a wetland was unexpected because the distance of the far from a wetland group was relatively small (500m to 2km). Yet the literature does not show a consistent difference in attitudes between rural and urban populations even though they are separated by a far greater distance. Therefore, it was surprising to identify a significant difference at such a small scale.

Much of the literature comparing urban and rural attitudes use Dunlap’s New Environmental Paradigm (NEP) to measure environmental attitudes. The NEP measures a person’s ecological world view which represents a more general environmental attitude (Dunlap et al. 2000), whereas the scale in this survey focused specifically on participants attitudes towards their local wetland. It may be that the specific focus of this survey on local wetlands is what brought out the difference in attitudes between those who live adjacent to a wetland and those who do not. Therefore would also be beneficial to explore the idea that perhaps due to its breadth the NEP is not the best scale to use in every situation by conducting this set of surveys again but additionally utilising the NEP.

It would be interesting to see if there is a relationship between general environmental attitudes measured (NEP) and the reported behaviour towards turtles, as Hinds and Sparks (2011) reported that there can be a disconnect between environment world views and reported pro-environmental behaviours. There often tends to be a greater connection to the environment with those living in rural areas, conceivably due to greater exposure to nature and a greater feeling of moral obligation (Berenguer et al. 2005). It would be useful to explore if the pattern would be reflected with this study’s participants, with respondents who live next to a natural wetland having a greater connection between broad pro-environmental world view and their general environmental behaviours.

The results from this study indicate that there is a relationship between attitudes towards wetlands and wildlife, and the distance from a wetland. These results only indicate that a relationship exists therefore further research is needed to investigate whether: people with positive attitudes seek out a place to live near wetlands; living close to wetlands results in more positive attitudes and greater appreciation for wetlands and wildlife; or, a more complex relationship exists. Stedman (2002) suggests that attachment, satisfaction and the meaning a place has for an individual will influence behaviours such as willingness to maintain the area or engage in conservation behaviours. If this is correct, these factors may drive human-turtle interactions. Further research is needed to
explore the relationship between attitude, behaviour and exposure to the local environment as this has potential to inform landscape design. Landscape design is critical as it modifies the habitat within which *C. colliei* live and has the potential to affect *C. colliei* populations in the future.

**Hypothesis Two**

People who had previously seen a turtle had a more positive attitude towards wetlands, wildlife and turtles. This suggests that people who have had turtle experiences develop a greater connection to their local wetland environment. Direct experience with wildlife can shape the values towards wildlife (Deruiter and Donnelly 2002) thus there is also the potential for these interactions to shape attitudes towards local natural areas. People who have positive interactions with wildlife tend to have greater support for land and wildlife conservation (Kretser *et al.* 2009). This could be used to the turtle’s advantage to engender additional support from the community for the assistance of turtle populations or to encourage locals to engage with turtle education.

There is a three-way association between living close to a wetland, seeing a turtle and visitation (Figure 5.5), which indicates that these three factors influence resident’s attitudes towards their local wetlands and wildlife. Attitudes are extremely complex and they have many drivers (Ajzen 2001, Barr and Gilg 2007, Swanwick 2009, Kurz and Baudains 2012). While living close to a wetland and prior turtle sightings were investigated in this study and are associated with positive attitudes towards wetland, further research exploring whether higher visitation to wetlands positively influences attitudes towards wetlands is needed. In addition, wetland visitation is also a contributing factor to turtle observation as increasing visitation improves the chance of observing a turtle.

**Hypothetical questions**

A set of hypothetical questions (H1-H5) were used to investigate Hypotheses three and four. These hypothetical questions provided insight regarding how people believe they would interact with turtles in the urban environment. While choice modelling has been used previously for biodiversity and environmental valuation (Bennett and Blamey 2001, Gazzani and Marinova 2007) there is little literature covering the use of these type of questions to explore human interaction choices with wildlife. There were a number of interesting results from responses to the hypothetical questions.
In H1 and H2 there was a marked difference in the number of participants who would try to assist the turtle (70% to 55% respectively) yet the only difference in the situations was the amount of traffic on the road. The way in which the respondent would deal with the situation, however, did not vary greatly between the two situations (Figure 5.6). This indicates that perceived danger to wildlife can influence people to interact with wildlife but does not influence how they would interact with the animal. This shows that there is a sufficient level of concern for wildlife in the community to lead to positive conservation action. Further community education can ensure that public concern is supported by appropriate knowledge regarding interaction with turtles.

The type of interaction that occurs between a human and a turtle can be influenced by the distance that this interaction occurs from a wetland. Hypothetical question H5 focused on participants encountering a turtle 500m away from a wetland. A majority of people indicated they would try and do something and a large proportion of these (67.5%) would take the turtle back to its wetland. This may be because the turtle is perceived to be far away from its habitat and therefore in need of assistance.

It is common to hear of residents who live next to wetlands finding turtles in their garden (Guyot and Kuchling 1998). Often these turtles are digging to lay their eggs, which is vital to the continued survival of the species. People finding turtles in digging their gardens (Hypothetical question H3) are most likely either to remove it (33.0%) or to call an expert (or someone they view as an expert) to give them advice (37.4%). These results reveal two areas where opportunity exists to improve the chances of viable offspring for the turtle species. The range of experts mentioned by respondents included local rangers, local government, wildlife rescue groups and state government departments. It is therefore vital that staff from these organisations are well informed in order to ensure that the correct advice is consistently given. Secondly, additional education may assist as understanding why a turtle visits a garden is likely to result in greater acceptance or at least more appropriate interaction. This is a complex issue and there are other factors that will come into play such as land use (residential land, parks or businesses), fear of wildlife and danger to wildlife from pets. For example, some respondents mentioned that they would remove the turtle from their garden specifically because they have pets (dogs) and were concerned that their pet might attack or injure the turtle. These potential perceived dangers to the welfare of the turtle highlight the complexity of human interactions with turtles in the urban area.
Hypothesis Three

People who have an interaction with a turtle are not likely to have had a negative impact on the turtle. The research data does not support hypothesis three. The results show that there is no relationship between having an interaction with a turtle previously and the outcome of the next interaction with the turtle. This is unsurprising, as experiencing an interaction with a turtle does not mean that an individual will have gained any new knowledge about the specific needs of the species. Without new information through education being sought out or received, it is unlikely that an individual would change their behaviour or take different actions between the first and subsequent interactions.

There was an, however, association between having interacted with a turtle previously and what the respondent would do for H5 (It is summer and you see a turtle moving along a road in your area where there is very little traffic. You know that the closest wetland is more than 500m away). This association may be due to the respondent having a greater level of concern for the turtle as they have interacted with others previously, as hypothesis two showed that people who had seen a turtle previously had a more positive attitude.

Turtle Knowledge

Hypothesis four explored the impact of knowledge on interaction outcomes. The results of the knowledge test in the survey were particularly low. All of the four (K11, K7, K9, and K2) lowest scoring questions were related to nesting behaviour. Due to this lack of knowledge about why a turtle may be encountered out of a wetland, it is unrealistic to expect well informed or suitable interactions with the animal.

Interestingly, only 6.2% of respondents were aware of incubation time for turtle eggs. This knowledge is particularly important for residents who have turtles that lay eggs in their garden. Anecdotal evidence reflected this lack of knowledge, with residents reported as wondering why the turtles hadn’t hatched yet and/ or digging up eggs/baby turtles whilst gardening. Understanding the existing level of C. colliei knowledge in the community will assist local government and environmental managers to identify where further community education is required.
Hypothesis four

People with good knowledge about turtles were not more likely to behave in a positive manner when they encountered a turtle. The research data does not support hypothesis four. However, in certain situations such as perceived danger, (e.g. Hypothetical Question 1: a turtle crossing a busy road) knowledge does play a small role because it is associated with both choice to interact with a turtle and outcome of the interaction. Knowledge can and does inform behaviour, however, the relationship is more complex with factors such as attitudes, current context, values and physical barriers also influencing behaviour (Allerup et al. 1994, Kollmuss and Agyeman 2002). Kaiser et al. (1999) showed that environmental attitudes are linked to behaviour and that environmental knowledge plays a part in this link. In this study a mixture of attitudes plus other factors such as (but not limited to) concern that their pets will attack a turtle left in their garden, personal safety, fear of handling native wildlife and concern about inappropriate handling may affect how a person chooses to interact with a turtle. Given that respondents who live close to a wetland are more likely to see a turtle and that they tend to have positive attitudes towards wetlands and wildlife there is the potential for targeted education to have some impact on when people choose to interact with a turtle and what they do with the turtle.

While often considered in a separate silo to ecological research and citizen science, social research can play a significant role through identifying a) human-based challenges which urban wildlife face and, b) where management could target humans to assist wildlife populations. For example, identifying the number and type of potential human interactions with turtles may assist in the future management of *C. colliei*. This study estimated that there is a potential for more than 2000 turtles to be affected per Local Government Area. At a minimum, 35% of these interactions are likely to be negative (resulting in death, removal from the population or an aborted nesting attempt). This, coupled with the results from Chapter Four which showed that many turtles are rescued and received by wildlife rehabilitation with no injuries supports the assertion that the effect of human interactions with *C. colliei* is noteworthy and the use of social research is needed to consider these interactions in more depth. Therefore, this provides information may be used to ensure that *C. colliei* education is well-targeted and identifies new areas for councils to consider in regards to turtle management.

Given the potentially large amount of human-turtle interaction that could occur in the urban environment and importance of maintaining breeding and population size, this
raises the question as to whether *C. colliei* populations are robust enough to deal this level of human interaction. Very small turtle populations were discussed in Chapter Three, which may be a result of human-turtle interactions (see Chapter Four). Therefore this area requires more research to determine the long-term impacts of human interaction on *C. colliei* populations.

As scientists it can be difficult to share our knowledge and findings with people who actually need the information, such as environmental managers, those driving change in the urban environment and residents. People who live close to a wetland or have an interaction with a turtle are more likely to have a positive attitude towards wetlands and wildlife. This could be used to build support for conservation or rehabilitation efforts around local wetlands. While having a prior interaction with a turtle does not influence how they interact with turtles in the future, there is a high probability of interactions with turtles being negative in certain situations. While resident’s turtle knowledge was generally poor, knowledge can influence if a person chooses to interact with a turtle they encounter. Therefore education of residents can play a role in assisting urban *C. colliei* populations, and citizen based conservation programs could be targeted at residential areas known to have existing positive attitudes towards wetlands and wildlife.

Social research is a valuable partner for ecological and citizen science conducted in urban environments. This social research provides us with an understanding of why community data shows turtles being rescued from the urban environment with no injuries – because of a mixture of lack of knowledge and positive attitudes towards the wetlands and wildlife. While it hasn’t been used here, this style of research could be used to quantify the level of interaction over a study areas to support ecological research. Social research supplements and supports these other type of research by; providing context for the motivations behind human-wildlife interactions, filling key gaps of researcher knowledge regarding these interactions, and, by identifying how changes could be made to improve wildlife’s urban experience.
Chapter Six - General Discussion

The use of a novel combination of methodologies from different disciplines has enabled this research to contribute to a more holistic understanding of Chelodina colliei in the urban environment. Each chapter in this thesis used a different research technique to build a greater understanding of C. colliei habitat, populations, movements, interactions with humans and the ramifications of these to the continued existence of urban turtle populations. Using just one of the three research methods (ecological, social and citizen science/community data) would not provide a complete picture of the nuances of C. colliei existence and the factors affecting them in the urban environment.

There are a number of key areas that need to be considered for the management of an urban wildlife population. Firstly there is population size and structure and the factors that are likely to influence the population such as; habitat, interaction with other species, and, movement and behaviour of the study species. Table 6.1 highlights the advantages and limitations of each research approach while the discussion below considers these in further depth and considers the necessity and usefulness of combining these approaches.

Population

Understanding population size and structure is key to understanding how a population is affected by the urban environment and is the first step in identifying how to appropriately manage that species. This section examines the strengths, weaknesses and limitations of using ecological research methods and citizen science and community data to understand urban wildlife populations and population structure with C. colliei as a case study.

Ecological research methods are used globally for aquatic, terrestrial and aerial species, and for organisms ranging from invertebrates to large mammals and reptiles (Williams et al. 2002). These methods have been refined over decades. For example, the mark-capture or Lincoln-Peterson method (used in this project) was first published in the early 1900’s (Pollock 1991, Goudie and Goudie 2007). A diverse array of methodologies have developed from this original method applicable to varying modes of animal behaviour, life cycles and movement patterns (Moss et al. 1982, Krebs 1989, Williams et al. 2002). A robust design approach (as used in this study), has short periods of continuous trapping where the population is considered “closed” (no births, deaths, immigration or emigration) separated by breaks in trapping where the
population is considered “open” (births, deaths, immigration or emigration may occur). This method (and the modelling which can be conducted from the data) is ideal for long-term studies (Kendall and Pollock 1992). Ecological methods such as these, result in quantitative, hard science, which can provide irrefutable facts (e.g. there are at least 100 *C. colliei* in Little Rush Lake) and allow for the application of a large array of models to analyse the data collected. These can provide additional details such as population size, survival, birth and migration rates for the population (Pollock 1991). The long history of ecological method design and analysis, coupled with its quantitative approach provides a level of confidence and trust in ecological methodology used by the research community.

Ecological research methods and techniques are valuable tools that provide a clear snapshot of wildlife populations in an urban environment at a particular time (as exemplified in Chapter Three). This ecological research provided an indication of the number of turtles present in each wetland along with specific details of turtle size, weight and sex. This hard data can only be collected by direct capture of individual turtles. Because the use of these defined, quantitative methodologies is so widespread, it also provides the opportunity for comparison between projects. This comparison is vital, as it allows identification of changes in populations spatially and temporally. For example, a significant population decline was found at Piney Lake Natural with 17 *C. colliei* captured during this project, compared to the 131 *C. colliei* captured by Giles *et al.* (2008) in 2001. Furthermore, comparison between projects can be used to infer if factors identified that affect other species are affecting our study species (for example, no sex skew towards males).
<table>
<thead>
<tr>
<th>Habitat: Ecological Research</th>
<th>Weaknesses/Limitations</th>
<th>Citizen science / Community Data</th>
<th>Weaknesses</th>
<th>Social Research</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengths</td>
<td>Failure to consider urban specific variables. Inability to identify why humans influence the urban environment. For certain approaches long-term studies or large scale studies can be costly.</td>
<td>Can provide people-power to assist in long-term or large scale studies</td>
<td>Citizen scientists require training.</td>
<td>Can identify the human drivers behind the structure of the urban environment.</td>
<td>Not designed to examine environments/ ecology.</td>
</tr>
<tr>
<td>Provide hard data regarding structure and composition of the environment. Many approaches available to examine structure of the environment. E.g. Satellite Imagery, Direct (on-ground) measurement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population: Highly specialised, well refined research methods available. Provide hard data regarding population size and structure. Data is high resolution. Consistent methodologies allow for comparison between studies.</td>
<td>Limited spatial and temporal scope due to the costs and effort required to collect sufficient data. Small populations/samples sizes limit ability to draw conclusions.</td>
<td>Can be conducted over larger temporal and spatial scale. Can be used to supplement or support findings from ecological research.</td>
<td>Data is lower resolution.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provides high resolution detail regarding location and movements of individuals.</td>
<td>Limited number of individuals can be tracked due to cost and technological limitations.</td>
<td>Provides long term, large scale locations of individual sightings</td>
<td>Data is lower resolution. May be concerns about reliability. May be a drop in participation over time (Citizen Science)</td>
<td>Can focus on sightings in a specific area.</td>
<td>Data is lower resolution. May be concerns about reliability.</td>
</tr>
<tr>
<td>Behaviour and movement: Not designed to examine humans and social factors. The movement of turtles through the urban environment as described by the community data/citizen science would not normally be considered when conducting ecological research in urban environments.</td>
<td></td>
<td>Provides long term, large scale locations of individual sightings. Provides detail regarding turtle injuries and mortality in urban environment.</td>
<td>May be a drop in participation over time (Citizen Science) Would provide more detail if community data sources collected data consistently.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human interaction and influence:</td>
<td></td>
<td></td>
<td>Can identify the drivers behind human interaction with wildlife. Provides understanding of what actions may be taken when wildlife is encountered.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1: The key advantages and limitations of using Ecological Research, Citizen Science/Community Data and Social Research to investigate urban wildlife populations.
Ecological research methods provide a robust approach to collecting hard data, however, they are heavily dependent on retrieving sufficient data. For this study the first trap season identified a very low capture and recapture rate. This may have been due to research error due to limited information about *C. colliei* habitat preference and movements within wetland waters because successful trapping can rely on existing knowledge about the species to optimise trapping. However, after the first trap season modifications were made to the trapping method to compensate for low capture rate and high trap shyness. Despite these changes, there was little appreciable difference in the numbers of captures and re-captures between the first and subsequent trapping seasons. This suggests that the low capture numbers were not the result of error and reflected the current status of *C. colliei* populations. Insufficient data was collected from this portion of the study, the low capture numbers coupled with the high heterogeneity in wetland conditions prevented the identification of key environmental conditions which influence *C. colliei* populations. More research examining factors such as behaviour in water, micro-habitat usage, peak movement times and temperature range in which *C. colliei* is most active would allow for refinement of trapping efforts and assist in the creation and modification of wetlands suitable for *C. colliei* in the future. However, even with this additional information our ability to identify key environmental conditions which influence *C. colliei* populations would still be compromised by the low number of urban wetlands and the small populations.

While ecological research provides high-resolution data (e.g. population metrics) the costs and effort required to collect sufficient data can limit its temporal and spatial scope. This can become a major limitation for ecological research as once populations become very small the effort to collect sufficient data to investigate these populations may become prohibitively expensive (in time and money). Additionally, small sample size reduces the ability of ecologists to effectively identify the impacts of environmental variables and other factors on populations. Citizen science can be used to some extent to fill this limitation of ecological research.

Citizen science provides engagement and education of the community while simultaneously supporting collection and analysis of scientific data (Cooper *et al.* 2007, Goffredo *et al.* 2010). Over recent years, citizen science has been increasingly used for projects that are too large (for both size of study area or hypothesis being tested) or costly for an ecologist to conduct on their own (see Chapter Four). This is due to the flexibility of citizen science, its applicability to a range of research topics and its ability
to allow for innovative ways to collect accurate detailed data (e.g. identifying age class from the comparison of *C. colliei* shell length to a soft drink can). Unlike the highly detailed small scale information provided by ecological techniques (e.g. turtle abundance, size, sex etc. in particular wetlands), community data and citizen science provide less detailed information (i.e. has a lower resolution) but over a much larger temporal and spatial scales.

Both citizen science and community data relied on people to report (or rescue) the species in question to provide data. In this study, sightings of *C. colliei* reported online and on a survey were utilised along with data from wildlife rehabilitation clinics. These reports identified the number and age class of turtles at specific locations outside the wetlands (within 500m of wetland waters, usually hatchlings or sexually mature adults). In the future if a more structured approach to combining this type of data with ecological research was available this data would be able to provide insights into these urban populations. Ecologists could argue that the reporting and recording of *C. colliei* was not conducted in a rigorous fashion as encountering *C. colliei* on land is a very rare event (i.e. during the trapping for this project only two turtles were observed on land) and not all of these events will be reported. In effect, the reporting of *C. colliei* is likely to be random, depending on variables such as presence of humans during turtle movement and whether the human is sufficiently concerned or the participant of a citizen science project. Since random sampling is one of the cornerstones of ecological methodology it would be reasonable to accept that the data collected through these methods can be reliable. Supporting the use of citizen science and community databases in this instance is the fact the citizen science and community data exactly matched our existing understanding of the drivers of *C. colliei* movements on land (see Chapter Four).

The bonus of community data is that the data is already collected by these groups for alternative purposes and in many cases, is an untapped resource. Given that these rehabilitation groups are likely to be active long-term, there is the potential for long-term datasets to be collected at a (potentially) cheaper cost than an ecological approach or even a citizen science approach, with a lower likelihood of participation decline over time.

Community data sources are ideal for collecting information about a species in the urban environment as they provide low resolution population data which can be used to support ecological studies. They collect data about individual turtles (size, weight and
sex) and their health status (such as death, illness, causes of injury) which could be used to explain certain population dynamics. For example, community data from TORRN identified 52 individuals that died over a two year period and found that a large percentage of turtles are translocated by humans. It may be possible to link this information with ecological research, especially population studies which rely on birth, death, immigration and emigration data. It can also assist the management of populations by allowing identification of trends in injury types and locations where these occur. This would provide managers with clear information to act upon, mitigate threats and address existing issues for urban populations.

There are, however, some challenges to using community data both generally and for population studies in particular. Data availability, type of data collected and terminology used can vary widely between stakeholders (as was the case for this study) and often this data is held independently by each group. As a result these data sources can be difficult to obtain and navigate limiting their ability to supplement ecological research. However, including community groups in ecological research into urban wildlife populations is a perfect way to encourage data collation, consistency or even encourage the move to centralised database (this is already the case in some other states (see Shine and Koenig 2001)). A centralised database of consistently recorded data would provide ecologists with a more robust and accessible source of data.

Coupling ecological research with citizen science and community data has the potential to provide a more robust source of data than either could achieve by themselves. These research types are complementary, ecological research on populations tends to be high resolution but have limited spatial and temporal scope while citizen science and community data tends to have lower resolution but very large spatial and temporal scope. From this study it is clear that is possible to monitor C. colliei populations year round using citizen science and community reported data and then to punctuate this data source with short ecological studies of populations at urban wetlands. Further research is needed to investigate creating appropriate standardised methodologies for coupling these two different research approaches however together they have the potential to provide much needed long-term understanding of wildlife populations in urban ecosystems.
Habitat

Alberti et al. (2003 p.1173) argued that “leaving humans out of the ecological equation leads to inadequate explanations of ecosystem processes on an increasingly human-dominated Earth”. Humans can be considered as part of the ecological equation in two ways, driving the modification of habitat and interacting directly with wildlife (DeStefano and DeGraaf 2003). Human driven modification of the environment can directly affect the habitat available for wildlife in these systems. The habitats in which urban wildlife live directly influence the survival of a species. All three research approaches presented in this thesis can be used to investigate the habitat of urban wildlife.

Similar to populations, ecological research methods provide the most robust and quantitative account of the urban environments structure and composition. In this study ecological research identified that natural and anthropogenic wetlands differ in the environmental conditions (water quality, provision of upland habitat and abundance of food sources) that they provide C. colliei. The limitations for ecological research on this particular topic are minimal, as multiple techniques are available to examine these habitats. This includes (but is not limited to) satellite imagery to cover large spatial scales and direct measurement to identify physical conditions or vegetation complements (as exemplified in this thesis). Limitations and issues for ecological research on urban habitat include failure to consider urban specific variables, the high cost for long-term studies and an inability to identify why humans change the urban environment in specific ways.

While ecological research provides the most robust understanding of the structure and composition of the urban environment, these urban environments do differ from natural ecosystems in many ways, including; thermal dynamics, water flow and retention, and climate (Kuttler 2008, Paul and Meyer 2001). Consideration of these differences between urban and natural environments must be considered in the design phase of ecological research to prevent erroneous conclusions being drawn. For example, soil temperatures are slightly higher in urban environments (Arnfield 2003) and sex determination in many turtle species (not including C. colliei) is temperature dependant (Hulin et al. 2009). Therefore, there is the potential for studies that consider the sex ratios of turtles in urban environments (e.g. Aresco 2005, Conner et al. 2005) but do not consider the influence of higher urban soil temperatures to draw erroneous conclusions about the drivers of sex ratios. Thus, unless ecological studies conducted in the urban
environment clearly indicate that they have considered or controlled urban specific variables, care needs to be taken in interpreting the results.

There are multiple approaches for examining the urban environments structure and composition. However, studies specifically focussed on habitat conditions (as presented in this thesis) can be costly (in both time and money) especially when conducting this type of research over large temporal or spatial scales. In these circumstances, citizen science can be used to reduce this time cost and enlarge the spatial scale. There are many projects world-wide where citizen scientists are trained and work with scientists to collect and collate data over either the long term (Lepczyk 2005) or to provide people-power (e.g. Earth Watch) which may allow researchers to increase the geographic scope of their study. Citizen science excels in providing additional support for ecological research to achieve greater scope in the intensity and range of habitat variables that can be measured both within and outside of the urban environment. This allows for the education of the community while supporting collection and analysis of ecological data (Cooper et al. 2007).

Humans drive the design and management of an urban environment through their attitudes and behaviour (Grimm et al. 2000). Therefore, when examining the environmental conditions within the urban environment understanding the human drivers behind its design and modification can provide ecologists with a better understanding of why the habitat is in its current state. Understanding the human drivers for habitat was not considered in depth for this study. However, projects that do examine long-term habitat change can be greatly enhanced by considering not only the physical habitat change (ecological research) but the cause of that change, the influence of humans on the environment (see socio-ecological systems, Grimm et al 2000) providing scope to mitigate deleterious effects to wildlife habitat. Ecological research is equipped to examine how environmental conditions change but is not equipped to investigate why humans have driven these changes. Social research methodology can supplement ecological research achieve this understanding as social research provides systematic evidence-based methods to investigate human attitudes and behaviour.

Ecological research is the most robust approach to understanding the environmental conditions and habitat that urban wildlife live within. The limitations that ecological research can be supplemented through the use of citizen science and social research methods. While it may not be always necessary to supplement ecological research it is
important that ecologists consider how the presence of humans and the built environment and how that may influence their research.

**Human/Species Interaction**

Recognising that urban areas are a shared space between humans and wildlife is critical to achieving a meaningful understanding of processes in the urban environment (Alberti *et al*. 2003). This recognition acknowledges a complexity that requires a multidisciplinary approach to resolve. Humans directly affect the urban environment and its structure through public pressure, policy, planning, and management strategies, all of which can be influenced by resident’s attitudes and concerns (Grimm *et al*. 2000). Indirectly residents affect an urban environment in varying ways such as the use of fertilisers, introduction of invasive species, lack of pet control, waste management etc. (Collins *et al*. 2000). Residents may also have direct, one on one interactions with urban wildlife (Leite *et al*. 2011). These one on one interactions are rarely considered in a systematic structured manner when conducting ecological research in urban areas.

In ecology, we regularly mark the importance of competition between species and predator-prey interactions. Yet when exploring the urban ecology of wildlife ecologists can fail to consider how humans interact and affect urban wildlife. Consideration for human influence and interaction with the urban environment and the study species is a key variable. An example of this is Hamada (2011) who captured thirty *C. colliei* from a number of wetlands (in a similar area to this study’s wetlands) to investigate if genetic divergence had occurred between urban *C. colliei* populations. Unfortunately, as identified in Chapter Four, there is a large degree of (mostly un-regulated) turtle relocation by both wildlife rehabilitation groups and individuals. Hamada (2011) concluded that there had been no genetic divergence of urban populations; however, this could be due to human relocation of turtles around these systems rather than an indication of *C. colliei*’s natural ability to maintain genetic diversity. This is a gap the ecology research must have filled to ensure that conclusions drawn in the urban environment are not being influenced by ignored human variables.

It is not an unfamiliar experience for many ecologists to be approached while conducting research and to have wildlife behaviour or interactions reported to them. While these anecdotes from random encounters with people in the field (e.g. five people saw turtles laying eggs over the last week) may partially fill this gap, for ecological methods to be effective the complexities of human behaviour and their influence on urban dwelling species need to be considered systematically. Social research
methodologies are able to achieve this by providing a structured, rigorous approach to collect this information. Thus, social research methodology replaces these anecdotes with quantitative data, which can be analysed to provide more substantive and reliable information (e.g. 49.3% of people who live near wetlands have seen a turtle in the last five years). This in turn allows researchers to quantify and typify human interactions occurring with their study species.

Social research provides systematic evidence-based methods that can be used to investigate how humans affect urban wildlife. In this study, how humans may choose to interact with urban *C. colliei* was assessed from the results of the social survey. This identified that humans in the area, while being clearly concerned about the wellbeing of turtles moving through the urban environment do not necessarily interact with *C. colliei* in a way that is conducive to its continued survival (for example, “rescuing” potentially nesting females and relocating them to different habitats). In addition, social research can identify different factors that influence these interactions such human’s knowledge and attitudes. Importantly, these social research methods can interlink with ecological methods by providing quantitative (and in some cases qualitative) data about human-wildlife interactions, which can help identify the effects of human behaviour on wildlife and on ecological methods. Social research also identifies how and why humans interact with wildlife, and this can be utilised by local government to target areas where potentially negative behaviours are prevalent and educate these residents.

This study investigated wetland visitation, attitudes towards wetlands wildlife and turtles, knowledge about turtles, hypothetical interactions and prior interactions with turtles (Chapter Five). Such exploration of social attitudes and values needs to be designed and conducted by a social researcher adept in the particular methodological design and analysis standards expected of the discipline. However, an ecologist may wish to conduct a small social survey to identify if there is direct interaction between humans and their study species before expanding their research further into the social realm or, to identify any potential interactions that may affect or influence the ecological methodology being used. If this is the case, using basic surveys investigating resident’s knowledge and interaction about wildlife in urban environments currently available in the literature is ideal (Fulton *et al.* 1996, FitzGibbon and Jones 2006, Dowle and Deane 2009). These can be adapted to refer to different study species, have already been tested and can be conducted by an ecologist. These basic surveys are not costly to
conduct, can provide quantitative data and would allow an ecologist to identify any potential gaps in their ecological research.

Alternatively, citizen science is extremely flexible and can be modified to meet the research questions, needs, or to fill a research gap. In this study, citizen science was primarily focussed on gaining more ecological information regarding *C. colliei*. However, it could easily have been modified to investigate human interactions with turtles in more detail, in a similar fashion to the social research. For example, when a person indicated that they have encountered a turtle, the online platform could have asked if the person took any action when encountering the turtle (i.e. moving the turtle, protecting the turtle from predators) and why they undertook such an action. Therefore if some information regarding human interactions is known before the commencement of a citizen science project it is possible design the project to integrate ecological and social information.

One issue with using such a multidisciplinary approach (i.e. using social research to complement ecological research) is the potential for mismatch in scale. This study used ecological research at a local scale considering individual wetland environments, the immediate upland habitat for *C. colliei* populations and *C. colliei* populations in twelve wetlands. The social research aspect was presented at a larger scale, grouping and presenting attitudinal and hypothetical interaction details for residents throughout the study area. When using an integrated approach, further consideration and investigation needs to be given to scale and it needs to be considered and incorporated from the outset of the project, as a mismatch may potentially result in error.

If the social research analysis was conducted at a smaller scale (site or wetland specific) it could identify if there were differences in attitude between areas and if they correlate to differences in behaviour. As some differences in wetland use by residents were noted during this project (e.g. crayfishing at some wetlands, turtle feeding at others). This could be very useful for future management and education (e.g. interpretive signage) and could identify particular areas where residents should be approached about certain behaviours.

Social research has historically been perceived by traditional ecologists as soft or non-rigorous, with concerns raised about validity (White et al. 2005). Yet the systematic, evidence-based social research approach complements ecological research and is necessary to achieve a more holistic understanding of wildlife in the urban environment. Use of social and ecological research in urban wildlife studies should be conducted
concurrently and in an integrated fashion, rather than considered in isolation. Researchers from these two different disciplines need to ensure that they communicate, recognise and understand the limitations of their methodologies and design projects with these deficiencies in mind. While we can model and understand the patterns of some human-wildlife interactions (Chion et al. 2011), finding ways to link and integrate ecological and social methods for research in urban areas will be vital. An important next step will be to investigate the impact that direct human interaction can have on wildlife at a population-level, potentially resulting in adapting population models to include human interactions. Ecology and humans are inextricably linked in the urban environment, therefore future research should be focussed upon creating a standard methodology for combining ecological and social methods.
Movement and behaviour (of wildlife)

The movement of wildlife through urban ecosystems is dependent upon their adaptations to the environment and their biological imperatives. Certain movements and behaviours in the urban environment hold more risk and are more likely to result in death. All three research methods can be used to examine the movement of wildlife in the urban environment and need to incorporate the effect of behaviour on these movements.

Ecological research methods can use approaches such as radio tracking or GPS tracking to closely monitor the movement of wildlife moving through both natural and urban environments. Similar to previous comments made regarding ecological research, this approach has limitations including high cost (monetary), yielding high resolution data but with relatively small scope. Traditional radio tracking methods usually only track 20 to 50 individuals (e.g. Bodie and Semlitsch 2000, Milam and Melvin 2001, Hartwig and Kiviat 2007, Attum et al. 2008b, Pittman and Dorcas 2009, Rees et al. 2009, Beaudry et al. 2010, Rasmussen and Litzgus 2010). For a species such as *C. colliei* which does not leave the confines of the water for the majority of the year a direct tracking approach is not ideal as the primary research focus was movement on land.

Citizen science is a flexible tool that (depending on the research question) can complement traditional ecological methods, be used as a stand-alone research methodology or, be formulated to fill the gap that exists between ecological research methods and social research methods. Citizen science filled a niche in investigating *C. colliei* movements on land. No *C. colliei* were seen on land further than 500 metres from a wetland, thus identifying a zone around wetlands where management can attempt to facilitate *C. colliei* land-based movements. The citizen science approach also allowed the collection of simple information such as size class, which can assist the monitoring of lifecycle features such nesting and emergence from nests. Information about movements and behaviour is extremely valuable for any species that is diffusely distributed or only transiently utilises the land in the urban environment. Using an ecological approach to quantify this can be difficult, time consuming and costly. Citizen science provides the opportunity to investigate movement patterns over greater periods of space and time through a community of citizen scientists.

One concern (often raised) about utilising citizen science for research, is the ability of citizen scientists to identify species correctly or their level of skill with the task they are asked to perform. This was not an issue for this project, as *C. colliei* is the only turtle...
found in the urban area and its long neck makes it very distinctive. For other projects this weakness can be addressed through project design which accounts for participants levels of knowledge (Foster-Smith and Evans 2003, Newman et al. 2003).

A weakness of using citizen science for monitoring of wildlife movement is the potential for participation decline. It is likely with the large range of citizen science projects available, especially those such as the online logging platforms (like ClimateWatch in this study or TurtleSAT), factors such as decreased enthusiasm after the initial ‘fad’, saturation of the citizen science market or competition from multiple projects collecting similar data using the same method could all lead to a decline in participation. The potential for participation decline needs to be considered if citizen science is being used for long-term monitoring, as it could result in inconsistent data collection and a reduction in the size and quality of the information. With such restrictions it makes sense to use citizen science for discrete, timed campaigns, or ways need to be found to ensure long-term consistency (e.g. through interaction with a dedicated community group). However, the approach taken to ensure long-term consistency may vary depending on the research project in question.

Alternatively, community databases are an ideal way for ecologists to gauge information about animal movement and human interaction with them, without having to venture into the realm of designing and implementing a citizen science project themselves. Community databases can provide data allowing for the estimation of species presence in the urban environment and the number of individuals with which humans interact. For example in this study, community data provided valuable detailed information about the number of healthy and rehabilitated C. colliei that were returned to wetlands other than the ones they came from. This type of movement data is invaluable as it provides an ecological researcher with information regarding immigration and emigration from wetlands which otherwise would likely be missed. This information can also allow managers to provide more detailed guidelines for the assisted movement of wildlife through the urban environment.

Human-wildlife interactions also have the ability to influence the behaviour of wildlife within the urban environment. While ecological research might try to address behaviour of a species, human influence has the capacity to affect this research in an unknown manner. Three of the anthropogenic wetland sites for this study had local residents who often fished for crayfish. In some instances the cray-traps that they used caught turtles as by-catch. It is known that prior capture in traps can increase trap shyness, so when
these wetlands were sampled there is the possibility that these populations were already trap-shy unlike other locations where cray-fishing does not occur. Therefore, this would negatively affect the results of trapping in these locations. At another wetland some residents fed turtles on a regular basis, the turtles adapted to this and were often observed swimming up to people. As the trapping in this study used bait to attract turtles to the traps and the turtles were being fed by humans it is unknown what impact this may have had on sampling. It may have artificially inflated capture (as turtles are used to having safe food provided) or decrease captures (reduced interest in bait as they are well fed). One way to counter these behavioural responses to trapping would be to use trapping techniques that rely on physical barriers. However, it is clear that the behaviour responses of the study species to humans and their actions need to be considered when conducting ecological research as these changes in behaviour have the potential to directly affect research findings.

Additionally, although not considered in this study, the presence of trapping equipment may affect how humans behave in the area, introducing yet another variable in the capacity of ecological research to assess wildlife behaviour. For example, the presence of trapping may cause residents to alter their normal interactions with wildlife. In capture-based research methodology there is no way to tell if humans are interacting differently than they normally would with wildlife while trapping is occurring. If there is a change in human behaviour this may influence turtle behaviour during trapping and skew capture numbers. As this variable in uncontrolled, it can limit our ability to provide local management with appropriate feedback regarding human interactions with wildlife. Human-interactions with urban wildlife may have significant influence on trapping and therefore needs to be monitored both before and during trapping stages of field work.

Similarly to the recommendation for populations, to build a detailed understanding of *C. colliei* movements in the urban environment a mixed approach of ecological research and citizen science would provide the most value. This would involve conducting year round monitoring of *C. colliei* movements using citizen science on a more focussed locations and then utilising tracking devices on a small number of individuals within this area during key movement times. Again further research is needed to create an appropriate standard methodology for combining these two approaches.
Building a holistic understanding of urban wildlife

Each species that exist in the urban environment have their own set of habitat requirements, movements and behaviour, and interactions with humans. Therefore, the structure and combination of ecological research, social research and citizen science used to investigate their life and populations will need to be refined specifically for the species.

While ecological methods have been refined to be accurate and effective, they have been primarily designed for natural locations. The significant differences between urban and natural environments have the capacity to severely compromise the veracity of the data collected through failing to consider, urban environmental physical variables, how traditional trapping techniques (or methods) are affected in urban areas and the human variable. By using a multi-disciplinary approach and coupling citizen science/community data and social research with ecological research it is possible to understand the complexities of life for urban wildlife. Further research is now required to design a fully integrated approach containing all of these research methodologies.
Recommendations for management and future research

This thesis used a combination of ecological and social research to investigate *C. colliei* population in the urban environment. The following outlines the key findings from this study and management recommendations arising from this holistic approach. Also outlined below are a number of gaps identified as part of this thesis which require further investigation.

- Resources and water quality significantly differed between natural and anthropogenic wetlands, with reduced resource provision leading to a significantly smaller population size, particularly of juveniles, females and older sexually mature turtles in anthropogenic wetlands. While it was not possible to identify the specific ecological drivers of turtle demography, clearly improving the ecological character of anthropogenic wetlands to more closely match that of natural wetlands in the area is supported, to improve the sustainability of urban *C. colliei* populations.

- This research suggests that remnant natural bush areas adjacent to anthropogenic wetlands may enhance the sustainability of turtle populations. In proposals for new residential areas the 500m zone should be taken into account and remnant bushland surrounding wetlands should be incorporated into the urban design. Connection between drying natural wetlands/bushland areas and permanent, anthropogenic wetlands may be a way of sustaining turtles into the future in urban areas in a drying climate. Creation of wildlife corridor between wetlands (natural/anthropogenic and bushland) should be a priority in urban planning.

- This study has shown that turtles are most often observed within 500m of the wetland water’s edge. This zone should be recognised during planning and development and, modifications within this zone such as reducing, removing or preventing creation of physical barriers (e.g. removing right angled curbs/gutters) should be considered in order to assist *C. colliei* movement and nesting success.
People have negative impacts on turtles despite good intentions. Education is required to reduce the impact of human interaction with *C. colliei*. Target areas for education should include residents within the 500m turtle movement zone and schools within or in close proximity to the zone. Permanent interpretive signage should be placed in wetland reserves or parks and temporary signage in the 500m zone should be erected during peak turtle movement times to provide information to people from outside the education zone.

Any permanent interpretive signage regarding *C. colliei* placed around wetlands needs to clearly explain *C. colliei* movements on land, the nesting process and the duration of egg incubation as currently the life cycle of *C. colliei* is poorly understood by local residents.

Data collected by wildlife rescue and rehabilitation groups (such as NativeArc, Wildcare and ToRRN) provides the opportunity for long-term monitoring of urban wildlife. To streamline ecologists ability to monitor; urban wildlife, impacts of a changing climate, introduced species, diseases and other human-related wildlife problems, an accessible centralised database containing consistent data from all rehabilitation groups should be established.

*Chelodina colliei* are moved within the urban environment by humans (including by wildlife rehabilitation groups). While there may be good reason for these movements this needs to be closely monitored. As female adults are most often rescued there is the risk of removing the breeding portion of the population from some wetlands and overpopulating others – which would place both populations under further stress.

For ongoing monitoring and future research a review (and potentially a study) of turtle trapping methods identifying the most effective trapping method in anthropogenic wetlands is needed. This would be invaluable as trapping in anthropogenic wetlands is difficult due to the structure and heterogeneity of urban wetlands along with interference from humans. This has the potential to result in inconsistencies in trapping results between anthropogenic wetlands.

Further research is also needed to understand the habitat requirement complexities of *C. colliei* as these may influence population persistence in urban
wetlands. Factors such as behaviour in water, micro-habitat usage, peak movement times and temperature range in which C. colliei is most active, should be considered as these would provide useful data for the construction of future anthropogenic wetlands more suitable for C. colliei and allow for improvement of existing habitats.

- There is a need to create a standard methodology for combining complementary research approaches from different disciplines i.e. Social research with ecological research, ecological research with citizen science and community data.

These recommendations above, however, are mostly helpful procedural items. If we want to truly manage the species and prevent local extinction we have to understand what drives population decline. To achieve this we must integrate ecological, social and citizen science for each species to discovery the answers necessary.
The outcome of combining ecological and social research in determining a holistic view of *C. colliei* in the urban environment

The persistence of populations is driven by environmental conditions and interactions with other life forms. Habitat and resource selection by wildlife can encourage population growth by allowing species to avoid predators or other less than favourable environments or circumstances (Buskirk and Millspaugh 2006). In urban environments however, environmental conditions can be highly heterogeneous which can affect populations (Pickett et al. 2001). In addition, interactions with other species, whether it be predator-prey relationships or competition for resources can also affect population persistence. Not only are these interactions changed by the urban environment (Urban 2007, Rodewald et al. 2011) but humans should also be considered as part of these relationships. Humans modify the environment and also interact with wildlife species in a myriad of ways (they may kill, injure, remove, feed, rescue and assist wildlife). Therefore, in an urban environment it is important consider the human influence on the study species.

This research used a combination of ecological and social research methods along with citizen science and community data to build a holistic picture of *C. colliei* populations in the urban environment which included humans. Figure 6.1 provides an overview of these findings and shows how these different methodologies can be linked to build this holistic picture of wildlife in the urban environment.

Ecological research methods can be used to measure and assess populations, the environment conditions, the effect of intra-species relationships and the overall effect that these may have on populations (Figure 6.1A). This study found that *C. colliei* had a very low abundance in many of the wetland sampled, which likely due to a combination of the urban environment, the resources it provides (Figure 6.1B) and the direct interactions of humans with *C. colliei* (Figure 6.1C). However, there is the potential that humans have directly interfered with the ecological research (Figure 6.1D) and affected the data collected, therefore, unless human influence is considered for urban wildlife populations there is a risk of drawing inaccurate conclusions. Social research can help to provide the full picture by quantifying human interactions with both the ecological research and the wildlife in question. Furthermore, social research can also identify the
motivations behind human behaviour and identify ways to mitigate or reduce the impact of humans (Figure 6.1E).

This study identified that in anthropogenic wetlands, larger populations of *C. colliei* were present when the wetland was adjacent to remnant bushland (Figure 6.1F). However, the key environmental conditions of importance to *C. colliei* continued existence in the urban environment could not be specifically identified due to both the significant heterogeneity of the urban environment and the low abundance of *C. colliei* (Figure 6.1G). In fact, this low abundance limited our ability to statistically analyse data to examine important issues for the future of *C. colliei* in the urban environment such as
habitat and resource requirements (Figure 6.1H). In order to gain more definitive information about the life and needs of wildlife in the urban environment, we need more sampling over both time and space. The cost of this in both time and money is likely to be prohibitively high (Figure 6.1I). This is where citizen science and community data can come to the fore, these techniques can reduce the cost of data collection and increase the temporal and spatial scale of data. Overall a combination of these three different research methodologies provides the best way forward for urban ecological research.

Conclusion

There are inherent issues with conducting wildlife research in urban environments, humans have made what are normally complex ecologies even more complex, through their behaviour and interaction with the ecosystem around them. This does not mean that as ecologists we should avoid examining these novel systems, but it requires the recognition that we must consider how humans influence and affect the wildlife we are studying in the urban environment. Further progress towards a fully integrated research methodology comprised of both ecological and social research techniques for examining wildlife in urban environments is needed. As this study has shown, using ecological and social research concurrently can provide insights into the urban ecology of a species that neither could provide by themselves.


References


Australian Bureau of Statistics. 2011b. Cockburn (C) (Statistical Local Area).

Australian Bureau of Statistics. 2011c. Melville (C) (Statistical Local Area).


Bush, B., B. Maryan, R. Browne-Cooper, and D. Robinson. 2010. Field guide to reptile and frogs of the Perth region. Western Australian Museum, Welshpool WA.


Hamada, S. 2011. Over 100 years of urbanisation have not affected the genetic population structure of the oblong turtle (*Chelodina oblonga*). Honours Thesis. University of Western Australia.


TORRN. 23rd October 2011. Personal communication - Founding meeting.


Weatherill, R. 24th June 2011. Personal communication - Meeting.


Western Australian Land Information Authority. 2015a. Aerial Imagery of Perth, 14/06/1983.


Appendix One: Social Survey Instrument

Social Survey Questions

(response options in italics)

Section One

Demographic questions

D1: Age (18-25, 26-35, 36-45, 46-55, over 55)
D2: Sex (Male, Female)
D3: Income (<15 600, 15 600 – 31 200, 31 200- 52 000, 52 00- 78 200, >78 200)
D4: Highest education qualification (Year 10, Year 12, TAFE certificate, Bachelor Degree, Postgraduate (Masters, PhD))
D5: If you have a TAFE/Degree/Postgraduate qualification what was your field of qualification?
D6: Do you rent or own the house you are currently living in? (Rent, Own)
D7: How many years have you lived in this house for?
D8: How many adults live in the residence?
D9: How many children live in the residence?
D10: Do you have pets? (Cat/s, Dog/s, Other)

Section Two

Wetland Use

U1: How often do you visit your local wetland? (tick the most appropriate response)
(Once or more per week, Once every 2 weeks, Once per month, Once every 2 months, Once every 6 months, Once last year, Never)

U2: When you normally visit? (tick the most appropriate response)
(Early Morning, Mid-Morning, Midday, Afternoon, Evening, All different times)

U3: How do you use the wetland and its surrounding area? (Tick all that apply)
(Bush walking, Use picnic facilities, Walking pets, Bird/animal watching, Playing sports, To attend public events, Use play equipment, Exercise (walking/running/other), Social gatherings (playgroup/birthdays), Other)

U4: Which wetlands do you visit most often?

U5: Do you visit the wetland? (By yourself, as a family (with spouse or children), with a friend)

U6: Which wetland is closest to your house?

U7: Have you seen wildlife (animals) use the wetlands? (Yes, No; If yes, what kinds of animals?)

U8: Have you ever seen a fox or other uncontrolled feral animals (cats or dogs) around the wetlands? (Yes, No; If yes, what kinds of animals?)
Section Three

Wetland Attitudes

(Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree)

A1: I care about what happens to the wetlands around here
A2: I plan to use the wetlands around here for some time to come
A3: I feel that the wetlands around here are an important part of this neighbourhood
A4: The wetlands around here feel as though they belong to the community not the council
A5: I feel the wetlands around here belong to me
A6: I have my own favourite spot in some of the wetlands around here
A7: If someone appeared to be damaging the wetlands around here, I would feel I had a responsibility to stop this happening
A8: I feel that I could change things in the wetlands if I really wanted or needed to
A9: I feel that I could plant trees in the wetlands around here and no-one would mind
A10: I would be willing to contribute my time to help keep the wetlands around here
A11: I would be willing to become involved in the planning of future wetlands for this area
A12: I would be willing to help in planting trees in wetlands around here
A13: It’s good to see other people using the wetlands in this neighbourhood
A14: My neighbours often use the wetlands around here
A15: I believe my neighbours would be concerned about what happens to the wetlands in this neighbourhood
A16: I feel that the people who use the wetlands around here agree with me about what is important in our neighbourhood
A17: I regularly stop and talk with people in the wetlands around here
A18: I often meet my friends in the wetlands around here
A19: People use the wetlands around here at any time of the day
A20: There’s always people in the wetlands around here
A21: The wetlands around here are well lit at night
A22: I feel safe when visiting the wetlands in this area
A23: I often go to the wetlands around here on my own
A24: There are often teenagers in the wetlands around here
A25: I often see broken glass in the wetlands around here
Section Four

Knowledge

K1: There are turtles in my local wetland. (True, False, Unsure)
K2: Female oblong turtles require sandy soil for nesting. (True, False, Unsure)
K3: Turtles don’t need vegetation around the edge of wetlands for protection. (True, False, Unsure)
K4: Roadside curbs do not hinder turtle movement. (True, False, Unsure)
K5: Oblong turtles live in the water for most of their life. (True, False, Unsure)
K6: Nesting is when female turtles lay their eggs. (True, False, Unsure)
K7: It is possible to see if a female turtle is carrying eggs by looking at it. (True, False, Unsure)
K8: Oblong turtles can move fast enough to avoid traffic when crossing roads. (True, False, Unsure)
K9: Female turtles can travel up to 500m from a wetland to lay their eggs. (True, False, Unsure)
K10: In what season/s do you think turtles lay eggs? (you may select more than one) (Winter, Autumn, Spring, Summer)
K11: How long does it take turtle eggs to hatch? (50-100 Days, 100-180 Days, 180-250 Days)
K12: Have you participated in any education about wetlands? (Yes, No; If yes, where? If no, where have you gained this knowledge?)

Section Five

Wildlife and Turtle Attitudes

(Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree)

WA1: I enjoy seeing birds around my home
WA2: I notice the birds and wildlife around me every day
WA3: Having wildlife around my home is important to me
WA4: I’m interested in making the area around my home attractive to birds and wildlife
WA5: An important part of my community is the wildlife I see there time to time.
WA6: I enjoy learning about wildlife
WA7: It is important that all Perth residents have a chance to learn about wildlife in the State
WA8: It is important that we learn as much as we can about wildlife
WA9: Turtles have a right to exist in their natural environment
WA10: Conservation of Turtles is necessary
WA11: Turtle survival is threatened by cars
WA12: Turtle survival is threatened by cats
WA13: Turtle survival is threatened by dogs
WA14: Turtle survival is threatened by foxes
WA15: Turtle survival is threatened by the removal of natural habitat
WA16: It is a pleasure to live with Turtles
WA17: Turtles should be protected by law
WA18: Turtles are an important part of the natural environment
WA19: People should be given more information about Turtles
Section Six

Hypothetical questions

(Yes, No; If yes, what would you do?)

H1: You are driving down a road and you see a turtle crossing the road heading away from the wetland. On the other side of the road are houses and the road is very busy with traffic. Would you do anything?

H2: You are driving down a road and you see a turtle crossing the road heading away from the wetland. On the other side of the road are houses and there is no visible traffic. Would you do anything?

H3: You see a turtle come into your garden and start digging in it. Would you do anything?

H4: You see tiny baby turtles walking around on the ground. They are 100m from the wetland. Would you do anything?

H5: It is summer and you see a turtle moving along a road in your area where there is very little traffic. You know that the closest wetland is more than 500m away. Would you do anything?

Section Seven

Turtle sightings

T1: Have you seen an Oblong Turtle around/in your local wetland in the last 5 years? (Yes, No; If yes, how many have you seen?)

T2: When you saw these turtles did you do anything?

T3: Do you have any comments you would like to make or share about turtles or your local wetlands?

T4: (MAP OF LOCAL AREA) Please put a cross (X) in the locations where you have seen a turtle. If you have seen a turtle laying eggs please place a small circle (O) on the map. Please note the year and (if possible) month next to each sighting.
Appendix Two: Example of map provided to participants

Please put a cross (X) in locations where you have seen a turtle. If you have seen a turtle laying eggs please place a small circle (O) on the map. Please note the **year** and (if possible) **month** next to each sighting.

---

Harmony Lake