UNDERSTANDING URBAN ECOLOGIES IN THE CONTEXT OF LOCAL BIODIVERSITY AND OPEN SPACE CONSERVATION AGENDAS IN TWO SOUTH AFRICAN CITIES

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Declaration

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Abstract

South Africa is the third most biologically diverse country in the world and has developed advanced biodiversity legislation and policies to protect its natural environment. Biodiversity is the natural wealth of all living things on earth, from which a multitude of ecosystem services that sustain life emanate. The dramatic shift towards urban living however, places tremendous pressure on these biological resources. Local government has received international recognition as the level of government that is key to securing long-term global sustainability. The cities of Cape Town and Durban in South Africa have each developed their own biodiversity and open space conservation systems to conserve and protect the remaining biodiversity and open spaces within their respective municipal boundaries. The aim of this research was to explore the local biodiversity and open space conservation strategies in these two cities, with a view to understanding: (1) the informants, and emerging form, of urban conservation strategies in these two cities in light of their variable biophysical templates and histories; and (2) the physical landscape pattern in each city, and from this information, infer likely ecological outcomes, for these two cities. The study made use of both qualitative and quantitative research methods. The results reveal that while both cities are facing similar issues in terms of biodiversity loss and natural habitats becoming increasingly fragmented, the way in which these issues manifest in these different cities is unique. The City of Cape Town is highly developed and fragmented but has more land secured under its conservation plan compared to the City of Durban. Durban however, has a large rural land component which remains under the governance of traditional leaders. The study reveals that there are many factors that play a role in the development and success of conservation plans, including: the local context, biophysical templates, city histories, social informants of how these plans emerge and evolve, contemporary governance structures as well as local pressures. Biodiversity conservation in South African cities still faces many challenges which need to be overcome in the near future. These solutions will need to be city specific.

Keywords: Biodiversity conservation, conservation strategy, local government, urbanisation, fragmentation

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Acronyms

Acronym	Name
ABT	Aichi Biodiversity Targets
BIAB	Biodiversity Impact Assessment Branch
BioNet	Biodiversity Network
BMB	Biodiversity Management Branch
BotSoc	Botanical Society of South Africa
BPB	Biodiversity Planning Branch
CBA	Critical Biodiversity Areas
CBD	Convention on Biological Diversity
CIP	Conservation Implementation Plan
CMOSS	Cape Town Metropolitan Open Space System
CoCT	City of Cape Town Municipality
CFR	Cape Floristic Region
DAEA&RD	Department of Agriculture, Environmental Affairs and Rural Development
DEA	Department of Environmental Affairs
DEA&DP	Department of Environmental Affairs and Development Planning
D'MOSS	Durban Metropolitan Open Space System
EIA	Environmental Impact Assessment
EMA	eThekwini Municipal Area
EMF	Environmental Management Framework
EPCPD	Environmental Planning & Climate Protection Department
ERMD	Environmental Resource Management Department
ESA	Ecological Support Areas
ESS	Ecosystem Services
GIP	Green Infrastructure Plan
GIS	Geographic Information Systems
GTI	GeoTerraImage
ICLEI	International Council for Local Environmental Initiatives
IDP	Integrated Development Plan
IMEP	Integrated Metropolitan Environmental Policy
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
JMOSS	Johannesburg Metropolitan Open Space System
KZN	KwaZulu-Natal
LAB	Local Action for Biodiversity
LBSAP	Local Biodiversity Strategy and Action Plan
MOSS	Metropolitan Open Space System
MSA	Municipal Systems Act
NBF	National Biodiversity Framework
NBSAP	National Biodiversity Strategy and Action Plan
NBT	National Biodiversity Targets
NEMA	National Environmental Management Act
NEM:BA	National Environmental Management: Biodiversity Act
NEM:PAA	National Environmental Management Protected Areas Act
NGO	Non-Governmental Organisation

NMB MOSS	Nelson Mandela Bay Open Space Management System
NPAES	National Protected Area Expansion Strategy
NSBA	National Spatial Biodiversity Assessment
SANBI	The South African National Biodiversity Institute
SANParks	The South African National Parks
SCA	Systematic Conservation Assessment
SCP	Systematic Conservation Planning
SDGs	Sustainable Development Goals
SDF	Spatial Development Framework
SPLUMA	Spatial Planning & Land Use Management Act
TMNP	Table Mountain National Park

Glossary

Biodiversity	The variety within and between all species of plants, animals and micro-organisms and the ecosystems within which they live and interact.
BioNet	The City of Cape Town's fine-scale systematic biodiversity plan which focuses on the conservation of biodiversity.
Conservation plan	A useful tool to assist with the future ecological health of an area.
City	A place with increasing number of people and more activities. It is larger than a town. The use of 'City' in this thesis, refers to a particular city in the sentence (like Cape Town or Durban), whilst the use of 'city' is used in a more general sense, when not referring to a particular city.
Critical Biodiversity Areas	Areas required to meet biodiversity targets for ecosystems, species or ecological processes, as identified in a systematic biodiversity plan. May be terrestrial or aquatic.
D'MOSS	The eThekwini Municipality's conservation system of green open spaces which incorporates areas of high biodiversity value.
Ecological functions	The different roles ecological processes play in an ecosystem. Often used interchangeably with ecosystem processes.
Ecological Support Areas	An area that is not essential for meeting biodiversity targets but plays an important role in supporting the ecological functioning of one or more Critical Biodiversity Areas or in delivering ecosystem services.
Ecosystem services	The benefits that people obtain from ecosystems, including provisioning services (such as food and water), regulating services (regulation of climate), cultural services (such as recreational benefits) and supporting services (such as nutrient cycling).
Edge effects	The result of the interaction between two adjacent ecosystems or patch types, when the two are separated by an abrupt transition (edge).
Habitat fragmentation	The process by which habitat loss results in the division of large, continuous habitats into smaller, more isolated remnants.
Landscape ecology	The study of the effects of landscape patterns and their changes on ecological processes.
Open Space System	A network of open spaces that accommodates human and natural ecologies in towns and cities.
Resilience	The capacity of a system to recover from difficulties and to absorb stress, to continue to develop, and to change without a loss of essential structure, function and identity
Sustainability	The avoidance of the depletion of natural resources in order to maintain an ecological balance. Sustainable development refers to development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.
Systematic Conservation Assessment	The technical, often computer-based, identification of priority areas for conservation. The data to support the planning and implementation of conservation interventions.
Systematic Conservation Planning	Systematic conservation planning is used to identify priorities for biodiversity conservation and inform policy and legislation to facilitate the long-term conservation of biodiversity. It is composed of

	a systematic conservation assessment coupled with processes for development of an implementation strategy and stakeholder collaboration.
Traditional authority	A form of leadership in which the authority of an organisation or community is largely tied to tradition and long-established customs.
Urban areas	A built-up area such as a town or city. Urban areas share several common characteristics: high population density, abundant built structures, extensive impervious surfaces, altered climatic and hydrological conditions, air pollution, and modified ecosystem function and services.
Urban ecology	Urban ecology is the study of ecological processes in urban environments. This includes all aspects of the ecology of any organisms found in urban areas as well as large scale considerations of the ecological sustainability of cities.
Urbanisation	An increase in the proportion of people living in urban areas compared to rural areas.

Chapter 1: Introduction to the Research

1.1 Background to the study

Urban ecology

Urban ecology has grown rapidly and expanded globally in both research and practice in the last two decades. It has emerged as a multidisciplinary field which integrates the theory and methods of both natural and social sciences to study the ecological patterns and processes of urban ecosystems (Grimm et al., 2008; Richter & Weiland, 2011; Wu, 2014; McPhearson et al., 2016). The field of urban ecology facilitates the understanding of urban systems and provides avenues to support the improvement of urban sustainability and resilience; conserving urban biodiversity; and promoting human well-being on an increasingly urbanised planet (McPhearson et al., 2016). In general, contemporary urban ecology consists of three strands of research that have increasingly been integrated (Figure 1.1), these are: the study of spatiotemporal patterns; environmental impacts; and the sustainability of urbanisation (with emphasis on biodiversity, ecosystem processes, and ecosystem services) (Wu, 2014). According to Richter and Weiland (2011), as an applied science, the study of urban ecology provides solutions about where and how the urban environment can be protected from harm, and how environmental quality and human well-being can be improved.

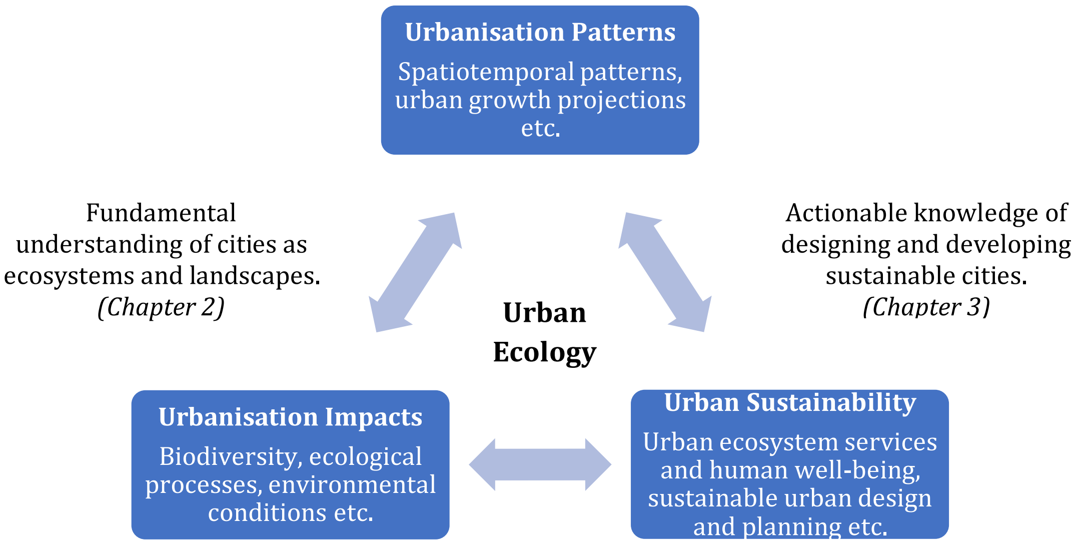

Figure 1.1: A conceptualisation of contemporary urban ecology, showing that urbanisation patterns, urbanisation impacts, and the sustainability of urbanisation interact with each other in the study of cities (Adapted from: Wu, 2014). The themes of pattern, form and impacts are central to this thesis, and as demonstrated here, are relevant in turn to sustainability.

While this kind of research is occurring at the global level, they are just as relevant in a South African context and perhaps even more so in light of the country's wealth of biodiversity. According to Cilliers and Siebert (2012), different approaches have been used in the study of urban ecology in different South African cities. From the literature it is evident that ecological studies have evolved along very different lines. For example, the City of Cape Town is situated in a biodiversity hotspot and is the only South African city which includes a national park within its boundaries. As a result, urban ecological studies have primarily been driven by nature conservation concerns (Cilliers & Siebert, 2012; Holmes et al., 2012). In other cities, such as Durban, previous ecological studies have been driven by open space planning and environmental management with the emphasis on the protection of key environmental areas for biodiversity conservation (Roberts, 2008; Cilliers & Siebert, 2012).

Although there are many shared biodiversity and ecosystem issues faced by and emanating from cities, the way in which these manifest in different cities is unique, not least because of the biome or region in which they are situated (Wilkinson et al., 2013). In addition, the perception of cities and ecological systems are both new and are constantly changing. Each city has a distinctive development history, cultural heritage, planning tradition and social structure (Wilkinson et al., 2013). Cities also have unique biologies, ecosystems and landscape features, all of which help shape their policies and plans. According to Richter and Weiland (2011: 1945), "the global perspective on the development of cities is heterogeneous and is dependent on growth dynamics, socio-economic conditions, cultural relationships, and last but not least on the ecological framework conditions of the regions". The knowledge base about the ecology of and in different cities is therefore uneven (Wilkinson et al., 2013). The values underpinning how contemporary cities should be managed is thus not a static field of enquiry (Wilkinson et al., 2013). In addition, according to Richter and Weiland (2011), when the differences between cities and the variety of urban development processes are taken into account, it becomes obvious that the general meaning of sustainable development has to be transferred to the prevailing local conditions of each city. Every city therefore, has to find its own way of striving for sustainability. As a result, there are many diverse understandings of sustainable urban development and conservation practices.

Whilst cities vary from context to context, they also share similar problems. The dramatic shift towards urban living, especially in growing cities, places increasing pressure on the biological features within these landscapes. The study of the ecology in cities therefore focuses on key ecological questions in urban areas, such as how ecological patterns and processes in cities compare with those in other environments and how urbanisation and development impact the ecology of organisms in urban habitats (McPhearson et al., 2016). These studies play a significant role in expanding ecological knowledge which informs biodiversity conservation, landscape design, and natural resource and wildlife management within urban areas. Cities are therefore, using this information to formulate policies which will halt biodiversity loss and retain the ecological functioning and processes within urban areas.

The importance of biodiversity and green space

Urban biodiversity, the variety and richness of living organisms and habitat diversity found in and on the edge of human settlements (Müller & Kelcey, 2010), is one of the key considerations in urban ecology. Urban vegetation in particular is diverse, and often exhibits greater heterogeneity and species richness than rural areas (Nagendra et al., 2012). Urban areas also contain a wide range of green spaces including parks, home gardens, office complexes, wooded streets, wetlands and remnant forests (Nagendra et al., 2012). In this study, green spaces can be defined as an area of natural land (including grass, trees, or other vegetation) set apart for recreational or aesthetic purposes in an urban environment (Taylor & Hochuli, 2017). Biodiversity and green open spaces provide a series of benefits including: supporting urban ecological and social systems; providing important ecosystem goods and services; creating stepping stones to non-urban habitats; facilitating responses to environmental change; stabilising the local climate; as well as improving the bio-physical conditions, aesthetics and human health and well-being in urban settings (Barbosa et al., 2007; Dearborn & Kark, 2010; Wendel, Zarger & Mihelcic, 2012). The concept of ecosystem services (ESS) can be described as the benefits which humans derive directly or indirectly from ecosystems (Cilliers et al., 2013). These include: provisioning services such as water and food; regulating services such as natural disasters and disease control; supporting services, such as nutrient cycles that maintain the conditions for life on earth; and cultural services such as recreational, spiritual and cultural benefits such as providing contact with nature (O'Farrell et al., 2012; Cilliers et al., 2013; Madureira et al., 2015). These benefits are seen as a way of demonstrating the relevance and value of biodiversity to society (O'Farrell et al., 2012). These natural spaces are valued for their environmental, amenity, psychological and health benefits as well as for their aesthetic contributions to the city's image (Madureira et al., 2015).

In general, biodiversity refers to a wide variety of plant and animal species living in their natural environment (Huston & Marland, 2003). Biodiversity houses and facilitates a multitude of ESS that sustain life on this planet. It essentially underpins our ecological infrastructure and plays a major role in the socio-economic growth of the country (Gordon et al., 2009; Güneralp et al., 2017). Large portions of the country's economy are heavily dependent on its biodiversity assets. These include the fishing industry, horticulture and agriculture industries, ecotourism, as well as the commercial and subsistence use of medicinal plants (Department of Environmental Affairs and Tourism [DEAT], 2009). There are thus, multiple motivations for preserving biodiversity and open space networks and for ensuring functioning ecology within urban areas.

Impacts on biodiversity

Urbanisation creates new challenges for biodiversity conservation and directly contributes to three of the main drivers of biodiversity loss which are habitat loss, overexploitation and the introduction of invasive alien species (de Oliveira et al., 2011). According to Güneralp et al. (2013), urbanisation essentially impacts biodiversity both directly through physical expansion over land, and indirectly due to land use and human behaviours within urban areas. Physical expansion changes the composition of the landscape, can alter and eliminate several habitats and species and has the additional effect of decreasing, fragmenting and isolating natural patches by altering the size, shape and interconnectivity of the natural landscape (Güneralp et al., 2013; Alberti 2005; Grimm et al., 2008). In addition, overexploitation and the introduction of invasive alien species as well as city activities which increase the levels of pollution, waste and local temperatures, have a myriad of cascading effects on biodiversity (de Oliveira et al., 2011). The increase of urbanisation due to human population growth and migration, places additional pressure on the natural and biological environment and increases the drivers of biodiversity loss. In addition, it significantly transforms the structure, function and processes of urban ecosystems, which further influences the quality of the urban ecological environment (Ren et al., 2013; McKinney, 2002).

There is still also growing pressure for urban areas to provide good living conditions for the citizens within the region. Accomplishing these goals in a way that ensures a resilient and equitable future for the human population while simultaneously maintaining earth's biodiversity and crucial ecological processes, is essential to achieve a transition towards sustainability (McPhearson et al., 2016). According to Richter and Weiland (2011), cities themselves are not only the sites of environmental degradation, but also the sites for innovation. Cities present both the problems and solutions to sustainability challenges of an increasingly urbanising world (Grimm et al., 2008; Weiland & Richter, 2011). Therefore, it is within the city that we find the solutions to environmental damage and the formulas for reconfiguring the socio-ecological system that is urbanisation (Richter & Weiland, 2011).

Governance of biodiversity in South Africa

The Constitution of the Republic of South Africa creates the overall framework for co-operative governance with "three distinct, interdependent and interrelated" spheres of government, namely national, provincial and local (The South African Government, 1996). Although there is a global drive for integrating biodiversity conservation approaches into all three government spheres, local governments (including district and local municipalities) play a major role in policy implementation and development planning and are directly responsible for taking action on the ground. This level of government is therefore better suited than any other to manage biodiversity and ecosystems and has the potential to affect positive change. With the increasing growth of the urban population, the importance of city governance to address the challenges of biodiversity loss has increased (de Oliveira et al., 2011). The way cities are designed, planned and governed, affects the degree of their direct and indirect impacts on biodiversity. In addition, according to de Oliveira et al. (2011), cities have a strong influence and a big responsibility regarding the outcomes of international treaties since local governments in many countries are in charge of key policies such as land use, energy and transportation. Cities therefore, have the means to integrate biodiversity considerations into decision-making processes and policies and create new policies with a biodiversity conservation agenda. Furthermore, given that local government is the closest level of government to the people, it is directly responsible for the well-being of communities, including the environment in which they live. Conserving key biodiversity areas and maintaining ecological processes not only protects the biodiversity, but also provides a better-quality environment for communities.

Conservation policies in cities

In an urban world the battle for biodiversity hinges on how effectively cities are governed, and how responsive those who run cities are in transforming the urban system to embrace ecosystem integrity and restoration (Wilkinson et al., 2013). According to South Africa's Department of Environmental Affairs (DEA, 2012a), the relationship between the population, environment and development needs to be understood within South African policy and legal context. The various national, provincial and local authority departments which are responsible for many relevant urban services including planning, housing, transport and environmental conservation, are recognising the urgent need to defend and protect the remnant biodiversity within cities for current and future generations (International Council for Local Environmental Initiatives [ICLEI], 2012). Conservation efforts are therefore becoming increasingly integrated into associated policy, especially within local government.

According to de Oliveira et al. (2011), there are certain urban processes that need to be reformed in order to improve the urban impact on biodiversity. One of these is the provision of a good network of urban green spaces. As stated, urban green areas are major sources of biodiversity in and around cities. Therefore, the creation of a network of biodiversity and green spaces is one of the most effective tools to preserve and enhance biodiversity within cities (de Oliveira et al., 2011). The inclusion of a biodiversity network into broader urban planning and processes can subsequently be used to control the type of urban development which has contributed to increased environmental deterioration. Although urban planning and biological conservation have come from diverse intellectual traditions and have had different practical applications over time, these movements may now be converging to share some common ground and principles (de Oliveira et al., 2011). Cities are exploring new ways of using planning and land use to enable the natural and built environment to co-exist. While the explicit inclusion of biodiversity concerns within urban planning is still in the early stages of conceptualisation at the global scale, there is growing recognition of the importance of including biodiversity issues when we think about cities (de Oliveira et al., 2011). The cities of Cape Town and Durban in South Africa have for a number of years recognised the need for a conservation network in order to prevent the further loss of biodiversity and green spaces to *ad hoc* development. Hence, the municipalities in each case have created conservation networks and formed conservation strategies which aim to protect the biodiversity and open spaces within their respective boundaries.

Conservation policy enactment

Developing cities within biodiversity rich areas however, face many challenges (Piracha & Marcotullio, 2003), particularly relating to meeting local and global conservation expectations, local service delivery, and navigating between these as they play out around land use allocation and associated trade-offs (O'Farrell et al., 2012). In addition, South Africa's colonial past places tremendous political, socio-economic and environmental pressure on the land, all of which emanate from previous inequitable land distribution and ownership, spatial mismatch in land management and past unsustainable land use practices (DEA, 2012a). Most South African cities today, with Cape Town and Durban being at the forefront, are sprawling in configuration, where the deep social and spatial divides that were established through Apartheid planning persist. According to Goodness and Anderson (2013), there is increasing pressure to address development issues of unemployment, poverty and housing shortages in South Africa, all of which place extensive demands on the remnant vegetation patches. These pieces of land are highly sought after for conversion to housing or industrial development. Environmental and development agendas have therefore created a significant dilemma for local government (Roberts, 2008). This has manifested itself in a growing tension between the need to introduce environmental issues and concerns into planning and decision-making processes versus the need to expedite development to address substantial socio-economic needs (Roberts, 2008). Urban areas are complex landscapes which should fulfil various functions, often with conflicting goals. According to Goodness and Anderson (2013: 469), the challenges faced in the conservation and stewardship of biodiversity in general are attributed to: ongoing land transformation at odds with a biodiversity conservation agenda, overexploitation and degradation of natural resources, suppression of indigenous vegetation by invasive alien plant species, different perceptions regarding needs for conservation of biodiversity, and inequitable access to natural space and resources.

Although conservation networks and strategies exist within local government, as is the case with the cities of Cape Town and Durban, there are still many challenges which hinder biodiversity conservation at the local government level. Conserving and protecting critical biodiversity in a rapidly expanding urban hub therefore poses unique challenges for municipalities. In addition, these conservation plans are non-statutory policies which means their purpose is to aid in the implementation of the city's broader mandate but not in terms of a specific legal duty. These conservation strategies therefore still do not have the legal power to stop developments which frequently take precedence over the conservation of the natural environment (Goodness, 2013; Roberts, 2008).

The process of habitat fragmentation

The process of urbanisation ultimately leads to an increase in habitat fragmentation. This is the process by which habitat loss results in the division of large, continuous habitats into smaller, more isolated remnants (Fahrig, 2003). Fragmentation therefore, greatly influences the spatial patterns and heterogeneity of the landscape. As landscape patterns are altered and landscapes become more fragmented and less connected, this usually impacts negatively on the biodiversity and the ecological patterns and processes within the region (Fahrig, 2003; Fahrig, 2005; Andrieu et al., 2009). According to Andrieu et al. (2009), species' responses to habitat fragmentation can be complex. The reduction of the total area of habitat results in a decrease of the size of fragments, an increase in their isolation and/or a change in their spatial arrangement (Andrieu et al., 2009). Broadly, the negative effects of fragmentation include: a reduction in both the population size and probability of persistence of species due to a larger number of smaller patches (Fahrig, 2003; Lindenmayer & Hobbs, 2008); a reduction in dispersal which can decrease species diversity (Krauss et al., 2004; Auffret, Plue & Cousins, 2015); and a disruption in species interactions which can lead to lower performance and population dynamics in fragments (Andrieu et al., 2009). Plant diversity and abundance can therefore, decrease in fragmented habitats because of specific threats imposed by small population size and the disruption of plant-animal and plant-pollinator interactions (Andrieu et al., 2009). In addition, changes in biodiversity are manifested by changes in plant functional diversity, including the value, range, and relative abundance of plant functional traits in an ecosystem (Díaz et al., 2007; Lavorel, 2013). These changes will subsequently have an effect on the delivery of ESS since the ecosystem properties would change (Díaz et al., 2007; Lavorel, 2013). The process of fragmentation as a result of urbanisation has therefore been recognised as a key issue facing the conservation of biodiversity.

Landscape ecology

The science of landscape ecology is based on the premise that there are strong links between spatial patterns and ecological function and process (Gustafson, 1998; Frohn, 1998; Li et al., 2001; Plexida et al., 2014). Interest in the quantification of spatial pattern and heterogeneity is a significant area in landscape ecology (Plexida et al., 2014). According to Yang and Liu (2005), innovations in the theories of landscape ecology and the technologies of remote sensing and Geographic Information Systems (GIS) offer promising tools for a quantitative assessment of landscape patterns. In addition, there are several possibilities of using landscape metrics as quantitative indices to describe spatial patterns caused by urbanisation (Uuemaa et al., 2009). Landscape metrics are widely used to describe the structure and pattern of landscapes which can subsequently be used to analyse ecological function and process. According to Plexida et al. (2014), these metrics are often used to describe landscape fragmentation, connectivity and human influences in a given region. Landscape metrics can be calculated from land cover and land use maps derived from remotely sensed imagery (Leitao & Ahern, 2002; Yang & Liu, 2005).

The quantification of spatial patterns and the heterogeneity of urban areas using landscape metrics and remote sensing techniques can provide useful data and insights on the levels of fragmentation and how this affects the ecological functioning and processes within cities. This information can subsequently be used to assist with land use and conservation planning in the management and containment of fragmentation in cities. Hence, understanding how the process of fragmentation directs spatial structure, distribution and heterogeneity of urban areas and how this affects the ecological functioning and processes within cities, is important information that can be drawn on in managing biodiversity within cities.

1.2 Aim and Objectives of this study

It is clear that biodiversity provides a series of benefits which support human well-being and socio-economic development. However, due to increased pressure from urbanisation, resulting in fragmentation and habitat loss, biodiversity and natural spaces are disappearing from our landscapes. The conservation of these natural and biological spaces is therefore of vital importance. In order to protect, optimise and enhance the biodiversity and natural areas within cities, local government departments have adopted unique biodiversity and open space conservation strategies.

The aim of this study is to understand the informants of urban conservation strategies and how these relate to the physical form of open space conservation in two different South African cities, namely Cape Town and Durban. It aims to understand the local conservation strategies and approaches to biodiversity and open space conservation in these two cities as well as how these strategies emerged; the similarities and differences between these conservation strategies; and to what extent different city histories and biophysical templates inform biodiversity conservation and management at the local government level. The study further aims to take a city-wide view and analyse the landscape pattern and spatial heterogeneity, with some consideration to the pressures imposed on remaining natural habitats from adjacent land uses in the cities of Cape Town and Durban. This information is used to understand the degree to which fragmentation has manifested and to consider how this might have impacted the functioning ecology of these cities as well as what impact this might have on conservation intiatives. In doing so, this project focussed on shedding light on a critically important subject: urban biodiversity and open space conservation and the systems and procedures that are currently in place in local governance structures to support them. The study aims to answer the following research question: what processes informed the establishment of the conservation strategies in these two South African cities, and in turn how do these relate to the emerging conservation estate?

Based on the overarching aim and research question, the objectives of the study were:

1. To establish the informants, and emerging form, of urban conservation strategies in these two cities in light of their variable biophysical templates and histories.
2. To establish the physical landscape pattern of conservation land in each city, and from this information, to infer likely ecological outcomes.

1.3 Study Sites

The study sites chosen for this research include: The City of Cape Town in the Western Cape and the eThekwini Municipality (City of Durban) in KwaZulu-Natal (illustrated in Figure 1.2 below).

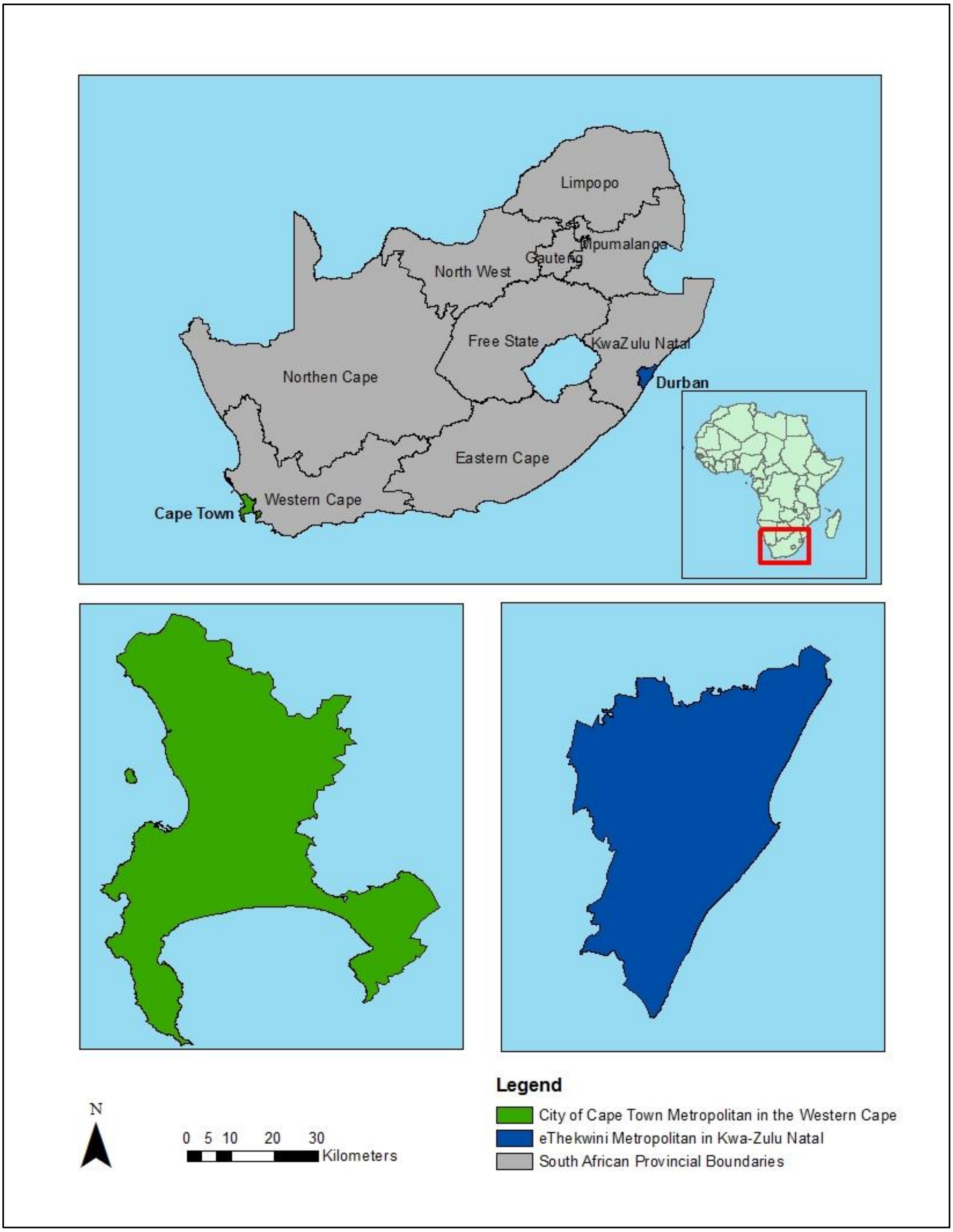

Figure 1.2: Locations of study areas in South Africa

1.3.1 The City of Cape Town

The City of Cape Town (situated at 33°55'7.89'' S, 18°25' 23.88'' E) is South Africa's most south-western city. Contained within the City's 2460 km^2 footprint is a diverse geography of mountain ranges including the Table Mountain National Park (TMNP) and Cape Peninsula; a coastline of over 300 km; lowland vegetated areas; 16 nature reserves; and a built environment (City of Cape Town, 2017a). Cape Town is located in the geographically restricted Cape Floristic Region (CFR), the smallest and most diverse floral kingdom on earth (Holmes et al., 2008; Goodness & Anderson, 2013). The CFR is recognised as one of the world's biodiversity hotspots and exhibits high levels of endemism and threatened biodiversity (Holmes et al., 2012). The region experiences a Mediterranean type climate with hot, dry and windy summers and cool, wet winters. Cape Town is home to four centres of fynbos plant endemism and contains 19 national terrestrial vegetation types, six of which are endemic to the City (Holmes et al., 2012; City of Cape Town, 2017a). According to Rebelo et al. (2011), there are approximately 3350 indigenous plant species in the City, with 190 being endemic to the City itself. In addition, about 450 of these indigenous plant species are listed as threatened or near-threatened, and 13 are identified as extinct (Rebelo et al., 2011).

Like other South African cities, Cape Town continues to grapple with development discrepancies that are remnants of unjust Apartheid governance in the past combined with the present-day challenges of urban sprawl. The City has experienced a 7% increase in its population size in five years, increasing from 3.7 million in 2011 to 4 million in 2016 (State of Cape Town Report, 2016). Urban expansion and development is threatening Cape Town's biodiversity and natural land cover, with invasive non-native species and suppressed natural fire regimes also playing a role (Goodness & Anderson, 2013). The City of Cape Town (CoCT's) Biodiversity Network (BioNet), a long-term biodiversity centred conservation plan, is a sign of the City's commitment in protecting its unique and globally significant biodiversity.

1.3.2 The City of Durban

The City of Durban is situated on the eastern seaboard of South Africa (at 29°51'28.44" S, 31°01'45.12" E) and is the largest city within the province of KwaZulu-Natal (KZN). The eThekwini Municipality covers an area of approximately 2556 km^2 and is home to some 3.82 million people (eThekwini Municipality, 2017a). The municipal area is characterised by steep escarpments in the west and coastal plains in the east. Added to this, the area has 97 km of coastline, with 17 river catchments and 16 estuaries which greatly increases the biodiversity within the region (eThekwini Municipality, 2017b). The City has a subtropical/temperate climate and is historically biologically rich as it occurs within a biogeographical transition zone (eThekwini Municipality, 2017b). The City is exceptionally diverse and occurs in the Maputaland-Pondoland region of floristic endemism, another global biodiversity hotspot (Cilliers, 2010). Durban also contains three of the country's nine terrestrial biomes (Savanna, Forest and Indian Ocean Coastal belt), eleven broad nationally recognised vegetation types, and over 2200 plant species (eThekwini Municipality, 2017b).

The Durban area has a diverse society which faces various social, economic, environmental and governance challenges. In general, the City is sprawling in nature and has large rural areas under the governance of traditional authorities. Threats to biodiversity in Durban include the transformation of natural areas; invasive alien species; overexploitation; pollution and diseases; and human-induced climate change (eThekwini Municipality, 2017b). As with the case in Cape Town, the eThekwini Municipal Area (EMA) consists of several habitat types, most of which are seriously threatened by the process of urbanisation (McLean et al., 2016). The City has however, committed to conserving its rich biodiversity areas and open spaces within an open space system known as the Durban Metropolitan Open Space System (D'MOSS).

1.4 Structure of the thesis

This study contains four chapters (Figure 1.3 below). Each chapter is methodologically different and have been separated accordingly. Since there are two different aspects of the study, the empirical research is presented in the two main chapters (Chapters 2 & 3), each addressing a different objective. Chapter 1 provides a general introduction to the study, while chapter 4 is a concluding chapter where the findings from the two main chapters are tied together and recommendations are discussed.

CHAPTER 1: INTRODUCTION TO THE RESEARCH

Chapter one provides a background to, and motivation for, the study. The research aim and objectives are also presented.

CHAPTER 2: AN ANALYSIS OF THE POLICIES RELATING TO LOCAL BIODIVERSITY AND OPEN SPACE CONSERVATION IN THE CITIES OF CAPE TOWN AND DURBAN

Chapter two explores the local biodiversity and open space conservation strategies for the cities of Cape Town and Durban. The chapter uses qualitative research methods to understand the emergence of these conservation strategies.

CHAPTER 3: AN ANALYSIS OF THE LANDSCAPE PATTERN AND SPATIAL HETEROGENEITY IN THE CITIES OF CAPE TOWN AND DURBAN

Chapter three provides an analysis of the emerging landscape pattern and spatial heterogeneity in each city. The chapter uses quantitative research methods to understand the spatial configuration of conservation land in each city.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

Chapter four presents findings of each empirical study. The overarching aim of understanding the central informing factors behind conservation plans, and how these manifest in the spatial arrangement of conservation land, is considered. Recommendations are also made on the findings of the research.

Figure 1.3: Outline of Thesis Structure

Chapter 2: An analysis of the policies relating to local biodiversity and open space conservation in the cities of Cape Town and Durban

2.1 Introduction

South Africa is the third most biologically diverse country in the world (Wynberg, 2002; Wilhelm-Rechmann & Cowling, 2013). The country has a spectacular array of landscapes and ecosystems, a great diversity of species and marine and coastal systems, as well as a high level of endemism (Wynberg, 2002). While South Africa occupies only 2% of the world's total land surface area, the county is home to 6% of the world's plant and mammal species, 8% of bird species and 5% of reptile species (DEA, 2012b). In addition, it is home to three of the world's thirty-six biodiversity hotspots: the CFR, the Succulent Karoo and the Maputaland-Pondoland-Albany (DEA, 2012b; Driver et al., 2012).

Despite the country's wealth of ecosystems and biological assets, South Africa's biodiversity is one of the most threatened on the planet (Wynberg, 2002; DEA, 2012b). The country's biodiversity rich and diverse landscapes face severe pressure from urban expansion, land transformation for agriculture and mining as well as water scarcity and climate change (Driver et al., 2012). According to Driver et al. (2012), approximately 20% of natural habitat has been permanently lost, with 48% of wetland ecosystem types critically endangered and 24% of coastal ecosystems being threatened by development pressure.

The decline and loss of biodiversity reduces nature's contributions to people in South Africa and impedes much needed social and economic development. One way to combat the loss and degradation of the earth's biological resources is implementing legislation and policies alongside effective management and governance. Rapid urbanisation in response to increasing population demand places significant pressure on biodiversity across the world as the demand for resources increases (Güneralp & Seto, 2013; Güneralp et al., 2017). In Africa, where the population is rapidly growing and expected to increase from 1.2 billion to 4.3 billion between 2015 and 2100 (United Nations, Department of Economic and Social Affairs, 2015), the ability of natural resources to produce ESS has already declined as a result of inappropriate management

(Davids et al., 2016). In addition, approximately 60% of the world's ESS are already degraded or used unsustainably (Millennium Ecosystem Assessment, 2005). It is clear that effective governance, management and protection of biodiversity and ESS is vital (Davids et al., 2016), with cities having a critical role to play in this regard (ICLEI 2012; Wilkinson et al., 2013).

Cities are home to more than half of the world's population, and are responsible for a disproportionately large ecological footprint. Furthermore, the reality is that many urban areas contain high levels of biodiversity and are located in or near biodiversity hotspots (Miller & Hobbs, 2002; Mittermeier, 2011; Secretariat of the Convention on Biological Diversity, 2012; McLean et al., 2016), as is the case with the cities of Cape Town and Durban. According to Seto, Parnell and Elmqvist (2013), urban land expansion is rapidly occurring in areas adjacent to biodiversity hotspots and faster in low-elevation, biodiversity-rich coastal zones than in other areas. It is envisaged that by 2030, new urban expansion will take up an additional 1.8% of all biodiversity hotspot areas (Seto, Parnell & Elmqvist, 2013). This urban expansion will draw heavily on natural resources on a global scale, and will ultimately consume prime natural and agricultural land (Secretariat of the Convention on Biological Diversity, 2012). According to Swilling (2016: 1), "if we continue to develop as if the planet can provide unlimited resources, then the near-doubling of the urban population will mean a doubling of the natural resources required to build and operate our cities, which is not sustainable". The reality is that urban areas will continue to expand, but the ecosystems upon which they depend will not, creating an increasingly stressed relationship.

According to Wilkinson et al. (2013), local governance of biodiversity and ESS will only be successful with collaborative, cross-scale efforts that better prioritise the value of biodiversity and ESS through effective urban governance. Furthermore, good management of urban areas can only be achieved with the collaboration of multiple jurisdictions as well as public and private actors from all levels of decision-making from national, provincial, and local governments to international organisations, citizen groups, scientists, Non-Governmental Organisations (NGOs), and businesses (Wilkinson et al., 2013).

Urban areas have become increasingly important, and local action for biodiversity is now an essential aspect of habitat protection. Local governments have a vital role to play in sustainable urban biodiversity conservation, enhancement, utilisation and management (ICLEI, 2012). Therefore, cities find themselves in the paradoxical position of being the consumers of vast amounts of ecological and natural resources, but also having the ability to play a key role in the sustainable management of these resources (de Oliveira et al., 2011).

Cities are complex social-ecological systems, and need to be considered beyond a particular density of people or area covered by human-made structures (Grimm et al., 2008; Elmqvist et al., 2013). According to Elmqvist et al. (2013: 723), "since cities represent a complex, interlinked system shaped by the dynamic interactions between ecological and social systems, preserving and managing urban biodiversity means going well beyond the traditional conservation approaches of protecting and restoring natural ecosystems". Hence, while there are many shared biodiversity and ecosystem problems faced by and emanating from cities, the way these manifest in different cities is unique (Wilkinson et al., 2013). South African cities for example, have all been shaped by common national processes but have their own distinctive features in terms of the natural environment, economic, social and cultural make-up, and current dynamics (Patel, 2005). Governance, conservation efforts and justification for action may therefore differ between cities as solutions for one may not be ideal for another.

2.2 Aim and Objectives

This chapter seeks to explore the local biodiversity and open space conservation strategies of two South African cities, namely Cape Town and Durban. Although these two cities are governed by the same national legislation, they differ in their local conservation strategies which aim to protect their local biodiversity and open spaces. The chapter seeks to understand (1) the local conservation strategies and approaches to biodiversity and open space conservation in Cape Town and Durban; and (2) the similarities and differences between the conservation strategies, and to what extent different city histories and biophysical templates inform biodiversity conservation and management at the local level. The chapter compares and contrasts the approaches used in each city in order to deepen our understanding of the biodiversity and open space initiatives in different city contexts. It also aims to highlight the success in the conservation practices, identifying what has worked in which city and why, so that we can provide some insights to guide and inform future management. In doing so, the chapter takes a critical look at the histories and development of the conservation systems; the approaches, methodology, development objectives and benefits of the networks; the current status of the systems; the implementation tools and challenges faced in the enactment of the conservation strategies; the influence they have at the local level as well as branding and access to information in relation to these local conservation strategies.

2.3 Relevant literature on local contexts to biodiversity management

While both the cities of Cape Town and Durban fall under common national legislation and global imperatives (see Appendix A) that inform many of the policies and plans below these levels, this is not the focus of this study which explores conservation at the local level. The study will focus particularly on the city level and how specific factors and local contexts are relevant and how they influence the local biodiversity conservation strategies in these two cities.

In South Africa, the largest metropolitan areas are governed by metropolitan municipalities. The cities of Cape Town and Durban are both considered metropolitan and 'Category A' municipalities, meaning that they have exclusive municipal executive and legislative authority in their area. Furthermore, both cities have biodiversity conservation strategies to protect their unique biodiversity, ecosystems, and natural open spaces. According to de Oliveira et al. (2011), as the urban population continues to grow at a rapid rate, the importance of city governance to manage the challenges of biodiversity loss has increased. The way cities are designed, planned and governed ultimately influences the magnitude of their direct and indirect impacts on biodiversity (de Oliveira et al., 2011).

2.4 Study Sites

Cape Town

In 2002, the CoCT was the first municipality in South Africa to initiate a Systematic Conservation Planning (SCP) approach to efficiently prioritise natural areas to meet biodiversity pattern and process targets (Holmes et al., *in press*). The BioNet (illustrated in Figure 2.1) is Cape Town's regularly updated, fine-scale systematic biodiversity plan. The agency for resource and environmental strategy in the CoCT is the Environmental Resource Management Department (ERMD), which contains a Biodiversity Management Branch (BMB). The BMB's objective is to improve the status and management of biodiversity in existing conservation areas, management effectiveness monitoring, and to secure priority areas of the BioNet (Holmes et al., 2012). The City has a long history of environmental management, dating back to the Integrated Metropolitan Environmental Policy (IMEP) (adopted in 2001 and reviewed in 2008). This was accompanied by a set of implementation strategies, a Biodiversity Strategy (2003) and a Local Biodiversity Strategy and Action Plan (LBSAP) (2009-2019 which was updated and replaced with the 2016-2026 plan) (Holmes et al., 2012; Goodness & Anderson, 2013). In 2015, the CoCT published a Bioregional Plan (in line with the National Biodiversity Framework (NBF) and sanctioned under the National Environmental Management: Biodiversity Act (NEM:BA)) which informs and guides planning, environmental assessment and natural resource management by all whose decisions which affect biodiversity in the City (City of Cape Town, 2017b). Thereafter in 2017, the IMEP was replaced by the contemporary Environmental Strategy (2017) which provides a revised approach to sustainability within the context of the City's Social Development Strategy and Economic Growth Strategy. The CoCT is also a member of ICLEI and was instrumental in developing the Local Action for Biodiversity (LAB) programme in conjunction with the organisation (City of Cape Town, 2016). Cape Town became a pioneer member of the LAB programme and also became a signatory to the Durban Commitment in 2008 (See Appendix A).

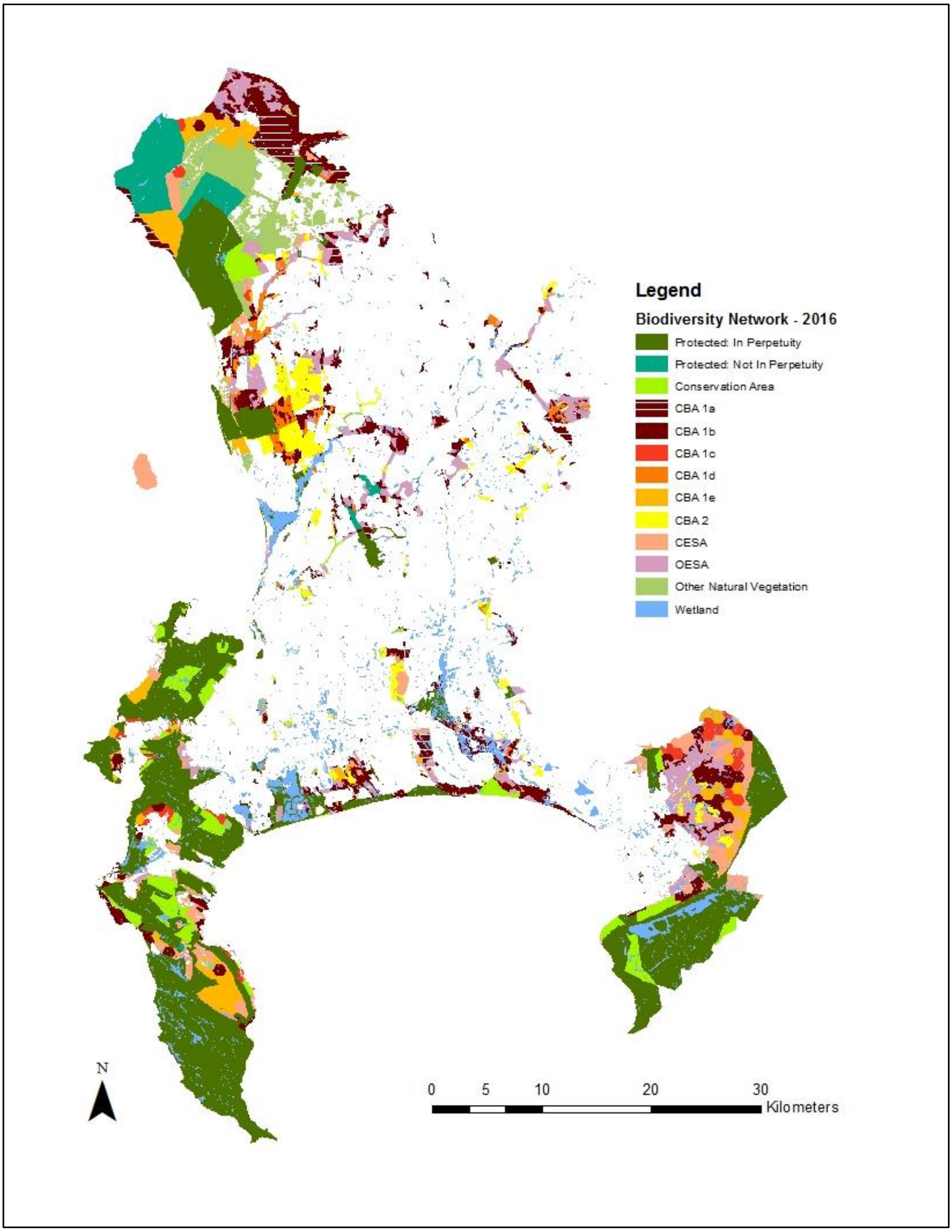

Figure 2.1: The Biodiversity Network for the City of Cape Town which highlights the City's Protected areas, conservation areas, Critical Biodiversity Areas, Ecological Support Areas, wetlands and other natural vegetation (Source: City of Cape Town Open Data Portal, 2016).

Durban

In 1983, the Durban City Council approved the creation of a Metropolitan Open Space System (MOSS) as an integrated means of preserving natural open land within the confines of Durban (McLean et al. 2016). The D'MOSS (illustrated in Figure 2.2) "is a system of green open spaces incorporating areas of high biodiversity value (private and public owned) composed of a variety of habitat types linked together in an ecologically viable network" (eThekwini Municipality, 2017b: 6). The lead agency for environmental management in the EMA is the Environmental Planning & Climate Protection Department (EPCPD). There are also three branches within the EPCPD which consists of: The Biodiversity Planning Branch (BPB) which identifies, protects and manages Durban's important terrestrial, freshwater and marine environments as part of the D'MOSS; the Biodiversity Impact Assessment Branch (BIAB) which assesses the potential impacts of development on the D'MOSS and initiates biodiversity related enforcement action when needed; and the Restoration Ecology Branch which manages additional areas that the City secures through land acquisition and runs the City's Green Economy Projects. The D'MOSS is mapped and updated by the BPB. In addition, the City has a Biodiversity Strategy and Action Plan (2017) which essentially highlights the key objectives of the D'MOSS. In 1994, Durban became the first city in South Africa to accept the Local Agenda 21 mandate as a corporate responsibility (Roberts & Diederichs, 2002). The City has since been at the forefront of the country's Local Agenda 21 movement. Durban has also committed to the conservation of biodiversity at the local level by becoming a member of ICLEI and approving its participation in the LAB Programme.

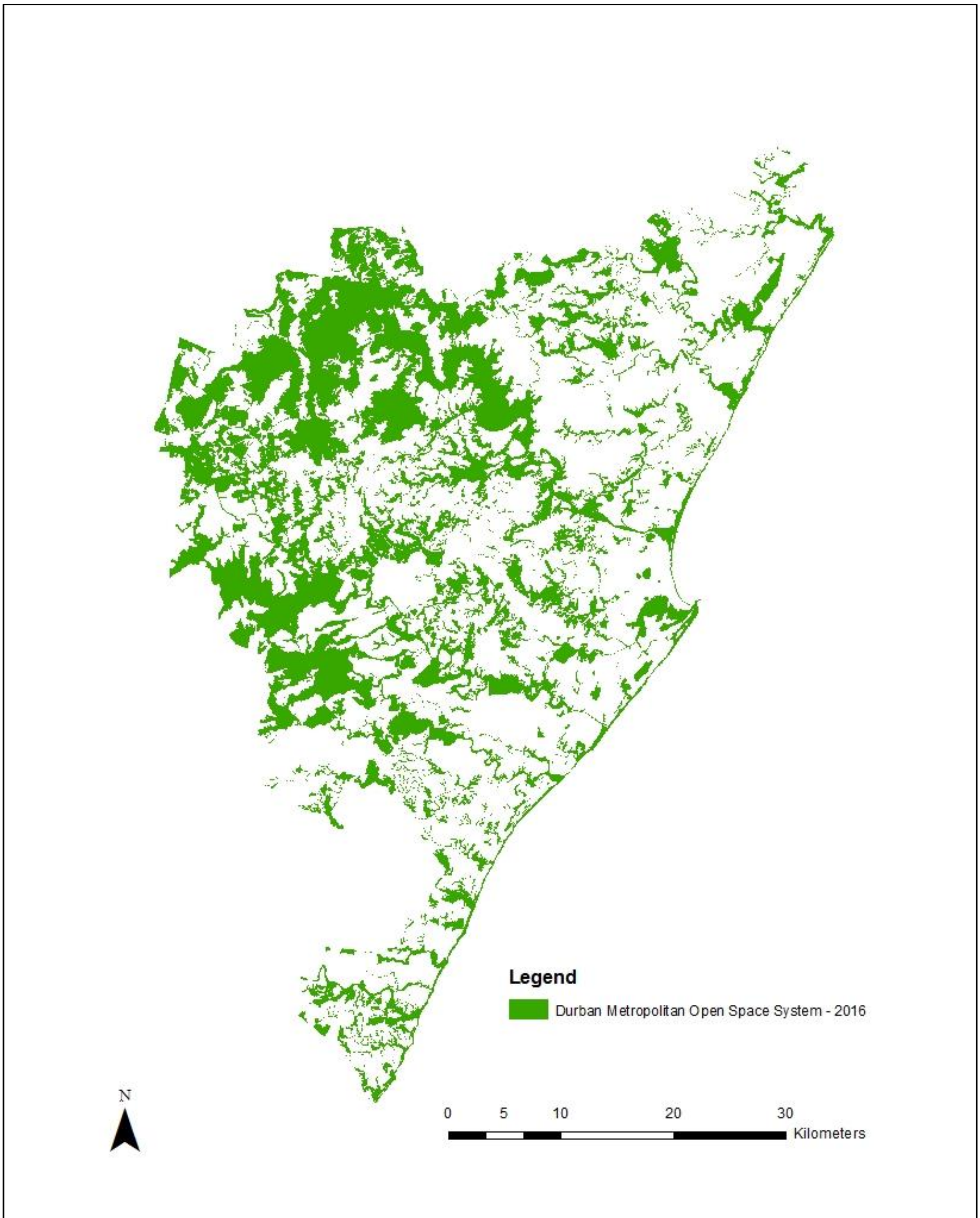

Figure 2.2: The Durban Metropolitan Open Space System for the eThekwini Municipal Area which highlights the City's Critical Biodiversity Areas and Ecological Support Areas in a combined layer (Source: eThekwini Muncipality, 2016).

2.5 Data and Methods

This chapter makes use of a qualitative research approach in order to help deepen our understanding of local biodiversity governance and management. Qualitative research is an approach used for exploring and understanding social phenomena and focuses on reports of experience (Creswell, 2014). In other words, it makes use of the narratives of individuals or groups to represent the findings of a study. The results of qualitative research are more descriptive in nature and cannot be obtained by statistical means or expressed numerically (Strauss & Corbin, 1990). The chapter is founded on the notion of concept analysis, with data generating methods consisting of a document and policy analysis as well as semi-structured interviews with city officials. These methods reflect on the information that can be drawn from biodiversity and open space policies and guideline documents as well as the narratives and opinions of city officials relating to the governance and management.

2.5.1 Document and policy analysis of the BioNet and D'MOSS

For the analysis of the relevant documentation I used document analysis, a recognised qualitative research method, which entails the systematic review and evaluation of documents in relation to set research questions (Bowen 2009). A document analysis is undertaken in order to elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009). The iterative process combines elements of content and thematic analysis (Bowen, 2009). A policy analysis was also undertaken for those documents that were official policy publications. A policy analysis is defined as "the evaluation and study of the formulation, adoption, and implementation of a principle or course of action intended to ameliorate economic, social, or other public issues" (Simon, 2016: 1). It requires careful systematic and empirical study and helps to outline and define and the goals and objectives of the policy and identify expected outcomes of the policy (Simon, 2016). A document and policy analysis was undertaken for the study in order to gain more information and understanding on the biodiversity and open space policies and regulations at the local level.

The analytic process of document analysis requires the selection of relevant documents (in the case of this thesis, the BioNet's Methods and Results and Durban's Systematic Biodiversity Assessment), and the appraisal and synthesis of data or information in the documents. The policies of interest in this case were those that are relevant to biodiversity and open space governance and management and that have been formulated at the municipal level. After the main documents were identified and obtained, the goals and objectives of each city in conserving their biodiversity and natural remnants within their boundaries were analysed. Excerpts and quotes were drawn from the documents, sourced as relevant to the research question, and then organised into, and reflected on, in relation to emerging themes. While the establishment of themes entails a degree of interpretation by the researcher (whether coded through the use of an electronic package, or simply through careful reading in search of particular terms), the use of supporting quotes and excerpts, presents empirical data to validate the view expressed. In the case of this thesis, the BioNet's Methods and Results and Durban's Systematic Biodiversity Assessment documents (along with others) were closely read with a view to drawing out all references to the BioNet, the D'MOSS, their goals, objectives, histories and methodologies, the status of these systems, the governance of biodiversity and open space at the local level, implementation projects, and how these plans hope to or are being implemented at the city scale and how they fit into the city's broader planning mandate.

The document and policy analysis involved a thorough examination and interpretation of the cities' respective local biodiversity and open space policies, plans and procedures. Table 2.1 below includes a list of the guideline documents and policies which were reviewed as per the methods indicated above. In this thesis the findings from the document and policy analysis were triangulated against the findings from the interviews in order to capture different dimensions of the same topics (Bowen 2009).

Table 2.1: List of reviewed documents and policies which relate to biodiversity and open space in the cities of Cape Town and Durban

Name of Policy Document	Description
The City of Cape Town Biodiversity Network: C-Plan & Marxan Analysis: 2016 Methods & Results	The document provides an analysis on the methods and results of the 2016 BioNet plan.
City of Cape Town Local Biodiversity Strategy and Action Plan 2016 – 2026	The Local Biodiversity Strategy and Action Plan lays out the biodiversity actions required by the City to implement the approved strategies from the Biodiversity Strategy (see below).
The Cape Town Bioregional Plan 2015	The Bioregional Plan for the CoCT includes a biodiversity profile for the bioregion, information on the BioNet and guidelines to inform land use planning and decision making for a range of sectors whose policies and decisions impact biodiversity.
Cape Town Biodiversity Strategy 2003	The Cape Town Biodiversity Strategy developed from the IMEP. The Biodiversity Strategy is one of the IMEP's six Sectorial Strategies and provides an overarching framework for a consolidated and coordinated approach to protecting and enhancing the rich biodiversity of Cape Town.
Durban's Biodiversity Strategy and Action Plan 2017	Durban's Biodiversity Strategy and Action Plan (also referred to as the Biodiversity Sector Plan) looks at the policy and strategy context for the conservation of biodiversity in Durban. It also provides an overview of Durban's biodiversity assets, and lists actionable goals and objectives to conserve this biodiversity.
Durban's State of Biodiversity Reports: 2016/2017 And 2017/2018	Durban's State of Biodiversity reports, which are published annually, aims to track the municipality's performance in terms of biodiversity protection and management. The report summarises the work that the EPCPD, and other branches, do in terms of protecting and managing the D'MOSS, and managing other programmes and plans relating to the natural environment.
Durban's Systematic Conservation Assessment Report 2016	The report describes the process and outputs of identifying important biodiversity areas in the EMA through the City's first use of Systematic Conservation Assessment methodology.

2.5.2 Interviews

Interviews, a common qualitative research method, are a specific form of conversation where knowledge is gained through an interaction between the person gathering the data and controlling the discussion, also known as the interviewer and the person responding to the enquiry also known as the interviewee (Kitchin & Tate, 2013). Depending on the scope of the study, an interview could either be a structured interview or a semi-structured interview (Rubin & Rubin, 2011). Structured interviews relate to cases in which there is a set of rigorous questions which are created in advance and have a limited set of responses. Semi-structured interviews on the other hand, make use of a set of pre-determined open questions with the opportunity for the interviewer to explore particular themes or responses further (Rubin & Rubin, 2011). In this case, face-to-face semi-structured interviews were held with city officials in Cape Town and in Durban in May and July 2017 respectively. The interviews were arranged in advance and each participant was sent an interview schedule before the meetings took place.

In order to obtain maximum information from the officials of the local environmental departments, the interview schedule included a set of open-ended questions relating to biodiversity and open space conservation. The questions were centred around and related to the following topics: the official's understandings on the histories and development of biodiversity and open space conservation in the respective municipalities; the goals and objectives of the systems; biodiversity and open space governance, management and challenges; policies and legislation, as well as the status and influence of such policies. The local government officials who were interviewed were selected as candidates because of their operational experience, their positions in the relevant biodiversity departments as well as their knowledge, involvement and exposure to the biodiversity and open space policies within the respective municipalities. The participant for the CoCT Municipality was Biophysical Specialist, Dr Patricia Holmes, who is directly responsible for compiling and updating the BioNet at the BMB. In Durban, the participants were Mr Richard Boon, Manager of the Biodiversity Planning Branch and Ms Natasha Govender, Senior Specialist Ecologist at the EPCPD in the eThekwini Municipality. Their narratives and perceptions were considered vital as they inform the governance and management of biodiversity and open space at the respective local government departments and provided information on the themes that are relevant to this study. In this case, having structured and standardised questions proved useful for comparing the two cities (Kitchin & Tate, 2013).

The responses of the city officials were derived from the interviews and the information was analysed by means of well-known qualitative data analysis techniques, including a thorough interpretation of the information and making detailed notes, identifying key themes that emerged, and organising and grouping the information into different themes for each city. The themes that emerged were then combined with the information gathered from the document and policy analysis.

2.5.3 Ethical considerations

This study adhered to ethical research principles. While almost all the information used in this study is already in the public domain, ethical considerations only related to those city officials interviewed for additional insights and further depth in understanding the development of the relevant plans. Interviewees were only interviewed in their professional capacity, and called on for information on history and context rather than individual opinion. The option to not be interviewed was included. All participants were informed of the research aim and objectives in detail before the interviews commenced and were asked whether or not they were willing to participate in the interview and about the use of full names, which every person agreed too. The participants were also asked to sign consent forms (see Appendix C) to indicate their willingness to participate in the study. All interviewees were informed that their participation in the study was voluntary and that they would be provided with an opportunity to read the chapter where their views were presented and have the opportunity to comment on their responses before the completion of the study. All interviewees were sent a copy of the relevant chapter at least five months prior to the submission of the thesis and no comments or concerns were raised.

2.5.4 Data analysis

After conducting the document and policy analysis and going through the responses from interviews, the data was analysed and grouped together under the relevant themes and topics of discussion. The findings from the document and policy analysis were therefore triangulated against the findings from the interviews in order to capture different dimensions of the same topics (Bowen 2009). The relevant themes included: the goals, objectives, histories and methodologies of the conservation systems, the status of these systems, the governance of biodiversity and open space at the local level, implementation projects, the challenges faced with implementation and how these plans hope to or are being implemented at the city scale and how they fit into the city's broader planning mandate. Results obtained from the above-mentioned methods are presented in a combined results and discussion section below and separated into the different themes corresponding to the information that emerged. I have also drawn up a timeline (figure 2.3) showing the progression and development of policies and documents relating to the biodiversity and open space conservation systems in the cities of Cape Town and Durban by using the information gathered from the document analysis and from the interviews conducted.

2.5.5 Limitations

Two notable limitations emerged from this section of the study. Firstly, the corresponding policy and guideline documents for each system differs for each city. While central to the study, it was not possible to compare documents and policies of the same nature, making interpretation sometimes difficult. Secondly, the biodiversity and conservation histories in these cities are not well documented. Hence, in order to gain more information and understanding on the history and development of conservation in Cape Town and Durban, the study had to draw on people's narratives and memories which presents a further limitation. While these cities have different approaches and different conservation systems in place to protect and conserve biodiversity and natural spaces within their boundaries, it is an interesting feature of the study which has helped in the comparison of two different systems in two very different urban landscapes.

2.6 Results and Discussion

2.6.1 An analysis of the conservation networks in the cities of Cape Town and Durban

Central findings and messages from the research are presented in Table 2.2 below:

Table 2.2: Key findings obtained from the document and policy analysis as well as key interviews highlighting the similarities and differences between each city with regards to relevant themes of the research

	Cape Town	Durban	Similarities/Differences
1. What kind of conservation systems are present in each city?	The CoCT has a Biodiversity Network, which is a fine-scale, systematic biodiversity plan that identifies sites necessary for conservation and protection from development and inappropriate management.	The eThekwini Municipality has an Open Space System, which incorporates areas of high biodiversity value linked together in an ecologically viable network that aims to conserve and protect the natural remnants within the metropolitan area.	Although the cities of Cape Town and Durban have different conservation systems in place, both systems aim to conserve biodiversity and natural space within their boundaries as well as ensure that the natural resource base which provide ESS to the communities do not get depleted.
2. How did these conservation agendas emerge?	Early conservation studies in Cape Town included: (1) The Greening the City Report (1982), where the concept of a system of open spaces was first mentioned; and (2) The Cape Flats Flora Core Conservation Sites project, in which 37 Core Flora Conservation Sites were identified as critically important to the overall protection of biodiversity in the City. Following this, and after the establishment of the ERMD in the CoCT, the first systematic biodiversity planning study to identify a representative conservation network was	The recognition of the importance and loss of Durban's open spaces to conservationists and planners, has its origins in the early 1980s. Early discussions on this matter included a seminar in 1983 that brought together various influential stakeholders and conservationists, who all shared the same concerns relating to Durban's natural environment. At this seminar, the need for a MOSS for the municipality was recognised. As a result, the first MOSS was produced in 1989.	The eThekwini Municipality was one of the first municipality's in the country to get its Open Space System adopted by Council in 1989. While the CoCT did have conservation projects in place such as Greening the City and the Core Flora Sites, the first BioNet study was only initiated in 2002. The CoCT had also initiated other conservation projects prior to this, however some of these failed to get recognition and get adopted by Council.

	initiated in 2002. The identification and prioritisation of the conservation network was a collaborative process between various departments and specialists. The study was later adopted by Council in 2004.		
3. Who were the key players involved in the creation of these systems?	The City's ERMD and key conservation partners, namely the South African National Biodiversity Institute (SANBI), the Botanical Society of South Africa (BotSoc), Table Mountain National Park (TMNP), CapeNature Conservation, provincial government departments and several environmental specialists.	The former NGO known as the Wildlife Society as well as the eThekwini Municipality, town planners, conservationists, planners, academics and applied scientists. The EPCPD's Dr Debra Roberts also played a significant role in developing the first MOSS in collaboration with the City department.	Cape Town's key players were all largely biodiversity specialists and government agencies whereas in the case of Durban, there was a broader group involved which included town planners with a Spatial Planning background as well as a former NGO.
4. When were these conservation strategies first produced and adopted by Council?	The first BioNet was produced and adopted by Council in 2004.	The first MOSS was produced and adopted by Council in 1989.	There is a 13-year difference between the creation of the D'MOSS and the BioNet.
5. What are the key objectives of the conservation systems?	The BioNet's objectives are centred on the protection and conservation of the City's rich and unique biodiversity and the safeguarding of species of	The central objectives of the D'MOSS are a combination of biodiversity conservation and the safeguarding of species of conservation interest and their	Since its inception, there has been a misconception that the D'MOSS has shifted from that of biodiversity and natural space

	conservation interest and their habitats In the City's view, the protection of its biodiversity and ecological support areas would lead to the ultimate protection of the ESS which are provided by these resources.	habitats as well as the human benefits of such a system, including recreation and aesthetics. According to the eThekwini Municipality, ESS were only retrofitted into the D'MOSS in the 1999 and subsequent versions.	conservation towards the provisioning of ESS. However, according to the representatives from the eThekwini Municipality, the D'MOSS network has always been and is, centred on a biodiversity conservation perspective, stating that the provision of ESS, while also contributing to the objectives of the D'MOSS, is used more as a marketing hook to sell the idea of biodiversity conservation as well as the D'MOSS brand. The BioNet on the other hand, has always been centred on a biodiversity conservation perspective.
6. What conservation planning approach is used in each city?	The CoCT has used the SCP approach since the creation of its conservation system in 2004, to align with best practice techniques and international standards.	In 2016, the eThekwini Municipality realised it needed a more rigorous approach to conservation planning and undertook its first Systematic Conservation Assessment using the Systematic Conservation Planning approach. The same	The CoCT has always used a more scientific and biological-centred approach to conservation planning, whilst the eThekwini Municipality has only recently started with the use of the SCP approach, which makes use of

	The approach used in the CoCT is very science based and biodiversity oriented and makes use of GIS technology and conservation planning software such as C-Plan and MARXAN.	software and technology is therefore used in eThekwini. Prior to this, previous approaches included vegetation studies, aerial mapping and GIS work.	explicit goals and targets for biodiversity.
7. What is the current status/percentage secured in each conservation system?	By 2016, the CoCT had secured 60.91% of the BioNet.	By 2016, the eThekwini Municipality had secured 8.2% of the D'MOSS.	Cape Town's mountainous areas however, including the TMNP, have always been well conserved and makes up a huge portion of the land conserved within the BioNet. These areas added approximately 30% of the BioNet being secured when the analysis first started. The eThekwini Municipality on the other hand, does not have large mountainous areas which can be conserved as a unit.
8. What influence do these systems have on the different policies and procedures at the local level?	The BioNet informs the Integrated Development Plan (IDP), Spatial Development Framework (SDF) and district plans of the City.	The D'MOSS is incorporated into the City's IDP, SDF, regional Spatial Development Plans and into the municipal town planning schemes as a controlled development layer.	The D'MOSS was integrated into the original 54 eThekwini Municipality schemes in December 2010. The Municipality also had the D'MOSS integrated into the IDP and SDF since as early as 1998.

	However, it does not preclude development since the municipal town planning and relevant zoning schemes essentially have more power than the SDF.	However, the D'MOSS does not entirely preclude development since the system in itself is not a zone.	Ethekwini was the first and only municipality in South Africa to get its conservation system integrated into the full hierarchy of municipal spatial plans. As a result, the D'MOSS has a lot more influence at the local level compared to the BioNet, as it is integrated into the municipal schemes and therefore has influence on the planning and development in the EMA.
9. What are the main challenges faced in each city regarding the implementation of these systems?	Stewardship on private land, where landowners resist entering into agreements with the City Department. Another vital issue is gaining and maintaining political support for biodiversity conservation. More often than not, developments gain more political support and are given the go ahead despite their negative impact on the natural environment.	The institutional arrangement in the EMA (which includes traditional authorities and dual-governance of municipal land) presents a number of challenges particularly with respect to land, planning and urban management Gaining political support for biodiversity is also an issue in the EMA.	The most pressing issue in the CoCT seems to be the failure of gaining stewardship agreements with private landowners, while the eThekwini Municipality is faced with the issue of traditional authorities and dual governance of municipal land. This makes for a particularly complex problem in a city environment. Both cities are also challenged with gaining and maintaining political support for biodiversity conservation.

10. Representations of the conservation systems	The BioNet area is divided into 13 different categories, differentiated by the significance of each portion of land within the system.	The D'MOSS exists as a single green layer which incorporates all the Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) in the municipal area.	The eThekwini Municipality has chosen not to distinguish between its CBAs and ESAs in the representation of the D'MOSS, as the CoCT does, because: (1) D'MOSS in its entirety is a brand with which people are familiar; and (2) if the areas were not combined people might identify certain areas as being less significant than others.
11. How often are the conservation systems updated?	The BioNet is updated continuously to reflect changes in habitat loss and vegetation statistics. It is also regularly updated to include the latest local and national biodiversity information.	The D'MOSS was last updated in 2017, and prior to that in 2016. However, the D'MOSS would be updated in a 2-year cycle to limit the times and process of getting the policy adopted and integrated into the town planning schemes.	According to the eThekwini Municipality, the process of getting the policy adopted and integrated into the town planning schemes again is a lengthy and time-consuming process.
12. Access to Information regarding the conservation systems	The BioNet's reports, maps and spatial datasets appear on the municipality's and SANBI's websites.	Information on the D'MOSS appears on the eThekwini Municipality's website which also includes a map viewer where landowners can see if the D'MOSS layer is situated on their property. However, the spatial dataset is not provided to the public.	It seems that there is more readily available and easily accessible data and information on the BioNet compared to the D'MOSS. The CoCT therefore makes more information available to the public.
13. Which departments and branches are	The CoCT's agency for resource and environmental strategy is the	The lead agency for environmental management in	The BMB within the CoCT and the BPB in Durban are both

responsible for the development and updating of the conservation systems?	ERMD, which contains the BMB. The objectives of the BMB is to improve the status and management of biodiversity in existing conservation areas, management effectiveness monitoring and to secure priority areas of the BioNet	the EMA is the EPCPD, which contains three branches. The objectives of the BPB are to identify, protect and manage Durban's important terrestrial, freshwater and marine environments as part of the D'MOSS.	responsible for compiling and updating their conservation networks. A major difference between these municipalities is that the CoCT has a dedicated environmental unit, which houses various environmental sectors. The eThekwini Municipality on the other hand, is not structured in this way and does not have a dedicated environmental unit. The various environmental sectors fall under different departments which are located in a whole range of units. The EPCPD itself, lies within the Spatial Planning unit. However, the situation of the EPCPD being positioned within the Spatial Planning department has been highly beneficial in getting the D'MOSS integrated into the IDP, SDF and municipal town planning schemes. This is a critical difference between the BioNet and D'MOSS and indicates the significant role that the positioning department had on

			the development and progression of the D'MOSS.
14. What other environmental or biodiversity related policies are there at the local level in each city?	The CoCT has a range of policies regarding the environment and conservation of biodiversity. These include: The Environmental Strategy 2017; The Local Biodiversity Strategy and Action Plan 2016 – 2026; The Cape Town Bioregional Plan 2015; The Cape Town Biodiversity Strategy 2003; and The Integrated Metropolitan Environmental Policy 2001 (which was replaced by the Environmental Strategy).	The D'MOSS layer along with Durban's Biodiversity Strategy and Action Plan (2017), is the only policy relating to the environment and the conservation of biodiversity in the eThekwini Municipality.	There are more policies in place with regards to the natural environment and its biological resources in Cape Town, compared to Durban. Hence, the policies related to biodiversity seem to be more extensive at the city scale in Cape Town.
15. Description and governance of the land under the conservation systems	The city of Cape Town is a predominately urban city and does not have traditional authorities administering municipal land. Municipal land is administered by the municipal authority.	The eThekwini Municipality is largely rural. Approximately 38% of the EMA is under the dual-governance of the eThekwini Municipality and the traditional authority known as the Ingonyama Trust Board.	Durban in particular, is the only metropolis in the country which encounters traditional authorities in an urban setting. This institutional arrangement is therefore unique to the eThekwini Municipality and presents a number of challenges particularly with respect to planning and urban management.

2.6.2 The history of biodiversity conservation and the emergence of the BioNet in the City of Cape Town

Prior to 1994, the protection and enhancement of biodiversity in what is now the CoCT was undertaken in a fragmented manner as a result of the structure of the dispensation. During this time, no less than nine government organisations were responsible for the protection of biodiversity within the City (City of Cape Town, 2003). This resulted in the lack of co-ordination as well as integration of efforts and approaches between these organisations, which led to the fragmented approach to biodiversity conservation. According to the City of Cape Town (2003), the concept of a system of open spaces for activities such as conservation and recreation, was first mentioned in 1982 in the "Greening the City" Report. The report, which was adopted by the City Council in 1984, identified some areas as conservation priorities and formed the basis for much of the conservation work that followed (City of Cape Town, 2003). By the early to mid-1990s, after the failure of a few conservation projects, many remnants of conservation areas were lost to development while others gradually degraded due to the lack of on-the-ground management (City of Cape Town, 2003). Thereafter, in 1997, the NGO known as the Botanical Society of South Africa (BotSoc) which considers vegetation conservation nationally, launched a study in Cape Town to identify flora conservation priorities based on the principles and practices of target-driven SCP (City of Cape Town, 2003). This resulted in the "Cape Flats Flora Core Conservation Sites" project, in which 37 Core Flora Conservation Sites were identified as critically important to the overall protection of biodiversity in Cape Town. These studies formed the basis for the conservation work that followed.

In December 2000, Cape Town saw the amalgamation of seven former municipalities to create its current structure of a 'Unicity' (Local Government Business Network, 2013; City of Cape Town, 2017a). Later, in 2002, the first systematic biodiversity planning study was initiated to identify a representative biodiversity conservation network. The identification and prioritisation of the conservation network was a collaborative process between the City's ERMD and key conservation partners, namely the South African National Biodiversity Institute (SANBI), BotSoc, TMNP, CapeNature Conservation, Provincial Government departments and several environmental specialists (The City of Cape Town, 2015). The biodiversity planning study built on earlier work including Greening the City and Cape Flats Flora Core Conservation Sites and has also included all Core Flora Sites in the conservation network (P. Holmes, pers. comm., 26 May 2017). After identifying important tracts of remnant indigenous vegetation, using existing local government nature reserves, the 37 Cape Flats Core Flora Sites and the best available data, conservation planning methodologies were used to define the best configuration for the BioNet. The study culminated in the Biodiversity Network Prioritisation Report (2004).

The objectives of the system were based on pure conservation reasoning (i.e. the safeguarding of species of conservation interest and their habitats) in order to protect and conserve Cape Town's rich and globally significant biodiversity and to direct spatial planning away from these sensitive areas. The system makes use of science-based methodologies with the key focus being biodiversity and species protection. The CoCT used the SCP approach to identify remnants of land within the municipal area that would need to be conserved to ensure the protection of a representative sample of key biodiversity areas. Dr Holmes stated that the CoCT decided to follow the best practice at the time and the City was at the forefront of systematic biodiversity planning in South Africa. The identification of priority areas was based on a set of conservation targets aimed at setting benchmarks for the conservation of vegetation types, floral species and a selected set of ecological processes (Holmes & Pugnalin, 2016). Setting the conservation targets was achieved by means of a consultative process, which engaged key stakeholders involved in conservation within the City (Holmes & Pugnalin, 2016). Data informants for the primary biodiversity layer for the 2002 study included a remnant layer based on 1998 aerial photography, available plant species information and a local vegetation map drawn up by botanical consultant Mr Barrie Low (Holmes & Pugnalin, 2016). A major challenge at this stage was insufficient information on vegetation remnants.

Subsequently, in 2006, and after the establishment of the BMB, a revised desktop systematic biodiversity planning study was initiated to update the BioNet using the latest: (1) remnant layer based on 2005 aerial photography; (2) species information and (3) a vegetation map aligned to the 2006 national vegetation map (Holmes & Pugnalin, 2016). This version of the BioNet was approved by the City Council in 2006 and was subject to continuing collaborations with Department of Spatial Planning and Urban Design (Holmes & Pugnalin, 2016).

During the years of 2007 and 2008, extensive ground-truthing of all vegetation remnants occurred (Holmes & Pugnalin, 2016). The remnant layer was then updated and the system included habitat condition as an added element. Additional tools were used to select the remnants that were needed to improve connectivity among selected remnants in the City. This, together with expert corridor sites, replaced the methodology used in the first analysis to detect corridors on the BioNet. Moreover, in the 2008 analysis, the National Biodiversity Targets

(NBT) were adopted for the first time. In 2009 and 2011, the analysis was repeated following the methodology used in 2008, but with improved input data. In 2009, a 'wetland mapping and prioritisation project' was undertaken and the results were incorporated into the BioNet (Holmes et al. 2012). In the 2011 re-run, the analysis took into account for the first time, the need for the BioNet to allow for biodiversity processes and ecosystems to adapt to climate change (Holmes & Pugnalin, 2016). The latest update of the BioNet is the 2017 version.

According to Dr Holmes, there were initially plans for a Cape Town Metropolitan Open Space System (CMOSS), and for the identification of open spaces in the City of Cape Town (P. Holmes, pers. comm., 26 May 2017). This had been worked on before the development of the BioNet and before the BMB was established. However, these plans were never formally adopted and were later replaced by the Spatial Development Framework (SDF) and Environmental Management Frameworks (EMFs).

2.6.3 The history of open space conservation and the emergence of the D'MOSS in the City of Durban

In 1979, the first attempt at an open space plan for the Durban Region was made by the former Wildlife Society (an NGO) in response to natural areas being lost to *ad hoc* urban development (eThekwini Municipality, 2007). The Wildlife Society produced the first MOSS plan for the City that aimed to protect conservation-worthy areas. However, this plan was not linked to the municipality. According to McLean et al. (2016), the recognition of the importance of Durban's open spaces to conservationists and planners, has its origins in the early 1980s, during a time of political transformation (after many of the restrictions of apartheid proved impossible to enforce) and an accelerated rate of urbanisation, with population growth rates between 2.5 and 3% in the country (Turok, 2012). At this time, the associated impacts made on Durban's natural and open spaces were becoming increasingly apparent and so was the need to protect the remaining natural remnants. Early discussions on this matter included a seminar in 1983 that brought together various influential stakeholders, town planners, NGOs, conservationists, academics and applied scientists, who all shared the same concerns. At this seminar, the need for a MOSS for the City was recognised as were the realities of implementing such a system in light of current town planning opportunities and impediments (McLean et al., 2016).

In 1987, the Wildlife Society's plan was further developed by a researcher, who was appointed by the former provincial Natal Town and Regional Planning Commission to prepare a more detailed version of the MOSS (eThekwini Municipality, 2007). However, this iteration was still not completely linked with the municipality. Thereafter, building on the work of the Wildlife Society, the former Durban City Council in conjunction with the University of Natal and Dr Debra Roberts, Chief Resilience Officer at the eThekwini Municipality, undertook a detailed ecological assessment of the open spaces within the municipal area (eThekwini Municipality, 2007). Dr Roberts' PhD work in Urban Biogeography (University of Natal) was fundamental to the open space system of Durban, and helped in the development and progression of the network within the municipality. Her work focused on mapping the MOSS using vegetation types for the City, and was later sent to Council for approval (N. Govender, pers. comm., 4 April 2018). This version of the MOSS was adopted by Council in 1989. Although this was a time of major political change within the country, going from the Apartheid regime to a soon to be Democratic state, the policymakers saw this as a "policy window", and an opportunity to get the policy presented to, and adopted by Council since a lot of the councillors at that time were very environmentally conscious (N. Govender, pers. comm., 4 July 2017).

Urban green spaces such as urban forests, parks and lawns are the major sources of biodiversity in and around cities. Hence, the provision of a network of green spaces is one of the most effective mechanisms to preserve and enhance urban biodiversity (de Oliveira et al., 2011). Durban became the first of several South African municipalities to implement its open space system approach in urban nature conservation where descriptive vegetation studies and ariel photography mapping formed the solid base for its open space planning (Cilliers & Siebert, 2012). Furthermore, according to McLean et al. (2016) the objectives of the system were a combination of pure conservation reasoning as well as the utilitarian interests of town planners (i.e. the human benefits of such a system, including recreation and aesthetics). The aim was "to shift the focus from conserving individual species to protecting functional plant communities, maintaining maximum sustainable biotic diversity and minimising extinction by following a biogeographical perspective along the lines of the island biogeography theory" (Cilliers & Siebert, 2012: 3).

As stated, one of the key players involved in the creation of the MOSS was the former Wildlife Society (N. Govender, pers. comm., 4 July 2017). According to Wynberg (2002:234), "South Africa's excellent record of conserving biodiversity occurred more by default than by design, driven by the committed efforts of many individuals and non-governmental organisations". The City of Durban had a broader group of specialists and organisations including town planners and NGOs, who were involved in the creation of the MOSS, whist those involved in Cape Town were all largely biodiversity specialists, consultants and the City's conservation partners. The town planners would have provided more insight into Durban's use of land and their plans and programmes for growth and development and how the MOSS would fit into the municipal area.

Initially, the MOSS was restricted to the central and mostly developed parts of the former Durban Metropolitan Council (McLean et al., 2016). By 1996, post-Apartheid local governments in South Africa had undergone a significant progressive transformation. This resulted in the local government in Durban establishing new priorities. In terms of its open space planning, this meant a shift from the primary concern of conservation and ecological viability, to the need for the implementation and management of a socio-economic and environmentally sustainable open space system (eThekwini Municipality, 2007). It was therefore recognised that a protected sustainable open space system would help ensure that the natural resource base would be able to supply continued ESS to the community in the long term (eThekwini Municipality, 2007). This was also around the time Dr Debra Roberts joined the local government department in Durban. After a brief hiatus of the system, in 1999 the MOSS was expanded to incorporate the subsequent Durban Metro Boundary which included the Central, North, Inner West, Outer West and South Local Councils as well as the concept of ESS and was henceforth referred to as the D'MOSS (McLean et al., 2016). These changes represent a turning point and highlights the changing dimensions of the City and municipal boundaries and how the MOSS expanded to protect a wider area. The changes were brought on by Dr Roberts who was responsible for driving the development of the system and started working on expanding the MOSS throughout the City shortly after joining the local department (N. Govender, pers. comm., 4 July 2017). The D'MOSS was subsequently adopted by the former local councils during 1999/2000.

In 2000, the borders of Durban were re-demarcated to redistribute resources from a fairly wealthy city centre to the poorer periphery and to recognise the functional interdependencies of the municipal economy (Marx & Charlton, 2003; eThekwini Municipality, 2007). This re-demarcation increased the physical size of the City by 68% (Marx & Charlton, 2003; eThekwini Municipality, 2007). The new metropolitan municipality was then renamed eThekwini Municipality, Durban's Zulu name, to reflect its indigenous history. The open space footprint was then expanded and updated to include the current EMA (including widespread traditional authority and rural areas) and was adopted by Council in 2003. The layer was then updated again in 2008 after the creation of a fine-scale land class layer, and was adopted in 2010 (McLean et al., 2016).

All four iterations of the system were necessary to accommodate changes in policy, metro-boundary extensions, improvements in conservation science, and because of social, economic and political drivers of change (McLean et al., 2016; Boon et al., 2016). In addition, nature reserves, large rural landscapes as well as and riverine and coastal corridors are all included in the D'MOSS. While most of the areas included in D'MOSS have been ground-truthed over time (R. Boon, pers. comm., 4 July 2017), this was not undertaken in a specific time period by means of a large-scale project as in the case of the CoCT. There is also a misconception that the D'MOSS is no longer planned and centred on specific biodiversity components, and is now set out to create a robust system likely to be able to provide a sustained supply of environmental goods and services. However, while the system does incorporate the concept of ESS, according to McLean et al. (2016) biodiversity features and processes along with the protection of species and habitats of conservation interest are still included in the D'MOSS and are the main focus of the system. By capturing key environmental areas, the City's biodiversity is expected to be conserved simultaneously along with its open spaces. The D'MOSS is therefore a municipal planning tool that seeks to protect natural environments (which includes biodiversity rich areas) and the ESS they provide.

In 2016, the City realised it needed a more robust and scientific approach to identifying areas for conservation. The EPCPD then undertook its first Systematic Conservation Assessment (SCA) where they adopted the principles of SCP in order to identify and prioritise areas for the conservation of biodiversity (McLean et al., 2016). This assessment was used to update the D'MOSS according to current biodiversity priority areas and to remove those areas that are no longer considered important to achieve biodiversity conservation targets (including degraded areas). The biodiversity planning technique was retrofitted into the D'MOSS in 2016 in order to conserve its important biodiversity and ESS and to follow best practice techniques. This gave the D'MOSS a further level of prioritisation, and enabled the municipality to separate the Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) within the conservation plan as well as improve decision making and the department's active and proactive work. This version of the D'MOSS was adopted by Council in December 2016. The boundaries of the EMA have since been expanded to incorporate the former Vulamehlo Local Municipality, located to the south of the eThekwini Municipality (eThekwini Municipality, 2016d). The wards added to the Southern Region of the municipality are characterised by a predominantly rural settlement pattern and are under traditional authority leadership. The landscapes are further characterised by a rugged and hilly terrain with valleys and river systems (eThekwini Municipality, 2017e). The EPCPD had to therefore update the D'MOSS in 2017 to include conservation worthy areas within this new region of the EMA (N. Govender, pers. comm., 4 July 2017). This map version however, is not yet available on the municipality's website. This again highlights the changing boundaries and expansion of the EMA, and how the D'MOSS has been updated to include new areas within the City since 1999. In comparison, the CoCT has only improved and updated the input data, methodology and analysis of the BioNet after the first production in 2004. The boundaries of Cape Town's municipal area however, have remained the same. The histories of biodiversity and open space planning in the cities of Cape Town and Durban are illustrated in a timeline in figure 2.3 below.

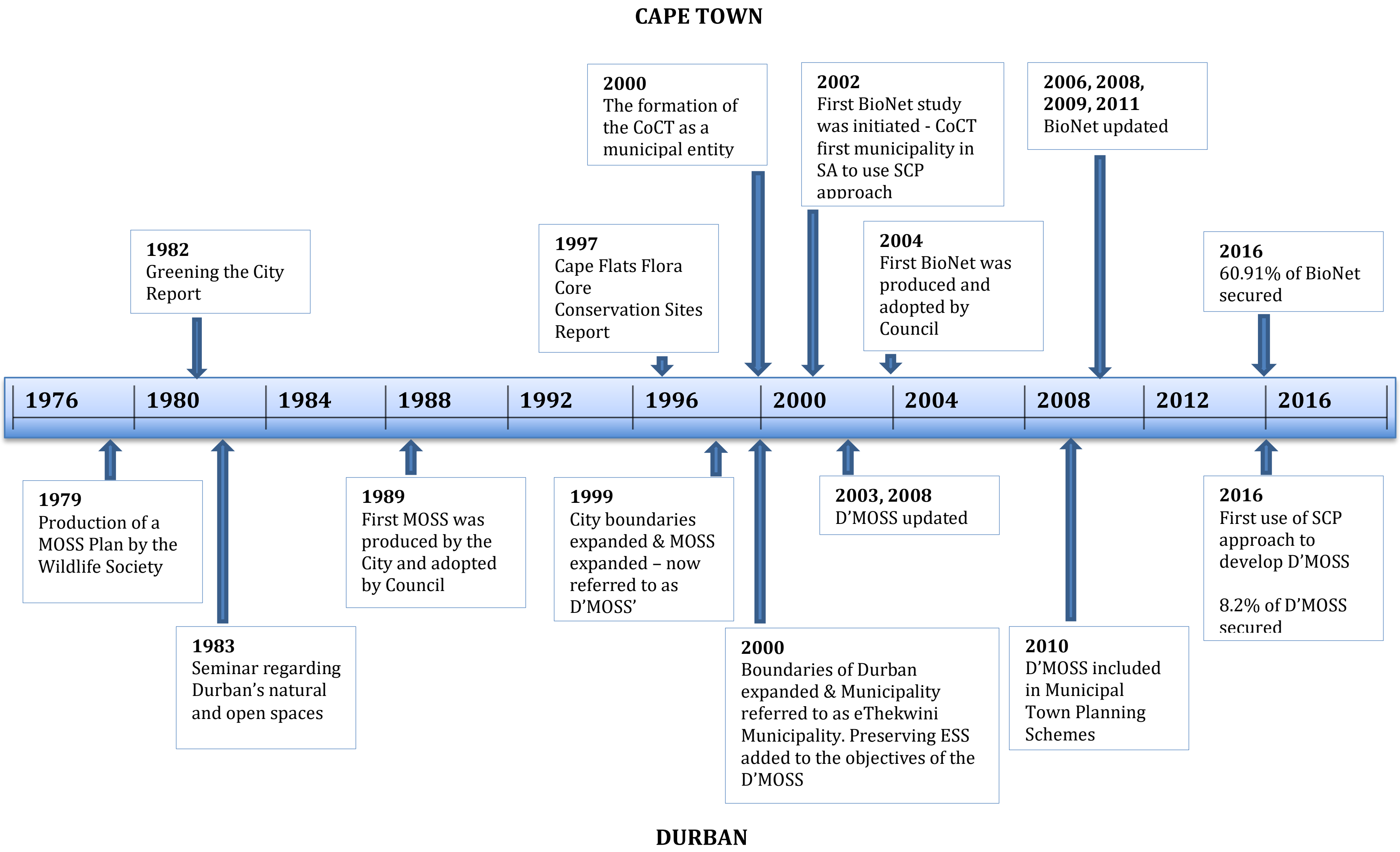

Figure 2.3: Timeline of the progression and development of policies and documents relating to the biodiversity and open space conservation systems in the cities of Cape Town and Durban

2.6.4 The Approach and use of the Systematic Conservation Planning methodology in the development of the BioNet and D'MOSS

As stated above, it has been reported that the emphasis of the D'MOSS had shifted from that of biodiversity and natural space conservation towards the provisioning of ESS (Cilliers & Siebert, 2012). However, according to the representatives from the eThekwini Municipality, the D'MOSS network has always been and is still centred on a biodiversity conservation perspective. The provisioning of ESS, while also contributing to the objectives of the D'MOSS, is used more as a marketing tool to sell the idea of conservation as well as the D'MOSS brand (N. Govender, pers. comm., 4 July 2017). The adoption of the SCP approach in the municipality validates their biodiversity centred approach. According to Cimon-Morin, Darveau and Poulin (2013), since the overall human valuation of biodiversity is low and may be insufficient to promote conservation, incorporating ESS into conservation plans and prioritising human well-being could prove to be a powerful incentive. Holmes et al. (2012: 7) further state that "it is important to present other key arguments for conserving biodiversity, which include the provision of ecosystem goods and services, job creation in the environmental and tourism sectors, and the building of a resilient, sustainable city". According to Ms Govender, the municipality has to constantly change its argument to stay relevant and to get recognition, buy-in and political support for its green layer (N. Govender, pers. comm., 4 April 2018). The municipality also uses the valuation of ESS and green economy projects as selling points to get conservation backing (N. Govender, pers. comm., 4 April 2018).

According to Holmes et al. (*in press*), apart from the CoCT, only two South African metropolitan municipalities have completed systematic conservation plans, namely: the eThekwini Municipality (as of 2016) and Nelson Mandela Bay Municipality in the Eastern Cape. Systematic Conservation Planning (Margules & Pressey, 2000) aims to identify a network of priority areas for conservation in order to meet biodiversity pattern and process targets (Cowling & Pressey 2003; SANBI, 2017a). In other words, it selects complementary areas of habitat in order to achieve explicit conservation targets that are designed to represent the full range of biodiversity and sustain its long-term survival (SANBI, 2017a; Gordon et al., 2009). Retaining habitat quality and connectivity simultaneously for multiple species are key features of the system. The method uses a rigorous, data-driven approach to meet conservation goals, which traditionally include representativeness, persistence and cost-efficiency (Margules & Sarkar, 2007, Cimon-Morin, Darveau & Poulin, 2014). Systematic Conservation Planning refers to the scientific methodology, as well as the broader planning process which involves the development of implementation strategies and tools and stakeholder collaborations (McLean et al., 2016). Systematic

Conservation Assessments on the other hand, generate the data to support the planning and implementation of conservation interventions and refers to the product used to identify priority areas for environmental action according to explicit goals or targets (McLean et al., 2016).

According to SANBI (2017a), with limited resources available for biodiversity conservation, it is essential to have a mechanism which prioritises areas for conservation action. The SCP approach represents best available science practice internationally (Margules & Sarkar, 2007; McLean et al., 2016) and is the standard approach to biodiversity planning in South Africa (SANBI, 2017a). The advantages of this scientific approach over more conventional methodologies such as vegetation studies and remote sensing include: repeatability, objectivity, efficiency and flexibility (eThekwini Municipality, 2017c). According to Gordon et al. (2009), software such as C-Plan, MARXAN and SITES are most commonly used to determine conservation networks that meet specified targets for protection while minimising other constraints such as costs (Gordon et al., 2009).

Systematic Conservation Planning techniques have been applied in many areas around the world (Margules & Pressey, 2000; Cowling & Pressey, 2003; Gordon et al., 2009). However, according to Gordon et al. (2009) these techniques have mostly been conducted in non-urban regions due to difficulties in undertaking conservation action in urban areas (Miller & Hobbs, 2002; Marzluff, 2002; Crossman et al., 2007). The undertaking of SCP methods in human dominated landscapes poses significant challenges, including: "the need to address multiple objectives, the likelihood that many priority areas will not be available for conservation and may degrade and alter in their availability over time" (Gordon et al., 2009: 184). Other difficulties include political pressures for development and economic growth, small parcels of land, high land prices as well as ownership of land (Gordon et al., 2009). In addition, according to Pressey et al. (2009), while the interactive design of networks of conservation areas has contributed significantly to planning processes around the world and has had real conservation outcomes, these systems are ultimately based on biodiversity targets and conservation priority areas and is a very systematic and biology-focused approach (Naidoo et al., 2006). This presents a problem when dealing with complex and interlinked peopled cities.

According to Marzluff (2002), the understanding of the complexities between the natural and urban environment in conservation planning is rudimentary. The advice given to urban planners by conservation scientists have been simplistic and refers to: preserving large areas of natural habitat, minimising edge, linking fragments with corridors, and maintaining keystone species (Marzluff, 2002). Such advice may be beneficial in vast, natural landscapes, but it does not translate in urbanising areas since it often fails to affect land use policy in a way that has beneficial consequences on the ground. The issue of conservation biologists placing relatively little emphasis on human dominated spaces may stem, in part, from deep-rooted traditions in conservation and ecology (Miller & Hobbs, 2002). Natural systems have often been thought of as undisturbed by humans and people have often been considered as separate from nature (Miller & Hobbs, 2002). However, urban regions are complex systems integrating both people and the natural environment. Hence, in order for conservation planning to be effective, it must be based on information derived from well-designed studies along the entire spectrum of land uses, from natural lands to the heavily populated urban environment (Miller & Hobbs, 2002).

In order to halt the global loss of the supply of ESS, a call has been made for the inclusion of ESS in conservation plans (Chan et al., 2006; Egoh et al., 2007; Cimon-Morin, Darveau & Poulin, 2014). The inclusion of ESS into conservation plans would allow for the development of an integrated approach to meeting different conservation objectives such as human well-being (Egoh et al., 2007). This would further contribute to improving the societal relevance of conservation planning, which should better support for effective conservation action (Egoh et al., 2007). Ecosystem services have gained an increase in attention in conservation assessments since the year 2000 (Egoh et al., 2007) and according to Cimon-Morin, Darveau and Poulin (2014), SCP is increasingly being recommended for the safeguarding of ESS provision. In order to include ESS in conservation planning, conservation goals must be expanded to address the spatial relationships between the supply of ESS and their human beneficiaries (Chan et al., 2006; Egoh et al., 2007; Cimon-Morin, Darveau & Poulin, 2014). More specifically, "ecosystems services conservation areas should be targeted as a complementary set of sites selected according to their capacity to ensure a sustainable and accessible supply of ecosystems services as well as deliver these benefits where they are needed" (Cimon-Morin, Darveau & Poulin, 2014: 12). Shifting the focus of conservation of biodiversity to include ESS requires broadening traditional conservation goals to better spatially link conservation actions to human beneficiaries (Cimon-Morin, Darveau & Poulin, 2014). However, while an increasing number of studies have included ESS into their conservation assessments (Chan et al., 2006; Egoh et al., 2007; Cimon-Morin, Darveau & Poulin, 2014), there is still a knowledge gap on how to effectively prioritise areas based on ESS provision, accessibility and demand (Egoh et al., 2007; Cimon-Morin, Darveau & Poulin, 2014).

It is clear that land use change and development around the world's urban regions is likely to be prevalent in the coming years. However, in order to prevent the further loss of biodiversity and natural habitat as well as to preserve the supply of ESS in the urban environment, conservation assessments will require a proper understanding of the ecology of ESS, its conservation and management requirements and the benefits to humans both in space and time (Egoh et al. 2007). According to Gordon et al. (2009), conservation planning tools must be incorporated into the various stages of urban land use planning in order to achieve better outcomes for biodiversity in urban areas. In this way, outputs from conservation planning can be used to plan for the future growth of cities and can help prevent developments in high valued sites (Gordon et al., 2009).

Over the years, the field of SCP has grown rapidly and has been applied in high-profile projects such as the selection of reserves in Australia, the Great Barrier Reef, and the CFR (Cowling & Pressey 2003; Langford et al., 2011; McIntosh et al., 2016). However, according to McIntosh et al. (2016:1), although there have been many systematic conservation plans developed around the globe, "the effects of systematic approaches on conservation actions and outcomes are not generally known, nor are the factors which distinguish effective from ineffective plans". In addition, previous evaluations of SCP outcomes have been limited in scope and to narrow time intervals, and have revealed very few formal evaluations of plans (McIntosh et al., 2016). Langford et al. (2011) state that the SCP method still encounters obstacles in bridging the gap from academic research to application and implementation. These obstacles range from undertaking conservation planning within a complex web of economic, social and political constraints (Langford et al., 2011).

2.6.5 The development and updating of conservation systems

The BioNet exists in the form of a GIS shapefile, with associated tabular information (Holmes & Pugnalin, 2016). The Cape Town municipality made use of GIS technology including: ESRI's GIS software, Spatial Analyst, biodiversity conservation planning software C-Plan and MARXAN/CLUZ, QGIS as well as Microsoft's Excel to prepare the data (Holmes & Pugnalin, 2016). Similar software is also used in Durban to produce the D'MOSS. According to Pressey et al. (2009) and Cowling and Pressey (2003) the target-based conservation planning software C-Plan, is an interactive software system linked to a geographic information system which presents spatial options for conservation management.

The BMB within the CoCT and the EPCPD in Durban are both responsible for compiling and updating their conservation networks. A major difference between these municipalities is that the CoCT has a dedicated environmental unit, which incorporates various environmental sectors such as biodiversity, coastal management etc. The eThekwini Municipality on the other hand, is not structured in this way and does not have a dedicated environmental unit. The various environmental sectors fall under different departments which are located in a whole range of units. The EPCPD itself lies within the Spatial Planning unit. In the case of the CoCT, the updating of the BioNet is an ongoing task and is updated continuously to reflect changes in the municipal area such as habitat loss and changing vegetation statistics. Cape Town is also the fastest developing city in South Africa, and hence there is more pressure at the city scale in having up-to-date, reliable maps. The EPCPD in Durban has an in-house conservation planner who is responsible for updating the D'MOSS. However, according to Mr Boon, the process of updating and getting the D'MOSS layer approved and adopted by Council is a lengthy and complicated process (R. Boon, pers. comm., 4 July 2017). The department would like to go through the process of updating and getting the policy adopted every two years. In addition, both conservation networks appear on the respective municipality's websites, giving users a picture of not only the situation on the ground but most importantly, where to focus their conservation efforts in light of biodiversity priority areas and remaining available open space (Holmes & Pugnalin, 2016).

2.6.6 The objectives and benefits of the conservation policies in each city

The cities of Cape Town and Durban are doing ground-breaking work to help conserve, protect and manage the biodiversity and natural spaces within their boundaries. Their biodiversity and open space conservation strategies have been formally recognised and help to conserve the important biodiversity assets found in these two cities. Other cities in the country which recognise the need to protect and conserve biodiversity and the natural environment include the Nelson Mandela Bay Municipality, who have implemented the Nelson Mandela Bay Open Space Management System (NMB MOSS) for the municipal area as well as the City of Johannesburg which has produced the Johannesburg Metropolitan Open Space System (JMOSS). Both systems address the management of natural open space resources and are regarded as a tool to conserve and protect biodiversity.

Generally, the strategic objective of both the BioNet and D'MOSS is to ensure the appropriate protection and management of all land which is important for the representation and persistence of biodiversity and ecological processes as well as the supply of ESS. The SCP approach, which is used in both cities provides a useful quantitative method for enhancing the persistence of biodiversity in the long term (McLean et al., 2016). Hence, both strategies are centred on the protection of biodiversity and natural space. This is achieved by various means and in collaboration with relevant stakeholders, for example, in partnership with the provincial conservation agency, private landowners and community-based organisations (Boon et al., 2016).

The conservation networks mainly include CBAs, ESAs as well as aquatic features such as wetlands and rivers. CBAs are essentially natural or near-natural features, habitats or landscapes (including terrestrial, aquatic and marine areas) that are considered critical for (i) meeting national and provincial biodiversity targets and thresholds, (ii) safeguarding areas required to ensure the persistence and functioning of species and ecosystems, including the delivery of ESS, and/or (iii) conserving important locations for biodiversity features or rare species (McLean et al., 2016). According to McLean et al. (2016) conservation of these areas is crucial, in that if these areas are not maintained in a natural or near-natural state, biodiversity conservation targets cannot be met. ESAs on the other hand, are functional, but not necessarily entirely natural, areas that are required to ensure the persistence and maintenance of biodiversity features and ecological processes within the CBAs (McLean et al., 2016). These areas are considered significant for a number of reasons, including: connectivity for species in the area, provision of ESS, and sites to be restored for habitat targets (McLean et al., 2016).

Apart from contributing to the attainment of national and provincial biodiversity conservation targets, the conservation of biodiversity provides for the protection of ESS which helps sustain the functioning of crucial life support systems (eThekwini Municipality, 2017c). The value of ESS, and the contributions they make to human welfare, represent part of the total economic value of the planet (Costanza et al., 1997). Cape Town's natural assets produce a flow of goods and services that have a net value estimated to be between R43 billion and R82 billion (De Wit et al., 2009). In addition, according to a World Bank report produced in 2017, natural and semi-natural systems within the EMA gives rise to flows of ESS worth at least R4.2 billion per year (eThekwini Municipality, 2017c), with the total asset value of these areas was estimated to be between R48 billion and R62 billion (eThekwini Municipality, 2017c). The contribution of natural capital including forests, wetlands, and natural land is an emerging concept known as Natural Capital Accounting which is used as a key mechanism to integrate the value of the environment and its services into the economic system (The World Bank, 2016b). According to the World Bank (2016b: 1), "natural capital is a critical asset, especially for developing countries where it makes up a significant share (36%) of total wealth". It is also used to highlight the importance of natural resources and the provision of ESS as well as to gain public and political support.

2.6.7 Current status of the conservation systems

Cape Town has six endemic vegetation types, meaning that they can only be conserved within the boundaries of the City. Holmes et al. (2012) put the conservation importance of Cape Town in perspective, stating that both locally and globally, nearly half of the country's most threatened ecosystems occur in Cape Town. Cape Town is also the only city in South Africa that has a national park within its borders. The TMNP is an iconic landmark which is extraordinarily rich in endemic plants and animals and is entirely surrounded by a city. Other cities with national parks within their boundaries include: the megacity of Mumbai which protects 104 km^2 within the Sanjay Gandhi National Park; and the city of Stockholm which includes the National Urban Park, comprising and protecting approximately 2700 hectares of rich biodiversity, right in the city centre (Secretariat of the Convention on Biological Diversity, 2012). Hence, while cities are faced with severe land use pressure as a result of urbanisation, it also challenges the common assumption that cities cannot have high levels of biodiversity (Secretariat of the Convention on Biological Diversity, 2012).

As mentioned previously, Cape Town lies within the CFR, a global biodiversity hotspot and thus its land area was incorporated as part of the conservation plan. According to Cilliers and Siebert (2012) this in itself provided a biodiversity theme to the early momentum of urban ecology in Cape Town. The BioNet is further centred on this biodiversity-centred approach. In addition, the approach has been that biodiversity and natural ecosystems contribute many ESS, and securing ecological processes as well as biodiversity pattern will help ensure the ongoing delivery of those services (P. Holmes, pers. comm., 17 October 2017). According to Egoh et al. (2007), in many conservation assessments, it is often assumed that conserving a biodiversity pattern will also conserve ESS. However, given the complexity of the relationship between biodiversity and ESS, there is limited evidence of spatial congruence between areas important to species conservation and those important to ESS (Egoh et al., 2007; Cimon-Morin, Darveau & Poulin, 2013).

According to the State of Cape Town Report (2016), although the total area of biodiversity lost has indeed increased, the total area under formal protection has expanded over the past century, with significant increases since the mid-1990s. The TMNP and mountainous areas of the City have always been well conserved and added to approximately 30% of the BioNet being secured when the analysis first started (P. Holmes, pers. comm., 26 May 2017). Cape Town is fortunate in that its mountainous areas are well conserved and take up a large portion of its conservation plan. As of 2016, CBAs comprising natural remnants along with critical ESAs covered approximately 87206 hectares of the City. According to Holmes and Pugnalin (2016), the BioNet lies mainly outside the urban edge with only 15% located inside the urban edge. In 2016, 60.91% of the BioNet (including both protected categories and conservation areas) had been secured and placed under conservation (P. Holmes, pers. comm., 17 October 2017). This achievement was considered remarkable and indicated Cape Town's commitment to long-term biodiversity conservation in the City. The CoCT further aims to have 65% of the BioNet conserved by 2019 (City of Cape Town, 2015). There are also plans for a new initiative in the CoCT called the Green Infrastructure Plan (GIP), which will cover the entire Cape Town area. The plan will serve as a planning and management tool for natural systems and open spaces in the City, including: nature reserves, parks, public open space, rivers, wetlands and the coast as well as the inclusion of the BioNet (City of Cape Town, 2017c). According to the City of Cape Town (2017c), the ESS that these natural assets provide will be a specific focus.

Although the City of Durban is not as well-known as Cape Town for its unique biodiversity, it is still wonderfully diverse and occurs in the Maputaland-Pondoland Region of Floristic Endemism (Cilliers, 2010). In addition, unlike Cape Town, Durban does not have large mountainous areas which can be conserved as a unit. By 2016, only 8.2% of the total area of the 78781 hectares (approximately one third of the EMA) of the D'MOSS enjoyed some form of protection (eThekwini Municipality, 2017b). This includes various categories of protection, including: "proclaimed and un-proclaimed private or public nature reserves; properties that have been acquired through the eThekwini Municipality's environmental land acquisition programme; sites where sensitive portions have been protected by non-user conservation servitudes during the development approval process; and sites that have been rezoned for conservation" (eThekwini Municipality, 2017b: 7). Hence, less than 3% of the entire EMA is protected. According to the eThekwini Municipality, (2017b) this figure is below the Convention on Biological Diversity's (CBD's) requirement for all governments to protect a minimum of 17% of terrestrial and inland water areas and 10% of marine and coastal areas. Furthermore, approximately 7.7% of the D'MOSS is formally managed for conservation (eThekwini

Municipality, 2017b). The management of D'MOSS areas are undertaken by various departments and agencies including the EPCPD and the Natural Resources Division of the Parks, Leisure and Cemeteries Department. According to the eThekwini Municipality's Integrated Development Plan (IDP) (2017f) an estimated 42% of the total area of D'MOSS is physically undevelopable. In addition, approximately 34% of this total area is in private or communal ownership (eThekwini Municipality, 2017f). Thus, while there are regions of undevelopable land, the municipality is still faced with challenges in getting these natural spaces into conservation.

The cities of Cape Town and Durban can be described as being at the forefront of biodiversity conservation in South Africa, with their conservation strategies seen as being aligned with other biodiversity and open space strategies around the world. In 2014, the City of Surrey produced a Biodiversity Conservation Strategy, with a main goal to preserve, protect, and enhance the City's biodiversity in the long-term (City of Surrey, n.d). The strategy also includes a Green Infrastructure Network, which is an interconnected system of natural and open spaces that conserves ecosystem functioning, while providing benefits to both wildlife and people. In addition, the cities of Edmonton and Montréal have also become active contributors to biodiversity conservation practices. Embedded in these cities' biodiversity planning and management frameworks is an 'Ecological Network Approach'. This model essentially comprises core biodiversity areas, corridors/linkages, stepping stones and buffer zones which allows for the expansion of ecosystems and species dispersal (ICLEI, 2013). The approach essentially embodies a methodology that includes urban areas as part of the overall ecological matrix, where ecologically important areas are conserved, and the region's environmental integrity is upheld. The cities of Edmonton and Montréal further recognise the importance of local governance in biodiversity management, and as a result, biodiversity considerations are integrated into other municipal plans (ICLEI, 2013). Other cities, including Hong Kong and Melbourne, have also formulated their own strategies in relation to biodiversity and natural space conservation, including a City-level Biodiversity Strategy and Action Plan in Hong Kong (Environmental Bureau, 2016) and a green strategy called 'Nature in the City' in Melbourne (City of Melbourne, n.d). Cities around the globe are stepping up with regards to biodiversity conservation practices and supporting sustainable development within the city context. Whilst management strategies, implementation practices and approaches may differ with respect to each city, the overall objective of conserving biodiversity and ecosystems for the well-being of the people and the biophysical environment remains the same. The cities of Cape Town and Durban are among other leading global cities in prioritising their agendas.

2.6.8 City led initiatives and implementation tools regarding biodiversity and open space conservation in the cities of Cape Town and Durban

Cape Town

Cities in South Africa are inherently different and have unique histories, configurations and challenges. This means it is not possible or practical to be prescriptive about specific interventions and implementation strategies. Despite significant challenges, the CoCT's BMB, who work closely with the spatial planning department, have been successful in securing more of the BioNet through a range of innovative measures to improve the conservation of biodiversity (included in Table 2.3). A key factor and a powerful tool in the success is undertaking both the planning and implementation simultaneously. In addition, collaboration with national and provincial conservation partners has been vital in implementing these tools. According to Dr Holmes, the following tools and projects have been used in the implementation of the BioNet (P. Holmes, pers. comm., 26 May 2017).

Table 2.3: Implementation tools used in the City of Cape Town

1. Proclaiming, securing and managing land with biodiversity value	The first step was for the municipality to try and get most of the City's managed areas, proclaimed and secured. This further includes the management of the land, since a piece of land would not be secured unless it is managed. The next step was to identify all other parcels of state land which have biodiversity value and seeing which areas can be transferred to the City for management. In this case the department acquires the land as well as the risk and manages it with the help of the local communities as far as possible.
2. Provincial Priorities	Establishing partnerships with the Provincial department in order to conserve and protect vital biodiversity rich areas together.
3. Ecological Restoration	Getting surrounding degraded areas incorporated into protected areas and restoring them.
5. Stewardship agreements	Biodiversity stewardship is a method by which conservation authorities enter into legal agreements with private or communal landowners, who secure their land for biodiversity while retaining ownership in return for benefits such as tax rebates. The BMB has a dedicated team to deal with the management of the land after agreements have been signed since this is a difficult task which requires establishing management plans and conducting audits. The BMB also works with the Cape West Coast Biosphere Reserve, who assist with resources and the removal of alien vegetation from private land.
6. The Conservation Implementation Plan (CIP) for the Cape Flats Dune Strandveld in the Metro South-East	The Metro South-East is the fastest growing area in Cape Town, where targets of the Endangered Cape Flats Dune Strandveld (unique to the region) can no longer be met in the area. Unfortunately, developments cannot be stopped in the region and hence the area needs to be managed urgently. The rationale of the Strandveld CIP is to secure a subset of the biodiversity target while facilitating development and climate change adaptation. The City therefore, hopes to consolidate and manage the important remnants of this vegetation type within a dedicated conservation area by means of a vegetation type implementation plan. The Strandveld CIP aims to conserve ~15% of the historical vegetation instead of the 24% target. The City would essentially provide operational management resources proactively to manage a smaller set of land while supporting development of the remaining land. The Strandveld CIP case describes an innovative and pragmatic approach for a specific ecosystem under imminent threat owing to its location (Holmes et al., *in press*). In cases such as these, pragmatic decision making and conserving a smaller set of the vegetation type can result in greater gains for conservation rather than the option of no development.

7. Atlantis land-banking project	This is an initiative in Atlantis where there is around 900 hectares of critical biodiversity left within the urban edge. The City however, can still meet the targets of those vegetation types outside the urban edge. Hence, instead of impeding developments within the urban edge, the City land banks (land held by a public or private organisation for future sale or development) areas outside the City and eventually when there is enough capital budget left, the land can be transferred and the City can try to buy the land from private owners and transfer it into conservation. Thereafter, if a developer comes along in the industrial area, they will not have to do the botanical work for the EIA process and hence this saves an additional cost to the developer. They will also not have to mitigate with an offset since the city has done it for them. This process therefore encourages industry to establish businesses in the Atlantis area which has an 80% unemployment rate.

According to Holmes et al. (2012), the BMB and its partners, are making progress in implementing the BioNet, but stronger political commitment is needed at all levels of government. Another particular challenge in the CoCT is conservation stewardship on private land, where landowners resist entering into agreements with the City Department (see section 2.5.9 below). According to Holmes et al. (2012), the most important tools for securing priority areas of the BioNet are: incorporating the plan into City spatial plans; communication, public awareness and education; negotiating appropriate management of public land; and conservation stewardship on private land (Holmes et al., 2012). However, it is unlikely that full success will be achieved without international or national funding and political will at all levels of government (Holmes et al., 2012).

Durban

According to Mr Boon, the situation of the EPCPD being positioned within the Spatial Planning department has been highly beneficial to getting the D'MOSS implemented in Durban (R. Boon, pers. comm., 4 July 2017). The department also has an in-house planner which helps in the prioritisation of environmental issues. This is a critical difference between the BioNet and D'MOSS and indicates the significant role that town planners and planning tools have on the D'MOSS. The key tools and methods used in the implementation of the D'MOSS are included in Table 2.4 below.

Table 2.4: Implementation tools used in the eThekwini Municipality

1. Integration of D'MOSS into the Municipality's Town Planning Schemes	The D'MOSS is incorporated into the City's town planning schemes and imposes environmental controls as the D'MOSS is used as a development overlay. If the D'MOSS layer is situated on a piece of land, which is intended to be developed or re-zoned, the landowner will need to substantiate that application with an environmental assessment which includes the environmental impacts of the proposal. This is considered an equivalent to an EIA process. The application is then reviewed and considered by the EPCPD. In this way, all developments or land transformation within D'MOSS are subject to approval by EPCPD. This process offers the most opportunity for ensuring compliance.
2. Planning tools	Since D'MOSS is not a formal zone within the municipal town planning schemes, developments are not precluded. The department therefore uses zones to further secure land that is of conservation importance. These include the Environmental Conservation Reserve and Conservation Zones. Nature Reserves are also proclaimed in order to ensure the highest level of protection in terms of The National Environmental Management Act (NEMA). After the department acquires land, it is usually zoned for conservation.
3. Municipal Rating System	This system is used in two ways. Firstly, through the creation of an Environmental Special Rating Area. In the area of the Giba Gorge environmental precinct for example, landowners contribute a little more to their rates every month and this money is put towards the conservation of Giba Gorge. Secondly, through the rates policy which essentially gives landowners a rates rebate if they: (1) had D'MOSS on their property; (2) if the land was zoned for conservation; and (3) if they were managing the land (i.e as a reserve).
4. Land acquisition programme	This programme prioritises CBAs, especially where other means of protection are ineffective or non-existent. In this case the municipality tries to increase the area of conservation estate by identifying pieces of land which have critical biodiversity assets and then identifying which of these areas can be purchased or transferred to the City for management. Land securement is the most effective way for municipalities to protect biodiversity and valuable areas. The programme originally focused on areas adjacent to nature reserves to increase the protected areas. After the land is acquired, the Restoration Ecology Branch is responsible for managing the land acquired. The majority of the properties that are acquired contain Critically Endangered KZN Sandstone Sourveld grassland, which has undergone considerable transformation throughout its range.
5. Stewardship agreements	Securing properties by entering into agreements with private landowners. The department is also trying to secure more of the Ingonyama Trust land by getting into biodiversity agreements with the traditional leadership groups of the area.

6. Nature Reserve Proclamation	The Municipality is currently working in partnership with Ezemvelo KZN Wildlife to proclaim eleven municipal Nature Reserves in terms of the Protected Areas Act. The areas currently have varying levels of legal protection, with a small number of sites zoned for 'Environmental Conservation Reserve'. The proclamation of these reserves will ensure the formal protection and conservation of the sites.

The EPCPD has made considerable progress by integrating the D'MOSS into the City's municipal town planning schemes. The eThekwini Municipality however, is faced with a particular challenge with regards to the administration and governance of municipal land. According to Mr Boon, in 2016, 38% of the EMA was jointly governed by the eThekwini Municipality and the traditional authority known as the Ingonyama Trust Board, with primary responsibilities falling under the latter (R. Boon, pers. comm., 4 July 2017; The World Bank, 2016a; Boon et al., 2016). The areas formally administered by the eThekwini Municipality occupied approximately 36% of the EMA (as part of its town planning schemes), while another 26% of the area fell under non-scheme agriculture areas, administered jointly by local and provincial government (The World Bank, 2016a). These figures however, would have likely changed since the incorporation of the Vulamehlo Local Municipality in the EMA. The Ingonyama Trust land covered an area of about 2.7 million hectares in extent, and spreads throughout the province of KZN (The World Bank, 2016a). Most areas under the Ingonyama Trust are of high biodiversity value, but since the traditional leadership structures in these areas are stronger than the local government, the land essentially falls under the Ingonyama Trust (R. Boon, pers. comm., 4 July 2017). A large part of the Outer West region (approximately 50%) of the EMA comprises communal lands (see Figure 2.4), which consists of large tracts of conservation worthy land (eThekwini Municipality, 2017e). According to the eThekwini Municipality (2017e), approximately 50% of the D'MOSS, which requires protection is found within this region. Unfortunately, there is a high level of distrust, which in the City's view, makes securing these biodiversity rich sites particularly challenging (N. Govender, pers. comm., 4 July 2017). In addition, whilst municipal plans show these parcels of land to be rural, "the current rate of development that is taking place without development restrictions or planning is resulting in the rapid transformation of these areas through the construction of new residential developments" (Davids et al., 2016: 4).

In rural areas under traditional authority leadership, customary land management systems are exercised. Currently, there are no land use schemes in traditional authority areas, with approximately only one third of the municipality having land use management schemes prepared and adopted. However, Section 24 of the newly enacted Spatial Planning & Land Use

Management Act 16 of 2013 (SPLUMA) (see Appendix A), requires all municipalities to adopt a single land use scheme for its entire area, within 5 years after the commencement of SPLUMA (The South African Government, 2013). While the eThekwini Municipality is committed to this, it is also mindful that the process has to be treated sensitively in these traditional tribal areas which makes meaningful progress slow in this regard (eThekwini Municipality, 2017e). It is unlikely that this process will be completed by 2018/2019, since it also requires the acceptance and buy-in from the traditional areas and Councils.

Since D'MOSS is a provision of the town planning schemes and there are currently no land use schemes in these areas, the traditional allocation of land for residential use in areas with high biodiversity value is able to bypass D'MOSS approval (Sutherland et al., 2016). According to the eThekwini Municipality (2017f), outside of scheme areas the D'MOSS operates as a policy of the Council. There is no way to regulate, manage or stop developments in these areas. According to Ms Govender, the department is trying to establish biodiversity stewardship agreements with the traditional leaders, known collectively as the *Amakhosi* (N. Govender, pers. comm., 4 July 2017).

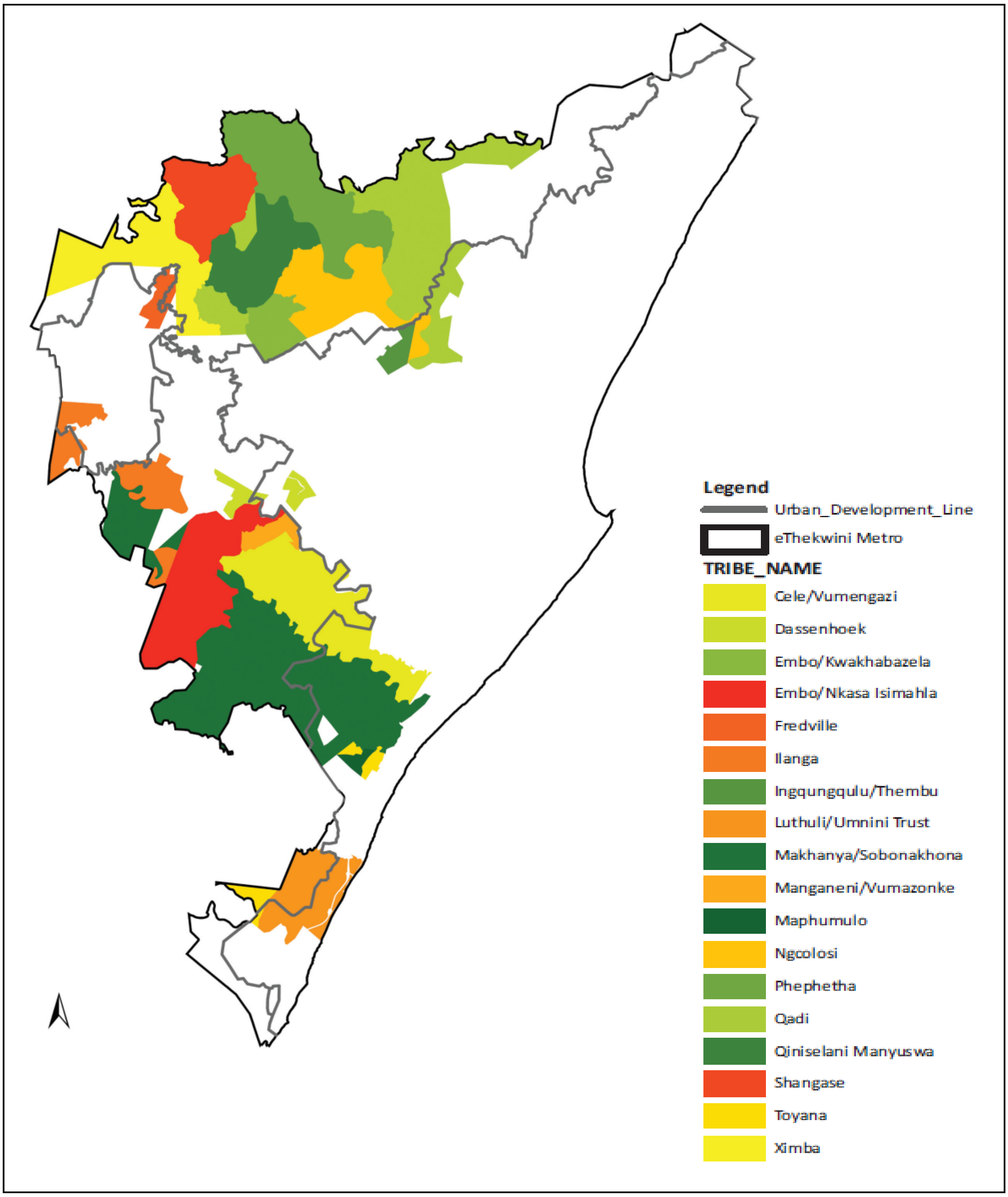

Figure 2.4: Traditional Authority areas within the eThekwini Municipal Area (old boundary) governed under the Ingonyama Trust Board (Source: Sutherland et al., 2016).

2.6.9 Challenges faced in the implementation of the biodiversity and open space strategies in Cape Town and Durban

The implementation tools used in the cities of Cape Town and Durban are similar to methods used in other cities around the world, including the cities of Surrey and Hong Kong. In South Africa however, despite the country's legislation and policies relating to biodiversity (see Appendix A), there is a lack of a clear biodiversity mandate, resources, skills and capacity for biodiversity management at the local level. Important factors such as incorporating the conservation plans into municipal spatial plans; gaining and maintaining political support; communicating with the public and raising public awareness; negotiating appropriate management of public land and conservation stewardship on private land, present many challenges in getting the conservation plans implemented. In addition, land acquisition is not always feasible nor affordable. Hence, the implementation of biodiversity and open space strategies is a difficult task. The main issues presented in the CoCT seem to be the issue of gaining and maintaining political support and the issue of private landowners not wanting to enter into biodiversity agreements. Significant challenges faced in Durban include the dual governance system shared by the eThekwini Municipality and the traditional authority and gaining and maintaining political support. In both these cases, underlying issues around trust and collaboration seem to be critical.

Conservation stewardship agreements with landowners

A major challenge faced in the implementation of the conservation strategies is that firstly, many environmentally sensitive areas under threat of development are privately and/or variably owned and cannot be easily acquired or protected from such development. Privately owned land usually makes up a significant proportion of a municipality's land and green space area. Engaging with private land owners to encourage stewardship and biodiversity awareness greatly enhances regional biodiversity and sustainable practices. However, there are many landowners who own large tracts of land of conservation importance, who are simply not interested in entering into stewardship agreements with city departments. This is due to many landowners having development aspirations and who are not be interested in biodiversity conservation. This results in large tracts of land with high biodiversity value being lost and degraded as they are not secured, protected or managed for biodiversity conservation. A key example for the CoCT is a large private estate of 3000 hectares in the Helderberg region, which is being invaded by pines, a fire-prone invasive alien species, that causes important indigenous vegetation to be overrun and lost through habitat transformation. The private landowner in this case is not interested in entering into a stewardship agreement with the CoCT (P. Holmes, pers. comm., 26 May 2017).

Restricting people's development rights

According to Ms Govender, many people also view the D'MOSS as 'exclusionary', because it restricts a person from developing on their land and is seen as taking away people's rights (N. Govender, pers. comm., 4 July 2017). The impact of having the D'MOSS integrated into the town planning schemes is that land is subject to development restrictions to maintain environmental integrity. These restrictions are often a problem for private landowners.

One of the other major challenges found in South Africa is the legacy of Apartheid Planning, where green open spaces were used as buffer zones to separate and divide the residential areas of different race groups. Land essentially underpins all human activity and has very deep emotional, cultural and political significance, especially in South Africa, which is why addressing any land issues in the country has always been fraught with tension (South African Cities Network [SACN], 2016). The issue of indigenous forms of governance (such as traditional authorities) and their integration with local governance, has proven to be difficult and problematic. It is not always easy to proclaim and protect natural land. The SACN Report (2016: 64) states that competing land interests need to be managed carefully since land is a "finite resource required for different and competing uses, from economic activity and meeting justice and restitution goals, to ensuring environmental and economic sustainability".

Gaining and maintaining political support for biodiversity and open space conservation

Another vital issue is gaining and maintaining political support for biodiversity conservation. More often than not, developments gain more political support and are given the go ahead despite their negative impact on the natural environment. In spite of the commitments regarding the conservation of biodiversity, conflicts between biodiversity conservation and the development of land for economic and population growth are acute (Gordon et al., 2009). In most cases, economic developments are usually favoured over the protection of biodiversity and the environment. This is largely because these developments produce a lot of revenue and create economic opportunities for both developers and the State. This suggests that there may be some internal conflict within local government, between competing policies and interests from different departments. Therefore, decisions usually tend to favour and maximise social-economic outcomes at the expense of ecological integrity. This causes globally significant biodiversity to be lost and the country and cities acting in contravention of their international treaties. According to Holmes et al. (2012), while South Africa is a signatory to various international instruments, has well developed biodiversity legislation and policies that embody those principles as well as various implementation projects and initiatives to conserve biodiversity, conservation action on the ground is slow, indicating a policy-practice divide. Political endorsement and a receptive political and institutional environment for the protection of natural space is crucial (ICLEI, 2012). Given the competing needs for both municipal resources and land, communication with and the support of local politicians is perhaps one of the most vital ingredients in the recipe for successful implementation of biodiversity conservation plans (ICLEI, 2012). It is therefore important to be able to articulate the value of biodiversity areas into the political spectrum as it is unlikely that full success of implementation plans will be achieved without political support and will at all levels of government (Holmes et al., 2012).

According to Barau, Ludin and Said (2013), there are many consequences for the neglect of urban biodiversity in the process of urban development in Africa. If we take the example of Kano city in Nigeria, rapid urbanisation has done serious damage to its biodiversity. The City has sustained one of the highest population densities in sub-Saharan Africa and consequently, it has progressively lost a large amount of its open spaces, scrublands, and ponds through urbanisation, gentrification and densification (Barau, Ludin & Said, 2013). This ultimately leads to the elimination of vital urban ecosystems.

Traditional authorities and dual-governance of land

In Africa, traditional authorities and customary forms of governance remain important and are deeply rooted in local institutions (Beall & Ngonyama, 2009). This holds true for countries including Ghana, Botswana and Zimbabwe (Beall & Ngonyama, 2009). South Africa is no different in having to accommodate indigenous institutions in its political order. Traditional leadership is recognised in terms of Section 211 of the Constitution which states that the institution, status and roles of traditional leaders, according to customary law, are recognised (The South African Government, 1996). Traditional authorities are the government closest to the people and many communities in which traditional leaders serve, regard them as leaders and symbols of unity in the community.

When it comes to traditional and municipal governance, traditional authorities and municipalities operate on two entirely different and separate administrative regimes and their planning and implementation systems are not always aligned (The World Bank, 2016a). As stated, the Ingonyama Trust land in the EMA, is governed by the Ingonyama Trust Board, which essentially make decisions on how to govern and manage activities in these areas. The Trust was established in 1994 by the KwaZulu-Natal Ingonyama Trust Act to improve the quality of life of the people living on the land and to manage the land for the benefit, material welfare and social well-being of the tribes and communities (Ingonyama Trust Board, 2014; Davids et al., 2016). The traditional authorities are required to inform and seek counsel from the municipality on land use decisions within Trust land. However, such co-ordination does not always occur consistently (The World Bank, 2016a). In addition, local government should not interfere with traditional land without prior consultation with the relevant authority, who will need to consult with the members of the community (Traditional Authorities Research Group, 1999). While the Trust Board has the authority to decide on affairs regarding its land, the Trust, Traditional Council, and rural residents are not exempt from adhering to the requirements of National and Provincial legislation or Local Authority By-laws (The World Bank, 2016a; Sutherland, 2016). In the case of the environmental regulations, the formal and adopted frameworks still regulate the use of the environment and natural resources on Trust land (The World Bank, 2016a; Sutherland, 2016).

According to Durban's Municipal Spatial Development Framework (2017), rural areas of the eThekwini Municipality make up about 68% of the municipal area which falls beyond the urban development line, with communal land occupancy under the ownership of the Ingonyama Trust Board and traditional authorities (eThekwini Municipality, 2017e). Of this percentage, 90% is defined by its geospatial features, including hilly, rugged terrain, dispersed settlement patterns in traditional dwellings and communal land properties under the Ingonyama Trust, whilst about 10% comprises commercial farms and metropolitan open space (eThekwini Municipality, 2017e). The remainder of the municipal area, approximately 32%, is urban and is dominated by residential, commercial and industrial land uses (eThekwini Municipality, 2017e).

According to Khan, Lootvoet and Vawda (2006; 86), "the eThekwini Municipality is unique as it represents the only urban environment in the country in which adaptation to co-operative forms of governance involving traditional leaders is being tested out at a metropolitan level". This institutional arrangement in the EMA, however, presents a number of challenges particularly with respect to land, planning and urban management (eThekwini Municipality, 2017e; Sutherland et al., 2016). Hence, the structures governing the cities of Cape Town and Durban are different, with there being no traditional leaders and no dual governance of municipal land in Cape Town. The eThekwini Municipality therefore, has certain challenges and opposing forms of governance which they have to overcome in order to protect the remnant biodiversity rich areas in the EMA.

Cost of security and management of land acquired for conservation

Another challenge presented to municipalities are the costs associated with acquiring conservation worthy land and the subsequent management and protection of that land (P. Holmes, pers. comm., 26 May 2017). However, without the acquisition and management of natural land for conservation, many of these areas would be lost to development. In many cases, especially when landowners are not interested in conservation, the municipality has to purchase the land in order to avoid further loss of priority areas of biodiversity. In addition, management interventions in natural areas are particularly important, preventing degradation and transformation by invasive alien plants. Land with high conservation value should be protected and managed to ensure the continued provision of ESS to enhance its contribution to the ecological viability of the broader system. Hence, local governments need to set objectives and manage the land to prevent degradation and secure biodiversity rich areas.

Ensuring that biodiversity management strategies are implemented is also difficult as it requires a dedicated implementation team and a management authority who is responsible for managing and protecting natural areas. The CoCT is fortunate in this regard, in that they have a dedicated biodiversity team (Holmes et al., 2012; Cilliers & Siebert, 2012) which currently operates with a permanent staff component of over 170, and manages 16 protected areas; undertakes SCP, conservation stewardship, a range of off-protected area activities and protected area expansion, invasive species control, job creation and skills development, environmental education and awareness, and land use advice (Wood et al., *in press*). In Durban, conservation areas are managed by two municipal departments, including the EPCPD and the Natural Resources Management Division of the Parks, Leisure and Cemeteries Department (Parks department) who is responsible for the management of Durban's nature reserves (Davids et al., 2016; N. Govender, pers. comm., 4 July 2017). However, the City realised that the Parks department lacked sufficient expertise and resources to take on additional responsibilities including newly proclaimed land under the conservation plan (Boon et al., 2016; N. Govender, pers. comm., 4 July 2017). As a result of this, the EPCPD created an additional branch for implementation through large scale projects such as restoration, known as the Restoration Ecology Branch, which as stated manages those additional areas that the City secured through land acquisition and runs the City's Green Economy Projects.

Communication, education and raising public awareness

Community engagement, education and training as well as raising public awareness for the support of biodiversity conservation is of critical importance, especially since conservation implementation is a transdisciplinary process (Holmes et al., 2012). People need to value biodiversity and the many ESS that it provides. However, although municipalities try communicating the importance of green open spaces and biological features, city departments often have to find new methods and create incentives to get people to participate in biodiversity conservation. Cimon-Morin, Darveau and Poulin (2013) state that the conservation of biodiversity can be difficult to justify, since most people interpret biodiversity as goods, whose worth is mainly determined by aesthetic, recreational, cultural, existential and intrinsic values. In keeping with global trends, both cities in this study draw on ESS and value methods to gather support for biodiversity (Chan et al., 2006; Egoh et al., 2007; De Wit et al., 2009; Cimon-Morin, Darveau & Poulin, 2014). Durban uses green economy projects as a method to get buy-in from the community for the work that the City does in terms of sustainability and the environment. However, the public is sometimes set against such initiatives and fail to understand the reasoning behind protecting and securing vast amounts of natural land. When interviewed on 4 July 2017, Ms Govender stated that people are not really interested in conservation just for conservation sake. However, concepts like climate change have taken off drastically even though it is a much more recent concept.

ICLEI's INTERACT-Bio project is a global project taking place in three countries in the Global South: Brazil, Tanzania and India. One of the objectives of the project is to provide training to stakeholders on ecosystem valuation and prioritization and thereby creating awareness of the values of nature and biodiversity and the steps that can be taken to conserve and benefit from nature. The project supports all levels of government, from national to local, to integrate their efforts for mainstreaming biodiversity and ESS into core subnational government functions such as spatial planning, land-use management and local economic development (ICLEI's Cities Biodiversity Center, n.d).

Biodiversity, open space governance and creating partnerships with local departments

According to the ICLEI (2012), the separation of different local government departments and functions, which have influence upon the environment, provides a significant challenge to biodiversity planning and management since views may differ. Elmqvist et al. (2013) state that, although the governance regarding biodiversity conservation and ESS is extremely important, it is also extremely complex. The environmental agenda of cities is intertwined with a number of issues and competing priorities and interests, as well as multiple temporal and spatial scales of ecosystem processes and their relation to numerous influencing and impacted actors. Furthermore, public institutions also experience a lack of co-operation and co-ordination across departments and levels of authority, and often lack the requisite capacity to handle diverse information and deal with change to respond to numerous environmental problems (Elmqvist et al., 2013).

It is important for municipal departments dealing with environmental issues to develop partnerships and to communicate amongst themselves and with stakeholders when establishing overarching goals and objectives which can be supported within the city administration. Biodiversity and ecosystems need to be valued and managed as part of a city's infrastructure. In addition, biodiversity needs to be integrated into all aspects of local governance including urban and financial planning, infrastructure development, economic incentive mechanisms, procurement policies, transportation and service delivery.

Multi-level governance and support for biodiversity and open space conservation in other policy sectors

The signing of international treaties by national governments (see Appendix A), means that all organs of state must embrace the responsibilities and implications of those treaties. However, this is unlikely if legislation and regulatory actions are distributed across various government structures. The extensive range of legislation involving various aspects of natural resource management, together with the three-tier system of government, has resulted in a number of government departments and agencies being responsible for environmental conservation and the management of protected areas the country (Pool-Stanvliet et al., 2017). All departments and agencies need to work to the same set of conservation priorities and co-ordinate their efforts in conserving biodiversity and open space (Pool-Stanvliet et al., 2017).

A further problem is created by conflicting policies such as the national housing policy which aims to provide formal housing, "but with insufficient funds to minimise the development footprint and loss of CBAs" in Cape Town (Holmes et al. 2012: 9). According to Roux et al. (2008), the defining feature of sustainable development is the incorporation of environmental policy objectives into other policy sectors. This would remove conflicts between and within policies of different sectors so that policies become mutually supportive (Roux et al. 2008).

2.6.10 The influence of the conservation systems at the local level in each city

According to Holmes et al. (2012) and Goodness and Anderson (2013), while the BioNet does not yet have legal status to serve in the protection of natural land, it does serve as a flag during the Environmental Impact Assessment (EIA) process and has been incorporated into the City's SDF, eight Spatial Development Plans and accompanying EMFs. Thus, establishing a foundation for future implementation action. It was further taken into account when devising the Western Cape's Spatial Biodiversity Framework (2010) and has been fully integrated into the Western Cape's Biodiversity Spatial Plan (2017). The City's latest IDP (2017-2022) has also included a biodiversity management project, which aims to securing the protection of a targeted 65% of the BioNet (City of Cape Town, 2017c). According to Holmes et al. (2012), the BioNet is recognised by the national and provincial environmental and conservation sectors and is used to inform environmental and land use decision making processes at all levels of government. However, while the BioNet does inform the IDP, SDF and district plans of the City, it does not preclude development since the municipal town planning schemes and relevant zoning schemes have more power than the SDF (P. Holmes, pers. comm., 26 May 2017).

Like the BioNet, the D'MOSS does not have legal status to serve in the protection of natural space, but it is incorporated into the City's IDP, SDF, regional Spatial Development Plans and into the Municipal town planning schemes as a controlled development layer (eThekwini Municipality, 2017b; Roberts & O'Donoghue, 2013). According to Boon et al. (2016), the D'MOSS was included in the eThekwini Municipality's IDPs and SDFs since as early as 1998. In 2010, the City passed a resolution to adopt D'MOSS as a formal part of the eThekwini Municipal town planning schemes. This was the first time that a major metropolitan in South Africa had officially incorporated its open space plan into the City's town planning schemes (Boon et al., 2016; Davids et al., 2016). According to Wilhelm-Rechmann and Cowling (2013: 1), "local land use planning processes, and the integration of spatial conservation assessments in these processes, have been proposed as an effective approach to conserving biodiversity outside of protected areas". The EPCPD is also situated within the Spatial Planning unit of the municipality which has been beneficial for the EPCPD having more opportunities to use various town planning tools and getting D'MOSS included into the IDPs and SDFs at an early stage (R. Boon, pers. comm., 4 July 2017). Whilst Durban has lacked in the overall broad environmental integration across the city, they have the opportunity of being situated within the planning unit and have used this to their advantage.

A key intervention in terms of ensuring sustainable development and implementing D'MOSS, was the integration of the policy into the municipality's town planning schemes as a controlled development overlay. This was done in order to resolve the legal uncertainty that arose from its previous status as a policy directive of Council. However, it is noteworthy that D'MOSS is not a formal zone within the town planning schemes and therefore, does not entirely preclude development. Ms Govender stated that the inclusion of D'MOSS into the municipal town planning schemes assists land owners and developers with planning the development and management of their properties and to clarify if there are any significant biodiversity assets on their land (N. Govender, pers. comm., 4 July 2017). If the D'MOSS layer is situated on a piece of land, despite the underlying zoning of the land, development may not occur without first obtaining environmental authorisation or support from the municipality, which may or may not be given. According to the eThekwini Municipality (2017d), in the case of any land affected by D'MOSS, "prior to developing, excavating, levelling, removing any natural vegetation, erecting any structure, dumping or carrying out any work on a site, the prior approval of the Council must be obtained. In this regard, no approval for such work will be given unless the municipality is satisfied that the proposed activities will not negatively impact the integrity of the biodiversity and/or environmental services that may be found or generated within the affected area" (eThekwini Municipality, 2017d: 1). This effort has however, been seen by some as restricting property and development rights, but there are also positive spin-offs. For example, the Durban's Treasury and Real Estates Department can now consider potential environmental restrictions when property taxes are calculated on vacant land (eThekwini Municipality, 2017d). At the December 2010 Council meeting, after considering various comments and enquiries received from the public on the matter, proposed controls and the associated D'MOSS shapefiles were formally adopted as a component of the 54 eThekwini Municipality town planning schemes (eThekwini Municipality, 2017d).

A small number of appeals were received. The restrictions placed on private landowners prompted one owner to challenge the municipality's competence to legislate on matters that were of an environmental nature. The private property owner subsequently applied to the High Court to have the resolution of the city council set aside, arguing that it was procedurally flawed and unconstitutional, and that local government lacked the authority to legislate on biodiversity related matters, which were exclusive to the national and provincial government (eThekwini Municipality, 2017d; Boon et al., 2016). In a ground-breaking ruling, the judge dismissed this argument, stating that municipalities do in fact have power to legislate on environmental matters such as biodiversity and conservation and that legislating for the environment through municipal planning was permissible. According to Mr Boon this judgment has allowed the EPCPD to enforce D'MOSS as a regulation applicable to its town planning schemes and was a turning point in the valuation of biodiversity and maintaining relationships with various stakeholders and departments (R. Boon, pers. comm., 4 July 2017).

The presence of the EPCPD in the Spatial Planning division, getting the D'MOSS included in the IDPs and SDFs at an early stage and the integration of the D'MOSS into the full hierarchy of municipal spatial plans are some of the major differences between the CoCT and the eThekwini Municipality. These aspects and particularly the integration of the D'MOSS into the City's town planning schemes, means that the conservation system is playing a key role and having a profound influence at the local level, even more than that of the BioNet.

Melbourne for example, is a city rich in biodiversity. It contains a high proportion of open spaces and supports a large number of flora and fauna species (both indigenous to the region and some introduced from around the world). However, like these South African cities, Melbourne is grappling with continued urban growth which is likely to result in a loss of biodiversity if it is not explicitly and carefully considered in planning, policy and management (Ives et al., 2013). According to Ives et al. (2013) in order to enhance biodiversity into the future, it must be aided by an understanding of underlying tensions between: (1) urban growth and conservation; and (2) the management of 'native' and 'exotic' vegetation that are currently embedded in a range of governance structures and public attitudes. This would enable the implementation of urban design that promotes biodiversity across the city as a whole.

2.6.11 Branding and access to information regarding the BioNet and D'MOSS

According to Holmes and Pugnalin (2016) the BioNet provides users with a picture of not only the situation on the ground but most importantly, where to focus their conservation efforts. Likewise, users can also identify areas that have a low biodiversity priority which can be considered potential development areas. The BioNet methods and results reports, shapefiles and maps can be found on both the City's and SANBI's websites. The reports give an overview of the methodology used, whilst the technical process of the GIS technology and the biodiversity planning software packages are described in a separate manual that can be provided by the City upon request.

Locating and obtaining information and documentation on the D'MOSS is a little more difficult. eThekwini Municipality does have a dedicated link to the D'MOSS information consisting of a background information document; frequently asked questions; and a map viewer for viewing the D'MOSS layer on your property. However, methods and results reports as well as the D'MOSS shapefiles are not readily available to the public. This creates a problem as it is critical to provide reliable information free to the public to raise awareness, keep people informed, encourage engagement, assist the citizens in making informed decisions and ultimately promote the idea and value of biodiversity and nature within cities.

The D'MOSS is essentially a single layer of green prioritisation areas which essentially signifies every piece of land that has biodiversity or ecological importance, unlike the BioNet which presents detailed differentiation between land use and conservation areas. When interviewed on 4 July 2017, Ms Govender confirmed that the Department knows where the necessary CBAs and ESAs are located but chooses not to distinguish between the two areas because: (1) D'MOSS in its entirety, is a brand with which people are familiar; and (2) if the areas were not combined people might identify certain areas as being less significant than the others. Consequently, it avoids confusion between the terms of CBAs and ESAs and the public thinking of certain areas not being as important as the others. The D'MOSS was consequently released as a single layer which corresponds to areas with significant biodiversity value within the EMA. According to Ms Govender, the Biodiversity Strategy (2017) document specifically highlights the goals and objectives of the conservation network as well as the approach for achieving them and supports the implementation and spatial representation of the D'MOSS (N. Govender, pers. comm., 4 July 2017). In addition, in the same way as the BioNet, all areas which are not mapped or covered by the green D'MOSS layer are considered to be transformed areas which no longer have any biodiversity or ecological value.

2.7 Conclusion

The cities of Cape Town and Durban in South Africa are doing ground-breaking work to help conserve, protect and manage the remaining biodiversity and open spaces within their boundaries. Whilst the BioNet and D'MOSS have emerged along very different lines, their central aim and objectives are centred on the conservation of biodiversity and open space and the continued provision of ESS in these municipal areas. The municipalities in each case, now both make use of the SCP methodology for their analysis, use similar planning software for their assessments, implementation tools and techniques and face a few similar challenges in the implementation of the conservation policies at the local level. However, the cities differ with regards to their development histories, local environmental policies, influence of the conservation policies at the local level, status and success of conservation systems, biophysical templates and governance of land as well as in the ways they distribute and display the conservation systems information.

The eThekwini Municipality has a long history of open space planning, dating back to the 1970s, with a broad group of specialists including town planners, NGOs, academics and applied scientists, being involved in the creation of the MOSS. The CoCT on the other hand, initiated the BioNet project in 2002 and those involved consisted mostly of biodiversity specialists, consultants and the City's conservation partners. The CoCT has numerous environmental policies relating to biodiversity conservation at the local level, which indicates an extensive approach to biodiversity conservation and management at the municipality. However, the eThekwini Municipality has integrated the D'MOSS into its municipal town planning schemes, which has given the conservation network more power and influence at the local level. The BioNet has a higher percentage of land secured, owing largely to the local topography and mountainous areas of the City which includes the TMNP. The eThekwini Municipality on the other hand, has a large rural portion of land, but has less land secured, owing to the significant challenge of having traditional authorities governing approximately 38% of the land within the municipal area. The CoCT seems to be more proactive in getting their conservation system recognised and making information available to the public compared to the eThekwini Municipality.

Local governments are taking the leading role in the action towards biodiversity conservation, which can be seen in these respective municipalities. However, in South Africa, there is a lack of a clear biodiversity mandate, resources, skills and capacity for biodiversity management at the local level, which present significant challenges to biodiversity conservation.

Chapter 3: An analysis of the landscape pattern and spatial heterogeneity in the cities of Cape Town and Durban

3.1 Introduction

In an urban world, the battle to retain biodiversity hinges on how effectively cities are governed, and how responsive those who run cities are in shaping the urban system to integrate natural habitats, ecosystem integrity and restoration into development (Wilkinson et al., 2013). Systematic conservation assessment identifies a network of spatial priority conservation areas that represents the biodiversity and environmental processes of a region (Knight et al., 2008). The emerging conservation plans should theoretically ensure continued ecological functioning of the landscape and the resilience of protected areas (Knight et al., 2008). However, the implementation of conservation plans as well as achieving actual conservation goals is difficult. Conservation in urban areas is particularly challenging as it needs to consider both natural ecosystems and the pressing social needs that result from increasing human populations, making these highly complex environments (Salafsky et al., 2002). Cities are also managed through the mandates of multiple departments, sectors and entities all with their own policies and regulations. Cities therefore, cannot be solely managed for conservation, as they need to meet multiple, often conflicting agendas, and the management and retention of biodiversity is restricted by competing demands. Cities in biodiversity rich areas are typically low-choice planning domains for systematic biodiversity conservation since there are few alternative planning units to meet set biodiversity criteria (Holmes et al., 2012). Thus, finding solutions that both conserve biodiversity and promote human well-being are often difficult to realise (McShane et al., 2011).

Despite this, there are a few cities that have completed conservation assessments to conserve the remaining biodiversity and natural habitats within their boundaries. In South Africa, conservation planning has taken great strides forward in the last decade, particularly in relation to the methods and approaches to conservation assessment, and in closing the gap between planning and implementation (Driver, Cowling & Maze, 2003). As discussed in chapter 2, the cities of Cape Town and Durban make use of SCP methods and have formal conservation systems in place, which are incorporated into the cities' policies and planning processes. For these cities, the next key area of understanding is assessing how successful these conservation plans are and are going to be in achieving conservation action in light of intense drivers of land cover change and the ecological effects of this.

Fragmentation poses a major threat to biodiversity at a global scale (Saunders, Hobbs & Margules, 1991; Fahrig, 2002; Krauss et al., 2004; Lindenmayer & Hobbs, 2008) and is an explicit challenge to conservation. Urban areas are fragmented environments which are a product of increasing developments and urban sprawl (Angel, Parent & Civco, 2012; Malkinson, Kopel & Wittenverg, 2018). The process of fragmentation which results in the division of large, continuous habitats into a number of smaller, more isolated remnants (Fahrig, 2003), influences landscape pattern and spatial heterogeneity. Subsequently, as landscapes become more fragmented and less connected, biodiversity and ecological patterns and processes within the region are negatively impacted (Fahrig, 2003; Fahrig, 2005; Andrieu et al., 2009; Auffret, Plue, & Cousins, 2015). The physical template of landscapes influences and controls many of the biologically significant processes and conditions as well as the communities within them. Hence, it is not only the size of the urban areas but also their spatial configuration and heterogeneity in urban land use that are significant for biodiversity (Güneralp & Seto, 2013).

Conservation areas around the world are becoming increasingly surrounded by an intensively modified built-up environment, thereby changing the land use context around the cores of conservation areas. This results in many changes to the biodiversity and ecological functions within these reserves (Hansen & DeFries, 2007) and causes them to function as isolated natural ecosystems (Midha & Mathur, 2010). By analysing landscape patterns, spatial heterogeneity and the pressures imposed on protected areas, we can better understand the levels of fragmentation and the likely effects this has on the ecology of cities. The science of landscape ecology is based on the premise that there are strong links between spatial patterns and ecological function and process (Gustafson, 1998; Frohn, 1998; Li et al., 2001). In these studies, the determination of spatial pattern and the heterogeneity of the landscape, are used to study the ecological functioning and processes within the area. According to Wu (2014), since landscape ecology integrates pattern, process and design, it must quantify the configuration and composition of the landscape. Landscape metrics are commonly used as the quantitative measures to describe the structure and pattern of a landscape and can be extracted from land cover and land use maps derived mostly from remotely sensed imagery. Various landscape ecology metrics have been used to quantify aspects of landscape pattern and correlate them with ecological processes.

3.2 Aim and Objectives

The process of fragmentation affects the ecological functioning and processes within landscapes. The aim of this chapter is to analyse the landscape pattern and spatial heterogeneity of the landscapes in the cities of Cape Town and Durban in order to understand the degree to which urbanisation has impacted the urban form and in turn the likely functioning ecology of these cities and what impact this is likely to have on achieving conservation action. In order to quantify the spatial pattern and heterogeneity of the landscapes, the study makes use of several landscape metrics, computed using the software FRAGSTATS (McGarigal & Marks, 1995). The chapter then gives attention through limited case studies, to the likely pressures imposed on remaining natural habitats from adjacent land uses by analysing which land uses most commonly encroach upon sites immediately surrounding key conservation areas in each city. The study takes a city-wide view and tests how feasible and useful landscape metrics are to apply and whether they provide information useful for managing for fragmentation and enhancing conservation in urban areas.

3.3 Relevant literature

3.3.1 Conservation assessments and planning to conserve biodiversity

The long-term survival and well-being of people depends on the effective conservation of the world's biodiversity. According to Poiani et al. (2000), approaches to conservation are largely influenced by perceptions of biodiversity and ecological systems. In recent times, biodiversity has been viewed more expansively to include species, populations, genes, communities, ecosystems and landscapes, with each level of biological organisation displaying characteristic and complex structure, composition and function (Poiani, 2000; Walz, 2011). The conservation of biodiversity focuses on the need of conserving dynamic, multiscale ecological patterns and processes that would sustain the biological communities and their corresponding natural systems (Poiani, 2000; Margules & Pressey, 2000).

Urban areas can contain high levels of biodiversity (Freeman, 2011) which requires protection. However, conservation within a city context is not easy, according to Sanderson and Huron (2011), cities are arguably the hardest places in the world to put conservation into practice. Preserving and protecting sensitive biodiversity in a rapidly expanding urban region therefore, poses unique challenges for municipalities (Local Government Business Network, 2013). Different cities are faced with different problems and developing cities within biodiversity rich areas are facing many specific challenges (Piracha & Marcotullio, 2003). These involve meeting local as well as global conservation expectations, local service delivery, and navigating the territories between these as they play out around land use allocation and associated trade-offs (O'Farrell et al., 2012). Landscape planners and environmental managers in urban areas are confronted with the problem that these complex landscapes should fulfil various functions, often with conflicting goals. In addition, while the pressures on biodiversity show no sign of abating, resources for conservation action are limited and implementation is slow.

While conservation schemes do exist within cities, they are worth little if they fail to deliver local scale conservation action. Relying on the importance of biodiversity or prioritisation to achieve conservation action has generally failed elsewhere (Knight et al., 2008; Holmes et al., 2012). According to Knight et al. (2008: 614), if a conservation assessment is to be actively applied, "it must be conducted in a context that situates it within the real world". This requires understanding how social-ecological systems function (Carpenter & Folke, 2006) and how implementation processes should embrace a transdisciplinary approach. Conservation work in human-dominated environments calls for better integration of natural and social sciences (Sanderson & Huron, 2011). Even though conservation policy should be based on scientific knowledge and data, it is also a social and political process, with stakeholders competing to promote various agendas and negotiate conservation goals (Apostolopoulou & Pantis, 2009). Holmes et al. (2012: 7) state that successful conservation implementation "means exploring economic, social, and human dimensions and engaging with key stakeholders such as local politicians, government officials from non-biodiversity sectors, land owners, and local communities to promote knowledge interfacing and enable conservation action".

3.3.2 Challenges faced with the implementation and effectiveness of conservation policies

South Africa is a signatory to various international agreements relating to the conservation of biodiversity and has developed good biodiversity legislation to align with these principles and objectives (see Appendix A) (Holmes et al., 2012). However, implementation and conservation action is still slow, suggesting a policy-practice divide (Gibbons et al., 2008; Holmes et al., 2012). According to Holmes et al. (2012), this is due both to conservation initiatives not being adequately funded, with insufficient money allocated to implement national policies at the provincial and local levels, and to conflicting policies at all levels of government which seriously hinders conservation action. In addition, there are different agencies and departments in charge of conservation, which makes implementation more difficult. In other countries such as Sweden, where the conservation of biodiversity is described as an agreed value amongst the citizens (Angelstam et al., 2003) and is incorporated into policies, implementation is still hampered due to key institutional gaps (Holmes et al., 2012). In addition, the failure to conserve Greece's European Natura protected area sites results partly from a lack of suitable national policies (because of political interference and conflicting interests) and from under-resourcing for management (Apostolopoulou & Pantis 2009; Holmes et al., 2012).

3.3.3 The process and effects of habitat fragmentation

Whilst the earth's surface is increasingly urbanised and habitat-modification continues, a new habitat is being created where only the small islands of original habitat remain and are isolated within this urbanised structure (Pauw & Louw, 2012). By definition, fragmentation is the process by which a large area of habitat is transformed, resulting in a number of smaller patches of the total area which is isolated from each other by a 'matrix' of habitats unlike the original (Fahrig, 2003). Fragmentation is a widespread form of habitat modification and is closely linked to the growth in human population, urban sprawl, agriculture, and settlements (Fahrig, 2003; Turner, 1996). Urban areas contain extremely fragmented habitats (Freeman, 2011), perpetuated and exacerbated by increasing development and sprawl (Angel, Parent & Civco, 2012; Malkinson, Kopel & Wittenverg, 2018).

According to Fahrig (2003), the four effects of fragmentation on landscape pattern are: (1) a reduction in the total area of habitat; (2) an increase in the number of habitat patches; (3) a decrease in the sizes of habitat patches; and (4) an increase in the isolation of patches. These effects form the basis for most quantitative measures of habitat fragmentation. The process of fragmentation therefore leads to the loss and removal of habitat, and a change in the properties of the remaining habitat (van den Berg et al., 2001; Fahrig, 2003). The configuration of the remaining habitat has many implications for biodiversity that are distinct from habitat loss. Fahrig (2003: 492) states that "the assertion that habitat fragmentation means something more than habitat loss depends on the existence of effects of fragmentation on biodiversity that can be attributed to changes in the pattern of habitat that are independent of habitat loss".

After decoupling habitat fragmentation from habitat loss, the effects of fragmentation seem to vary widely and can be either negative or positive. Fragmentation has two important consequences for biota: the reduction in the total area of habitat and the isolation of the remaining habitat (Saunders, Hobbs & Margules, 1991), both of which negatively impact the biotic patterns and processes of the region. Broadly, the negative effects of fragmentation include: a reduction in both the population size and probability of persistence of species due to a larger number of smaller patches (Fahrig, 2003; Lindenmayer & Hobbs, 2008); a reduction in dispersal which can decrease species diversity (Krauss et al., 2004; Auffret, Plue & Cousins, 2015); and a disruption in species interactions which can lead to lower performance and population dynamics in fragments (Andrieu et al., 2009). The process of fragmentation has been coupled with a variety of theories (MacDonald, 2018). The most prevalent includes the 'Theory of Island Biogeography' (MacArthur & Wilson, 1967), of which spatial structure is a key component, where predictions suggest that habitat fragmentation increases the gradual loss of species which reduces overall species diversity (below what is predicted based on habitat loss alone) (MacDonald, 2018). However, in contrast to this theory, the 'Habitat Amount Hypothesis' proposes that the size and isolation of habitat patches has little effect on species diversity, stating that the gradual loss of species is linked to habitat loss at the landscape level and is unrelated to the configuration of the remaining habitat (Fahrig, 2013).

Fragmentation further contributes towards reduced habitat quality, as well as ecosystem degradation, resulting in the loss of ecosystem functioning and diversity (Turner, 1996; Alberti, 2005). Through habitat fragmentation, the quality of a habitat declines and affects the occupancy, reproduction and species existence within the habitat. The fragmentation of natural habitats and the subsequent allocation of land parcels to different land uses also increases the amount of edge habitat (Sisk, 2008). Organisms in remaining habitat patches are therefore exposed to conditions of a different surrounding ecosystem and consequently, to 'edge effects' (Murcia, 1995). Edge effects are often pronounced and tend to be stronger at edges with strongly contrasting adjacent patch types (Sisk, 2008). The ecological effects of edges have been studied for many decades, with the negative effects of edges on biodiversity becoming well recognised (Murcia 1995; Sisk, 2008). According to Murcia (1995), there are three types of edge effects on fragments: (1) abiotic effects, relating to changes in environmental conditions that result from proximity to a structurally unalike matrix; (2) direct biological effects, which involve changes in the distribution and abundance of species caused directly by the physical conditions near the edge and determined by the physiological tolerances of species; and (3) indirect biological effects, which include changes in species interactions, such as predation, competition, herbivory, and biotic pollination and seed dispersal.

Some positive effects of habitat fragmentation on biodiversity include: enhancing the persistence of a predator-prey system since habitat patches provide refugia to prey species; enhancing the stability and co-existence of two-species competition; increasing overall immigration rates since the landscape comprises a larger number of smaller patches; and reducing the probability of simultaneous extinctions of whole populations (Fahrig, 2003). In addition, fragments of natural land also expand the ease of access to nature for all people across the city as apposed to having one large patch.

3.3.4 The study of spatial patterns through the field of landscape ecology

The process of urbanisation significantly transforms the structure and function of urban ecosystems, influencing the quality of this ecological environment (Ren et al., 2013). Urban open spaces, containing important biodiversity, are often limited in size, and are occluded within a built-up matrix, which separates patches of inhabitable developed areas (Malkinson, Kopel & Wittenverg, 2018). The fragmentation of urban areas is a key factor in terms of the ecology of the open spaces in and around cities (Angel, Parent & Civco, 2012). According to Angel, Parent and Civco (2012), landscape ecology studies have long been concerned with measuring fragmentation, as it involves the study of the interactions between landscape pattern and ecological processes (Turner, 1989; Frohn, 1998; Li et al., 2001). According to Kupfer (2012: 401), "the central tenet of landscape ecological theory is that the spatial pattern of organisms, populations, and ecosystems across a landscape reflects the influence of underlying gradients and processes but in turn acts to shape ecological processes such as dispersal, competition, disturbance, and fluxes of energy and matter across space". Hence, it is the study of how landscape structure affects the biotic patterns and processes within the region (Fahrig, 2005; Kupfer, 2011).

According to Pickett and Rogers (1997), physical environments and habitats have complex spatial patterns which influences the ecology within them. The determination of spatial patterns and the heterogeneity of a landscape, are key factors to understanding the functioning of nature (Pickett & Rogers, 1997; Uuemaa, Mander & Marja, 2013). The term landscape pattern (or spatial pattern) has been widely used in landscape ecology literature, primarily to describe the structure, composition and configuration of landscapes (Gustafson, 1998). Landscape patterns result from complex interactions between the physical, biological, and social aspects of the environment (Turner, 1989). These patterns subsequently affect the biotic processes such as the movement and interactions of species as well as the biotic patterns such as the abundance and distribution of organisms (Fahrig, 2005). Most landscapes are altered by human land use, resulting in a landscape 'mosaic' – a mixture of both natural and human dominated patches that vary in size, shape, and arrangement (Turner, 1989; Midha & Mathur, 2010). The heterogeneity of landscapes, a parameter of landscape structure, can be used to describe the complexity and variability of a landscape in time and space (Gustafson, 1998). It can be observed as the differences and variations between elements in the landscape, or the observed patchiness of the landscape. In general, ecological systems are considered to be spatially heterogeneous, displaying substantial complexity and variability (Gustafson, 1998).

Landscape pattern is inextricably linked to biodiversity and other ecological values of the landscape and is vital for the maintenance of biodiversity. According to Walz (2011), biodiversity in all its facets and dimensions are firmly tied to the landscapes and habitats in which they reside and need a distinct section of the earth's surface to survive. Any disturbances to the landscape pattern may therefore, compromise its functional integrity by interfering with critical ecological processes required for the maintenance of biodiversity and ecosystem health (McGarigal, n.d). For these reasons, much emphasis has been placed on the development of methods for the quantification of landscape patterns, which is a pre-requisite for the study of pattern – process relationships (Turner, 1989; Li et al., 2001; McGarigal, n.d; Uuemaa, Mander & Marja, 2013). According to Li et al. (2001), studies on the theory and methodology for quantifying landscape patterns by the development and application of landscape metrics are at the centre of landscape ecology research. Landscape metrics are one of the frequently used methods for quantifying aspects of landscape pattern (McGarigal, n.d) and to correlate them with actual ecological processes (Riitters et al., 1995; Frohn, 1998; Gustafson, 1998; Li et al., 2001; Turner, Gardner & O'Neill, 2001; Schindler, Poirazidis & Wrbka, 2008; Midha & Mathur, 2010; Lopez & Frohn, 2017).

3.3.5 The use of landscape metrics to quantify spatial patterns

Landscape metrics essentially represent improved information about landscape pattern and are simple quantitative measures which reflect on the composition of landscape structure and characteristics of spatial land use allocation (Frohn, 1998; Ren et al., 2013). Consequently, if landscape metrics provide important spatial distribution information and are closely related to ecological functions, then these metrics can act as a connection between landscape structures and ecological processes (Li & Wu, 2004; Ren et al., 2013). Most applications of landscape metrics include: the evaluation of spatial patterns and their changes, habitat fragmentation, biodiversity and habitat analysis, water quality and ecosystem health and functioning (Uuemaa et al., 2009). For example, the study of spatial patterns and changes in a particular habitat can be used to determine the effects of fragmentation on certain species or a community of organisms and if they would be able to remain and survive in the new habitat (Lopez & Frohn, 2017). The metrics used in studies assessing fragmentation usually consist of: area, density and edge metrics as well as shape and contagion/interspersion metrics (Li et al., 2001; Midha & Mathur, 2010).

There are several landscape metrics currently available (McGarigal, n.d; Schindler, Poirazidis & Wrbka, 2008) which can quantify specific spatial characteristics of patches, classes of patches, or entire landscape mosaics (Uuemaa et al., 2009; Midha & Mathur, 2010). According to McGarigal (n.d), it is important to interpret each metric in a manner appropriate to its scale. Class indices specifically, are often used as an indicator for fragmentation as these separately quantify the amount and distribution of a particular patch type (Midha & Mathur, 2010). In addition, most landscape level metrics can be interpreted more broadly as pattern and heterogeneity indices because they measure the overall landscape pattern. Landscape metrics have also proven to be useful since they are easily obtainable over large areas, are comparable and their calculations are less demanding in terms of time and money than collecting detailed ecological data (Schindler, Poirazidis & Wrbka, 2008; Uuemaa, Mander & Marja, 2013).

According to Herold, Couclelis and Clarke (2005), there has been increasing interest in the application of spatial metric techniques in urban areas, since these metrics help highlight the spatial component in urban structure as well as the dynamics of change and growth processes. These understandings of urban patterns can then be used to deduce information on ecological processes since landscape metrics reflect spatial distribution information which is closely related to ecological functions. There is an increasing number of studies relating the quantification of landscape patterns to the functioning and processes of ecology by utilising landscape metrics. On the basis of these existing understandings, this study will use similar methods to analyse the landscape pattern and heterogeneity in the cities of Cape Town and Durban in order to understand the ecological function and processes within these regions. The study will therefore make use of spatial metric measures and not ecological field measures.

There are however, limitations to the use of landscape metrics. For example, landscape metrics are sensitive to changes in the spatial and thematic resolution of the data and the area (extent) of the landscape. In addition, there are numerous correlations among landscape indices (Riitters et al., 1995; Kupfer, 2012; Uuemaa et al., 2009). These limitations, however, can often be addressed through careful data manipulation, analysis and interpretation (Kupfer, 2012). Another limitation is the interpretation of landscape indices (Gustafson, 1998), which remain difficult. This is because the values and limitations attached to metrics are poorly understood (Li & Wu, 2004; Kupfer, 2012; Uuemaa et al., 2009). Thus, it can become difficult to relate spatial pattern to ecological process, and to establish the ecological relevance of landscape metrics. In spite of these problems, landscape metrics are still widely used since they are seen as simple, intuitive tools for analysing and monitoring changes in landscape pattern and, by extension, the effects on the underlying ecological processes (Kupfer, 2012).

According to Yang and Liu (2005), the technologies of remote sensing and GIS offer promising tools for quantitative assessments in the field of landscape ecology. In addition, the software FRAGSTATS has been widely used in the computation of landscape metrics to quantify spatial patterns (McGarigal & Marks, 1995). FRAGSTATS offers a wide variety of indices and is at present considered to be the most comprehensible software package for the calculation of landscape metrics (Saikia et al., 2013; Jung, 2016). The program calculates metrics as represented in categorical map patterns. Categorical maps (a kind of thematic map) illustrate non-numerical data where the system of interest is represented as a mosaic of discrete patches. Land cover/land use data are usually depicted using this kind of mapping technique. Hence, landscape metrics can be derived from classified land cover/land use datasets (Jung, 2016; Yang & Liu, 2005).

3.3.6 The use of land cover data to study spatial characteristics of landscapes

The difference between land cover and land use is that land cover indicates the biophysical land cover type such as forest, grassland or wetland whereas land use documents how the land is being used by humans. According to DEA (2015), land cover data is a vital reference dataset that informs a wide range of activities, including: development planning, environmental planning and protection, economic development and resource management. The data needs to be reliable and accurate. According to Herold, Couclelis and Clarke (2005), the use of remote sensing methods has been widely applied in mapping land surfaces since it provides spatially reliable coverage of large areas with high geometric detail and high temporal frequency. The advancements in remotely sensed data presents an unprecedented opportunity in monitoring and planning efforts. Currently, the available land cover data for South Africa is the 2013-2014 National Land Cover dataset, which is used in this study.

3.3.7 Pressures on natural protected areas from adjacent land uses

Human land uses are essentially expanding and intensifying in the areas surrounding many of the world's protected areas (Hansen & DeFries, 2007). Güneralp and Seto (2013) state that protected areas around the world will experience significant increases in the existence of in urban land within 50 km of their boundaries with the largest urban expansion occurring in biodiversity hotspots. Most conservation reserves today are becoming increasingly surrounded by an intensively modified built-up environment, thereby changing the land use context around the core areas of conservation areas and making them function as isolated natural ecosystems (Midha & Mathur, 2010). According to Wade and Theobald (2010: 152), “an ideal conservation system may consist of protected conservation “cores” surrounded by “buffer zones” of relatively unaltered land-use types that protect the cores from external threats, effectively expanding and providing connections between them”. Development encroachment of core areas however, ultimately reduces the effectiveness of the conservation system and limits the options available for future expansion and conservation action (Wade & Theobald, 2010). In addition, according to Hansen and DeFries (2007), increased development encroachment and human proximity adjacent to protected areas has potential ecological implications including: the intensification of edge effects, a reduction of the effective size of protected areas, and the reduction in connections and linkages between protected areas which results in a disruption of ecological flows. Hence, while the immediate surrounding buffer zones may not provide equal conservation value, they are important for future expansion of protected areas, providing connections and linkages for species and ecological processes as well as minimising negative boundary influences (Hansen & DeFries, 2007; Wade & Theobald, 2010).

3.4 Study Sites

The study was carried out in the municipal regions of the City of Cape Town in the Western Cape and the eThekwini Municipality (including the City of Durban and surrounding towns) in KwaZulu-Natal. The extent of the municipal areas is 2460 km^2 and 2556 km^2 respectively. Cape Town includes the TMNP within its borders, which conserves an area of approximately 250 km^2. This area under conservation gives a false sense of conservation achievement as it only conserves some of the vegetation types in the Cape Town, predominantly only Peninsula Sandstone Fynbos. It is imagined to seriously skew averages of the indicators used in the study.

In light of these various considerations, the analysis is performed with the TMNP both included and excluded from Cape Town boundary. Durban, on the other hand, has no similar concerns and is treated only once. The focus will therefore be on: (1) The City of Cape Town; (2) The City of Cape Town excluding the Table Mountain National Park; and (3) The eThekwini Municipality.

3.5 Data and Methods

This chapter makes use of a quantitative research approach in order to understand the landscape pattern, spatial heterogeneity and, though to a lesser extent, the pressures imposed on key conservation areas within the cities of Cape Town and Durban. Quantitative research is the approach used for testing objective theories by investigating the relationship between variables and explaining phenomena by collecting numerical data and analysing the data using statistical procedures (Creswell, 2014). While there are a variety of techniques and approaches used to characterise spatial patterns, this study makes use of the spatial analysis techniques of remote sensing, GIS and the spatial analysis software FRAGSTATS. These methods help in understanding the landscape pattern and spatial heterogeneity of the landscapes, which can then be used to infer on the ecological functioning and processes within these cities.

3.5.1 The analysis of landscape pattern and spatial heterogeneity

Land cover data

The data used in this study was the 2013-2014 South African National Land Cover Dataset which was produced by GeoTerraImage (GTI), as a commercial data product in January 2015. The data is defined as the 72 Class South African National Land Cover Dataset (2013/2014) and was obtained from the Department of Environmental Affairs GIS website (https://egis.environment.gov.za/). The dataset, which covers the entire area of South Africa was generated from digital, multi-seasonal Landsat 8 multispectral imagery, which was acquired between April 2013 and March 2014 (GeoTerraImage, 2015). The Landsat 8 satellite imagery presented the opportunity to create a new, national land cover dataset which replaced the previous 1994 and 2000 land cover datasets (GeoTerraImage, 2015).

According to GeoTerraImage (2015: 7), more than 600 Landsat images were used to produce the land cover data, which was based on "an average of 8 different seasonal image acquisition dates, within each of the 76 x image frames required to cover the whole of South Africa". The 2013-2014 dataset is presented in a map-corrected, raster tiff format, based on 30x30m cells which corresponds to the image resolution of the source Landsat 8 imagery (GeoTerraImage, 2015). The original land cover dataset was processed in the UTM North WGS84 map projection format (GeoTerraImage, 2015). The dataset contains 72 land cover and land use classes, which covers a wide range of both natural and man-made landscape characteristics and are collectively referred to as 'land cover'. The map legend, which is also available on the website provides a code and description of the landscape class. Each data cell on the map contains the code which represents the main land cover class (by area) within that unit, as determined from the analysis of the multi-date imagery acquired over that image frame (GeoTerraImage, 2015). This study will use and make reference to the land cover types described in the map legend. According to SANBI (2014), the overall map accuracy for this dataset is 81%, with a mean land cover/land use class accuracy of 91%.

While the resolution of 30m makes the analysis of smaller fragments quite difficult, I have used this data set across areas (including Cape Town and Durban) and so the comparative was not affected, just the actual. There might also be some inaccuracies in the data at the local scale as well (eg. where sports fields are labelled as natural areas etc). Hence, while this layer may be accurate enough for broad national use, its errors make working at the finer city scale more difficult. In addition, the number of classes is limited and does not effectively capture urban features like roads and buildings, hard infrastructure as well as other typical urban features. The data is further limited in the degree to which it captures degradation. Hence, it makes no reference to the quality of natural vegetation and so there is no class distinction between good and poor conditions of vegetation types.

Image processing and classification

Since the land cover dataset covered the whole of South Africa, the data had to be clipped to the extent of the city boundaries in each case. The individual municipality land cover maps were created based on the clipped extents of the municipalities boundaries (obtained from http://www.demarcation.org.za/site/shapefiles/), using the ArcMap (version 10.2) software and the relevant raster clip function. The new and extended boundaries (2017 version) of the EMA was used in this study. The resulting raster images represented the land cover classes included in each city. To further exclude the TMNP from the Cape Town image, a shapefile of the boundary of the national protected area (including all three sections) was obtained from the SANBI Biodiversity GIS website (BGIS) and imported into ArcMap. The erase function was thereafter used to remove the extent of the national park from the Cape Town raster land cover image. Three 30x30m unit land cover raster maps (Figures 3.1-3.3 below) characterising the cities spatial configuration and land cover and land use, were created for the analysis. A total of 57 land cover classes were identified in Cape Town, whilst 61 land cover classes were represented for the eThekwini Municipality.

The computation of landscape metrics

The computation of landscape metrics was executed using the raster version of the spatial pattern analysis program FRAGSTATS (version 4.2) (McGarigal, Cushma & Ene, 2012). As stated, the indices computed by FRAGSTATS can characterise each patch in the mosaic, each patch type (class) in the mosaic and the landscape mosaic as a whole. Patch metrics are computed for every single patch in the landscape, which was not needed for this study. Hence, only class and landscape level metrics were calculated. Class level metrics characterise the spatial distribution and pattern within a landscape of a single patch type; which holds important information about the composition of the landscape mosaic. On the other hand, landscape level metrics represent the spatial pattern of the entire landscape mosaic, considering all patch types concurrently and thereby giving an indication of the heterogeneity of the landscape. Upon selecting the GEOTIFF option and corresponding map images, an eight-neighbourhood no-sampling criterion was used for the computation of the metrics. The selection of metrics used in this research was based on several similar studies. Ten landscape level metrics and nine class level metrics were used to characterise the spatial patterns and heterogeneity of the landscape. The metrics used represent five components: area/density and edge; shape; isolation and proximity; connectivity; and diversity. In order to assess the level of fragmentation and its effects on ecological function and process within conservation land, landscape metrics were computed separately for seven of the natural land cover types (including wetlands) found in each city. The landscape metrics were selected based on what was available and provided for in the software package and was also cross referenced to the research question. On that basis, I chose the following landscape metrics: total area, edge density, PAFRAC, number of patches, CONTAG, IJI, PR, PDR, SHDI, SHEI. A list of all landscape and class level metrics used in this study, along with their definitions are presented in Tables 3.1 and 3.2 below.

Table 3.1: List of landscape level metrics used in this study including units and definitions

Landscape level metrics		
Metrics and ID	**Units**	**Definitions**
Total Area (TA)	Hectares	TA equals the total area of the landscape.
Edge Density (ED)	Meters per hectare	ED equals the sum of the lengths of all edge segments in the landscape per hectare.
Perimeter-Area Fractal Dimension (PAFRAC)	None	PAFRAC is based on the ratio of perimeter per unit area and increases as patches become more irregular.
Number of Patches (NP)	None	NP equals the number of patches in the landscape.
Contagion (CONTAG)	Percentage	CONTAG equals the extent to which patch types are aggregated or clumped as a percentage of the maximum possible. This index deals with both dispersion and interspersion.
Interspersion & Juxtaposition Index (IJI)	Percentage	IJI equals the extent to which patch types are interspersed as a percentage of the maximum possible.
Patch Richness (PR)	None	PR equals the number of different patch types present within the landscape boundary.
Patch Richness Density (PRD)	Number per 100 hectares	PRD equals the number of different patch types present within the landscape boundary per 100 hectares.
Shannon's Diversity Index (SHDI)	None	SHDI equals the proportional abundance of each patch type; multiplied by that proportion.
Shannon's Evenness Index (SHEI)	None	SHEI equals the proportional abundance of each patch type multiplied by that proportion, divided by the logarithm of the number of patch types.

**Definitions adapted from the University of Massachusetts FRAGSTATS website.*

Table 3.2: List of class level metrics used in this study including units and definitions

Class level metrics		
Metrics and ID	**Units**	**Definitions**
Total Class Area (CA)	Hectares	CA equals the sum of the areas of all patches of the corresponding patch type.
Percentage of Landscape (PLAND)	Percentage	PLAND equals the sum of the areas of all patches of the corresponding patch type, divided by total landscape area.
Edge Density (ED)	Meters per hectare	ED equals the total length of all edge segments (involving the corresponding patch type) per hectare.
Largest Patch Index (LPI)	Percentage	LPI equals the area of the largest patch of the corresponding patch type.
Number of Patches (NP)	None	NP equals the total number of patches of the corresponding patch type.
Patch Density (PD)	Number per 100 hectares	PD equals the number of patches of the corresponding patch type per 100 ha.
Proximity Index	Meters	The proximity index measures both the degree of patch isolation and the degree of fragmentation of the corresponding patch type within the specified neighbourhood of the focal patch.
Cohesion (COHESION)	Percentage	COHESION is proportional to the area-weighted mean perimeter-area ratio divided by the area-weighted mean patch shape index.
Effective Mesh Size (MESH)	Hectares	MESH equals the size of the patches when the landscape is divided into S areas (each of the same size) with the same degree of landscape division as obtained for the observed cumulative area distribution.

**Definitions adapted from the University of Massachusetts FRAGSTATS website.*

3.5.2 The analysis of surrounding land uses adjacent to conservation areas

In order to determine which land uses are adjacent to key conservation areas, an explorative approach including a visual analysis was undertaken. Three randomly selected conservation areas for each city were analysed using Google Earth's high-resolution imagery. The nature reserves chosen for Cape Town included: the Rondebosch Common, Edith Stephan's Nature Reserve, and the Kenilworth Racecourse Conservation Area. The reserves chosen in Durban included: Virginia Bush Nature Reserve, Bluff Nature Reserve, and Burman Bush Nature Reserve. In order to determine the neighbouring land uses to these protected areas, a 50 m buffer zone was determined around the borders of the entire protected area. The predominant neighbouring land uses within this buffer zone were thereafter assessed and recorded. Historical imagery of the conservation areas was also assessed in order to determine the land use of greatest change through time. The Google Earth platform provided images dating back to 2000 and 2001 – allowing for a 18-17-year time gap. Only one reserve within each city was chosen to highlight similar trends of the surrounding land uses to key conservation areas and these are represented in the results section below.

3.5.3 Limitations of the study

A limitation of this chapter includes using the 2013-2014 South African National land cover data, since this dataset was captured between 2013 and 2014. Some landscape features may consequently, not be the same in the present day due especially to increased urban developments and land transformation. In addition, the dataset was very large, and errors could have occurred whilst reducing the size of the required data. However, the 2013-2014 National Land Cover Dataset produced by GTI, is the most recent national land cover dataset, available in the public domain. Whilst the municipalities in each case have produced their own respective land cover maps, the use of the 2013-2014 national land cover map ensures classification consistency so that municipal areas are classified under the same land cover and land use types.

3.6 Results

3.6.1 Overall land cover maps for each city

Overall land cover and dominant land cover types in each study site

There are a total number of 57 land cover types in Cape Town and a total of 61 classes in Durban. However, 56 land cover classes are represented in Figures 3.1 and 3.2, and 58 classes are represented in Figure 3.3. This is due to those missing land cover types accounting for less than 0.001% of the landscape and therefore not being visually represented on the maps. The overall landscapes of the cities are dominated by both natural land cover and human land uses. Table 3.3 below summarises the overall land cover in each city by separating all identified classes (as according to the land cover classification) into four different categories, including: natural, urban, cultivated and other.

Table 3.3 Percentages of overall land covers for different categories

Classification	2013-2014 Land Cover Data		
	Cape Town	Cape Town w/o TMNP	Durban
Natural	55.58%	50.45%	47.66%
Urban	25.63%	28.81%	41.50%
Cultivated	17.94%	19.83%	10.32%
Other	0.84%	0.91%	0.52%
Total	100%	100%	100%

The central and inner parts of the Cape Town (Figure 3.1) are dominated by urban land use and cultivation, whilst the outer regions, towards the southwest and east represent the mountainous regions of the City which are largely natural and dominated by shrubland fynbos. These mountainous regions, including the TMNP, cover a large area of the City and are formally protected. With the national park removed from the analysis (Figure 3.2), the amount of natural land cover (mainly including shrubland fynbos) is significantly altered. In the case of Durban (Figure 3.3), there appears to be a mix of urban land uses in the central region, a concentration of cultivation of the commercial sugar cane crop in the north, and natural areas (including large areas of thicket/dense bush) dominating the outer west and southern regions.

According to table 3.3, the highest land cover category in each city is still natural (around 50% in each case), with urban land use being the second highest category, followed by cultivation (including plantations) and other land uses. The overall landscape in the Cape Town, covering an area of about 2460 km^2 is dominated by natural features which covers approximately 55.58% of the overall landscape. The remaining area is covered by urban land use (25.63%), cultivation (17.94%) and other land covers (0.84%). When the TMNP (an area of 250 km^2) is removed, the area of the Cape Town now comprising 2210 km^2, consists of 50.45% natural land cover. Hence, 5% of the natural land cover appears to be removed with the TMNP. Durban, covering an area of 2256 km^2 is also dominated by natural features which covers approximately 47.66% of the overall landscape, whilst urban land use, cultivation and other land uses cover approximately 41.50%, 10.32% and 0.52% of the landscape respectively.

Percentages of dominant land cover types in each city

A total of eleven classes of land cover types make up 80% of the landscape in Cape Town, whilst eight classes are identified for Durban. The remaining land cover types together account for an overall 20% of the landscape. The dominant land cover types for Cape Town are: shrubland fynbos (31%), thicket/dense bush (9%), cultivated commercial fields (high) (8%), grassland (6%), urban residential (dense/trees bush) (5%), urban residential (low veg/grass) (5%), cultivated commercial fields (med) (4%), wetlands (2%), urban commercial (2%) and low shrubland (2%). These classes are still the dominant land cover types when the TMNP is removed from Cape Town, with only a change in the percentages (relative to the new area). The most significant change is the percentage of shrubland fynbos which drops to 27% when the TMNP is removed. The dominant land cover types for Durban are: thicket/dense bush (33%), urban village (dense trees/bush) (10%), grassland (8%), urban residential (dense/trees bush) (8%), urban village (low veg/grass) (6%), cultivated cane commercial crop (6%), indigenous forest (2%), urban township (dense trees/bush) (2%) and urban informal (dense trees/bush) (2%).

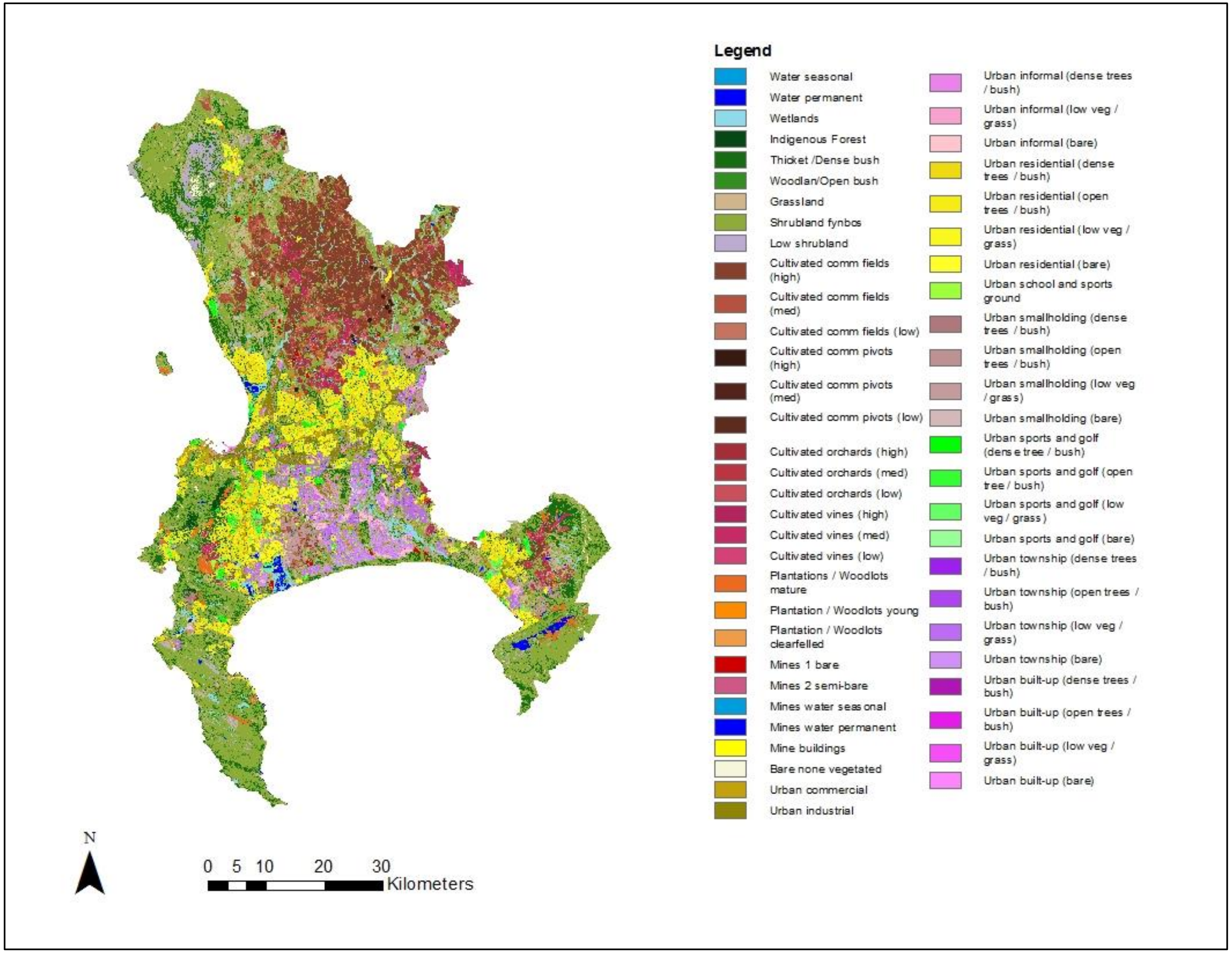

Figure 3.1: Land cover map for the City of Cape Town

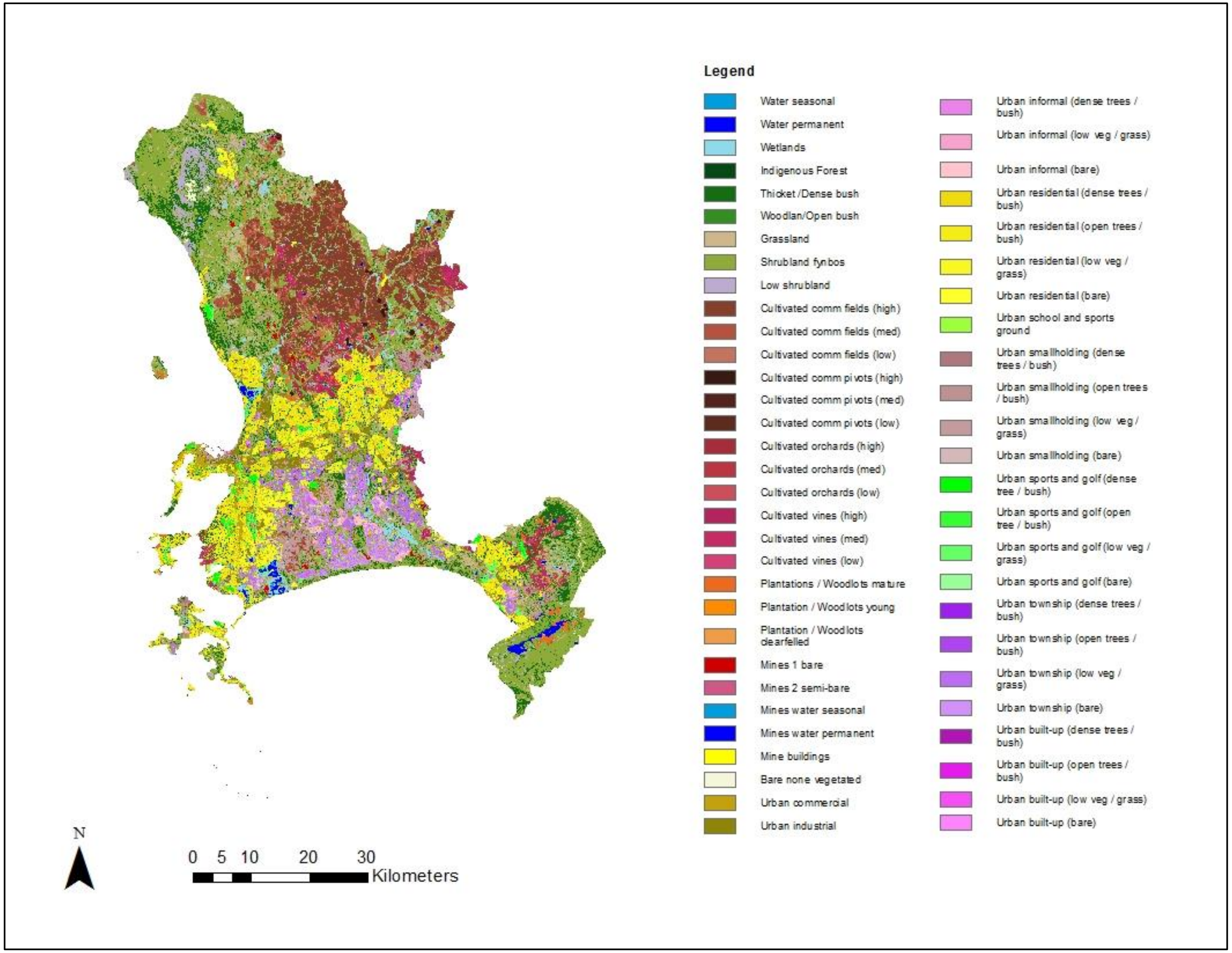

Figure 3.2: Land cover map for the City of Cape Town excluding Table Mountain National Park

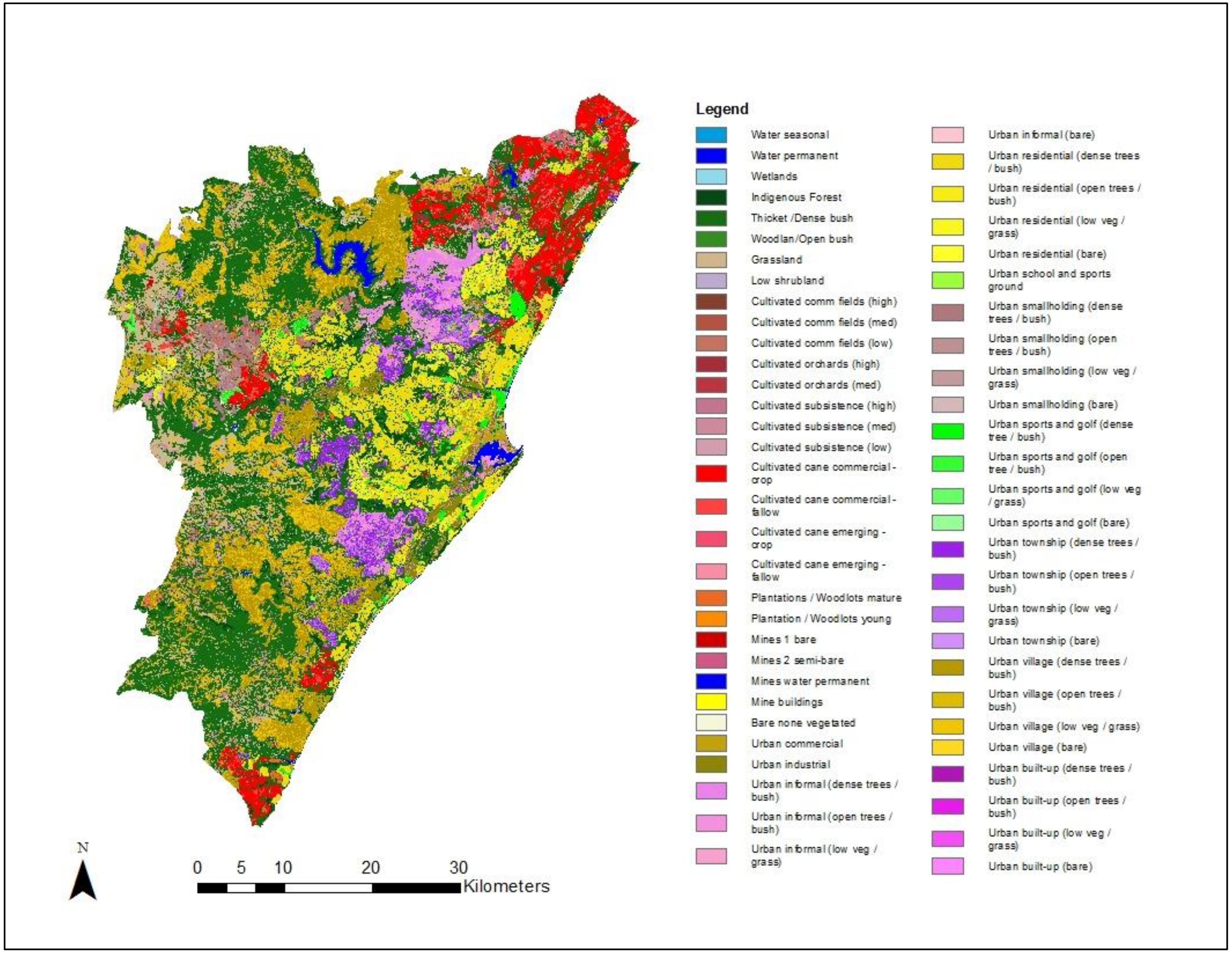

Figure 3.3: Land cover map for the eThekwini Municipality

3.6.2 Landscape metrics computed at the landscape and class levels

a) Landscape level metrics

As stated, spatial patterns can be observed at the landscape level. Landscape pattern metrics focus on the structure, distribution and diversity of patches (table 3.4 below).

The total area for Cape Town, Cape Town without TMNP, and Durban are close to the actual areas of the study sites. This indicates an appropriate level of accuracy given that these calculations were based on a raster data layer. The total length of edge for the entirety of the landscape is much higher in Cape Town (both with and without TMNP) than in Durban, suggesting an increase in edge effects. The results for PAFRAC, indicate an increase in patch shape complexity. At all sites, patch shapes can be identified as highly complex and irregular, further indicating that patch perimeter increases more rapidly as patch area increases – reflecting a consistency of complex patch shapes across spatial scales. Cape Town has the highest number of patches, followed by Cape Town without TMNP and Durban. Generally, an increase in patch number is an indication of the fragmentation level in the area. This indicates that Cape Town has a more complex and subdivided landscape and is consequently more fragmented than Durban. With the TMNP removed, 14229 patches are removed from Cape Town alone. Contagion values are roughly around 50% in the two Cape Town cases, and 57% in Durban. High values of contagion usually result from highly aggregated and poorly interspersed patch types, whilst low values indicate many small patches characterised by poor aggregation and high interspersion. Because these values lie in the middle of the spectrum, there is a fair amount of dispersion and interspersion of the patch types in the landscapes. This is further highlighted with the interspersion and juxtaposition index, with values around 50% in each case and indicating that patches are fairly interspersed. The number of patch types indicated by the patch richness is 57 for Cape Town including and excluding the TMNP and 61 for Durban. The richness to a per area basis shown by the patch richness density indicates that, in terms of the number of patch types, the compositional makeup of the Cape Town and Durban is fairly similar. The evenness index (SHEI) is also similar for each site, which indicates that the distribution of area among patch types is not even. Lastly, larger values of the diversity index (SHDI) indicate a greater number of different patch types and/or greater evenness among patch types. Cape Town without TMNP represents the landscape with more diversity. However, in comparison, there is little difference between the diversity of all sites. Hence, all three sites can be described as complex, subdivided and diverse landscapes.

Table 3.4: Landscape level metrics computed for each city

City	TA (ha)	ED (m/ha)	PAFRAC	NP (No.)	CONTAG (%)	IJI (%)	PR	PRD (No./100 ha)	SHEI	SHDI
Cape Town	249382.37	201.30	1.48	167868	52.92	52.07	57	0.02	0.66	2.69
Cape Town w/o TMNP	220305.91	203.94	1.48	153639	51.74	53.08	57	0.02	0.68	2.77
Durban	256264.16	164.39	1.45	135901	57.13	52.55	61	0.02	0.62	2.56

b) Class level metrics for the land cover types accounting for 80% of the total land cover in each city

Class metrics represent the spatial distribution and pattern within a landscape of a single patch type (table 3.5-3.7 below).

Cape Town

A total of eleven land cover types make up 80% of the landscape within Cape Town. The most dominant land cover type in the City, consisting of an area of 78952 ha, is shrubland fynbos. This land cover type has the highest values of edge density, number of patches and patch density – indicating more edge effects as well as more complexity and subdivision within this class type. The land cover type with the second highest class area is thicket/dense bush and the third is cultivated commercial fields (high). Thicket/dense bush has high values of edge density, number of patches and patch density, whereas cultivated commercial fields (high) do not. Whilst cultivated commercial fields (high) consists of 21817 ha of the landscape, it has the second lowest number of patches and patch density, which indicates a few large areas of cultivation. The rest of the land cover types make up 6% or less of the total landscape. Edge density values range from 8.38 m/ha in the urban townships to a high of 105.33 m/ha in shrubland fynbos. Patch density values range from as low as 0.80 for urban township (low veg/grass) to 10.43 for shrubland fynbos, with higher values representing complexity and subdivision into many patches indicating more fragmentation.

Table 3.5: Class level metrics for land cover types accounting for 80% of the total land cover in Cape Town

City	Dominant Classes	CA (ha)	ED (m/ha)	NP (No.)	PD (No/100 ha)
Cape Town	Shrubland fynbos	78952.90	105.33	26020	10.43
	Thicket/dense bush	23622.79	49.66	24574	9.85
	Cultivated commercial fields (high)	21817.60	14.22	2256	0.90
	Grassland	16336.34	39.40	25921	10.39
	Urban residential (dense trees/bush)	13239.19	24.35	5350	2.14
	Urban residential (low veg/grass)	13089.26	27.16	9833	3.94
	Cultivated commercial fields (medium)	10074.37	15.90	5132	2.05
	Urban commercial	6517.99	10.40	4557	1.82
	Wetlands	6503.41	10.93	5233	2.09
	Low shrubland	6249.63	13.28	8429	3.38
	Urban township (low veg/grass)	5615.17	8.38	2002	0.80

Cape Town excluding the Table Mountain National Park

The eleven land cover types that make up 80% of the landscape within Cape Town excluding TMNP remain the same as the case above. With the TMNP removed from City, the observed total class area and number of patches for the natural land cover types has decreased. The most significant decreases can be observed in the shrubland fynbos, thicket/dense bush, grassland and wetland land cover types. This suggests that the TMNP contains many patches of these land cover types. The trends of ED and PD remain the same for the two most dominant land cover classes. Observed area decreases in urban land use types are due to the settlements in and around the TMNP which were removed by clipping the extent of the park. The slight increase in cultivation is a function of the method used relating to the raster land cover data layer.

Table 3.6: Class level metrics for land cover types accounting for 80% of the total land cover in Cape Town without TMNP

City	Dominant Classes	CA (ha)	ED (m/ha)	NP (No.)	PD (No/100 ha)
Cape Town w/o TMNP	Shrubland fynbos	61261.66	99.49	24723	11.22
	Thicket/dense bush	19706.10	47.89	22071	10.01
	Cultivated commercial fields (high)	21818.69	16.10	2261	1.02
	Grassland	14614.65	39.49	23138	10.50
	Urban residential (dense trees/bush)	13156.10	27.30	5309	2.40
	Urban residential (low veg/grass)	12991.09	30.43	9789	4.44
	Cultivated commercial fields (med)	10076.79	18.00	5124	2.32
	Urban commercial	6489.74	11.70	4514	2.04
	Wetlands	5937.40	11.55	5063	2.29
	Low shrubland	5694.69	13.70	7679	3.48
	Urban township (low veg/grass)	5609.08	9.47	2001	0.90

Durban

A total of eight land cover types make up 80% of the landscape within Durban. The most dominant land cover type in the City, consisting of an area of 85453 ha is Thicket/dense bush. This land cover type has the highest value of edge density and the second highest number of patches and patch density, suggesting high edge effects and that the land cover class is more subdivided. The land cover type with the second largest class area, is urban village. Grassland, the third most dominant cover has the highest number of patches and patch density and the second highest value of edge density. This suggests that grasslands are the most subdivided land cover type in Durban and has high edge effects, making it the most fragmented land cover in the City. In addition, edge density values range from 6.86 m/ha in the urban informal (dense trees/bush) land use to a high of 78.89 m/ha in thicket/dense bush. Patch density values range from as low as 0.43 for urban informal (dense trees/bush) to 9.13 in grasslands.

Table 3.7: Class level metrics for land cover types accounting for 80% of the total land cover in Durban

City	Dominant Classes	CA (ha)	ED (m/ha)	NP (No.)	PD (No/100 ha)
Durban	Thicket/dense bush	85453.23	78.89	17326	6.76
	Urban village (dense trees/bush)	26080.50	29.33	5380	2.09
	Grassland	22229.60	39.69	23421	9.13
	Urban residential (dense trees/bush)	21078.08	20.98	2764	1.07
	Urban village (low veg/grass)	15628.32	25.71	8389	3.27
	Cultivated cane commercial crop	15528.55	10.76	1478	0.57
	Indigenous forest	7474.88	10.52	2811	1.09
	Urban township (dense trees/bush)	6097.53	9.44	2207	0.86
	Urban informal (dense trees/bush)	5925.06	6.86	1111	0.43

c) Class level metrics for natural land cover types in each city

Class metrics for all natural land cover types in each city are presented below in table 3.8.

Wetlands: Cape Town has the largest area of wetlands, which comprises 2.60% of the landscape, whilst Durban has the smallest area of wetlands, comprising 0.29% of the landscape. Edge density values, number of patches and patch density values are greater in Cape Town (with and without TMNP) than in Durban. Durban has the smallest LPI value, indicating that the largest patch of wetland is extremely small. The proximity index values are also much greater in Cape Town than Durban, suggesting that these patches are located in a neighborhood containing more of the corresponding patch type and are distributed in larger, more contiguous, and/or closer patches, compared to Durban. In addition, cohesion values are high in Cape Town, indicating that the patch types are more clumped or aggregated in its distribution and more physically connected. The mesh values range from 2.43 ha in Cape Town without TMNP, to 0.005 ha in Durban. Thus, there is much more fragmentation and less connectivity with this land use type in Durban than in Cape Town.

Indigenous Forest: Durban has the largest area and percentage of indigenous forest compared to the two cases for Cape Town. However, with the exclusion of TMNP, a large portion of the area and number of patches are lost. Hence, the TMNP appears to account for a large amount of the total indigenous forest in the Cape Town landscape. Edge density values, number of patches and patch density are also higher in Durban. The LPI values between Durban and Cape Town suggest that the largest patch of indigenous forest represents a similar proportion in both landscapes, with the largest patch in Cape Town being situated in the TMNP. The proximity index and cohesion values are larger in Cape Town suggesting that these patches are located in a neighborhood containing more indigenous forest and have closer patches which are more connected, compared to Durban. This makes sense since almost all of the patches of indigenous forest are located within the TMNP. The mesh values are also very small when the TMNP removed, suggesting that the land cover type is highly fragmented and less connected in Cape Town.

Thicket/dense Bush: Durban has the largest area and percentage of thicket/dense bush, which represents 33% of the total landscape. Cape Town with and without TMNP consist of 9% and 8% of thicket/dense bush respectively. This land cover type is the most common with respect to all three sites. Durban has the highest edge density and number of patches but a lower patch density value. This suggests that the patches are not as subdivided as those in Cape Town. The largest patch index in Durban is 6.86%, which represents a fairly large patch of thicket/dense bush in the landscape, compared to the lower values in Cape Town which are less than 1%. From the proximity, cohesion and mesh values in Durban, which are all high, the land cover type can be described as having patches in close proximity to each other, which are well connected and the least fragmented in the landscape. However, in the cases of the Cape Town, the patches are not as aggregated or connected, and have more barriers between patches.

Woodland/Open Bush: This land cover type has the most similar area and percentage distribution between the cities of Cape Town and Durban, representing 1.73% and 1.19% of the landscapes respectively. With the TMNP removed, the percentage of landscape decreases to 0.86% which corresponds to the decrease in the number of patches. Edge density values are greater in Cape Town with and without TMNP, compared to Durban with only 0.01 m/ha – suggesting that there are little to no edge effects here. The LPI values are the same in Cape Town and Durban and it decreases when the TMNP is removed. This indicates that the largest patch of woodland/open bush lies within the TMNP. In general, the patches of woodland/open bush are smaller and more dispersed in all cases, with a high amount of fragmentation.

Grassland: Durban has the largest area of grassland, followed by Cape Town and Cape Town without TMNP. Cape Town however, has a greater number of patches and a higher patch density value compared to Durban, suggesting that the patches are more subdivided in the landscape in Cape Town. Edge density values are similar in all cases indicating similar edge effects. The largest patch of grassland occurs in Durban, with much smaller patches occurring in the cases of Cape Town. Patches of grassland are situated closer together and are more connected in Durban, whilst they are more dispersed and have barriers restricting movement in Cape Town.

Shrubland Fynbos: There is typically no fynbos in Durban. Cape Town's main land cover type, has a LPI value of 4.26%, suggesting a large patch of continuous fynbos within the landscape. This is also represented when the TMNP is removed from the analysis. The proximity index, cohesion and mesh values are high in both cases, indicating that these patches are located in close proximity to each other, are highly aggregated and physically connected with lower amounts of fragmentation.

Low shrubland: Cape Town has the largest area of low shrubland, which comprises 2.50% of the landscape, whilst Durban has the smallest area of this land cover type, comprising only 0.14% of the landscape. With the TMNP removed, the area and number of patches of low shrubland decreases. Edge and patch density values are higher in Cape Town (with and without TMNP) than in Durban. The LPI values are small in all cases, suggesting that this land cover type will be found in small patches in all sites. Patches of low shrubland are located closer and are more connected in Cape Town compared to Durban, where there are more sparse and less connected. The mesh value is also extremely small in Durban, indicating more fragmentation of this land cover type.

Table 3.8: Class level metrics for natural land cover types

Natural Classes	City	CA (ha)	PLAND (%)	ED (m/ha)	LPI (%)	NP (No.)	PD (No. per 100 ha)	PROX_ MN (m)	COHESIO N (%)	MESH (ha)
Wetlands	Cape Town	6503.41	2.60	10.93	0.21	5233	2.09	16.64	92.21	2.23
	Cape Town w/o TMNP	5937.40	2.69	11.55	0.24	5063	2.29	16.33	92.12	2.43
	Durban	756.64	0.29	2.59	0.01	3224	1.25	0.36	56.01	0.005
Indigenous Forest	Cape Town	485.42	0.19	0.49	0.09	106	0.04	114.03	96.32	0.28
	Cape Town w/o TMNP	15.01	0.006	0.03	0.002	23	0.01	0.61	75.18	0.0002
	Durban	7474.88	2.91	10.52	0.10	2811	1.09	17.92	92.67	1.40
Thicket/dense Bush	Cape Town	23622.79	9.47	49.66	0.67	24574	9.85	51.36	93.92	18.57
	Cape Town w/o TMNP	19706.10	8.94	47.89	0.76	22071	10.01	53.23	94.04	20.08
	Durban	85453.23	33.34	78.89	6.86	17326	6.76	2757.44	99.37	2391.62
Woodland/Open Bush	Cape Town	4325.11	1.73	15.33	0.01	15016	6.02	1.72	66.47	0.03
	Cape Town w/o TMNP	1912.94	0.86	8.57	0.009	9457	4.29	0.82	54.02	0.01
	Durban	3049.89	1.19	0.01	0.01	13034	5.086	0.86	63.42	0.03

Grassland	Cape Town	16336.34	6.55	39.40	0.08	25921	10.39	9.97	87.27	1.87
	Cape Town w/o TMNP	14614.65	6.63	39.49	0.10	23138	10.50	10.57	87.69	2.04
	Durban	22229.60	8.67	39.69	0.46	23421	9.13	20.30	92.21	12.75
Shrubland Fynbos	Cape Town	78952.90	31.65	105.33	4.26	26020	10.43	1736.18	99.15	1262.38
	Cape Town w/o TMNP	61261.66	27.80	99.49	4.36	24723	11.22	1135.46	98.91	838.79
	Durban	-	-	-	-	-	-	-	-	-
Low Shrubland	Cape Town	6249.63	2.50	13.28	0.52	8429	3.38	56.68	94.75	7.70
	Cape Town w/o TMNP	5694.69	2.58	13.70	0.59	7679	3.48	61.77	95.06	8.71
	Durban	369.14	0.14	1.48	0.004	2061	0.80	0.22	42.99	0.001

3.6.3 Land uses adjacent to key conservation areas in each city

Rondebosch Common

The Rondebosch Common is situated in the southern suburbs of Cape Town and is approximately 40 hectares in extent. The common conserves the critically endangered Cape Flats Sand Fynbos, a few patches of Renosterveld and a seasonal wetland. There are also many plant species, small mammals, reptiles, amphibian and bird species which are protected by the common. The Rondebosch Common however, is located in the midst of a suburb, and is surrounded by five major roads, residential housing, a school and a hospital. The most dominant land use surrounding the Rondebosch Common, outside a 50 m buffer zone from its borders, is residential housing which makes up approximately 60% of the surrounding area. This is similar to other nature reserves in the City, such as Edith Stephans (with surrounding areas of approximately 40% residential and 50% industrial use) and the Kenilworth Racecourse Conservation Area (where the surroundings are close to 60% of residential housing). The historical image represented in figure 3.5 below, shows a similar landscape with residential housing being the dominant surrounding land use which indicates that the areas surrounding the nature reserve have long been developed.

Virginia Bush Nature Reserve

The Virginia Bush Nature Reserve is a 38 hectare reserve in Durban. The reserve contains the original (upper) section of the reserve as well as the lower section, which conserve an area of coastal bush. A large portion of the vegetation however, which was once natural grassland is now alien. A variety of birds and small mammals are protected in the reserve. Like the Rondebosch Common, the Virginia Bush Nature Reserve is located in a suburb. The most dominant land use surrounding the reserve, using a 50 m buffer zone from the borders, is residential housing which makes up close to 80% of the surrounding. This is similar to other nature reserves in Durban, such as the Bluff Nature Reserve (consisting of approximately 70% of residential housing) and the Burman Bush Nature Reserve (with close to 50% residential housing in surrounding areas). The historical image represented in figure 3.7, shows a similar landscape to the current, with residential housing being the dominant surrounding land use.

Figure 3.4: Image of the Rondebosch Common conservation area in Cape Town in 2018 (Google Earth Image, 2018).

Figure 3.5: Historical image of the Rondebosch Common conservation area in Cape Town in 2000 (Google Earth Image, 2000).

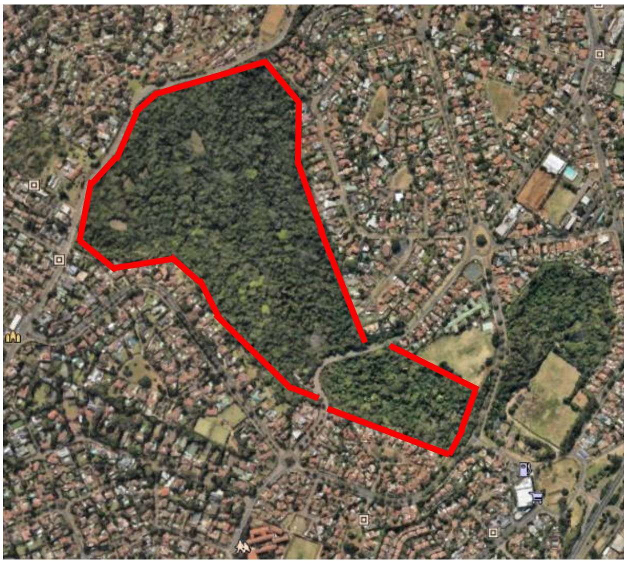

Figure 3.6: Image of the Virginia Bush Nature Reserve in the eThekwini Municipality in 2018 (Google Earth Image, 2018).

Figure 3.7: Historical image of the Virginia Bush Nature Reserve in the eThekwini Municipality in 2001 (Google Earth Image, 2001).

3.7 Discussion

3.7.1 Spatial pattern, heterogeneity and surrounding land uses – A city-wide view

By studying and describing the spatial patterns within the cities of Cape Town and Durban, it becomes clear that these landscapes are highly complex, variable, and display high levels of fragmentation characterised by mosaics of different land cover and use. In general, urban landscapes exhibit rich spatial and temporal heterogeneity as a result of both natural processes and human actions (Alberti, 2005). This is evident in these two cases. The spatial heterogeneity exists, in part, due to gradients in resource distribution, with topography, climate, and geology adding to the broader scale constraints that determine its distribution (Kupfer, 2011). While the mountainous regions of Cape Town are mostly pristine and well conserved, the central lowland regions have been severely impacted by land transformation, resulting in extensive fragmentation (Rebelo, 1992). The eThekwini Municipality displays a fragmented and heterogenous central region as a result of land transformation, but it also has a large rural component in the outer regions. Owing to the greater number of patches and larger edge density and shape index values, Cape Town has the higher level of fragmentation.

Cape Town's highly fragmented urban form can be attributed to a number of factors. It is South Africa's first city and has the oldest municipal structure in the country (Turok & Watson, 2001; Local Government Business Network, 2013). Prior to 1994, South African cities were shaped by modernist planning paradigms and Apartheid social policies (Turok & Watson, 2001) which left these cities with an extremely inefficient urban structure that reflects: spatial fragmentation, separation and a high degree of urban sprawl. The situation in Cape Town is no different with its fragmented urban form coupled to low density urban sprawl and a coarse-grained urban fabric. Urban sprawl in the City radiates from the main transportation axes (Dewar & Uytenbogaardt, 1991). In addition, the City can be seen as comprising four separate landscapes (Rebelo, 2011): in the south-west, and the east, are the sandstone mountains of the Table Mountain chain and the Hottentots Holland - Kogelberg ranges, in the centre lies the sandy Cape Flats which are bordered on the western and southern coastal edges by the dune-dominated strandveld, and inland on the flats are the low shale and granite hills which have been converted to farmland (Figure 3.1). Cape Town therefore, has high topographic heterogeneity and is bordered and constrained by mountainous regions and the ocean which has determined the spatial development. The central and relatively flat lowlands of the Cape Flats form the focal point of urban development. The Cape Flats started becoming densely developed under the Apartheid planning model (McDowell et al., 1991) and intensified from the late 1980s (Rebelo, 2011). The lowland areas of the City, however, are home to the bulk of the diversity of vegetation types which are under serious threat of extinction as a result of habitat loss due to urban development, agriculture, mining, and degradation by invasive alien plants (Holmes et al., 2012). Cape Town has seen significant development since its formation, with limited space for new development zones. Without redevelopment and densification, fragmentation will increase, threatening remaining natural habitats in the City.

From the analysis it is clear that the TMNP skews the landscape indicators used in the study. The size of the park represents a sizeable single conservation area in Cape Town, which contributes approximately 5% of natural cover to the City. According to Schichoff (2011), mountains are globally significant as core areas of biodiversity and are characterised by higher species richness than lowland regions. The TMNP represents a globally significant hotspot of plant and invertebrate biodiversity, and is home to a variety of plant species, many of which are endemic to the region (van Wilgen, Forsyth & Prins, 2012). The dominant vegetation of the TMNP however, is fynbos shrublands with isolated patches of afro-montane forest in sheltered areas (van Wilgen, Forsyth & Prins, 2012). The Table Mountain chain is not representative of the biodiversity in lowland ecosystems in the City (Rebelo et al., 2011). With the significant transformation and development occurring in the City, natural areas are exposed to negative edge effects. Shrubland fynbos is the land cover type with the highest edge value, indicating a high degree of fragmentation of this land cover type – a large portion of which sits in the TMNP. This can be attributed to the lowland regions as well as the areas surrounding the national park being exposed to transformation and increasing fragmentation.

The eThekwini Municipality is less fragmented and about 68% of the municipal area is considered rural, with pockets of dense settlement. While Apartheid policies were abolished in 1994, the structure of Durban remains segregated and fragmented. There is a concentration of more intense land uses in the central and north planning regions, whilst the outer west and southern planning regions have a relatively low-intensity of use. The central region of the City, to the eastern coast is considered the urban core, with economic development occurring in directions around the main transportation axes. This central area of Durban can be considered the most fragmented region in the City. In addition, large numbers of informal settlements are scattered across the City. Due to Durban's dual governance system some areas within the EMA are not administered by the municipality and as a result, cannot be used for municipal development. The outer west and southern regions, which are largely under the governance of traditional authorities, are mostly undeveloped and considered rural. A large portion of conservation worthy-land can be found in these regions. Durban does not contain spatially heterogeneous biodiversity as Cape Town. A significant contribution of thicket/dense bush can be found in Durban, with the patches more aggregated and connected compared with other land cover types in the City. However, the thicket/dense bush land cover type still has the highest value of edge density suggesting that the surrounding areas of these patches are transformed. Unlike Cape Town, the boundaries of Durban have changed considerably throughout the years and in the year 2000, shifted to incorporate 68% of the rural land portion into the municipal area. Durban therefore, does not have an old municipal structure like Cape Town, and different processes and factors have shaped the City's form. Approximately 90% of the rural component can be defined by geospatial features, such as hilly, rugged terrain, and dispersed settlement patterns (in traditional dwellings and communal land holdings under the Ingonyama Trust) (eThekwini Municipality, 2017e). Threats to biodiversity are exacerbated in some regions since developable land is constrained because of Durban's steep and incised topography.

The most prevalent land use surrounding the natural conservation areas in the cities of Cape Town and Durban is residential housing. With these cities' fast-growing populations, more housing developments are constantly being established, and these encroach on remnant patches and on formal conservation areas. According to Goodness and Anderson (2013), formal housing development is a key driver of the ongoing conversion of remnant land. Both the Rondebosch Common and Virginia Bush Nature Reserve are situated within residential suburbs and are surrounded by roads and residential housing. The urgent demand for housing presents a major challenge where some policies come into conflict (Holmes et al., 2012), for example between the housing policy and open space conservation policies in this case. The National Housing Policy, which essentially proposes housing for all, is in truth insufficiently funded to build denser developments to minimise the development footprint and loss of CBAs (Holmes et al., 2012). Cape Town for example, contains unique biodiversity areas inside the urban edge with approximately 13% of the lowlands inside the urban edge earmarked for conservation (Holmes et al., 2012). However, these are further threatened by the high demand for housing.

These conservation areas are surrounded by human land uses which present barriers for species and limit connectivity within the landscape (McDonald, Kareiva & Forman, 2008). The landscapes around the reserves have long been transformed and have been developed for residential purposes in the years before the availability of the historical imagery used in this study. Urban land uses between remnant habitat patches affects the biological communities within patches and leads to the effective isolation of plant and animal populations. In addition, transport infrastructure creates further barriers which according to Ricketts (2001) and Forman et al. (2003) increases the migration mortality of animals, leads to inaccessibility of resources, as well as the subdivision and isolation of populations. Certain land uses limit movement and interactions of species and forces natural and conservation areas to function as isolated entities within the landscape. Since the nature reserves in both cities are completely surrounded by human land use, they can be considered to be functioning as isolated systems within the environment.

Cape Town has a significantly higher value of overall edge density compared to Durban which can be attributed to the fact that Cape Town contains a higher number of patches and is more subdivided. For areas with high human populations, settlements and agricultural lands, like the cities of Cape Town and Durban, there tends to be more edge as a result of abrupt transitions of natural cover and therefore, more edge effects. Negative edge effects of a habitat subsequently increase the chances of animals leaving the habitat and entering the 'matrix' which may increase overall mortality rates and reduce the reproductive rates (Fahrig, 2003). They could also cause abiotic effects as well as direct and indirect biological effects (Murcia, 1995; Laurance et al., 2007). Hence, land use can drive fundamental changes in biodiversity and ecosystem function as well as cause intense changes in disturbance regimes (Alberti, 2005). While this study does not explore the functional ecology of these landscapes or how these processes play out and impact on the actual functional ecology, ecological effects are well documented in the literature and can be assumed to be at play to some degree in these cities in response to the established fragmentation metrics.

As a direct consequence of land cover change as well as altered biophysical conditions resulting from urbanisation the vegetation covers of urban landscapes change dramatically in space and time. The terrestrial environment of Cape Town is largely made up of vegetation from the fynbos biome, whilst a mosaic of thicket/dense bush, open grassland, woodland, and forest can be found in the Durban. Since most development and transformation has taken place in the central lowland regions of Cape Town, figure 3.8 shows that the Cape Flats Sand Fynbos as well as the Cape Flats Dune Strandveld are the most impacted and transformed vegetation types. According to Holmes et al. (2012), there is insufficient habitat left to meet the minimum national targets of the endemic Cape Flats Sand Fynbos, making it a conservation priority. However, there are no plans at either national or provincial levels to increase conservation protection for this vegetation type (Holmes et al., 2012). The Peninsula Sandstone Fynbos as well as the Peninsula Granite Fynbos however, can be seen as adequately conserved in the TMNP. In addition, most development and transformation in the EMA occurs in the Kwa-Zulu Natal Coastal Belt Grassland region (Figure 3.9), which contains a mosaic of grassland and forest habitats. According to Jewitt (2018), by 2011, the Indian Ocean Coastal Belt and Grassland biomes of KZN had the least remaining natural habitat, the highest rates of habitat loss and the least amount of formal protection. Furthermore, the critically endangered KwaZulu-Natal Sandstone Sourveld has received special attention from the EPCPD of the eThekwini Municipality. A large percentage of this ecosystem has been converted as a result of agriculture and development as it occurs in a prime agricultural area for timber and sugar cane plantations. This has led to significant habitat loss and fragmentation of the vegetation type. It is therefore prioritised because of high levels of transformation and degradation, low levels of protection and the fact that opportunities still exist for conservation action. These opportunities will soon be lost because of urban development pressures (Boon et al., 2016). The rapid rate of habitat loss and fragmentation and its impacts to endemic vegetation types within cities should be seen as an urgency to protect the remaining natural habitats, particularly those in biodiversity hotspots such as Durban and Cape Town.

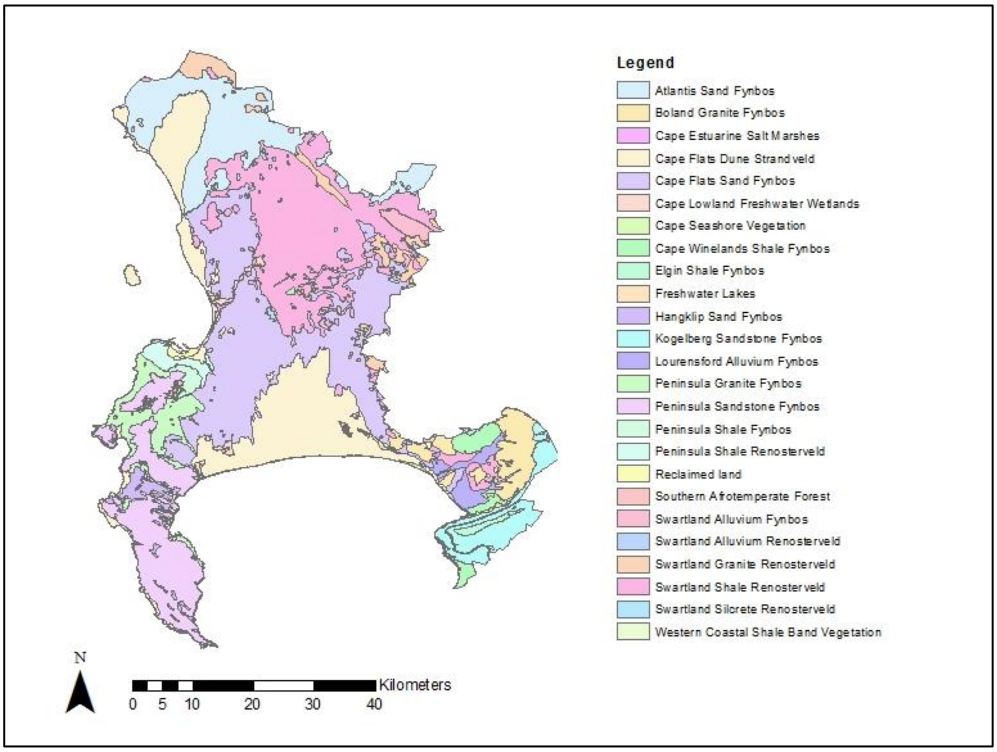

Figure 3.8: Vegetation Map for the City of Cape Town (Source: SANBI BGIS, Vegetation Map of South Africa 2012).

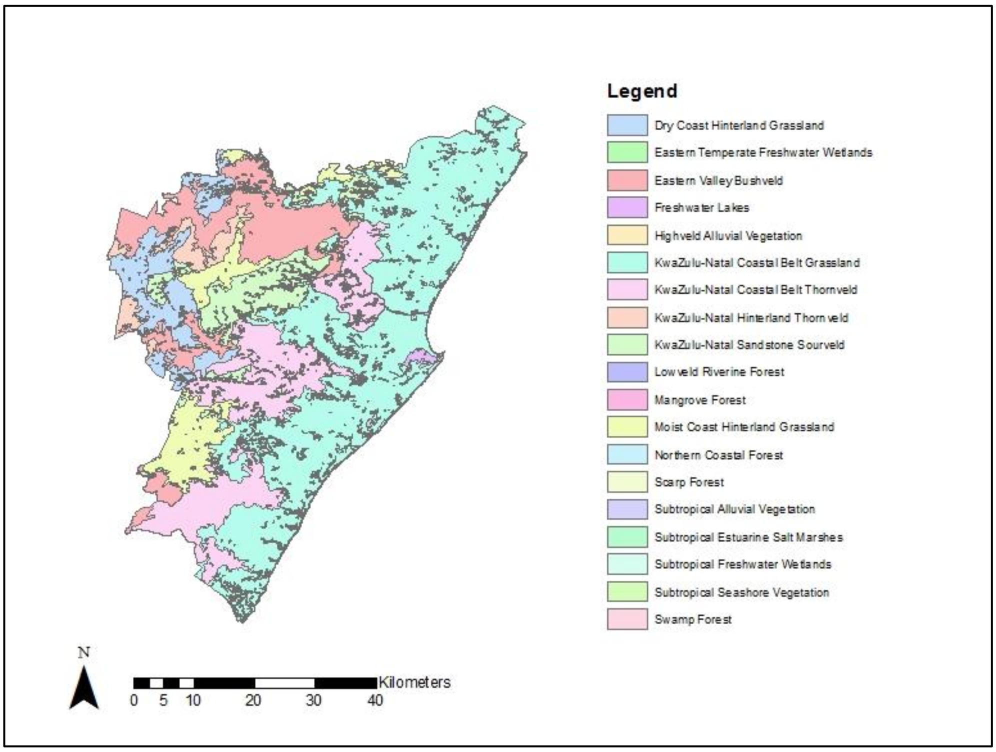

Figure 3.9: Vegetation Map for the eThekwini Municipality (Source: SANBI BGIS, Vegetation Map of South Africa 2012).

3.7.2 Impacts of fragmentation on ecological function and process: a conservation consideration

Following on from Fahrig (2005) (Figure 3.10), changes in landscape structure affect the biotic patterns and biotic processes of the region. I draw on this structure in discussing my findings for the cities of Cape Town and Durban.

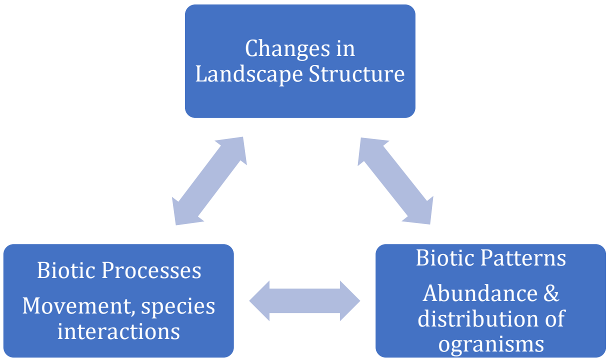

Figure 3.10: Landscape ecological interactions (Adapted from: Fahrig, 2005)

Biotic Processes: Since the cities of Cape Town and Durban exhibit high levels of fragmentation, with smaller patches of habitat, which are isolated from adjacent fragments and are surrounded by a human-modified matrix, the biological communities within these habitats are threatened and greatly affected by the increasing influences of human activities. Low levels of connectivity are directly linked with the high degree of habitat loss and fragmentation. The mountainous areas of Cape Town are largely unaltered and are well connected. The central regions of the City however, contains different patches of habitat which are smaller, highly interspersed and less connected. Similarly, habitat patches outside the eThekwini central region show higher levels of connectivity compared to the those within and around the Central Business District.

From the analysis it is evident that there are sometimes large distances between habitat fragments, especially in those areas which are highly developed. This typically lowers the level of connectivity within a landscape and increases the isolation from adjacent fragments and source populations. According to Auffret, Plue and Cousins (2015: 51), connectivity in ecology is traditionally defined as "how the movement of various ecological units or entities is facilitated by their surroundings". Connectivity is important for understanding and managing the ecological systems as well as the relationships between individuals, populations, and communities and the surrounding habitats, landscapes, and regions which they inhabit (Auffret, Plue & Cousins, 2015).

The expansion of urban areas alters habitat configuration and connectivity with adverse impacts on species dispersal (Güneralp & Seto, 2013). The low levels of connectivity between habitat patches in certain areas in the cities of Cape Town and Durban are likely to affect the movement, distribution and interactions of species within them. According to Alberti (2005), native plant and animal species in isolated patches decline with decreasing patch size, restricted interspecific interactions (Dickman, 1987) and reduced connectivity. However, while original species within the habitat may decline, some invading species that are capable of establishing in fragmented systems may increase (Saunders, Hobbs & Margules 1991). Consequently, one of the major threats to biodiversity within Cape Town and Durban are alien invasive species which can invade and suppress native species, alter ecosystem functions and disrupt flows of ESS (Potgieter et al., 2018).

In addition, dispersal processes (an important factor regulating competition, co-existence, and community organisation, particularly in plant communities) will be significantly impacted by habitat fragmentation. According to the Metapopulation Theory (Hanski, 1999; Hanski, 2011), a reduction in dispersal can decrease opportunities for locally extinct species to recolonise, leading to loss of diversity at larger scales. In the longer term, reduced connectivity can have further negative effects on a population's long-term viability through the loss of genetic diversity (Lienert, 2004). Furthermore, increasing biogeographical barriers, especially in urban areas, reduces species access to resources which can lead to lower survival and reproductive rates, which may, in turn, reduce population persistence (Di Giulio, Holderegger & Tobias, 2009). For example, the population of the endemic Western Leopard Toad in Cape Town has declined significantly through the process of urbanisation and associated road traffic. Similarly, the vulnerable Dwarf Chameleon population in the eThekwini Municipality has declined because their habitat in the Coastal Belt Grasslands has been transformed by urbanisation and the cultivation of sugar cane. The barrier effect of roads also affects species' migration patterns and those which require multiple habitats (Di Giulio, Holderegger & Tobias, 2009). Isolated populations may also suffer a lack of gene flow which could potentially lead to inbreeding (Di Giulio, Holderegger & Tobias, 2009; Hanski 2011). In addition, ecosystems in fragmented habitats are more vulnerable to disturbances, stresses and diseases, less resilient, and less able to supply humans with needed services (Saunders, Hobbs & Margules 1991; Alberti, 2005).

Ensuring the connectivity of the landscape is paramount in sustaining biodiversity in the region. Fragments of open space should be conserved and linked where possible, to provide important "stepping stones" for the dispersal of flora and fauna between larger open spaces. The cities of Cape Town and Durban have planned for the creation of landscape corridors (strips of habitat that connect isolated patches of habitat) in their conservation systems. However, it is often difficult for city officials to monitor and prevent disturbances to all the different patches of habitat in the municipal areas which are small, fragmented, and spread over large geographic areas. Remnants and corridors may still be destroyed in the wake of development.

Biotic Patterns: The size and shape of habitat patches and their edges, are particularly important patch characteristics that can affect habitat quality and diversity, ecosystem integrity, resource availability, and competition (Alberti, 2005). Patches represented in both cities are smaller, with complex irregular shapes and high amounts of edge. According to Fahrig (2003), as habitat patches become smaller, they are less likely to sustain native species populations (Wu, 2014) or even provide an individual territory. This has long term impacts on species numbers and species abundance (Fahrig, 2003), and ultimately threatens species survival (Murcia, 1995). In addition, species that are unable to move through transformed landscapes will be restricted to these small natural patches, which will ultimately result in reduced overall population size and probability of persistence (Fahrig, 2003). These effects can already be observed in the cities of Cape Town and Durban with certain plant and animal species decreasing due to changes in biotic patterns.

Plant and animal diversity and abundance, will most likely decrease as habitats shrink, disrupting species interactions, which can lead to lower performance and deleterious population dynamics or even species extinction (Young & Clarke, 2000; Andrieu et al., 2009). Some researchers have also associated the process of fragmentation with the Theory of Island Biogeography which suggests that habitat fragmentation increases the gradual loss of species and reduces overall species diversity (MacDonald, 2018). Complex patch shapes and an increase in the proportional abundance of edge influenced habitat are likely to have further implications for species which are interior-sensitive species, and general ecosystem integrity. In addition, habitat fragmentation may not only have a direct impact on species and populations, but can also change abiotic conditions of the surrounding landscape and of the habitat itself, which will inevitably influence biotic interactions (Saunders, Hobbs & Margules 1991). While some plants and animals may live in naturally fragmented habitats and can cope with the conditions associated with fragmentation, the current extent of habitat fragmentation associated with increasing urbanisation far exceeds natural fragmentation rates and is occurring at a much faster time-scale than many populations can adapt to (Lienert, 2004).

Habitat fragmentation however, could also have positive effects on biodiversity. Some species for example, can show a positive response to edge effects where some animals even have a positive preference for edge environments. Furthermore, having different habitat types in close proximity could be beneficial to species which require more than one kind of habitat. For example, an increase in residential housing units could also result in more private gardens which could enhance biodiversity and provide biodiversity benefits such as year-round water provision (Goddard, 2010).

The levels of fragmentation evident in the cities of Cape Town and Durban pose a significant threat to biodiversity, species, and ecosystems and to the overall ecosystem processes and functioning of these regions. Residential areas can also be seen as making up a large component of the "matrix", where species are increasingly exposed to human influences. In addition, with increasing areas allocated to residential housing and urban land use encroaching upon the immediate surrounding areas of natural reserves in the cities, these systems can be considered as functioning as isolated systems with little to no space available for the future expansion of the reserves (Wade & Theobald, 2010; Güneralp & Seto, 2013). Fragmentation patterns and their impacts on ecology need to be properly identified and considered in conservation planning as well as in the overall city planning and decision-making processes.

By analysing landscape pattern, spatial heterogeneity and the pressures imposed on nature reserves in urban areas, we can better understand the levels of fragmentation and how it affects the ecology in cities, and hence how to plan for conservation in urban environments. Cities need to adopt an adaptive management approach to biodiversity conservation with additional steps in achieving conservation outcomes. These can consist of: ground-truthing the remnant vegetation patches within cities, fund regular updates of land cover mapping, analysing and monitor fragmentation patterns and their effects on ecological processes, and continuously monitoring remnant patches and conservation areas in cities to avoid further loss and degradation.

3.8 Conclusion

Fragmentation and habitat modification as a result of human activities are considered to be major threats to biodiversity globally and pose significant challenges for conservation. While urban areas are considered extremely fragmented environments, they can contain areas with high levels of biodiversity that need to be protected. While the cities of Cape Town and Durban have completed conservation assessments to facilitate the conservation of the remaining biodiversity and natural habitats within these cities, urban development and transformation still pose major threats for conservation.

In the cities of Cape Town and Durban, the processes of fragmentation and habitat loss are accelerating and are changing landscape pattern and the spatial heterogeneity of these urban landscapes. Cape Town has a higher level of fragmentation and topographic heterogeneity and contains spatially heterogenous biodiversity. While the TMNP represents a single extensive conservation estate within the City, this is not representative of the City's overall biodiversity, much of which is still under threat from development. The central regions of the City of Durban are also highly fragmented. However, while Durban contains a large rural component in the outer regions, with most of the ecosystems and vegetation in these areas remaining intact, these regions are not formally protected. Different processes and factors have shaped each of these city's forms and present different challenges for conservation. Fragmentation, a key outcome of many of these processes, while affecting regions within cities differently, poses a major threat to the biodiversity, species, natural ecosystems as well as the ecological patterns and processes within both cities. Increased urban land use, population pressure and cultivation, are the major drivers of habitat fragmentation. The predominant land use surrounding a number of nature reserves in both cities is residential housing, highlighting increasing population pressure that further impacts the ecological processes within these protected areas.

Understanding how the process of fragmentation directs the spatial structure, distribution and heterogeneity of urban areas and how this affects the ecological functioning and processes within cities is important information that can be drawn on when managing biodiversity within cities. This information can be used to determine how successful conservation plans are likely to be in achieving conservation success. City level quantification of habitat fragmentation provides a useful tool, assisting with land use planning and conservation planning in the management and containment of fragmentation in cities, either in general or through specific focus on ecological features such as vegetation types. In addition, by determining the current levels of habitat fragmentation, cities can ensure that natural habitats and ecosystems are properly considered and monitored, and that further degradation is prevented. Furthermore, since urban areas usually have a variety of land uses in close proximity to one another, the identification of priority conservation areas can better inform the planning of land uses in the vicinity of these areas. The different city departments need to work in an integrated and co-operative manner in planning and managing the urban environment to prevent the further loss and degradation of the biodiversity and natural spaces within these complex social-ecological systems.

Chapter 4: Conclusions and Recommendations

South Africa has developed advanced biodiversity legislation and policies (SANBI, 2017b). Like many other developing countries however, South Africa's need for economic growth comes at a great risk to its natural resources (SACN, 2016). This in part, stems from the lack of integration between biodiversity conservation and development, which ultimately challenges the biodiversity sector's work.

The long-term survival and well-being of people depends on the effective conservation of the world's biodiversity. The majority of the world's population now live in urban areas, and increased urbanisation and land transformation creates new challenges for biodiversity conservation. There is now a global drive for biodiversity conservation approaches to be integrated into all spheres of government. Local government in particular, has received international recognition as being the most significant in directing and achieving sustainability. Given the influence local governments have in policy implementation and that the 21st century has been dominated by city growth and development and has been called the "urban era", it is fitting that the road to sustainable development begin with cities (SACN, 2016). While cities are arguably the hardest places in the world in which to put conservation into practice, conservation and restoration in these highly developed areas are often essential to the preservation of biodiversity.

The cities of Cape Town and Durban in South Africa are doing ground-breaking work to help conserve, protect and manage open spaces and the associated biodiversity within their city boundaries. The municipalities have developed their own biodiversity and open space conservation strategies that have been formally recognised and help to conserve the important biodiversity and natural habitats within these cities. In advancing our understanding in this space I focussed on determining the informants and emerging form of the urban conservation strategies in these two cities in light of their variable biophysical templates and histories. I also set out to establish an understanding of the physical landscape pattern, heterogeneity and land uses adjacent to conservation land, and from these infer likely ecological outcomes of the emergent form, for these two cities. It is useful to compare and contrast these cities in order to highlight and identify the key challenges and drivers which shape these cities and it further provides an opportunity to understand the local informants of conservation plans and their spatial outcomes. The main findings from both empirical chapters are synthesised below bringing together the two sets of empirical findings towards a broader urban ecology focused consideration. Broadly, the thesis shows that urbanisation patterns, urbanisation impacts, and the sustainability of urbanisation interact with each other (as shown in figure 1.1). Hence, the themes of pattern, form and impacts were central to this thesis, and as demonstrated, are relevant in turn to sustainability

4.1 Applying a conservation lense in understanding emergent urban form

The BioNet in the City of Cape Town and the D'MOSS in the eThekwini Municipality represent these municipalities' fine-scale systematic conservation plans which aim to conserve, protect and manage the biodiversity and natural spaces within their boundaries. Whilst the BioNet and D'MOSS have emerged along very different lines, their core aim and objectives are centred on the conservation of biodiversity and open spaces and the continued provision of ESS in these municipal areas. The municipality in each case makes use of SCP methods and face similar challenges in the implementation of their conservation plans at the local level. However, the cities differ with regards to their: histories and development of conservation plans; local environmental policies; the influence of these conservation plans at the local level; the status and success of the conservation systems; biophysical templates and governance of land; and in the ways they distribute and display the conservation systems information.

The eThekwini Municipality has a long history of open space planning, dating back to the 1970s, with a broad group of specialists including town planners, NGOs, academics and applied scientists being involved in the creation of the MOSS. The CoCT on the other hand, initiated the BioNet project in 2002 and those involved consisted mostly of biodiversity specialists, consultants and the City's conservation partners. The eThekwini Municipality therefore had a broader group involved in the development of their conservation plan, which included town planners with a spatial planning background as well as a former NGO.

The CoCT has several environmental policies relating to biodiversity at the local level, including an Environmental Strategy, Local Biodiversity Strategy and Action Plan and a Bioregional Plan, that indicates an extensive approach and strong interest among those that direct the City in its governance and management of biodiversity conservation at the municipal level. The eThekwini Municipality does not have many environmental policies relating to biodiversity, apart from its open space conservation system and Biodiversity Strategy and Action Plan which highlights the objectives of the D'MOSS. The municipality has, however, successfully integrated D'MOSS into the City's town planning schemes and this ultimately ensures that biodiversity concerns inform all development planning and assessment processes in the City. Hence, it offers the most opportunity for ensuring compliance. Durban's conservation plan has a greater influence at the local level than that of Cape Town.

The eThekwini Municipality, however, had only 8.2% of the D'MOSS secured in 2016, while the conservation status of the BioNet stood at 60.91%. Thus, the CoCT appears to be more successful in having more than 50% of its conservation plan secured and protected. This status of the BioNet however, can be attributed in part to the TMNP as well as the other large mountainous regions in the Cape Town region which contribute significantly to the conservation estate of the City and status of the BioNet. In addition, the eThekwini Municipality is faced with the significant challenge of being the only metropolitan municipality in the country which has traditional authorities governing land within the municipal area. A total of 38% of the land within the municipal area was administered by the Ingonyama Trust Board in 2016. Since land use schemes are yet to be developed in these communal areas, the D'MOSS development control layer does not have influence in these spaces. Conservation worthy land, most of which lies in these traditional authority areas, cannot be secured or protected unless biodiversity agreements are established with the traditional leaders in these areas.

The differing biophysical templates of these cities have served to shape their conservation policies and plans and have also influenced the conservation status of these plans. The CoCT is situated within the CFR hotspot and is the only South African city which includes a national park within its borders. As a result, urban ecological studies have primarily been driven by nature conservation concerns (Cilliers & Siebert, 2012; Holmes et al., 2012). In Durban however, ecological studies have been driven by open space planning and environmental management with the emphasis on the protection of key environmental areas for biodiversity conservation (Roberts, 2008; Cilliers & Siebert, 2012).

The way in which these two cities distribute and display their conservation systems' information is also different. It is easier to find updated information on the CoCT's BioNet than on the D'MOSS. The CoCT's BioNet reports and spatial datasets are made available to the public and are easily accessible on both the SANBI BGIS website and the CoCT's open data portal. The eThekwini Municipality however, does not issue annual reports on its conservation system, nor does it make the D'MOSS spatial dataset available to the public. However, the municipality does provide an open map of the D'MOSS on its GIS portal so that land owners are able to ascertain if the D'MOSS control layer is situated on their property. Hence, while the D'MOSS is very integrated into Durban's town planning, it is less accessible to society compared to the BioNet which is still fighting for better integration into spatial planning but is far more accessible to society. This shows different approaches to the governance and management of biodiversity at the local level.

While the cities of Cape Town and Durban are making some headway at implementation and have been successful in securing portions of their conservation plans, both cities still face several challenges in the effective application of their conservation agendas. These include: gaining and maintaining political support as well as citizen buy-in; negotiating conservation stewardships on private land; balancing development needs and biodiversity conservation imperatives between city departments; overcoming the lack of integration and co-operation across different departments and sectors; and not having a clear biodiversity mandate, funding and sometimes limited skills and a lack of expert capacity for biodiversity management at the local level. These challenges tend to prevent the effective implementation of conservation policy.

4.2 Understanding landscape heterogeneity and the drivers of urban form

Fragmentation and habitat modification as a result of human activities are considered to be major threats to biodiversity globally and pose significant challenges for conservation. These are further exacerbated in cities with intensified, high levels of urbanisation which lead to extremely fragmented urban environments. Taking a city-wide view in Cape Town and Durban, the process of fragmentation has significantly changed the landscape pattern and spatial heterogeneity of these urban landscapes. These changes to landscape structure and composition can have several effects on biodiversity and the ecological patterns and processes of the region. In addition, land uses surrounding the remaining natural habitats in cities are becoming intensively developed, modified and transformed, further impacting the species and ecological patterns and processes within these natural reserves. Urban form therefore affects the ecological performance of the urban environment (Tratalos et al., 2007).

My analysis highlights that Cape Town and Durban's landscapes are highly complex, variable, and display high levels of fragmentation characterised by mosaics of differing land cover and use. While these are both South African cities, different processes and factors have shaped each city's form, resulting in different characteristics, structures and features which ultimately influence the biotic and abiotic components within them and, in turn, their ecological systems.

The City of Cape Town, South Africa's oldest city, displayed a higher level of fragmentation and topographic heterogeneity and also contains spatially heterogenous biodiversity. While sprawling in nature, Cape Town is in fact intensely developed with extensive cover and contains limited space for new development zones. The City is bordered and constrained by mountainous regions and the ocean which has determined and constrained its spatial development. Without re-development and densification, fragmentation will increase, threatening remaining natural habitats of this fynbos floral kingdom in the City. While the TMNP represents a single extensive conservation estate within the City (and contributes to the conservation status of the BioNet), this area is not representative of the City's overall biodiversity. The majority of the TMNP for example, contains the Peninsula Sandstone Fynbos vegetation type which is well conserved. However, other vegetation types in the City are still largely under threat from development, with little habitat remaining to meet conservation targets. Hence, while the conservation status may be high in Cape Town, this is not representative of the overall biodiversity in the City.

The central regions of the City of Durban are also highly fragmented. Durban incorporates a large rural land component in the outer regions, with most of the ecosystems and vegetation in these areas remaining intact. These regions, however, are not formally protected and fall under the governance of traditional authorities. In addition, Durban does not contain the same levels of spatially heterogeneous biodiversity as Cape Town. A significant contribution of thicket/dense bush, grassland and forest habitats can be found in this City. Durban's rural component can also be defined by a hilly, rugged terrain with dispersed settlements. Developable land is thus constrained by this steep and incised topography, which appears to be better suited for rural land use. The municipality's boundaries have also changed considerably over the years and new areas have been incorporated into the municipal region. Durban therefore, is not as highly developed and does not have an old municipal structure like Cape Town.

While habitat fragmentation is evident in both cities, it affects certain regions within these cities differently, and poses a major threat to the biodiversity, species, natural ecosystems as well as the ecological patterns and processes within these cities. Increased urban land use, population pressure and cultivation are identified as the major drivers of this habitat fragmentation. The predominant land use surrounding a number of the nature reserves in both cities is residential housing, highlighting increasing population pressure that further impacts the ecological processes within these protected areas. In addition, with increasing areas allocated to residential housing and urban land use encroaching upon the immediate surrounding areas of natural reserves in the cities, these systems can be considered as functioning as isolated systems with little to no space available for the future expansion of the reserves (Wade & Theobald, 2010; Güneralp & Seto, 2013).

Understanding how the process of fragmentation directs the spatial structure, distribution and heterogeneity of urban areas and how this affects the ecological functioning and processes within cities is important information that can be drawn on in managing biodiversity within cities. This information can be used to determine how successful conservation plans are likely to be in achieving conservation outcomes. The use of spatial analysis techniques, remote sensing and landscape metrics offer promising tools in the field of landscape ecology, and in assessing levels of fragmentation. Studies around the world have used similar techniques to quantify landscape structure, including the Heihe River Basin in north-west China (Li et al., 2001), as well as to assess fragmentation patterns like the conservation priority areas in the Dudhwa landscape in India (Midha & Mathur, 2010). A city level quantification of habitat fragmentation can provide useful data and insights which can be used to assist with land use and conservation planning in the management and containment of fragmentation in cities, either in general or through specific focus on ecological features such as vegetation types. This was further suggested by Nagendra et al. (2012) who explored patterns of fragmentation in the rapidly expanding City of Bangalore. In addition, by determining current levels of habitat fragmentation, cities can ensure that natural habitats and ecosystems are properly considered and monitored, and that further degradation is prevented. Furthermore, since urban areas usually have a variety of land uses in close proximity to one another, the identification of priority conservation areas can better inform the planning of land uses in the vicinity of these areas. Cities need a greater understanding of interacting factors that influence biodiversity so that they can undertake biodiversity planning and management more effectively.

4.3 Looking forward

Biodiversity underpins our existence, providing critical life-support systems and the natural resources upon which we depend. This has been acknowledged by national governments, for example according to DEA (2016: 3), "one of the biggest challenges for our society is the need to establish a sustainable relationship with the living world in which the intrinsic value of our biodiversity is respected and where the benefits derived from living systems are realised and used in such a way that they add value to people's lives without being degraded".

A significant proportion of earth's biodiversity is located in those areas of the world which contain high levels of human populations and where development is increasing. In the next few decades urban expansion will continue at an unprecedented rate in many countries, especially in Asia and Africa (United Nations, Department of Economic and Social Affairs, 2015; City of Cape Town, 2017c). The crises of urban and suburban sprawl are rapidly transforming critical habitats and threatening biodiversity in many areas around the world, including: the Cape of South Africa, coastal Central America, the Atlantic Forest Region of Brazil and Paraguay and south-west Australia (Miller & Hobbs, 2002). An incredible amount of native biodiversity can be found in some of the world's largest metropolitan areas (Miller & Hobbs, 2002), with this biodiversity and its associated ecological functions, helping to sustain the local populations and communities. The cities of Cape Town and Durban are no exception and are situated within biodiversity hotspots. However, similar to cities around the world, South African metropolitan areas are important to the country's development path, with more than 60% of the country's population currently concentrated in the urban centres. This is expected to increase to 71.3% by 2030 (City of Cape Town, 2017c). Other examples of cities with rich biodiversity include: the remnants of Mata Atlantica forests in Rio de Janeiro, the Singapore Botanic Garden, the Ridge Forest in New Delhi, and urban green space in Calcutta (Miller & Hobbs, 2002). The dramatic shift towards urban living places increasing pressure on the biological features within these urban landscapes. In an evaluation of the relationships between urban form and measures of environmental quality and biodiversity potential in five United Kingdom cities, Tratalos et al. (2007) state that there are clear potential impacts on the ecological and environmental performance of urban areas associated with high urban development.

Urban ecology plays an important role in this regard as it strives to understand urban systems and provides many avenues to support the goals of conserving urban biodiversity thereby improving urban sustainability and resilience and promoting human well-being on an increasingly urbanising planet (McPhearson et al., 2016). Global sustainability depends critically on cities, and urban ecology can and needs to play a key role in the transition toward sustainability (Wu, 2014). In keeping with Wilkinson et al. (2013), this research has found that, although the cities of Cape Town and Durban are facing similar issues in terms of biodiversity loss and natural habitats becoming increasingly fragmented, the way in which these issues manifest in the two cities is different. In addition, as Richter and Weiland (2011) state, the development of cities is heterogeneous and is dependent on growth dynamics, socio-economic conditions, cultural relationships, and on the ecological framework conditions of the regions. From the research it is evident that both cities have indeed been shaped by distinctive development histories, and have different biophysical templates, cultural heritages, planning traditions and social structures which have ultimately shaped each city's form. They also have unique biologies, ecosystems and landscape features, all of which have shaped their policies and plans at the local level. Hence, the ecology of and in different cities is unique and it is clear why ecological studies and conservation plans have evolved along different lines.

The knowledge base of the ecology of and in different cities is therefore uneven (Wilkinson et al., 2013), and the values underpinning how contemporary cities should be managed is also not a static field of enquiry (Wilkinson et al., 2013). While urban ecology presents us with useful rules and continues to seek a unified response to the urban environment, all cities are unique and there is no one-size-fits-all approach when it comes to conservation plans for a city. The local context, biophysical templates, city histories, social informants of how these plans emerge and evolve, contemporary governance structures and local pressures, all play a significant role in the development of conservation plans. These elements, together with how they play out and in combination with the locally derived conservation plans and the local urban form, will further result in different conservation land configurations.

Cities around the world are officially recognising the importance of biodiversity and open spaces within their boundaries and are establishing conservation plans and policies to protect and conserve the remaining biodiversity. To name a few, the cities of Surrey, Hong Kong, Melbourne, Edmonton and Montréal have focused on biodiversity conservation practices. In South Africa, the cities of Cape Town and Durban along with other cities, have established formal conservation networks at the local government level. The conservation plans in the cities of Cape Town and Durban follow best practice techniques and can be seen as being aligned to other conservation plans around the world. However, due to several limitations and constraints in budget, capacity and resources at the local government level, and due to the fact that the local government is not officially recognised as a conservation implementation partner in national legislation, implementation has been slow and has constrained the rollout of conservation practices. In addition, while these plans are similar in their objectives and planning techniques, they differ with respect to how they play out in reality. While cities are facing similar issues relating to biodiversity and open spaces, there are essentially many factors which determine how conservation plans are formed, how they are implemented and how successful they will be in achieving conservation action, all of which are unique to the city in question. In keeping with Richter and Weiland (2011), the differences between cities and the variety of urban development processes means that the general meaning of sustainable development has to be transferred to the prevailing local conditions of each city.

In conclusion, the timeframe to retain biodiversity in cities' is short. People need to be recognised as an integral part of ecological systems where we recognise our role as forces of change and acknowledge that our well-being depends on the flow of goods and services from ecological systems (DEA, 2016). A good conservation plan is simply not enough. Success will depend on a variety of other factors, including: cross department collaborations and across hierarchy collaborations; how well the conservation plan is received and embedded in the rest of the city's functions and departments; local government skills and budgets for biodiversity conservation; and co-operation from other governance structures. In South Africa, national capabilities need to be improved in order to manage natural living resources, mitigate risks, adapt to changing climates, and provide evidence to support the development and implementation of policies that reduce biodiversity loss and improve sustainable benefits to society. In addition, the local government should officially be recognised as an important biodiversity implementation partner in national legislation, and more resources should be made available to them for conservation purposes. A clear biodiversity mandate, resources, skills and capacity for biodiversity management at the local level is needed. In addition, continued discussions and improved implementation techniques are needed to challenge how cities manage and integrate biodiversity within their landscape and the need for development. Hence, as cities are spatially heterogeneous, complex adaptive systems, urban sustainability can be viewed as a dynamic process instead of a fixed goal (Wu, 2014). The results of this study might be relevant to many cities around the world, who harbour large amounts of biodiversity but where population growth and urbanisation is causing the rapid depletion of important biodiversity assets. Conservation planning methods and the integration of a biodiversity mandate into local policies can be seen as a way of identifying key areas of biodiversity and protecting these areas from future development.

It is suggested that further research place emphasis on the importance of biodiversity conservation in an urban context and how the earth's biological resources are increasingly being threatened by various human activities within city limits. In addition, we need to explore how cities are integrating biodiversity concerns into policy and decision making; identify the specific challenges faced by local governments in actively achieving biodiversity protection; and design strategies to overcome these challenges and attain effective biodiversity governance in an urban environment. Finally, we require knowledge of the ecological functioning of species in relation to the configuration of urban space so that this can be used to guide and inform policy and plans of the future.

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6. Appendices

6.1 Appendix A - The different levels of biodiversity governance in South Africa

South Africa recognises the urgent need to protect the natural environment and is doing ground-breaking work to conserve and manage biodiversity in the wider landscape by means of its legislation, agreements, institutions, and plans and programmes that range in scale from the international level down to the city level (DEA, 2012b; Goodness & Anderson, 2013). Ultimately, the South African government is the primary source of funding for biodiversity management, with donor funds being an important additional source of income for the sector. While limited resources do present a significant constraint to the biodiversity sector, South Africa has nevertheless made considerable progress with prioritising its biodiversity.

6.1.1 South Africa's international agreements and obligations

The state of the environment concerns the entire international community. The establishment of a number of environmental conventions is proof of the world's commitment to sustainable development. At the international level, South Africa is a signatory and party to numerous international conventions, treaties and protocols that "relate to wide-ranging aspects involving biodiversity and ecosystem health on land and at sea" (DEA, 2012b: 124). These commit South Africa to sustainable development and inter-country co-operation on matters of global interest. These agreements have been translated into, and inform, various national policies and legislation.

International agreements and obligations which are most relevant to South Africa's biodiversity and ecosystems include: The World Charter for Nature, 1982; the Rio Declaration on Environment and Development, 1992; the Convention on Biological Diversity (with commitments in Rio de Janeiro in 1992 and Nagoya in 2010); and the agreement to the establishment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in 2012 (DEA, 2012b; Goodness & Anderson, 2013). The IPBES's key objective is to ensure the long-term well-being of humans and sustainable development, through the conservation and sustainable use of biodiversity and ecosystem services (IPBES, 2017).

In 2015, the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) were adopted by world leaders at a historic UN Summit (Schultz, Tyrrell & Ebenhard, 2016). The SDGs universally apply to all countries, including South Africa and attempts to mobilise efforts to end all forms of poverty, fight inequalities and tackle environmental protection and climate change (United Nations Development Programme, 2018). The 2030 Agenda also recognises that sustainable management of the earth's natural resources is relevant to achieving all SDGs (Schultz, Tyrrell & Ebenhard, 2016). Furthermore, South Africa has also committed to the United Nations CBD's Strategic Plan for Biodiversity 2011–2020 and its Aichi Biodiversity Targets (ABTs), which includes 20 time-bound, measurable targets relating to biodiversity (CBD, n.d). According to Schultz, Tyrrell and Ebenhard (2016), there is a strong overlap and linkage between the SDGs and ABTs in terms of the elements covered. If effectively executed, the overlap between these processes will strengthen the message that effective conservation of biodiversity and ESS can ultimately lead to significant gains in many facets of sustainable development (Schultz, Tyrrell & Ebenhard, 2016).

These agreements establish and outline terms that are used in the country's legislation, including sustainable development and biodiversity. According to de Oliveira et al. (2011) city governments in particular, are central to successfully implementing international environmental agreements. Even though many cities are not directly involved in the negotiation of these international treaties, which are signed by national governments, most of the agreements are implemented at the city level. The CBD has formally recognised the importance of involving cities and local governments in its implementation since the Ninth Conference of the Parties (COP-09) of the CBD in 2008 (de Oliveira et al., 2011). This was further strengthened in 2010 at the CBD COP-10 in Nagoya, by the official endorsement of 'The Plan of Action on Sub-National Governments, Cities and Other Local Authorities for Biodiversity' (de Oliveira et al., 2011). Under this plan, national governments now have an obligation to consider and involve other levels of government in their national biodiversity strategies and action plans (Holmes et al., 2012).

Furthermore, Local Agenda 21 of the Rio Earth Summit in 1992, officially identified the importance of the local government in achieving sustainable development (Roberts & Diederichs, 2002). Agenda 21, a comprehensive plan of action was thus the introduction of environmental concerns and sustainable development into the local government sphere of South Africa. In addition, ICLEI – Local Governments for Sustainability has recognised the importance of local government as the key to sustainability. ICLEI is an international association of local governments that have made a commitment to building a sustainable urban future. ICLEI develops and runs a broad range of projects and programmes that address local sustainability issues and also offers support to its members. The organisation essentially has a flagship biodiversity programme developed with the International Union for Conservation of Nature (IUCN) called Local Action for Biodiversity (LAB). The programme is customised for a network of local and regional authorities around the world, seeks to improve biodiversity planning and management at the local level and focuses international attention on the importance of urban biodiversity and the role that local governments can play in preserving their biodiversity. All cities participating in the LAB Pioneer Project signed the Durban Commitment, a non-binding agreement at the 2008 international LAB workshop in Durban.

6.1.2 South Africa's National biodiversity legislation

Ultimately, the biodiversity sector, policy and legislative framework for biodiversity in South Africa is well established and provides a strong basis for the conservation, management and sustainable use of biodiversity. South Africa has dedicated legal policies and planning tools for biodiversity conservation and management which are linked to broader environmental management objectives at national, provincial and local levels, as well as commitments to international biodiversity targets (Pool-Stanvliet et al., 2017). According to Wynberg (2002), although a coherent and integrated policy on biodiversity in South Africa had long been recognised, the political changes in 1994, combined with South Africa's ratification of the CBD in 1995, brought a new direction and urgency to biodiversity conservation (Wynberg, 2002). The 1994 democratic election was the catalyst for a series of fundamental changes to South Africa's legislative, policy and institutional framework for biodiversity management. The White Paper on Biodiversity 1997 establishes South Africa's central policy. The White Paper is a comprehensive policy, with six main goals and supporting objectives that follow the themes of the CBD (Wynberg, 2002).

In addition, the Constitution of the Republic of South Africa Act 108 of 1996 gives concurrent legislative competence to both national and provincial governments for most functions relevant to biodiversity conservation (Wynberg, 2002). The Constitution ultimately outlines and establishes basic environmental rights, and assigns powers and functions (Holmes et al., 2012; Goodness & Anderson, 2013). Section 24 of the Constitution states that: all South Africans have the right to a healthy environment which is protected, for present and future generations (The South African Government, 1996). As a result of this constitutional provision, there are several pieces of legislation which have been enacted in order to ensure the protection of the environment. These pieces of legislation have direct implications for biodiversity in South Africa.

The National Environmental Management Act 107 of 1998 (NEMA) serves as the main framework structure that establishes the overarching principles for environmental legislation and the procedures for environmental management, assessment and governance in South Africa (Goodness & Anderson, 2013). The two subsequent Acts central to biodiversity conservation and management are: the National Environmental Management: Biodiversity Act 10 of 2004 (NEM:BA), and the National Environmental Management Protected Areas Act 57 of 2003 (NEM:PAA) (Holmes et al., 2012; Goodness & Anderson, 2013).

The Biodiversity Act provides for the co-ordinated management, conservation and sustainable use of the country's biodiversity within the framework of the NEMA and is of particular importance with respect to South Africa's commitments under the CBD. The Act promotes an ecosystem orientated approach to the management of biodiversity in the country, and takes into account the need for social transformation and development goals to be met. It further recognises that biodiversity conservation involves working beyond the boundaries of formally protected areas. The Protected Areas Act is the primary legislation for the establishment and management of South Africa's protected area network and is usually read in conjunction with the Biodiversity Act. It therefore provides for the formal protection of a network of ecologically viable areas that are representative of the country's biodiversity and natural landscapes.

According to Goodness and Anderson (2013) and Holmes et al. (2012), there are five key policy tools which are legislated in the Biodiversity Act, these include:

1. The National Biodiversity Strategy and Action Plan (NBSAP), 2005: provides a framework and plan of action for the conservation and sustainable use of the country's biodiversity;
2. The National Spatial Biodiversity Assessment (NSBA) 2011: outlines the threat status and protection levels of ecosystems within the country and provides a frame for the development of provincial and local spatial biodiversity assessments and plans;
3. The National Protected Area Expansion Strategy (NPAES) 2008: provides an action plan for acquiring and aggregating land for conservation by expanding protected areas;

4. The National Biodiversity Framework (NBF) 2008: sets out 33 priority biodiversity actions for the country; and
5. Bioregions and Bioregional Plans: includes a systematic biodiversity plan and measures for effective management.

The first four policy tools defined above function at the national level, with biodiversity plans and assessments being guided by these policies at all levels of government. However, while the national government has developed these policy tools, the implementation of the policies has been slow as conservation initiatives are not sufficiently funded (Holmes et al., 2012). While all three tiers of government are implicated under section 28 “duty of care” in NEMA, the biodiversity legislation is a primary function of the national and provincial government (Holmes et al., 2012). According to Holmes et al. (2012), the problem with the lack of implementation is also the fact that the local government has not been officially recognised as an important implementation partner.

At the national level, the primary environmental custodian and authority for biodiversity management and conservation is the Department of Environmental Affairs. The responsibility is, however, becoming increasingly shared, where appropriate, among different government departments, institutions and both public and private agencies at the national, provincial and local levels. The public entities reporting directly to DEA consist of the following (DEA, 2012b):

- The South African National Biodiversity Institute (SANBI);
- The South African National Parks (SANParks);
- The iSimangaliso Wetlands Park Authority; and
- The provincial conservation authorities whose work is co-ordinated by DEA.

6.1.3 Provincial biodiversity legislation relating to the provinces of the Western Cape and KwaZulu-Natal

National legislation is further implemented at the provincial and municipal levels. Some provinces in South Africa have their own provincial biodiversity legislation, as natural and biological conservation is a concurrent function of both the national and provincial government. At the provincial level, environmental and conservation departments as well as provincial departments of agriculture are responsible for implementing an array of policies and laws aiming to conserve biodiversity. The provincial lead agency for the environment in the Western Cape is the Department of Environmental Affairs and Development Planning (DEA&DP) while the Department of Agriculture, Environmental Affairs and Rural Development (DAEA&RD) is the agency in KZN. In addition, CapeNature, a public entity which forms part of DEA&DP was established as a provincial agency parastatal responsible for biodiversity conservation in the Western Cape. KwaZulu-Natal's equivalent is Ezemvelo KZN Wildlife – the statutory nature conservation body in the region delegated to protect the region's natural resources, manage its biodiversity and implement and enforce both national and provincial conservation legislation (Davids et al., 2016).

These provincial entities are mandated to ensure effective conservation and sustainable use of their province's biodiversity. They are also involved in helping to establish biodiversity stewardship agreements with private landowners. These agreements fall within different legal categories, including: biodiversity agreements and contracts with nature reserves and conservation areas (Goodness & Anderson, 2013).

6.1.4 Local biodiversity legislation in the cities of Cape Town and Durban

In response to national and provincial legislation, local governments have committed to assess and conserve the natural space and biodiversity within their boundaries. In effect, provinces and municipalities in South Africa have adopted the NSBA, and detailed conservation plans for many regions and municipal areas have now been finalised.

According to Pool-Stanvliet et al. (2017: 5), "over the past 20 years, local municipalities have come to play an increasingly important role as users and managers of biodiversity, and it is at local government level that many day-to-day, operational decisions about land and biodiversity resources are made". Furthermore, since municipal planning is essentially assigned to local government who decide over all land use decisions within their borders (Pool-Stanvliet et al., 2017), municipalities can include environmental and biodiversity issues into their planning processes. The Municipal Systems Act 32 of 2000 (MSA) sets out the rights and duties of municipalities with regards to the environment, which must be taken into account and accommodated in institutional frameworks and policies of the local government authority. The MSA essentially provides a framework for local government functioning and requires all municipalities to develop an IDP. The IDP is essentially a five-year business plan and represents the principal planning instrument that guides and informs all planning and developments in a municipality. Each municipal IDP is supported by a SDF, a tool used to achieve the desired spatial form of the municipality. In addition, the recently promulgated Spatial Planning & Land Use Management Act 16 of 2013 (SPLUMA) which came into force in 2015, provides for a uniform system of spatial planning and land use management for South Africa (The South African Government, 2013). It sets out a framework for the alignment between environmental management instruments (including biodiversity plans), IDPs, SDFs and municipal land use schemes, which are planning tools used to deliver quality environments (Pool-Stanvliet et al., 2017). This presents an important and strategic opportunity to incorporate biodiversity information into IDPs and SDFs and commits local governments to developing and considering biodiversity in their plans.

6.2 Appendix B - Interview questions for each municipality

Interview 1: City of Cape Town

Participant: Dr Pat Holmes

Date: 26th May 2017

Interview Questions:

1. Why did the BioNet come about?
2. How did the BioNet come about?
3. Who were the key players involved in the creation of the BioNet?
4. What challenges were faced in the creation of the BioNet?
5. What informs the BioNet and influences its design?
6. What are the main goals of the BioNet?
7. How is the BioNet implemented at the city scale?
8. What challenges were faced in the implementation of the BioNet?
9. Who is responsible for updating and compiling the BioNet and how often is this done?
10. Is the BioNet a non-statutory policy and how does it fit in with other policies/documents, such as the IDP and SDF of the City?
11. Does the BioNet try to conserve and protect green open spaces in the city or is this seen as the goals of CMOSS?

11.1 What patches of land are deemed worthy of inclusion into the BioNet?

12. How do the BioNet and CMOSS relate to each other?

12.1 Is the CMOSS currently active and is it also a non-statutory policy?

12. 2 How does it fit in with other policies/documents?

13. In your view, what are the main drivers of land cover change that influence the BioNet?
14. While the BioNet does include corridors to ensure connectivity through the fragmented landscapes of the CCT, do you think this is sufficient? Would you consider the BioNet system to be highly fragmented?

Interview 2: eThekwini Municipality

Participants: Mr Richard Boon and Ms Natasha Govender

Date: 4th July 2017

Interview Questions:

1. Why did the DMOSS come about?
2. How did the DMOSS come about?
3. What are the other local environmental policies in place in Durban which informs/influences the DMOSS?
4. Who were the key players involved in the creation of the DMOSS?
5. What challenges were faced in the creation of the DMOSS?
6. What informs the DMOSS and influences its design?
7. What are the main goals of the DMOSS?
8. How is the DMOSS implemented at the city scale?
9. What challenges were faced in the implementation of the DMOSS?
10. What methods and software is used to map the DMOSS?
11. Who is responsible for updating and compiling the DMOSS and how often is this done?
12. What is the latest version of the DMOSS spatial layer and sector plan?
13. Is the DMOSS a non-statutory policy and how does it fit in with other policies/documents, such as the IDP and SDF of the City?
14. What patches of land are deemed worthy of inclusion into the DMOSS?
15. What is the most protected biome/vegetation type within the DMOSS?
16. What percentage of the DMOSS is currently secured?
17. In your view, what are the main drivers of land cover change that impacts the DMOSS?
18. Would you consider the DMOSS to be highly fragmented? If so, which region would you say is the most fragmented?
19. Would you agree that urban environmental management and the protection of key environmental goods and services provided by urban open spaces are the most important drivers of urban ecology in Durban?

6.3 Appendix C - Consent forms from interviews

DEPARTMENT OF ENVIRONMENTAL & GEOGRAPHICAL SCIENCE

UNIVERSITY OF CAPE TOWN
PRIVATE BAG X3
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SOUTH AFRICA

RESEARCHER: Quraisha Bux
TELEPHONE: 081 432 1311
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E-MAIL: qbux777@gmail.com
URL:

Informed Voluntary Consent to Participate in Research Study

Project Title: Understanding urban ecologies in the context of local biodiversity and open space agendas in two South African cities.

Invitation to participate, and benefits: You are invited to participate in a research study conducted with persons who are involved or have knowledge on the local biodiversity/open space agendas in the cities of Cape Town and Durban. The study aim is to develop an understanding into the urban ecologies in the context of local biodiversity and open space agendas in the cities of Cape Town and Durban. I believe that your experience would be a valuable source of information, and hope that by participating you may gain useful knowledge.

Procedures: During this study, you will be asked to answer a number of questions relating to the local biodiversity and open space agendas in the cities of Cape Town or Durban.

Risks: There are no potentially harmful risks related to your participation in this study.

Disclaimer/Withdrawal: Your participation is completely voluntary; you may refuse to participate, and you may withdraw at any time without having to state a reason and without any prejudice or penalty against you. Should you choose to withdraw, the researcher commits not to use any of the information you have provided without your signed consent. Note that the researcher may also withdraw you from the study at any time.

Confidentiality: All information collected in this study will be kept private. However, the names of your affiliated organisations and job titles may need to be included in this study. For this reason you may be identified by name or by affiliation to an institution depending on your consent.

What signing this form means:

By signing this consent form, you agree to participate in this research study. The aim, procedures to be used, as well as the potential risks and benefits of your participation have been explained verbally to you in detail, using this form. Refusal to participate in or withdrawal from this study at any time will have no effect on you in any way. You are free to contact me, to ask questions or request further information, at any time during this research.

I agree to participate in this research (tick one box)

☑ Yes ☐ No _______ (Initials)

Fac Sci Res Ethics Comm: Ethics Application Form, revised January 2017

DEPARTMENT OF ENVIRONMENTAL & GEOGRAPHICAL SCIENCE

UNIVERSITY OF CAPE TOWN
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RESEARCHER: Quraisha Bux
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Risks: There are no potentially harmful risks related to your participation in this study.

Disclaimer/Withdrawal: Your participation is completely voluntary; you may refuse to participate, and you may withdraw at any time without having to state a reason and without any prejudice or penalty against you. Should you choose to withdraw, the researcher commits not to use any of the information you have provided without your signed consent. Note that the researcher may also withdraw you from the study at any time.

Confidentiality: All information collected in this study will be kept private ~~in that you will~~ not be identified by name or by ~~affiliation to an institution~~. Confidentiality and anonymity ~~will be maintained~~ as pseudonyms will be used.

What signing this form means:

By signing this consent form, you agree to participate in this research study. The aim, procedures to be used, as well as the potential risks and benefits of your participation have been explained verbally to you in detail, using this form. Refusal to participate in or withdrawal from this study at any time will have no effect on you in any way. You are free to contact me, to ask questions or request further information, at any time during this research.

I agree to participate in this research (tick one box)

☑ Yes ☐ No ________ (Initials)

DEPARTMENT OF ENVIRONMENTAL & GEOGRAPHICAL SCIENCE

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Confidentiality: All information collected in this study will be kept ~~private in that you will not be identified by name or by affiliation to an institution~~. Confidentiality and anonymity ~~will be maintained~~ as pseudonyms will be used.

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I agree to participate in this research (tick one box)

☑ Yes ☐ No N.G ________ (Initials)

Name of Participant	Signature of Participant	Date
Dr P. M. Holmes		26/5/17
QURAISHA BUX		26/5/17
Name of Researcher	Signature of Researcher	Date

Name of Participant	Signature of Participant	Date
Richard Boon		4/7/17.
QURAISHA BUX		4/7/17
Name of Researcher	Signature of Researcher	Date

Name of Participant	Signature of Participant	Date
NATASHA GOVENDER		04/07/17
QURAISHA BUX		04/07/17
Name of Researcher	Signature of Researcher	Date