There might be a frog in McElligot's Pool:

A study of the habitat characteristics and social factors associated with amphibian presence in urban residential gardens in a suburb in Cape Town

M.Phil Thesis

August 2017

Thesis presented for the Degree of Master of Philosophy in the Department of Environmental and Geographical Sciences, University of Cape Town, South Africa.

University of Cape Town

By: Peta Brom

Student Number: BRMPET006

Supervisor: Dr Pippin Anderson

Co-supervisors: Prof. Alan Channing, Prof. Les Underhill

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

University of Cape Town

Declaration

I, Peta Brom, hereby,

1. Grant the University of Cape Town free license to reproduce the above thesis in whole or in part, for the purpose of research;
2. Declare that:
   i. The above thesis in my own unaided work, both in concept and execution,
   ii. Neither the substance nor any part of the above thesis has been submitted in the past, or is being, or is to be submitted for a degree at this university or at any other university

I am now presenting the thesis for examination for the degree of Master.

Signed by candidate

Signature removed

Peta Brom

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

My deepest and sincerest gratitude for this work is held for the following people, without whom, my project would have been dead in the water:

My supervisors, Pippin Anderson, Alan Channing, and Les Underhill who made their valuable time, knowledge and insights available to me.

Anneli Hardy, consultant at UCT's Department of Statistical Sciences, for undertaken the analysis of the data from the social survey.

Siphelele Khanye, Fatima Mohamed, Hannah Simon who ably, assisted me during the garden visits. All of them proceeded with a quiet sensitivity to the nature of home visits, providing support where needed and executing their roles with diligence.

The community members and residents of Observatory, Rosebank and Mowbray who so willingly gave me access to their properties and humoured me with what often felt like peculiar questions. After visiting 50 homes in the neighbourhood, I walked away feeling that people are truly beautiful and with a heart full of love.

Wanjiru Thoithi, Nosive Ngcawe, Sesethu Nika and Sandiswe Malenga had contagious enthusiasm helping me gather respondent data for the social survey in record time and, whether they knew it or not, inspiring me to get out of bed and face the crowds of people when all I wanted to do was hide.

My good friends Emma Aragundade and Firoz Khan, whose doors were always open as sounding boards, or to listen to me whine, gloat or dance. Without hesitation, they agreed to read early drafts of my thesis and provided invaluable editing advice and feedback.

My husband, Jo, who continues to share life's great adventures, inspires me to follow my dreams and encourages me believe in myself. Lastly, I thank my children, Noah and Maia, who have reawakened a sense of wonder in the world in me and who have turned my little burning fire for a better future, into an inferno.

ABSTRACT

This thesis engages with urban ecology through the lens of garden amphibians within a community in Cape Town. The study explores habitat and maintenance features associated with amphibian presence and the social processes underpinning attitudes towards amphibians, with the aim of strengthening knowledge underpinning the “what” (knowledge of natural requirements), “Why” (social drivers for urban landscape form and management), and the “how” (working with people, for garden biodiversity initiatives.

To explore the “Why” component, a social survey was conducted with 192 members of the community. One-way anova and correspondence analysis were used to explore the relationship between values, culture, knowledge and memories of early childhood experiences against a general attitude towards frogs and toads. The findings are consistent with the theoretical framework of *Connectedness To Nature* where positive attitudes are supported by normative values, cultural beliefs, knowledge and positive experiences with care-givers and role-models.

The garden habitat component of the study sought to explore the technical questions of the “What” requirement for amphibian presence in gardens. It was loosely based on the BIMBY tool with adaptations for context and targeted species. 50 gardens were visited and surveyed. They were divided into two groups for comparison: Those in which residents reported amphibian presence, and those which did not. Results indicate that the cape river frog (*A. fuscigula)* and clicking stream frog (*S. grayii)*, are attracted to gardens with moderate to dense vegetation at groundcover level. Gardens with moderately planted beds were more likely to report frogs if they had additional resources, in particular, ponds and mulch.

The “How” question brought together the two themes in a discussion on citizen mobilization and ways in which community groups are successfully implementing urban ecology conservation and reconciliation strategies. This work is important for urban nature conservation which seeks to engage private land-owners (garden enthusiasts) and community and citizen groups in implementing urban biodiversity projects.

1

INTRODUCTION, LITERATURE AND STUDY SITE DESCRIPTION

1.1 Study Rationale

Amphibians have ecological importance in many ecosystems around the world. They are an essential link in the natural food web and are important bio-indicators in determining wetland and river health whilst regulating invertebrate populations (Hocking & Babbitt, 2013). They are also the most threatened vertebrates on earth with approximately 41% of the entire class recognised as such (Stuart *et al.* 2004). Beebee and Griffiths (2005) documented that reports on amphibian declines had been produced as far back as the 1960s, but global declines only began in the 1990s. The most widely attributed reason for amphibian decline is habitat loss associated with land use changes and development (Measey, 2011), but none of the factors associated with agriculture and urbanisation can readily account for the declines that have been found in areas apparently unaffected or remote from land-use change. Declines occurring in remote areas are instead attributed to climate change, UV radiation, and diseases such as ranavirus and chytrid fungus (Beebee & Griffiths 2005). The spread of these diseases is facilitated by species invasions and climate change (Ibid.) Climate change is also becoming a driver of land-cover change because predictions indicate shifts in natural habitats that will occur 80 years from now at rates 500 times faster than current trends (Measey & Mokhatla, 2016). In short, amphibian species are threatened globally by a changing world.

Cities are arguably the most altered sites of change. Urban environments are prone to urban warming, and local climate changes within cities have occurred at faster rates than surrounding areas (Magle *et al.* 2012) with important indications for understanding the changes in thermal physiology, physiological adaptation and modified phenology (Hahs & Evans, 2015). This, amongst other reasons, makes them an important site laboratory for ecological processes and species adaptation (Shochat *et al.*, 2006). Studying urban environments and ecological processes occurring in their associated ecosystems is a research topic that is gaining increasing attention (Seto, 2013). Urban environments have historically been considered to be depauperate ecosystems, devoid of ecological value, but this perception is shifting. Ives *et al.* (2015) found that Australian cities consistently supported a greater number of threatened species than "all other non-urban areas on a unit-area basis" (Ives *et al.* 2015:25) and Goddard *et al.* (2010:90) recognise that "globally declining taxa can attain high densities in urban habitats" indicating the need for a reassessment of the value that urban ecosystems can contribute towards conservation. For amphibian populations, a large-scale citizen science study in North America found that although urban populations of amphibians are smaller than their wild counter-parts, they do not appear to be declining at faster rates. (Westgate *et al.*, 2015), suggesting that urban environments may be able to provide refuge for some species of amphibians if certain conditions are favourable.

In many cities around the world, the use of retention ponds, attenuation ponds and rain-gardens as a component of stormwater systems has seen amphibians take up residence and use these artificial waterbodies as breeding habitat (Simon *et al.* 2009; Le Viol *et al.* 2012; Scheffers & Paszkowski, 2012: Kruger *et al.* 2015). Studies which focused on urban ponds have found that natural urban wetlands and constructed habitats have similar occupation (Hassall & Anderson 2014), but that the quality of terrestrial habitats is as important to amphibians as the in-pond conditions (Scheffers & Paszkowski, 2013; Kruger, Hamer & du Preez, 2015), highlighting the fact that amphibians rely on both aquatic and terrestrial habitats.

Urban landscapes are characterized as a patchwork of different land-uses and landscaping practices. Of the urban landscape uses that have been studied, developed residential landscapes have been found to be a good indicator for amphibian presence in urban ponds (Trumbo *et al.*, 2012) and residential gardens can make up a significant portion of the land-cover types (Larson *et al.*, 2011). Therefore, residential gardens can present an important opportunity for supplementing conservation strategies (Goddard, *et al.*, 2010) and remnant patches (Doody *et al.*, 2010; Standish, *et al.*, 2013), potentially increasing the area associated with a particular habitat or patch.

In urban environments, human beings are viewed as the keystone species of the ecosystem (Adams, 2005; Standish *et al.,* 2013). Levels of biophilia, attitudes and perceptions as well as perceptions of nature result in certain species being prioritised for conservation, whilst less charismatic or "liked" species attract smaller budgets and less research attention (Tarrant, *et al.*, 2016). Additionally, social norms (Nassauer, *et al.*, 2009), individual preferences (Larson *et al.*, 2009), attitudes (Goddard, *et al.*, 2013), perceptions (Clayton, 2007), cultural beliefs (Ceríaco, 2012), and even identity (Kiesling & Manning, 2010; Freeman *et al.*, 2012) can result in different gardening practices and a desire to cultivate or remove one plant species over another. (Goddard, *et al.*, 2013; Beumer & Martens, 2014). In this way, urbanised nature is as much shaped by social processes as it is by ecological processes.

Novel ecosystems are those ecosystems which have been significantly altered by a variety of local and global changes and influences, but which have reached a state of functionality that is no longer analogous to their origins (Hobbs, *et al.*, 2009). Those points of self-regeneration within urban environments are still largely under-researched (Corbyn, 2010), yet they represent an important opportunity for conservation (Ikin *et al.*, 2015). An understanding of amphibian presence within urban space at the micro-scale is an important step towards understanding their habitat needs and behavioural responses within altered landscapes. Residential gardens are an important component within urban habitats and are shaped by social processes. This study draws on multidisciplinary fields to focus on the habitat characteristics of gardens associated with frog presence and unpack the features that provide a favourable habitat for amphibian presence. Additionally it explores human attitudes, preferences and perceptions to amphibians at the neighbourhood level.

1.2 Aims and Objectives

Urban ecology differs from traditional ecology in that it demands consideration of the social informants of nature in cities. The aim of this study is to describe the social and ecological factors associated with amphibian presence in domestic gardens. There are two primary objectives:

> Objective 1: To identify and describe the environmental factors associated with amphibian presence in domestic gardens as a potential informant of garden design and maintenance practices (the 'what').
>
> Objective 2: To explore human attitudes towards amphibians in order to understand why people would or would not want to attract amphibians to their gardens.
>
> Objective 3: To briefly discuss 'how" citizens are engaging with ecological stewardship within the Cape Town context.

1.3 On Words

Amphibians as a group include frogs (including toads), salamanders, and caecilians. Only frogs (including toads) occur in South Africa; these are classified scientifically as anurans, or tail-less amphibians.

Much of the research referenced in this study, particularly in the section on urban habitats is drawn from international studies in countries where newts and salamanders also occur. In this section, I have therefore referred to amphibians for studies which included newts and salamanders and to anurans where it refers only to frogs and toads. For the rest of the thesis, amphibians should be taken to include anurans only.

1.4 Description of Thesis and Chapter Layout

The focus of this study is to explore urban ecology through the lens of a traditionally less popular group of species. Urban ecology is the cross-over between natural sciences and social sciences because it brings together society and nature. Chapter One includes the study rationale objectives and aims and then turns to an overview of the history and principles of urban ecology, summarising emerging findings of patterns and processes. The chapter then provides a description of the study area in order to contextualise the research at the local level. The following two chapters then split into studies of urban nature and society respectively and each of these topics is dealt with separately.

Chapter two focuses on the nature aspect of urban ecology considering what technical habitat features are supportive of amphibian colonisation, movement and foraging needs. It covers the study of garden habitats for amphibians within the context outlined at the end of Chapter One. It gives a comprehensive literature review of international studies on urban amphibians and then turns to the methodology, analysis and discussion of what was explored at the local level.

In Chapter Three, the social aspects shaping urban nature are explored. The discussion unpacks current understandings of why people, as a social species, are motivated to engage in ecological conservation with particular focus on gardens. The empirical evidence gathered in this study surveys attitudes and preferences towards frogs within the target community. The results lead into a discussion of the drivers of pro-environmental behaviour as framed by the concept of *Connectedness To Nature*.

Chapter Four brings these two separate streams of nature and society together by first summarising the findings in terms of ‘What’ and ‘Why’ and then briefly turns to a discussion of existing strategies for the ‘How’ of community-based environmental stewardship on private and community land. The thesis ends with brief suggestions for further research.

1.5 Literature Study – Urban Ecology, Background and Context

Urban ecology as a field emerged in the late 20th century from multi-disciplinary roots including studies within the fields of sociology, urban planning, architecture, ecology, natural sciences, geology and engineering. Its genesis in China has been eloquently traced through the lens of urban planning by Wu *et al.* (2014) and an ecological perspective was documented by McDonnell (2013) and by Adams (2005). Table 1.1 summarises the key dates as documented in the texts by Wu *et al.* (2014), Adams (2005) and McDonnell (2013).

Early ecologists focused as much on urban systems as wild systems, but in 1864, environmentalist George Perkins Marsh described ecology in terms of the *Equilibrium Paradigm* (Marsh, 1864). This paradigm was based on Aristotle's notion of *the balance of nature* and placed human beings as separate, outside agents, to nature. Study of urban systems was therefore abandoned as anti-nature (McDonnell, 2013). There was very little activity in urban ecological research for over 100 years, then ecological landscaping entered the field of landscape architecture in the Netherlands, whilst the rest of the world largely ignored urban ecosystems. (Adams, 2005). Two events in the 1970s changed this, namely, the economic reforms in China and the launch of the UNESCO Man and Biosphere (MAB) forum in the UK (Ibid.)

By the 1980s it became clear that the *Equilibrium Paradigm* was flawed and the idea of the balance of nature was abandoned (McDonnell 2013). Instead, ecology was described as process-driven and notably, humans were acknowledged as important agents of change within those processes. The recognition that humans were part of ecosystem processes redirected focus towards cities and amalgamated efforts from sociologists (McDonnell, 2013). In the UK the MAB was gaining traction through a number of smaller publications (Ibid.) whilst in China, studies focused on the environmental problems in major cities (Wu, *et al.*, 2014). America took up the mantle when the US National Department of Science funded two long-term ecological research programs in Baltimore and Phoenix and the UK founded local city Urban Wildlife Trusts (Adams, 2005; McDonnell, 2013). The shape of urban ecology studies in South Africa have ultimately had a planning and legislative impact through the spatial planning tools and frameworks adopted by city planners. Early urban ecological research mapped and documented public open space using a provisioning of ecosystem goods and services approach which sees the establishment of the Durban Municipality Open Space System (DMOSS). This is followed a few years later by Cillier's work in Potchefstroom which conducted a thorough species mapping project in Potchefstroom, taking all types of green space including larger remnants as well as degraded spaces. Early work in Cape Town documented the biodiversity of the city and considered the significance of vegetative ecosystems and remnants for conservation, rehabilitation or development and this was translated into the biodiversity network (Bionet) which became a planning tool as part of the spatial development framework and motivated for the establishment of Table Mountain National Park as a world heritage site (Cilliers & Siebert, 2012).

1.5.1 Definitions and Important Concepts in the Study of Urban Ecology

By the 1990s urban ecology had emerged as an interdisciplinary field of study that was beginning to gain formal recognition and traction. Likens (1992:8) defined ecology as “The scientific study of the processes influencing the distribution and abundance of organisms, the interactions among organisms and the interactions between organisms and the transformation and flux of energy and matter”. Both Wu *et al.* (2014) and McDonnell (2013) offer their own definitions of urban ecology which reflect the discipline differences across the Chinese and European continents. Wu *et al.*’s definition is “The study of spatiotemporal patterns, environmental impacts and sustainability of urbanisation with emphasis on biodiversity, ecosystem processes and ecosystem services” (Wu *et al.* 2014:223) and McDonnell (2013) defines it as ”[integrating] both basic and applied natural and social science research to explore and elucidate the multiple dimensions of urban ecosystems” (McDonnell 2013:9). Contrary to the proposed integration of natural and social sciences, studies within the field have tended to focus either on ecological processes or on social processes and seldom manage to transgress the two different entry points into the understanding of urban ecology. Having said this, Wang *et al.* (2011) developed an approach to analysing urban ecosystems that views them as a Social-Economic-Natural Complex Ecosystem (SENCE) and which includes production and resource flows and providing an additional entry point into the study of urban ecosystems defined in economic terms through the provisioning services offered by healthy ecosystems.

Studies of urban natural systems over the past quarter century have primarily focused on describing the patterns of biodiversity in cities and towns using broad, aggregate predictor variables (Mcdonnell & Hahs, 2013) usually along urban-rural gradients (LaPoint *et al.*, 2015). A number of reviews have called for a more textured approach that moved beyond gradients and explores *inter alia* functional relationships (Scherer, *et al.*, 2012), habitat analogues (Lundholm & Richardson, 2010) and functional connectivity (LaPoint *et al.*, 2015) and asked that we compare patterns across regional and global scales. It is worth pausing here, to unpack the definitions of biodiversity as described by Noss (1990). The definition, although not dissimilar to ecology includes variability among living organisms and the ecological complexes in which they occur. Primary distinction here is the omission of nutrient and energy flows and the emphasis of variability. Noss (1990) unpacks biodiversity in terms of structural biodiversity, relating to patterns and form, functional biodiversity, relating to processes, interactions and life-histories and compositional biodiversity relating to classifications and communities. Notably it is argued that the use of hierarchy theory indicates that biodiversity should be studied at multiple scales and across multiple spatial and temporal scales and that "The importance of higher-order constraints should not suggest that monitoring and assessment be limited to higher levels (e.g. remote sensing...)" (Noss, 1990:357). Critically Noss (1990) stresses the importance adequately selecting indices which measure disruptions in biodiversity and consider the structural and functional biodiversity as well as the compositional biodiversity. Consequently, qualitative changes may be better indicators of ecological disruption (Noss, 1990).

Those entering from the perspective of social drivers have focused on neighbourhood biodiversity in relation to socio-economic and demographic make-up (e.g. Melles 2005; Barau *et al.* 2013; Hunter & Luck 2015; Ikin *et al.* 2015) or the drivers of yard choices and the meanings derived therefrom (Clarke *et al.*, 2014; Belaire, Westphal & Minor, 2015; Uren, *et al.*, 2015). The objectives of the social set tend to be focused on describing the factors that would influence human behaviour towards stewardship and management for biodiversity (e.g. Knight 2008; Freeman *et al.* 2012; Uren *et al.* 2015; Chan *et al.* 2016), whilst the objectives of the studies of natural systems tend to derive understanding of the unique biophysical processes that occur within urban systems (McDonnell, 2013). Another way of thinking about it, is to look at it as a bottom-up approach to studying the processes within the systems versus a top-down approach concerning the management styles and the social, economic and political or legislative environments that drive the ways humans manage urban nature.

Table 1.1.. Summary of the history of urban ecology in South Africa, China, Europe and the US, as drawn from Cilliers & Siebert (2012), Anderson & O'Farrell (2012), Wu et al. (2014), McDonnell (2013), and Adams (2005) respectively.

	SOUTH AFRICA	CHINA	EUROPE	AMERICA
1850	*Formal colonisation & large-scale environmntal extraction*			**1864** George Perkins Marsh describes the *Equilibrium Paradigm* . Nature is considered separate from people.
1900			*Ecology described as a "fad" by ecologists*	
1910			**1912** Shemstone describes flora of building sites in London	
1920				**1925** Establishment of Chicago School of Human Ecology / Sociology
1930			**1930** Publication of first game management book	
1940	**1948** The National Party is voted in.	**1949** National Land Use Policy	**1945** Fitter's natural history of London	**1945** Chicago School of Urban Sociology pioneers the use of ecological theory to describe the structures and function of cities.
1950	**1950** Promulgation of group areas act *Apartheid spatial planning*			*Population Boom and rapid urbanisation.* **1959** Kieran's natural history of New York
1960			**1960** Netherland introduces the concept of ecological landscapes.	**1960** Publication on rising atmospheric CO_2
1970		**1977** Establishment of plant ecology major at Inner Mongolia University **1978** *Economic Reform*	**1971** UNESCO launches UK *Man ad the Biosphere* (MAB) forum bringing together Natural Science, Engineering / Planning and Humanities.	

	SOUTH AFRICA	CHINA	EUROPE	AMERICA
1980		*Urban Ecology Emergent Period* Early translations of texts from English to Chinese. Chinese studies applied to projects to solve specifice environmental problems in major Chinese cities. **1983** Song review describes the field of ecology in terms of seven research areas	**1980** *Equillibrium paradigm* is flawed. *Ecological systems viewed as proces driven.* Humans as important agents of change. **1985** UK and US adopts *Ecological Landscape* concept within the discipline of Landscape Architecture. **1986** Georg Barker summarises European urban wildlife programmes for national symposium.	
1990	**1994** Durban adopts provisionin of ecosystem goods and sevices approach **1995** Establishment of Durban Metropolitan Open Space System **1998** Cilliers & Bredenkamp document the biotopes and biodiversity of Potchefstroom, including disturbed and degraded areas	*Urban Ecology Early Growth Period* Characterized by rapid urban growth. Articles appeared in environmental science journals predominantly in Chinese.	**1991** Urban Wildlife Trusts founded.	**1990** US National Dept. Science funds two long-term ecological research programs in Baltimore and Phoenix.
2000	**2001** Establishment of the Cape Town Biodiversity Network **2004** Work of Cilliers & Bredenkamp incorporated into Potchefstroom Municipal Integrated Development Plan. **2004** Table Mountain National Park declared a world heritage site.	*Urban Ecology Rapid Development Period* Central Government increasingly emphasises high-quality urban development. Chinese publications are frequently translated for Western consumption.		
2010	**2012** Van Wilgen engages with public perceptios of alien clearing.		**2015** Calls to integrate Urban Ecology with Natural Ecology. **2017** Comprehensive reviews summarise principles and processes of Urban Ecology.	

1.5.2 Urban Stressors as Insights to the Future

Hahs and Evens (2015) argue that fundamental ecological knowledge can be expanded by studying urban ecosystems. They defined functional ecology as the sum of interactive processes "i. Occurring between organisms and their environment; ii. Biotic interactions between organisms; iii Adaptive processes driven by natural selection." (Hahs & Evans 2015:683). They motivated their call for urban ecology to be incorporated more generally into the field of ecology by highlighting that ecosystem responses to urban stressors can provide invaluable insights into responses to climate change. Noting that urban warming is an under-studied phenomenon, the observed climatic changes seen within cities are similar to those predicted for global warming. Species responses include changes in phenology and temporal patterns (Hahs & Evans, 2015). Empirical evidence suggests that extended warm seasons coupled with irrigation, has meant that food sources are often abundant in cities whereas they are scarce elsewhere. Many species have moved into cities to take advantage of these factors, altering migration patterns and ranges. Observing shifts in urban systems deepens the understanding of urban responses but also provides some insights into the kinds of changes we could observe under changed climatic conditions (Mcdonnell & Hahs, 2013; Hahs & Evans, 2015)

Urban warming is one of four major identified urban stressors: 1. Landscape fragmentation, 2. Non-native species introduction, 3. Environmental contamination and 4. Urban warming (Hahs & Evans, 2015). Landscape fragmentation renders different responses in different species. For some, it destroys their habitat, for others it alters it and for a few it creates new habitats. Specialists tend to be severely impacted and generalists with more flexible habitat preferences and diet, tend to do well (Adams, 2005). Species responses have been characterised in three ways: i. Urban avoiders which have specific habitat and food requirements and whose natural habitat must be preserved if the species is to persist; ii. Urban adapters, for which, if competition is controlled and functional movement is understood and facilitated, metapopulations can persist; and iii. Urban exploiters which are well adapted to urban environments and need no special attention or care for population continuation (Shochat *et al.*, 2006).

1.5.3 Novel Ecosystems

Urban ecosystems are characterised by the predominance of novel ecosystems. A novel ecosystem is defined as one which has changed beyond the point where it can viably be restored to its historical state, but is self-maintaining (Hobbs, *et al.*, 2009). Ecosystem changes can arise out of abiotic, or biotic changes, but urban systems are more likely to be changed both by the abiotic conditions as well as through changes in species combinations. As a result, conservationists consider whether it matters if the changes have been abiotic, or biotic or both; they also have to decide the point at which a system should be managed as an adapted system, a restored/protected system, or recognised to be completely novel such that functional relationships exist between species that would not have historically interacted but the system is essentially stable and self-maintaining (Hobbs, *et al.*, 2009; Norton, 2017).

Another view is that the novelty of ecosystems has been over-emphasised and that some of the harshest anthropogenic ecosystems are able to support indigenous biodiversity due to their structural or functional resemblance to natural ecosystems which are present in the region, but not necessarily in the historic ecosystem on a particular site. In this instance, colonisation may be prevented by limits to dispersal by appropriate species. The most widely studied artificial habitats are quarries, buildings and walls which are analogues of natural rock and cliffs (Lundholm & Richardson, 2010). Lundholm and Richardson (2010) suggest that habitat analogues represent an important principle to guide reconciliation ecology (encouraged biodiversity in human-dominated ecosystems) in urban lands, for which shortcomings in suitability can be overcome by ecological engineering and/or assisted dispersal. On the other hand, where the habitat attracts pests, altering it to be less analogous can help reduce the impacts of pest species (Lundholm & Richardson, 2010).

1.5.4 Movement by Structural and Functional Connectivity

The ways in which species move through the landscape shape the home-range size, and influences individual survival, recolonization potential, and gene flows. Traditional measures of connectivity predominantly study the structural connectivity in terms of patch size and proximity to other habitat patches within a matrix. However functional connectivity considers the ways in which individual species move in relation to their traits (Riviero *et al.,* 2011. What is needed for urban environments is to understand how species move and respond to barriers and stressors (Hahs & Evans, 2015). For example, LaPoint *et al.* (2015) highlight that sugar gliders (*Petaurus breviceps)* did not reduce the distance they moved from their range within the urban fabric providing there was adequate tree cover. They concluded that “functional connectivity for *Petaurus breviceps* could be facilitated by reducing high-contrast land cover edges between residential properties and conservation areas”. Unfortunately it would not be possible to conduct exhaustive studies for all individual species and so alternative methods of drawing generalisations based on functional guilds, trait approaches, gene-flow, and GPS and radio-tracking provide options for developing the field further (LaPoint *et al.*, 2015)

1.5.5 Urban Ecology in Review

Notwithstanding the above insights about functional connectivity, Beninde *et al.* (2015) conducted a meta-analysis on intra-urban biodiversity from 75 cities worldwide. They found that patch area and corridors had the strongest positive effects on biodiversity, complemented by vegetation structure, in particular the level of herbaceous cover. Biotic, management and local variables were more important than abiotic, design or landscape variables and sites of greater than 50 ha are necessary to prevent the loss of area-sensitive species (Beninde, *et al.*, 2015).

Forman (2016) scanned the history of urban ecology and identified 90 urban ecology principles that were underpinned by four criteria: predictability, applicability, supported by evidence, and importance. The principles were grouped into 11 categories which are widely used by ecologists and other disciplines. When grouped by attributes, four groups arise: land uses, built structures, permeating anthropogenic flows and human decisions/activities. Hardly any of these attributes are present or significant in natural areas and so these attributes frame the ecology of urban areas (Forman, 2016). For the purposes of this study it highlights the significance of the human-social impact on urban ecological processes.

In summary, there is growing evidence that urban ecosystems can provide valuable havens for biodiversity and are worth considering in conservation plans. Studying urban ecosystems can provide insights into the patterns and processes that will become prevalent in a changing climate and provide clues as to how we can engineer more resilient systems and adapt human behaviours and social drivers towards providing robust and integrated urban ecological habitats.

1.6 Context of this Study

The study area falls within the City of Cape Town, which is considered a biodiversity hotspot of global significance and priority for conservation (Mittermeier *et al.* 2011; Rebelo *et al.* 2011).The city is home to 27 species of local amphibians and three introduced species (Rebelo *et al.*, 2011). The study site selected is a residential area close to the Central Business District, 8 km from the city centre (Figure 1.1). It is a medium density, mixed-use suburb in which properties vary in size from approximately 100 m^2 to 300 m^2 in Observatory and Mowbray and 500 m^2 to 1000 m^2 in Lower Rosebank (City of Cape Town Emap, accessed June 2016). There are two significant remnant patches on the edges of the study area, namely the Rondebosch Common in the south-west where *Vandijkophrynus angusticeps, Amietia fuscigula, Breviceps gibbosus* and *Strongylopus grayii* have been documented (ADU, 2015). In addition, it was the site at which the Cape Dainty Frog

Cacosternum capensis was discovered by Walter Rose (Rose, 1929), but it has since disappeared from the site (Rebelo *et al.*, 2011). The second area is the Raapenberg Wetland Bird Sanctuary which is a protected area and hosts one of the breeding sites for the critically endangered Western Leopard Toad *Sclerophrys pantherinus* (Jean Ramsy, WLT committee member and resident at South African Astronomical Observatory SAAO pers. com.).

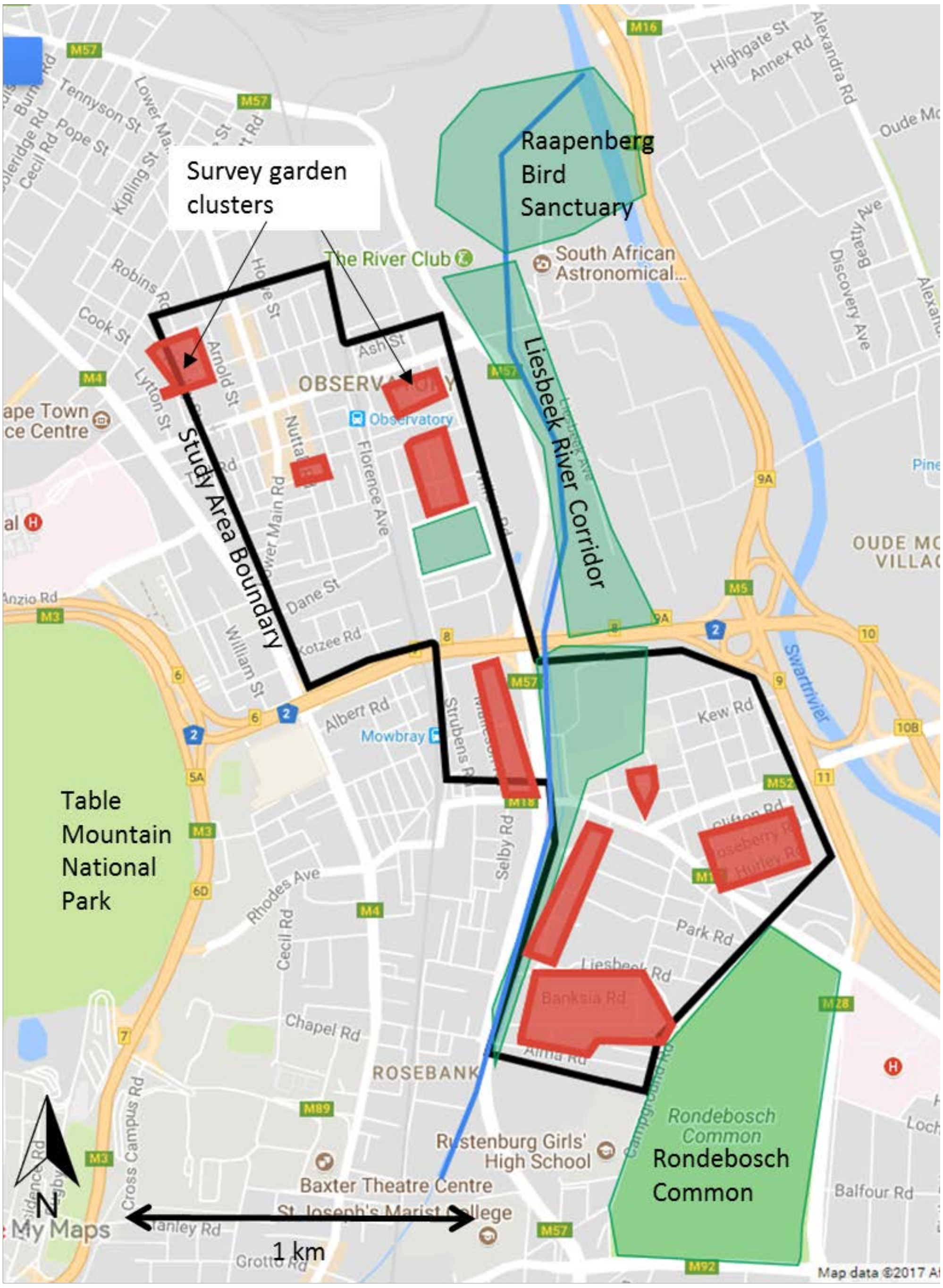

Figure 1.1 The study area in Cape Town, Western Cape, South Africa, showing remnant patches, significant green areas and sampling locations (Google Maps, 2016).

The historical vegetation type is Peninsular Shale Renosterveld (Rebelo *et al.*, 2006). Renosterveld is one of three vegetation types that make up the Fynbos Biome. Renosterveld is found on comparatively fertile soil, and is therefore threatened due to the transformation of land for agricultural and pastoral purposes. It is characterised by the renosterbos shrub from which it derives its name. Both fynbos and renosterveld are fire-driven vegetation, however the fire cycle of renosterveld is shorter (2–10 years) than fynbos (10–50 years) and reflects adaptations accordingly. Consequently renosterveld is characterised by grasses and geophytes. Peninsula Shale Renosterveld is critically endangered due to land transformation (Rebelo *et al.*, 2006). Only one plant species, the small, blue-centred flower, *Morea aristata,* is endemic to Peninsula Shale Renosterveld, of which the last wild population is found on the banks of the Raapenberg Wetland at the South African Astronomical Observatory (information board displayed at the SAAO). Cowan and Anderson (2014) studied the restoration potential of the largest remnant patch at Groote Schuur Estate on the slopes of Devils Peak. Their findings are that "historical drivers have created a novel ecosystem with vegetation states ranging from relatively healthy Renosterveld vegetation, indigenous vegetation requiring intervention to maintain its integrity, and regions of the study area are... dominated by alien grasses and *Pinus* plantations." (Cowan & Anderson, 2014:135)

Frog species commonly reported in gardens within the study area include *Amietia fuscigula, Strongylopus grayii* and *Sclerophrys pantherinus.* However the full list of indigenous amphibian species which are likely to be found within the area has been summarised below (Table 1.2), (A. Channing, pers. com.) along with documented behaviour, pond and landscape preferences compiled from Channing, (2001), (Rebelo *et al.*, 2006), du Preez *et al.* (2009), Doucette-Riise (2012) and Measey, (pers. comm., 2016).

Factors that could contribute to the biodiversity of this area when compared with other neighbourhoods would include its proximity to the Table Mountain National Park, which is located in the centre of the metropolitan area, as the largest remnant patch within the city. The suburbs within the study area are characterised by their establishment in the first half of the 20th century and portions of it have been declared a heritage protection zone due to the rows of Victorian-era houses. The neighbourhood is therefore older, established development with observable large and old trees. It is therefore expected that the suburb would support greater biodiversity within gardens than more newly established neighbourhoods in accordance with findings of Kendal *et al.* (2012b).

Table 1.1. Summary of documented preferences, and life-histories of endemic species likely to be found in the study area as summarised from Channing, (2001), (Rebelo et al., 2006)*, du Preez* et al. *(2009), Doucette-Riise (2012) and Measey (pers. comm., 2016).*

Latin Name	Common Name	Vegetation preference	Road behaviour response	Breeding pond	Soil type	Barrier behaviour response	Breeding period	Calling time	Documented calling habit & other notes	Eating habits	aesti-vation?
Amietia fuscigula	cape river frog	grassland	undocumented	permanent water	undocumented	unknown	continuous	day & night	concealed at edge/ floating in deep water	generalist (canibalistic)	no
Breviceps gibbosus	cape rain frog	renosterveld	undocumented	none	loamy soils & clays	unknown	Apr-Nov	day & night	well hidden under vegetation in shallow depressions - poor swimmers	undocumented	yes
Cacosternum capensis (historically)	cape dainty frog	renosterveld	undocumented	shallow, temporary puddles	poorly drained loamy to clay soils	unknown	Apr-Aug	mostly at night	Partially submerged in muddy water. Poisonous to other frogs?	undocumented	yes
Sclerophrys capensis	raucus toad	grassland	undocumented	farm dams	undocumented	unknown	Summer	mostly at night	exposed nr water	undocumented	undoc.
Sclerophrys pantherinus	western leopard toad	not documented	dispersal corridor	Shallow, temporary wetlands	undocumented	unknown	Aug-Oct	night	concealed at edge/ floating in deep water	undocumented	undoc.
Strongylopus grayii	clicking stream frog	generalist	undocumented	damp ground near to a pond approx. 30-60cm tolerant of poor water	generalist	unknown	winter	day & night	Well concealed by vegetation or leaf litter	undocumented	undoc.
Vandijkophrynus angusticeps	cape sand toad	renosterveld	crossing during breeding season otherwise undocumented	shallow, temporary puddles	sandy, also clay sandy in gardens	unknown	May-Sept	mostly at night	exposed nr water	insects, small snails	undoc.

The study area falls within a precinct containing six medical and hospital institutions, including Groote Schuur Hospital, the chief academic hospital of the University of Cape Town. The University of Cape Town lower campus is in Rosebank and overall education levels are high with 33% of the population having completed some form of higher education and 13% holding post-graduate qualifications (Statistics South Africa 2011). Of the three suburbs in the study area, Mowbray has the most highly educated population with 40% holding some tertiary education (Ibid.). The high education rates can be attributed to economic status, proximity to the University of Cape Town, the presence of designated student accommodation in all three suburbs and academic and medical staff who seek accommodation close to their places of work. Should urban trends mirror findings in the literature, then higher education levels would also indicate greater biodiversity in the residential gardens of the precinct (Kendal *et al.* 2012b).

The study area is fragmented by the road network. It is situated at the confluence of three highways. The first of which, Motorway 3, along with the Main Road isolates the suburb from Table Mountain. In addition the National 2 runs through the centre of the area and, the Motorway 5 runs parallel to Motorway 3 on the other side of the Liesbeek River. The Liesbeek Parkway isolates the suburb of Observatory from the Liesbeek River. One would therefore expect greater species abundance in the section of the study area north of Liesbeek Parkway and east of the National 2, namely in Lower Rosebank, where the built structure density is lower and the buildings marginally older.

The Liesbeek River runs from the south in a northerly direction towards the sea. It is taken as the eastern boundary of the Observatory part of the study area and the western boundary of the Rosebank portion of the study area cutting through Mowbray in-between. The source of the Liesbeek River is a spring on Table Mountain. At the boundary with the Table Mountain National Park the river is canalised and remains so for most of its length towards Raapenberg Bird Sanctuary. Some rehabilitation efforts have been undertaken by Friends of the Liesbeek River along the banks and flood-planes north of Rosebank. According to the 2005 State of Rivers Report for Greater Cape Town, the Lower Liesbeek River health was fair to poor with a desired health of fair (Republic of South Africa, 2005).

In conclusion, the study area can be defined as a low to medium density urban setting, established development with middle to upper socio-economic conditions. It is spatially fragmented with low-quality water-bodies and severely altered land-cover.

2

HABITAT CHARACTERISTICS OF FROG-INHABITED GARDENS IN A SUBURB IN CAPE TOWN

2.1 Introduction

Urban environments can contribute to biodiversity and consequently strategies for conservation have been proposed which include cities within the suite of programmes under implementation (Goddard, *et al.*, 2010; Mcdonnell & Hahs, 2013; Ives *et al.*, 2015). The extent to which there are opportunities for amphibian conservation within urban contexts is unclear because studies are still exploring whether or not urban habitats are sinks or opportunities for population stability (Garcia-Gonzalez *et al.* 2012; Le Viol *et al.* 2012; Cosentino *et al.* 2014; Gallagher *et al.* 2014;Hassall & Anderson 2014). Although gardens represent a significant portion of land-cover within urban contexts (Goddard, *et al.*, 2010), they are often overlooked for the potential contribution they could make to supporting remnant patches, for example by extending habitat and metapopulation size. Doody *et al.* (2010) found that the seeds of woodland species were spread to gardens by birds and wind, but that New Zealand gardeners were unable to recognise indigenous species. In spite of evidence that suggests that gardens can make a positive contribution they are seldom included for consideration in urban conservation strategies *(Doody et al., 2010; Goddard, et al., 2010*). This may be due in part, to small individual patch size and the autonomy of residents in management styles, undermining the feasibility of engagement and apparent scale of impact (Dewaelheyns, *et al.*, 2016)

Urban frog populations tend to be smaller than their rural counterparts, but they do not appear to be declining at an overall faster rate. Studies that examined urban terrestrial land-cover types associated with frog species richness and abundance found that residential land-cover is a predictor for frog presence (Trumbo *et al.* 2012; Cosentino *et al.* 2014). Although there are many social drivers shaping garden form, without access to quality information, even communities with a desire to employ ecological garden practices will have unrealistic expectations (Gaston *et al.*, 2005). This study therefore seeks to unpack what amphibians need from a garden in order for it to provide a supportive habitat.

2.2 Aims

The aim of this chapter is to determine which habitat characteristics attract amphibians to gardens in order to inform garden design and maintenance best practice – i.e. What do Cape Town's garden frogs prefer?

Objectives:

1. To document the habitat resources and maintenance practices found in gardens in order to compare gardens reporting frog presence with those reporting absence.
2. To determine if the recommendations for frog friendly gardens disseminated in popular media are accurate.

2.3 Literature Study

2.3.1 Introduction

Studies of urban environments have tended to focus on amphibian presence and diversity in constructed wetlands, agricultural dams and stormwater retention ponds (e.g. Hazell *et al.* 2004; Shulse *et al.* 2010; Scheffers & Paszkowski 2013). This literature review seeks to document the challenges and opportunities that are presented by current research for amphibian conservation within urban settings. It describes and presents current research findings on amphibians in urban environments and then discusses the implications for gardens. The review of the literature begins by exploring predictors for amphibian presence within ponds and then summarises the findings of studies on terrestrial characteristics. Turning to threats to amphibians, special attention is given to the impact of roads and mitigation efforts. The findings of these studies demonstrate a complexity in the systems governing amphibian ability to persist and concludes by discussing the opportunities presented by urban garden habitats.

2.3.2 Fish, Pond Permanence and Hydroperiod

Studies conducted in the first decade of the 21st century identified that amphibians were more likely to persist in wetlands that did not contain fish because tadpoles are included in the diets of many predatory fish (Ficetola & De Bernardi 2004; Porej & Hetherington 2005). Concern has been raised that ponds that contain fish could represent a species sink for taxa that are susceptible to fish predation (McCarthy & Lathrop, 2011). Fish introduced to ponds connected by intermittent or permanent streams pose a wider threat to populations of tadpoles beyond the initial pond borders. (Goldberg & Waits, 2009). For this reason, ephemeral ponds which cannot support fish life, but, depending on the hydroperiod, can be used by amphibians for breeding are often favoured by certain species (Smallbone, Luck & Wassens, 2011). Cases have been recorded where species prefer to seek out shallow ponds and ephemeral wetlands, or even wheel ruts, for breeding purposes (Scherer *et al.* 2012; O'Brien 2015). Shallow, well-vegetated and ephemeral wetlands are not common in urban landscapes (Smallbone, e*t al.*, 2011) because they tend to be removed as part of the urbanisation process and through traditional stormwater management techniques. Smallbone *et al.* (2011:49) note that ponds within urban areas tend to be permanent in nature because ephemeral wetlands "are more likely to occur in towns with flood plains, lower development pressure, and in fringe/peri-urban areas".

The uptake of Sustainable Urban Drainage Systems (SUDs), to upgrade and bolster capacity of urban stormwater management systems in cities around the world, is changing the dynamics that drive the establishment of permanent water bodies containing predatory fish (Le Viol *et al.* 2012; Hassall & Anderson 2014; Church 2015). SUDs incorporate a range of mechanisms which are used to manage stormwater above ground within designed landscape features. The aim is to mimic natural water processes such as slow water progression and infiltration within an artificial riparian buffer (Katsifarakis, *et al.*, 2015). Little research has been done on the presence and use of smaller, upstream SUDs mechanisms with temporary water such as attenuation ponds and rain-gardens (although Church (2015) studied them as instances of education) and this represents a gap in research raising the question as to whether species with a preference for temporal ponds could use street and patch level ponds as readily as the larger ponds or if they have already disappeared from urban environments altogether due to lack of breeding habitats.

Studies have been done on amphibian colonisation of stormwater retention ponds and consistently found that permanent artificial ponds which did not contain fish were colonised by breeding amphibians with comparable species richness to their natural counterparts (Simon *et al.* 2009; Birx-Raybuck *et al.* 2010; McCarthy & Lathrop 2011; Hamer *et al.* 2012; Le Viol *et al.* 2012; Gallagher *et al.* 2014; Hassall & Anderson 2014; Holzer 2014; O'Brien 2015). Furthermore, in Helsinki, a study comparing golf course populations with natural populations of breeding amphibians found that "The golf course populations did not differ from natural populations in terms of genetic variability or differentiation." (Saarikivi *et al.* 2013:1057) This finding suggested that (amongst others) golf courses could provide suitable water bodies for reproduction and green corridor dispersal (Saarikivi *et al.* 2013:1057). The following section discusses the details of the findings of the studies on in-pond conditions and amphibian colonisation.

2.3.3 In-pond Habitats

Amphibians use ponds, streams and puddles as breeding sites during the breeding season. For this they need suitable calling and spawning sites (du Preez, *et al.*, 2009), and are readily able to use both artificial waterbodies and natural wetlands for this purpose (Shulse *et al.* 2010; Le Viol *et al.* 2012; Holzer 2014; Romano *et al.* 2014). In dry and non-breeding periods, amphibians require suitable habitats for foraging, avoiding predation, avoiding desiccation and aestivation which are provided in terrestrial habitats, often at considerable distances from the breeding pond (Gagné & Fahrig, 2007). The findings on the usefulness of the provision of habitats by urban, peri-urban and artificial ponds is thus arranged into the role of in-pond habitat characteristics and terrestrial habitat characteristics. In-pond habitat features studied tend to included shore depth and littoral shelf, macrophytes (both emergent and underwater), conductivity, and chemical composition.

Pond vegetation was consistently studied as an important predictor of species richness, but results varied. In New South Wales, a study of 22 farm dams and 22 natural ponds found that the presence of emergent vegetation showed positive correlations with species abundance (Hazell *et al.*, 2004). In contrast, a study of 42 replacement wetlands in Idaho showed no evidence for amphibian association with amount of emergent vegetation cover (Porej & Hetherington, 2005).Another study, also in Idaho, found that emergent vegetation was important for one of the three species of amphibians surveyed (Goldberg & Waits, 2009). In Canada a number of pond characteristics were modelled, and returned no influence for two of the three species recorded, but where pond characteristics were predictors, emergent vegetation was positively correlated (Gagné & Fahrig, 2007). Shulse *et al.* (2010) found that chorus amphibians, spring peepers, and salamanders were most abundant in heavily vegetated and fish-free wetlands. Holzer (2014:963) reflected in a review that “Twelve out of sixteen studies found aquatic vegetation cover to be positively associated with native amphibian presence, abundance, richness and/or diversity”. She observed during fieldwork undertaken in Portland, that in ponds containing sparse vegetation, egg masses could be found on 90% of the plant stems whereas at ponds that entirely lacked vegetation, egg masses were deposited on materials such as plastic fencing and barbed wire that had fallen into the water (Ibid.) indicating adaptive capabilities of the species within her study area.

Shulse *et al.* (2010), Hamer *et al.* (2012) and Scheffers and Paszkowski (2013) discuss littoral shelf depth as a design feature for promoting the growth of emergent vegetation with suitable calling sites. Whilst Hamer *et al.* (2012) note that the combination of shallow littoral shelf and emergent vegetation provides suitable calling sites for many species they contrast it with deeper shores which may “provide preferred [for some common species] calling and oviposition sites such as undercuts and burrows in waterbody banks” (Hamer *et al.* 2012:463). It is not clear from the reference if the steep side would need to be suitable for burrowing, or if rockeries or uneven stone walls would be suitable.

There were some correlations with pond age – although again, this varied between species (Birx-Raybuck, *et al.*, 2010) and pond size, where it is noted that larger ponds also tend to offer a variety of habitat opportunities (Hamer, *et al.*, 2012) and hence support a wider spectrum of species. Other pond characteristics which were studied included conductivity, pond depth and chemical composition, but with the exception of nitrogen compounds, these did not register as a predictor for amphibian presence (Gómez-Rodríguez *et al.* 2009; Simon *et al.* 2009; Hamer *et al.* 2012; Trumbo *et al.* 2012; Scheffers & Paszkowski 2013; Holzer 2014).

In conclusion, the presence of emergent vegetation and edge treatments were consistently reported as important characteristics for predicting amphibian presence when in-pond characteristics were studied. Species preference dictated which combination of shallow littoral shelf, and/or undercuts and borrowing sites were favoured within the waterbody bank.

2.3.4 Terrestrial Habitats and Landscape

In general, urban pond studies have found that the quality of the terrestrial habitats was a greater predictor for amphibian in-pond presence than the in-pond conditions (e.g. Simon *et al.* 2009; Cosentino *et al.* 2014). But this statement is also qualified. Trumbo *et al.* (2012) conducted an extensive study over two years at 103 ponds for nine species with 38 biotic and abiotic environmental variables. They found that “landcover and climate factors may be more influential for species near the edge of their geographic ranges, while local breeding pond factors may be more important for species nearer to the centre of their ranges” (Trumbo *et al.* 2012:1183). Again this highlights the importance of both terrestrial and aquatic habitats. When suitable terrestrial habitats are in abundance, then the amphibians can move more readily through the landscape and select preferable conditions at the pond level, but when suitable conditions at the landscape scale are limited, then amphibians will seek out better terrestrial conditions at the expense of pond quality. Logically, it follows that in highly altered landscapes such as are found in urban environments, the landscape level characteristics are better predictors for species presence, than individual pond characteristics. This is supported by Trumbo *et al.* (2012) findings which suggest that the relative importance of terrestrial habitats depends on the amount of time that different species spend terrestrial.

Species preferences and behavioural responses feature strongly throughout the studies referenced in this thesis. Brown *et al.* (2012) in their review article indicated variations in results depending on the species found in the study areas. For example, preferences for terrestrial habitat reflected species preference for woodland versus grassland (Trumbo *et al.*, 2012). In essence there must be a match between the life-history requirements with both the terrestrial and in-water conditions for a species to be able to thrive in a given area (Brown *et al.* 2012; Trumbo *et al.* 2012). As Shulse *et al.* (2010:925) put it, "True habitat generalists are rare". Accordingly, when planning and designing constructed wetlands, the suitability of water habitats for individual species likely depends on incorporating habitat requirements into wetland plans and considering the placement within landscapes that have characteristics supportive of the individual species preferences (Shulse *et al.*, 2010). The corollary would also hold; that where breeding colonies exist at pond level, the landscaping practices within foraging and migratory ranges can determine whether or not the pond remains active as a breeding facility.

Looking more closely at specific findings where thresholds and metrics were defined the results provide the following characteristic thresholds:

- *tree-cover*, a study in the Baltimore-Washington metropolitan area found that species richness and the occurrence of individual species were positively related to forest cover (at more than 40% coverage). Introducing tree-cover and dense vegetation at restored ponds have been demonstrated to lead to faster colonisation from source wetlands (Rannap, *et al.*, 2009)
- *Vegetation* - dense, moist vegetation was more likely to be used for dispersal in Taiwan than sparse alternatives (Lee *et al.*, 2006)
- *Impervious coverage* - Species richness at pond level, was negatively correlated with impervious land-cover (at more than 20% coverage) (Simon *et al.*, 2009).
- *Developed land* - ponds surrounded by residential land-use supported the greatest numbers of species (Simon *et al.*, 2009). This observation is corroborated by other studies which have found that developed land around wetlands has small, even positive, effects on amphibian species richness distributions after controlling for road effects (Cosentino *et al.*, 2014).
- *Habitat Split* – had only weak effects on species richness or individual species distributions (Cosentino *et al.*, 2014) implying that if the split between desirable habitat was permeable

or contained adequate ecological corridors, then it would not necessarily have a negative impact on amphibian metapopulations.

- *Terrestrial radius of influence* – Predictors for species richness occur at various intervals and may vary spatially. For example, for the same species, tree canopy at 500 m from the pond may be a predictor, whilst at 2 km from the pond, grassland correlates (Goldberg & Waits, 2009). Overall, predictors for species presence at pond level were found in terrestrial habitats at radii from 30 m (pond verge vegetation) to 2 km with peak predictions at 500 m from the pond edge (Nyström *et al.* 2007; Goldberg & Waits 2009; Simon *et al.* 2009; Hartel *et al.* 2010; Smallbone *et al.* 2011; Westgate *et al.* 2015)

2.3.5 Connectivity and Landscape Permeability

The influence of landscape-level factors also includes connectivity, permeability and fragmentation. Four aspects of the above are discussed within the literature reviewed. These can be summarised as: i. Matrix of ponds or the pattern of ponds dispersed through the landscape (Shulse *et al.*, 2010; Ribeiro *et al.*, 2011); ii. Functional connectivity (Birx-Raybuck *et al.* 2010;); iii Physical barriers and roads (e.g. Löfvenhaft *et al.* 2004; Garcia-Gonzalez *et al.* 2012; Chang *et al.* 2014; Cosentino *et al.* 2014) and iv. Behaviour. More attention is given here to the discussion of roads and landscape-level permeability as there are additional factors that add complexity.

2.3.5.1 Matrix of ponds

Shulse *et al.* (2010:928) stress the importance of a network of ponds in creating resilience in metapopulations. "Nearby wetlands allow for movement between breeding sites, re-colonization following local extinctions and 'stepping stones' during dispersal." To begin to understand the relative importance of each pond within a network in a natural landscape, Ribeiro *et al.* (2011) weighted the relative importance of the ponds in their study by systematically removing each one from a model to determine the effect of the individual waterbody on species richness. Their results found that in a relatively undisturbed landscape, the ponds at the centre of the networks had the greatest significance, however they caution that their results may not be valid if the model is tested in a less permeable landscape.

Whilst some studies have corroborated their findings of pond connectivity, for example establishing a relationship between distance from riparian zones and species richness (Birx-Raybuck, *et al.*, 2010), there have also been studies that demonstrate that pond/wetland connectivity may be most significant to species that use waterways for dispersal. For example (Hamer, *et al.,* 2012) modelled the predictors for seven species in Melbourne and found that only one of them correlated positively with aquatic connectivity within 1000 m radius from the site (measuring and recording the total length of drainage lines) and concluded that smaller ponds could be important in maintaining landscape connectivity, "Because they reduce distances between wetlands… and may assist in the dispersal of [species which use water for dispersal]" (Hamer *et al.* 2012:463).

2.3.5.2 Functional Connectivity

The distinction must be made between structural connectivity and functional connectivity, where the former is based on the characteristics of the landscape without considering the behavioural response of the organism. The behavioural responses are, however, what is relevant to functional connectivity (Ribeiro *et al.*, 2011). Peterson *et al.* (2013) suggest that connectivity within urban landscapes needs to be more deeply explored in order to expand the understanding of how species move through altered environments and respond to barriers so that more informed conservation decisions can be made for both the assistance of dispersal and the control of invasive species where required (Peterson *et al.*, 2013).

2.3.5.3 Physical Barriers and Roads

Roads are widely acknowledged as a contributor to amphibian population decline and mitigation measures often feature in road planning and design (Schmidt & Zumbach, 2008). Citizen science involvement at 1617 sampling sites in North America has established that amphibian species richness and individual species distributions are consistently constrained by both road density and traffic volume (Cosentino *et al.*, 2014). Ponds surrounded by highways support the fewest species whilst road density at 50 m – 1000 m from ponds correlates with nutrient levels in the water (Simon *et al.*, 2009), indicating that both road mortality and pollution play a role in limiting urban populations.

A study that mapped amphibian population decline after urban development in Sweden noted that the effects of road development may be underestimated as the full effects on local populations are only seen several decades after the development of roads which indicated that estimates of the impact of roads may be conservative (Löfvenhaft, *et al.*, 2004). Having said that, other research has determined that whether or not road mortality contributes to the decline of a population depends on a number of factors, namely species migration patterns and diel activity, traffic intensity and peak periods (or distribution over the day), species behaviour when entering the road reserve or attempting a crossing (species velocity), and relative pond isolation (Hels & Buchwald 2001; Mazerolle 2004; Schmidt & Zumbach 2008; Bouchard *et al.* 2009; Chang *et al.* 2014).

Research has tended to focus on mortality rates during annual migration from winter hibernation locations to pond breeding habitats because of the concentration of movement both temporally and spatially. Mass migrations of pond breeding species tend to occur in springtime from over-wintering habitats during which time-intensive crossing corridors can be as narrow as 100 m which has made studying mortality during the migration particularly feasible. (Schmidt & Zumbach, 2008). Unfortunately dispersion of juvenile amphibians is less widely studied due to the unpredictability of dispersal migration patterns to summer habitats thus the behavioural patterns of juveniles are identified as a gap in several sources of literature (Schmidt & Zumbach 2008; Woltz *et al.* 2008; Bouchard *et al.* 2009). It is worth noting that species that do not migrate from wintering sites to breeding ponds and then to summer habitats are suggested by theory to be at lower risk of road mortality (Bouchard *et al.*, 2009). A study of stormwater ponds in France, found that ponds within 50 m of a highway estimated with traffic of over 8000 vehicles per day, had significant breeding populations and concluded that even “highway ponds may contribute in altered landscapes to the biodiversity of the pond network at a regional scale” (Le Viol *et al.* 2012:146).

2.3.5.4 Behaviour

Given widespread acknowledgment of the impact of roads on amphibian populations, mitigation interventions have often featured in road planning design (Schmidt & Zumbach, 2008). Common forms of engineering solutions include combinations of barriers that lead amphibians into an underpass. The height, texture or material and curvature or shape of the barrier have all been analysed against species variances in behaviour as were the characteristics of the tunnel (floor surface, material, diameter, length and diffuse light) in order to determine differences in species responses and preferences (Woltz, *et al.*, 2008). Similarly, species may alter their behaviour when entering the road reserve or attempting to cross a road and thus some species are less likely to succumb to road mortality than others. For example a study of the northern leopard amphibian (*Lithobates pipiens*) found that “amphibians took longer to move near roads with more traffic and that their movement was quickest in areas without roads nearby… All amphibians released near roads attempted to cross the road… [and] on very low traffic roads (10.86 mean vehicles per hour), 94% of amphibians crossed the road successfully.” The study closed by suggesting that slower movement and an inability to avoid roads made this particular species vulnerable to road mortality (Bouchard *et al.*, 2009).

Understanding behavioural responses is important for another reason. If an assisted crossing intervention is implemented, then it should not present a barrier which prevents crossing the road altogether to the breeding pond. In other words, designers of an assisted crossing intervention must ensure that it will be used by the target species and not present a total barrier to crossing. The results of 100% survival and 0% successful breeding would be extirpation (Bouchard *et al.*, 2009). It is important to ensure that the design of the mitigation intervention adopted will render the desired result, that is that there will be low mortality and that the amphibians will manage to reach the breeding pond successfully (Gibbs & Shriver 2005; Schmidt & Zumbach 2008; Woltz *et al.* 2008).

2.3.5.5 Traffic Intensity and Mortality Rates

Considering that there are differences in species behaviour, diel activity and migratory requirements, it follows that the results of the studies that explore the relationship between road traffic volumes and mortality rates vary significantly and indicate population losses of between 30% and 100% for similar traffic volumes (Löfvenhaft, *et al.*, 2004).

Perhaps the most revealing study on species differences was conducted over an eight year period on a 20 km stretch of secondary road in a national park in eastern Canada. Live amphibians were captured, counted, identified and released on the side of the road they were heading toward. Dead frogs were collected and counted and this was correlated with variations in traffic intensity (5—26 vehicles/hr). The results for American toads (*Anaxyrus americanus*) demonstrated increased mortality with greater traffic intensity, but the greatest number of ranid frogs (*Lithobates clamitans, L. pipiens, and L. sylvatica*) deaths were correlated with medium intensity traffic (10–18 vehicles/hr) and the greatest number of amphibians moving on the roads. This contrasted with results for the spring peeper (*Pseudacris crucifer*) for which mortality increased with lower traffic intensity and finally, ambystomatid salamanders (*Ambystoma laterale* and *A. maculatum*) showed no correlation between road mortality rates and traffic intensity (Mazerolle, 2004). Mazerolle (2004) attributed these differences to the responses in behaviour that different species had when entering the road reserve such as slowing movement and whether they chose to attempt a crossing or not.

The results bare some optimism for the ability of suburban areas with lower traffic intensity to support some species of amphibians, providing the surrounding landscape is also supportive, but even at the upper end of the intensity of this study the traffic intensity is still relatively low in terms of the spectrum that can be expected in an urban environment. The results of studies for higher intensity roads have been consistent, with for example, mortality rates of 89–98% on highways (approximately 15 000 vehicles/day) (Hels & Buchwald, 2001).

2.3.6 Discussion of Significance for Urban Gardens

This section discusses the opportunities and constraints associated with residential gardens within an urban context. The urban fabric is characterised by a patchwork of privately owned units, where residential units make up one type of privately owned patch within the matrix. Cameron *et al.* (2012:192) define the urban domestic garden as "the area adjacent to a domestic dwelling, which itself is either privately owned or rented. A key element is that the resident/s have autonomy over the garden, albeit they may wish to delegate responsibility to others". The autonomy, small patch size, altered land-cover and independence of garden practices make up some of the reasons that the impacts and potentials for conservation within the urban fabric have been largely ignored or discounted by conservation efforts to date.

The changes to land-cover that occur during urbanisation affect a myriad of species and ecological processes, and in most instances, this has been a negative impact (Ikin *et al.*, 2015). However, evidence suggests that threatened species are finding habitat in the novel ecosystems within urban settings. In Australia, a study of 90 cities found that the urban environments supported 30% more threatened species than comparative natural environments, with better representation of faunal species than flora (Ives *et al.*, 2015). That amphibians are migratory herpetofauna, and that they are breeding in urban stormwater retention ponds, reservoirs, and dams indicates their presence and the potential for persistent use of urban habitats. Indeed, citizen science has shown that although there are smaller populations in cities, they are not declining faster than rural areas and that "population trajectories are strongly influenced by vegetation provision in both the riparian zone and the wider landscape. Future increases in the extent of urban environments in our study area are likely to negatively impact populations of several amphibian species. However, existing urban areas are unlikely to lose further amphibian species in the medium term" (Westgate *et al.* 2015:1).

When urban gardens are considered as potentially contributing to a conservation network, the associated challenges and opportunities are multi-faceted. First there is the question of fragmentation characterised by garden design and maintenance practices, the popularity of predatory pet-keeping (Ikin *et al.*, 2015) , solid walls presenting relatively impenetrable barriers (Chang, *et al.*, 2014), road mortality (Gibbs & Shriver, 2005), use of chemical fertilizers and pesticides

(Lenhardt *et al.*, 2013; Ikin *et al.*, 2015), paved over surfaces and mowed lawns that compounded render variances in permeability and hospitability at patch scale.

Second, residential areas vary significantly in their contribution to green networks and infrastructure (Pauleit & Breuste, 2013), and residential land-cover can make up significant portions of the urban fabric (Dewaelheyns, *et al.*, 2016). Of interest therefore for further research is the treatment of medium and low-density urban residential gardens and the opportunity to support biodiversity within the patch network by linking to regional objectives for green corridors and remnant patch conservation.

Gardens represent an important opportunity for conservation management (Goddard, *et al.*, 2010; Standish, Hobbs & Miller, 2013) but very little research has been done at the patch level on understanding and unlocking this potential (but see these studies for examples of anthropocentric assessments Gaston *et al.* 2005; Clayton 2007; Goddard *et al.* 2010; Goddard *et al.* 2013). In their review paper on options for ecological restoration within the urban fabric Standish *et al.* (2013) identify four strategies for adoption namely, conservation of nature at the fringes; restoration of remnant patches; management of novel ecosystems; and gardening with iconic species to foster a sense of place. The focus of their discussion is on how to facilitate opportunities for human engagement and connection with nature. To this end the last point, gardening with iconic species, uses natural symbols as a way of underpinning community, belonging and identity as a counter-point to the homogenising effect of urbanisation on local flora and fauna and this could be a useful point of departure for engaging gardeners in altering design and maintenance practices to provide more hospitable habitats for faunal species if they can be viewed as iconic species.

2.3.7 Summary

Brown *et al.* (2012:1) summarise best the habitat requirements of amphibians when they say “Use of… wetlands by individual species [is] driven by aquatic and terrestrial habitat preferences, as well as ability to disperse from source wetlands.” In urban environments the terrestrial habitats are constrained by development, but some of the most promising potential habitats within urban landscapes can be found in residential gardens and public open space (Simon *et al.*, 2009). Therefore it is suggested that the quality and likelihood of species presence can be influenced by garden maintenance practices and design elements (such as water features and ponds, rockeries and structurally analogous shelters), land-cover types (open lawn, impervious, tree-canopy, groundcovers and shrubs), and maintenance practices (mowing, chemical use, amphibian removal).

Research into the individual species requirements for micro-habitats, urban habitat behaviour responses, life-history and preferences would make a valuable contribution to our understanding of amphibian survival potential within urban environments.

2.4 Methodology

In order to understand what brings frogs to a garden, this study was designed to be comparative. It gathers data on the characteristics of garden landscapes in order to directly compare which of the features and maintenance practices produce a favourable garden environment for attracting local amphibian species. It seeks to determine why amphibians would take up residence in one garden and not in a garden next door assuming that the locations are equally accessible at the landscape level. To this end, a targeted approach was adopted that considered only precincts where amphibians were reported as being generally present.

The tools for capturing observations were developed iteratively by considering different points of information. The first pass considered life-history needs and documented possible garden features that would meet these needs. The selection of potentially supportive garden features was based on the combined assessment of the literature, field-guides, and popular internet websites. This has been documented in Table 2.1 and provides a framework informing the selection of observations within the gardens.

Table 2.1 Framework informing the development of observation tools.

Aspects contributing to frog presence		Indicator / garden feature	Variable
Accessibility		Boundary Treatment	Permeability %
Food		Compost heap Leaf Litter Mulch Undergrowth Density Rock/Wood piles	Presence/absence Presence/absence Presence/absence Categorical scale
Shelter	From sun	Tree canopy Shrubbery Decks	Area Area Presence/absence

	From predators	Undergrowth density Pot plants Rock/ wood piles	Categorical scale Presence/absence Presence/absence
	Aestivation	Soil conditions Rock piles	Soil profile Presence/absence
Breeding / respite	Water	Ponds	Presence/absence
Ecological quality	Process-based	Maintenance Practices	Maintenance Intensity Score
	Major disturbance	Age of building Length of residency	Years (continuous)

Soil profiling as an indicator of burrowing species requirements was abandoned because the majority of the sample reported species that were generalists and whose distribution was not correlated with a specific soil type.

The surveys were administered by the researcher so that qualitative observations could be made in the field and so that the measurement tools could be fine-tuned in the field. Photographs were used so that themes and indicators could be revisited without having to return to the study sites.

2.4.1 Popular Media Suggestions for Stewardship

No modern public communication strategy is complete without a digital or web-based component, but whilst popular media is a powerful tool for reaching the general public it is also rife with mis-information and incomplete information. For those biophiles with a preference towards amphibians who wish to attract them to their gardens, information has already been made available on popular media sites explaining how to make a frog-friendly garden. Therefore when designing this study, a review of popular media recommendations was incorporated into the development of the observation tools. Table 2.2 documents the findings of the popular media scan. These suggestions were worked into the assessment tools used for observations of the garden in order to assess the accuracy of their claims.

Table 2.2. Summary of recommendations for designing frog-friendly gardens as found on blogs and popular websites (accessed 7/12/2015).

Source	nationality	Pond	Submergent plants	Emergent plants	Compost heap	Log piles & rockeries	Bog garden	Small water feature	Border plants	Native plants	Planting cues from larger wetland	Long Grass / dence groundcovers	Vegetation variety	Flowering Plants	Wintering Sites	Decking / platforms	Mulch beds/ leaf litter	Outside light	Eliminate chemicals	Garden wall holes	Web Address
Count		22	4	7	7	13	3	1	10	7	1	5	6	1	6	2	4	5	2	1	
% of total		81%	15%	26%	26%	48%	11%	4%	37%	26%	4%	19%	22%	4%	22%	7%	15%	19%	7%	4%	
Wikihow	?	1			1												1				www.wikihow.com/Attract-Frog
Flora for Fauna	AU	1		1						1		1					1				www.floraforfauna.com.au
Domain	AU	1				1							1					1			https://www.domain.com.au/news/frogs-how-to-attract-them-to-your-garden-20131116-2xncw/
Perth Zoo	AU	1				1				1											http://perthzoo.wa.gov.au/animals-plants/fauna-friendly-gardens/frog-friendly-garden/
Logan	AU	1							1	1											http://www.logan.qld.gov.au/environment-water-and-waste/wildlife/wildlife-friendly-backyards
Australian Government	AU	1							1	1			1								https://www.environment.gov.au/biodiversity/threatened/publications/factsheet-australian-frogs
Australian Associatio nof Bush	AU		1	1																	http://www.aabr.org.au/frog-friendly-native-pond-and-bog-plants-of-the-sydney-basin/
Sustainable Gardening Austral	AU						1						1				1				http://www.sgaonline.org.au/frog-ponds/
Burke's Backyard	AU	1		1	1	1												1			http://www.burkesbackyard.com.au/fact-sheets/pets/pets-pet-care-native-animals/building-a-frog-pond/
Froglife.org	UK	1			1	1	1	1				1	1		1	1					www.froglife.org/info-advice/frogs-toads-in-my-garden
Th Guardian	UK																				http://www.theguardian.com/environment/2008/jan/09/wildlife.conservation
ARG UK	UK																				
Wildlife gardener	UK	1			1	1				1	1		1				1				www.wildlifegardener.co.uk/encouraging-toads-garden.html&www.wildlifegardener.co.uk/attractingFrogsToYour
ARC Trust	UK	1				1			1			1									www.arc-trust.org
National Wildlife Federation	UK	1													1						www.nwf.org
Royal Horticultural Society	UK	1			1	1															https://www.rhs.org.uk/advice/profile?pid=493
The Kids Garden	UK	1				1	1		1												http://www.thekidsgarden.co.uk/how-create-frog-friendly-pond.html
Suffolk Wildlife Trust	UK	1			1	1							1								http://www.suffolkwildlifetrust.org/attracting-amphibians
Save the Frogs	USA	1																			www.savethegrogs.com/wetlands
Eco Living advice	USA	1	1						1					1							http://www.ecolivingadvice.com/attracting-frogs-to-your-garden/
Gardening Know How	USA	1													1				1		https://www.gardeningknowhow.com/garden-how-to/beneficial/attracting-frogs-to-garden.htm
Grow a Good Life	USA	1													1				1		https://growagoodlife.com/frogs-and-toads/
North Carolina Wildlife	USA	1		1		1			1	1					1						http://www.ncwildlife.org/Portals/0/Conserving/documents/InvitingReptilestoYourBackyard.pdf
Gardening at Leisure	ZA	1	1	1		1			1			1						1			www.gardeningatleisure.co.za/gardening-for-frogs-2
IOL News	ZA	1	1	1		1			1			1			1	1		1			http://www.iol.co.za/lifestyle/home-garden/garden/gardening-for-frogs-1.1276849#.VmWQS3YrLIU
Eco Man Durban	ZA	1		1					1	1											http://ecomandurban.blogspot.co.za/2014/02/attracting-frogs-to-your-proudly-south.html
Western Leopard Toad	ZA				1	1			1									1		1	http://www.leopardtoad.co.za/toadfriendly_garden.html

2.5 Methods

Each garden was visited and photographed. Wildlife resources, maintenance intensity, boundary treatment and basic household composition were documented on site with the household representative. The tool used to record these factors was developed by combining and adapting Goddard *et al.*'s (2010) Wildlife Resources Index with Beumer and Martens' (2014) Biodiversity In My Backyard (BIMBY) Framework. The tool was adapted using the descriptions of the habitat preferences found in frog field-guides (Channing, 2001; Minter *et al.*, 2004; du Preez *et al.,* 2009) and the claims made in popular media websites for attracting amphibians to the garden (Table 2.2). After initial testing, some of the metrics from the BIMBY framework were adjusted to account for maintenance routines that were neither weekly nor monthly at 1-3 times per week and 1-2 times per month. The resulting tool is reproduced below in Table 2.3.

Landscape characteristics that were visible from aerial view such as tree canopy, dwelling and erf size were measured using the City of Cape Town's GIS powered eMap and ground-truthed on site, whilst those aspects below tree canopies (e.g. lawns and impervious paving) were paced out and estimated on site.

The photographs (figures 2.2 and 2.3) afforded a record to return to and consider qualitative themes that were not captured on the survey form. Gardens were classified for the presence of dense vegetation beds that were post-coded according to density at ground level on a three point scale where 1 = barren, 2 = moderate, 3 = dense.

2.5.1 Sampling

In order to solicit participants in the study, a notice was put up on social media local community groups. The notice stressed that I was looking for both gardens with amphibians and those without. The study area has several active community organisations including three "friends of groups" for the Rondebosch Common, Rosebank Green, and Liesbeek River. There are two neighbourhood watch groups, a civic organisation and two improvement district special levy zones. In addition to the social media posts, an email was distributed in the local neighbourhood watch newsletters, to members of the Civic Association and to members of the Observatory City Improvement District (OBSID). The communication briefly explained the research and asked two questions, namely if residents had amphibians in their gardens and also if they would be willing to grant access to their gardens for the purposes of research.

Table 2.3. Survey sheet used to record habitat observations in residential gardens

				Block Group:	
	Section A - Property Details			Respondent No:	
	Contact Details	Name		Ph:	
	Address				
	Frogs Reported?	Yes/No		List species if known	
	Size of property (m2)				
	Size of House				
	Remainder (landscaping)				
	Approx. Age of main building		yrs		
	Section B - Household Composition				
1	Length of residency		yrs		
3	Person responsible for management of the garden's highest level of education achieved?				
			0	1	2	3
			Primary	High	dipl/ deg.	post-grad
4	Do you have children which live with you?		0	1	2	3
			No	Toddlers	Children	Teens
	State how many					
5	how many cats and dogs do you own?					
		1	2	3	more than 3	
	Cats	☐	☐	☐	☐	
	Dogs	☐	☐	☐	☐	

	Section C - Maintenance Practices					
5	On Average, how frequently do you (or your gardener) undertake the following gardening activities in the summer months?					
		Never	Less than monthly	1-2 times per month	1-3 times per week	Daily
		0	1	2	3	4
	Mowing the lawn	☐	☐	☐	☐	☐
	Dead-heading flowers	☐	☐	☐	☐	☐
	Weeding	☐	☐	☐	☐	☐
	Applying chemical fertilisers	☐	☐	☐	☐	☐
	Applying pesticides / herbicides	☐	☐	☐	☐	☐
	Watering the lawn or plants	☐	☐	☐	☐	☐

	Section D - Wildlife Resources				
	Which of the following habitat resources are present on the site? Circle 1 if present and 0 if absent. Note the approximate percentage of the garden given over to each soft-landscaping				
			(circle)	**Estimated area m2**	**Estimated % of cover**
1	Pond / bog garden		yes / no		
2	Fish in pond?		yes / no		
3	Reeds/ emergent vegetation in pond?		yes / no		
4	Compost heap		yes / no		
5	Log Pile / rockery		yes / no		
6	Flowering plants		yes / no		
7	Predominantly Native Plants		yes / no		
8	Shrubs		yes / no		
				(Canopy area)	
9	Trees >4m height		yes / no		
10	Ground covers >15mm height		yes / no		
11	Man-made damp hiding structures… Decks, suspended floors, basement,		yes / no		
12	Mulch beds / leaf litter		yes / no		
13	Irrigation system		yes / no		
		TOTAL SCORE			

Section E - Boundary Permeability

		1	2	3	4
1	Types of Boundaries (pallisade/ brick/ vibercrete/ wire/ hedge)				
2	Permeability (open spaces as percentage of boundary)				
3	Shared/ road-facing				
4	General Notes on entry points				
4	Photograph Reference				

Section F - Non-resources

1 Indicate the approximate percentage of landscaped area given over to this cover type.

	Approx area	Approx % landscape Cover
Impervious paving		
Lawn		
Swimming pool presence?	0/1	

Section H - General Remarks

Initial responses rendered 35 gardens which were mapped to determine where amphibians were present and absent and were grouped together in precincts to ensure that gardens that had no amphibians were within areas that generally had amphibians so that the characteristics for reported absence were directly comparable with the characteristics for reported presence. This was to ensure that gardens had similar location characteristics and that amphibians were not absent due to colonisation patterns associated with broader landscape scales. Respondents with frogs in their gardens were asked to email a photograph of the frog from their garden or a sound recording of the call in order to identify them. Where possible, tadpoles and live animals were observed on location to confirm identification. A series of informal questions about call, behaviour and size provided an indication of the most likely species where live animals could not be directly observed at the time of visiting or through recorded media.

On the streets that boasted high presence and volunteer response rates, a letter drop was done in order to have a greater number of comparable gardens, specifically to increase the size of the "frog absent" sample. Finally, a snowballing technique was used so that when surveying a volunteer's garden, they were asked for the contact details of their direct neighbours and if they could make an introduction. This rendered the final sample size of 50 gardens.

2.5.2 Ethics

The relevant ethical clearance was sought and granted by the University of Cape Town for this study. The research conducted required that I and an assistant gain access to people's private residences and photograph and document same. Volunteers were made aware of the aims of the project and the activities we undertook on their property through an introductory letter. Signed consent was sought for access to properties. Respondents were given the opportunity to withhold permission for use of images in reports or publications. Attention was drawn to the right to withdraw participation at any time. Anonymity was guaranteed. No identifying features of properties such as street numbers, house names or full street elevations are in any report material. No respondent names are included in the reporting. Any example narratives are quoted using respondent numbers as a reference only.

The City of Cape Town Invasion Biology Unit (CoCT IBU) has made me aware of their work with guttural toads (*S. gutturalis)*, painted reed frogs (*H. marmoratus)* and some concerns about raucous toads (*S. capensis)* within the area. If I found these on properties, the respondents were given a letter indicating that they may be harbouring an invasive species and requesting they make contact with CoCT IBU. No respondent contact details were shared with a third party.

2.5.3 Analysis

The presence or absence of amphibians in a garden was modelled using a generalised linear model with a logistic link function and the binomial distribution (McCullagh & Nelder, 1989). The maintenance variables such as herbicide use and the habitat characteristic variable such as presence of mulch and ponds were used as explanatory variables. Akaike Information Criterion (AIC) was used as a guide to model selection (McCullagh & Nelder, 1989). The best fitting models had the smallest AIC values and explained the most deviance. AIC penalises models with large numbers of explanatory variables and this was taken into consideration when selecting the models. A model with 4 variables will automatically have a higher AIC than a model with 1 variable for similar levels of fit. For example, a model that explained 60% of the deviance with an AIC of 45 was immediately viewed as a better fit than a model which explained 7% of the deviance with an AIC of 70. The combination of AIC and deviance were considered together for selection purposes. Separate models were then fitted for *A. fuscigula* and *S. grayii* which were the two most commonly recorded species. Probabilities of frog presence were then calculated using the formula p= exp(y)/(1+expy(y)), for selected models based on the AIC interpretation.

2.6 Results

A total of 50 gardens was documented, 22 reporting no amphibians and 28 reporting amphibians. Of those reporting amphibians, five reported western leopard toad (*Sclerophrys pantherinus)*, 16 reported clicking stream frog (*Strongylopus grayii)*, 10 reported cape river frog (*Amietia fuscigula)* and two gardens reported raucous toad (*Sclerophrys capensis*), which I confirmed through the photographic submissions. Tadpole identities were confirmed on location as well as adult animals and / or calls.

The model was built up consecutively starting with individual explanatory variables and then combining them to determine the best fit using AIC as an indication. The results are presented in Table 2.4. Presence of a compost heap, use of herbicide, presence or absence of pond, use of mulch, and use of fertilizer were significant explanatory variables, but each accounted for less than 10% of the deviance explained. The impacts of herbicide use and fertilizer use were negative, but the impacts of the presence of a compost heap, pond, and mulch were positive (see below). The area of the pond explained 16.5% of the deviance, so that the area of a pond contributed more to the explanation of the presence of frogs than the pond, as a binary variable, did. This in part can be explained by the qualitative observation that larger “ponds” in the study set tended to be the constructed wetland component of an eco-pool complete with running water and emergent vegetation.

Table 2.4 Summary of the key steps in the fitting of the generalized linear model relating the presence/absence of frogs to explanatory variables. The table is ordered on the basis of the Akaike information criterion.

Explanatory variables included in model (entered as factor variables unless otherwise stated)	Variables in model	Percentage deviance explained	Akaike information criterion
Overall permeability of boundary (0 to maximum value of 85%, continuous)	1	2.6%	70.2
Number of bricksides (0 to 4, continuous)	1	2.7%	70.2
Compost heap (P/A)	1	5.6%	67.2
Herbicide (two levels – never, used)	1	4.4%	66.3
Pond (P/A)	1	7.6%	65.8
Mulch (P/A)	1	9.8%	64.4
Fertilizer (two levels – never, used)	1	8.9%	63.4
Pond area (0–33 m2, continuous)	1	16.5%	59.9
Vegetation density (three levels – barren, moderate, lush)	2	39.2%	47.4
Vegetation density, compost heap	3	42.8%	46.3
Vegetation density, mulch	3	44.7%	45.0
Vegetation density, compost heap, mulch	4	48.0%	44.8
Vegetation density, compost heap, mulch, pond area	5	51.2%	44.6
Vegetation density, compost heap, mulch, pond area, fertilizer	6	55.3%	43.2
Vegetation density, compost heap, mulch, pond area, fertilizer, herbicide	7	60.0%	42.1
Vegetation density, mulch, pond area, synthesized fertilizer, herbicide	6	60.0	40.1

Vegetation density was represented in three levels (barren/sparse cover, moderate, lush/dense, see Figures 2.2 and 2.3). Vegetation density had the largest positive impact of any of the single explanatory variables, accounting for 39.2% of the deviance. The interesting explanatory variables were combined in various ways, summarized in Table 2.4, and the best model, with both the most deviance explained and also the smallest value for the AIC included vegetation density, presence of mulch, and the area of the pool as variables with positive signs for the estimates of the regression coefficients, and with the use of fertilizer and herbicides having negative signs.

The model produces estimates using the logit transformation of the probability of the presence of frogs. These needed to be back transformed into probabilities to be intuitively understandable. The predicted estimates for each of the explanatory variables in the final model is made using the average values for all other explanatory variables.

For sparse, moderate and dense gardens, the back transformed estimates of the predicted probabilities of the presence of frogs were 0.43, 0.82 and 0.97 respectively. Similarly, the estimate of the probability of the presence of frogs when mulch was used was 0.78, and was 0.69 when absent. When fertilizer was used the estimated probability of presence of frogs was 0.66, and 0.79 when fertilizer was not used. When herbicide was used the probability of presence of frogs was 0.56, and 0.82 when herbicide was not used. For the continuous variable pond area, the prediction was made for ponds absent, and for square ponds with sides of 1, 2, 3 and 4 m (ie areas of 1, 4 and 16 m2). The estimated probabilities of the presence of frogs, with all other variables held at the average values was 0.52, 0.58, 0.77 and 1.00 respectively. These probabilities are displayed visually in Figure 2.1.

In terms of interpreting the ranking of the deviance explained, the density of the vegetation at ground level was the most significant, followed by ponds. Mulch appears to be able to supplement habitats well by providing breeding ground for food and moist refuges. Although these measures contribute to the probability of frog presence, there is no substitute for dense vegetation.

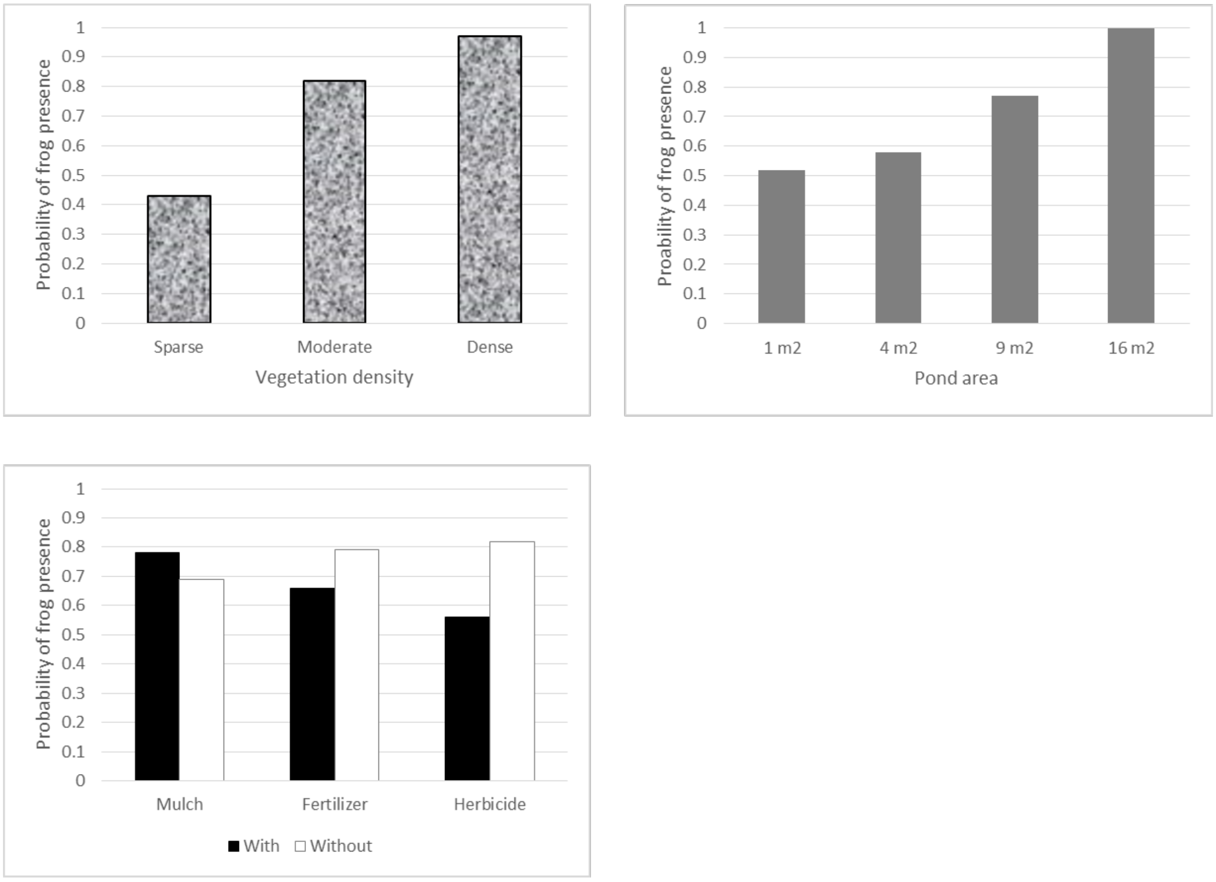

Figure 2.1 Habitat and maintenance characteristics affecting frog presence in gardens

The use of herbicides and pesticides were ranked by frequency. All responses fell into 0 = never used, 1 = less than monthly, 2 = monthly. No respondents reported more frequent applications and those that reported using pesticides, tended to say they did not use them until they were prompted more specifically with “What about snail bait?” Although infrequent, the use thereof had a strongly negative effect on frog presence. Similarly, synthesized fertilizer was normally applied less than monthly, and again, the effect was strongly negative on the probability of amphibians being present.

Qualitative observations were made of the water-bodies where different species were found. *A. fuscigula* were more often associated with water and demonstrated a preference for gardens with a pond of any size and typically took up residence in small fish ponds. *S. grayii* tended to be found in channels and drain lines, sprinkler systems and manifolds and more frequently between pot-plants, however when they were found in ponds, they tended to colonise larger bodies of water and this was reflected in the results from the model.

Figure 2.2 Photographs of gardens where amphibians were reported.

Figure 2.3 Photographs of gardens where there were no amphibians.

The types of boundary treatments observed in the study included timber fences, brick walls, vibracrete, diamond wire fence, palisade fences, and combinations of these. Each property had four sides to consider, which meant there were up to 60 boundary combinations. Notional permeability factors were assigned to each type of boundary according to the amount of open spaces at ground level. After first considering overall permeability, this was cross-checked by using brick walls as a notional measure of isolation of the plot and giving the boundaries a negative score of 1-4 based on the number of sides that were entirely brick. Both assessments accounted for very low explanation of deviance. Boundary permeability was not significant explanatory variable, explaining 2.6% of the deviance in relation to overall permeability, and 2.7% of the deviance in relation to the number of brick sides to the property.

2.7 Discussion

The results show that the amphibians tend to go where their physical needs are met and are consistent with the needs associated with life-history requirements. Mulch provides food sources by attracting invertebrates and other small herpetofauna such as lizards and geckos. Additionally, it is high in organic matter, and holds moisture thereby providing a degree of protection from desiccation whilst the decomposition processes in mulch can produce heat. Dense vegetation at ground level explained the most deviance within the results however the area available did not make a significant difference to the amphibians providing there was adequate cover for them to escape predation. Consequently amphibians were reported in gardens that had at least relatively small areas of dense vegetation such as a path edged with 40 cm wide beds or garden beds as small as 1 m x 2 m, even when the rest of the garden was open paving or well-tended lawn. The attraction and use of dense vegetation is consistent with the descriptions found in field guides for *S. grayii* that are described as calling from dense vegetation (Minter *et. al.,* 2004). However, a number of amphibians in this study were reported in gardens amongst groups of pot plants or under decks where conditions are cool and damp with adequate protection, food and refuge from predation and the cover was structurally similar to beds of vegetation in terms of meeting these needs. Although small areas were able to support frog habitation, it must be noted that only presence was measured and not population size. Further research is required to determine the relationship between area and population size.

Beninde *et al.* (2015) conducted a meta-analysis of biodiversity studies done in 75 cities in all inhabited continents and considered variables which fall on three continua, namely, local versus landscape, abiotic versus biotic and design versus management. The current study did not explore local vs. landscape level variables except to target specific localities where anurans were known to be present and exclude those city blocks where anurans were absent. Across all three variables, Beninde *et al.* (2015) found that those with greatest influences on biodiversity are design factors including corridor and patch area. Although the influencing factor could be taken to be one and the same, there are distinctly different biodiversity responses within corridors that indicate that the contribution they make is different to patches (Beninde, *et al.*, 2015). Of the 11 biotic factors that are significant for species richness, vegetation cover, density and the structure of a subset thereof (herbaceous plants, shrubs or trees) are the most significant factors influencing biodiversity. It is noted that the majority of the studies referenced avifauna and that this would bias the results towards the requirements of birds (Beninde, *et al.*, 2015). The findings of the current research support the importance of herbaceous cover, specifically at ground level but add mulch as a requirement for consideration in future studies of urban biodiversity.

Raking of the beds was not directly measured by this study, however the effects of this maintenance practice were observed in a number of gardens where the ground-level vegetation and mulch had been stripped away from the surface underneath shrubs. In his book on the Principles of Ecological Landscape Design, Beck (2013) discusses the role of competition in vertical and horizontal distribution of space and argues for creating layered plantings or habitats at different heights throughout the tree canopy and understory. Using niche theory and referencing Grime (1997), Beck (2013) explains how different species evolve to occupy mutually exclusive niches within the same eco-system. Beck (2013) proposes creating a mixed garden using plants with different life-history strategies that share resources and occupy different spaces in order to provide a variety of niche habitats for different species. The species present in this study set were all ground creeping as opposed to those that might climb, such as reed frogs and tree frogs with feet adapted for the purpose. Their use of dense vegetation at ground level indicates their use of this niche space whilst other qualitative observations brought to light the more subtle preferences and life-history adaptations of the different species. The more species, the greater the need for structured density.

The exclusive use of ground level vegetation and low statistical influence of tree canopy can be explained by considering the endemic vegetation type of the study area. Peninsula Shale Renosterveld is characterised as scrubby grassland and does not have many trees within it. Looking more regionally at the Fynbos biome, it is dominated by shrubs and bushes (Rebelo *et al.*, 2006). It stands to reason therefore that the amphibians occupying this vegetation type would not be particular about tree canopy. Species with different preferences found in other regions may prefer gardens with different vegetation cover structures (Trumbo *et al.*, 2012). When designing frog-friendly gardens, assessing endemic vegetation types and local species of amphibians would provide insight into the types of covers that may support amphibian presence.

The finding that pesticides and chemical fertilizers had a strong negative effect on frog presence is consistent with the findings of Lenhardt *et al.* (2013), who demonstrated that the use of agricultural pesticides and fertilizers affects landscape level permeability and can isolate metapopulations at the pond (Lenhardt *et al.*, 2013). The product sold as "snail bait" at the local nursery has the active ingredient of metaldehyde. Metaldehyde is fatal to molluscs and toxic to mammals. Consequently poisoning is common among pets and small children. Symptoms include *inter alia* hyperthermia, vomiting, convulsions and tremors (Rumbeiha, 2014). Its toxicity to amphibians however is not well documented and so it is unclear if the reason for avoidance of gardens where pesticide is applied is due to the chemicals or the effect it has on food sources. Both common species of frog present in the study set have a relatively high tolerance to poor quality water (Minter *et al.* 2004), however these species were still evidently negatively affected by the application of fertilizers.

That boundary permeability accounted for so little deviance indicates that anurans are able to move through very small channels in the walls and find routes through penetrations made by pipes, drainage and gaps under vibracrete cracks. During radio-tracking of *Sclerophrys pantherinus,* Measey reported tracking toad movement through the stormwater drainage system (pers. com, 2016). In a few instances where backyards had a house on one side and three brick walls around it without any gates, apparent drainage points or visible wall penetrations, some residents indicated that the cat had introduced the frog, or that tadpoles had been caught and brought to the pond, but there were too few records of this nature to be able to draw any conclusions from them. This study only recorded presence and did not measure population size. The measurement was therefore not sensitive enough to determine if boundary permeability had an influence on population size. Further research would be required to determine what role (if any) boundary permeability (and method of introduction) plays in the size of the population of amphibians present in gardens.

Returning to the initial summary of popular media advice (Figure 2.2), of the 26 sites summarised, the overwhelming majority of websites emphasise pond construction and design with secondary attention given to garden structure. Less than half the sites discussed pond vegetation and fewer still mention mulch. About half the sites make mention of garden plants, but none of them consider the requirement for density and fail to emphasise the need to ensure the presence of protective cover against UV and predation and for the provision of food. This study has demonstrated that a discussion on frog-friendly gardens is incomplete if it does not discuss foraging habitat. Although ponds will likely be visited as seen in Gaston *et al.* (2005), it is unlikely that frogs will take up residence unless the garden habitat requirements are met. On reflection, the information contained in popular media is of mixed quality. 23 of the 26 websites assessed focused predominantly on ponds, eight discuss pond vegetation, and ten include some recommendations for border plants. Eight of the sites mention compost heaps and 14 of them suggest log-piles or rockeries, neither of which were significant in this study. Of those that discuss garden landscaping, only five mention dense groundcovers and long grass, whilst the remainder recommend a variety planting schemes including *inter alia* planting native species, flowers or trees. The results indicate that following popular media advice would be hit-and-miss as to whether it would result in attracting resident amphibians.

2.7.1 Limitations

Amphibian habitation is a dynamic process and although the presence of a frog in a given area can be determined with certainty, confirming absence is more difficult. The results will be somewhat biased towards the conspicuous calling of mate-searching males. Having said that, many of the gardens provided cases of frog presence where the individuals were not calling, but were found in the mulch, drowned in the pool, hopped into the house of their own accord or were brought in by the cat. A second bias is that the likelihood of finding frogs in the garden will be proportional to the amount of time that the individual spends working in the garden. In order to mitigate this bias, the researcher sought to conduct interviews and presence assessments with the person who regularly tended the garden as far as was possible. As female amphibians do not call, solitary males are more likely to be recorded than females. This means that it is likely that there are possible false negatives within the study set, that the data is skewed towards calling habitat as well as properties with more active gardeners or individuals who spend time in the garden at night, when frogs are most active. The small size of the study limited the ability to draw statistical conclusions, especially from the less commonly recorded species within the study set.

2.8 Conclusion

The two most common species (*A. fuscigula* and *S. grayii)* within the study are abundant and appear to be urban adaptors. The demonstrated sensitivity to urban stressors and requirement for minimum habitat conditions to be met implies that they are not urban exploiters and that their habitat preferences can provide valuable insights into the requirements of other frog species more generally. The evidence clearly suggests that *A. fuscigula, S. grayii, S. capensis, S. pantherinus,* and *V.*

angusticeps are attracted to gardens with dense vegetation at ground level. In gardens with only moderately dense undergrowth, or reduced coverage, then the addition of mulch contributes significantly to the attractiveness of the garden to amphibians. Similarly, in gardens with moderately dense cover, the negative impact of chemical applications are most significant. The findings confirm that amphibians forage where their needs for food and cover are met and that ponds play an important role but are not the strongest predictor of frog presence / absence in a garden setting. This is in direct contradiction to most of the information available through popular media websites.

3

PREFERENCES TOWARDS AMPHIBIANS IN HOMES AND GARDENS, CAPE TOWN

3.1 Introduction

It is predicted that global urban land cover will triple between 2000 and 2030 and it is estimated that urban human populations will increase from 3.5 billion to 5 billion (Hahs & Evans, 2015). The places where humans are most densely located, are also the sites where human actions have direct impacts on the environment and are the reasons why, until recently, urban ecosystems have been shunned as depauperate and valueless (Corbyn, 2010). Yet, urban environments are characterised by novel ecosystems that have demonstrated ability to support biodiversity and provide sanctuary for threatened species (Ives *et al.*, 2015). Emerging research describing novel ecosystems is questioning the assumption that urban-generated eco-systems are valueless and suggesting they are instead deserving of research attention in order to understand how species are responding and what systemic dynamics are at play (Marris, 2009; Corbyn, 2010).

Turning specifically to amphibians in non-natural environments, it has been established that artificial aquatic structures are used as effectively by anuran (tail-less amphibians including frogs and toads) species for breeding, with comparable species abundance and diversity to natural waterbodies (Le Viol *et al.*, 2012; Holzer, 2014; Romano *et al.*, 2014). A citizen science study conducted in the USA that measured amphibian declines in urban populations and compared the results to data from wild ecosystems, concluded that although populations in urban environments were generally smaller, older areas where development had stabilized were not declining at faster rates than populations in natural habitats concluding with recommendations for “the revegetation of urban wetlands to facilitate the re-expansion of urban sensitive species” (Westgate *et al.* 2015:1). Additionally residential gardens have been shown to provide adequate terrestrial habitats for amphibian populations (Cosentino *et al.*, 2014). Cosentino *et al.* (2014:1) note that “developed land around wetlands had small, or even positive effects on anuran species richness and distributions after controlling for road effects” thereby offering potential spaces for supporting remnant patch ecology as part of conservation strategies (Salako *et al.*, 2013).

How successfully residential gardens can contribute to a patchwork that collectively make up a biodiverse ecosystem, depends on the management practices of the residents responsible for the care of the gardens and is subject to the forces that govern human and social behaviour. These forces include social factors such as norms; individual factors such as preferences and values; and demographics such as age, education and tenure (Knight 2008; Goddard *et al.,* 2013a; Melendez-Ackerman *et al.,* 2014; Belaire *et al.,* 2015). Dewaelheyns *et al.* (2016) describe the aggregation of gardens as small units that collectively make up a large area and suggest an approach that gives credence to "the tyranny of small decisions." (Dewaelheyns *et al.,* 2016:1) and the collective contribution that small actions across scale by multiple parties can make (ibid.) Understanding the social forces that influence individual actions on residential gardens can therefore provide important indicators for ways of facilitating change to better ecological management practices.

3.2 Research Aims:

The aim of this study is to understand why people would be motivated to protect and conserve amphibians or to harm them.

Objectives:

1. To understand differences and drivers for people's attitudes and preferences towards amphibians in the study area.
2. To establish the role of life-experiences as an informant of attitudes towards amphibians.
3. To explore shifts in attitude across dimensions of the preference ladder.

3.3 Literature Study

After acknowledging the relevance of gardens as a component of conservation strategy (Goddard, *et al.*, 2010), the need to engage with residents becomes paramount. It is at this level that humans are most directly associated with the shape and form of the natural environment and the management practices that are carried out over time. If gardens are to become part of an active conservation management strategy, the first step is to understand the drivers that shape the ways in which people engage with nature in their immediate surroundings and the benefits (ecosystem services) that they seek to derive from these gardens. It becomes a question of how people actualise the resources presented by a garden, how they derive meaning from their interactions there, and what motivates them to make changes to their autonomous natural surroundings. In this way, one can see that it is not simply a matter disseminating information on best practice for biodiversity but determining what the priorities for a specific group are where the points of wildlife-human conflict may lie and how biodiversity management may fit into that picture. The following text explores the findings of studies that describe the social aspects governing garden choices and behaviour and then describes the relationships between animals, gardens and people.

Urbanised nature is as much shaped by social processes as it is by ecological processes. Figure 3.2. has been synthesised from a range of sources in order to map out the pyramid of influence on garden form (Clayton 2007; Larson *et al.,* 2009; Nassauer *et al.,* 2009; Martini *et al.,* 2014; Beumer & Martens, 2014). The details of this framework are unpacked below.

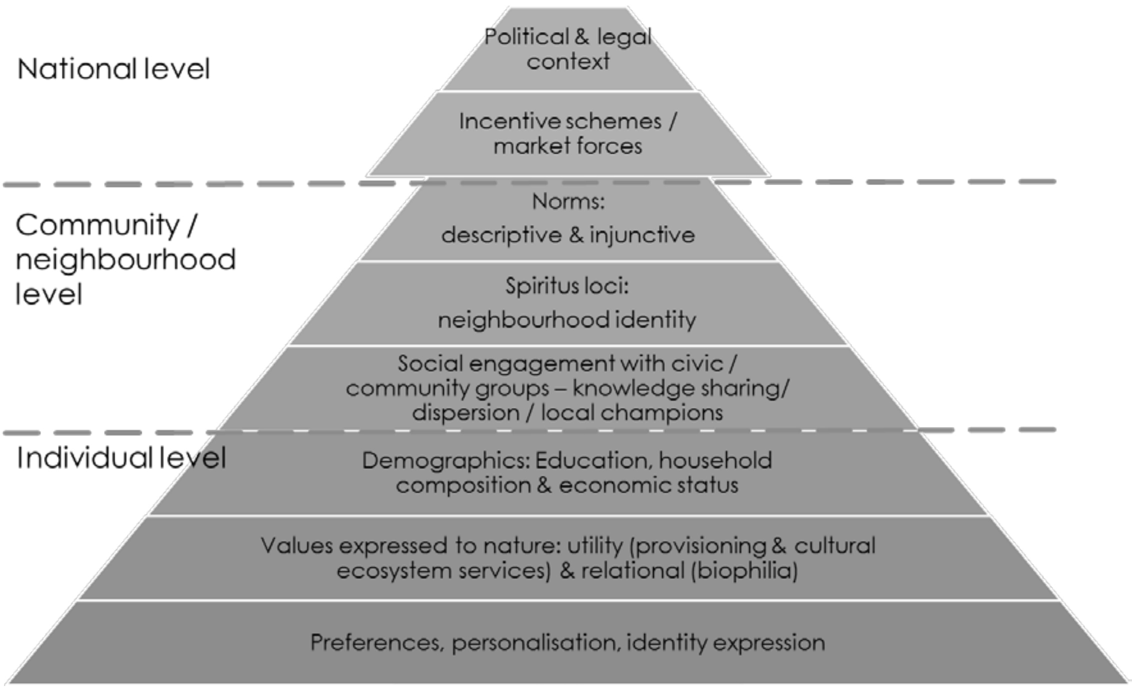

Figure 3.1 Pyramid of influence - social drivers for yard choices.

3.3.1 Norms

To begin with, there are patterns within society that determine social acceptability and are based in a general set of preferences that are perceived to be acceptable at the neighbourhood level. Nassauer *et al.* (2009) explored how homeowners' preferences for their own yards were affected by the design of nearby yards. They found that when asked to rank preferred garden designs "the rank of the most conventional and most ecologically beneficial front yard designs were reversed depending upon the design of nearby neighbours' yards". In other words whether people liked ecologically designed gardens in the front yard, depended on what people generally did in the neighbourhood and the perceived social acceptability of the design.

Uren *et al.* (2015) explored the themes that made up a set of norms in Fremantle, Australia. They used Causal Layer Analysis (CLA) which requires the researcher to identify themes according to four different layers of understanding, namely *litany layer, systemic causes layer, worldview layer, myth/metaphor layer*. For the purposes of this discussion, only the *litany layer* and *systemic causes layer* findings are presented.

At the *litany layer* consisting of the uncontested truth of an issue, they identified *functionality of native vegetation.* The suitability of native varietals to the local environmental conditions and associated low maintenance costs were commonly acknowledged as beneficial. At the *systemic causes layer,* researchers must identify the social, institutional and contextual drivers that appear to influence an issue or topic, the themes described were *local cultural practices* and *local social norms* which correlate with the results of the Nassauer *et al.* (2009) study mentioned above. The local cultural practices of the neighbourhood included community activities that supported ecological gardening, including gardening clubs, street tree planting days and involvement in environmental education programmes. In addition the government offered free mulch and rebates on local native plants from a local nursery. The results suggested "that co-operation between members of the community as well as the influence of governing bodies are important in order to drive ecological gardening practices… notably, these sorts of initiatives were not perceived as radical or exceptional on the part of participants, but rather they were part of the broader holistic culture of the Fremantle community" (Uren *et al.,* 2015:80).

Local social norms were arranged into *Descriptive norms* and *Injunctive norms.* Descriptive norms are driven by what people think others are doing. In this case, participants had noticed the rise of native gardens and described being "inspired by a neighbouring garden design" (Uren *et al.,* 2015:80).

Respondents noticed a flow-on effect of how their designs were influenced by the designs of their neighbours by opting to extend or complement the designs that were installed in neighbouring front yards. This phenomenon is described as "spatial contagion" and is driven by social processes (Zmyslony & Gagnon, 1998). Larson (2009) adds that front yards are more likely to be maintained to impress the neighbours or meet neighbourhood expectations than back yards where self-expression is managed as a personal "'dreamscape' designed for private leisure" (Larson 2009:924).

Injunctive norms are characterised by what people believe others will approve of. In Freemantle, where ecological gardening was endorsed by the neighbours, it found its way into street-side gardens (Uren, *et al.*, 2015), which form part of the semi-public space. Elsewhere where the results of ecological practices were seen as unkempt, opportunities for ecological gardening were constrained to the backyard and where individual values take precedence over injunctive norms (Goddard, *et al.*, 2013), this is supported by Belaire *et al.* (2015) who found that greater biodiversity was provided by backyards than in front yards where front yards were more susceptible to norms. In Goddard *et al.* (2013), this result was corroborated by the belief that householders had a duty to maintain neighbourhood standards. This was supported by the notion that compliance with the injunctive norm had financial consequences as it affected property values thus neighbourhood standards were actively enforced at the street level. Uren *et al.* (2015) found that when neighbourhood norms conflict with broader social norms, neighbourhood norms were a more powerful driver of landscaping and suggested that descriptive norms motivated behaviour in the immediate observable context, but that injunctive norms motivated behaviour across a variety of conditions.

3.3.2 Values

A second theme emerging in the literature which appears to affect individual usage and spatial arrangement choices are the values that are satisfied through the use and engagement within a garden. It relates closely to ecosystem services and reflects the ways in which people actualise the opportunities presented by a private garden. A study in Dunedin (Freeman *et al.*, 2012) visited 55 gardens in order to explore householders' relationships with their garden. Respondents were asked to identify 10 features in the garden that were important to them and explain the meaning behind them. The results were analysed thematically and provided insight into what people value about their gardens as follows:

- *Health* was expressed in terms of de-stressing, psychological well-being, sense of purpose and a space for physical rehabilitation after injury or illness.

- *Refuge* was expressed as a counterpoint to work-stress an oasis from city life and retreat from family.
- *Identity* was expressed by the importance of personalization, the ability to express and take pride in the ways in which the garden had been developed over time and the ongoing process of creation.
- *A Duty to Care* was expressed as a feeling of responsibility for nature and a broader environmental stewardship, "Gardens were seen as a means for learning to care about life." (Freeman *et al.* 2012:140).
- *Social relationships* are supported through the time spent engaging socially with others in the garden space, or engaging with neighbours, community members and even clubs over a shared interest.
- *Productivity* related to the provision of food, but the reasons for growing food varied from connecting with the earth, to a distrust in commercial farming practices to provision of food out of financial necessity.
- *Connection with Nature* reflects the biophilia hypothesis of an innate tendency to focus on life and lifelike processes. Although more direct references were made, "feeding birds, planting and watching things grow were more commonly expressed ways of connecting with nature." (Freeman *et al.,* 2012:141)

These results corroborate an earlier study by Clayton (2007) which identified aesthetics, stress relief/ mood, exercise, provisioning, socialising, and connection to nature as themes of importance. With the exception of productivity, the rest of the values fall into the class of cultural eco-system services (Beumer & Martens, 2014) and although some vegetable growers are doing so strictly for the provisioning benefit, many of the respondents in the Freeman *et al.* (2012) study expressed their motivations for vegetable gardening in terms of cultural services such as education and biophilia which was characterised as a desire to connect with nature and an affiliation or love of nature that supported a green-living identity.

A study in Beijing explored spatial and economic relationships between vegetable gardening and ornamental gardening and found that the choice between the two was directly related to economic standing and access to markets. Those with higher income and access to quality food markets selected ornamental plant types, whilst those in peri-urban, impoverished areas tended towards vegetable gardening. The study concluded that gardening choices in Beijing were made on the basis of a hierarchy of needs (Clarke *et al.*, 2014). This suggests that there are differences in the ways in which values can be realised or expressed that can be plotted as a set of continua and trade-offs.

The outcomes demonstrated in Beijing, express a gradient of density and income disparity between urban centres and rural peripheries which reflect specific geographic and economic dynamics of the locality. Other populations faced with the same continuum trade-off decisions will have different outcomes against different spatial and economic dynamics. According to Dr. G. Haysom (2016) at the African Centre for Cities, University of Cape Town, the situation in Cape Town is significantly different to Beijing. Vegetable gardening tends to be a practice pursued by the middle classes and is driven, by a distrust in available food quality, the pursuit of novel food-types and the desire to teach children where food comes from. Soil quality in impoverished areas is often too poor for viable food gardening and gardens, which experience lower property security than in middle-class areas and are subject to produce theft. In addition, unemployed people prefer to spend their time pursuing employment opportunities rather than gardening, whilst middle-income earners often have the means to employ someone to tend the garden on their behalf. Finally it has been demonstrated that the poor have access to informal markets which provide access to healthy, cheap food on a daily basis. The most accessible way to generate income from subsidized housing, is by erecting backyard shacks to generate rental income and so vegetable gardening falls away as a lower order priority for land use (Haysom, Pers. Com. 2016; Haysom 2014). The reasons given for middle-class vegetable gardening in Cape Town are consistent with the findings of the Dunedin study which amongst others reflected a desire to connect with nature as the source of food. This is in line with the biophilia argument put forward in Freeman *et al.* (2012).

Biophilia as a driver emerges again in Belaire *et al.* (2015) who concluded that variations in backyard biodiversity were explained by perceptions of birds and that "residents' connections with neighbourhood birds appear to translate to on-the-ground actions" (Belaire *et al.,* 2015:401). Chan *et al.* (2016) argue that cultural ecosystem services do not adequately explain the biophilia phenomenon adding that the current dual conceptualisation of nature value must be expanded to include a third type. The current model includes instrumental value - characterised as the value of nature for human use; and intrinsic value - characterised as the value of nature for itself. The authors argue for a third type that recognises the value of the relationship that humans have with nature. Chan *et al.* (2016) suggest that relational value is an important conceptual contribution for conservation decision-making, providing a framework for considering appropriate ways of engaging and relating to nature and encompasses "preferences, principles and virtues associated with relationships, both interpersonal and as articulated by policies and social norms" (Chan *et al.,* 2016: 1462) and gives substance to the motivations based in "cues to care" and the "duty of care" that are identified as themes in Freeman *et al.* (2012) and Uren *et al.* (2015) respectively. In this way, the conceptualisation of relational values neatly incorporates the nexus of themes emerging from the qualitative studies of social drivers for gardening practice and "link and enliven intrinsic and instrumental considerations" (Chan *et al.,* 2016:463).

Embedded in this model are the ways in which people see and derive value from nature. Chan *et al.* (2016) propose in addition to the notion of nature as being valued either for itself or for its utility value, that there is value in the relationship that people have with nature and that consideration of this value could shift policy towards engaging with debates around appropriate ways of engaging with nature as cues to care are triggered. The model, reproduced below (Figure 3.2), maps out the ways in which people value the relationship they have with nature.

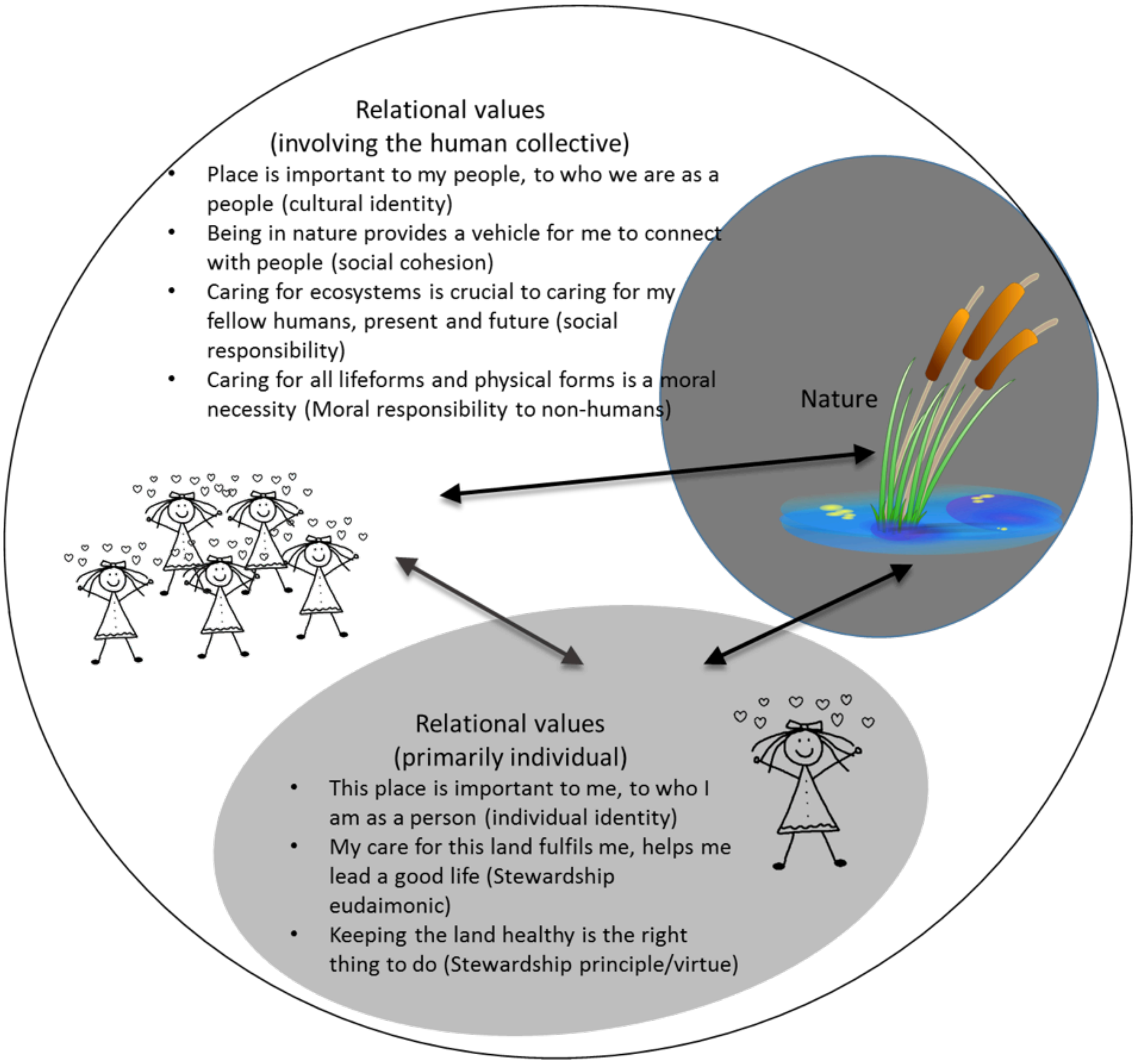

Figure 3.2. Chan et al.'s (2016) proposed diagram of relational values (adapted).

3.3.3 Preferences

Preferences have specific and direct impacts on the types of flora planted in gardens and the form that it takes. In gardens where residents have lived for more than five years, there is a correlation between people's plant trait preferences and the composition of their gardens. Additionally, preferences may be influenced by self-proclaimed gardening style, education and age cohort, suggesting that a neighbourhood with high social heterogeneity would also have higher plant heterogeneity (Kendal *et al.*, 2012b). Preferences for fauna can also influence planting patterns as seen by Belaire *et al.* (2015) who found that gardeners with an affiliation for birds planted more berry and fruiting plants to attract birds and tended to have higher biodiversity in their gardens.

Preferences can have a psychological basis. Van den Berg and van Winsum-Westra (2010) describe preferences in terms of *personal need for structure* (PNS). They hypothesised that the level of PNS would result in different preferences for wild versus manicured landscapes because the meaning ascribed to them tends to vary depending on whether they are viewed from the perspective of understanding one's environment or from the perspective of exploration. When the desire to understand one's environment is paramount, then manicured gardens are liked where the opposite is true if there is a strong affiliation for exploration and discovery (Van den Berg & van Winsum-Westra, 2010). The study, which took place in Germany, drew the parallel between PNS and the epistemic motivation for acquisition of knowledge. "In general, individuals with a strong need for structure desire a quick answer and are averse to ambiguity"(van den Berg & van Winsum-Westra 2010:181). The authors concluded that individuals with a high PNS score preferred manicured gardens (ibid).

A similar study in the Netherlands sought to describe the images that people hold of nature and the perceptions of appropriate relationship between people and nature whilst noting people's preference of broadly defined landscape types (de Groot *et al.*, 2003). The Netherlands is a highly biophilic society (90% self-identify as nature-friendly). As such, the results of de Groot *et al.*'s (2003) study reflected overall biophilia, demonstrating that respondents adhered to the participation-in-nature image relationship. Penetrative nature comprising elements such as mosquitoes and rats in the barn was ascribed a high degree of naturalness whilst more than half the respondents expressed preference for landscape of the "greatness and forces" of nature. De Groot *et al.* (2003) analyse the disjuncture between an expressed preference for the "greatness and forces" of nature and the real behaviours of everyday life in terms of a ladder with three rungs. At the top are preferences elicited in general and verbal terms. Below this are preferences elicited by visuals which depict more tangible landscapes with specific characteristics. On the third rung are preferences for behaviours as expressed in behaviours of daily life. Preferences are not constant when going up and down this ladder from general verbal terms to behaviours of daily life. Although landscapes of the "greatness and forces" of nature were highly preferential to the Netherlands respondents, that does not mean that it is desired at all times for all activities of life. "[P]utting it more positively, it may all be true that on the rungs of the ladder in people's cognitive and value schemata, the great blue whale should swim the ocean even if only for us to dream about, the wilderness should be there even if peak experiences of wilderness solitude are rare, the recreational landscapes should be there to admire their visual beauty, the picnic sites should be accessible, cosy and safe, and nature around the block should be our children's challenging playscape" (de Groot *et al.,* 2003:137). In this way, we can see that it may be possible to feel differently about a landscape or species of fauna being protected in the wild to its presence in the residential garden.

Preferences do not only determine what is planted in a garden and the design features introduced to attract the preferred species of fauna, but also what is removed or actively excluded. Negative attitudes can translate into preferences for (or against) conservation and consequently financial and research priorities. Findings by Knight (2008), conducted with a sample of students from Susquehanna University, USA, demonstrated that the two-striped garter snake (*Thamnophis hammondii)*, ozark big-eared bat *(Corynorhinus townsendii ingens)* and dolloff cave spider (*Meta dolloff)* were conceptualized differently to other species within their study. The authors argued that this may be the result of phobias, culture or emotional reactions to the pictures of the snake, bat and spider which were viewed as "ugly, somewhat fearful", and received mild support for protection. In contrast, the authors noted that birds, mammals and fish may be receiving more financial and conservation support because they are more positively socially constructed than reptiles, amphibians and invertebrates, although they also note that the rule should rather be applied to fearsome creatures as opposed to a blanket notion on each class of animals (Knight, 2008). Knight (2008) lists the popular cultural images associated with bats, snakes, wolves and spiders as frightening and suggests that emotional reactions guide aesthetic preferences as well as fear. Aesthetics in this study played an important role in the perceptions of species and was significantly related to governmental protection of species. The variance explained by aesthetics and fear was 23% lower for snakes, bats and spiders (Knight, 2008).

3.3.4 Attitudes Towards Amphibians

All over the world, amphibians are steeped in myths and superstitions that have been brought to us through time. In Western society, familiar imagery in Grimms Fairy Tales includes a frog that turns into a prince, whilst Shakespeare's famous witches brew (Macbeth) included "Eye of newt and toe of frog". Tarrant *et al.* (2016) explain some of the mythology as an inability for many people to make sense of amphibians as animals. This is reflected in stories where frogs are turned into human-like creatures with mystical powers. In South Africa, pervasive cultural beliefs within certain groups have fuelled negativistic attitudes towards amphibians, which were documented as the second most feared animal amongst 120 Zulu respondents across various age groups (snakes were the first) and that this fear often led to direct killing (Tarrant *et al.*, 2016). Tarrant *et al.* (2016) found that the influence of cultural beliefs varied significantly between education levels with less-educated respondents showing stronger associations with commonly held myths than more highly educated respondents. Older people also held more cultural beliefs (Tarrant, *et al.*, 2016).

In a report edited by Measey (2011), it is noted that all the contributing herpetologists had developed their interest in amphibians before they were 10 years old, which suggests a possible link between childhood experiences and biophilia in adults. A closer examination of the type of childhood experiences associated with biophilia may provide valuable insights into how these attitudes are fostered in the formative years. Tarrant *et al.* (2016:1) note, "That the average amphibian receives 75% less funding than the average listed mammal, bird or reptile, and 90% less funding than the average listed fish "reflecting the less-popular status of amphibians in general" (Tarrant, *et al.,* 2016). As one of the effects of pervasive negativistic attitudes is that it translates into lower prioritisation for conservation it becomes important to focus on the ways that attitudes are shaped and influenced if conservation efforts are to gain the traction required from the public in order to reach its targets.

3.3.5 Summary

Understanding preferences, perceptions attitudes, culture and norms provides us with valuable insights into how to work with people towards partnered conservation efforts with public co-operation. Without the basic understanding of attitudes within a given society, campaign efforts for conservation may miss the mark. Therefore unpacking social drivers and in particular the factors that are associated with biophilic attitudes is an important step towards developing strategies for conservation within populated and urban environments.

3.4 Methodology

This study took a grounded theory approach (Brymen & Bell, 2014). The central features of grounded theory are the development of theory out of data and that it is an iterative processes. In this way, data collection and analysis proceed in tandem, repeatedly referring back to each other. Comparisons were made between the data and concepts with particular attention to the relationship between childhood memories and disposition towards frogs.

The traditional method for testing and measuring attitudes is to use the Likert scale (Likert 1931). They are particularly useful in unpacking perceptions when there isn't a correct or incorrect answer. Likert scales therefore are not suitable for testing knowledge about a particular issue (Gliem & Gliem, 2003). The scale poses statements to the respondent who is asked to say how much they agree or disagree with its position. Validity is more likely to hold if the questionnaire poses multiple statements that are measured on the scale and then the attitudes analysed as a total score for all scales. The statements should include equal numbers of negative and positive attitudes and the total scores should be reported. When these conditions were met, then the Cronbach's alpha reliability coefficient remains acceptably valid even if one statement is removed from the set. Gliem and Gliem (2003) conducted this study after their review of the literature found that the majority of studies used multiple statements, but only reported on individual items. Their results showed that when only an individual statement is used to measure attitudes it can compromise validity.

The number of alternatives in a Likert scale also needs to be finely tuned. If the number of options on the scale are insufficient, then subtleties in the data set are lost, but too many options become redundant and respondents do not use them (Jacoby & Mattel 1971; Maurer & Andrews 2000). Garland (1991) argued that a four-point Likert-scale produced better results for measuring attitudes because respondents tend to use the neutral response when they do not want to displease the researcher due to the perception of the desired answer (Ibid.). Different cultures use more (or less) points to describe their position on an issue. How the Likert scale is designed will depend on the specific goals and, if neutrality in response is helpful, what the cultural set is and the level of subtlety that is required in the analysis. Should a blunt measure of attitudes be required, then a three-point Likert scale is enough to understand if people have a positive, negative or neutral outlook on a particular issue (Jacoby & Mattel, 1971)

Because the aims of this study are layered at different levels and scales of preference, the measurements of the relationships and the levels need to be able to be separated out from within the measurement tool to be able to correlate relationships and causation. Although a Likert scale represents a powerful tool of assessing attitudes it is not sensitive enough to reveal relationships between preference, demographics and behaviour if used in isolation. Therefore a suite of measurements will need to be used for this study.

For the purposes of determining general attitude towards amphibians, the tool need only be blunt enough to determine a self-identified positional statement against which correlations can be tested at other levels of the preference ladder. Specific preferences are typically determined by describing details or using flash cards along with forced choices, rank ordering, and open question responses (de Groot *et al.,* 2003; Knight 2008; Dandy *et al.,* 2011; Williams, *et al.,* 2012). Therefore in order to meet the objectives of this study, a variety of measurement methods were employed against a carefully considered framework. The framework (Figure 3.3.) attempts to map out the possible causes or drivers of actions on amphibians in the study suburbs in Cape Town. This framework forms the basis of the questionnaire described in the methods section of this thesis.

After data was gathered and analysed, this framework was revisited against the existing theories and conceptualizations of the drivers of nature-value orientations and behaviours in accordance with the iterations of the grounded theory approach (Bryman & Bell, 2014). The results are discussed in section 3.7 of this thesis.

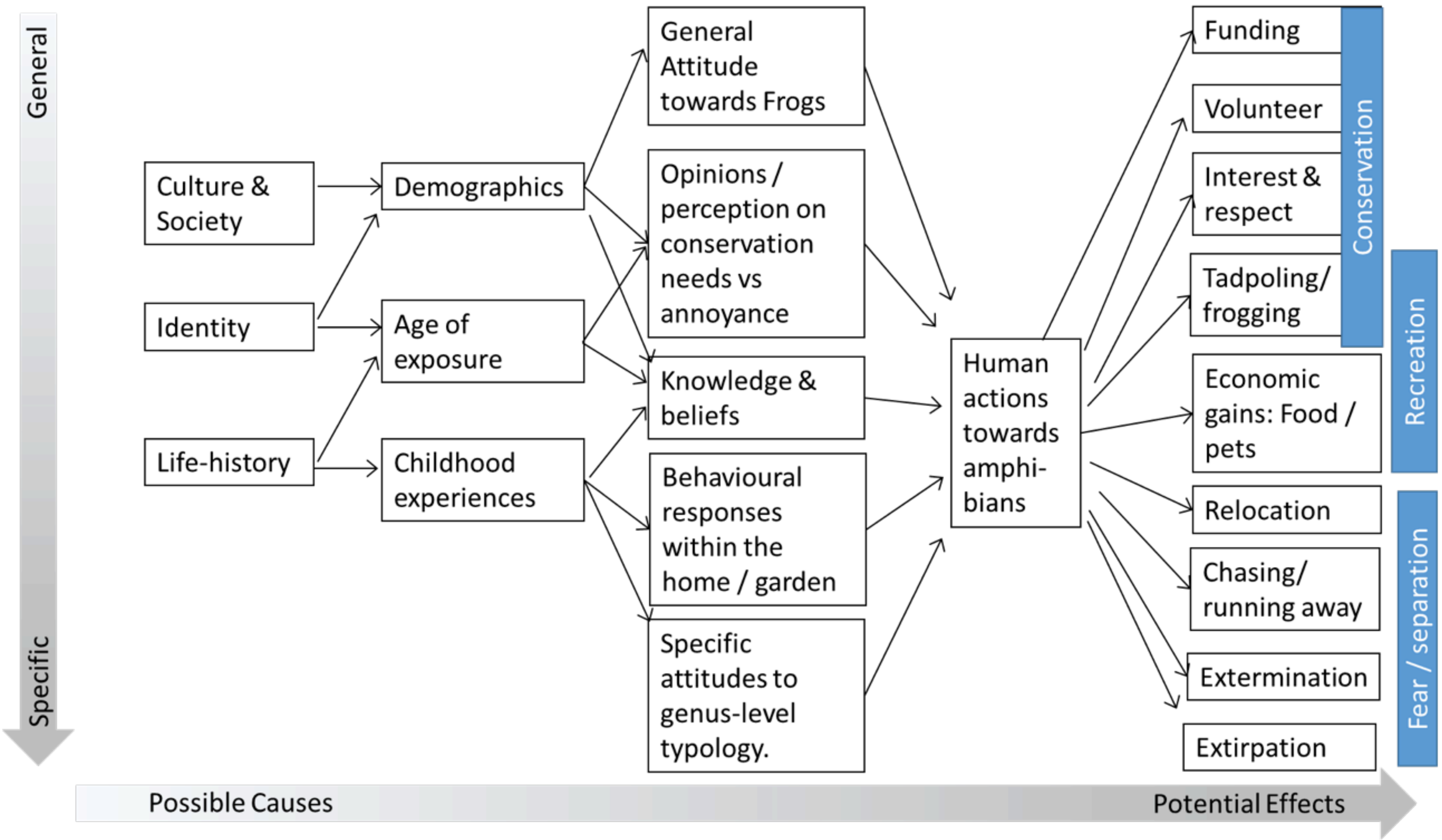

Figure .3.3. Conceptual framework of analysis of human preferences and actions.

3.5 Methods

The study took the form of a survey questionnaire (See addendum A) administered in the first phase by myself and four assistants with a fine-tuned questionnaire available as self-administrated digital survey by respondents in the second phase. The questions were drawn from Tarrant *et al.* (2016) who aimed to test knowledge, beliefs and liking amphibians. Tarrant *et al.*'s (2016) questions were all measured on a 10 point Likert scale, whereas I asked instead that respondents select from a list which best describes the feelings towards amphibians with choices between, 'I like frogs', 'frogs are ok', 'frogs are gross', 'frogs are scary' and 'I have no feelings about frogs'. Although blunt, this self-identified response held valid as a position and framework throughout the cases.

The cultural belief questions were used in the same format as Tarrant *et al.* (2016), whereas the knowledge questions were drawn from both Tarrant *et al.* (2016) and added to from du Preez *et al.*'s (2009) introductory section on amphibians resulting in "Frogs/toads are considered harmless to people" and "Some frogs/toads secrete a mild toxin on their backs as a defence mechanism (e.g. when hurt)." Preferences questions were added based on the work of Belaire *et al.* (2015), who measured residential preferences towards birds. This produced questions that asked respondents to agree or disagree on a five point scale with the statements "I like listening to frog/toad calls when it rains" and "Frog/ toad calls keep you awake at night".

In order to relate the questions to de Groot *et al.*'s (2003) preference ladder questions were designed to consider behavioural responses at scales within the home by asking respondents first what respondents would do if they found a frog in their garden and then if they found it in their homes. Respondents were also asked if they thought amphibians should be protected in the wild and then in green spaces in the city. To test the specific levels of preference, respondents were asked to look at four images of amphibians that each represented the typology of a. rain frog, b. reed frog, c. toad and d. river frog to determine how attitudes to specific types of frogs would differ from general ideas. The frogs selected for the images are native to the City of Cape Town and could be encountered in gardens (Figure 3.4)

Type A: rain frog,
B. gibbosus.
Credit image:
www.hardaker.co.za

Type B: reed frog
H. horstockii
Credit image: Helen
Lockhart retrieved from
www.aquarium.co.za

Type C: toad,
S. Pantherinus
Submitted to this study
by respondent.

Type D: river frog
A. fuscigula
Credit image:
www.hardaker.co.za

Figure 3.4. Flash-cards used to measure specific attitudes towards different frog types as would occur within the City of Cape Town

Tarrant *et al.* (2016) hypothesised that those who had positive experiences of frogs in their childhood at an age younger than 10 were more likely to have a strong affiliation towards frogs and so in order to explore the relationship between childhood experiences, cultural beliefs and attitude towards frogs, respondents were asked for a narrative response to the question "Do you have any strong memories of coming into contact with frogs from your childhood, or any memories of something that someone, a parent or teacher told you about frogs that you would like to share?" An open-ended narrative question was selected in order to identify themes.

3.5.1 Sampling

36 respondents were visited in their homes and questionnaires were administered directly. During this time the questions were fine-tuned both in the phrasing and prompting. The questionnaire was then converted to a digital format using survey monkey and a link was posted to social media groups. In order to ensure that those without access to digital platforms were not excluded, administration was undertaken by researchers on the street even after the digital platform was made available, so that respondents had a choice of platform for engagement. The team was assembled from Environmental and Geographical Sciences undergraduates at UCT and comprised of five women, three of which were Xhosa first-language, one was Kenyan and one was South African English first-language.

On a Sunday morning two members of the team went to the village green in the centre of Observatory and interviewed 15 street-dwellers who had come to take advantage of a soup kitchen that would be setting up later in the day. A team of three visited the Observatory Library on a Wednesday morning. The library had suggested this time because a number of community groups would be meeting. Specifically, there was an elderly knitting circle, and a children's story-reading group. 24 responses were obtained; four from the knitting group, 16 nannies and mothers and four responses from walk-in library visitors.

Posters and flyers were printed inviting respondents to find the survey questionnaire online. The posters were put up in local restaurants, bars and teahouses in Rosebank, Little Mowbray and Observatory. A team of four then stood on Mowbray, Rosebank and Observatory railway station platforms between 7:45 and 9:30am on one morning each during the week and interviewed commuters leaving the respective suburbs. Additionally flyers were handed out inviting commuters to logon using their phones during their train-ride.

Recognising that street harassment and begging are problems in these areas, the team wore matching T-shirts with bold print that said “Urban Biodiversity Research” on the back announcing the team’s intention and legitimacy. Overall, the community was receptive and we were received with a mixture of enthusiasm, curiosity and tolerance.

3.5.2 Ethics

The relevant ethical clearance was sought and granted by the University of Cape Town for this study. Respondents were made aware of the aims of the project. Signed consent was sought for participation in the survey. Attention was drawn to the right to withdraw participation at any time. Anonymity was guaranteed. No respondent names are included in the reporting. Any example narratives are quoted using respondent numbers as a reference only.

3.5.3 Analysis

Results were processed descriptively (counts, percentages, means and standard deviations) then cross-tabulated to explore the relationships between demographics and attitudes and preferences, then knowledge and beliefs, responses to amphibian presence in the garden and home and finally the relationship between childhood memories and disposition towards amphibians was assessed. Associations were evaluated using Chi-square test and one- way anova between disposition towards amphibians and demographics, attitudes, preferences knowledge and beliefs. Correspondence analysis was performed to explore the relationship between disposition towards amphibians and themed narratives visually.

3.6 Results

A total of 192 survey responses were obtained. The respondents were predominantly between the ages of 18 and 50, with less than 5% falling below 18 years of age and above 70. The majority of respondents (57%) said that English was their mother tongue reflecting the dominant demographic of the area. Xhosa (19%) was the second language group in the respondent set, whilst the remainder self-identified as Afrikaans (3%), Bilingual Afrikaans-English (3%), Zulu (2%), and Other (15%) which included a group of nine international languages from African and European countries of origin.

Overall education levels were high. 60% (n=113) of respondents had completed at least some form of higher education, reflecting both the dominant age-groups of the interviewees and the education levels of the suburb due to its socio-economic status and proximity to tertiary educational institutions. It may also reflect a response bias of willingness to engage with research from those holding higher education. 69% (n=129) of respondents liked frogs or said they were 'OK' whilst 10% (n=18) had a neutral response and 21% (n=40) had a negative response, saying they were 'scary' or 'gross'.

Those that liked frogs tended to leave them alone, remove them from their houses to the garden or to a lesser extent take them to the river or nearest wetland and release them. In these instances, the reason given for removal from property was due to perceived threat from pets, or the perception that the frogs were not in their natural or preferred habitat. Those that did not like frogs would either call someone to remove them from the property or respond in fear.

The majority (89.5%, n=162) agreed that frogs should be protected in the wild, but protecting them in the city came into competition with other objectives including access for leisure and social pursuits. In this instance, respondents asked if protecting them would compromise their ability to use green spaces freely and asked for clarity on what was meant by "green spaces" expressing uncertainty, the definition given covered public open space and corridors. In spite of the hesitation in the tone of the interviews, 83% (n=161) of respondents agreed that frogs should be protected in green areas within the urban edge. Respondents were more ambiguous about making it easier for frogs to move through the city, citing feasibility as the main concern and prioritized human needs within the urban and city space. When prompted with the statement that there may be simple cheap ways to improve mobility, 65.6% (n=118) of respondents agreed or strongly agreed that we should make it easier for frogs to move through the city. Those that did not like frogs tended to express the view that frogs should stay in the "wild" and disagree with this statement.

3.6.1 Language and Culture

Language was used as a proxy for culture within the study and so the language results are discussed in terms of culture within this paper. Of the Xhosa speaking respondents who said they disliked frogs, a cultural belief was reported that individual frogs found on their property out of the rainy season were sent by witchcraft. The remedy is to kill the frog, preferably by sprinkling salt on its back and then sweeping up the body. These qualitative responses were revealed in the coding of the "other" answers to the question "if you found a frog in your house, what would you do?" Xhosa-speakers were most likely to report being phobic of frogs to the extent that they were unable to look at the flash-cards of examples of frogs. A few respondents reported a shift in attitude with urbanisation or education.

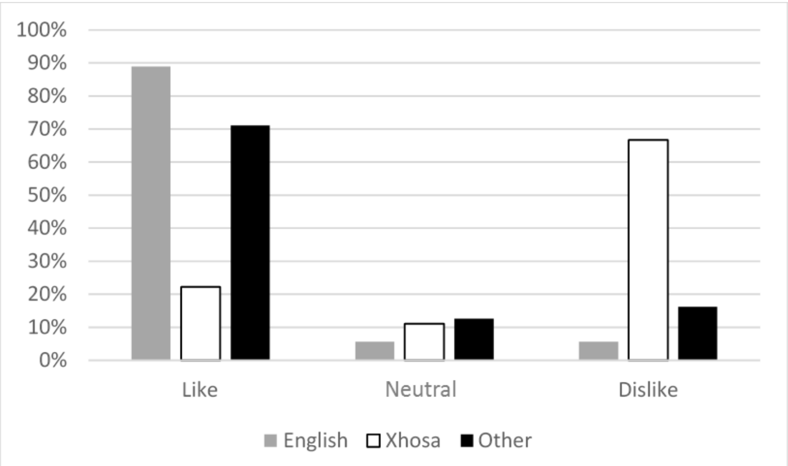

Figure 3.5. Feelings towards frogs split by dominant language groups

3.6.2 Knowledge and Beliefs

The knowledge and belief scores were cross-tabulated against liking frogs in order to make the link between knowledge of an animal and attitudes (Table 3.1). The knowledge of those who liked frogs was significantly better (more accurate) than the knowledge of those who disliked frogs (two sample t-test $t=5.99$, $d.f.=161$, $P<0.001$). This is also reflected in the knowledge means of the 3 groups. Knowledge means were lower in the group that were afraid of frogs. Therefore, a correlation between positive attitude towards frogs and higher knowledge scores demonstrates that those that like frogs have more accurate knowledge of them. It does not however appear to be a causal relationship as people who like frogs may be inclined to search out accurate knowledge about them as much as those that have more accurate knowledge about frogs may develop an interest and affinity towards them. When cross-tabulated against education achieved, those with post-graduate education had lower knowledge and belief scores than those with tertiary education, but both groups had higher scores than the group with secondary education. This drop in post-graduate scores can be attributed to the fact that those with higher education tended to refuse to guess their answers choosing rather to say they did not know. Table 3.1 presents the median scores for each preference group.

Table 3.1 Cross-tabulation of means for knowledge and belief scores against attitudes towards amphibians.

Feelings (collapsed categories)	Knowledge Cat. Score	Beliefs Cat. Score	Total Knowledge Scores
1 Like	2.93	2.56	5.49
2 Neutral	2.18	1.94	4.12
3 Dislike	2.21	1.66	3.87
Total (average)	2.71	2.31	5.02
N	180	180	180
Min.	0	0	0
Max.	4	3	7

3.6.3 Specific Preferences

The most popular frog was *H. horstockii* which was reported by 76.64% of respondents as being 'likeable'. This was followed by the *A. fuscigula* (55.3%), the *S. pantherinus* (54.8%) and finally, *B. gibbosus* at (32.4%). The spread of results are presented figure 3.6 and show specific attitudes towards individual species differs from the general conception of "frogs" as an animal.

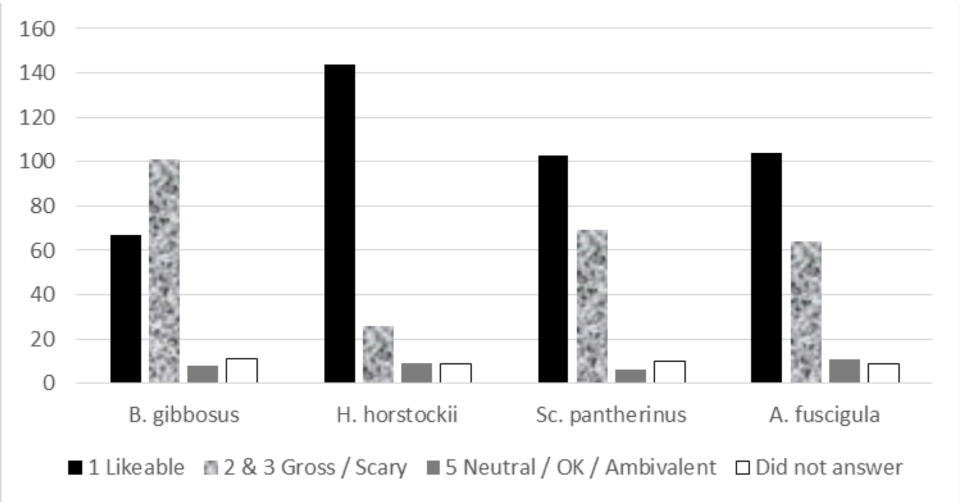

Figure 3.6. Specific preferences towards different frog species B. gibbosus, H. horstockii, S. pantherinus and A. fuscigula

3.6.4 Behaviour at Spatial Scales

Behaviour responses did not change significantly between the house and the garden. The exception was for those who said they would try to find out more about the frog if it was in the garden (19.4%) and those who said they would leave the frog alone if it was found in the garden (55%). 60% of all respondents said that they would remove frogs from the house and put them in the garden (or call someone to do so); whilst 12.9% of the sample said that they would kill it, put salt on it or chase it away. Only 4.3% said they would leave it if it was found in the house. 12.4% of the sample would remove the frog from the property or take it to the river, either due to the perception that the river was where it belonged, out of concern for feline predation or due to fear and disgust.

Table 3.2 demonstrates the differences in behavioural response between house and garden presence of frogs. If the responses are the same, then the central blocks along the diagonal will register 100% as is the case with "kill it/put salt on it". Where the behavioural responses are different then the spread of numbers moves out from the diagonal line. The higher the percentage that within a particular combination, the darker the shading.

Table 3.2. Cross-tabulation of response behaviour if a frog is found in the house versus in the garden by percentage of responses in each garden category.

What would you do if you found a frog/toad in your garden?	What would you do if you found a frog/toad in your house?							
	Kill it / put salt on it	(Call someone to) remove it from the property	Leave it	Find our more about it	Run / Chase it away	Take it to the river	Keep it as a pet	(call someone to) put it in the garden
Kill it / put salt on it	100	0	0	0	0	0	0	0
(Call somone to) remove it from the property	7.7	76.9	0	0	7.7	0	0	1
Leave it	4.9	9.8	4.9	1	2	2.9	1	73.5
Find out more about it	0	5.6	5.6	11.1	0	0	0	77.8
Run/Chase it away	0	33.3	0	0	33.3	0	0	33.3
Take it to the river	10	0	10	10	0	50	0	20
Keep it as a pet	0	0	0	0	0	0	50	50

3.6.5 Life Experiences

Responses to the question "How old were you the first time you remember coming into contact with a frog?" (figure 3.7), fell broadly into the following categories; i. did not know or couldn't remember (n= 21); ii. under the age of five (n= 93) or iii. between the age of six and 10 (n=61). Only a few outliers within the sample did not have recollection of some contact with frogs before they were ten years old (n=13). When the age of recollection of first contact with frogs was cross-tabulated with attitude towards frogs, the proportion of those that dislike frogs peaked in the 6–10 year age category, and the proportion of those that liked frogs peaked in the 0–5 yrs. group. Having said this, the samples have large overlapping areas indicating both positive and negative outlooks within both age groups. This rejects the hypothesis that the age of exposure is the significant predictor in frog attitude and may point more to the quality of the experience, the prevailing cultural and primary care-giver attitudes and specifically, the level of facilitated engagement with tadpoles and frogs at preschool age – ie. an indication of a culture of engaging in activities collecting and observing tadpoles and the acknowledgement of the value of the experience from the adults who facilitate early childhood experiences.

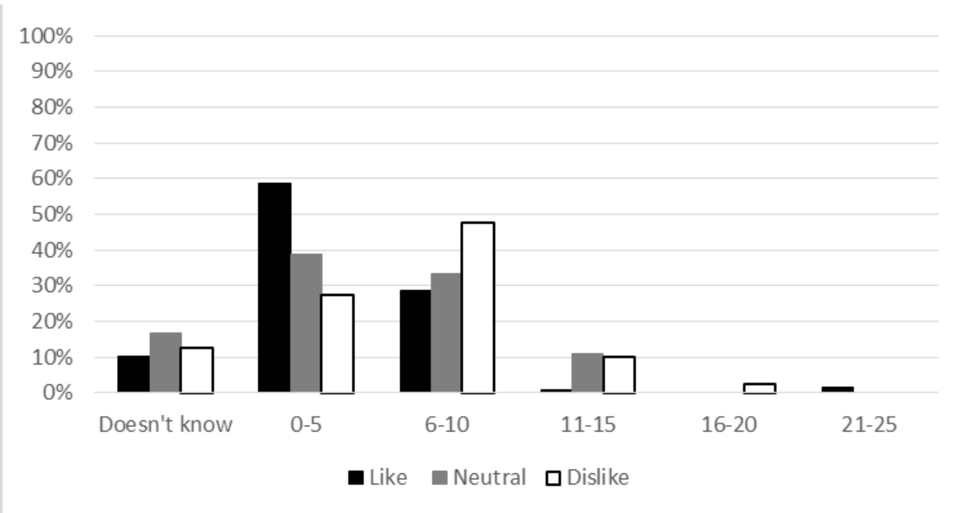

Figure 3.7. Respondent recollection of age when they first saw or came into contact with a frog, cross-tabulated with their attitude towards frogs.

The thematic analysis of the narrative of a memory from childhood show clear distinctions between those that find frogs 'gross' or 'scary' and those that find them 'likeable' or 'OK'. Those that have no feelings did not reveal any clear consistency in themes, but 61% (n=11) of them had no recollection of a particular memory to share. Catching tadpoles (n=19) featured frequently as a theme amongst those that had an affinity for frogs. The second theme was childhood discovery (n=14) recounting playing with and discovering frogs, seeing them or hearing them, often characterised by a sense of wonder. Respondent #129, who liked frogs said "*I remember at Mafikeng as a child I went to the garden, playing with water and a lot of tiny frogs popped out and I was so amazed and held them on my hands."* Respondent #93 said *"looking for frogs on the sides of mountain pools (often around* Disa uniflora*) after a long hot walk on the mountain. If you could stay in the cold brown water long enough, we used to see how close we could swim to them before they jumped into the pool."*

Parental biophilia also featured among this group (n=5), in which a primary care-giver would tell the child not to harm the animal or would be involved in facilitating the interaction, either by instruction or taking them frogging. Respondent #4 said *"My dad calling us all into the garden at night to show us a leopard toad by torchlight. It happened fairly often! And then did not see one for years until about 12 years ago in our Mowbray Garden ...a long space in between!",* Some (n=5) reported trying to keep them as pets, and some reported playing with them more destructively, or using them to play practical jokes on their friends (n=7) *"I once found a frog and put it in my sister's room and she freaked out.",* others remember listening to them during the rain or at night (n=4), and lastly, there were those who witnessed the killing of frogs with some distress, implying that they were already familiar with them, were unafraid and held some empathy (n=5). These themes and accounts had in common direct interaction, fond recollection and that the adults either facilitated, or allowed engagement with minimal interference or warning.

On the other hand, those that reported fear of frogs tended to hold beliefs in the ability of amphibians to harm them. Two main themes emerge. Firstly that they were told by an adult or parent, that touching them (or even looking at them in one case) can result in severe rashes or infections (n=7) and secondly that frogs are associated with witchcraft (n=6), *"Where I come from, some people say frogs are sent by witchcraft, especially if it's not raining or it's unseasonably dry."* Additionally, those that had been chased with frogs or startled also featured (n=6). Respondent #83 who thought frogs were 'scary' said "*Someone put it on me and I ran away and that's when I knew I was scared".* Respondents across the like-dislike spectrum described frogs coming into the house, out of the ground, out of the drains in large numbers. One respondent who liked frogs said *"I remember living on an old farm in [place name] and one very rainy, stormy night we woke up to hundreds of frogs popping up from under the floorboards and trying to put on a pair of my mom's high heels to avoid them jumping on my feet."*

Figure 3.9 presents the correspondence analysis between the narrative themes and the attitude and illustrates the clustering of narratives that documented experiences, role-model attitudes and cultural beliefs with categories of attitudes and feelings towards amphibians in general. The model is statistically significant with the chi-square value at 86.295 (df=36) and p= 0.000. Dimension 1 shows the correspondence between the attitudes 'dislike', 'neutral' and 'like' and the themes found in the narrative. The theme 'startled' is an outlier on Dimension 2, because respondents with a memory of being startled by a frog had varying attitudes depending on the context of the story and factors recorded in the other categories such as cultural background, parental biophilia etc. The close clustering of the 'like' and 'dislike' themes on both dimensions indicate the strength of the correspondence between the memories and the attitude.

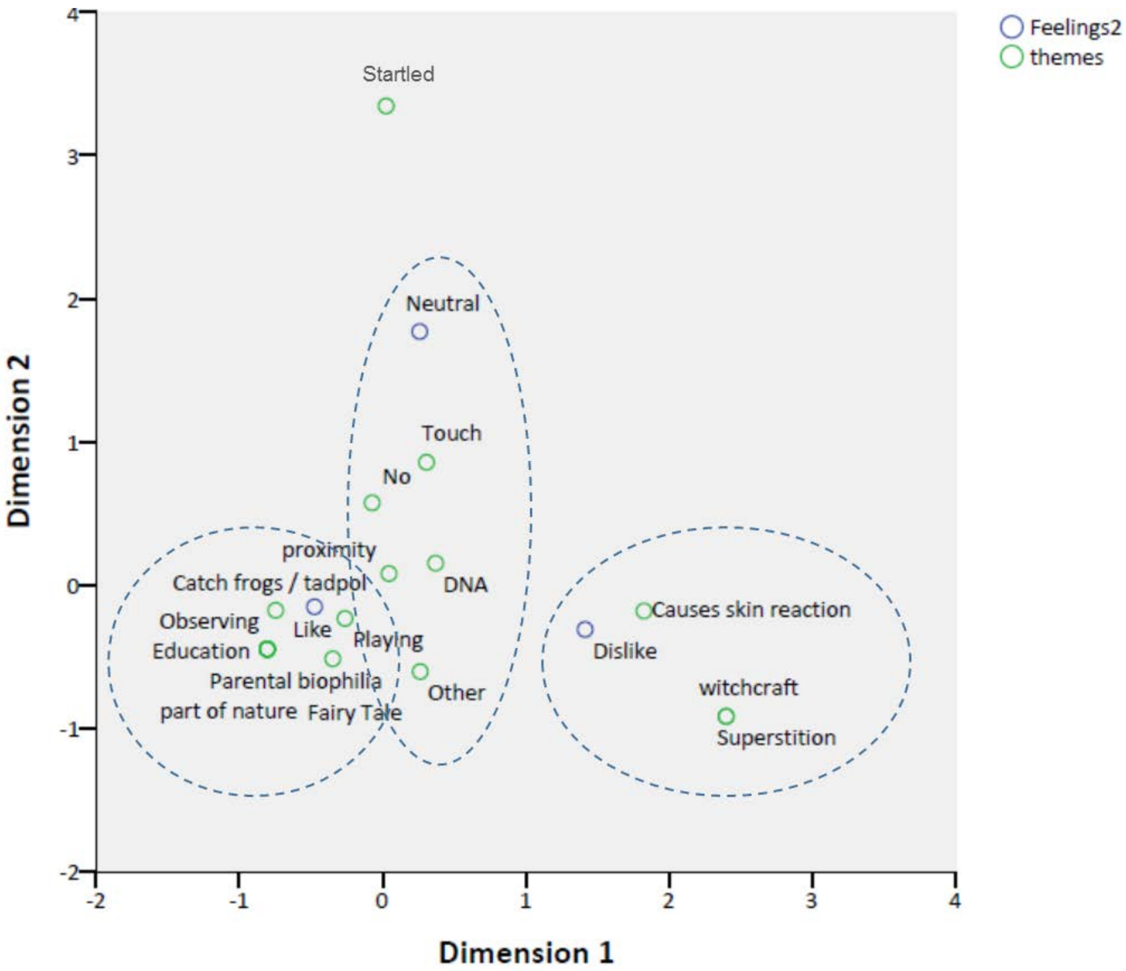

Figure 3.8. Correlation analysis of narrative themes and attitude towards amphibians.

3.7 Discussion

This study examined the preferences of a Cape Town community towards amphibians and explored attitudes using a composite approach drawing from a number of sources. De Groot *et al.'s* (2003) preference ladder was used as a theoretical framework for exploring preferences. The findings of this study were consistent with those of de Groot *et al.'s* (2003) in that general preferences at the broad conceptual level can be different to the specific level. This study compared general preferences to specific preferences in terms of space, behaviour and individual species. When asking about individual species, the arum reed frog, *H. horstockii* was much more popular than other species and many people who were generally afraid of frogs said they thought it was 'likeable' and were more likely to leave it alone if they found it in their garden. Knight (2008) found that people preferred animals that were 'cute' with more human-like proportions to their faces and proportionately larger eyes. The arum lily frog is smaller than the other species presented and has a smoother pattern (as opposed to the mottles, warts and striking patterns of the other 3 species) and softer colouring to it (white, cream and beige as opposed to dark browns and kakis). It was described specifically and variously as being 'beautiful', 'elegant', 'harmless' and 'it looks poisonous'. In contrast, those with strong dislike or fear of the other species often compared the appearance of the skin to a snake. Those that liked the rain frog, tended to laugh at it and see it as 'funny' or 'grumpy', personifying its ugliness into something relatable. As the least popular frog, the rain frog's image was often met with dismay and exclamations of "What is that?!" and "is that even a frog?!" The results of this study suggest that reasons for liking an individual species correlate with aesthetic appreciation and relatability. This is consistent with Knight's (2008) findings that personification and relatability feature highly in the likelihood that individuals will respond to calls to champion a specific creature for conservation (Knight, 2008). The findings suggest that it is easier to promote urban biodiversity using charismatic species such as has been argued by Goddard *et al.* (2010) and Knight (2008), however the differentiation between the specific and the general means that it may only improve attitudes towards an individual species without necessarily affecting overall attitudes to say, amphibians in general.

Impacting the general preference level is more complex given the multiple social influences and individual life-experiences that shape human preferences towards nature. De Groot's (2004) research closely associated a general preference for nature with a biophilic self-identity. Biophilia has a number of related concepts that closely align with an affiliation with nature (Martin & Czellar, 2017) and underpin the framework of *Connectedness To Nature* (CTN) (Mayer & Frantz, 2004). Although CTN was not directly measured by this study, the themes that emerged within the results are consistent with the themes underpinning CTN theory (Klassen, 2010) and thus this framework is used for discussing the results of the general preferences towards frogs.

Positive conservation efforts within the urban context would require a shift towards a culture of pro-environmental behaviour. A predictive relationship has been demonstrated between biospheric values and pro-environmental behaviour (Martin & Czellar, 2017). Biospheric values are held when "People judge phenomena on the basis of cost or benefits to ecosystems or the biosphere" (Stern & Dietz 1994:70) and are a result of CTN (Martin & Czellar, 2017). CTN is a framework which measures an individual's ability to see themselves as part of nature (Martin & Czellar, 2017). To harm a part of nature is similar to harming oneself. They therefore hold biospheric values and are more likely to engage in pro-environmental behaviour (Mayer & Frantz, 2004). Klassen (2010:10) summarised the interrelationships of concepts and precursors of CTN in terms of four underpinning pillars, namely, *lived experiences; encounters and conversations with passionate, caring or dedicated role models; cultural background; and prior knowledge*. This study has rendered similar findings in terms of the themes emerging from the results correlated with liking or disliking frogs in general and will be discussed below.

3.7.1 Lived Experience

Early exposure to frogs was not, on its own, a key predictor in liking frogs as an adult because children playing in nature tend to come into contact with them. Instead, the quality of the interactions (often coupled with the attitudes of role-models facilitating those experiences) influenced attitudes. This builds on the concept of relational values as suggested by Chan *et al.* (2016). For example, Palmer *et al.* (1999) found that 75% of Canadians, and 71% of Australians selected childhood experiences in nature as the number one reason for personal responsibility being felt towards the natural world. Hunter and Brehm (2004) suggest that particular events during a youth's life could result in environmental values being enhanced or altered depending on the values as being positive or negative and Lekies and Beery (2013) determined that children who collected natural objects as a child scored higher than non-collectors on a measure of connection to nature, which is corroborated by this research that found that tadpole collecting was prominent feature amongst the stories that were related by the group that reported liking frogs. However, it is perhaps not the collecting itself, but the time and quality of the experiences within nature that leads to collecting that builds the CTN. Wells and Lekies (2006) conducted an earlier study in America that suggested that children who participated in both "wild" and "domesticated" nature were put on a trajectory towards environmentalism and Klassen (2010) had similar results when he compared the experiences of rural children and urban children. Duerden and Witt (2010) found that children who engaged in direct educational experience were more likely to engage in pro-environmental behaviour after the course had ended. Klassen (2010) also pointed to multiple or regular positive experience in nature.

The current research has produced some additional results that indicate that the attitude of the carer, or adult facilitating these activities, has a prominent role to play in this trajectory. Individuals that were actively discouraged from playing with, observing or going near to amphibians in early childhood, retained their fear into adulthood.

3.7.2 Role Models and Parental Figures

The role of parent was often mentioned in the narrative results as someone who either passed on an attitude of affiliation for nature, a superstitious outlook or a set of warnings. Klassen's (2010) summary of CTN theory included encounters with passionate role models including friends, family, teachers, community members, social movement leaders and writers. These role models can shape the kind of experiences and learning about nature that takes place through facilitated nature engagement (e.g. taking the family to the beach, or leading a hike) or knowledge dissemination in all its formal and informal forms. Likewise Duerden & Witt (2010) explored the affective behavioural and knowledge retention of environmental impacts that were indirect (classroom based), direct (nature based) or vicarious (stories, plays and entertainment). Three different types of role-modelling can be identified, that of family and friends (home), that of teachers, educators and community leaders (community), and that of public figures (public). This research has highlighted the role of home-based figures in early childhood foundation years and noted that positive experiences tended to be imprinted at preschool age, whilst negative attitudes were associated with recollection from the primary school age. Having said that, Klassen (2010) emphasised that CTN was influenced by multiple positive lived experiences with passionate, caring role-models. A primary care-giver is a role-model who will be present on a continuous and regular basis. When children are encouraged and facilitated by adults to explore, play and engage with nature it enables sense of wonder and connection – a desirable precondition for establishing connection to nature (Klassen, 2010). This research recognises the importance of parental attitude in the formation and transfer of values and attitudes and suggests that further research is required to understand how to effectively shift whole-family attitudes by engaging both children and parents in positive nature experiences.

3.7.3 Cultural Background

Cultural background includes cultural beliefs, values, attitudes and opinions of family and community members (Klassen, 2010). It is reinforced by the norms that are enforced by community members (injunctive norms) as well as what individuals observe or believe of others (descriptive norms). These find expression in community practices and role-model enforcement (Nassauer *et al.*, 2009). In this study, language was used as a proxy for cultural identity and showed stark differences between groups. One Xhosa-speaking male even refused to participate in the study saying “Why do you want to know that? Everybody hates frogs” thereby revealing the descriptive norm within his group. Xhosa people tend to hold the belief that frogs are dangerous and are able to spit a poison that causes infection in humans, therefore one should not touch them and should rather run away if you see them. This belief seems to preclude children from early encounters with frogs and discourages them from playing too close to them, so they are unlikely to have positive life experiences with frogs and the resulting phobia, or disaffiliation, is carried through into adulthood. Nassauer *et al*. (2009) suggested that recruiting community leaders or celebrities to champion pro-environmental behaviour can assist in fostering positive norms within a given society. It is important that environmentalists are sensitive to the cultural beliefs and systems of the people that co-exist with the ecosystems they seek to conserve. Understanding the underlying suspicions, beliefs and impacts is an important step towards garnering support for conservation efforts. Further research may look at groups with a particularly negative outlook on an animal class, e.g. snakes, or frogs, and explore the qualitative themes amongst the minority group who do like them. Put more specifically: what is different about the life experiences that those that like frogs within the Xhosa group have had?

3.7.4 Knowledge

The knowledge results within this study showed a correlation between accurate knowledge and beliefs and liking frogs. The group that disliked frogs had a lower mean score for knowledge and beliefs. It is not clear if lack of accurate knowledge was as a result of disliking frogs or if disliking frogs meant that individuals were disinterested in accurate knowledge. Furthermore, those who reported direct positive experiences with frogs in their childhood also scored higher on knowledge and beliefs and may be a precursor to retaining accurate knowledge as described by Duerden & Witt (2010).

This research did not seek to measure the impacts of educational strategies but rather to determine what the factors associated with a general attitude of liking frogs was. In this instance, the research confirmed that there is a relationship between knowledge and liking frogs but it is unclear beyond that what the relationship is. Klassen (2010) discusses knowledge in terms of both inter-generational knowledge and the use of knowledge in sustainable decision-making. In the first instance the knowledge of others (role-models) is a factor in driving the value-basis during the formation/ deepening of CTN during childhood, whilst in the second instance, knowledge becomes a factor that shapes decision-making and pro-environmental actions. In this way it is clear that learning, whether formal, informal, direct or indirect is an integral foundation to fostering pro-environmental behaviour, however it is not an actor that drives the formation of positive attitudes on its own. It is therefore important that quality information continue to be made regularly available to the public in order to facilitate appropriate pro-environmental behaviour and continue the cycle of generating experiences that drive biospheric values. Figure 3.9 below attempts to map out the relationships between the different aspects which work together to shape general attitudes.

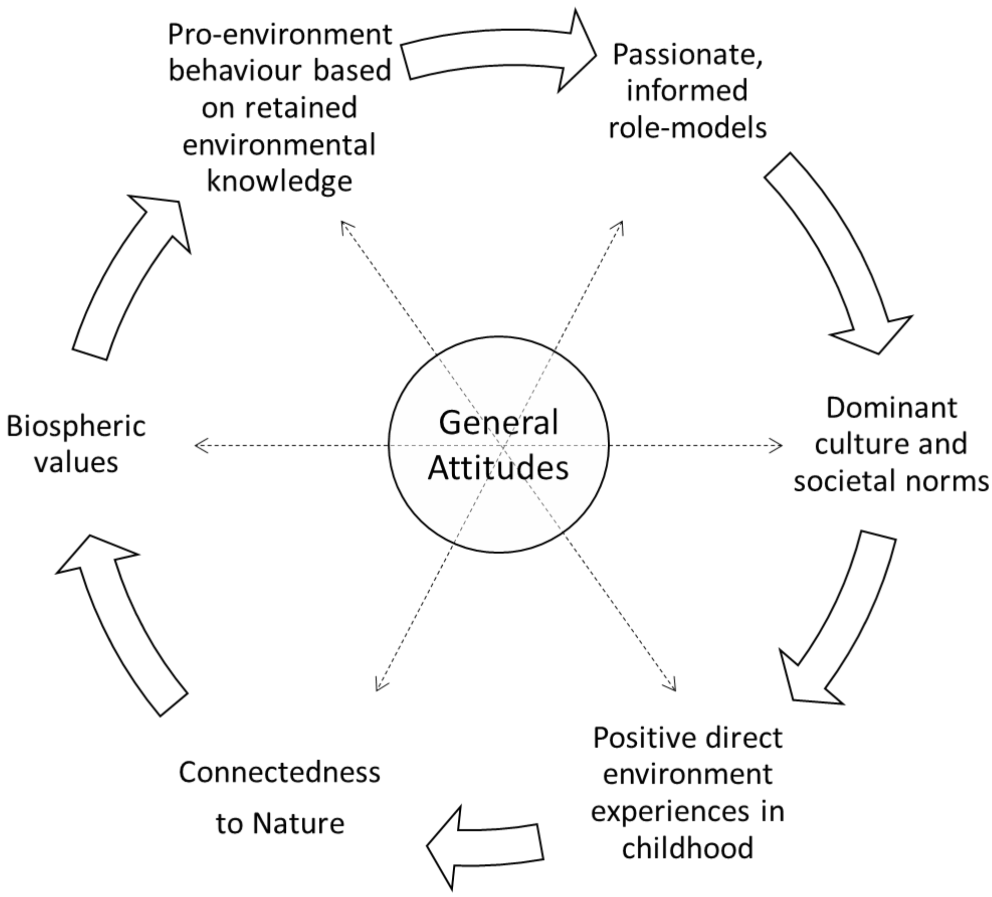

Figure 3.9. Cycle of knowledge, values and behaviour as the drivers of general attitudes adapted from Klassen et al. (2010).

3.8 Conclusion

This study used a traditionally unpopular group of animals in order to explore why people like or dislike amphibians and consequently what might motivate them to pro-amphibian stewardship behaviours. It found that individual, charismatic species can be championed amongst groups regardless of affinity towards the class of animals, however positive general attitudes are shaped by a combination of complex social forces, most notably, cultural norms and the concomitant engagement (or lack thereof) with the species as children.

People and Frogs in Lower Liesbeeck Suburbs

Section A: Demographic Details (circle applicable)

1 How old are you roughly?

1	2	3	4	5
0-17	18-30	31-50	51-70	>70

2 Highest level of education achieved:

1	2	3	4
Primary	High	College/ Tech/ Uni	Post Grad

4 What is your mother tongue/ cultural identity

1	2	3	4
English	Afrikaans	Xhosa	Other

If other specify ______________________

Section B: Preferences and Behaviour

Select one from the list below which best describes your feelings towards frogs:

1 ☐ I like frogs
2 ☐ Frogs are OK
3 ☐ I have no feelings about frogs
4 ☐ Frogs are gross
5 ☐ Frogs are scary

If you found a frog in your **garden** would you:

1 ☐ Kill it
2 ☐ Call someone to remove it from the property
3 ☐ Leave it alone
4 ☐ Find out more about it
5 ☐ Other

If you found a frog in your **house** would you:

1 ☐ Kill it

2 ☐ Call someone to remove it from the property

3 ☐ Put it in the garden or ask a household member to do so

4 ☐ Leave it to find it's own way back out.

5 ☐ Find out more about it

6 ☐ Other ____________________

How much do you agree or disagree with the following statements?	Don't know	Totally Disagree	Disagree	Neutral	Agree	Totally agree
All Frogs should be killed	0	1	2	3	4	5
Frogs should be protected in the wild	0	1	2	3	4	5
Frogs should be protected in green places in the city	0	1	2	3	4	5
We must make cities easier for frogs to move through.	0	1	2	3	4	5
Frog calls keep you awake at night	0	1	2	3	4	5
I like listening to their calls when it rains.	0	1	2	3	4	5
I don't know what a frog's call would sound like.	0	1	2	3	4	5

Section C: Perceptions

Indicate which of the following statements you believe to be true and which of them are false

	1	0	
You will get warts if you touch frogs & toads	TRUE	FALSE	Don't know
Frogs cause lightning	TRUE	FALSE	Don't know
Frogs spread disease to humans	TRUE	FALSE	Don't know
Frogs are harmless to people	TRUE	FALSE	Don't know
Some frogs secrete a mild toxin on their backs when hurt	TRUE	FALSE	Don't know
Frogs eat garden pests such as slugs, snails & mosquitos	TRUE	FALSE	Don't know
Amphibians* are dying out faster than any other animal	TRUE	FALSE	Don't know

* includes frogs, toads, newts, salamanders & caecilians

How old were the first time that you can remember coming into contact with a frog? ______

Can you share something from your life experiences about frogs, a memory or something an elder told you..

4

IN CONCLUSION, IMPLICATIONS FOR CONSERVATION AND FURTHER RESEARCH

This thesis has explored urban ecology through the lens of a less popular class of animals. The framing of the chapters has sought to consider different aspects of garden conservation efforts through conceptualizing natural processes and habitat characteristics as the technical “what” that informs design and maintenance practices. To this end, I have aimed to understand amphibian habitat choice as a layer of analysis for landscaping. The results indicate that local amphibian species prefer gardens with dense vegetation beds at ground level and that those gardens with only moderately dense vegetation are most positively affected by supplementary habitat features, in particular ponds and mulch and negatively affected by the application of synthezised fertilizers and pesticides. This information provides guidance for designing niche habitats that can support urban amphibian species in a garden setting in Cape Town, South Africa.

In chapter three, I considered why private individuals would want to change their gardening and maintenance practices to attract amphibians to their garden. In the literature, I explored social informants and processes and discovered a number of important theoretical frameworks for unpacking individual and collective preferences towards a specific type of animal. As Knight (2008) highlighted, the creatures people have an affiliation for determine how funding is directed, but more specifically it shapes what is valued and determines the kind of community and gardening activities and choices that people make. I therefore surveyed the attitudes of individuals within the local community in order to dig deeper into the aspects that shaped their preferences towards amphibians both on the general and the specific level. The results showed that cultural norms and the attitudes of primary care-givers have a powerful role to play in shaping whether people like or dislike frogs. Within the response group, children of English-speaking families were encouraged to go tad-poling at a young age, whilst children in Xhosa speaking families were told that frogs were dangerous, could spit at them, and that they should keep away from them or put salt on their backs. These two distinctively different outlooks have demonstrated that attitudes are formed at an early age and that they tend to remain intact into adulthood.

These findings are important for informing urban conservation efforts that engage with people who manage private gardens. But, the above is incomplete without considering how conservationists can engage with communities. Therefore the remainder of this chapter will review and discuss the ways in which citizens, individuals and communities are currently collaborating with conservation efforts. This discussion is aimed at pulling together the "what" and the "why" by pragmatically framing the "how" of human community engagement and mobilization.

4.1 People and Nature in Partnership

Given that residential gardens comprise of a multiplex of small, privately owned patches, subject to rapid changes and prone to all the stressors associated with urban ecosystems, it would seem that engaging in garden conservation may present an unrealistic and insurmountable challenge. Dewaelheyns *et al.* (2016) argue that intervening at the garden scale may present an opportunity to make a large impact through the 'Tyranny of small decisions' and that collective intervention can make a significant positive impact. As such, understanding what shapes human-nature interactions, in general and in gardens in particular, is necessary to understand how to work with people towards achieving conservation objectives for gardens. A number of cross-disciplinary environmental-sociological and environmental-psychology studies have explored the ways broader social processes drive yard choices but have tended to explore this from the perspective of elemental social variables such as either social norms (Uren, *et al.*, 2015), values (Freeman *et al.*, 2012), or preferences (Dandy *et al.*, 2011). *Connectedness To Nature* (CTN) theories begin to pull together a framework for integrating some of the influences on the individual that would affect environmental outlook and behaviour (Martin & Czellar, 2017). Chan *et al.* (2016) build on this notion by proposing consideration of a relational value position that drive cues to care (Ikin *et al.*, 2015).

The potential benefits of engaging with gardens as a space for conservation are multi-fold. Firstly, as the most readily accessible nature to humans, it provides an important site for fostering CTN. As demonstrated by Martin and Czellar (2017) CTN underpins biospheric values and ultimately pro-environmental behaviour. Secondly, as conservation targets are not being met, urban green space has been shown to possess characteristics that can provide havens for endangered species (Ives *et al.*, 2015) and appropriately managed gardens and street landscaping can provide habitat beyond the boundaries of remnant patches (e.g. Doody *et al.,* 2010; LaPoint *et al,.* 2015). Thirdly, many of the changes occurring within cities are consistent with those predicted for climate change and provide an opportunity for studying the kind of futures that can be expected in a hotter world (Magle *et al.*, 2012; Hahs & Evans, 2015).

One theory that has received some attention and debate, is that of the Actor-Network Theory (ANT). ANT is a method for analysing interactions between actors where the actors are in the process of evolving through their interactions (Murdoch, 2001). For example, the act of gardening co-creates both the gardener and the garden. In assessing human-nature interactions, it is arguably problematic as both humans and nature have strong internal processes and are independent of each other and exist separately (Murdoch, 2001). ANT has however, been successfully applied to natural systems when it has been used to facilitate objective analysis of different human groups or actors and the relationship they have with natural systems. ANT allows analysis that dismantles power dynamics and views all parties as equal actors and co-creators of nature. In this instance, nature is viewed as a passive subject rather than an actor within the network (Burgess, *et al.*, 2000). As such, ANT could be a useful approach to use when considering interactions between conservationists as 'experts', communities as 'gardeners' and the effect that combined activities have on urban nature. Burgess *et al*. (2000) conducted a study of farmers and conservationists at The Levels in the UK. The farmers had been viewed as technicians who must implement the conservation strategies developed by conservationists who saw themselves as experts. Through a series of intensive interviews and focus groups, Burgess *et al*. (2000) revealed the value of the experiential knowledge of the farmers and that they see themselves as stewards and managers of the environment, working within and responding to the order of nature. Of particular relevance are the passive observations of seasonal changes and processes and intimate knowledge of the specifics of their own patch. The results revealed that the farmers had an intimate knowledge of the nuances in their respective parts of the Levels (Burgess, *et al.*, 2000). Urban gardeners may turn out to hold similar knowledge depending on the duration of residential occupation and could be equally valuable in contributing to the growing body of knowledge about urban systems.

4.2 Towards Citizen Action: Current Ways Citizens Are Improving Urban Biodiversity.

Cape Town, and in particular the areas around the lower Liesbeek River, offer case studies of three active citizen groups that actively monitor and conduct restoration activities. They are the Friends of Rosebank Green (FRoG), which is a field and park on the banks of the Liesbeek River, the Friends of the Liesbeek (FOL), which is a larger area and consequently a larger organisation, and the Friends of the Rondebosch Common (FoRC). As a precursor to this thesis, I joined the social media groups of all three of these organisations and have been monitoring their activities and newsletters for the better part of two years. FRoG is relatively newly formed. Their activities to date have been predominantly social and neighbourhood based and were aimed at increasing safety and usage and aesthetic value of the green in order to supplement the activities of FOL. FOL have engaged in flood management, restoration, maintenance – including monthly river cleaning days – and wildlife monitoring – including with camera traps and informal sightings. FoRC is a community forum for promoting safe use, information sharing and celebration of the history and biodiversity of the common as a remnant patch.

Following on from the ANT discussion above, Aalto and Ernstson (2017) discuss three case studies of civic collaboration for the design and management of urban nature spaces. Through the different contexts of the case studies they were able highlight the importance of co-authoring the value and meaning of urban natural landscapes. One of these case studies falls within the Cape Town Metropolitan area. About 15 km to the south of Rosebank, Mowbray and Observatory areas, lies Princess Vlei. In 2008, the *vlei* (colloquial for marsh) area was earmarked for redevelopment as a shopping centre. The community formed the Princess Vlei Forum and put a stop to the mall. The community drove the articulation of a landscape design. In this case study, powerful narratives of oppression emerge, personifying the "Princess" of the *vlei* within the context of a historical story of oppression. The restoration of the *vlei* came to be symbolic for the restoration of dignity to previously oppressed people (Aalto & Ernstson 2017).

The value and power of civic organisations in protecting and maintaining remnant patches within urban environments should not be under-estimated. To this end, Dewaelheyns *et al.* (2016) identified the importance of the role of the neighbourhood as key because gardeners are embedded in a local, social context and highlighted the management constraints associated with norms. While Dewaelheyns *et al.* (2016) discuss this in terms of social drivers, the above case studies and work of Aalto and Ernstson (2017) demonstrate how these drivers can also organise around common space and this creates a forum for the production of pro-environmental narratives and cues to care.

4.2.1 Citizen Science

Citizen science as a movement appears to be gaining momentum. Globally it has been used as a method for detecting and monitoring species presence and range shifts, with one or two projects that estimate population size. In South Africa, there are three online databases where volunteer citizen scientists can log on to an app and upload species observations, recording location and date of observation. The three are i-spot, CasaBio and the Animal Demography Unit (ADU). Differences exist between the ways in which the data is curated as well as the way species identities are confirmed. Citizen Science has been used for mapping a range of environmental attributes beyond species demographics and ties in closely with participatory mapping projects. Participatory mapping is defined as "community-based research and development approaches that use local people to map places" (Sieber, 2006:419). Williams *et al.* (2014) offer some insights into the sensitivity and reliability of citizen science data, noting that whilst casual observations are valid in establishing range, they are not reliable enough to factor out false-negatives at the individual patch level for diurnal species and that human aspects such as behaviour (how much the observer is outdoors at night) are more likely to be the causal factor in positive observations than is presence. Having said that, they found that citizens were able to accurately record habitat features and suggested that citizen scientists could play a more involved role than casual observations (Williams, *et al.*, 2014).

4.2.2 Financial, Market and Regulating Instruments

Financial, market and regulatory instruments can be successfully used to incentivise the protection of nature. Cerra (2017) identifies emerging strategies for voluntary urban ecological stewardship on private property. Amongst those, indirect incentives and market-based certification are included here as financial market and regulatory instruments. Similarly Dewaelheyns *et al.* (2016) explored garden governance levers and discuss the value of planning instruments, standards and agreements.

The market instruments highlighted by Cerra (2017) include voluntary certification standards with examples from LEED Green building Council Certification and the National Wildlife Federation's Garden for Wildlife certification scheme. In this instance, the incentive is in the perceived desirability certification schemes bestow, the status symbol and the concomitant market value associated with the property. LEED and other green building standards such as the Australian Green Star are designed to improve property values in the market place and lower vacancies of rental stock by making environmental performance a value-add to an asset (Milne, 2012). Dewaelheyns *et al.* (2016) describe standards in more general terms implying that compliance could be mandatory or voluntary under different contexts. An example of a regulatory standard, is the Management of Urban Stormwater Impacts Policy for Catchment, stormwater and river management (City of Cape Town, 2009). The policy lays out performance requirements for amongst others, detention ponds, Water Sensitive Urban Design which include requirements for private land-owners.

Cerra (2017) defines indirect incentives, in terms of incentives bestowed by regulating bodies which encourage preservation, restoration or ecosystem maintenance activities. Mechanisms for implementation offer land-owners and developers favourable alternatives such as tax reduction or development rights. This is less applicable to citizens and small gardens and more applicable to larger redevelopment programmes. However it is useful to consider it in terms of the types of agreements that underpin such incentives. Dewaelheyns *et al.* (2016) frame it in terms of agreements or charters that are established at a local level between the municipality and themselves. This suggested regulatory lever would be particularly useful as strategies for supporting and establishing practices at the neighbourhood level that support the ecology of the remnant patch. An example in Cape Town where this has been successfully adopted is in the community of Scarborough which was designated as a Conservation Village. The community committed to reverse past environmental damage and avoid future impacts. The undertaking, has found manifestation in landscaping practices that extend the natural and historical vegetation into privately owned gardens and throughout the fabric of the town and streetscapes (Municipal signage on location and personal observations. 2016).

4.3 Knowledge and Nature

The review of the CTN framework (Klassen, 2010), highlighted a number of interlinking processes that foster biospheric values and ultimately pro-environmental behaviour (Martin & Czellar, 2017). Amongst this framework, while not a central theme in this thesis but still worthy of mention is that of prior knowledge. It follows logically that behaviour towards nature is shaped by the quality of the knowledge of nature. Dewaelheyns *et al.* (2016), reported on access to sustainable gardening knowledge as an enabling factor in promoting ecological gardening best practice amongst citizens. Knowledge is qualified by amongst others, experiences, frame of reference pre-existing attitudes, values, cultural approach, and norms. Fundamentally, the quality of the approach is shifted by the quality of the knowledge available. As an under-studied area, urban ecosystems, have gaps in scientific knowledge and so it becomes the role of research to plug those gaps and disseminate the knowledge in accessible ways (Dewaelheyns, *et al.*, 2016). For example, this study revealed that frogs preferred gardens with dense vegetation cover at ground level or moderate vegetation at ground level supplemented with mulch and that consequently, raking garden beds detracts from biodiversity potential of creeping animals. Additionally, it was found that the presence of ponds had a minor role to play and that chemical fertilizers and pesticides have a negative effect of presence. For those gardeners who like frogs and would like to attract them to their gardens, access to this kind of knowledge may produce changes in behaviour.

But, as seen in the example of the analysis of actor networks in The Levels, knowledge is not only generated by science “experts” alone and that local, experiential, and experimental knowledge can have a lot to add to conservation management practices (Burgess, *et al.*, 2000). Dewaelheyns *et al.* (2016) further suggested that ecological gardening needs space both literally and figuratively for gardeners to experiment thereby contributing to the formal and informal sustainable gardening knowledge base.

Natural processes within urban environments therefore need to continue to be studied in isolation from social processes in order to understand the internal responses to structural changes in the environment. For scientific knowledge to be effective in this environment, it necessitates that it is disseminated in accessible formats to the social context and does not undermine local knowledge and empirical observations. Given the mandate to establish the value of nature within human settlements, careful consideration must also be given to the existing norms and informal knowledge of the target audience. This study showed that within a multi-cultural neighbourhood, diverse attitudes experiential knowledge can exists in relation to the same animal group.

4.4 Concluding Remarks

This study provided insights into the habitat characteristics of gardens that create favourable conditions for the species *A. fuscigula* and *S. grayii* in residential gardens in suburbs adjacent to the lower stretches of the Liesbeek River in Cape Town South Africa. For the same community it provided explorative and descriptive data on factors that influence people's perceptions and attitudes towards amphibians. It highlighted the influence of culture and role-models in early childhood in informing attitudes towards a class of animals. The findings are important for researchers in urban ecology who wish to understand or influence people's attitudes and behaviours towards the natural world, in particular, the natural world which confronts people on their doorsteps in their daily lives.

Suggestions for future research are for studies that extend the methodological toolbox for community engagement and stewardship approaches, whilst projects that broaden the technical knowledge of niche habitats and spontaneous species colonisation processes within urban gardens would be beneficial to the field.

5 REFERENCES

Adams, L.W., 2005. Urban wildlife ecology and conservation: A brief history of the discipline. *Urban Ecosystems* 8(2):139–156.

ADU, 2015. *Frogmap.* Available: www.vmus.adu.org.za [2015, November 15]

Anderson, P.M.L. & O'Farrell, P. (2012) An Ecological View of the History of the City of Cape Town. *Ecology and Society* 17(3)28

Barau, A.S., Ludin, A.N.M. & Said, I., 2013. Socio-ecological systems and biodiversity conservation in African city: Insights from Kano Emir's Palace gardens. *Urban Ecosystems.* 16(4):783–800.

Beebee, T.J.C. & Griffiths, R.A., 2005. The amphibian decline crisis: A watershed for conservation biology? *Biological Conservation.* 125(3):271–285.

Belaire, J.A., Westphal, L.M. & Minor, E.S., 2016. Different social drivers, including perceptions of urban wildlife, explain the ecological resources in residential landscapes. *Landscape Ecology* 31:401–413.

Beninde, J., Veith, M. & Hochkirch, A., 2015. Biodiversity in cities needs space: A meta-analysis of factors determining intra-urban biodiversity variation. Ecology Letters, 18(6):581–592.

Beumer, C. & Martens, P., 2014. Biodiversity in my (back)yard: towards a framework for citizen engagement in exploring biodiversity and ecosystem services in residential gardens. *Sustainability Science.* 10(1):87–100.

Birx-Raybuck, D.A., Price, S.J. & Dorcas, M.E., 2010. Pond age and riparian zone proximity influence anuran occupancy of urban retention ponds. *Urban Ecosystems.* 13(2):181–190.

Bouchard, J. *et al.*, 2009. Behavioral Responses of Northern Leopard Frogs (Rana pipiens) to Roads and Traffic: Implications for Population Persistence. *Research.* 14(2):23 - 33

Brown, D.J. *et al.*, 2012. A Place to Call Home: Amphibian Use of Created and Restored Wetlands. *International Journal of Ecology.* 2012:1–11.

Bryman, A. & Bell, E., 2014. *Research Methodology Business and Management Contexts*, Cape Town: Oxford University Press.

Burgess, J., Clark, J. & Harrison, C.M., 2000. Knowledges in action: an actor network analysis of a wetland agri-environment scheme. *Ecological Economics.* 35:119–132.

Cape Town Emap. 2016.*Observatory, Cape Town, South Africa.* Available: http://emap.capetown.gov.za/EGISSub/ [2017, August 18]

Cameron, R.W.F. *et al.*, 2012. The domestic garden – Its contribution to urban green infrastructure. *Urban Forestry & Urban Greening.* 11(2):129–137.

Ceríaco, L.M., 2012. Human attitudes towards herpetofauna: The influence of folklore and negative values on the conservation of amphibians and reptiles in Portugal. *Journal of Ethnobiology and Ethnomedicine.* 8(1), p.8.

Cerra, J.F., 2017. Emerging strategies for voluntary urban ecological stewardship on private property. *Landscape and Urban Planning.* 157:586–597.

Chan, K.M.A. *et al.*, 2016. Opinion: Why protect nature? Rethinking values and the environment. *Proceedings of the National Academy of Sciences.* 113(6):1462–1465.

Chang, Y-H., Wu, B-Y. & Lu, H-L., 2014. Using ecological barriers for the conservation of frogs along roads. *Ecological Engineering.* 73:102–108.

Channing, A. 2001.*Amphibians of Central and Southern Africa.* South Africa: Protea Book House

Church, S.P., 2015. Exploring Green Streets and rain gardens as instances of small scale nature and environmental learning tools. *Landscape and Urban Planning.* 134:229–240.

Cilliers, S. & Siebert, S., 2012. Urban Ecology in Cape Town: South African Comparisons and Reflections. *Ecology and Society* 17(3):33.

City of Cape Town, 2009. *Management of Urban Stormwater Impacts Policy.* August 2017. Available: https://www.westerncape.gov.za/assets/departments/transport-public-works/Documents/management_of_urban_stormwater_impacts_policy.pdf.

Clarke, L.W. *et al.*, 2014. Drivers of plant biodiversity and ecosystem service production in home gardens across the Beijing Municipality of China. *Urban Ecosystems.* 17(3):741–760.

Clayton, S., 2007. Domesticated nature: Motivations for gardening and perceptions of environmental impact. *Journal of Environmental Psychology.* 27(3):215–224.

Corbyn, Z., 2010. Ecologists shun the urban jungle. *Nature.* July 2016. Available: http://www.nature.com/news/2010/100716/full/news.2010.359.html

Cosentino, B.J. *et al*., 2014. Citizen science reveals widespread negative effects of roads on amphibian distributions. *Biological Conservation.* 180:31–38.

Cowan, O.S. & Anderson, P.M.L., 2014. The peninsula shale renosterveld of devil's peak, western cape: A study into the vegetation and seedbank with a view toward potential restoration. *South African Journal of Botany.* 95:135–145.

Dandy, N. *et al.*, 2011. Preferences for wildlife management methods among the peri-urban public in Scotland. *European Journal of Wildlife Research.* 57(6):1213–1221.

de Groot, W.T. *et al.*, 2003. Visions of nature and landscape type preferences: an exploration in The Netherlands. *Landscape and Urban Planning.* 63(63):127–138.

Dewaelheyns, V., Kerselaers, E. & Rogge, E., 2016. A toolbox for garden governance. *Land Use Policy.*51:191–205.

Doody, B.J. *et al.*, 2010. Urban realities: The contribution of residential gardens to the conservation of urban forest remnants. *Biodiversity and Conservation.* 19(5):1385–1400.

Doucette-Riise, S., 2012. Migration and dispersal of the Western Leopard toad Amietophrynus pantherinus in a fragmented agricultural landscape. M.Sc. Thesis. University of Cape Town

du Preez, L.H., Carruthers, V. & Burger, V., 2009. *A Complete Guide to the Frogs of southern Africa, Cape Town*: Struik Nature.

Duerden, M.D. & Witt, P.A., 2010. The impact of direct and indirect experiences on the development of environmental knowledge, attitudes, and behavior. *Journal of Environmental Psychology.* 30(4):379–392.

Erixon Aalto, H. & Ernstson, H., 2017. Of plants, high lines and horses: Civic groups and designers in the relational articulation of values of urban natures. *Landscape and Urban Planning.* 157(January):309–321.

Forman, R.T.T., 2016. Urban ecology principles: are urban ecology and natural area ecology really different? *Landscape Ecology*, 31(8):1653–1662.

Francesco Ficetola, G. & De Bernardi, F., 2004. Amphibians in a human-dominated landscape: the community structure is related to habitat features and isolation. *Biological Conservation.* 119(2):219–230.

Freeman, C. *et al.*, 2012. “My garden is an expression of me”: Exploring householders’ relationships with their gardens. *Journal of Environmental Psychology.* 32(2):135–143.

Gagné, S.A. & Fahrig, L., 2007. Effect of landscape context on anuran communities in breeding ponds in the National Capital Region, Canada. *Landscape Ecology*, 22(2):205–215.

Gallagher, M.T. *et al.*, 2014. The role of pollutant accumulation in determining the use of stormwater ponds by amphibians. Wetlands Ecology and Management VO - 22, (5), p.551.

Garcia-Gonzalez, C. *et al.*, 2012. Rural road networks as barriers to gene flow for amphibians: Species-dependent mitigation by traffic calming. *Landscape and Urban Planning.* 104(2):171–180.

Garland, R., 1991. The mid-point on a rating scale: Is it desirable? Marketing Bulletin, 2:66–70.

Gaston, K.J. *et al.*, 2005. Urban domestic gardens (II): Experimental tests of methods for increasing biodiversity. *Biodiversity and Conservation.* 14(2):395–413.

Gibbs, J.P. & Shriver, W.G., 2005. Can road mortality limit populations of pool-breeding amphibians? *Wetlands Ecology and Management.* 13(3):281–289.

Gliem, J.A. & Gliem, R.R., 2003. Calculating, interpreting, and reporting Cronbach’s alpha reliability coefficient for Likert-type scales. Midwest Research to Practice Conference in Adult, *Continuing, and Community Education.* (1992):82–88.

Goddard, M.A., Dougill, A.J. & Benton, T.G., 2010. Scaling up from gardens: biodiversity conservation in urban environments. *Trends in Ecology and Evolution.* 25(2):90–98.

Goddard, M. a., Dougill, A.J. & Benton, T.G., 2013. Why garden for wildlife? Social and ecological drivers, Motivations and barriers for biodiversity management in residential landscapes. *Ecological Economics.* 86:258–273.

Goldberg, C.S. & Waits, L.P., 2009. Using habitat models to determine conservation priorities for pond-breeding amphibians in a privately-owned landscape of northern Idaho, USA. *Biological Conservation.* 142(5):1096–1104.

Gómez-Rodríguez, C. *et al.*, 2009. Mediterranean temporary ponds as amphibian breeding habitats: The importance of preserving pond networks. Aquatic Ecology, 43(4):1179–1191.

Google Maps. 2016. *Observatory, Cape Town, South Africa.* Available: https://www.google.com/maps/d/u/0/edit?mid=1oIPodtO6a97-t_3_Y2EJYp9I29o&ll=-33.9455105714878%2C18.475270249999994&z=14 [2017, August 18]

Hahs, A.K. & Evans, K.L., 2015. Expanding fundamental ecological knowledge by studying urban ecosystems. *Functional Ecology.* 29(7):863–867.

Hamer, A.J., Smith, P.J. & McDonnell, M.J., 2012. The importance of habitat design and aquatic connectivity in amphibian use of urban stormwater retention ponds. *Urban Ecosystems.* 15:451–471.

Hartel, T. *et al.*, 2010. Amphibian distribution in a traditionally managed rural landscape of Eastern Europe: Probing the effect of landscape composition. *Biological Conservation.* 143(5):1118–1124.

Hassall, C. & Anderson, S., 2014. Stormwater ponds can contain comparable biodiversity to unmanaged wetlands in urban areas. *Hydrobiologia.* 745(1):137–149.

Haysom, G., 2014. Food System Governance for Urban Sustainability in the Global South. M.Sc. Thesis. University of Cape Town.

Hazell, D. *et al.*, 2004. A comparison of constructed and natural habitat for frog conservation in an Australian agricultural landscape. *Biological Conservation.* 119(1):61–71.

Hels, T. & Buchwald, E., 2001. The effect of road kills on amphibian populations. *Biological Conservation.* 99:331–340.

Hobbs, R.J., Higgs, E. & Harris, J.A., 2009. Novel ecosystems: implications for conservation and restoration. *Trends in Ecology and Evolution.* 24(11):599–605.

Hocking, D. & Babbitt, K.J. 2013. Amphibian Contributions to Ecosystem Services. *Herpetological Conservation and Biology*. 9(1):1 – 17.

Holzer, K.A., 2014. Amphibian use of constructed and remnant wetlands in an urban landscape. *Urban Ecosystems.* 17(4):955–968.

Hunter, A.J. & Luck, G.W., 2015. Defining and measuring the social-ecological quality of urban greenspace: a semi-systematic review. *Urban Ecosystems.* 18(4):1139–1163.

Hunter, L.M. & Brehm, J.M., 2004. A Qualitative Examination of Value Orientations Toward Wildlife and Biodiversity by Rural Residents of the Intermountain Region. *Human Ecology Review.*11(1):13–26.

Ikin, K. *et al.*, 2015. Key lessons for achieving biodiversity-sensitive cities and towns. *Ecological Management & Restoration.* 16(3):206–214.

Ives, C.D. *et al.*, 2015. Cities are hotspots for threatened species. *Global Ecology and Biogeography.* 25:117–126.

Jacoby, J. & Mattel, M.S., 1971. Three-Point Likert Scales Are Good Enough. *Journal of Marketing Research*. 8(4):495–500.

Katsifarakis, K.L., Vafeiadis, M. & Theodossiou, N., 2015. Sustainable Drainage and Urban Landscape Upgrading Using Rain Gardens. Site Selection in Thessaloniki, Greece. *Agriculture and Agricultural Science Procedia.* 4:338–347.

Kendal, D., Williams, K.J.H. & Williams, N.S.G., 2012a. Plant traits link people's plant preferences to the composition of their gardens. *Landscape and Urban Planning.* 105(1–2):34–42.

Kendal, D., Williams, N.S.G. & Williams, K.J.H., 2012b. Drivers of diversity and tree cover in gardens, parks and streetscapes in an Australian city. *Urban Forestry and Urban Greening.* 11(3):257–265.

Kiesling, F.M. & Manning, C.M., 2010. How green is your thumb? Environmental gardening identity and ecological gardening practices. *Journal of Environmental Psychology.* 30(3):315–327.

Klassen, M.J., 2010. Connectedness to nature: Comparing rural and urban youths' relationships with nature. M.A. Thesis. University of Manitoba

Knight, A.J., 2008. "Bats, snakes and spiders, Oh my!" How aesthetic and negativistic attitudes, and other concepts predict support for species protection. *Journal of Environmental Psychology.* 28(1):94–103.

Kruger, D.J.D., Hamer, A.J. & du Preez, L.H., 2015. Urbanization affects frog communities at multiple scales in a rapidly developing African city. Urban Ecosystems.

LaPoint, S. *et al.*, 2015. Ecological Connectivity Research in Urban Areas. *Functional Ecology.* 29:868–878.

Larson, K.L. *et al.*, 2009. Residents' yard choices and rationales in a desert city: Social priorities, ecological impacts, and decision tradeoffs. *Environmental Management.* 44(5):921–937.

Larson, K.L. *et al.*, 2011. The Influence of Diverse Values, Ecological Structure, and Geographic Context on Residents' Multifaceted Landscaping Decisions. *Human Ecology.* 38(6):747–761.

Le Viol, I. *et al.*, 2012. More amphibians than expected in highway stormwater ponds. *Ecological Engineering.* 47:146–154.

Lee, Y.-F. *et al.*, 2006. Composition, Diversity, and Spatial Relationships of Anurans Following Wetland Restoration in a Managed Tropical Forest. Zoological Science, (23):883–891.

Lekies, K. & Beery, T., 2013. Everyone Needs a Rock: Collecting Items from Nature in Childhood. *Children Youth and Environments.* 23(3):66–88.

Lenhardt, P.P. *et al.*, 2013. An expert-based landscape permeability model for assessing the impact of agricultural management on amphibian migration. *Basic and Applied Ecology.* 14(5):442–451.

Löfvenhaft, K., Runborg, S. & Sjögren-Gulve, P., 2004. Biotope patterns and amphibian distribution as assessment tools in urban landscape planning. *Landscape and Urban Planning.* 68(4):403–427.

Lundholm, J.T. & Richardson, P.J., 2010. Habitat analogues for reconciliation ecology in urban and industrial environments. *Journal of Applied Ecology.* 47(5):966–975.

Magle, S.B. *et al.*, 2012. Urban wildlife research: Past, present, and future. *Biological Conservation.* 155:23–32.

Marris, E., 2009. Ragamuffin earth. *Nature.* 460:450–453.

Marsh, G.P. 1864. *Man and Nature: Physical Geography as Modified by Human Action.* New York: Scribner & co.

Martin, C. & Czellar, S., 2017. Where do biospheric values come from? A connectedness to nature perspective. *Journal of Environmental Psychology.* 52:56–68.

Martini, N.F., Nelson, K.C. & Dahmus, M.E., 2014. Exploring Homeowner Diffusion of Yard Care Knowledge as One Step Toward Improving Urban Ecosystems. *Environmental Management.* 54(5):1223–1236.

Maurer, T.J. & Andrews, K.D., 2000. Traditional, Likert, and Simplified Measures of Self-Efficacy. *Educational and Psychological Measurement.* 60(6):965–973.

Mayer, F.S. & Frantz, C.M., 2004. The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology.* 24(4):503–515.

Mazerolle, M.J., 2004. Herpetologists League. *Herpetologica.* 60(1):45–53.

McCarthy, K. & Lathrop, R.G., 2011. Stormwater basins of the New Jersey coastal plain: Subsidies or sinks for frogs and toads? *Urban Ecosystems.* 14(3):395–413.

McCullagh, P. & Nelder, J.A., 1989. *Generalized Linear Models, Second Edition.* London: Chapman and Hall.

McDonnell, M.J., 2013. The History of Urban Ecology - An Ecologist's Perspective. In J. Niemela *et al.*, eds. *Urban Ecology, patterns, processes, and applications*. New York: Oxford University Press: 5–14.

Mcdonnell, M.J. & Hahs, A.K., 2013. The future of urban biodiversity research : Moving beyond the " low-hanging fruit ." *Urban Ecosystems.* 16(3):397–409.

Measey, G.J., 2011. *Ensuring a future for South Africa's frogs: a strategy for conservation research.* Cape Town: SANBI.

Measey, J. & Mokhatla, M., 2016. The future for frogs looks bleak, unless humans change their habits. *The Conversation.* Available at: http://ewn.co.za/2016/04/11/OPINION-The-future-for-frogs-looks-bleak [2016, November 11].

Melendez-Ackerman, E.J. *et al.*, 2014. Socioeconomic drivers of yard sustainable practices in a tropical city. *Ecology and Society.* 19(3).

Melles, S.J., 2005. Urban bird diversity as an indicator of human social diversity and economic inequality in Vancouver, British Columbia. *Urban Habitats.* 3(1):25–48.

Milne, N., 2012. *The Rands and Sense of Green Building*, Cape Town: GBCSA

Minter, L.R. (ed.), 2004. *Atlas and Red Data Book of Frogs of South Africa, Lesotho and Swaziland.* Washington DC: Smithsonian Institution.

Mittermeier, R.A. *et al.*, 2011. Global Biodiversity Conservation: The Critical Role of Hotspots. In F. E. Zachos & J. C. Habel, eds. *Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas.* Berlin, Heidelberg: Springer: 3–22.

Murdoch, J., 2001. Ecologising Sociology: Actor-Network Theory, Co-construction and the Problem of Human Exemptionalism. *Sociology.* 35(1):111–133.

Nassauer, J.I., Wang, Z. & Dayrell, E., 2009. What will the neighbors think? Cultural norms and ecological design. *Landscape and Urban Planning.* 92(3–4):282–292.

Norton, B.G., 2017. Novel Ecosystems: Adaptive Management and Social Values in the Anthropocene. *Reference Module in Earth Systems and Environmental Sciences,* (June).

Nyström, P. *et al.*, 2007. A documented amphibian decline over 40 years: Possible causes and implications for species recovery. *Biological Conservation.* 138(3–4):399–411.

O'Brien, C.D., 2015. Sustainable drainage system (SuDS) ponds in Inverness, UK and the favourable conservation status of amphibians. *Urban Ecosystems.* 18(1):321–331.

Pauleit, S. & Breuste, J.H., 2013. Land-Use and surface-Cover as Urban Ecological Indicators. In J. Niemela *et al.*, eds. *Urban Ecology, patterns, processes, and applications.* New York: Oxford University Press: 5–14.

Palmer, J.A. *et al.*, 1999. Significant Life Experiences and Formative Influences on the Development of Adults ' Environmental Awareness in the UK , Australia and Canada. *Environmental Education Research.*5(2):181–200.

Peterson, A.C. *et al.*, 2013. Investigating the dispersal routes used by an invasive amphibian, Lithobates catesbeianus, in human-dominated landscapes. *Biological Invasions.* 15(10):2179–2191.

Porej, D. & Hetherington, T.E., 2005. Designing wetlands for amphibians: The importance of predatory fish and shallow littoral zones in structuring of amphibian communities. *Wetlands Ecology and Management.* 13(4):445–455.

Rannap, R., Lõhmus, A. & Briggs, L., 2009. Restoring ponds for amphibians: a success story. *Hydrobiologia.* 634(1):87–95.

Rebelo, A.G. *et al.*, 2006. Fynbos Biome. In M. C. Mucina, L., Rutherford, ed. T*he Vegetation of South AFrica, Lesotho and Swaziland*. Pretoria: South African National Biodiversity Institute: 53–220.

Rebelo, A.G. *et al.*, 2011. Impacts of urbanization in a biodiversity hotspot: Conservation challenges in Metropolitan Cape Town. *South African Journal of Botany.* 77(1):20–35.

Republic of South Africa, 2005. State of Rivers Report: Greater Cape Town's Rivers. Available: http://soer.deat.gov.za/dm_documents/greaterCapeTown_05_lxjlG.pdf [2017, August 18]

Restall, B. & Conrad, E., 2015. A literature review of connectedness to nature and its potential for environmental management. Journal of *Environmental Management.*159:264–278.

Ribeiro, R. *et al.*, 2011. The pond network: Can structural connectivity reflect on (amphibian) biodiversity patterns? *Landscape Ecology*, 26(5):673–682.

Romano, A. *et al.*, 2014. Importance of a traditional irrigation system in amphibian conservation in the Cinque Terre National Park (NW Italy). Journal for Nature Conservation, 22(5):445–452.

Rumbeiha, W.K., 2014*. Metaldehyde A2*. In Wexler, Philip BT - Encyclopedia of Toxicology (Third Edition). In Oxford: Academic Press: 227–229.

Saarikivi, J. *et al.*, 2013. The role of golf courses in maintaining genetic connectivity between common frog (Rana temporaria) populations in an urban setting. *Conservation Genetics.* 14(July 2015):1057–1064.

Salako, V.K. *et al.*, 2013. Home gardens: an assessment of their biodiversity and potential contribution to conservation of threatened species and crop wild relatives in Benin. Genetic *Resources and Crop Evolution.* 61(2):313–330.

Scheffers, B.R. & Paszkowski, C.A., 2013. Amphibian use of urban stormwater wetlands: The role of natural habitat features. *Landscape and Urban Planning.* 113:139–149.

Scherer, R.D., Muths, E. & Noon, B.R., 2012. The importance of local and landscape-scale processes to the occupancy of wetlands by pond-breeding amphibians. *Population Ecology.* 54(4):487–498.

Schmidt, B.R. & Zumbach, S., 2008. Amphibian Road Mortality and How to Prevent It: A Review. *Urban Herpetology* St Louis, Missouri: University of Zurich: 157–167.

Seto, K.C., 2013. Regional Assessment of Asia. In T. Elmqvist *et al.*, eds. *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment*. Dordrecht Heidelberg New York London: Springer Open: 53–56.

Shochat, E. *et al.*, 2006. From patterns to emerging processes in mechanistic urban ecology. *Trends in Ecology and Evolution.* 21(4):186–191.

Shulse, C.D. *et al.*, 2010. Influences of Design and Landscape Placement Parameters on Amphibian Abundance in Constructed Wetlands. *Wetlands.* 30(5):915–928.

Sieber, R. 2006. Public Participation Geographic Information Systems: A literature Review and Framework. *Annals of the Association of American Geographers.* 96(3):491 – 507.

Simon, J.A. *et al.*, 2009. Spatial correlates of amphibian use of constructed wetlands in an urban landscape. *Landscape Ecology*, 24(3):361–373.

Smallbone, L.T., Luck, G.W. & Wassens, S., 2011. Anuran species in urban landscapes: Relationships with biophysical, built environment and socio-economic factors. *Landscape and Urban Planning.* 101(1): 43–51.

Standish, R.J., Hobbs, R.J. & Miller, J.R., 2013. Improving city life: options for ecological restoration in urban landscapes and how these might influence interactions between people and nature. *Landscape Ecology*, 28(6):1213–1221.

Statistics South Africa, 2011. Census 2011 community Profiles Dataset.

Stern, P. & Dietz, T., 1994. The Values of Basis of Environmental Concern. *Journal of Social Issues.* 50(3):65–84.

Stuart, S., Chanson, J.S. & Cox, N.A. *et al.* 2004. Status and trends of amphibian declines and extinctions worldwide.*Science*. 306: 1783–1786.

Tarrant, J., Kruger, D. & Preez, L., 2016. Do public attitudes affect conservation effort ? Using a questionnaire- based survey to assess perceptions, beliefs and superstitions associated with frogs in South Africa. *African Zoology*: 1–8

Trumbo, D.R. *et al.*, 2012. Integrating local breeding pond, landcover, and climate factors in predicting amphibian distributions. *Landscape Ecology*. 27(8):1183–1196.

Uren, H. V., Dzidic, P.L. & Bishop, B.J., 2015. Exploring social and cultural norms to promote ecologically sensitive residential garden design. *Landscape and Urban Planning*. 137(0):76–84.

Van den Berg, A.E. & van Winsum-Westra, M., 2010. Manicured, romantic, or wild? The relation between need for structure and preferences for garden styles. *Urban Forestry and Urban Greening.* 9(3):179–186.

Wang, R. *et al.*, 2011. Understanding eco-complexity : Social-Economic-Natural Complex Ecosystem approach. *Ecological Complexity.* 8(1):15–29.

Wells, N.M. & Lekies, K.S., 2006. Nature and the life course: Pathways from childhood nature experiences to adult environmentalism. Children, youth and environments, 16(1):1–25.

Westgate, M.J. *et al.*, 2015. Citizen Science Program Shows Urban Areas Have Lower Occurrence of Frog Species, but Not Accelerated Declines. *PloS one*. 10(11):1 - 15

Williams, R.L., Stafford, R. & Goodenough, A.E., 2014. Biodiversity in urban gardens: Assessing the accuracy of citizen science data on garden hedgehogs. *Urban Ecosystems.* 18:819–833.

Woltz, H., Gibbs, J. & Ducey, P., 2008. Road crossing structures for amphibians and reptiles: Informing design through behavioral analysis. *Biological Conservation.* 141(11):2745–2750.

Wu, J., Xiang, W.-N. & Zhao, J., 2014. Urban ecology in China: Historical developments and future directions. *Landscape and Urban Planning.* (125):222–233.

Zmyslony, J., and D. Gagnon. 1998. Residential management of urban front-yard landscape: A random process? Landscape and Urban Planning 40:295-307.