A Social-Ecological Investigation into Urban Domestic Gardens and Avifauna in Medium-Sized Towns of the Eastern Cape, South Africa

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ABSTRACT

Urban domestic gardens are an often overlooked component of urban green infrastructure, despite their potential to contribute to the preservation of urban biodiversity. As opposed to public greenspaces, private gardens are individually owned and managed, thus act as social-ecological systems, where the cumulative actions of urban residents can scale up to influence ecological patterns and processes on a larger scale. The diversity of fauna and flora within urban gardens provide a range of ecosystem goods and services, as well as less tangible benefits in the form of recreation, education and culture. However, little is known about the contribution of urban domestic gardens to urban biodiversity and its potential conservation value in South Africa. This study investigated urban domestic gardens along a socio-economic gradient in two medium-sized towns, Grahamstown and Port Alfred in the Eastern Cape, South Africa.

This study found distinct differences among urban resident garden management practices as well as the avifauna which were seen within the gardens across the socio-economic gradient. The Garden Management Intensity index was higher within affluent households compared to other socio-economic levels, with subsequent management scores not differing statistically along the gradient. While there was variation within garden management practices, as well as the number of residents who participated in supplementary bird feeding, little variation was seen in the activities which were enjoyed by the residents, indicating numerous benefits the garden environment provides for all urban residents.

The bird community composition along the socio-economic gradient displayed patterns directly reflecting the “luxury effect”, where households with a higher socio-economic status had harbour gardens with greater levels of biodiversity. This study showed that affluent gardens displayed far greater diversity, richness and abundance of urban birds. Multivariate analyses confirmed the patterns by highlighting a distinct bird community in the affluent zone, compared to other two socio-economic zones, which housed a second bird community. Furthermore, the main driver of the bird community composition was dominated by vegetation complexity, most notably tree cover within the gardens. Therefore, this study highlighted that patterns of

ecological inequality are highly evident in medium-sized towns in South Africa, where older, affluent suburbs households display greater diversity and abundance of birdlife, compared to subsequent socio-economic zones within the study. Prioritisation with regards to the benefits a garden environment brings to urban residents in terms of a connection to nature, access to urban greenery, and relationship to urban wildlife is vital and should be promoted and planned for across all socio-economic zones.

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CHAPTER 1: INTRODUCTION

Broadly expressed as changes in human population densities and land cover (Elmqvist et al. 2008); the process of urbanisation is undeniably at the forefront of global land transformation (Pickett et al. 2001; Grimm et al. 2008). Urbanisation is occurring predominantly in developing countries, which are expected to hold up to 80% of the urban population by the year 2030 (UNFPA 2007). In addition to these global urban changes, the majority of the creation of new megacities is occurring in developing countries which attract occupants from rural villages and smaller towns (Grimm et al. 2008). For example, the Sub-Saharan African urban population is predicted to increase by 473% between 1990 and 2020 (Cilliers et al. 2013). As the human population continues to expand, accompanied by economic growth and demographic shifts, systemic changes within social-ecological systems will greatly increase the resources demanded from the natural world, leading to increased consumptive footprints, pollution, habitat destruction and biodiversity losses (McKinney 2006).

Rapid urbanisation is resulting in significant changes in biodiversity through habitat fragmentation, biotic homogenisation, alien species invasions, species losses and depletion of ecosystem services (Grimm et al. 2008). As the density of people residing in urban environments increases, urbanisation is altering the way in which humans interact with nature and in so many settings is resulting in the 'extinction of experience', a term describing the increased disconnection from the natural world through time and across generations (Miller 2005).

Urban ecosystems are loosely defined as "those areas in which people reside at high densities, where built structures and infrastructure cover much of the land surface" (Pickett et al. 2001) and are often thought of as the opposite of a wild, unspoilt or rural and agrarian landscapes. However, urban ecosystems include a continuum of areas varying in human density including, but not limited to, suburban or residential areas, smaller settlements and towns as well as completely built up areas (Pickett et al. 2011). Boundaries of urban ecosystems are often set by watersheds, commuting distances or by administrative radii (Pickett et al. 2011).

Two main definitions of urban ecology emerge within the literature, the first within urban planning and the second within the natural sciences (Pickett et al. 2011). Within urban planning, urban ecology focuses on decreasing the environmental impact of urban areas through design of facilities and built infrastructure which require ecological justification for planning approaches and goals

(Deelstra 1998). Within ecological sciences, urban ecology was initially defined as the study of the distribution and abundance of organisms within and around urban regions as well as on their biogeochemical budget (Pickett et al. 2011). However, over the last decade or so, it has evolved in a more systems thinking discipline of the interactions between humans and urban nature.

1.1 Development of Urban Ecology

Urban ecological research is thought to have begun in 16th century observations of vegetation growth on European stone walls and castles, although the formal discipline of urban ecology did not exist at the time (Weiland & Richter 2009). Despite these early beginnings, much of the research dominating the first 60 years of the 20th century was devoid of any investigation into the human influence on the landscape, as ecological sciences were subject to the Balance of Nature Paradigm, whereby nature is maintained in a state of stability unless disrupted by the influence of humans, therefore much of the research was conducted in study sites which excluded humans (McDonnell 2011). Over the last 30 years, evidence has indicated that the Balance of Nature Paradigm is limited and thus gave rise to the Non-Equilibrium Paradigm whereby ecological systems are process driven and not end-point driven, allowing the inclusion of humans as a component of the ecosystem (McDonnell 2011). As a result, urban ecology integrates conceptual frameworks from both natural and social sciences to understand the patterns and processes of urban systems (McHale et al. 2013).

Following the industrial revolution, typifying North American and European cities of the 19th and 20th centuries, a researcher within the “Chicago School” of urban sociology attempted to investigate the interrelations between the city and its society. Drawing on theories of major sociologists of the time, Robert Park attempted to explain the impact on society of the development of the Chicago area by using ecological theories such as succession, adaptation and competition (Weiland & Richter 2009). Although these approaches have since been criticised, the research questions and methods established by the school were pivotal in the development of social-ecological theory with the urban ecosystem (McDonnell 2011).

By the 1990s, urban ecology had emerged fully as a sub-discipline of ecology (Grimm et al. 2000), driven by the widespread understanding that the expansion of cities and increased population sizes have altered virtually all ecosystems globally on multiple scales (Pickett et al. 2011). However, it is important to note three main paradigms within urban ecological sciences following the middle of the 20th century. That is, ecology in the city, ecology of the city and ecology for the city, each differing in disciplinary focus, questions posed, research approaches and modelling techniques (Pickett et al. 2011).

The first paradigm, ecology in the city, pioneered in Europe and Asia following the Second World War, involved the study of biological organisms within natural or semi-natural habitats or ecosystems in urban areas. For instance, research focussed on measuring descriptive variables of forest patches, parks, cemeteries, vacant lots or wetlands (Pickett et al. 2016) and urban wildlife ecology such as biodiversity measures, food web structures or biotic community assemblages (Adams 2005), mirroring ecological investigations in rural and relatively wild areas.

The second paradigm, ecology of the city, involved a more inclusive interdisciplinary approach to urban ecology (Pickett et al. 2016). This approach allowed for an entire metropolitan area to be surveyed, as compared to mostly green patches in the first approach. This paradigm took into account all types of habitats within the city (not only urban green spaces) as well as spatial heterogeneity. Most importantly, it included humans and social systems at all scales from individuals to municipalities, which were included and linked to the biophysical characteristics of the urban area and increased the focus on complexity and links between the social and ecological sciences (Pickett et al. 2016).

The ecology for the city paradigm involved the inclusion of civic processes with ecology, extending beyond the academic realm (Pickett et al. 2016). This paradigm adopted the philosophy of stewardship pioneered by Aldo Leopold, whereby scientific knowledge of urban ecosystems is integrated with dialogues with a 'steward' or household member or institution, or citizens, groups, or agencies who are responsible for the functioning of their environment, thus integrating an ethical component to scientific understanding (Palmer 2014). Since the paradigm holds a strong philosophy of environmental stewardship within the social-ecological studies, factors such as power, politics and wealth should not influence the outcome of the research but may guide questions and research (Pickett et al. 2016).

The integration of natural and social sciences within urban ecology is important for two reasons. Firstly, as urban ecosystems represent novel combinations of stressors, disturbances, structures and habitats, understanding how they function, are changed or are limited, will contribute to understanding of ecosystems in general (Pickett et al. 1997). Secondly, the expansion of urban ecosystems often extends into agricultural lands or relatively natural habitats, and thus plays a major role in habitat fragmentation and transformation (Pickett et al. 1997; Grimm et al. 2000). Land that was originally studied using traditional ecological approaches now requires a greater understanding of how humans are altering the landscape (Pickett et al. 1997). Furthermore, observed patterns and processes within the behaviour of urban dwellers are inherently linked to the degree of direct pressure placed upon exploiting natural resources and responding to environmental impacts, thus emphasising the importance of an integrated approach to urban ecological studies (Pickett et al. 1997; McHale et al. 2013).

1.2 The Role of Urban Biodiversity

Despite the global impact of cities, humans as a species have lived as isolated hunter-gatherers, migratory herders or small scale agriculturalists for the majority of the course of history (Grove & Burch 1997; Keniger et al. 2013). Urbanisation dramatically modifies ecosystems and biodiversity on numerous scales, therefore creating novel environments to which humans, plants and animals were previously unexposed (Lowry et al. 2013). Furthermore, the diversity of fauna and flora within urban environments plays a vital role in the supply of ecosystem goods and services and disservices.

Defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al. 1997), ecosystem goods and services are used to describe how the environment and humans are inherently linked (Cilliers et al. 2013). According to the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) Conceptual Framework, "Nature's benefits to people" refers to the benefits that humans on all scales, derive from nature, whether in a rural or urban context, and makes up one of six interlinking pillars within the framework (Diaz et al. 2015). Ecosystem goods and services (including the provisioning, regulating and cultural services), fall within the benefits derived from nature. Urban greenspaces (UGS) potentially play a vital role in the provision of these goods and services within urban ecosystems by providing numerous environmental, economic and social benefits (Kinzig et al. 2005).

Urban greenspaces are defined as the areas which consist of mostly permeable, unsealed surfaces such as grass, shrubs, soils and trees, while "grey spaces" include the largely sealed, impermeable surfaces such as concrete and paving (Swanwick et al. 2003). Recently, the term 'urban green infrastructure' has been used to describe all green areas within urban environments, including but not limited to conservation areas, green corridors, public parks, railway verges, wetlands, remnant lands, etc. (Tzoulas et al. 2007). Ecologically, urban green infrastructure provides an increase in overall connected vegetation cover, in turn contributing to the conservation of biological diversity through decreasing the amount of impervious area (McKinney 2008). Green infrastructure is fundamental to maintaining ecological connections and networks within the urban landscape, which further mitigate the impact of habitat fragmentation while allowing for the movement and dispersal of species (du Toit et al. 2018). Green infrastructure contributes to decreasing the impacts of biotic homogenisation by preserving and enhancing diversity in terms of processes, habitats, species and genes (Tzoulas et al. 2007). Species-rich ecosystems have increased resistance and resilience, use resources more efficiently, and display higher productivity (Tzoulas et al. 2007). Furthermore, urban green infrastructure contributes to reduced flood risk and surface runoff, lower wind speeds, air filtering, decreases in noise pollution and microclimate regulation and may further reduce the ecological footprint of humans within concentrated systems (Keeley & Benton-Short 2019).

Urban green infrastructure provides the primary spaces for urban citizens to have interactions with elements of biodiversity (Kinzig 2005; Jennings & Bamkole 2019). Some of the negative effects of a lack of direct, regular encounters with the natural environment include decreased health and wellbeing, apathy towards the value and benefits of nature and a diminished affinity towards biodiversity, and hence a lowered interest in its conservation (Soga et al. 2016). This has implications not only for biodiversity conservation, but also for the supply of other ecosystem goods and services which rely on sufficient richness and abundance of biodiversity. The “people-biodiversity paradox” highlights the effects of increased isolation from natural systems, where a mismatch occurs between (a) people’s biodiversity preferences and how these relate to subjective wellbeing and (b) the limited ability of individuals to accurately perceive the surrounding biodiversity (Fuller et al. 2012). The resultant effects foster limited public interest and involvement in urban ecology and conservation (Miller 2005).

A large body of literature highlights the positive physical, psychological and social effects of regular interaction with nature on health and wellbeing (Keniger et al. 2013; Hartig et al. 2014; Soga et al. 2017; Jennings & Bamkole 2019). Positive effects on mental processes include reduced anxiety, mental fatigue, stress, increased psychological wellbeing, cognitive functioning, productivity, attention restoration, healing and positive spiritual and cultural wellbeing (Keniger et al. 2013; du Toit et al. 2018; Jennings & Bamkole 2019).

1.3 Urban Wildlife

Urban environments have provided wildlife with novel selection pressures, vastly different to those under which the species evolved. Wildlife which are able to adjust their survival, reproduction and fitness accordingly should have a greater success within these modified environments (Lowry et al. 2013). Urban environments provide highly fragmented and spatially heterogenous habitats such as parks, road verges, golf courses, cemeteries and private gardens. Urban areas may exert negative effects on wildlife such as increased mortality risk from roads and traffic, increased predation from the high abundance of domestic animals, chemicals which reduce food availability and increase risk of poisoning and disturbance by humans (Baker & Harris 2007). Urban areas may also provide positive influences on some fauna such as a constant, aseasonal food supply, human waste as food, decreased abundance of natural predators, increased temperatures, intentional feeding, and wildlife-friendly gardening practices (Baker & Harris 2007).

The term synurbanisation (related to synanthropisation and urbanisation) refers to how some animal populations adjust to conditions within the urban environment (Bruch et al. 2002). The process of synurbanisation is of particular interest to urban ecological studies as it demonstrates behavioural plasticity and microevolutionary changes within faunal populations in urban environments (Bruch et al. 2002). Synurbanisation is based upon the idea that while the majority of faunal ecology and behaviour has been shaped over the past 1 to 500 million years; urbanisation has occurred within a much shorter time frame. Therefore, anthropogenic pressures have created novel urban habitats within rapidly expanding areas along with the creation of ecological niches previously unavailable. It is thought that this 'ecological vacuum' attracts certain animal species, thus overcoming the barriers imposed by urbanisation and successfully adapting to conditions within the new ecological niche. In order for a species or population to expand into urban areas, prerequisites such as ecological, demographic or behavioural plasticity, as well as a general spectrum of habitat and dietary requirements are needed (Lowry et al. 2013). Some of these adjustments include living at higher population densities compared to rural populations, reduction in migratory behaviour due to favourable conditions, increased length of breeding season, increased longevity due to better winter conditions (food and microclimate), resulting in a more sedentary life and decreased predation pressure and mortality risks from migrations, increases in circadian activity, with associated negative health effects, changes in nesting habits and feeding behaviour, increased tameness towards humans, and increased intraspecific aggression (Lowry et al. 2013).

Blair (1996) developed the first means of directly characterising wildlife responses to urbanisation by distinguishing the urban avoider, adapter or exploiter terminology, which was later refined by McKinney (2002). Fischer et al. (2015) highlighted the shortcomings of these definitions to categorise urban fauna and redefined them into a gradient of urbanisation responses of an *urban avoider*, *urban utiliser* and *urban dweller* (Figure 1.1). This gradient of responses is based on population dynamics of a species within developed urban areas compared to natural areas. Therefore, the term *urban avoider* included populations which range from completely extirpated in urban areas to self-sustaining populations within natural areas embedded within the urban matrix (e.g. Leopard *Panthera pardus*), in comparison *urban utiliser* ranges from the occasional to breeding within urban areas (various bird species), whereas *urban dwellers* included species having viable populations in natural and highly developed areas to species entirely dependent on developed areas to maintain a viable population (e.g. Rock Dove *Columbia livia*). This framework allows for a species to exist along the gradient of urbanisation within more than one category depending on the responses of individual populations and local context.

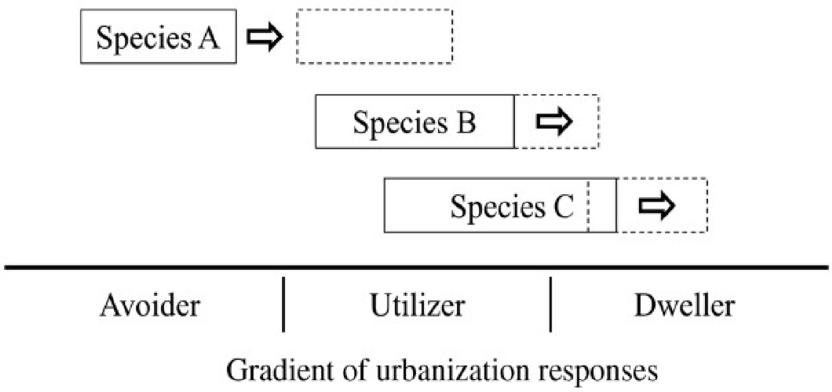


Figure 1.1: Faunal species responses along a gradient of urbanisation. Solid lines represent the range of population responses, while the dashed line represents the shifts in population responses to urbanisation that could alter the range of responses for a species that may result in the transition from one category to another (species A), broaden the range of responses so that the species functions in multiple categories (species B), or shift the species from multiple categories into a single category (species C) (Fischer et al. 2015).

Previous reviews found that generally, plant species richness increased in cities due to the introduction of non-local species, while faunal species often decreased in richness, although this varied substantially across taxa (McKinney 2008; Faeth et al. 2011). The majority of the studies within the meta-analyses took place within temperate urban areas, thus the results cannot be extrapolated to other climatic regions (Faeth et al. 2011).

Urban fauna can be categorised into (a) commensal species, which benefit from a human-derived food source (rats, mice), and (b) synanthropic species, those species which share and benefit from humans but are not dependant on them (Baker & Harris 2007). Synanthropic species can further be divided into resident species, those which live and breed in conurbations; and vagrant species, which occasionally move through surrounding habitats to forage but not breed (Baker & Harris 2007).

The presence of urban fauna can provide numerous benefits through the provisioning and regulating of ecosystem services, as keystone species or through providing cultural ecosystem services (Soulsbury & White 2015). For instance, many animals utilise urban waste as a food source (Araujo et al. 2018). Although some are considered pests, certain animals play a vital role in waste disposal through scavenging, specifically in developing countries. Furthermore, many urban fauna act as important agents of rodent and pest control, pollinators and dispersers of indigenous vegetation, a source of food through bush meat hunting, while also providing cultural ecosystem services such as faunal-derived products for food, clothing, tools and medicinal and ritualistic practices (Alves & Souto 2015).

For instance, in ecosystems less influenced by urbanisation, a loss of a keystone species or an ecosystem engineer may have disproportionately large effects on ecosystem patterns and processes (Soulsbury & White 2015). It is thought that certain species in urban areas may play such a role in the maintenance of biodiversity. For example, the decline in vulture populations in India leading to increases in feral dog populations within rural and urban areas, which in turn increased the risk of rabies transmission to humans as well as increased competition and predation on wildlife (Markandya et al. 2008). Although keystone species in urban areas may not directly affect humans, fauna that contribute to increasing or maintaining urban biodiversity will be vital to the integrity of urban ecosystems and thus, indirectly to humans. Pauw & Louw (2012) found that urbanisation dramatically reduced the functional diversity of nectivorous bird species along a gradient of urbanisation in Cape Town, South Africa. Nectivorous birds within the Cape Floristic Region fulfil an important ecosystem service by pollinating up to 320 plant species, and thus contribute to maintaining biodiversity within urban areas and are likely to play a keystone role that forms central nodes holding pollination spheres together. Highly mobile generalist pollinator species and seed dispersers are becoming increasingly important in highly fragmented urban landscapes, where they act as functional links between isolated plant populations and maintain gene flow networks (Pauw & Louw 2012).

1.4 Urban Domestic Gardens

Urban domestic gardens (UDGs) are defined as a garden adjacent to a privately owned (or rented) residential dwelling (Cameron et al. 2012). Despite their relatively small size on a parcel scale, UDGs often make up a substantial proportion of urban green infrastructure (Cameron et al. 2012), contributing up to 50% of the available greenspace within some cities (Gaston et al. 2005; Mathieu et al. 2007; Shanahan et al. 2014; Lin et al. 2017). Urban domestic gardens do not include communal or allotment gardens, as those are managed by a committee, association or local authority and are often situated some distance from the urban dwelling. Conservation of residential parcels of vegetation is becoming increasingly important in the face of urbanisation, therefore UDGs may play a vital role in the contribution to and maintenance of urban biodiversity (Belaire et al. 2015). Despite their potentially large contribution to urban conservation, UDGs have often been excluded from large-scale estimates of urban green infrastructure as they lie outside the management domain of the local authorities (Gaston et al. 2005).

Urban domestic gardens have the potential to provide numerous benefits through the provision of ecosystem services providing a positive impact on human health and wellbeing (Goddard et al. 2013). Private gardens are often the primary or even only interactions people may have with elements of biodiversity such as plants and birds, and are therefore vital in cultivating a sense of connection to nature, interest in its conservation or a sense of stewardship (Goddard et al. 2010; Brock et al. 2017).

1.5 Urban Domestic Gardens as Social-Ecological Ecosystems

Residential gardens typify social-ecological systems as they are better understood from an interdisciplinary framework that provides insight into human behaviour and the ecological repercussions thereof (Goddard et al. 2013). Goddard et al. (2010) provides a comprehensive conceptual framework highlighting the dominant ecological and socio-economic components influencing urban domestic gardens at multiple scales (Figure 1.2). Although the conceptual framework is separated into the landscape, neighbourhood and patch scales, the ecological and socio-economic factors influencing biodiversity of UDGs act at multiple scales. For instance, the biophysical characteristics of UDGs are managed on an individual basis, such as yard design, plant choice, maintenance, or wildlife-friendly features such as bird baths, bird feeders, compost heaps, etc.

(Belaire et al. 2015, Aronson et al. 2017), therefore the collective decisions of individuals can often scale up to influence ecosystem service provision, biodiversity and landscape heterogeneity at broader scales (Kinzig et al. 2005).

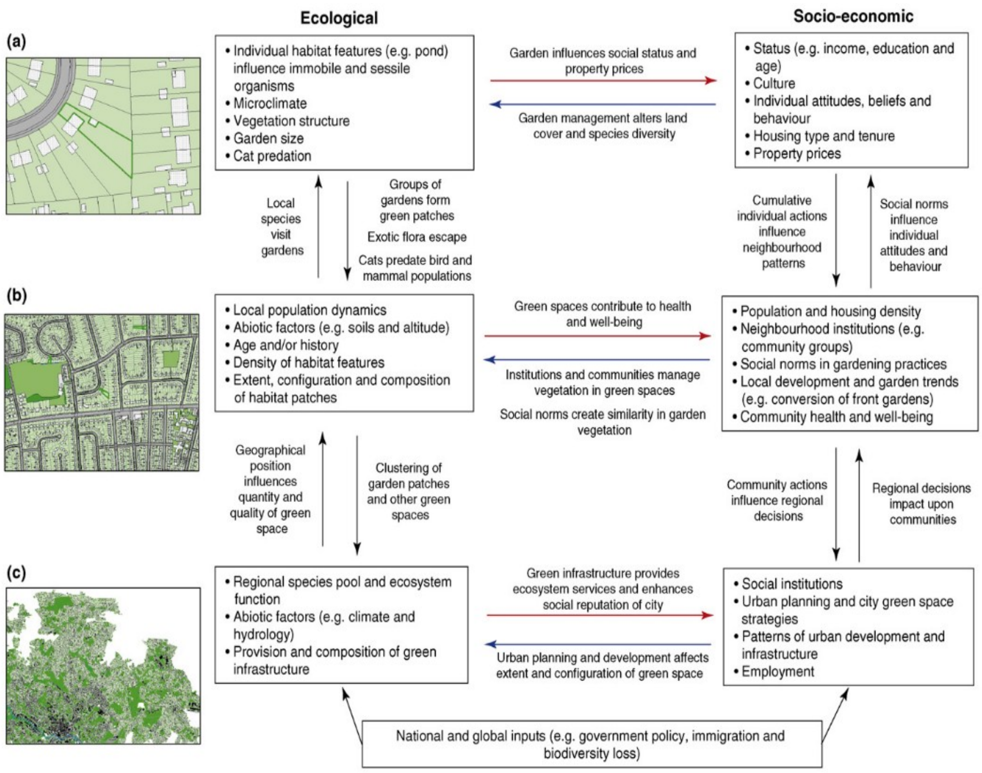


Figure 1.2: A conceptual model showing a nested hierarchy of the main ecological and socio-economic components impacting urban domestic gardens at various scales. (a) The individual scale; (b) the neighbourhood scale; (c) city or landscape scale. Many of these factors act on multiple scales where feedbacks (black arrows) exist between scales, while ecological factors influence socio-economic factors through the provision of ecosystem goods and services (red arrows) and socio-economic factors influence ecological factors through decision-making and management (blue arrows) (Source: Goddard et al. 2010).

For example, Zmyslony & Gagnon (1998) found that front gardens within an area are more likely to be similar to each other than those in an adjacent street or neighbourhood, and described it as a ‘mimicry effect’, thus highlighting how cultural as well as individual attitudes and behaviours may influence neighbourhood patterns of biodiversity. However, these individual and collective decisions may also include negative impacts on biodiversity, such as the use of pesticides and herbicides, domestic cat predation as well as a source of non-native plants and animal species (Goddard et al. 2013). Through this conceptual model, the significance of top down (municipal or city level management decisions) and bottom up influences (individual or household management) become equally important in influencing urban biodiversity, and act simultaneously within the urban ecosystem. While the framework clearly illustrates the scales on which research on domestic gardens is required, it does not include temporal influences on how domestic gardens may contribute to biodiversity conservation. Legacy effects such as previous landscaping decisions, development patterns (close to water courses and fertile land) and historic land use practices may have further influence on the neighbourhood and subsequently influence garden design and its contribution to biodiversity (Cook et al. 2012).

Many urban ecological studies utilise a gradient approach which relies on regular patterns of biodiversity in relation to the gradients of land use, distance from an urban centre or human population density (Kinzig et al. 2005). These gradients serve as a surrogate for drivers such as disturbance regimes, pollution or predation pressure, all of which influence biodiversity. To best understand an urban ecosystem, the characteristics of human populations interacting with the ecological system can be incorporated into the gradient approach. For instance, people are usually socialised by their cultural and social histories, and thus cultural influences and economic constraints often cluster people within the urban matrix (Goddard et al. 2010). Therefore, by incorporating a socio-economic gradient within ecological studies, the thoughts, perceptions, desires and preferences become driving forces which structure the surrounding environment from a parcel to landscape scale (Kinzig et al. 2005). Numerous studies have provided evidence for the "luxury effect" (ecology) "prestige effect" (sociology) (Kinzig et al. 2005; Hope et al. 2008), whereby patterns of biodiversity or environmental quality follow economic wealth, including bird diversity (van Heezik et al. 2013; Melles 2005; Goddard et al. 2017), herpetofauna (Smallbone et al. 2011), and plants (Hope et al. 2008; Lubbe et al. 2010; Cilliers et al. 2011). For instance, van Heezik et al. (2013) found that the size of the vegetated area within a domestic garden was able to best explain both plant and bird diversity, while plant diversity was best explained by socio-economic status, highlighting the importance of incorporating human gradients into ecological studies. Lerman & Warren (2011) found a strong evidence of the 'luxury effect' where higher income neighbourhoods supported more native bird species, as well as a link between attitudes of urban residens and the actual bird community within the neighbourhood.

1.6 Urban Domestic Garden Wildlife

For over fifty years, it was thought that UDGs are highly managed, species poor habitats dominated by alien species that provided few resources to support native fauna (Elton 1966). Over the years, more literature emerged highlighting the potential for UDGs to host a variety of biodiversity. Owen (2010) revealed that over the course of 30 years, her garden had been visited by a quarter of all the insect species present within the United Kingdom as well as discovering 15 new species to the UK. Through a series of studies surveying 61 gardens, the Biodiversity of Urban Domestic Gardens in Sheffield project (BUGS) attempted to broaden the understanding of resources that UDGs may provide for biodiversity and ecosystem functioning (Gaston et al. 2005; Smith et al. 2006). Although it is argued that due to the heterogeneity, gardens support only generalist, highly mobile and adaptable species (Cameron et al. 2012), these studies showed that UDGs are complex habitats supporting a wide range of biodiversity.

Birds are the most frequently studied taxa within urban environments (Faeth et al. 2011). Birds use a variety of urban habitats across multiple scales and under private and public management, and are often the most prevalent and visible species within these habitats and are often thought of as ecological indicator species, making them a cost-effective and valuable taxon to monitor. Both private and public management decisions will affect the resources, habitat, predation and nesting sites available to birds. Within public greenspaces, bird diversity is expected to be predominantly affected by top-down control (municipal authorities), while within private greenspaces, bottom-up control is more likely to influence bird diversity through the provision of wildlife-friendly gardening practices such as bird baths, feeders, compost heaps, etc. (Fuller et al. 2008). Fuller et al. (2008) found that both bird species richness and abundance varied across a socio-economic gradient, while avian abundance showed a strongly positive relationship to the density of bird feeding stations. Although the density of feeding stations did not influence bird species richness, the prevalence of the stations decreased as socio-economic deprivation increased.

Bird species richness and abundance often peaks within intermediate levels of urban developments (suburbs and residential gardens) where apparent urban adapter species thrive and relatively few urban avoiders and urban exploiters will flourish (Blair 1996; Tratalos et al. 2007). Recent studies are finding that the management of UDGs greatly influence the conservation of birds and urban biodiversity (Pauw & Louw 2012; Goddard et al. 2017). These studies highlight the influence that cumulative, bottom-up decisions by individual households can influence faunal communities on a larger scale, as well as how cultural, social or economic factors may be driving the decisions which provide food and habitat resources to local biodiversity.

Gardens are often thought of as source populations of exotic plants, especially in affluent neighbourhoods where cultivated gardens and access to nurseries are more widespread. Yet, in Hobart, Australia, Daniels & Kirkpatrick (2006) found that gardens with indigenous vegetation hosted significantly more native birds than those with less. The possible cascading effects of exotic vegetation were seen by Burghardt et al. (2008), where indigenous gardens supported an increased abundance and richness of caterpillars which in turn provided a food resource to bird species of conservation concern. Early ecological studies in natural habitats have demonstrated the importance of vegetation structure to avian community composition (MacArthur & MacArthur 1961), emphasising the role which affluent, often older and thus more vegetated, suburbs may play in influencing the urban bird community (ecology of prestige). Savard et al. (2000) found vegetation complexity to be a significant driver in increasing the diversity of birds and other animals.

1.7 A South African Context

Sub-Saharan Africa is experiencing the highest rate of urbanisation in the world, with South Africa hosting an urban population of roughly 64% (UN 2014, World Bank 2015). South African urban areas create unique and interesting study sites for social-ecological studies as the socio-economic development is characterised predominantly by a third world sector while it holds relatively strong first world infrastructure (Cilliers et al. 2011). However, compared to the Global North, developing countries and tropical zones are severely lacking in urban ecological research. While urban expansion may lead to the creation of more residential gardens, increases in the urban population require the creation of infrastructure and possibly new gardens. However, increasing densification places pressure on green infrastructure due to space required for buildings (Cilliers et al. 2017).

The racially segregated patterns of urban development during the colonial and apartheid regimes in South Africa have been well-documented and are still highly prevalent (Christopher 1997). In brief, governments in power at the time enforced numerous racially-biased legislation through laws such as the Natives (Urban Areas) Act no. 21 of 1923 and later by the Group Areas Act of 1950. The first act regulated the movement of black males between rural and urban areas, while the second act ensured the relocation of people of colour into areas designated to their specific race. These laws dictated where South Africans of colour were to live and work, while the limited social and infrastructural services provided in these areas was less than those of the unaffected areas designated for white South Africans. Millions of black South Africans were required to live in areas called 'bantustans' where minimum investment in infrastructure and services were provided.

In urban areas, black South Africans were required to live in areas called 'townships', located on the periphery of a city where no formal economic base and minimal infrastructure were provided. After the apartheid era ended in the mid-1990s, large amounts of money were invested into improving the living conditions of the townships by building low-cost housing units referred to as RDP suburbs (Reconstruction and Development Programme) which are managed by the local municipality. The segregated racial profile of South African urban areas has persisted and as a result of the political processes shaping the urban spatial development, usually visually distinct residential areas emerge within towns (Kaoma & Shackleton 2014), 1) relatively new low-cost RDP housing occupied by poor, black South Africans, 2) older townships occupied by poor and less poor black South Africans, and 3) middle to high income suburbs occupied by predominantly white South Africans, with a slowly increasing presence of black South Africans. However, in urban areas there is a rapid influx of people into towns and cities for employment and perceived better living conditions and services. This results in the creation of multiple informal settlements, characterised by houses built of scavenged or low cost materials and irregular building arrangements (Shackleton et al. 2014).

Small to medium-sized towns within South Africa are important sites to study urban social-ecology because; 1) the majority of the urban ecological research has taken place in larger cities, (Shackleton et al. 2017), 2) the majority of urban growth is occurring in small- and medium-sized towns in sub-Saharan Africa (less than half a million inhabitants) (Shackleton et al. 2017), 3) small to medium towns are collectively home to a larger proportion of people than cities, and socio-economic gradients are often more apparent compared to large cities (Shackleton et al. 2017), 4) inhabitants use less resources and thus produce a smaller ecological footprint (Shackleton et al. 2017), and 5) growth within urban centres is on a more flexible trajectory and has the potential for more sustainable growth in the future and may become more resilient (Shackleton et al. 2017).

Few urban ecological studies in South Africa have described the changes in biodiversity along socio-economic gradients created by the past governments. Donaldson-Selby et al. (2007) attempted to analyse the ecological impacts of the low-cost RDP developments. However, past urban ecological descriptions have often excluded private greenspaces from the study. For instance, phytosociological descriptions of open urban spaces within two cities within the North-West Province included widespread and diverse green infrastructure such as natural grasslands and woodlands (Cilliers et al. 1999a) to vacant lots (Cilliers & Bredenkamp 1999b) and road verges (Cilliers & Bredenkamp 2000), yet excluded private gardens. Later, McConnachie & Shackleton (2010) determined the area of public greenspace within nine small towns of the Eastern Cape, but did not include private greenspaces. The study showed that a large proportion of the land within the towns is under some form of green infrastructure, while the majority were under the control of individuals rather than the local municipality. A lack of research directly quantifying biodiversity within urban residential gardens in the country leaves gaps in the understanding of the contribution they may have to urban green infrastructure and urban ecological patterns and processes.

While there have been studies emphasising the importance of homegardens (a garden used for cultivating small-scale ornamental or agricultural plants for subsistence or economic benefit) within South Africa (Nemudzudzanyi et al. 2010; Molebatsi et al. 2010), especially in rural communities, few studies have recorded the biodiversity within UDGs along a socio-economic gradient. Lubbe (2011) showed that gardens within affluent, white-dominated suburbs of the Tlokwe City Municipality, North-West Province, South Africa, showed a higher plant species diversity, yet were dominated by alien species, whereas gardens within lower socio-economic, black-dominated suburbs included more indigenous and utilitarian plants. Botha (2012) found significantly higher arthropod diversity within affluent areas, while a higher plant diversity was found in less affluent areas. These studies provide evidence that domestic gardens can harbour differing levels of biodiversity and should be included in further quantifying and analysing green infrastructure. No known quantitative studies have been done investigating vertebrate fauna within urban domestic gardens within South Africa. Large gaps exist within present knowledge of how faunal communities may be utilising these human modified environments (Faeth et al. 2012) and human perception and management thereof.

This study aimed to determine bird community patterns in urban domestic gardens as well as urban residents' practices and sentiments towards garden fauna across a socio-economic gradient within small towns of the Eastern Cape, South Africa. This study contributes to understanding of faunal patterns within urban ecology as well as the social mechanisms driving these patterns. The specific objectives were to determine:

1. How does the bird species richness, diversity, abundance and composition within urban domestic gardens change across a socio-economic gradient within small towns of the Eastern Cape, South Africa?
2. What are the primary mechanisms driving these patterns within urban domestic gardens in terms of: 1) garden habitat composition and structure and 2) garden management decisions/biophysical characteristics?
3. How do urban residents' practices and sentiments towards garden fauna compare across socio-economic gradients within small towns of the Eastern Cape, South Africa?

CHAPTER 2: METHODS & MATERIALS

2.1 RESEARCH DESIGN

This study utilised a mixed methods approach that included an ecological survey as well as household questionnaires along a socio-economic gradient within two medium-sized towns in the Eastern Cape, South Africa. The Eastern Cape province shares borders with the Western Cape, Northern Cape, Free State, Kwa-Zulu Natal provinces and Lesotho. Being the second largest province in South Africa, the Eastern Cape covers an area of 169 580 km^2 making up 13.8% of the total land area of South Africa (CSIR 2004). The Eastern Cape lies at a confluence between the temperate and subtropical climatic regimes, resulting in a complex and varied climate. Wide variations in temperature, rainfall and wind patterns exist as a result of variation in altitude and proximity to the Indian Ocean, with approximately 300 mm per annum mean annual rainfall in the west, to 1 000 mm per annum in the east (CSIR 2004). The Eastern Cape hosts approximately 14% of the country's population and is the poorest province inflicted by poverty and unemployment (CSIR 2004).

2.2 STUDY SITES

2.2.1 HISTORY

The study focussed on two medium-sized towns in the Eastern Cape, namely Grahamstown and Port Alfred (Figure 2.1). Grahamstown (33°18'S; 26°31'E) was originally established by John Graham as a military outpost in the early 1800s to secure the eastern frontier of the British Cape Colony against the Xhosa ranges to the east (Marshall 2009). By 1904, Rhodes University was established as a fully functioning university. Grahamstown is currently situated within the Makana Local Municipality, and hosts a population of approximately 80 000 residents, of which 67% identify as Xhosa people (Stats SA 2011).

Port Alfred (33°35'S; 26°53'E) lies within the Ndlambe Local Municipality and hosts a population of roughly 26 000 residents. Situated on the eastern side of the Kowie River mouth, halfway between the larger cities of Port Elizabeth and East London. Port Alfred was initially established in the 1820s by British settlers who were moved into the area by Lord Charles Somerset as a means to separate the Cape Colony from the Xhosa people of the region.

Figure 2.1: Map of (a) Grahamstown and (b) Port Alfred.

2.2.2 Vegetation and Geology

Both towns are situated within the Albany Thicket Biome which includes a transition between the Cape and subtropical vegetation types. The Eastern Cape is best described as a convergence zone of four major vegetation biomes, including the Succulent Thicket, Nama-Karoo, Cape Fynbos and Grasslands. Grahamstown falls within the Albany Hotspot, with approximately 4 000 vascular plant species of which 15% are endemic or near endemic (Victor & Dold 2003). More specifically, according to Mucina & Rutherford (2006), Grahamstown includes the Kowie Thicket, Bisho Thornveld, Grahamstown Grassland Thicket, Albany Coastal Thornveld and Albany Valley Thicket subtypes, each dominated by distinct plant species composition. Port Alfred is composed of mainly Kowie River Thicket, Albany Coastal Belt, Albany Dune Strandveld and Cape Seashore vegetation (Mucina & Rutherford 2006).

Grahamstown is situated within the eastern part of the Cape Fold Belt primarily with rocks of the Witteberg Group and Cape Supergroup, as well the Dwyka and Ecca groups of the Karoo Supergroup. The oldest rocks of the area form the Cape Supergroup and include shales and sandstones of the Weltevrede Formation, as well as resistant quartz of the Witpoort Formation. The quartz is covered by fine-grained shales and sandstones of the Lake Mentz and Kommadagge subgroups (Jacob et al. 2004). The majority of Port Alfred and the Kowie River lie within the Bokkeveld Series, which consists of mainly shale and sandstone bands. Closer to the Port Alfred railway, evidence of the Alexandria Formation can be found in the form of thin marine sediments. The Dwyka Series and Witteberg Series can also be found within the area (Mountain 1962).

2.2.3 Climate

Grahamstown is situated at an altitude of 650 m above sea level with an average annual rainfall of 669 mm. The region receives the lowest rainfall in July (16 mm) and highest in March (57 mm). Average seasonal temperatures range from 9 to 23 °C, ranging from 18.9 °C in July to 26.8 °C in February. Port Alfred is situated on the coast, with an average annual rainfall of approximately 500 mm, with the lowest rainfall in July (25 mm) and highest occurring in March (56 mm). Temperatures within Port Alfred range from 9 to 30 °C.

2.2.4 Socio-Economic Profile

Demographic and socio-economic information were obtained via Statistics South Africa (accessed in March 2019) and includes, demographics, age structure, employment, education and household service information for Grahamstown and Port Alfred (Table 2.1). The information provides brief insight to the socio-demographics of each study site.

Table 2.1: Demographic and socio-economic profile of study towns, Grahamstown and Port Alfred. (Data obtained from Statistics South Africa, accessed in March 2019).

Category	Grahamstown	Port Alfred
Population	80 000	26 000
Male	47.4%	46.3%
Female	52.6%	53.7%
Age structure		
0 – 14 years	23.2%	19.6%
15 – 64 years	71.0%	60.7%
Elderly (+ 65)	5.8%	19.8%
Labour Market		
No income	13.2%	15.2%
Education (aged 20 +)		
No formal schooling	5.5%	3.9%
Matric	24.1%	33.2%
Higher education	14.5%	21.5%
Household services		
Flushing toilets	73.2%	58.0%
Weekly refuse removal	97.3%	89.2%
Piped water within household	51.9%	84.3%
Electricity for lighting	90.2%	90.8%

2.3 Sampling Methods

2.3.1 Bird Survey

Sampling took place during October to December 2017 as per the main bird breeding season, where point-count surveys were used to record richness and abundance of bird species within each garden. A total of 45 houses per town were sampled, 15 in each socio-economic zone. Houses were selected randomly as to obtain maximum coverage within the socio-economic zone. If a resident declined to allow us to sample the property, the next house was chosen, until a positive was found. Point-count surveys involve an observer remaining stationary for a pre-determined length of time, during which all bird species seen or heard are recorded (Gregory et al. 2004). Birds were sampled for ten minutes at a time with a total of four visits per garden, while gardens larger than 100 m^2, or where parts of the garden were not visible from one section of the property, were sampled for an additional ten minutes in the extended areas. Bird surveying took place from 06h00 – 10h00 in the morning and from 15h00 – 19h00 in the evening to coincide with the period of greatest bird activity. Visitation time to each property was rotated so that each garden was sampled at a different time in the morning and evening. Only birds using, i.e. perched, feeding or roosting within the garden area, were recorded and identified to species level, while birds flying overhead or heard or seen in neighbouring gardens were excluded. Bird sampling ceased during periods of heavy rain or strong wind. Any species that were unable to be identified were recorded as “unknown” and included in all analyses. It was assumed that the observer was unlikely to have a large effect on the presence of the birds since they would be used to a degree of human activity by being present in a garden and residential neighbourhood habitat. Bird species diversity was calculated using the Shannon-Wiener diversity index (Krebs 1999). Bird species were also classified into feeding guilds (frugivore, omnivore, granivore, nectivore or carnivore) based on their dominant source of food (De Graaf & Wentworth 1986).

2.3.2 Garden Habitat Characteristics

In each UDG, various physical (garden size and tree, grass, ground vegetation and grey area cover) and structural (vegetation height, vegetation structural diversity, growth form cover, proportion of local and exotic plants) variables were measured, along with household surveys to assess the possible management features which may influence the bird community patterns (Tews et al. 2004). Tree cover was defined as the proportional area (%) of the garden covered by the tree canopy. Trees situated beyond the outer edge of the garden boundary, whose canopy extended into the garden area were included in the estimate of tree cover. Ground vegetation cover was the proportional area of the garden (%) covered by ground vegetation, other than lawn (< 0.4 m) or soil had been been tempered with the intention of growing plants, while grass cover was the proportion of the garden area (%) under lawn. The grey area cover (%) referred to all impervious surfaces within the garden area (e.g. paving, cement, tiling, etc.). All cover estimates were performed visually.

Total planted area was physically measured on site and 1 x 1 m quadrats were randomly placed within the ground vegetation to account for 25% of this area. Subsequent structural habitat measurements (vegetation height, vegetation structural diversity, growth form cover, proportion of local and exotic plants) were taken in each quadrat based upon the assumption that measurements performed within 25% of the vegetation area will be a proportional representation of the entire vegetated area. This method may allow for error in representation of the garden, yet allowed for a proportional effort scaled to the area of vegetation cover. Vegetation height (m) was measured using an extendible ruler at the centre of each quadrat. A mean vegetation height (m) was calculated for each garden. Vegetation structural diversity was calculated using the inverse of Simpson’s index of diversity (Simpson 1949), where S (richness) is replaced by the number of vegetation layers (i.e. large tree, tree, shrub, forb) within the quadrat and n (number of individuals of each species) is replaced by the number of individuals in each vegetation layer (i.e. large tree, tree, shrub, forb) of each quadrat (van Heezik et al. 2016). Structural diversity was calculated using the Simpson's index = E n(n-1)/N(N-1) (Simpson 1949).

Growth form cover was calculated by recording the percentage cover of each growth form class, i.e. forb 0-1 m, shrub 1-2 m, tree 2-5 m and large tree >5 m within each quadrat. Large shrubs and small trees were differentiated based on structure; with trees having a distinct main trunk, while shrubs are defined as having low, multi-branching stems and visual density. All plant species were recorded within each quadrat and classified as indigenous or exotic species and their relative proportions calculated.

2.3.3 Questionnaire Survey

Socio-economic and garden management information was obtained by interviewing household residents with the aid of a translator as the majority of the residents living within the RDP and informal settlement were isiXhosa-speaking (See appendix for survey/interview form). A Garden Management Intensity index, Garden Wildlife Awareness, Wildlife-Friendly Garden Practices and Socio-economic Status were calculated using information which residents provided. Questionnaire surveys were given to 45 participants per town and were comprised of four sections of closed- and open-ended questions. Sections included; (1) Garden Management and Use, which assessed the water use, activities and importance of the garden to homeowners, (2) Garden Wildlife which assessed the wildlife features, knowledge, attitudes towards garden fauna, and their place in a larger ecosystem, (3) Social Information, which included socio-economic information on income and schooling and finally a section on (4) Environmental Awareness which included information on conservation activities and environmental concern. Questionnaires were formulated in English. The Garden Management and Use, Garden Wildlife and Environmental Awareness sections have been modified to suit a South African context and the context of the study from Goddard et al. (2013), while the Social Information questionnaire were modified from Davoren (2016).

2.4 Data Analysis

All analyses were conducted in R Studio and PRIMER Version 6 (Clarke 1993). Bird survey replicates for each garden were combined and each town was analysed separately. Species Accumulation Curve was created in PRIMER V6. Non-metric Multidimensional Scaling (NMDS) was used to evaluate the garden bird community structure for each town using the abundance recorded within each garden. NMDS is a preferred ordination technique as it is an unconstrained method that does not require the data to conform to rigid assumptions concerning the relationships among the variables. As a rule of thumb, a stress value, a measure of how well two points fit together, produced for the ordination plot indicates its level of accuracy, where a stress value smaller than 0.05 is a very good representation of the data, a value <0.1 is a good ordination, <0.2 is an acceptable ordination and stress values larger than >0.2 are misleading and inaccurate (Clarke 1993). For both towns, bird abundance data was standardised, square root transformed using the Bray-Curtis similarity matrix, which accounts for differences in abundance between species while taking into consideration the species identity. An Analysis of Similarity (ANOSIM, Clarke 1993) was used to assess the significance of the separation of the bird communities based on the location. The ANOSIM reveals a Global R value which indicates the strength of separation between the communities (a higher R-value indicating a greater separation, or less similarity between communities), as well as a p-value indicating the significance of the separation. The Similarity Percentages analysis (SIMPER, Clarke 1993) was run to assess the percentage contribution of the factors (bird species) to the dissimilarity of the observed patterns. A BIOENV routine was used to assess which subset of environmental variables best explained the patterns observed in the multivariate analyses (Clarke 1993). Prior to running the BIOENV, variables were square root transformed to improve normality and then normalised. The BIOENV uses the rank Spearman's rho to determine the strength of correlation between the Euclidean distance matrix from the environmental data and the Bray-Curtis dissimilarity matrix, derived from the biological data. The subset of environmental data with the best match (i.e. highest rho value) best describes the bird community patterns determined by the NMDS. Species accumulation curves were calculated using PRIMER V6, while the Chao 1 richness estimator (used to estimate the species richness for abundance data) was calculated to assess the percentage of the bird community that was sampled (Gotelli & Colwell 2011).

Tests for normality were performed on the variables using the Shapiro-Wilks test in R Studio. If the data normal, T-tests were used to assess the differences in bird species richness and diversity between the study towns, while ANOVAs (analysis of variance) were used to assess the differences in bird species richness and diversity along the socio-economic gradient within the towns (all descriptive statistics and boxplots were performed in R Studio). If data was shown to be non-normal, nonparametric tests were used (i.e. Kruskal Wallis). Tukey's honestly significant difference (HSD) test was used to compare pairwise means of samples in a *post hoc* analyses.

2.5 Socio-Economic Gradient and Indices

Due to the Apartheid regime In South Africa, all towns and cities were racially segregated and relied on an inequitable distribution of economic and infrastructural resources, resulting in the overlap of socio-economic and racial patterns within society (Shackleton et al. 2016). As previously mentioned, certain geographical locations were designated for white South Africans, where neighbourhoods are dominated by large houses, paved roads, a number of large street trees. These areas are often well planned and with sufficient infrastructure. Therefore, gardens in these areas are large, well-vegetated with a highly manicured appearance and invariably fenced or walled around the perimeter (Figure 2.2a).

Figure 2.2: Examples of typical neighbourhood and garden environments along the socio-economic gradient within Grahamstown and Port Alfred. (a) Affluent zone (b) RDP zone (c) Informal settlement zone.

Houses within the RDP zone (refer to Chapter 1: Introduction, for information on the formation of RDP zones), are planned in a grid-like structure, while houses are generally small (40 m^2), with a small garden area (Figure 2.2b). Houses are built in high-density manner using brick and plaster and often have running water within the premises or on the property (Figure 2.2). Informal settlements are formed when citizens other parts of South Africa migrate towards cities in search of economic opportunity and in hope of receiving an RDP house. Here, the residents are allocated a piece of land by the Ward Councillor, and allowed to build an informal structure, often made of of zinc and mud or scavenged materials (Figure 2.2c). In some informal settlements, local municipalities will provide basic infrastructure such as piped water, street lights or electricity. Informal housing is at times, illegal, unregistered, unplanned and dominated by the urban poor (Adegun 2017), thus gardens are often highly irregular in shape and size, and may be fenced or unfenced. The "gradient" which this study utilises includes affluent areas, RDP housing and informal areas, where affluent neighbourhoods are dominated by higher income residents, while RDP and informal settlements include lower income residents.

A total of four indices were calculated to gauge a relative measure of how each resident conforms to the categories measured, namely, Socio-economic index, Garden Management Intensity index, Wildlife-Friendly Garden Practices index and Garden Wildlife Awareness index (Table 2.2-2.5). Each resident interviewed was asked the relevant questions, and a score calculated into a percentage.

Table 2.2: Socio-Economic Status index. A higher score indicated a higher socio-economic standing.

Question	Score
How many people live in your household?	$Count^{-1}$
Do you have any young children (12 years or under) in the house?	$Count^{-1}$
How many rooms does your house have?	Count
What type of light do you use at night?	Electricity 1, Candles/Paraffin 0
House type	Suburban 2, RDP 1, Informal 0
What is the employment status of the main earner in your household?	Full-time 2, Part-time 1, State grants 0, Student 0, Unemployed 0
What is the highest level of education within the household	Tertiary 3, High 2, Primary 1, None 0
How far is the nearest tap situated?	House 2, Garden 1, Communal 0
Did you spend your childhood mostly in a rural or area or a town/city?	Town/city 1, Rural 0

Table 2.3: Garden Management Intensity index. A higher score indicated an increased in frequency and intensity of garden management practices.

Question	Score
On average, how long do you (or your gardener) spend gardening per week in the summer months?	Daily 4, Weekly 3, Monthly 2, Less than monthly 1, Never 0
On average, how frequently do you (or your gardener) undertake the following gardening activities in the summer months? Planting flowers/shrubs Watering the garden Weeding the garden - chemically Weeding the garden - mechanically Remove dead plant material Fertilise the garden Rake the lawn Apply chemical fertilisers Apply pesticides or herbicides	Less than 1 hour 1 1-5 hours 2 6-10 hours 3 >20 hours 4

Table 2.4: Wildlife-Friendly Garden Practices index. A higher score indicated an increase in gardening practices favourable to wildlife within the garden.

Question	**Score**
Apply pesticides or herbicides	Daily 0, Weekly 1, Monthly 2, Less than monthly 3, Never 4
Wildlife-friendly features	Count
Do you participate in any activities actively attracting wildlife to your garden (e.g. Mow less, avoid chemical use, keep cats inside)?	Yes 1, No 0
On average, how often do you feed the wildlife in your garden?	Daily 4, Weekly 3, Monthly 2, Less than monthly 1, Never 0
Do you own any pets/domestic animals which utilise the garden, if so, please state	Yes 0, No 1
Does your cat/a neighbour's cat hunt small animals and lizards in your garden?	Yes 0, No 1

Table 2.5: Garden Wildlife Awareness index. An increased score indicated a greater awareness of surrounding wildlife living in or utilising the garden space.

Question	**Score**
Watching/attracting wildlife, e.g. birds	Yes 1, No 0
Spend some time watching wildlife in your garden, even if just a few minutes?	Daily 4, Weekly 3, Monthly 2, Less than monthly 1, Never 0
Do you think the wildlife in your garden are important? Please explain.	Yes 1, No 0
Do you perceive the wildlife in your garden to be part of a larger community/environment in your neighbourhood or town?	Yes 1, No 0
Do you view your garden to be part of a larger ecosystem/environment?	Yes 1, No 0
Have you noticed any changes in the types of wildlife you see visiting your garden over the last 10 years?	Yes 1, No 0
Have you noticed any changes the amount of wildlife you see visiting your garden over the last 10 years?	Yes 1, No 0

Chapter 3: Garden management practices and sentiments toward garden fauna along a socio-economic gradient in medium-sized towns of the Eastern Cape, South Africa

3.1 Introduction

By the year 2030, the current urban population within Sub-Saharan Africa is expected to double (FAO 2012). In developing countries, increases are often attributed to the in-migration of people from rural areas seeking economic opportunities, employment security and basic services such as education, sanitation and health care (Cilliers et al. 2017). The increases in the urban population, combined with the use of natural resources, places increasing pressures on the space required for adequate allocation of green infrastructure and subsequently the composition, structure and function of biodiversity and ecosystem services (Cilliers et al. 2011). The impacts of urbanisation have been shown to extend to not only the biosphere, but the physical, mental and social wellbeing of urban residents, fundamentally altering the way in which humans interact with elements of biodiversity (Bell et al. 2018).

Urban green infrastructure is of particular importance in mitigating some of the negative effects of urbanisation, as well as contributing to ecosystem services, resistance and resilience (Schram-Bijkerk et al. 2018). Despite often being overlooked in academic literature (Mathieu et al. 2007), urban domestic gardens typically constitute a large proportion of the greenspace within cities and towns, such as 36% in Dunedin, New Zealand (Mathieu et al. 2007), 86% in Leon, Nicaragua (Gonzáles-Garcia & Gómez Sal 2008) and 48% in the Eastern Cape, South Africa (Shackleton et al. 2016). Therefore, urban domestic gardens are a vital biological resource within the urban matrix. Because domestic gardens are the only type of greenspace managed by individual homeowners, they are best understood through a social-ecological systems framework, which refers to the relationship between human and biophysical systems as well as the reliance and benefits derived from the ecosystem (Langemeyer et al. 2016).

Urban domestic gardens not only contribute a substantial portion of urban green infrastructure, they also contribute numerous provisioning, regulating, cultural and supporting ecosystem services to urban residents (Cameron et al. 2012). Provisioning services include food supply as well as medicinal and aromatic plants (Lubbe et al. 2010; Molebatsi et al. 2010), while garden vegetation has the ability to mitigating the urban heat island effect through reducing the amount of grey surface area and decreasing air temperatures, purifying air and mitigation of flood risks (Cameron et al. 2012). Studies have highlighted that gardens make significant contributions to provisioning of resources for urban wildlife (Goddard et al. 2010; Fuller et al. 2012; van Heezik et al. 2013). Vegetation structure (Leong et al. 2018), supplementary feeding (Davies et al. 2012), wildlife features (Goddard et al. 2010) have also been shown to influence numerous bird (Galbraith et al. 2015; Leong et al. 2018) and arthropod species diversity and abundance (van Heezik et al. 2016) within domestic gardens, emphasising their vital importance in maintaining ecological processes within the urban ecosystem at multiple scales (Goddard et al. 2010).

Perhaps the more widely studied benefits of urban gardens include the cultural ecosystem services. For instance, physical health and psychological wellbeing are often reported as benefits from interacting with nature, although the majority of literature focuses on public greenspace (Keniger et al. 2013). A meta-anaylsis by Soga et al. (2017) found significant positive effects of gardening on health for all groups studied, while gardening also had positive effects on life satisfaction, psychological wellbeing, sense of community and food security for residents across socio-economic levels (Langemeyer et al. 2016; Adegun 2017). Furthermore, the presence of a shared social ideal may result in a spatial autocorrelation of gardening practices or beliefs. Private gardens are often the only form of nature that some urban residents interact with (Beumer & Martens 2015), while factors such as ownership, identity and culture vary the intensity or relationship between people and their gardens (Clayton 2007; Clucas & Marzluff 2011).

Furthermore, regular observation or interaction with wildlife has been shown to enhance interconnection, stewardship towards nature and subjective wellbeing (Brock et al. 2017). Brock et al. (2017) highlighted that interaction with common wildlife such as birds, fosters a sense of value to nature which is fundamentally different to that of the value system created by encountering iconic wildlife through media. Merely hearing and seeing birdlife has the potential to contribute to human wellbeing (Bell et al. 2018). Cultural significance has shown that animals perceived as meaningful in one society may be deemed as a bad omen in another, yet most of these studies have been conducted the Northern Hemisphere and developed countries (Bell et al. 2018), with relatively little from a developing country context.

Wildlife gardening has been described as any actions undertaken within domestic gardens to increase its suitability for particular fauna (Davies et al. 2008), and is often thought to be related to feeling a sense of connection to nature (Shaw et al. 2013). While gardening as a pastime has been well-studied, much of the emphasis has been placed on community or allotment gardens (Lewis et al. 2018). Wildlife-friendly activities include supplementary feeding, planting trees and shrubs to attract certain wildlife or providing water. Supplementary bird feeding is the most popular wildlife-friendly gardening practice in developed nations (Lepczyk et al. 2012; Galbraith et al. 2017). Comparative to wildlife-friendly practices, little research has been conducted on wildlife gardening awareness (except for Lepczyk et al. 2012; Gaston et al. 2005; Gaston et al. 2007; Davies et al. 2008; Shaw et al. 2013), and particularly in the Global South. Goddard et al. (2013) found that residents were motivated to participate in wildlife-friendly gardening practices based on their personal wellbeing and moral responsibility to nature, while Shaw et al. (2013) showed that a strong connection to nature was not a prerequisite for wildlife gardening.

Because domestic gardens hold a strong place in the lives of many urban residents, they are often seen as extensions of historical and cultural heritage (Barthel et al. 2010; Leong et al. 2018), reflecting the past political or economic regime of the time through design, management or functionality (Clayton 2007; Cameron et al. 2012; Bhatti et al. 2017). Gardens may reflect the "luxury effect" in urban neighbourhoods, whereby private greenspaces within wealthier suburbs show higher biodiversity (Leong et al. 2018). Due to past laws of racial segregation, South Africa hosts steep socio-economic gradients, which are often reflected in the urban environment, and more importantly, within private garden spaces. For instance, socio-economic factors such as status, culture, individual attitudes and beliefs influence garden management practices and, in turn, the biological resources available to fauna and flora (Goddard et al. 2010). Although research on urban domestic gardens in South Africa has been limited, evidence of plant (Lubbe 2011; Davoren et al. 2016) and arthropod (Botha 2012) community shifts along socio-economic gradients has been found. While these studies considered resident management practices, no studies have investigated urban residents wildlife awareness and wildlife-friendly management practices.

This study aimed to examine the garden management practices and sentiments towards wildlife within three socio-economic zones within two medium-sized towns in the Eastern Cape. Three indices including, Garden Management Intensity, Wildlife-Friendly Garden Practices and Garden Wildlife Awareness were compared across the socio-economic gradient to gain insight into the attitudes and practices of urban residents towards garden fauna.

3.2 Methods and Materials

Refer to Chapter 2: Methods and Materials.

3.3 RESULTS

3.3.1 GARDEN FAUNA

Within Grahamstown and Port Alfred, birds were the most commonly seen animal within gardens across the socio-economic gradient (Figure 3.1). The second most commonly seen fauna were small mammals, followed by spiders, lizards and worms, with some variation between socio-economic zones. In Grahamstown a number of fauna were more frequently seen within affluent homesteads, including spiders ($\chi^2 = 18.65$, $p < 0.001$), lizards ($\chi^2 = 22.65$, $p < 0.001$), butterflies ($\chi^2 = 10.21$, $p < 0.01$), insects (including beetles) ($\chi^2 = 53.91$, $p < 0.001$), bees ($\chi^2 = 37.72$, $p < 0.001$), bats ($\chi^2 = 11.93$, $p < 0.01$), and predatory birds ($\chi^2 = 17.76$, $p < 0.001$), compared to RDP and informal households, while small mammals ($\chi^2 = 9.31$ $p < 0.01$) and snakes ($\chi^2 = 28.57$, $p < 0.0001$) were seen the most frequently in gardens within the informal settlements.

In Port Alfred, similar patterns were found, where spiders ($\chi^2 = 22.55$, $p < 0.001$), slugs and snails ($\chi^2 = 51.17$, $p < 0.001$), butterflies ($\chi^2 = 13.76$, $p < 0.001$), insects ($\chi^2 = 80.99$, $p < 0.001$), bees ($\chi^2 = 71.52$, $p < 0.001$), and predatory birds ($\chi^2 = 26.39$, $p < 0.001$) were more frequently noticed in affluent homesteads, while snakes were mostly seen within the lower income, informal settlement ($\chi^2 = 26.39$, $p < 0.001$). Apart from birdlife, small mammals, slugs and snails, lizards, insects and bees were the most frequently seen animals within the two towns. Scorpions and predatory birds were far less frequently seen.

Within Grahamstown, the majority of the residents within the RDP zone fed garden birds on a daily or weekly basis, typically in the form of leftovers or the dog's food (Figure 3.2). However, only 50% of the residents in the informal zone did so. In contrast, the majority of the residents within the informal settlement in Port Alfred did not participate in bird feeding activities at all, while residents in the more affluent and RDP households fed garden birds on a daily or weekly basis. Overall, residents within the affluent areas fed garden wildlife more frequently than the lower socio-economic zones.

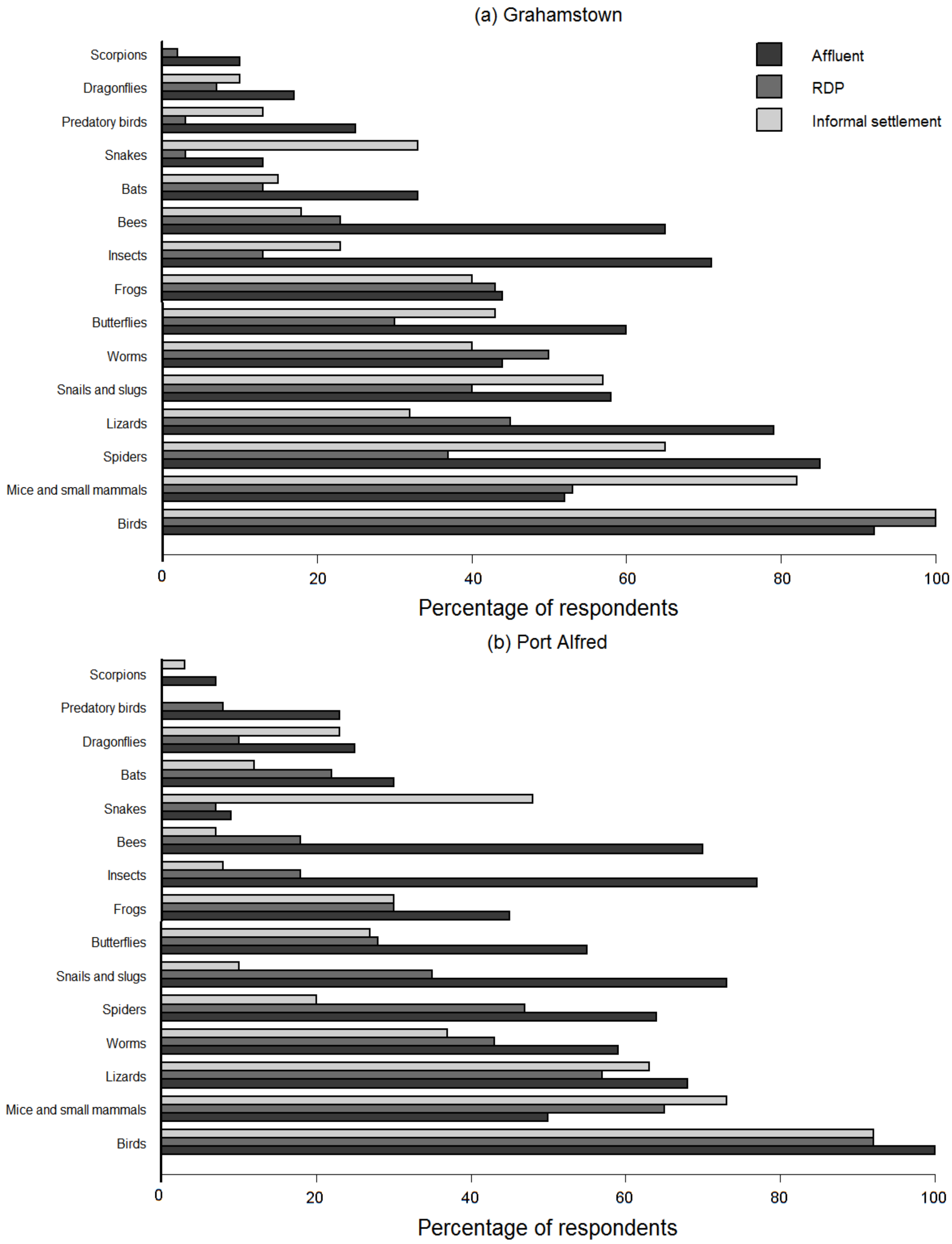


Figure 3.1: Garden wildlife that residents noticed and ranked, according to frequency within (a) Grahamstown and (b) Port Alfred within the socio-economic zones.

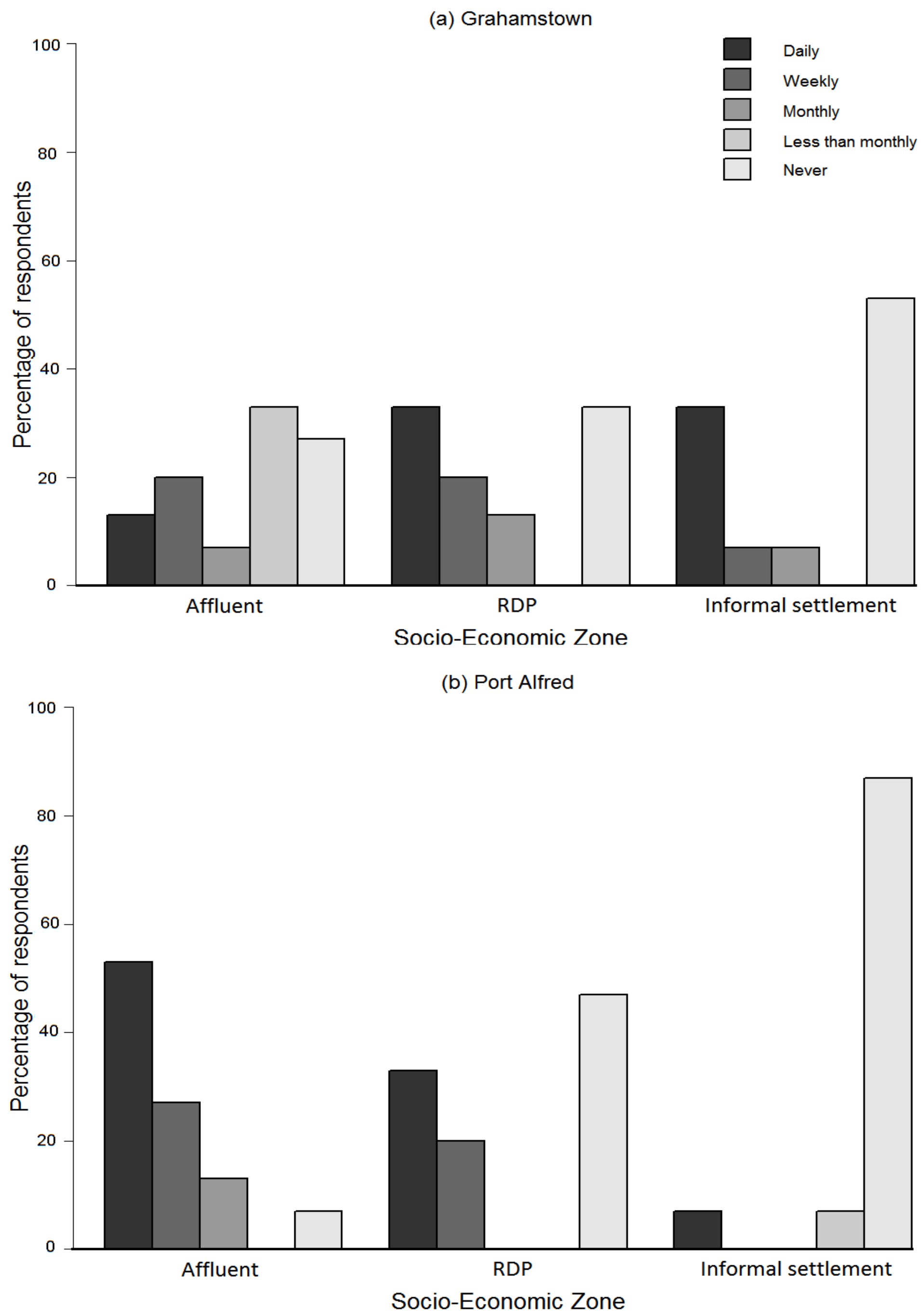


Figure 3.2: Frequency of feeding garden birds within (a) Grahamstown and (b) Port Alfred by socio-economic gradient.

3.3.2 Garden Management

As expected, garden size in affluent areas was almost double that of the informal and RDP zones for both towns (Figure 3.3). The mean garden sizes differed significantly (F-vlaue = 13.69, $p < 0.0001$) along the socio-economic gradient within Grahamstown and Port Alfred, however, the RDP and Informal settlement were not significantly different to one another (F-vlaue = 13.69,p = 0.99 and F-vlaue = 13.69, p = 0.80, respectively).

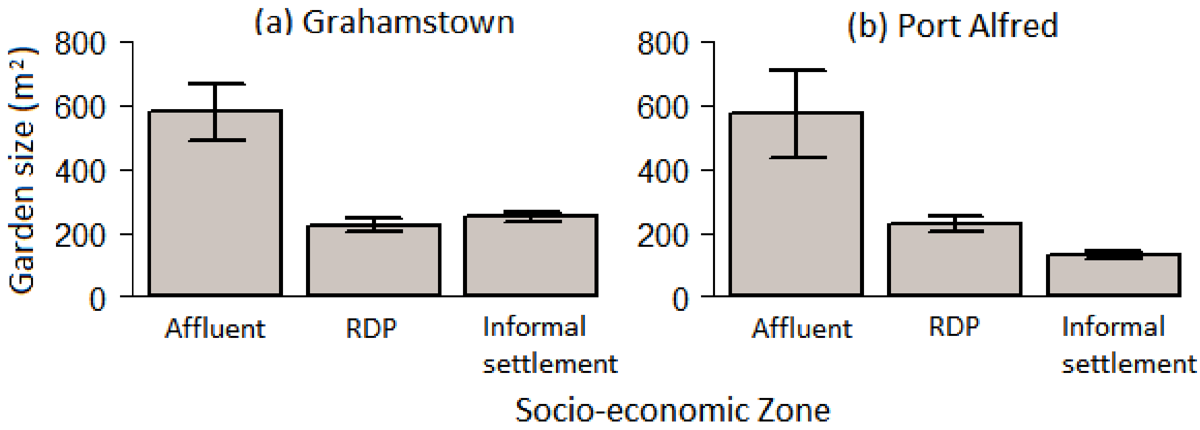


Figure 3.3: Garden size within (a) Grahamstown and (b) Port Alfred.

When asked whether residents partake in gardening activities or hire a gardener, roughly 50% of the residents within the affluent homesteads in Grahamstown hired a gardener, which decreased in the RDP homesteads (Figure 3.4). All residents interviewed within the informal zone mentioned that they undertook their own gardening practices, highlighting clear differences along the socio-economic gradient. In contrast, no difference was found between the number of residents who participated in gardening activities in Port Alfred, although it appeared that more residents within the affluent neighbourhoods participated in household gardening activities.

Within Grahamstown, grass cover was the dominant garden cover along the socio-economic gradient (F-value = 2.28, $p < 0.001$, Figure 3.5). Although grass cover was highest in the affluent areas, the gardens had more variation in the types of plant cover (tree cover F-value = 66.99, $p < 0.0001$; ground vegetation cover F-value = 17.69, $p < 0.0001$), compared to the RDP and informal zones which were dominated by grass and grey infrastructure, as well as <10% tree and ground vegetation cover. Within Port Alfred, grass cover was also the dominant land cover within gardens across the socio-economic zones, with no significant change across the zones, and >60% of the cover within gardens in the RDP zone. Affluent areas displayed more variation within the garden cover types, while the RDP and informal zones again displayed a significantly decreased tree (F-value = 3.16, p = 0.05) and ground vegetation cover (F-value = 9.6, $p < 0.0001$). Overall, as per the "luxury effect", affluent homesteads within Grahamstown displayed a higher vegetation cover, as opposed to the lower socio-economic zones, including increased tree and ground vegetation cover, and increased grass and grey area cover in other socio-economic zones.

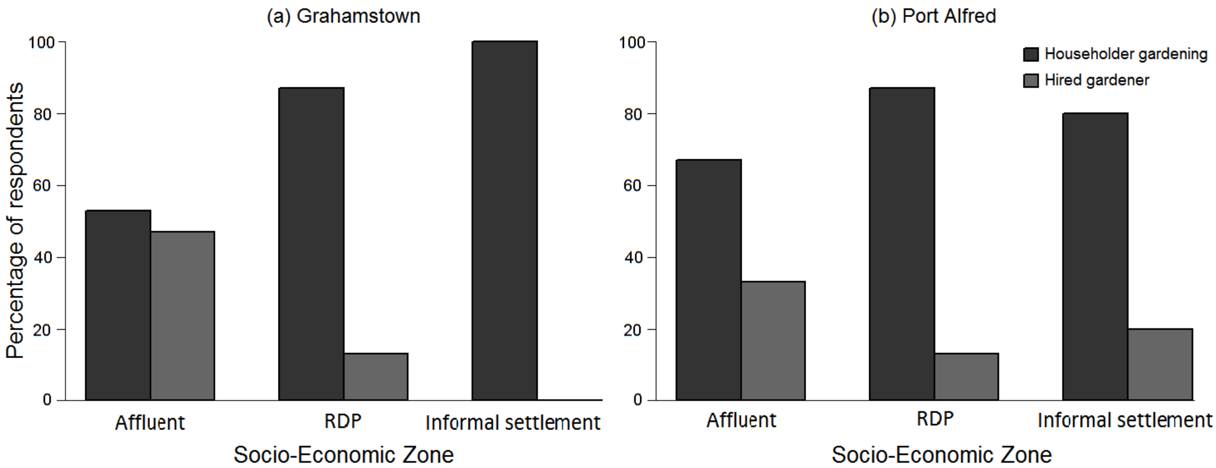


Figure 3.4: Resident participation in gardening activities vs a hired gardener in (a) Grahamstown and (b) Port Alfred.

For both towns, Garden Management Intensity was highest within the wealthier homes, while it was relatively similar in the RDP and informal areas (F-value = 11.1, $p < 0.0001$ for both towns), indicating socio-economics may play a significant role in shaping the amount of effort and energy needed to maintain gardens (Figure 3.6). Although the Garden Wildlife Practices and Garden Wildlife Awareness indices were highest in the affluent areas of Port Alfred indicating that socio-economics may effect the outcome, results were not statistically significant and did not display a significant change across the socio-economic zones for both towns.

To gain a broad understanding of how they use their outside spaces, residents were asked whether they partake in a number of leisure activities within their garden. Within Grahamstown, no significant difference was found in a few of the activities along the socio-economic gradient (Figure 3.7), with the majority of the participants claiming that their garden allows them to enjoy the plants and flowers, relax and reflect, connect to nature and watch and attract wildlife, highlighting that an appreciation of nature and wildlife are linked to the activities that residents perform in their garden. A few participants within the affluent homesteads used their garden environment to keep fit, yet a number of residents used their garden for recreation. The majority of the residents within the affluent area used their garden to grow vegetables and herbs, while fewer residents in the lower socio-economic zones were found to grow vegetables and herbs and medicinal plants ($\chi^2 = 16.48$, $p < 0.001$).

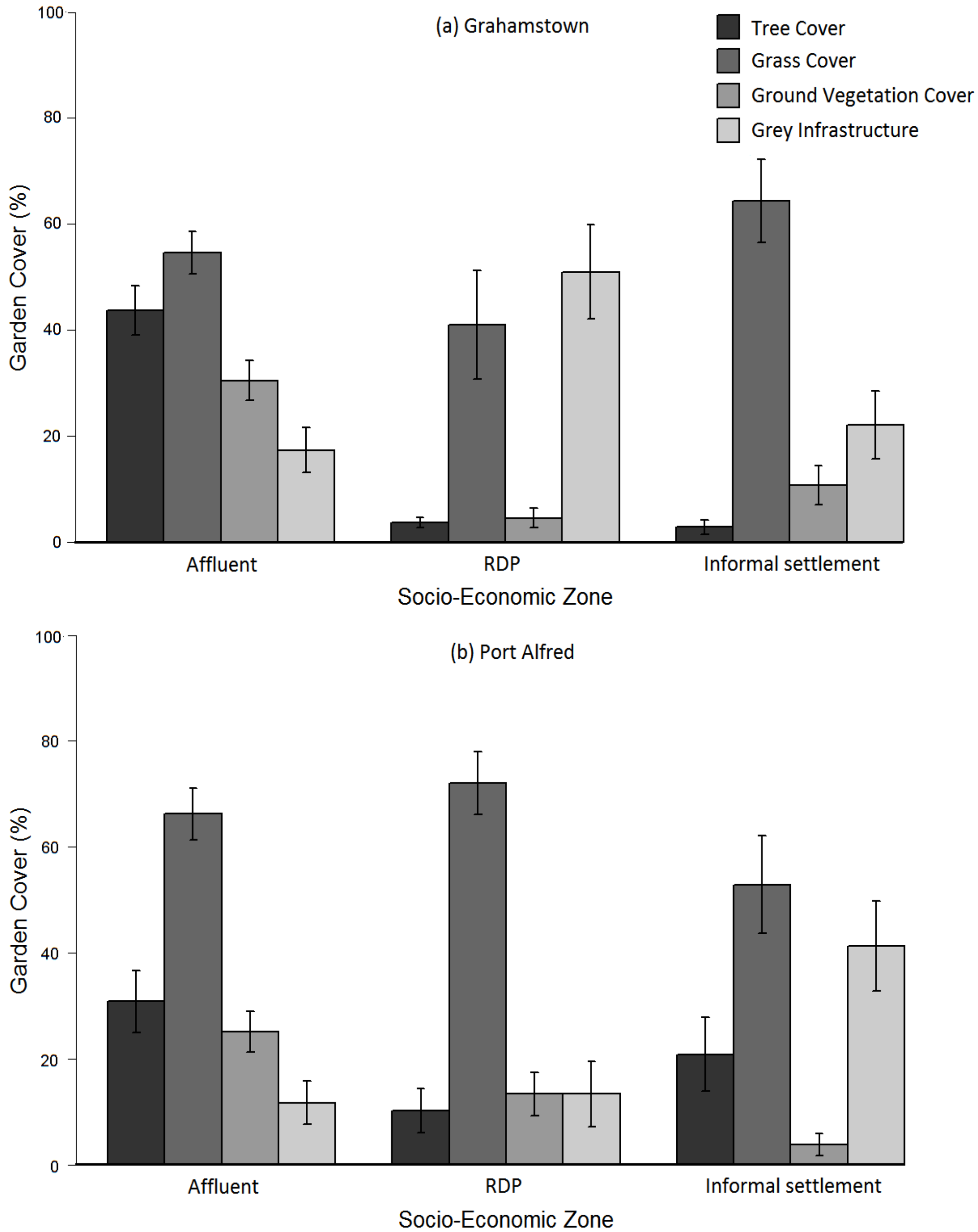
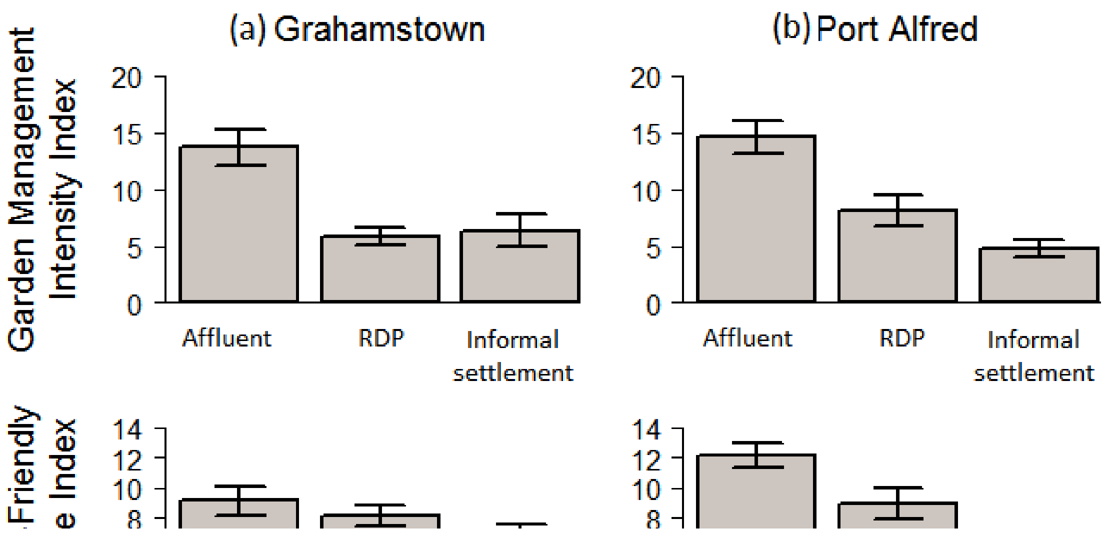
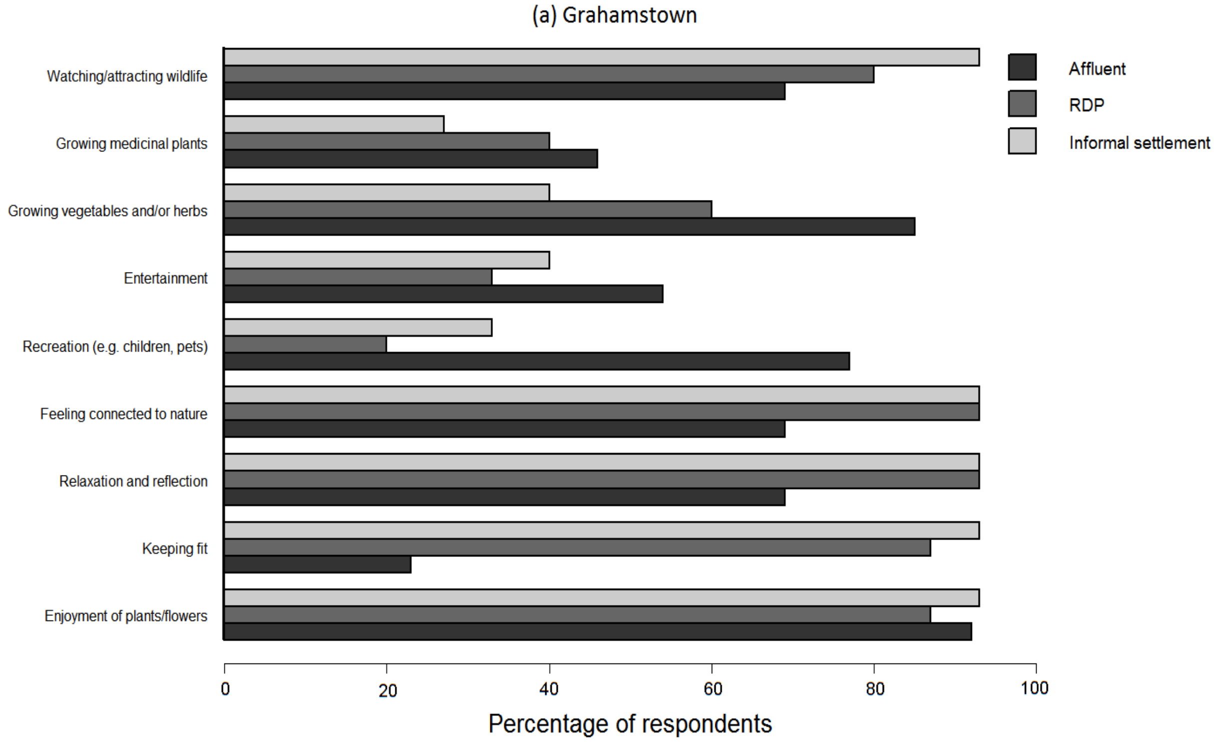
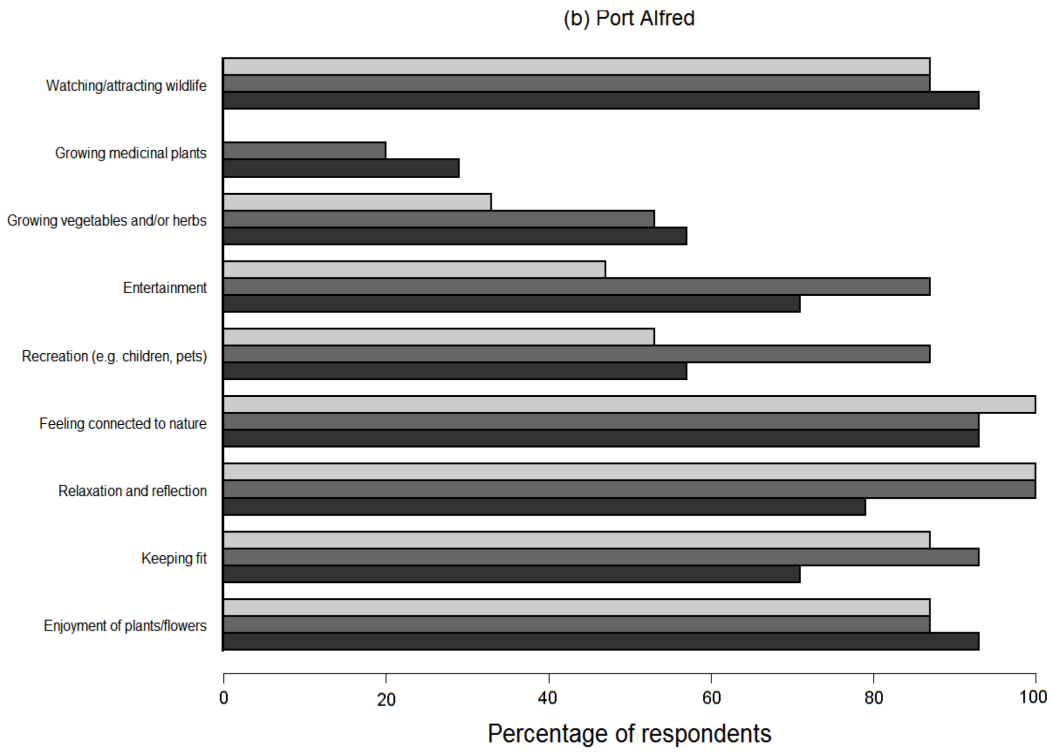


Figure 3.5: Vegetation cover in urban domestic garden habitats for (a) Grahamstown and (b) Port Alfred.


Garden Management Intensity Index
(a) Grahamstown
(b) Port Alfred
20
15
10
5
0
Affluent
RDP
Informal settlement


(a) Grahamstown
Watching/attracting wildlife
Growing medicinal plants
Growing vegetables and/or herbs
Entertainment
Recreation (e.g. children, pets)
Feeling connected to nature
Relaxation and reflection
Keeping fit
Enjoyment of plants/flowers
Affluent
RDP
Informal settlement
0
20
40
60
80
100
Percentage of respondents


(b) Port Alfred
Watching/attracting wildlife
Growing medicinal plants
Growing vegetables and/or herbs
Entertainment
Recreation (e.g. children, pets)
Feeling connected to nature
Relaxation and reflection
Keeping fit
Enjoyment of plants/flowers
0
20
40
60
80
100
Percentage of respondents

Similar results were found in Port Alfred, where the majority of the residents enjoyed the plants and flowers, kept fit, felt connected to nature, and watched and attracted wildlife within their gardens, again highlighting that the garden may be a space to interact with elements of nature. Most of the residents in the RDP zone mentioned that they use their gardens as a recreation space and for outside entertainment, highlighting differences in garden use along the socio-economic gradient. Relatively few residents in Port Alfred mentioned a utilitarian use of their gardens in terms of growing vegetables and medicinal plants, with the majority of the cases in the affluent homesteads.

Urban residents were asked about the perceived importance of garden wildlife. Among the results, five main themes emerged, namely connectivity of nature, the intrinsic value of nature, spirituality, property damage and the aesthetic value of nature (Table 3.1). Residents alluded to a sense of connectivity between fauna within their garden and the environment by mentioning the ability of animals to cross property boundaries, the importance of wildlife to the functioning of the garden, and the role that they play in warning of danger. By acknowledging that the wildlife brings them a sense of hope and happiness, as well as their ability to beautify the community, could provide evidence of the contribution of wildlife to health and quality of life in the urban sphere. The representation of ancestral beliefs through the presence of bird life alludes to a sense of spirituality and safety. Two residents mentioned that the birds are not getting enough food in the forests and that they have to look after the animals, creating a sense of stewardship that the presence of animals in gardens may bring to urban residents.

Table 3.1: Urban residents' sentiments regarding domestic gardens and fauna in Grahamstown and Port Alfred.

Theme	Quotes
Garden provision	• I can have something to eat and [it] makes more fruit than other yards. • Yes, it produces a lot. • The garden produces food to eat therefore it makes my life easier.
Connectivity and interactions in nature	• They are a part of nature e.g. some birds can warn if snakes are nearby. • The garden only works as an ecosystem. The more critters, the healthier the garden is. The birds eat the earthworms. • I see some birds in the open bush as I do in my garden, therefore they travel.
Resident wellbeing	• It has the most calming effect to watch them [the birds] and their ways. It makes the garden atmosphere more pleasant. • The birds make me happy. They give me a sense of hope. • The animals are important because I clear my mind when I see them.
Stewardship	• The birds might not be getting enough food from the forests therefore come to eat here. • Birds are a part of nature because we have to look after them because we don't know where they sleep or eat.
Spirituality	• I believe that if birds come into the house early morning, your ancestors are watching over you. • Xhosa people believe that the ones that build the nest close to the house are ancestors. • Ancestral beliefs, especially wagtails, bring good things. • I love birds, birds are the animals of the house (as they used to say). Older people taught me that if you chase away the birds, you chase away good things.
Property damage	• The birds do not destroy anything, only eat between other plants. • The birds do not destroy anything, they are part of nature; I like the songs. • I loves birds because I do not experience any problems with them.

3.4 Discussion

3.4.1 Garden Management

When comparing the garden vegetation cover across the socio-economic zones, grass cover was dominant within both towns (Figure 3.3), while tree cover was significantly greater in more affluent homes. Similar results found for street trees within Grahamstown and Port Alfred in affluent areas (Kuruneri-Chitepo & Shackleton 2011), and for public greenspace provision (McConccachie & Shackleton 2010), reflecting the inequitable distribution of urban greening within many South African towns (Lubbe 2011; Davoren 2016). Furthermore, the Garden Management Intensity index was significantly greater in the more affluent neighbourhoods (Figure 3.6). Garden management intensity was calculated using the frequency and intensity of management activities such mowing lawns, removing plant material, or watering practices. The garden characteristics of the affluent areas, including larger garden size and greater shrub and tree vegetation cover, and more variation within the types of covers (Figure 3.5) may contribute to the greater management intensity within the affluent zones, while socio-economic factors such as constrained disposable income available to manage the garden in lower socio-economic zones may play a role.

The greater homogenisation of the vegetation and overall layout of the RDP and informal neighbourhoods, compared to the affluent zones may further contribute to the increased intensity of gardening practices in the more heterogeneous landscapes in affluent areas. Shackleton et al. (2014) found that although many households had and appreciated trees within their households, RDP suburbs had much smaller plot sizes and thus a lower number of tree species per household. The small plots (Figure 3.3), can be attributed to the monetary constraints adopted when building RDP settlements, with small plot sizes decreasing per unit costs for services such as roads, water and sanitation. Therefore, smaller plots resulted in a smaller area available for residents to create a garden to grow vegetables for food (Adegun 2018) or medicinal plant use (Maroyi & Mosina 2014) and aesthetic places for leisure and biodiversity within the urban sphere (Shackleton et al. 2014).

Lewis et al. (2018) mentioned output in the form of food production as one of the primary motivations for gardening, alongside wellbeing and social aspects in Lausanne, Switzerland. Residents within this study often mentioned the tangible benefits derived from their domestic garden in the form of food (Table 3.1). While a larger number of residents within the affluent areas grew food (Figure 3.7), when combined, the RDP and informal zones outweighed the affluent areas. Overall, the results provide baseline evidence that food production plays a vital component in the lives of urban residents across socio-economic levels. More nuanced evidence is needed to provide insight into motivations across socio-economic gradients.

The ability of residents to conceptualise their yard as part of a larger ecosystem may be important in understanding what is happening within the ecosystem, and any subsequent management decisions taken (Dahmus and Nelson 2013). In this study, urban residents provided sentiments on whether they perceived their garden to be part of the larger community or environment. The connectivity of the garden environment was an often-mentioned theme within residents' responses. Connectivity was inferred through statements which alluded to one process within nature affecting another process. For instance, residents remarked on an ecological knowledge of interconnection between the garden space and the larger ecosystem which may stem from observing the processes within the garden boundary (Table 3.1). In an in-depth study on residents' conception of their gardens or yards as a part of the ecosystem in Minnesota, USA, Dahmus and Nelson (2013) found that residents had large gaps in ecological knowledge and often only referred to birds and butterflies with regards to biodiversity. Residents often managed their garden in terms of keeping it at a steady state or partook in activities which limited the linkages between yards or the environment and attributed these practices to viewing the garden as an extension of the home space.

3.4.2 Garden Fauna

Cook et al. (2012) argue that the most important service provided by private gardens is cultural, where the residential garden space provides a sense of physical and mental wellbeing (Soga et al. 2017). Previous studies have shown the importance to health and wellbeing that interacting with wildlife provides (Bell et al. 2018; Fuller et al. 2008; Luck et al. 2011), and a possible apathy towards nature that a lack of interaction may enhance (Shaw et al. 2013). Almost all residents across the socio-economic gradient used their garden space to relax and reflect, enjoy the plants and flowers and feel connected to nature (Figure 3.7, Table 3.1). Previous studies in South Africa have highlighted that the level of appreciation for elements of urban green infrastructure such as street trees (Shackleton et al. 2014; Adegun 2018) did not differ according to socio-economic status. The notion that gardens offer a 'sense of place' and are extensions of the home space are undeniable (Bhatti & Church 2001; Larson et al. 2005), while the notion of individual management of nature is a definite contributing factor to a 'sense of space' and responsibility involved in tending to nature.

Residents also alluded to a sense of responsibility or stewardship towards the wildlife utilising the garden space (Table 3.1). Through the autonomy involved in managing a private greenspace, residents may foster a sense of personal responsibility to their immediate environment and wildlife. Similar results were found by Goddard et al. (2013) where motivations for wildlife gardening included a sense of personal obligation. As previously mentioned, by fostering awareness of the connectivity of garden elements, residents may further benefit from the wellbeing aspects of an urban garden. However, the overall results within the Garden Wildlife Awareness index did not reflect this, as no difference was found between socio-economic zones with regard to the index (Figure 3.6). Furthermore, discrepancies are often found between sentiments and action, and thus a sense of stewardship towards nature may not translate into wildlife-friendly practices.

Schram-Bijkerk et al. (2018) mention that the practice of feeding garden birds may be a physical manifestation of a fundamental connection between people and nature, while other studies have demonstrated that a connection to nature is vital to urban residents' wellbeing (Bhatti and Church 2001). A possible mechanism may be that by observing and connecting to life cycles, allows for a conscious or subconscious integration on ecological principals within an urban garden system. Urban areas are often thought of as being static and unchanging but to be connected to living beings allows for a sense of being part of something moving, dynamic and alive. In all findings, the urban residents who participated in feeding birds (either less than monthly to daily) far outweighed those who had never fed birds within their garden (except for residents in the informal settlement in Grahamstown (Figure 3.2). Results of this study are similar in that there is a vast appreciation of various aspects of private greenspaces across socio-economic zones (Figure 3.7). Residents in the RDP and informal zones frequently mentioned that they feed the dogs food scraps from household meals, while the birds opportunistically feed on the scraps. Although we are unable to mention what the specific type of food was fed to the birds, it will most likely be in the form of staple foods such as rice and maize porridge.

Results within this study showed that residents within the affluent areas fed garden birds far more than those in other socio-economic zones, particularly in Port Alfred (Figure 3.2). Studies in the Global North showed that socio-economics did not influence bird-feeding (Davies et al. 2012; Lepczyck et al. 2012) although it is thought that residents within the affluent zones have a greater knowledge or interest in the local environment and past times such as bird watching. A positive relationship to bird diversity and socio-economics has been widely documented (Lepczyck et al. 2012), while in this study there may be a relationship between Garden Management Intensity (Figure 3.6) and supplementary feeding (Figure 3.2). It is speculated that residents which spend more time gardening or more input into maintaining the garden, may foster a greater interest in the garden and thus the fauna utilising the habitat, which may further increase the supplementary feeding provided by the residents.

Some isiXhosa-speaking residents within the RDP and informal zones mentioned a positive association between birds and ancestral beliefs, highlighting an alternative form of environmental insight and appreciation for nature underpinned by traditional ancestral belief systems extending to the novel urban residential sphere (Table 3.1). Upon investigating the ethno-ornithologiy of the amaXhosa people, Gijsbertsen (2012) mentioned that, according to those who retain ancestral beliefs, birds maintain a relation between living and dead relatives and transfer messages from the forest, river and fields. Respondents in the study also mentioned that an *igqirha* (Xhosa traditional healer) is required to interpret the behaviour of the birds, often indicated by absence or unusual behaviour in and around the homestead (Gijsbertsen 2012). This indicates that birds are highly valued by some urban residents, and that Garden Management Intensity or wildlife-friendly practices which favour the presence of urban birds may be applied in certain isiXhosa-speaking urban communities still retaining ancestral belief systems, which was shown to be up to 80% of urban residents in Grahamstown (Cocks et al. 2016). Previous studies have found that supplementary bird feeding promotes an increase in bird species richness or abundance in the garden environment (Daniels & Kirkpatrick 2006), which may create a positive feedback loop within communities who value the presence of birds. Despite this possible mechanism, residents within the affluent areas fed garden birds more often than within the other socio-economic zones, however, more research is required to adequately dissect the meanings and attachments between birdlife and urban residents within South Africa.

Not all interactions with fauna were found to be to positive for urban residents (Table 3.1). Although few residents in affluent areas in Grahamstown did mention that cows enter their property on occasion, cattle are a fundamental component of a number of cultural practices within the Xhosa culture (Davenport & Gambiza 2009). Residents remarked that due to a lack of money they were unable to build a fence around their house while their garden was at the mercy of local domestic livestock such as cattle, goats and pigs (Adegun 2018). Therefore, appreciation for the birdlife was reflected in their non-impact behaviour or inability to contribute to the detriment of residents' quality of life and can thus be appreciated. The persistent presence of domestic cattle within some gardens may also influence the management index of residents living in lower socio-economic zones, where the constant presence of grazing within the garden environment may influence the levels of disturbance within the plant communities and thus diminish the levels of intensity required (in mowing lawns for instance). If residents are unable to grow the plants they require due to livestock, they would in turn decrease their levels of gardening intensity. Furthermore, cultural beliefs possibly altered the responses when asked what animals are seen within residents' gardens (Figure 3.1) due to beliefs associated with the implications around meeting that animal. For instance, there is a belief that the owl is a bad omen, and thus they were not mentioned. While the beliefs cannot be extrapolated and may be geographically defined to certain areas, less obvious or unknown cultural beliefs may be a confounding factor when collecting biological data regarding fauna in among all urban residents, regardless of socio-economic standing.

The concept of biocultural diversity refers to the intimate link between nature, culture and indigenous communities and later extended to urban and rural contexts (Cocks et al. 2016). Combined with the intimate sense of place the gardens provide in the form of an extension of the home environment and autonomous control of the urban resident, research into the cultural associations that fauna and flora provide is vital in understanding the urban residents' relationship to the natural environment. Elements of the natural environment are part of a shared identity and heritage among urban isiXhosa-speaking residents (Cocks et al. 2016) thus investigation into the biocultural diversity within the context of domestic gardens may prove to be important in Southern Africa and the Eastern Cape. Investigating the complex relationship between people and nature within the urban environment can further inform policy to provide residents with not only the material value of nature but more intangible benefits as well.

Bhatti & Church (2004) mentioned that the application of pro-environmental behaviour (such as avoiding chemical use) is linked to the idea that nature is threatened, and thus associated with a sense of risk and uncertainty with regards to the environment. In this study, wildlife-friendly practices were calculated to form an index which included behaviours which promote the suitability of the garden environment for animals and thus promote environmentally favourable behaviours. The Wildlife-Friendly Practices and Garden Wildlife Awareness indices were common across the socio-economic gradient, despite being slightly greater in the affluent areas. In this case, socio-economics may not play a strong role in determining the awareness that residents have of wildlife. However, with the recent increase in pro-environmental behaviour and campaigns to decrease plastic (increase in paper bag use in large shopping franchises and the increase in biodegradable straws) to change behaviour of residents, directly aimed at South African citizens, might explain the higher prevalence in wildlife-friendly practices in the affluent zones within the study (Brien & Thondhlana 2019).

Within both towns, fauna such as spiders, lizards, butterflies, insects and bees were reported by far more residents within affluent areas than RDP and informal zones (Figure 3.1). These results may be attributed to either a lack of perception by the household residents, or a lack of abundance of the fauna within certain urban residential environments. When taking into consideration the evidence of the "luxury effect" seen within South African towns (Lubbe et al. 2010; McConnachie & Shackleton 2010; Kuruneri-Chitepo & Shackleton 2011), along with the various cultural associations with fauna, many of which are not known (Gijsbertsen 2012), we can assume that fauna are lacking in richness and abundance within suburbs with limited public and private greenspace. This study has provided baseline evidence that urban fauna may provide urban residents with a sense of wellbeing, although more research is needed to dissect the intricacies of wellbeing (in the form of comfort, connection or aesthetics) and its link to fauna. Therefore, residents without adequate greenspace are less able to enjoy the benefits provided by fauna as well as the ecological role urban wildlife play in pollination, dispersal, predation or competition, the implications of which are unknown.

Overall, this research shows that garden wildlife may have potentially positive effects on residents quality of life and connection to nature and are a valuable component in the urban sphere, as well as deeper connections to cultural beliefs and practices. Practices which increase the abundance of wildlife or connection residents have to noticing or interacting with wildlife may provide intangible yet valuable benefits. Although indirectly, residents highlighted an ecological understanding of connectivity through being present within their garden.

Chapter 4: Avian community patterns in urban domestic gardens in small towns of the Eastern Cape, South Africa

4.1 Introduction

With rapidly expanding urban landscapes the need to understand the impacts on biodiversity is imperative (Goddard et al. 2017). By the year 2050, more than 70% of the world's population will reside in urban areas (Montgomery 2008). As a result of habitat alteration and fragmentation, urban expansion is resulting in changes to faunal communities within public and private greenspaces. While most urban ecological research focuses on public greenspaces, private greenspaces (such as urban domestic gardens, UDGs) have been greatly understudied, despite potentially offering important habitat and resources for urban wildlife and the provision of ecosystem services generally (Goddard et al. 2010; Cameron et al. 2012). Restricted access, multiple ownership, unregulated management and exotic species have made ecological studies within domestic gardens increasingly challenging (Gaston et al. 2005; Mathieu et al. 2007). However, urban gardens contributed up to 27% of the urban area in the United Kingdom (Gaston et al. 2005), 36% of the urban area in Dunedin, New Zealand (Mathieu et al. 2007), and up to 73% in medium-sized towns in South Africa (Shackleton et al. 2016), making up a substantial part of the vegetated area within urban landscapes. Although individual gardens are relatively small in size, they are often the only type of greenspace which allows for connectivity to create larger patches of complex heterogeneous habitats that can function as an important refuge for native biodiversity and provide vital ecosystem goods and services (Davies et al. 2008; Goddard et al. 2010).

The importance of UDGs are highlighted by two projects executed in the UK. Through a series of studies surveying 61 gardens, the Biodiversity of Urban Domestic Gardens in Sheffield project (BUGS) attempted to broaden the understanding of resources that UDGs may provide for biodiversity and ecosystem functioning (Gaston et al. 2005; Smith et al. 2006). The 'My Back Yard' project involved research and citizen science to gather and inform citizens within Manchester, UK, of the amount of greenspace constituted by gardens and subsequently create an action plan to enhance the amount of garden wildlife (Cavan 2018).

Urban biodiversity can be influenced by top-down (town-planners or policy-makers) and bottom-up (individuals, homeowners) decision-makers (Kinzig et al. 2005). As most of the gardens are privately owned, management decisions in support of or against native and non-native biodiversity are largely influenced by home-owner socio-economic status (SES), cultural motivations and attitudes or environmental viewpoints (van Heezik et al. 2013). For instance, available resources can either limit or enable residents to change their environment, thus reflected in the socio-economic status of the households (Kinzig et al. 2005). Concepts such as the "luxury effect", whereby affluent neighbourhoods appear to have higher vegetation cover and plant diversity, have showed that patterns of urban diversity are integrally linked with social stratification in many settings (Hope et al. 2008; Davoren et al. 2016; Leong et al. 2018), while faunal studies have found correlates between vertebrate species richness and SES (Kinzig et al. 2005; Melles 2005; Botha 2012). Urban domestic gardens exemplify social-ecological systems as the collective decisions of private homeowners can scale up to influence ecosystem services and biodiversity at landscape scales (Kinzig et al. 2005). Some residents may adopt a stewardship attitude towards garden fauna which may further foster interest in urban conservation and connections to nature (Cox & Gaston 2015).

Birds are important components of urban biodiversity as they are highly mobile, and use a variety of patches depending on the availability of resources such as food, water, habitat and nesting sites or avoidance of predation. Birds play a keystone role in providing ecosystem services through pollination, seed dispersal or controlling invertebrate populations, contributing to plant reproductive success and community composition, as well as controlling gene flow between plant populations within isolated urban patches (Pauw & Louw 2012). Birds provide various provisioning services through meat or feathers or cultural significance, and may contribute to human health and wellbeing through fostering a sense of connection to nature through feeding and interaction and observation, leading to mental rest and rejuvenation (Sekercioglu et al. 2016).

A number of factors determine the suitability of urban areas for birdlife, including 1) the occurrence and size of remnant native vegetation patches, 2) the occurrence of predators (usually non-native), 3) the structure and composition of planted vegetation and 4) supplementary feeding by urban residents (Chace and Walsh 2006). A number of studies have investigated bird community composition within UDGs while highlighting the various drivers of avian diversity at a local scale. For instance, the bottom-up decisions of urban residents to keep domestic cats often has negative implications for bird communities (Belaire et al. 2014), while heterogenous vegetation structure can positively influence bird diversity in UDGs (Daniels & Kirkpatrick 2006) as well as the presence of native vegetation (Lerman & Warren 2011) or supplementary feeding within gardens (Fuller et al. 2012). Thus, socio-economics, landcover and personal choices cannot be ignored as major factors in structuring bird communities within UDGs (Goddard et al. 2017).

The majority of urban ecological studies have been conducted in the Global North, while developing countries are often neglected or overshadowed by more pressing socio-economic issues (Cilliers et al. 2011). Ecological theories developed in the Global North cannot always be extrapolated to the Global South due to differing climates, values, cultures and political histories (Cilliers et al. 2011, Shackleton 2012). Due to its political history of racial segregation and economic enablement of the minority during the Apartheid regime (1940s-1993), South Africa hosts steep socio-economic gradients which are still prevalent within urban environments (Lubbe et al. 2010). During the Apartheid regime, urban areas were geographically separated based on race (Shackleton et al. 2014). Black South Africans were required to live in high-density, inadequately serviced suburbs called 'townships', while South Africans of European descent resided in formal, well-maintained and highly vegetated suburbs of low density. Following the demise of the Apartheid regime, the newly elected government began the Reconstruction and Development Programme (RDP), which involved the construction of low cost single story houses on a 40 m^2 foundation, in an attempt to address the backlog in housing provision (Wilkinson 1998). Additionally, as the laws which restricted access of black South Africans to urban areas were lifted, there was a rapid influx of people into towns and cities for employment and perceived better living conditions and services which resulted in the creation of multiple informal settlements, characterised by houses built of scavenged or low cost materials and irregular building arrangements (Shackleton et al. 2014). Therefore, stark socio-economic gradients still remain in South African cities and towns. Little attention has been given to how these affect the ecological attributes of urban public and private greenspaces (Shackleton et al. 2014).

Small to medium-sized towns within South Africa are important sites to study urban social-ecology because; 1) the majority of the urban ecological research has taken place in larger cities, (Shackleton et al. 2017), 2) the majority of urban growth is occurring in small- and medium-sized towns in sub-Saharan Africa (less than half a million inhabitants) (Shackleton et al. 2017), 3) small to medium towns are home to a larger proportion of people than cities, and socio-economic gradients are often more apparent compared to large cities (Shackleton et al. 2017), 4) inhabitants use less resources and thus produce a smaller ecological footprint (Shackleton et al. 2017), and 5) growth within urban centres is on a more flexible trajectory and has the potential for more sustainable growth in the future and may become more resilient (Shackleton et al. 2017).

Within South Africa, urban domestic garden vegetation (Lubbe 2011; Kaoma & Shackleton 2014; Davoren et al. 2016) and arthropod (Botha 2011) diversity patterns have been investigated along socio-economic gradients, but no studies have provided insight into patterns of avian communities. This study aimed to determine the nature of bird communities within urban domestic gardens along a socio-economic gradient in two medium-sized towns of the Eastern Cape, South Africa, as well as the primary mechanisms underlying avian community composition in terms of: 1) garden habitat composition and structure and 2) garden management practices.

4.2 Methods and Materials

Refer to Chapter 2 Methods and Materials.

4.3 Results

4.3.1 Garden Characteristics

Garden size in affluent areas was almost double that of the informal and RDP zones for both towns (Figure 4.1). The mean garden sizes differed significantly (F-value = 13.86, $p < 0.0001$) along the socio-economic gradient within Grahamstown and Port Alfred, however, the RDP and Informal settlements showed no differences (F-value = 13.86, $p = 0.99$ and F-value = 4.87, $p = 0.80$, respectively). In Grahamstown, the affluent areas exhibited the highest mean vegetation height and vegetation structural diversity, with height subsequently decreasing along the gradient (F-value = 15.71, $p < 0.001$; Figure 4.1). In Port Alfred, the affluent gardens had the highest mean vegetation height and structure, but it was not significantly different to the other socio-economic zones (Figure 4.1). In Grahamstown, the percentage of indigenous plant species were roughly 50% higher in the affluent gardens than the RDP and informal zones, and steadily decreased along the socio-economic gradient (Figure 4.1). No differences were recorded in the percent of indigenous plant species along the socio-economic gradient within the gardens of Port Alfred (Figure 4.1).

In Grahamstown, tree cover (F-value = 66.99, $p < 0.0001$), ground vegetation cover (F-value = 17.69, $p < 0.0001$) and grey infrastructural cover (F-value = 7.08, $p < 0.05$) changed along the gradient, while grass cover remained relatively constant (Figure 4.2). Gardens within the RDP zones displayed the highest grey infrastructural cover. Tree cover and ground vegetation cover were the highest in the affluent zones. In Port Alfred, only ground vegetation (F-value = 9.6, $p < 0.0001$) and grey infrastructure cover (F-value = 6.53, $p < 0.001$) changed along the gradient (Figure 4.2). Grass cover was the highest cover along all zones whereas grey infrastructure was significantly higher in the informal zone (F-value = 6.53, $p < 0.005$) and tree and ground vegetation cover the highest in the affluent gardens. The growth form cover, which was recorded within the planted areas of the gardens in Grahamstown, shrub cover (F-value = 8.06, $p < 0.01$) and large tree cover (F-value = 7.09, $p < 0.01$)

changed across the various zones, with the affluent areas having the greatest shrub and large tree cover within the gardens (Figure 4.3). Only large tree cover (F-value = 8.79, $p < 0.001$) appeared to decrease along the socio-economic gradient within Port Alfred (Figure 4.3).

For both towns, the score measuring the intensity of garden management practices was highest within the affluent areas (Figure 4.4), while it was relatively similar over the RDP and informal areas (F-value = 11.1, $p < 0.0001$ for both towns). Although the Wildlife-Friendly Practices and Garden Wildlife Awareness were highest in the affluent areas of Port Alfred, the scores remained relatively constant throughout Grahamstown, thus socio-economics may not strongly influence the input provided by residents. The age of the affluent households in Grahamstown were significantly older (F-value = 9.67, $p < 0.001$) than the RDP and informal houses (Figure 4.5), reflecting the older, more established areas of the town. Similar results were found in Port Alfred (F-value = 6.30, $p < 0.01$), where the age of the houses decreased along the socio-economic gradient.

In summary, gardens in the affluent zones for both Grahamstown and Port Alfred were larger and more vegetated and older than gardens within the other two zones, reflected by the mean age of houses, mean vegetation height and garden cover. Generally, the affluent gardens hosted a greater tree cover, while the gardens within the other socio-economic zones hosted a greater grey infrastructural cover. Of the indices that attempted to gauge how resident participation in Garden Management Intensity and Garden Wildlife Awareness, only the Garden Management Intensity and Wildlife-Friendly Practices appeared to decrease along the socio-economic gradient.

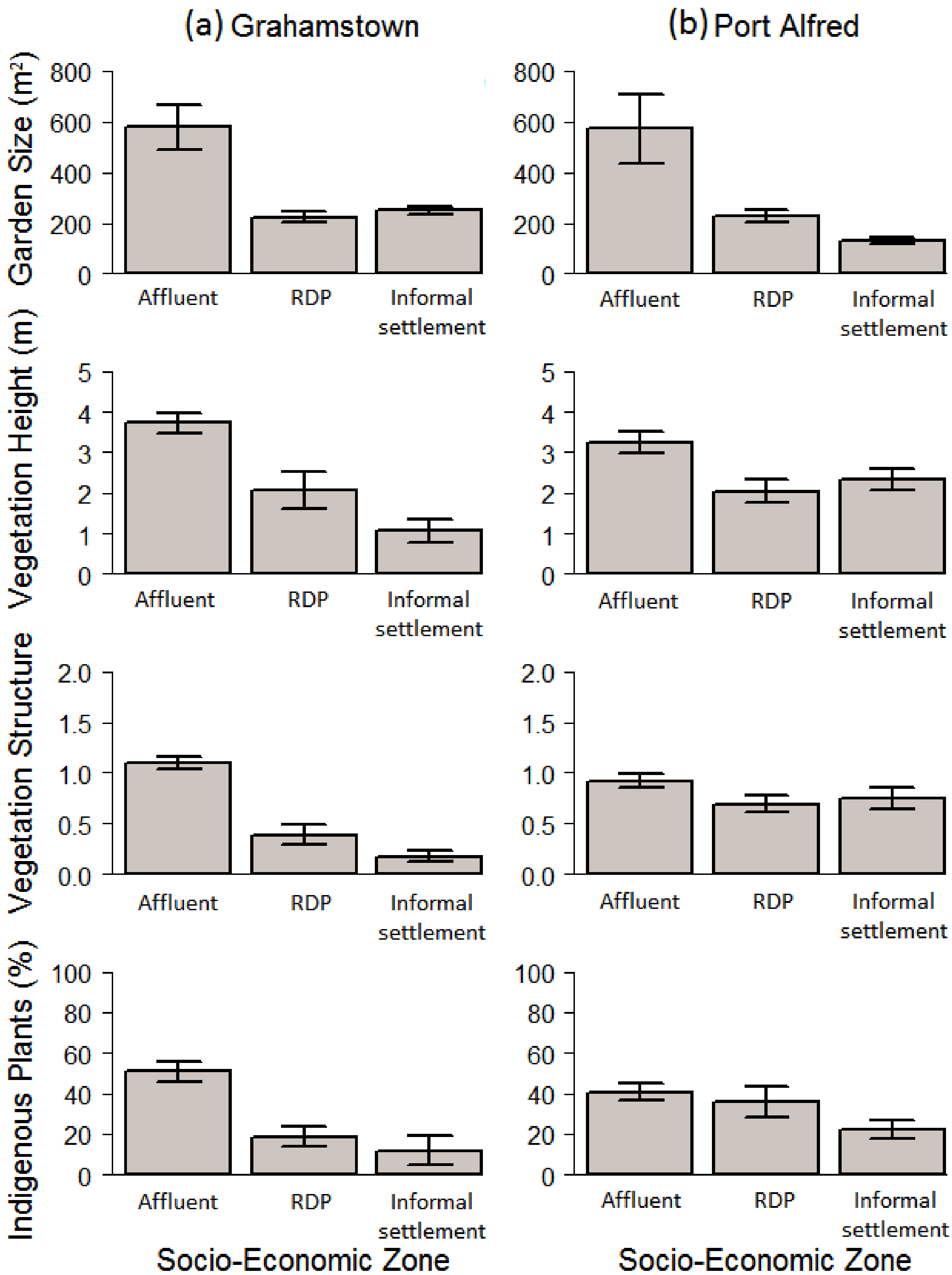


Figure 4.1: Vegetation characteristics for gardens including Garden size, Vegetation height, Vegetation structure, and the Percentage of indigenous plant species recorded within (a) Grahamstown and (b) Port Alfred gardens.

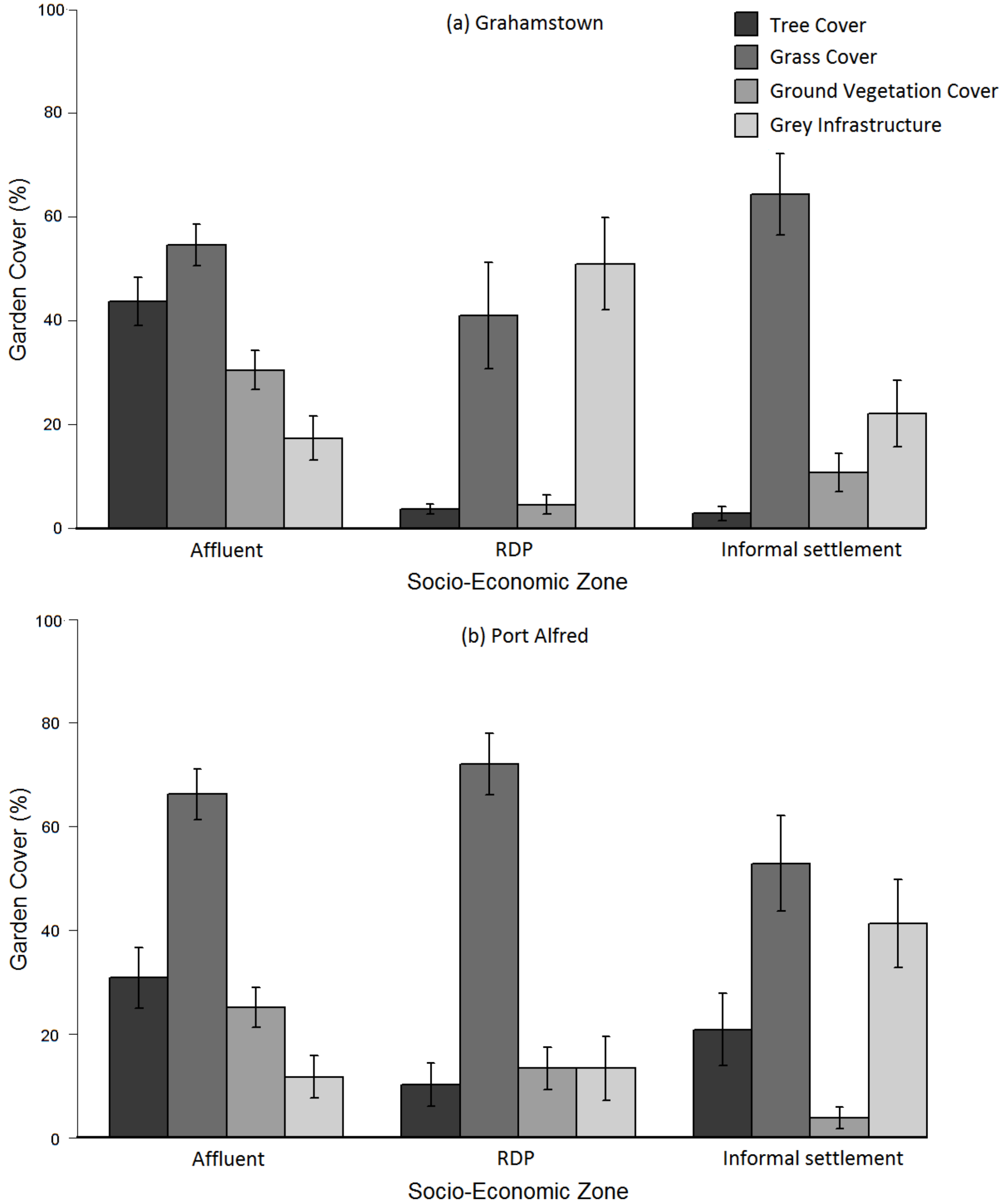


Figure 4.2: The percentage of the planted areas in gardens including tree cover, grass cover, ground vegetation cover and grey infrastructure cover in (a) Grahamstown and (b) Port Alfred.

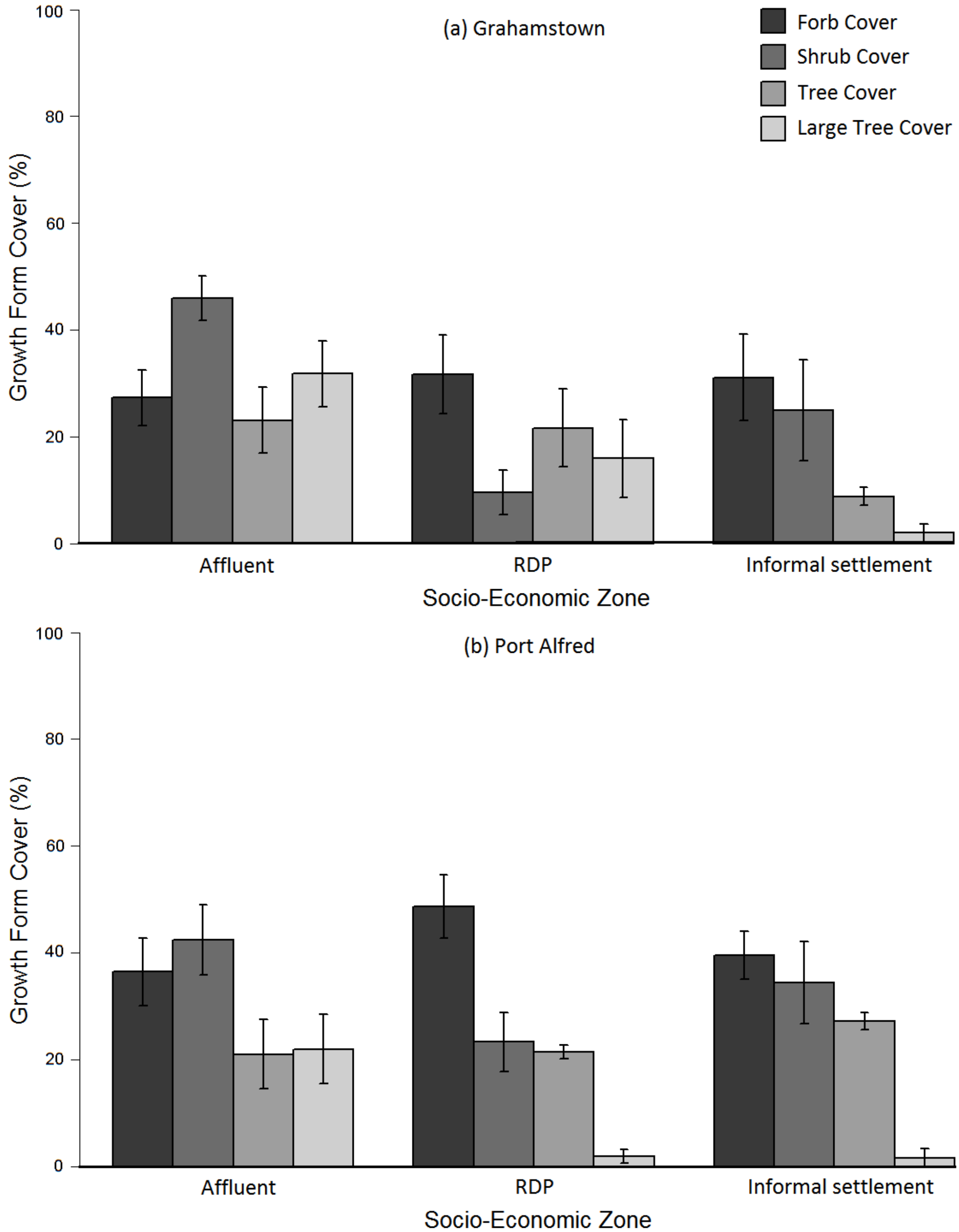


Figure 4.3: The percentage of each growth form within planted areas gardens including forb, shrub, tree and large tree cover in (a) Grahamstown and (b) Port Alfred.

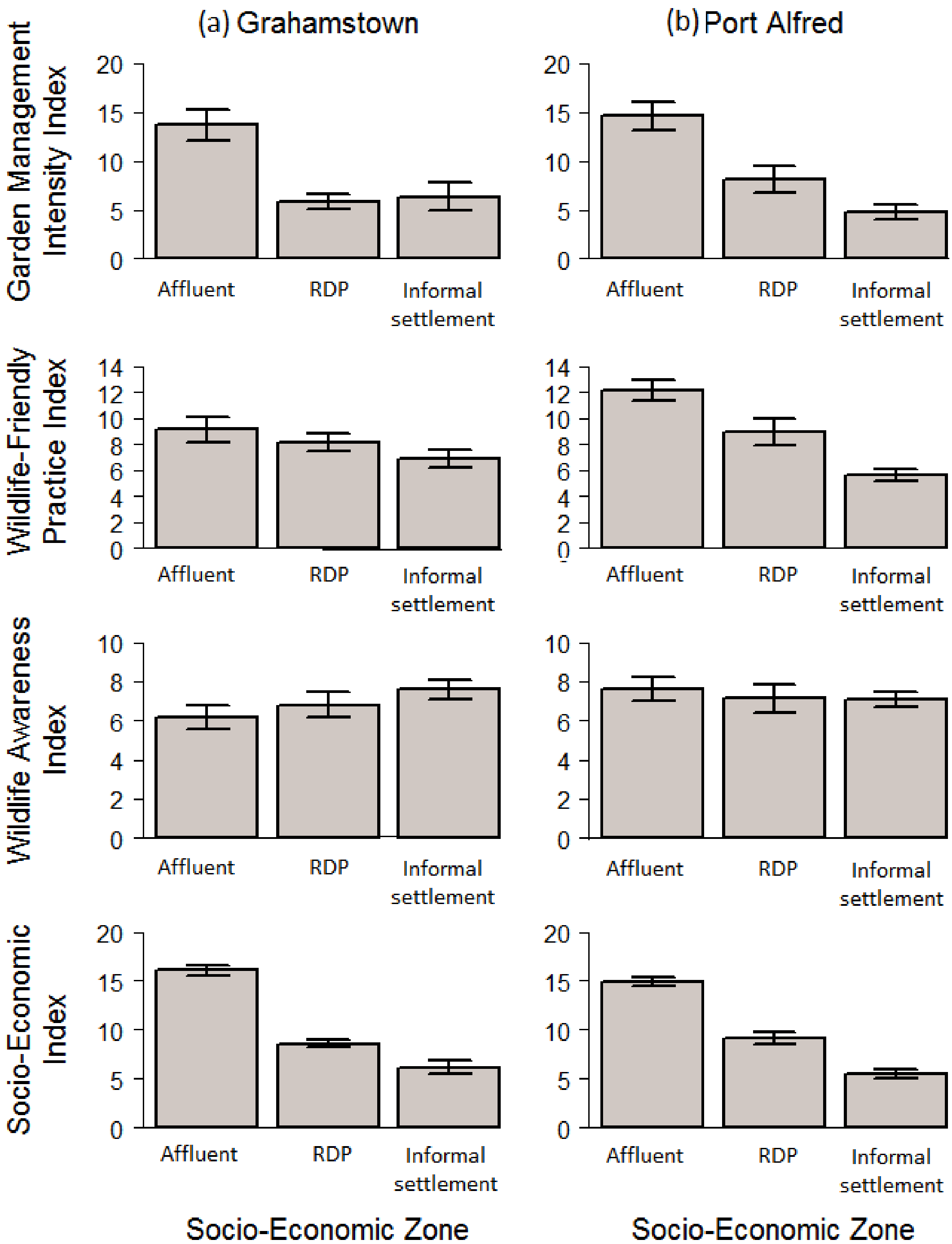


Figure 4.4: Indices measuring the Garden Management Intensity, Wildlife-Friendly Garden Practices, Garden Management Intensity and the Socio-Economic Status of urban residents within (a) Grahamstown and (b) Port Alfred.

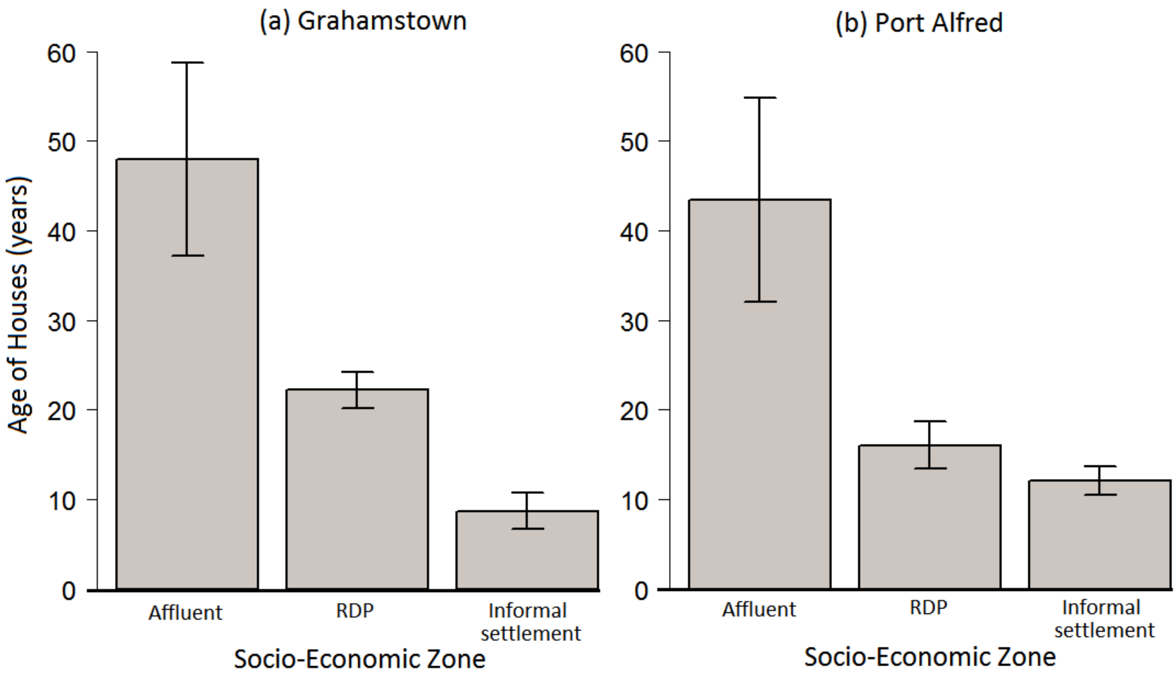


Figure 4.5: House age (a) Grahamstown and (b) Port Alfred.

4.3.2 Bird Species Richness, Diversity and Abundance

Species accumulation curves for the number of bird surveying events in Port Alfred and Grahamstown displayed an asymptote indicating that a sufficient number of sampling events were recorded to capture a representative proportion of the bird community in gardens (Figure 4.6). For Grahamstown, the Chao 1 richness estimator revealed that 94% of the bird community was sampled, while for Port Alfred, 76% of the bird community was sampled.

A total of 43 bird species were recorded in all 90 gardens, with 43 species in Port Alfred and 39 species in Grahamstown (See Appendix 1 for species list). Table 4.1 summaries the most frequently recorded bird species in each location across Grahamstown and Port Alfred. No significant difference was seen in bird species richness ($t^{(87.7)} = 0.31$ $p = 0.76$), diversity ($t^{(87.3)} = 0.42$ $p = 0.68$) and abundance ($t^{(87.3)} = -0.42$ $p = 0.68$) between gardens in Port Alfred and Grahamstown (Figure 4.7). However, within towns, a significant difference was seen for bird species richness, diversity and abundance along the socio-economic gradient, where post-hoc analyses using Tukey HSD revealed a difference between the affluent and both RDP gardens and informal gardens for both Grahamstown and Port Alfred, while no significant difference was seen between the RDP and informal gardens (significance figures summarised in Table 4.2). Thus, the overall findings read that the bird species richness, diversity and abundance were significantly higher in the wealthier gardens, compared to those recorded within the RDP and informal zones.

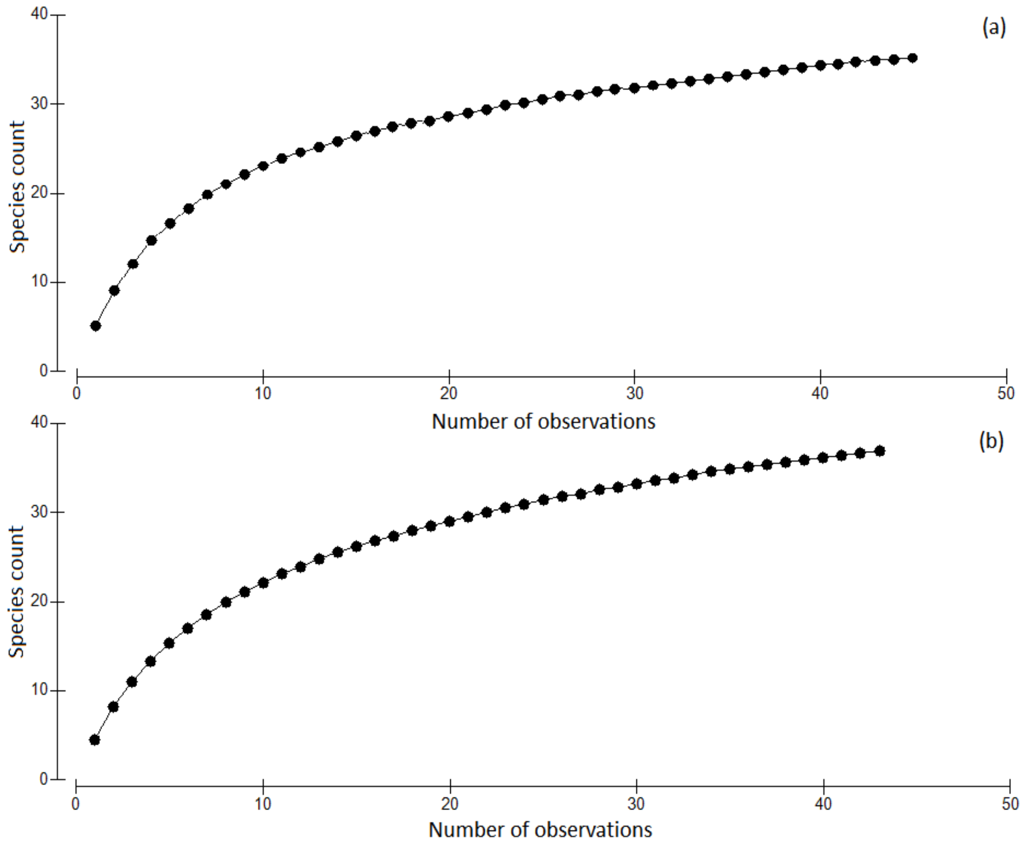


Figure 4.6: Species accumulation curve for the number of bird sampling events within (a) Grahamstown and (b) Port Alfred where bird species richness is a function of the number of sampling events within the gardens.

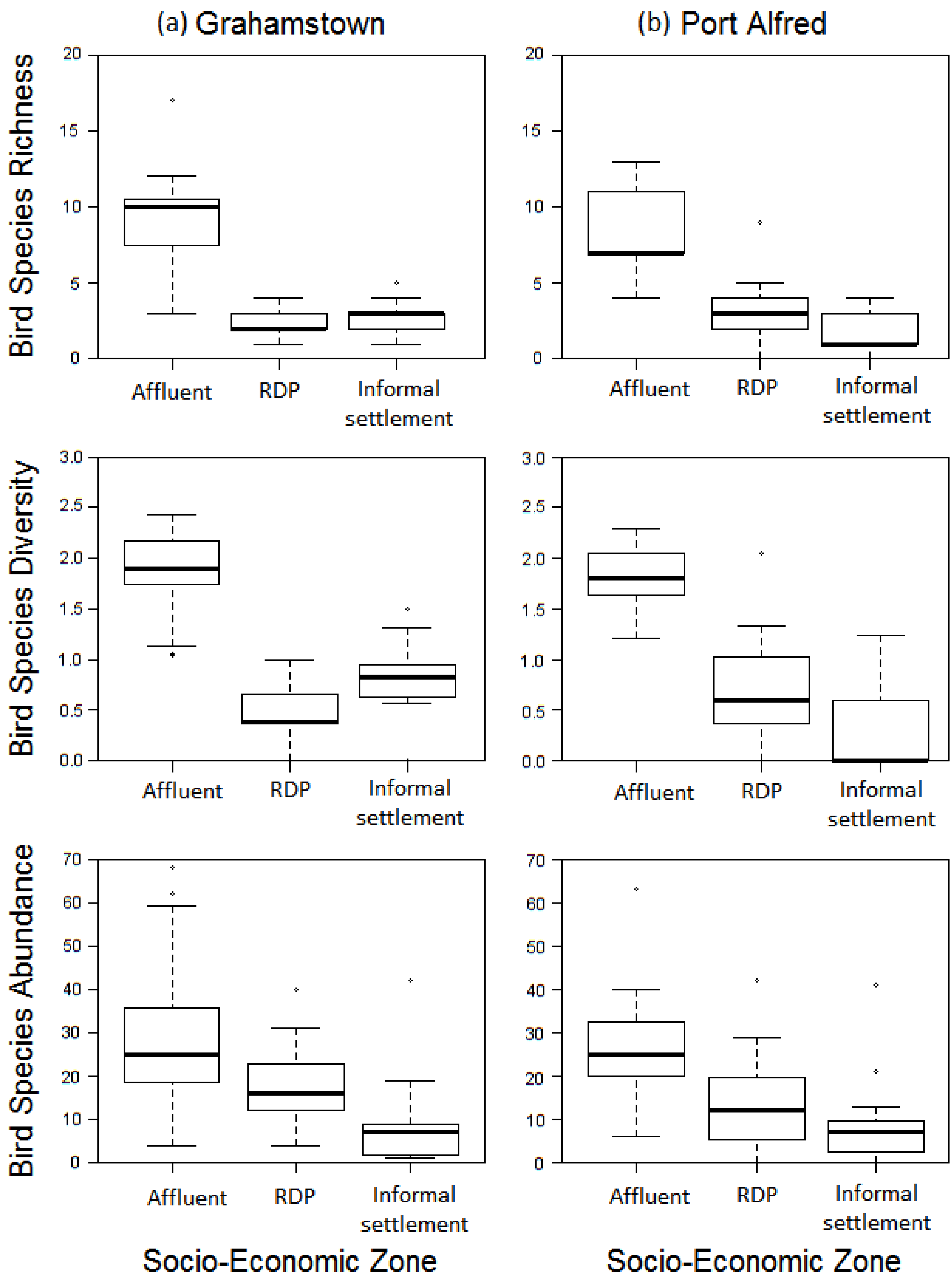


Figure 4.7: Boxplots indicating (a, b) bird species richness, (c, d) diversity and (e, f) abundance, within the urban domestic gardens of Grahamstown and Port Alfred, where n = 90 houses. See Table 4.2 for statistical results.

Table 4.1: The most commonly recorded bird species at each location.

Town	Socio-economic zone					
	Affluent		RDP		Informal	
	Species	No.	Species	No.	Species	No.
Grahamstown	Laughing Dove Cape White Eye Cape Turtle Dove Dark-capped Bulbul Olive Thrush	94 67 54 34 29	House Sparrow Cape Sparrow Common Starling Cape Wagtail LDC Sunbird	220 11 10 7 5	House Sparrow Cape Sparrow Common Starling Fiscal Shrike Bokmakierie	68 25 12 4 4
Port Alfred	Laughing Dove Cape White Eye Dark-capped Bulbul Cape Turtle Dove Speckled Mousebird Cape Wagtail	88 77 23 23 24 24	Cape Sparrow Chicken Laughing Dove Cape White Eye Dark-capped Bulbul	104 29 19 13 8	Cape Weaver Chicken Cape Sparrow Cape White Eye Laughing Dove	49 53 24 4 3

4.3.4 Bird Community Composition

Distinct changes in bird community composition were seen within UDGs along the socio-economic gradient within Grahamstown and Port Alfred. A bird community was distinguishable within the wealthier homesteads and another bird community within in the RDP and informal gardens for both Port Alfred and Grahamstown (Figure 4.8). Results coincide with findings in bird species richness and diversity within the gardens where affluent areas had higher species richness, diversity and abundance, while no difference existed between RDP and informal gardens (Figure 4.7). The NMDS for Grahamstown (stress = 0.19, acceptable level of accuracy of the ordination) revealed that the bird communities residing in the informal and RDP gardens were relatively similar ($R = 0.25$, $p < 0.01$), while there was a high degree of separation between the affluent and RDP gardens ($R = 0.94$, $p < 0.01$) and affluent and informal gardens ($R = 0.75$, $p < 0.01$, Figure 4.8). Tree cover, ground vegetation cover, shrub cover, % indigenous plant species, and socio-economic status ($R = 0.54$, $p < 0.01$, Table 4.2) accounted for most of the variance in the observed bird community patterns within Grahamstown, revealing that vegetation composition and structure to be a major driver the observed patterns. The SIMPER analysis showed that the House Sparrow (*Passer domesticus*), Laughing Dove (*Spilopelia senegalensis*) and the Cape White Eye (*Zosterops virens*) contributed up to 55% of the dissimilarity between the affluent and RDP gardens and affluent and informal gardens, while House Sparrow, Cape Sparrow (*Passer melanurus*) and Common Starling (*Sturnus vulgaris*) contributed approximately 80% of the dissimilarity between the RDP and informal gardens.

Table 4.2: Results of ANOVAs comparing bird species richness and diversity recorded within urban domestic gardens along the socio-economic zones within Grahamstown and Port Alfred, including results of post-hoc Tukey HSD tests within each town. Significance indicated in bold. AFF= Affluent zone; RDP = Reconstruction and Development Program; INF = Informal settlement.

	Grahamstown		**Port Alfred**	
Species richness	**AFF – RDP – INF**	F-value = 39.33 p < 0.001 ***	**AFF – RDP – INF**	F-value = 38.8 p < 0.001 ***
	AFF - RDP	p < 0.001 ***	**AFF - RDP**	p < 0.001 ***
	AFF - INF	p < 0.001 ***	**AFF - INF**	p < 0.001 ***
	RDP - INF	NS	RDP - INF	NS
Species diversity	**AFF – RDP – INF**	F-value = 46.64 p < 0.001 ***	**AFF – RDP – INF**	F-value = 40.37 p < 0.001 ***
	AFF - RDP	p < 0.001 ***	**AFF - RDP**	p < 0.001 ***
	AFF - INF	p < 0. 001 ***	**AFF - INF**	p < 0.001 ***
	RDP - INF	NS	RDP - INF	NS
Species abundance	**AFF – RDP – INF**	F-value = 8.81 p < 0.01 ***	**AFF – RDP – INF**	F-value = 8.94 p < 0.001 ***
	AFF - RDP	p = 0.05 .	**AFF - RDP**	p < 0.01 **
	AFF - INF	p < 0. 01 ***	**AFF - INF**	p < 0.001 ***
	RDP - INF	NS	RDP - INF	NS

Within Port Alfred, the NMDS (stress = 0.2, acceptable level of accuracy of the ordination) revealed similar results in that the bird communities of the informal and RDP gardens were comparatively similar (R = 0.20, p < 0.01), while there was a significant degree of separation between the affluent and RDP gardens (R = 0.51, p < 0.01) and affluent and informal gardens (R = 0.80, p < 0.01, Figure 4.8). Ground vegetation cover, forb cover, shrub cover and wildlife-friendly practices (R = 0.41, p < 0.01) accounted for most of the variance in the observed bird community patterns, revealing that again, vegetation structure is a major contributing factor for bird communities (Table 4.2). The results also revealed that individual home-owner decisions in the form of practices favouring the presence of wildlife can make a strong contribution in structuring bird communities. The SIMPER analysis showed that the Cape Sparrow, Laughing Dove and Cape White Eye contributed to 33% of the dissimilarity between the affluent and informal gardens, while Chickens and Cape White Eye's contributed 25% to the average dissimilarity between the affluent and informal gardens, and the Chickens, Cape Sparrow and the Laughing Dove contributed up to 60% of the dissimilarity between the RDP and informal gardens. It is important to note that for both towns, garden size was did not appear to be a strong correlate of bird community composition, indicating that the larger garden size within the affluent areas did not skew the results. Although Chickens are regarded as domestic animals, they were included in the data analyses due to possible competitive effects with urban bird species using the same resources.

When bird abundance data for both Grahamstown and Port Alfred were combined, the NMDS (stress = 0.16, acceptable level of accuracy of the ordination) plot displayed similar results to the previous ordination plots, whereby bird communities of the affluent gardens were less similar to the RDP ($R = 0.50$, $p < 0.01$) and informal gardens ($R = 0.61$, $p < 0.01$) while the RDP and informal gardens were more similar ($R = 0.085$, $p = 0.09$) to each other producing a second bird community (Figure 4.8). These patterns indicate that geographical separation between the two towns does not alter the bird community and that within town differences were of greater significance than between towns.

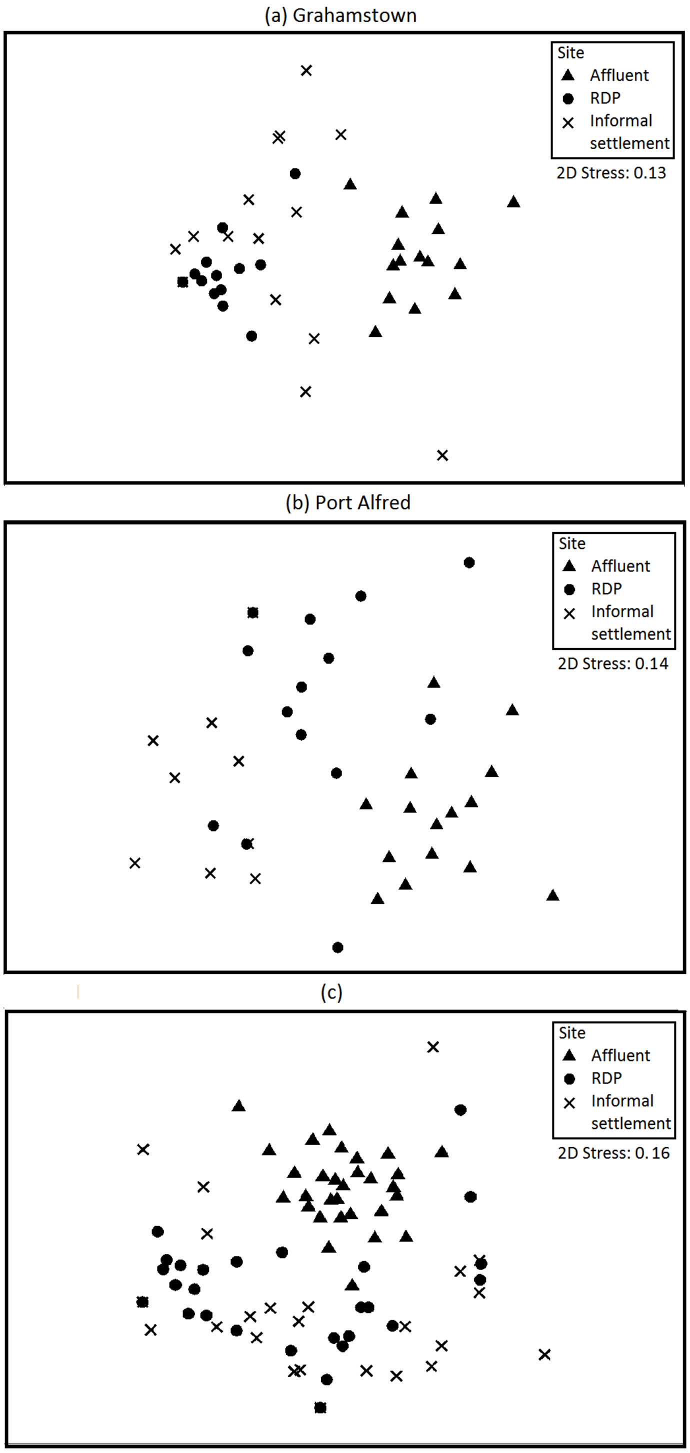


Figure 4.8: Non-metric multidimensional scaling plot of bird species composition recorded in urban domestic gardens for (a) Grahamstown (b) Port Alfred and (c) combined.

Table 4.3: Summary of the significant variables contributing to the greatest to the variance observed in bird community patterns for both Grahamstown and Port Alfred, including Rho-value and significance.

Grahamstown	**Rho-value**	**p-value**
Tree cover Ground vegetation cover Forb cover Indigenous plant species Socio-economic status	0.54	0.01
Port Alfred	**Rho-value**	**p-value**
Ground vegetation cover Forb cover Shrub cover Wildlife-Friendly Garden Practices Socio-economic status	0.41	0.01

4.3.5 Feeding Guild Composition

The most common bird species were generalist omnivores and insectivores along the socio-economic gradient. The lower income zones lost more specialised guilds such as granivorous and nectivorous bird species in Grahamstown, and granivorous and carnivorous species in Port Alfred (Figure 4.9). A greater occurrence of all feeding guilds were recorded in the higher income gardens, while the feeding guilds become more simplified within the RDP and informal zones.

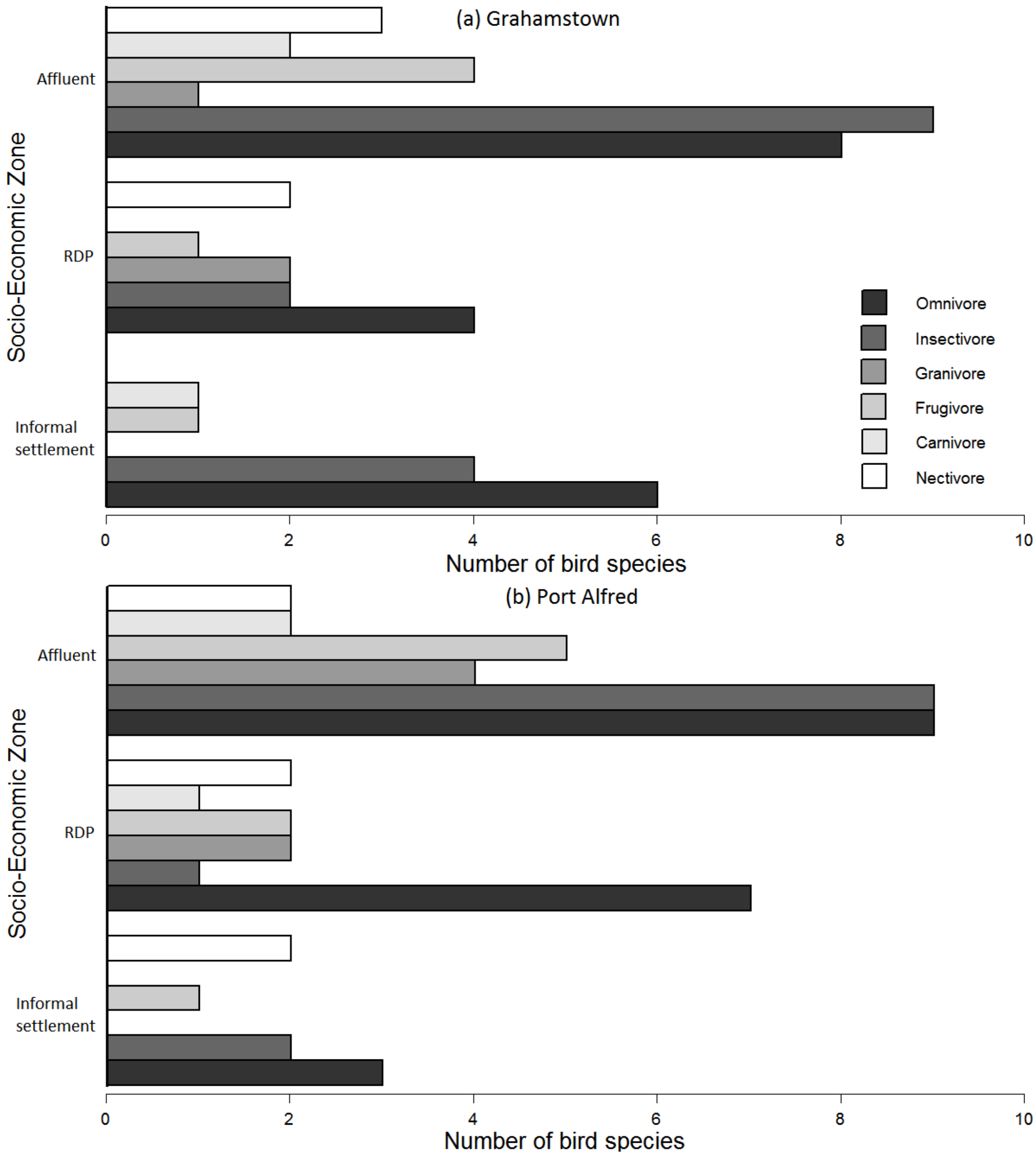


Figure 4.9: Number of species per feeding guild recorded in urban domestic gardens within (a) Grahamstown and (b) Port Alfred.

4.4 Discussion

Evans et al. (2009) mentioned that the ability of a bird species to maintain a viable population within urban areas ultimately depends on the availability of habitat at a localised scale. This study provides evidence that bird community composition within urban domestic gardens varied greatly along socio-economic gradients Grahamstown and Port Alfred. The phenomena is most likely explained by the "luxury effect", where a positive association is found between human resource (financial or labour) abundance and urban biodiversity (Hope et al. 2008, Leong et al. 2018), which is further amplified by the legacy of racial segregation during the Apartheid era in South Africa. The affluent homesteads within both Grahamstown and Port Alfred showed a higher bird species richness, diversity and abundance, representing separate community, highlighting that a distinction in the garden environments is driving the variation in the bird communities (Figures 4.7 and 4.8). In contrast, a different bird community characterised the poorer RDP and informal settlements, with lower richness, diversity and abundance measures.

4.4.1 Bird Community Composition

Within both Grahamstown (tree cover, ground vegetation cover and shrub cover) and Port Alfred (ground vegetation cover, forb cover and shrub cover), the garden variables, which can be interpreted as vegetation complexity by accounting for the multiple layers within a garden, were the strongest correlates with the bird community patterns (Table 4.3). Garden cover as well as growth form cover clearly highlighted the discrepancies between the structural composition of the gardens along the socio-economic gradient (Figure 4.2 and 4.3). As far back as the 1960s (MacArthur and MacArthur 1961), ecological studies have highlighted the importance of vegetation complexity in shaping bird species richness and diversity, showing that more vegetation strata increased structural niches, to allow for a greater diversity of species to use the various layers of vegetation, and increasing the available habitat. Within an urban context, by using occupancy models, Threlfall et al. (2016) found that it was understory vegetation that allowed for a 30 -130% increase in occupancy by native birds, bats and bees, while tree cover produced a neutral effect. Thus, vegetation strata become important in increasing bird diversity and richness as well as functional diversity, more so than any one single layer (Ikin et al. 2012).

Various studies have highlighted greater vegetation in higher income neighbourhoods (Lubbe et al. 2010; Luck et al. 2013; Shanahan et al. 2014; Goddard et al. 2017; Avolio et al. 2018). This pattern could arise for numerous reasons, such as older, more affluent households usually having larger gardens, thus retaining more vegetation (van Heezik et al. 2013). Within South Africa, the creation of the RDP program began in the early 1990s, allowing only a few years for vegetation to establish and as yet limited establishment of complex vegetation (Figure 4.3). Furthermore, Donaldson-Selby (2007) highlighted the various ecological effects of the land clearing associated with building the RDP neighbourhood included the clearing of topsoil and subsequent removal of seedbanks. The removal of seedbanks limits the establishment of native vegetation, which could therefore limit the bird communities, resulting in lower richness and diversity.

Within Grahamstown, a number of the gardens within the RDP zone had been paved. Long-term residents of the area mentioned that the houses within that particular area had been built on a wetland, thus the area is prone to floods when it rains (pers. comm. anonymous resident). Had appropriate measures been taken in planning the RDP zone, such instances could be avoided, allowing for greater levels of household greening. While various studies have found that the age of house or neighbourhood is strongly correlated to the biodiversity (Loss et al. 2009; Warren et al. 2010; Kaoma & Shackleton 2014; Avolio et al. 2018), the age of the house did not appear to be a significant driver of the bird community patterns in this instance, despite the mean age of houses increasing in more affluent suburbs (Table 4.3). Similar results found by (van Heezik et al. 2013)

Within Port Alfred, numerous residents complained of the lack money to erect a secure fence around their property. Consequently, free-roaming domestic animals (cows, goats and pigs) frequently used many of the domestic gardens as a thoroughfare or for fodder. It is commonplace for Xhosa-speaking residents to own livestock which are used in numerous cultural ceremonies, as an economic resource, or as a food resource (Davenport & Gambiza 2009). The residents mentioned that when they would attempt to grow vegetables, the pigs would consume them. Thus, the presence of livestock may affect bird communities through either direct disturbance or damage to vegetation. Previous studies in the region have highlighted the damage inflicted to street trees and trees in parks by free-roaming livestock (Richardson & Shackleton 2014; Shackleton et al. 2017). In affluent suburbs, most gardens are fenced and thus the management of the garden is under individual control, devoid of external threats to vegetation. Another consideration was that the households in the RDP and affluent settlements had electricity, and thus electricity poles provided perching sites for the birds, which aid hunting by carnivorous species such as the Fiscal Flycatcher (*Melaenornis silens*), which were not present in the informal areas of Grahamstown and Port Alfred. In contrast, the houses in the informal areas did not have infrastructure for electricity and thus did not have electricity lines or poles for birds to use. Although these observations, such as the presence of livestock and electricity lines, have not been tested, future studies should take into consideration infrastructural resources available for avifaunal communities, especially in light of the inequalities in urban zonation within South Africa.

In this study, chickens were recorded within the lower income zones. Although chickens are considered domestic animals, they were included as part of the bird community, as their use of the garden habitat is dependant on the resources available and may have competitive interactions with other bird species, possibly displacing various ground-foraging species.

The Wildlife-Friendly Garden Practices index was a strong correlate of the bird community composition within gardens in Port Alfred but not Grahamstown. This highlights that the individual decisions that homeowners make on a garden/parcel scale may structure the avifaunal communities within the area (Figure 4.4, Table 4.3, Goddard et al. 2017). While supplementary bird feeding can structure bird populations at multiple scales (Fuller et al. 2012; Galbraith et al 2015; Goddard et al. 2017), this study included multiple wildlife features which may attract birds (including flowering or fruiting plants, a compost heap, bird bath, pond, etc.) and practices such as avoiding pesticides and herbicides. According to the "luxury effect", how residents choose to manage their land depends on disposable income, culture and individual preferences (Kinzig et al. 2005). Residents earning a higher income have access to a greater range of management features and the ability to hire labour, which could explain the increase in wildlife-friendly practices in more affluent homesteads (Figure 4.4). Avolio et al. (2018) found a positive relationship between tree composition and the plants available in nurseries to urban residents. Furthermore, Coetzee et al. (2018) showed that the presence of sugar-water feeders increased the number of nectar-specialist birds within domestic gardens in Cape Town, South Africa. This could provide evidence that resources available to urban residents may influence their decisions regarding plant composition or biodiversity resources and lend to structuring urban bird communities.

The percentage of indigenous plant species was a strong predictor of the bird community composition within Grahamstown, and was significantly higher in the affluent gardens (Figure 4.1). Similar results have been found in a number of studies where bird species diversity was greater in gardens with increased native vegetation (Daniels & Kirkpatrick 2006; Burghardt et al. 2008; Lerman & Warren 2011) as well as for street trees (Shackleton 2017). While indigenous plant species provide resources such as food and shelter to more specialised bird species, urbanisation has been shown to homogenise the functional diversity of faunal species, allowing more omnivorous and generalist species to thrive (Chace and Walsh 2006; Pauw & Louw 2012; Aronson et al. 2016). However, more complex ecological interactions have been recorded within domestic gardens, where Burghardt et al. (2008) found that indigenous plants within gardens of Pennsylvania, United States, supported a higher abundance and richness of caterpillars, which subsequently provided a food source for insectivorous bird species and nestlings. Botha (2012) found that affluent gardens within the North-West Province of South Africa had a significantly higher arthropod diversity which was strongly influenced by the surrounding vegetation. Within Port Alfred and Grahamstown, the number of generalist omnivorous and insectivorous bird species were the highest functional groups recorded in the gardens with a large number of insectivorous bird species recorded within the affluent homesteads (Figure 4.9). Thus, emphasising the need for investigation into the relationship between arthropod diversity, bird species functional diversity and indigenous vegetation within urban domestic gardens (Aronson et al. 2016).

4.4.2 Connectivity and Homogenisation

Urbanisation is thought to be one of the most homogenising of human activities (McKinney 2006). When the bird composition data was combined for both towns, despite their geographical separation and different biomes, the bird assemblages displayed the same pattern as individual towns, where the bird community within the affluent residential gardens were less similar to the RDP and informal. Subsequently, there was a high degree of overlap between the garden bird communities in the RDP and informal communities (Figure 4.8). These patterns may be a result of the homogenising effects of urbanisation, where urban-adaptable species become more widespread and locally abundant in highly modified urban environments (Aronson et al. 2016). Typically, highly specialised bird species (frugivores, nectivores) are sensitive to changes in the ecosystem and are thus the first to be displaced following modifications in their environment or removal or a key resource, whereas generalist, omnivorous bird species tend to be more successful in exploiting urban resources (Faeth et al. 2005; Coetzee et al. 2018). A recent study by Coetzee et al. (2018) found that habitat generalism and tree nesting were the more important traits determining bird occurrence in domestic gardens in Cape Town, South Africa. Pauw & Louw (2012) found a steep decline in a specialist nectivorous bird species, the Malachite sunbird (*Nectarinia famosa*), in urban areas in Cape Town, South Africa, while van Rensburg et al. (2009) found evidence of biotic homogenisation along a rural-urban gradient in Pretoria, South Africa. The high occurrence of omnivorous bird species in both towns (Figure 4.9), as well as the lower occurrence of frugivorous, nectivorous and granivorous bird species recorded in the lower income gardens may provide evidence of the homogenisation of functional diversity within urban bird communities resulting in a loss of more specialised functional as well as a loss in pollination, flow of genetic material of plant communities.

4.4.3 Conclusion

Urban domestic gardens are highly complex environments that often echo past histories, political legacies, as well as contemporary cultural and personal beliefs of the home owners (Goddard et al. 2017). In turn, biological communities are structured by this range of interacting factors. This study investigated the changes in bird community composition and structure along a socio-economic gradient within two medium-sized towns in the Eastern Cape, South Africa. Political history of racial segregation during the Apartheid era is still highly prevalent in the socio-demographic structuring of small-to-medium-sized towns in South Africa. The results clearly reflected trends following the "luxury effect", where gardens within older, more affluent, white-dominated suburbs held a greater richness, diversity and abundance of bird species, as well as a distinct bird community, compared to the lower income RDP and informal communities. These findings are driven by the increase in vegetation cover and structure allowing for a greater range in habitat for urban bird communities, as well as the greater relative contribution of indigenous plant species in gardens within Grahamstown. Domestic gardens within Port Alfred showed that the individual decisions that homeowners make regarding the number of wildlife-friendly practices within their gardens may also be structuring the bird communities within the area, highlighting the effects that urban residents may have on urban biodiversity, and can be equated to the effects of supplementary feeding in found in other parts of the world. When the bird communities for both towns were combined and analysed, the same trends emerged within the structuring of the bird communities as individual towns, providing evidence of the possible homogenising effects of urbanisation, and verified by the functional diversity of birds recorded within the gardens. These results reflect that there is not only an inequitable distribution of infrastructural resources within previously disadvantaged communities within South Africa, but of biological and ecological resources too (Shanahan et al. 2014), thus disproportionately favouring those with socio-economic advantages.

CHAPTER 5: CONCLUSION

5.1 GENERAL CONCLUSION

As the urban population steadily increases all around the world, the reliance on ecosystem services provided by urban greenspaces becomes more imperative (Belaire et al. 2015). Private greenspaces such as urban domestic gardens are an often overlooked component of urban green infrastructure, despite making up a significant proportion of the urban environment (Mathieu et al. 2007). Private gardens also contribute greatly to ecosystem services such as provisioning (food and medicinal plants), regulating (purifying air), supporting (maintaining habitats for urban biodiversity), and cultural (place-making, health and wellbeing, relaxation, heritage) services (Langemeyer et al. 2016).

South Africa hosts steep socio-economic gradients and highly heterogeneous urban landscapes due to past political policies on racial segregation. This makes South Africa an ideal context in which to study urban domestic gardens and their contribution to urban biodiversity. Therefore, the two results chapters in this study emphasised the differences in garden management practices, sentiments towards fauna and garden bird community composition found along socio-economic gradients in medium-sized towns in South Africa. This study provides baseline evidence which highlights how previously racially and currently economically segregated communities produced a variation in the types of gardens created, the relationship towards urban avifauna as well as the actual faunal communities present. The overall aim of this study was to determine the attitudes and practices that urban residents have towards their gardens and garden fauna as well as investigate the bird community patterns within these urban domestic gardens, of which were all answered. This study provided insight into how social patterns are often reflected within the urban ecosystem in terms of biodiversity.

Chapter three provides an overarching view of the attitudes and practices towards urban domestic gardens and garden fauna along a socio-economic gradient within Grahamstown and Port Alfred. This study was broken into two sections, comprised of management practices and urban domestic garden fauna. The garden management section provided evidence of garden size, hiring vs individual gardening management, and the activities which were enjoyed within the garden. The garden fauna section provided insights into what fauna were seen by respondents within the gardens and how frequently residents fed garden birds. The study also included indices measuring the Garden

Management Intensity, Wildlife-Friendly Garden Practices and Garden Wildlife Awareness among urban residents and a few sentiments regarding the gardens and garden fauna.

Chapter four involved an ecological investigation into the bird community patterns along the socio-economic gradient within Grahamstown and Port Alfred. It showed that gardens differed in vegetation characteristics such as height, structure, indigenous plant content, and the dominant types of vegetation, and the age and size of the households, all of which were greater within the older, affluent areas. Bird species richness, diversity and abundance showed similar results in that they were greater in affluent areas, and with no statistical difference was seen between the RDP and informal zones. Multivariate analyses showed two distinct bird communities in both towns, where the affluent areas housed one community and the RDP and informal zones, supporting a second bird community within the towns. The results showed that within Grahamstown, various vegetation measures such as tree cover, ground vegetation cover and indigenous plant content as well as socio-economic status, were the strongest correlates of the avifaunal community patterns. In Port Alfred, similarly, vegetation characteristics such as ground vegetation cover, forb cover, shrub cover as well as the Wildlife-Friendly Garden Practices and Socio-Economic Status produced the greatest effect on the bird community patterns.

This study highlighted the "luxury effect", where socio-economic patterns are reflected in patterns of biodiversity. Vegetation characteristics of the garden appeared to be one of the strongest influences on shaping bird community patterns seen within the towns. These patterns were influenced by factors resulting from the past racial segregation within South Africa, as older houses had more established vegetation, and thus greater vegetation complexity, thus supporting a distinct bird community, verified by the increase in more specialised bird species such as frugivores and granivores. The RDP and informal houses were built more recently than the affluent houses, and vegetation was unable to fully establish due to the removal of topsoils and seedbanks when being established, as well as challenges such as the presence of livestock which graze in gardens, and the need to pave some gardens due to flooding.

This study also found that the Wildlife-Friendly Garden Practices were a strong correlate of bird community composition in Port Alfred, indicating that individual decisions that homeowners make on a parcel scale, may influence bird communities on a greater scale. The results provided evidence of biotic homogenisation due to the bird community patterns being similar in Grahamstown and Port Alfred, when combined, as well as the decrease in more specialised feeding guilds as previously mentioned.

5.2 General Discussion

Upon integrating the finding within the thesis, two main themes appear. Firstly, the results clearly reflect theories on the "luxury effect" or "ecology of prestige", mirrored in studies from across the globe (Leong et al. 2018). Secondly, the study reflects how gardens act as complex social-ecological ecosystems, where the actions of urban residents on a parcel scale are able to influence biodiversity on a larger scale (Goddard et al. 2010).

5.2.1 Luxury Effect

The phenomenon of higher biodiversity in more affluent areas is termed the "luxury effect". While the majority of studies around the world have been done on plants (Leong et al. 2018), fewer studies have shown how these patterns are reflected in urban fauna. Within Grahamstown and Port Alfred, clear differences are seen in the structural characteristics of the garden vegetation along the socio-economic gradient, where affluent gardens are more highly vegetated, complexly structured and have a greater variety of native vegetation (Chapter 4; Figure 4.1, 4.2, 4.3). Due to the past political history of racial segregation in South Africa, the social patterns are still highly evident in the patterns of biodiversity. Often times with vegetation or species with longer generational times, the legacy effects are more evident (such as trees), while species with shorter general times (such as birds) may respond more rapidly to the current patterns of affluence within the landscape. The "luxury effect" is thought to increase with time (Hope et al. 2008), therefore further exaggerating the vegetation differences seen in Grahamstown and Port Alfred as the affluent areas are double the age of the RDP and informal areas (Figure 4.5). However, household age may not be the only factor structuring plant communities in affluent areas. Avolio et al. (2018) found that plants provided by nurseries contributed to the tree species people planted in their garden and therefore the "luxury effect", as affluent residents were able to shop at nurseries offering a far larger species pool, and highlighting that there are various lifestyle factors contributing to the variation in vegetation along the socio-economic gradient.

The most striking results reflecting the "luxury effect" are seen in Chapter 4, Figure 4.7, highlighting the differences in bird species richness, diversity and abundance along the socio-economic gradient. The BIOENV showed that many of which were plant structural variables (Table 4.3), further emphasising the important of urban green infrastructure and its contribution to maintaining avifaunal community patterns. Brunbjerg et al. (2018) showed that birds are sensitive to vegetation characteristics on both a small (100 m) and large (1 000 m) scale, showing that relatively small patches of vegetation such as gardens are supporting distinct bird communities. While there is extensive literature on the reliance of bird communities on suitable habitat (Goddard et al. 2010), there is much scope available to assess how other fauna populations are affected by local habitat alterations on a garden scale.

Various South African studies have reflected the results found here, where affluent neighbourhoods display an increase in vegetation (Lubbe 2011; Davoren 2016) and arthropods (Botha 2012). Botha (2012) found that not only did arthropod diversity increase along the socio-economic gradient, but habitat type (vegetation or lawn) influenced the arthropod diversity. Personal observation in the field highlighted the vast opportunities to investigate the community composition of fauna such as small mammals, lizards, butterflies and arthropods in urban domestic gardens along a socio-economic gradient.

When looking at the data provided by urban residents on the frequency in which animals are seen within their gardens, results indicate that certain socio-economic zones are left with a paucity of interactions with garden fauna. Based on the numerous benefits of interacting with wildlife (Mumaw et al. 2017; Bell et al. 2018), there may be undocumented effects of a lack of interaction with urban wildlife. Furthermore, with a paucity of fauna such as insects and bees within the less affluent zones, comes a lack of direct ecosystem services provided by key pollinators. Therefore, the effects of the "luxury effect" span social as well as ecological spheres, as well as multiple scales as seen in this study. Evidence of the "luxury effect" was extended to garden management practices as well, where affluence influenced the intensity of garden management provided by residents (Figure 3.6), as well as the difficulties which residents in the RDP and informal settlement face, such as access to basic infrastructure and the damage of roaming livestock within their gardens, not faced by more affluent residents.

The results from the study emphasise how multiple temporal and spatial factors within urban gardens combine to create a biologically heterogeneous urban landscape. While the injustices of the past political structure are well documented, the resulting ecological injustices remain scarcely recorded. The ecological injustices may not only include the lack of biodiversity, but the biocultural associations forged with fauna in the landscape.

5.2.2 Complex Social-ecological Systems

In Chapter 2 (Figure 1.2), a conceptual framework by Goddard et al. (2010) outlined how gardens act as social-ecological constructs, whereby the actions of individual urban residents with regards to how their garden is managed, can scale up to influence biodiversity on a larger scale. When applying the conceptual framework to this particular study, we see that socio-economic factors such as status (Socio-Economic Status indices), culture or individual attitudes and beliefs, can influence how the garden is managed as well as the species diversity. Therefore, in the Garden Management Intensity index, we see how variation in socio-economic status influences the frequency and intensity of management practices. We also see evidence of this in the difference in garden size, and vegetation characteristics along the socio-economic gradient. In turn, the garden influences the social status and property prices.

On a neighbourhood scale, bird communities varied distinctly between the affluent zones and the RDP and informal zones. Therefore, the ecological status of the gardens can scale up to influence local population dynamics, abiotic features as well as the configuration and composition of habitat patches and biological refugia within the urban landscape. These in turn contribute to health and wellbeing of the urban residents. Although the relationship between garden greenspace, faunal diversity, vegetation characteristics and resident wellbeing was not explicitly tested, this study provides evidence for a potential relationship and further studies. Furthermore, when the bird community data was combined for both towns, the same patterns emerged, where the affluent area hosted a distinct community and the RDP and informal zones overlapped. This highlights that despite the geographical, vegetation and climatic separation between the towns, socio-economics override the ecological differences between towns.

Perhaps the most well-known evidence of social-ecological interaction within urban gardens is bird feeding. Bird feeding is amongst the most popular human-wildlife interaction throughout the Western World, and is often motivated by enjoyment, stewardship, education or connection with nature (Clark et al. 2019). While the motivations may be positive, studies have provided evidence that the practice may enhance the spread of disease transmission through the unusually high bird densities and associations between species which may not usually congregate (Lawson et al. 2018). Furthermore, Galbraith et al. (2015) showed that supplementary bird feeding can alter the structure of the bird community within urban areas, as well as out competing a native insectivore species. This study showed that residents across the socio-economic gradient partook in bird feeding at least once a month (particularly in Grahamstown), indicating that bird feeding could either be contributing to structuring bird communities on a larger scale, or have subsequent effects on specialist native bird species as well. Although more research is needed on the meaning, attachments, motivations and possible ecological effects of garden bird feeding in small towns.

5.3 General Assessment

5.3.1 Environmental Awareness Score

The final section of the questionnaire survey (Section D) attempted to gauge a measure the environmental awareness of urban residents. However, this proved to be unsuccessful as the questions could not accurately assess a resident's conception of the environment from a conceptual basis. For instance, global warming and climate change are not part of the day to day life that many urban residents face, while those with access to popular media may have varying ideas of the subject based on their exposure to the ideas and concepts. However, residents mentioned that their relationship to the birds may be one that connects them to their ancestors in the Xhosa communities, yet the scale does not account for "environmental awareness" beyond a numerical scale, rendering the scale inaccurate to measure environmental awareness in this context. Future studies should take into consideration a more context appropriate measure to gauge the environmental awareness or connection of all urban residents.

5.3.2 Future Studies

While many future studies have already been mentioned, further recommendations may involve a deeper look at urban residents' relationship towards wildlife and may provide evidence of their ecological insight and traditional knowledge which has been adapted to an urban context. While expertise is needed for identification purposes, opportunity exists to create citizen science monitoring programs to educate and incorporate the urban resident into scientific research. Chapter 2 provided baseline evidence of the animals which urban residents noticed, which can be a used to highlight a shift in awareness of pre- and post- citizen science participation. More research is needed to investigate the effects of free-roaming urban cattle on domestic garden faunal and floral communities as well as the variation in the use of infrastructure such as electricity poles and grey surfaces between more affluent areas and lower socio-economic zones.

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Appendices

Appendix A: Consent Forms

To whom it may concern

My name is Shayla Tricam. I am a student at Rhodes University, Grahamstown and am currently conducting research for a Masters degree in Environmental Science. This is a letter to request permission to conduct research within your household garden.

My research project is about the diversity of birds and small mammals in urban domestic gardens within Port Alfred and Fort Beaufort. Gardens and garden wildlife are an important component of the urban environment yet very little research of this kind has taken place in South Africa. My research will look at human influences on garden wildlife.

My research will involve the setup of small, non-harmful traps and brief morning and evening visits to your garden to record the bird species and check for small mammals. The traps are a <u>safe</u> method of observing and recording small mammals and do not involve harming the animal in any way. I will also perform brief non-invasive measurements of the plants growing within in your garden (such as garden size and vegetation height). All data collected will be kept completely anonymous and confidential and will only be used solely for this project.

Your permission and agreement to sample your garden my research will be greatly appreciated.

Kind regards

Shayla Tricam

Homeowner Information

Name ___________________________ Date _________________________

Signature ___________________________ Contact ___________________________

May I take photographs of your garden?

Yes		No	

Would you like feedback on the project?

Yes		No	

Consent form – Questionnaire

To whom it may concern

My name is Shayla Tricam. I am a student at Rhodes University, Grahamstown and am currently conducting research for a Masters degree in Environmental Science. This is a letter to request for you fill in a questionnaire regarding your household garden.

My research project is about the diversity of birds and small mammals in urban domestic gardens within Port Alfred and Fort Beaufort. Gardens and garden wildlife are an important component of the urban environment yet very little research of this kind has taken place in South Africa. My research will look at human influences on garden wildlife.

The questionnaire is made up of questions regarding garden management and use, garden wildlife which you see, environmental awareness and social information. All data collected will be kept completely anonymous, confidential and private and will only be used solely for this project.

Your permission and agreement to fill out the questionnaire will be greatly appreciated.

Kind regards

Shayla Tricam

Homeowner Information

Name ____________________________ Date __________________________

Signature ____________________________ Contact ___________________________

Would you like feedback on the project?

Yes		No	

For any inquiries or questions please call me on 072 761 8046 or email shaylatricam@gmail.com.

You may also contact my supervisor, Professor C. Shackleton on c.shackleton@ru.ac.za at the Department of Environmental Science, Rhodes University.

APPENDIX B: QUESTIONNAIRE

Please complete all questions. There are no right or wrong answers.

Four Sections:

A. Garden use and management	Question 1 - 21
B. Garden wildlife	Question 22 - 42
C. Social information	Question 43 - 52
D. Environmental awareness	Question 53 – 54

A. Garden use and management

4. Are you the main gardener in the household?

Yes		No	

. If no, why is?

____

5. What is the approximate age of your house?________

6. What is the approximate size of your garden? _____m × _____m

7.What is the main land cover type in your garden? (Please select one)

	Lawn		Grey surfaces (e.g. patio, paving, gravel)
	Trees/shrub		Flower beds
	Vegetable plot		Other (Please specify)

8. Which of the following descriptions best applies to you? (Please select one)

	Gardening enthusiast (I enjoy gardening all year round.)
	Fair weather gardener (I only do gardening in good weather or during spring/ summer.)
	Gardener out of necessity (I only do what is necessary to keep the garden tidy.)
	Wildlife-friendly gardener (I garden mainly to provide food and shelter for wildlife.)
	Rent-a-gardener (I pay someone else to do the gardening.)
	Non-gardener (I do not do any gardening and I do not hire a gardener.)

9. On average, how long do you (or your gardener) spend gardening per week in the summer months?

	Less than 1 hour		1–5 hours		6–10 hours		11–20 hours		More than 20 hours

10. On average, how frequently do you (or your gardener) undertake the following gardening activities in the summer months?

	Never	Less than monthly	Monthly	Weekly	Daily
Mowing the lawn					
Planting flowers/shrubs					
Watering the garden					
Weeding the garden - chemically					
Weeding the garden - mechanically					
Remove dead plant material					
Fertilise the garden					
Rake the lawn					
Apply chemical fertilisers					
Apply pesticides or herbicides					
Other (please state):					

11. What type of irrigation system do you use?

	Fixed irrigation with timer		Hose-pipe or hand watering can		Fixed irrigation without timer		None

12. Do you use the following fertilisers in your garden?

Fertiliser	Yes	No	Less than monthly	Monthly	Weekly	Daily
Chemical fertiliser						
Kraal manure						
Homemade compost						
Commercial compost						
None						
Other (please specify):						

13. How <u>important</u> are the following reasons for <u>using your garden</u>?
Please score each reason from 1 to 5 where **1=not important, up to 5=very important**

	1 Not important	2	3	4	5 Very important
Enjoyment of plants/flowers					
Keeping fit					
Relaxation and reflection					
Feeling connected to nature					

Recreation (e.g. for children, pets)					
Entertainment and outside dining (e.g. braais)					
Growing vegetables and/or herbs					
Growing medicinal plants					
Watching/attracting wildlife, e.g. birds					
Other (please specify):					

14. How important are the following sources of information for influencing your gardening?
Please score each source of information from 1 to 5 where 1=not important, up to 5=very important

	1	2	3	4	5
Friends, family, community, etc.					
Books, magazines, TV					
Internet					
Local experts in gardening clubs/associations					
Viewing public greenspaces					
Viewing the surrounding landscape/biome					
Other (please specify):					

15. Who/what determines which species are planted in your garden? Please score each source of information from 1 to 5 where 1=not important, up to 5=very important

	1	2	3	4	5
You are a collector of specific plants					
You have a bird/butterfly garden					
Advice from gardening services					
Gardening shows/magazine articles					
What friends/neighbours have in their gardens					
Availability at the nursery					
Surrounding landscape/biome					
Food					
Other (please specify):					

16. What is the origin of the plants currently in your garden?

	Most plants were already in the garden when you moved
	Most plants were planted by you after you have moved in
	You created an entirely new garden

17. How much is your garden design and/or appearance influenced by the appearance of other gardens in your neighbourhood?

1 **Not at all**	2	3	4	5 **Very much**

18. Do you feel that you have a duty to maintain neighbourhood standards and keep your garden neat and tidy?

Yes		No	

19. Reason

20. Do you maintain your front and back gardens in the same way?

Yes		No	

21. Why?

B. Garden wildlife

22. Please indicate which (if any) of the following features are present in your garden (please select all that are present):

	Bird feeder
	Bird bath
	Bird nest box
	Other nest box (e.g. bat, bees)
	Pond
	Compost heap/ leaf pile
	Log pile
	Wild/undisturbed vegetation
	Plants with fruit/berries
	Lawn
	Flowering plants
	Hedge/shrubs
	Trees taller than 2m (circle): 1 | 2-5 | 6-10 | >10
	Other (please specify):

23. Have you deliberately chosen to include any native/indigenous plants in your garden (i.e. plants that grow naturally in the wild in the Eastern Cape or South Africa)?

Yes		No	

24. Why?

25. Are you aware of any non-native plant species in your garden?

Yes		No	

25. Are you aware of any invasive plant species in your garden?

Yes		No	

26. On average, how frequently do you spend some time watching wildlife in your garden, even if just a few minutes?

	Never		Less than monthly		Monthly		Weekly		Daily

27. On average, how frequently do you see the following types of wildlife in your garden in the summer months?

	Never	Less than monthly	Monthly	Weekly	Daily
Birds					
Predatory birds (e.g. owls, hawks)					
Butterflies					
Bees					
Mice and small mammals (e.g. shrews, moles)					
Lizards					
Snakes					
Bats					
Frogs					
Spiders					
Scorpions					
Insects (e.g. beetles)					
Snails and slugs					
Worms (e.g earthworms, centipedes)					
Dragonflies					
Other (please specify):					
I do not see any animals in my garden					

28. Have you noticed any changes in the **types** of wildlife you see visiting your garden over the last 10 years?

Yes		No	

29. Please elaborate:

28. Have you noticed any changes the **amount** of wildlife you see visiting your garden over the last 10 years?

Yes		No	

29. Please elaborate:

30. Do you participate in any activities actively attracting wildlife to your garden (e.g. Mow less, avoid chemical use, keep cats inside)?

Yes		No	

31. Please elaborate:

32. On average, how often do you feed the wildlife in your garden?

	Never		Less than monthly		Monthly		Weekly		Daily

33. Do you consider any of the following animals to be unwelcome in your garden? (Please select all that apply).

	Never	Less than monthly	Monthly	Weekly	Daily
Birds					
Predatory birds (e.g. owls, hawks)					
Butterflies					
Bees					
Mice and small mammals (e.g. shrews, moles)					
Lizards					
Snakes					
Bats					
Frogs					
Spiders					
Scorpions					
Insects (e.g. beetles)					
Snails and slugs					
Worms (e.g earthworms, centipedes)					
Dragonflies					
Other (please specify):					

I do not see any animals in my garden					

24. Why?

35. Do you or would you use any of the following means to get rid of unwelcome wildlife from your garden?

	Insecticides
	Snail and slug poison
	Rat poison
	Rat traps
	Kill manually
	Doom or similar poison
	Call an animal removal expert
	Other (please specify):

36. Do you own any pets/domestic animals which utilise the garden, if so, please state.

		Number
	Dogs	
	Cats	
	Guinea pigs	
	Rabbits	
	Chickens	
	Ducks	
	Geese	
	Pigeons	
	Donkeys	
	Goats	
	Sheep	
	Other (please specify):	

37. Does your cat hunt small animals and lizards in your garden?

Yes		No	

38. Do you view your **garden** as part of a larger ecosystem/environment?

Yes		No	

39. Why?

40. What role do you perceive the wildlife in your garden to play, if any?

41. Do you perceive the **wildlife in your garden** as part of a larger community/environment in your neighbourhood or town?

Yes		No	

42. Why?

C. Social Information

2. Age: ____________

3. Gender:

M		F	

43. How many people live in your household? ______________________________________

44. Do you have any young children (12 years or under) in the house?

Yes		No	

45. Tenure:

Owned		Rented		Other	

46. How long have you been living in your house? __________years

47. How many rooms does your house have? ____

48. What type of light do you use at night?

	Electricity		Paraffin lamps		Candles		Other (please specify):

49. What is the employment status of the main earner in your household?

	Full-time		Part-time		State grants		Retired		Student

50. What is the highest level of education of the homeowner? ____________________________

51. What is the occupation of the main earner in your household?

52. How far is the nearest tap situated?

	In the garden		100 m from the garden		200 m from the garden		More than 200 m from the garden

How old is the head of the household? ________________years

Gender of the head of the household:

M		F	

Home language:

	English		Xhosa		Afrikaans		Other (please specify):	

Did you spend your childhood mostly in a rural or area or a town/city?

	Rural area		Town/city

D. Environmental Awareness

53. Do you participate in any of the following conservation or environmental activities outside of your garden? (Please select all that apply)

	Household waste recycling, water conservation, composting
	Practical conservation (e.g. beach clean-ups, tree planting)
	Wildlife surveys
	Permaculture practices
	Wildlife societies (e.g. WESSA)
	Bird watching
	Hiking clubs
	Other (please specify):

54. How important do you consider the following environmental issues?
Please score from 1 to 5 where 1=not important, up to 5=very important.

	1 Not important	2	3	4	5 Very important
Climate change and global warming					
Pollution (air, water, light, noise, etc.)					
Plastic waste					
Population expansion					
Urban and industrial growth					
Food issues (e.g. organic farming, GM crops)					
Conservation and wildlife					
Energy supply					
Recycling and waste management					

Thank you very much for your time and contribution to my research!

APPENDIX C: BIRD SPECIES RECORDED IN GRAHAMSTOWN AND PORT ALFRED.

Table 1C: Abundance of bird species recorded within Grahamstown.

Common name	Scientific name	isiXhosa name*	Guild	Affluent	RDP	Informal settlement
Black crow			omnivore	0	0	1
Bokmakierie	*Telophorus zeylonus*	Ingqwangi	insectivore	1	0	4
Bulbul, Dark-capped	*Pycnonotus tricolor*	Ikhwebula	omnivore	34	0	0
Cape White-eye	*Zosterops virens*	Intukwane	insectivore	67	0	0
Chicken, Domestic	*Gallus gallus domesticus*		omnivore	0	0	3
Dove, Cape Turtle	*Streptopelia capicola*	Ihobe	omnivore	54	0	0
Dove, Laughing	*Spilopelia senegalensis*		omnivore	94	2	2
Dove, Rock	*Columba livia*		granivore	0	3	0
Drongo, Fork-tailed	*Dicrurus adsimilis*	Intengu	carnivore	4	0	0
Hadeda Ibis	*Bostrychia hagedash*	Ing'ang'ane	insectivore	3	0	0
Hoopoe, African	*Upupa africana*	Ubhobhoyi	insectivore	4	0	0
Loerie, Knysna	*Tauraco corythaix*	Igolomi	frugivore	2	0	0
Mousebird, Speckled	*Colius striatus*	Indlazi	frugivore	24	0	0
Olive thrush	*Turdus olivaceus*	Umswi	insectivore	29	0	4
Oriole, Black-headed	*Oriolus larvatus*		omnivore	1	0	0

Pigeon, Green	*Treron calvus*		frugivore	2	0	0
Pigeon, Speckled	*Columba guinea*	Ivukuthu	granivore	20	0	0
Racing pigeons			granivore	0	5	0
Robin-Chat, Cape	*Cossypha caffra*	Ugaga	insectivore	23	0	0
Seedeater, Streaky-headed	*Crithagra gularis*		granivore	5	0	0
Shrike, Common-fiscal	*Lanius collaris*	Inxanxadi	carnivore	7	0	4
Sombre Greenbul	*Andropadus importunus*	Inkwili	frugivore	1	0	0
Sparrow, Cape	*Passer melanurus*	Ingqabe	frugivore	2	11	25
Sparrow, House	*Passer domesticus*	Umosi	omnivore	0	220	68
Starlings, Common	*Sturnus vulgaris*		insectivore	10	10	12
Starlings, Red-winged	*Onychognathus morio*	Isomi	omnivore	6	3	2
Sunbird, Amethyst	*Cinnyricinclus leucogaster*	Ingcungcu	nectivore	7	0	0
Sunbird, GDC	*Cinnyris afer*	Ingcungcu	nectivore	9	2	0
Sunbird, LDC	*Cinnyris chalybeus*	Ingcungcu	nectivore	10	5	0
Swallow		Inkonjane	insectivore	6	0	0
Wagtail, Cape	*Motacilla capensis*	Umcelu	insectivore	1	7	1
Weavers, Cape	*Ploceus capensis*	Ihobo-hobo	omnivore	16	3	2
Unknown	NA	NA	NA	7	1	6

Table 2C: Abundance of bird species recorded within Port Alfred.

Common name	Scientific name	isiXhosa name*	Guild	Affluent	RDP	Informal settlement
Bronze Mannikin	*Spermestes cucullatus*		granivore	6	0	0
Bulbul, Dark-capped	*Pycnonotus tricolor*	Ikhwebula	omnivore	23	8	0
Cape White-eye	*Zosterops virens*	Intukwane	insectivore	77	13	4
Chicken	*Gallus gallus domesticus*		omnivore	0	29	49
Crow, Pied	*Corvus albus*	Igwangwa	omnivore	2	0	0
Dove, Cape Turtle	*Streptopelia capicola*	Ihobe	omnivore	23	4	0
Dove, Laughing	*Spilopelia senegalensis*		omnivore	88	19	3
Dove, Rock	*Columba livia*		granivore	12	1	0
Drongo, Fork-tailed	*Dicrurus adsimilis*	Intengu	carnivore	6	0	0
Familiar Chat	*Oenanthe familiaris*		insectivore	1	0	2
Francolin	*Pternistis capensis*	Inwali	insectivore	3	0	0
Hadeda Ibis	*Bostrychia hagedash*	Ing'ang'ane	insectivore	3	0	0
Loerie, Knysna	*Tauraco corythaix*	Igolomi	frugivore	1	0	0
Mousebird, Speckled	*Colius striatus*	Indlazi	frugivore	24	0	0
Olive thrush	*Turdus olivaceus*	Umswi	insectivore	7	0	0
Oriole, Black-headed	*Oriolus larvatus*		omnivore	1	0	0
Pigeon, Green	*Treron calvus*		frugivore	1	0	0
Pigeon, Speckled	*Columba guinea*	Ivukuthu	granivore	10	0	0
Robin-Chat, Cape	*Cossypha caffra*	Ugaga	insectivore	8	0	0
Seedeater, Streaky-Headed	*Crithagra gularis*		granivore	11	3	0

Shrike, Common-fiscal	*Lanius collaris*	Inxanxadi	carnivore	2	4	0
Sombre Greenbul	*Andropadus importunus*	Inkwili	frugivore	0	1	0
Sparrow, Cape	*Passer melanurus*	Ingqabe	frugivore	2	104	24
Sparrow, House	*Passer domesticus*	Umosi	omnivore	10	7	0
Starling, Glossy	*Lamprotornis nitens*		insectivore	0	1	0
Starlings, Common	*Sturnus vulgaris*		omnivore	4	0	0
Starlings, Red-winged	*Onychognathus morio*	Isomi	nectivore	3	0	0
Sunbird, Amethyst	*Cinnyricinclus leucogaster*	Ingcungcu	nectivore	3	4	1
Sunbird, GDC	*Cinnyris afer*	Ingcungcu	nectivore	0	2	1
Sunbird, LDC	*Cinnyris chalybeus*	Ingcungcu	nectivore	19	0	0
Swallow, Barn	*Hirundo rustica*	Inkonjane	omnivore	4	0	0
Wagtail, Cape	*Motacilla capensis*	Umcelu	insectivore	24	0	0
Weavers, Cape	*Ploceus capensis*	Ihobo-hobo	omnivore	7	3	53
Weavers, Masked	*Ploceus velatus*		frugivore	5	0	0
Woodpeckers,		Isinqolamthi	insectivore	1	0	0
Unknown	*NA*	*NA*	*NA*	13	4	0