IMPACTS OF ANTHROPOGENIC ACTIVITIES ON THE ECOLOGICAL INTEGRITY OF NAIROBI CITY PARK, KENYA

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DECLARATION

I declare that this document and the research that it describes are my original work and that they have not been presented in any other University for academic work

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This research was conducted under our supervision and is submitted with our approval as University supervisors.

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DEDICATION

This thesis is dedicated to my beloved parents, Mr. and Mrs. Kimaiyo and the Friends of City Park association for the immense support and motivation they gave me.

ACKNOWLEDGEMENT

I would like to thank God, for the opportunity He has given me to be alive this day and his strength, grace and blessings that have enabled me to start and finish this research and to write this thesis. I express my special appreciation to my supervisors Dr. Mark Ndunda Mutinda and Dr. Gabriel M. Muturi for their unwavering support during proposal development, study implementation and writing the thesis. I also extend my gratitude to Mr. Ernest Chege the Senior Parks superintendent, Nairobi City County for supporting me and the expert advice he gave me. I cannot forget the Friends of City Park Association for their unending dedication towards this research. It is my prayer that God will bless you all abundantly.

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ABSTRACT

The effects of human disturbance on the ecosystem processes influence the management of recreational areas and the benefits that can be obtained. Public urban parks provide environmental, economic and social benefits to the urban communities. The Nairobi City Park (NCP) located on 49 ha of land divided into a conserved area of 33 ha and 16 ha recreational area. The park has a high level of biodiversity and provides recreation to the visitors. Currently many changes have occurred within the Park, which have caused a decline in the biodiversity and hence the ecosystem services derived from the resource. This study, therefore endeavored to find out the causes and impact of these change. The study was guided by the following objectives: (i) to determine species composition of herbaceous and woody plants within the NCP, (ii) to measure vegetation cover of the conserved area of NCP, (iii) to assess plant biodiversity within the NCP, (iv) to ascertain trees physical attributes (height, diameter, number of stumps, and debarking) in NCP's conserved area, (v) determine number of humans who traverse through NCP's conserved area (vii) to assess the influence of intensity of human activities on the ecological integrity of the park. The study area was stratified into three strata representing different degrees of anthropogenic influences (the outer, middle and the inner core areas). Data on species composition, cover, biodiversity, and physical tree attributes were collected within each strata using ecological methods. Estimate of the number of people visiting the park was averaged from tallies collected over a period of time. The collected data was analysed using descriptive and inferential statistics. The results indicate that: there were 62 plant species divided into 33 families. Species richness varied within the strata, the outer strata had 1066, middle strata had 1195 and the inner strata had 1403. Plant species abundance ranged between 0.19 and 5.12 in the outer stratum, 0.08 to 5.44 in the middle stratum and 0.21 to 9.98 in the inner core stratum. Ground cover was highest (82.8 %) in the inner core area and lowest (51.5 %) in the outer area and medium (70.5 %) in the middle areas. Bare areas an indicator of degradation was highest (37.4 %) in the outer area, followed by (20.2 %) in the middle area and lowest (3.6 %) in the inner core area. Plant diversity (H') increased from the outer stratum to the inner stratum respectively (H'-1.602 in outer), (H'-1.691 in the middle) and H'-1.702). Tree characteristics varied within the three strata with the outer showing more impact on debarking, cut stumps and young regenerating plants compared with the inner stratum. The number of people traversing the NCP was highest in the outer stratum followed by the middle and finally the inner core stratum, these differences were statistically ($p < 0.05$) significant. Negative statistical ($\beta = -.918$, $t = -12.89$, $p < 0.001$) influence of intensity human activities on the ecological integrity were realized. The anthropogenic influences negatively impacted on the ecological integrity of the park and without managerial intervention the park would eventually not be able to provide the ecological services it was meant to provide. The study ends by recommending: educating the visitors to the park on how to use the resources sustainably, park interpretation to enhance learning to visitors, planting adaptable grass and tree species in the degraded areas, sourcing funding from international organizations dealing with carbon trade to aid in rehabilitating the park.

DEFINITION OF TERMS

Anthropogenic: relating to, or resulting from the influence of human beings on nature

Biodiversity: the variety and variability of life on Earth.

Ecology: the branch of biology that deals with the interaction among organisms that live in the same environment and the interaction of such organisms with their physical surroundings.

Ecosystem: biological community of interacting organisms and their physical environment.

Exotic plants: plants that do not naturally grow in an area.

Indigenous plants: plants that are naturally found in a given area.

Landscape: is the visible feature of an area of land, its landforms and how they integrate with natural or man-made features

Public parks: an area of natural, semi-natural or planted space set aside for human enjoyment and recreation or for the protection of wildlife or natural habitats

Recreation area: a type of protected are designated in some jurisdictions

Recreation: activity done for enjoyment when one is not working

LIST OF ABBREVIATIONS AND ACRONYMS

DBH	Diameter at breast height
NCP	Nairobi City Park
FOCP	Friends of City Park
NCC	Nairobi City County

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The study was an assessment of the impacts of anthropogenic activities on the ecological integrity of Nairobi City Park located within the city of Nairobi, Kenya. The dependent variable for this study was the ecological integrity of the park that was assessed using an index composed of plant diversity, species richness, ground cover of the area and the characteristics of the tree species. The independent variable was anthropogenic activities within the park, which included: pressure from increase in the number of people visiting the park, extractive use of the park, trampling, recreational activities, and loss of plant species. This chapter introduces the study under the following sub-headings: background of the study, statement of the problem, purpose of the study, objectives of the study, research questions, significance of the study, scope of the study, delimitation of the study, limitations of the study, assumptions of the study, theoretical framework, and conceptual frame work.

1.1 Background of the Study

Kenya has contrasting landscapes ranging from high mountains to lava deserts and flat savanna plains, disposed over an uncommonly broad altitudinal range (Friends of City Park, 2014). Such varied altitudes have given rise to numerous microhabitats supporting extraordinary rich ecological sites (Simiyu, 1996). Of these are public urban parks. Urban park is one of the most important and public open space in big cities. It is a multifunctional area that can be used for wide range of activities (Ahmad et al., 2014).

Public urban parks are public lands that have been developed and are managed by public authorities for the recreational, environmental or visual benefit to the community (City of South Perth, 2012). Public urban parks support and conserve biodiversity, provide migratory channels for park animals and are used to protect water courses and wetlands. Therefore, they provide environmental, economic and social benefits to the urban communities. Of these social benefits, recreational services are a major component to the residents of a town. Long-term quality of life for urban residents depends on the non-material benefits gained from nature (e.g., green and blue spaces), which have been called cultural ecosystem services (CES). The 'material' ecosystem services (i.e., provisioning and regulating services) tend to receive more attention the CES, which parks tend to provide (Dou, Zhen, De Groot, Du, Yu, 2017; Cheng, Damme, Li, Uyttenhove, 2019). Recreational open spaces (ROS) like parks and playgrounds are vital cultural ecosystem services. Provision of universally accessible, safe and inclusive green public spaces is one of the 17 sustainable development goals (SDGs) of United Nations enacted in 2015. A case study conducted to gauge peoples' perception on parks found that, overall the most valued ecosystem subservice was "aesthetic appreciation". Other ecosystem subservices that scored highly were recreation, air quality control and social setting (Buchel, & Frantzeskak, 2015).

The Nairobi City Park, located a short distance from the central business district, lies on a patch of evergreen highland forest that is at the center of the once extensive belt of semi-deciduous forest that extended from the Oloolua forest near Ngong and from Nairobi National Park to Thika town (Figure 1). It was designed by Mr. Peter Greensmith in 1932, one of Kenya's pioneering landscapers and park planners.

The park covers a total area of 49 hectares and is made up of two sections. The conserved/forest area and the open/recreational area. The conserved forest area covers 33 hectares and forms an ecological site with rich biodiversity with a variety of plant species. The open area covers 16 hectares and is mainly used for recreational purposes and is open to the public.

Ecological integrity has been defined as: "The ability of an ecological system to support and maintain a community of organisms that has species composition, diversity, and functional organization comparable to those of natural habitats within a region. An ecological system has integrity when its dominant ecological characteristics (e.g., elements of composition, structure, function, and ecological processes) occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions" (Parrish et al. 2003, p. 852). In plain language, ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact (Wilkinson, 2003).

Biodiversity loss in tropical forest has been associated with many factors such as: deforestation and fragmentation, over-exploitation, invasive species and climate change (Morris, 2010). Human activities without balance can create changes to the natural landscapes and in so doing alter the structure, composition and/or function of an ecosystem. These changes can disturb the equilibrium of the ecosystem components, thus affecting the ecological functions and services of the park. It is important therefore to assess and monitor these trends so as to formulate plans to mitigate these changes

Global Forest Resources Assessment has shown declining areas of natural forests, particularly in Africa (Sloan and Sayer, 2015). Local communities in Africa are heavily dependent on forests for fuel wood as a source of household energy (Clancy, 2008; Bailis et. al, 2015; Sassen et. al, 2015) and for building.

The quality of urban parks in many cities globally has continued to deteriorate over the years, it has been observed in many cities globally, with current trends observing that in many cities globally, there is increasing degradation of existing urban green spaces (Greenkeys, 2008). Nairobi City Park's original area of 150 acres (61 ha), only 120 acres (48.6ha) now remain (Friends of City Park, 2010). This has led to the increased pressure on the resources at NCP due to, the area has decreased and is expected to accommodate the ever increasing numbers of visitors into the park caused by the increasing population of Nairobi city. Due to these anthropogenic pressures, the important ecological resources are vulnerable and open to exploitation.

This study therefore endeavored to confirm the ecological changes that have taken place within the NCP and determine the influence of anthropogenic pressures on the ecological integrity of the park resources so as to recommend on the management of the park.

1.2 Statement of the Problem

Nairobi City Park is a hub of conservation and recreation in the busy bustling Nairobi city. The park is rich in biodiversity and contains some important endemic species specific to the ecological area. It is in close proximity to the Nairobi city, where people can access it easily. These and other factors caused the government to set it aside for conservation, recreation and aesthetic purposes. The park was therefore designed to meet ecological, social, emotional needs and wants of the people visiting the facility and for a long time it has been frequented by a lot of people seeking these services. Currently, the conserved area of the park has been adversely impacted due to the decline of forest size and the growing urban pressure resulting in a high number of visitors whose interest are inconsistent with the originally intended non-consumptive recreational park services. This has led to significant degradation of the once intact ecosystem causing it to gradually lose its importance and function and without intervention this state of affairs will make the park to be a desolate piece of land without benefit to the country.

In the light of the above, this study therefore seeks to assess the influence of anthropogenic impacts on the ecological integrity of Nairobi City Park with specific emphasis on trends in ground vegetation cover, plant biodiversity and physical tree damage and use this information to inform the stakeholders and formulate an effective park plan that will protect the ecological resources and provide recreation for the people.

1.3 Purpose of the Study

The purpose of this study was to assess the ecological integrity of the park using plant cover, plant biodiversity and physical tree damage, so as to inform and recommend to the stakeholders viable solutions to the problem.

1.4 Research Objectives

The objectives of the study were to:

(i) Determine species composition of herbaceous and woody plants within the three strata (the outer, middle and the inner areas) within the Nairobi City Park in Nairobi, Kenya;

(ii) Determine the ground cover of the conserved area of the Nairobi City Park in Nairobi, Kenya;

(iii) Assess plant species diversity in the three strata (the outer, middle and the inner core areas) within the Nairobi City Park in Nairobi, Kenya;

(iv) Describe tree physical attributes (tree height, tree diameter, tree stumps, tree debarking) in the conserved area of Nairobi City Park in Nairobi, Kenya;

(v) Determine the average number of human beings who traverse through the conserved area of the Nairobi City Park in Nairobi, Kenya;

(vi) Determine the extent of intensity of human activities on the ecological integrity of Nairobi City Park in Nairobi, Kenya.

1.5 Research Questions

(i) What is the composition of the herbaceous and woody layers of NCP's conserved area?

(ii) How the NCP's ground is presently covered?

(iii) What is the plant diversity within the three strata (the outer, middle and the inner areas) of NCP?

(iv) How can the tree physical attributes (tree height, tree diameter, tree stumps, tree debarking) be described within the conserved area of the NCP?

(v) How many people traverse the park and what is their impact on the park resources?

(vi) What is the impact of humans on the vegetation within the conserved area of the Park?

(vii) What is the extent of the intensity of human activities on the ecological integrity of the park?

1.6 Significance of the Study

Urban parks in Kenya are inadequate compared to the areas and population they are meant to serve (Rabare et.al, 2009). The findings from this study provide insight into the situation on the ground on the extent of human impact on the ecological integrity of Nairobi City Park, the species composition of the park, the biodiversity of the park and the relationship between tree damage and the visitors of the park. The study also provided useful information to the management of NCP on future interventions for the management of the park. As much as findings and recommendations from this research have contributed to the field knowledge on the importance of maintain ecological integrity on urban parks, they will also serve as a baseline for future studies on the impact of anthropogenic activities on urban parks in Kenya.

1.7 Scope of the Study

Simon & Goes (2013) hold that the scope of the study are the parameters under which the researcher wants to operate the study. The study was designed to focus on NCP which is greatly used by humans for purposes that are affecting the ecological standards of the conserved area. Located in the middle of several humans involved activities like business centers, schools, traffic highways and a number of roads, City Park is bound to be frequently visited by the residents of Nairobi County and others.

The study aimed at assessing the impact of anthropogenic activities on the ecological integrity of the park. The study was carried for five months between 1st April 2018 and 30th August 2018.

1.8 Assumptions of the Study

This study will mainly assume that the anthropogenic impacts in Nairobi City Park have manifested over time and their consequences have reached unbearable threshold at the moment. The study will also assume that NCP is the most appropriate location to carry out a study on the impact of anthropogenic activities on urban parks sustainability because of its accessibility.

1.9 Delimitation of the Study

The study will be focused basically on NCP. The focus will be carried out in the park through ecological measurements. This will be helpful in giving quantitative and quantitative results.

NCP was chosen not only due to its proximity but also due to existence of previous studies that would enable periodic comparison of species dynamics. Moreover, availability of census and park entry data will be useful in assessing and inferring anthropogenic impacts on the park.

1.10 Limitation of the Study

The study will be influenced mainly by prevailing physical and environmental circumstances of the park. This may make it difficult to traverse throughout the NCP alone. As such, I will use the help of two other people in order to cover more ground in data collection.

1.11 Theoretical Framework

The study was guided by one theory named the “Tragedy of the commons” developed by Garret Hardin to explain the behaviour of human beings when it comes to shared resources or the commons, the Nairobi city park is a shared or public resource.

1.11.1 The Tragedy of the Commons

The tragedy of the commons is an economic theory of a situation within a shared resource system where individual users acting independently according to their own self-interest behave contrary to the common good of all users by depleting or spoiling that resource through their collective action. In this context commons are taken to mean any shared and unregulated resource.

The concept and name originate in an essay written in 1833 by the Victorian economist William Forster Lloyd, who used a hypothetical example of the effects of unregulated grazing on common land (Lloyd, 1833). The concept became widely known over a century late due to an article written by the ecologist Garrett Hardin in 1968 (Hardin, 1994). Garrett Hardin explored this dilemma in his article “the tragedy of the commons”. The essay derived its title from the pamphlet by Lloyd. Hardin discussed problems that cannot be solved by technical means as distinct from those with solutions that require “a change only in the techniques of natural science, demanding little or nothing in the way of change in human values or ideas of morality” Hardin focused on population growth, the use of the Earth’s natural resources and welfare of state.

Derrick (2007) contested the tragedy of common theory arguing that it was propaganda for private ownership. The argument was driven by political realities whereby the political right wing had used the theory to hasten the final enclosure of the ‘common resources' of third world and indigenous people worldwide, as a part of the Washington Consensus. He stated that in real situations, those who abuse the commons would have been warned to desist and if they failed would have had punitive sanctions on them. Based on this reality, Derrick (2007) proposed changing the theory from "The Tragedy of the Commons", to "the Tragedy of the Failure of the Commons".

The tragedy of the commons is often used in connection with sustainable development, meshing economic growth and environmental protection. The theory illustrates the argument that free access and unrestricted demand for a finite resource ultimately reduces the resource through over-exploitation temporarily or permanently. This occurs because the benefits of exploitation accrue to individuals or groups, each of whom is motivated to maximize use of the resource to the point in which they become reliant on it while the costs of exploitation are borne by all those to whom the resource is available. This in turn cause demand for the resource to increase, which causes the problem to snowball until the resource collapse.

1.12 The Conceptual Framework

The study conceptualized that anthropogenic activities within the park have direct negative impacts on the ecological integrity of the Park. The independent variables included anthropogenic activities such as increased number of visitors to the park, illegal extractive use of the park resources, destructive recreational activities to the parks natural resources, and reduced area of the park. The reduction of the park area and the increase in the number of visitors to the park has lowered the ecological integrity of the Park. The dependent variable, ecological integrity of the Park was conceptualized as any negative impact to the natural resources and this was to be determined by examining plant attributes which change very fast under pressure. The indicators of the ecological attribute, included: plant species composition, plant diversity, plant cover, plant condition, and tree physical attributes.

The relationship between anthropogenic factors and ecological integrity can be affected by other factors not considered in this study, these include climate and climatic changes which are depicted here as the intervening variables.

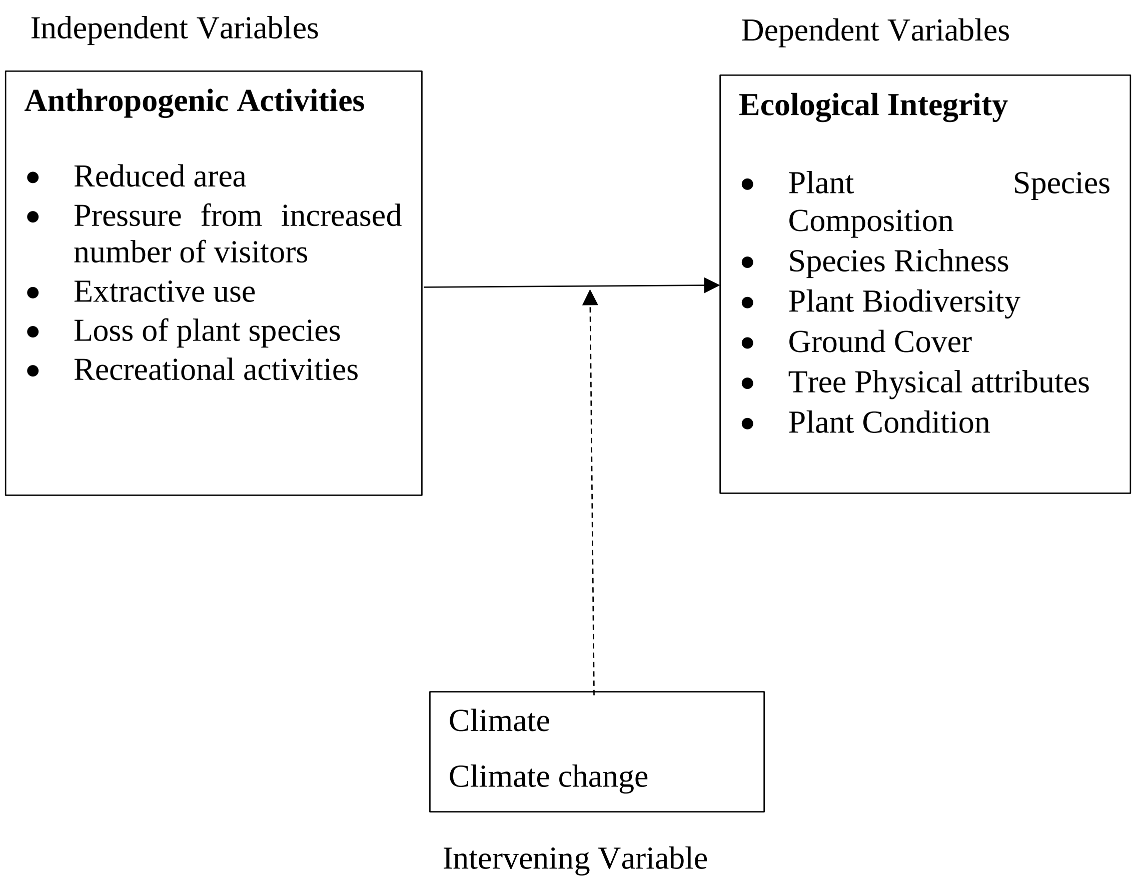

Figure 1: Conceptual framework depicting the relationship between anthropogenic influences and ecological integrity within the Nairobi City Park

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter contains a comprehensive review of literature pertaining this study. It includes: the tragedy of the commons as a theory that explains the utilization of a resource that is shared among many individuals for different purposes; Nairobi City Park's origin, purpose and management; vegetation and plant species description and dynamics; species composition with relation to ecological environments; plant biodiversity; tree physical attributes and vegetation cover.

2.2 Nairobi City Park

It was not until the nineteenth century that the Nairobi City public park became as we know it today, an area of land laid out primarily for public use amid urban surroundings. The creation of useful landscapes within the town for the use and enjoyment of the public at large is essentially a Victorian idea. First due to the phenomenal growth of the "insensate industrial town|" which created the basic idea for such areas, and second, perhaps to the later Victorian zeal for reform of sprawling and overcrowded settlements that became synonymous with the Industrial Revolution. There seems to be a general agreement that a complete system of parks and other open areas is an essential part of the urban structure, although often used to separate zones of different uses or as providing thoroughfares for major roads (Chadwick, 1966).

City parks and open space improve our physical and psychological health, strengthen our communities, and make our cities and neighborhoods more attractive places in which to live and work (Makworo and Mireri, 2011). Regular physical activity has been shown to increase health and reduce the risk of a wide range of diseases (Makworo and

Mireri, 2011). Green space in urban areas provides substantial environmental benefits. For example, trees reduce air and water pollution, they help keep cities cooler, and they are a more effective and less expensive way to manage storm water runoff than building systems of concrete sewers and drainage ditches (Ashish, 2014).

City parks make inner-city neighborhoods more livable; they offer recreational opportunities for at-risk youth, low-income children and low-income families; and they provide places in low-income neighborhoods where people can feel a sense of community (Makworo and Mireri, 2011). Access to public parks and recreational facilities has been strongly linked to reductions in crime and, in particular, to reduced juvenile delinquency (Sherer, 2006). In the study of Fairmount Park System of Philadelphia, Brownlow (2006) applied political ecology to explain the nature of public space. He noted that the relative "health" (normatively defined) of local ecologies and ecosystems are indicative of larger patterns of social inequality and marginality.

The decline of social control mechanisms, both formal and informal, changes the nature of human environment experience from one of perceived safety and order to one of perceived fear and disorder (Makworo and Mireri, 2011). Public open spaces are important not only for leisure and recreation, but also for economic and political functions. However, the quality of public open spaces provided in a city depends on the long-term political commitment of the city. Failure to prioritize development of public open spaces is detrimental to the city due to increasing risks of congestion, insecurity and environmental degradation (Makworo and Mireri, 2011).

2.2.1 The Origin of Nairobi City and its Growth in the Colonial Era

In 1899, the builders of the Kenya-Uganda railway line decided to set up camp at "*Ewaso Nai´beri*", because of two main reasons (Makworo and Mireri, 2011):

- It was cool and well supplied with fresh water. It is no wonder that the local Maasai people had named it "*Ewaso Nai´beri*" meaning "a place of cool waters". The cool temperature was a welcome relief for the railway builders from the hot Mombasa coastal sun they had contended with before.
- It offered an escape from the man-eaters of Tsavo that killed 135 of the railway workers around Voi a year earlier. The fact that "*Ewaso Nai´beri*" was a swampland reduced the likelihood of an encounter with lions.

This railway line, meant to connect the East African interior with the rest of the world, had been named the "Lunatic Express" by skeptics doubting its economic worth. The Looney express camp gave rise to the town that would later become the City of Nairobi.

2.2.2 The Growth of Nairobi City since Independence in 1963

Nairobi City has registered a rapid rate of urbanization since 1963, mainly because of the following factors (Makworo and Mireri, 2011);

First, during the colonial period the immigration of Africans to the city was restricted to those whose skills/labor were required, which resulted in a modest rate of urbanization. However, attainment of independence in 1963 guaranteed freedom of movement, leading to the higher rate of urbanization.

Second, the increasing incidence of poverty in the rural areas against perceived better opportunities for earning a living in urban areas spurred a rapid rate of rural-urban migration.

Third, the rapid population growth (3–4%) in the country during the period 1963/99 because of improved health care contributed to the rapid rate of urbanization. In addition, improved transport and communication has made it easier for people to move to and from urban areas. Further, an increasing incidence of insecurity in the rural areas, particularly during the last two decades, has triggered a movement of people to the urban areas. Increased insecurity has been caused mainly by deteriorating poverty as well as politically instigated ethnic clashes. As a result, the relatively well off and displaced persons seek refuge in the urban areas where security is relatively better. The rapid rate of urbanization has overstretched the capacity of the existing infrastructure and services and even public open spaces have not been spared.

2.2.3 The Origin and Location of Nairobi City Park

Nairobi City Park is located within walking distance of Nairobi's Central Business District, off the Limuru Road between Parklands and Muthaiga. The forest hosts the recreational park and city Park Forest. The forest is indigenous, with a number of tree species that are endemic to Kenya. The Nairobi city Forestry department is tasked with the maintenance of the park and they have a large tree and plant nursery in the park.

The park was established in 1920 as a zoological garden on a 91hectare piece of land and formally declared a public park in 1925 (friends of city park, 2010). Much like the other green spaces in the city, it was not spared encroachment by land grabbers. However, remaining 60 hectares of Nairobi City Park were later declared as protected area as per legal notice no.59 of 4th September 2009.

2.2.4 Purpose of Urban Parks

Urban parks have been critical sites of cultural, political, and economic life from early civilizations to the present day by enabling achievement of sustainable urban development (Greenkeys, 2008). They are culturally understood as; sites of aesthetic reflection and specific social practices, improve the natural ecological environment and enhance the city's charm (Sirong, 2012), (Stanley et al., 2013).

Large patches of natural vegetation protect aquifers and low order streams, provide habitat for small and large home range species, permit natural disturbance regimes such as forest fires to occur in which many species can interact and evolve, maintain a range of microhabitat proximities for multi-habitat species, act as noise buffers and reduce the urban heat islands effect (Wesley et al., 2011). Considering the high level of global urbanization urban parks are imperative for maintaining and improving public health by increasing physical activity through recreation which reduces stress and mental disorders besides increasing satisfaction of the living environment and social interaction (Konijnendijk et al., 2013), (Wesley et al., 2011), (International Federation of Parks and Recreation Administration, 2013). However, other related concepts, such as increasing biodiversity, the planting of native species, and the full meaning of ecosystem health beyond merely tree health have not been addressed profoundly as contributors to urban forest integrity.

2.3 Ecological Integrity

The dynamics and functioning of ecosystems, and hence the ability of ecosystems to provide humans with essential goods and services, depends to a great extent on the diversity of life (Cardinale et al., 2012). But the diversity of species, genetics, and communities is being lost at an alarming rate (Cardinale et al., 2012). Human-induced species losses are arguably leading to a sixth mass extinction (Ceballos et al., 2015). The conservation and management of species, ecosystems, and diversity at various levels are crucially important in sustaining natural structures and functions. The management of biological diversity on the landscape requires its accurate measurement, so as to compare alternatives, choose management actions, and monitor progress in achieving objectives.

An ecological integrity assessment is a multi-metric index in the form of an ecological scorecard that is intended to assess ecosystem structure, composition, function, species composition, diversity, and functional organization (Faber-Langendoen et al., 2012). It is useful for measuring and monitoring biological diversity as well as ecosystem integrity. Plants and associated vegetation measures are at the core of the ecological integrity assessment version developed by Nature Serve, whose Natural Heritage programs use vegetation as the primary means of assessing ecosystem condition (Faber-Langendoen et al., 2012). Vegetation thus serves as the key biological entity in ecological integrity assessment (Zelený, Bicking, Dang, & Müller, 2020).

2.4 Plant Diversity

Biodiversity is the variety within and among species, biological system and biological process found on Earth" (UNCBD). Biodiversity then is the diversity of and living nature (Wilson, 1988). Scientists usually define biodiversity in terms of genes, species and ecosystems and of plant and animal life within species (genetic diversity), among species (species diversity) and among ecosystems (ecosystem diversity), corresponding to three fundamental and hierarchically kind of biodiversity such as genetic diversity, species diversity or taxonomic diversity and ecosystem diversity (Heywoodand Watson, 1995).

Harrison (2004), distinguishes seven levels of biodiversity: genetic diversity, species diversity, ecosystem diversity, community diversity, landscape diversity, population diversity and organism diversity. Biodiversity has several components, such as the numbers abundance, composition, spatial distribution and interactions of genotypes, populations, species, functional types and traits and landscape units in a given ecosystem (Diaz et al., 2005). All these components may play a role in maintaining life support systems in the long term. Diversity within the natural environment is important. It provides variety that people enjoy, both in species and landscape. Species variety plays a dual role of ensuring and signaling the variety of the natural environment. Furthermore, it protects the health of natural environments, which provide people need to depend (SIG, 2007).

2.4.1 Status of Plant Diversity in Nairobi City Park

Nairobi City Park hosts a variety of plant species. As described by Friends of City Park (2011), this vegetation is characterized by *Croton megalocarpus, Calodendrum capense* (*L. F.*) *Thunb., Diospyros abyssinica (Hiern) F. White*, and *Brachylaena huillensis O.Hoffm*. The only comparable vegetation occurs on the dry lower slopes of Kilimanjaro in northern Tanzania. The Park's greatest attraction lies in its hitherto intact rich biodiversity. The potential this offers as a major draw card has been under-utilized and largely under-unappreciated, even among botanists, who in their explorations have-in recent decades-largely neglected the City Park Forest.

Two detailed surveys have since been conducted-one by Friends of City Park, a dry season survey, in July 2009, and the other, a wet season survey, in February 2010, following good rains. Collectively, the surveys of July 2009 and February 2010 identified 415 plant species not previously recorded in the Park. The surveys further revealed that 169 species (30% of the overall mix) are plants that have been introduced to the forest. The introduced species are from other parts of Kenya and countries in other continents. Notably, Australia, Asia and South America. Most of the introduced species are mainly ornamentals or for cut-flower purposes. Several weeds and invasive species (22%) were noted and some of these are spreading quickly in the Park, threatening to undermine healthy plant diversity.

Woody shrubs and trees were found to make nearly half (46.3%) of the Park's entire plant diversity. This indicates that the forest is not only diverse, but that it also represents a valuable habitat relic a typical of the Nairobi vegetation type. Other species of priority conservation concern include several of the typical upland dry forest species, such as *Croton megalocarpus, D. abyssinica*, *Teclea* spp., and *Markhamia lutea*.

2.5 Tree Physical Attributes

Tree physical attributes is a concept used to describe trees using the following factors related to the how the plant looks like; tree diameter, tree height,

2.5.1 Tree Diameter

A variety of different attributes has been used in the international literature to characterize tree structure. Tree diameter is the most ubiquitous measure of tree size in the literature concerning forest structure, and it is typically quantified in terms of mean tree diameter at breast height, the standard deviation of tree DBH and the number of trees exceeding threshold diameter (i.e. the number of large trees). Spies and Franklin (1991) identified these three attributes as amongst the most important for characterizing wildlife habitat, ecosystem function and successional development in Douglas-fir forests. Mean DBH generally increases with stand age and has been used to discriminate between successional stages in Douglas-fir forests (Spies &Franklin, 1991), hemlock-hardwood forests (Ziegler, 2000) and between managed and virgin boreal forests in Finnish and Russian Karelia (Uuttera et al., 1997). The standard deviation of tree DBH is a measure of the variability in tree size, and is considered indicative of the diversity of micro-habitats within a stand (Acker et al., 1998, Van Den Meerschautt & Vandekerkhove, 1998). It is straight forward attribute to quantify and can be comparable to more complex attributes and indices as a descriptor of stand structure (Neumann & Starlinger, 2001).

This diameter is measured over the outside bark using a diameter tape at the point foresters call (breast height". DBH has traditionally been the "sweet spot" on a tree where measurements are taken.

2.5.2 Tree Height

Because the relationship between height and diameter is non-linear it is often more meaningful to use attributes directly associated with height when characterizing vertical elements of structure. For example, the standard deviation of tree height will be more indicative of the vertical layering of foliage than the standard deviation of DBH (Zenner, 2000).

Variation in tree height is considered an important attribute of structure because stands containing a variety of tree heights are also likely to contain a variety of tree ages and species thereby providing a diversity of micro-habitats for wildlife (Zenner, 2000). Sullivan et al., (2001) quantified this type of variation in terms of a simple measure called structural richness, which was based on the number of height classes occupied by the trees in the stand.

2.6 Ground Cover

Vegetation extent is defined as all plant life in a given area (Thackway & Lesslie, 2005; 2006). Keith and Gorrod (2006) identified intrinsic values of vegetation cover, derived from three concepts: (i) aesthetics: human perspectives about what makes a ‘good’ patch of vegetation; (ii) subjective; varies between people and landscapes, and (iii) production: derive from the ability of native vegetation to deliver resources for human consumption.

Assessment of vegetation condition is a context-dependent concept and includes economic drivers such as sustainable production capability, and environmental drivers such as ecological function and biodiversity conservation (Oliver et al., 2002). Indicators include the capacity for economic goods, the degree of land cover or degradation, the presence of different plant species, important habitat for wildlife, ecological productivity and regeneration capacity, and the extent and type of past disturbance (Thackway et al., 2006). Plants have the potential to convey important information on the state and ecological consequences of anthropogenic stressors. As such, measures of ground vegetation are potentially useful indicators of EI. The use of ground vegetation as EI indicators is challenged by issues of scale and difficulties that may be encountered when interpreting responses in an anthropogenic natural context. For example, natural disturbances may influence plant communities in ways that are similar to certain anthropogenic stressors and can alter the several stage of monitoring plots to a degree that limits their comparability to reference sites.

Ground Cover types that can be attributed to a City Park Forest includes: Cover of the soil surface with plants, litter, rocks or gravel.

Cover is thought to be more ecologically significant than density or frequency because it is an estimate of how much a plant dominates an ecosystem. Cover is more highly related to biomass than density and frequency and therefore reflects the amount of CO and light that the plant captures and turns into phytomass (above-ground plant biomass)

Ground cover (especially vegetation or litter) influences infiltration and potential erosion. Cover is also good for characterizing ecosystems across life forms. Cover is expressed as % of area.

2.6.1 Shannon-Weiner Diversity Index

Working as one of the main gears inside the vast machinery of environmental science, biodiversity – both directly and indirectly - plays a pivotal role within many research areas - often linked to other terms such as ecosystem service, indicator species, signal species, keystone species and sustainable development (Wheeler et al., 2012). As a result, many attempts have been made during the latest six decades in order to comprehensively uncover and define the fundamental causes to variation between, and in some cases also within species in ecological systems. Those attempts have further come to give rise to one special and, within the many topics of conservation biology, commonly used type of tools in terms of certain mathematical models collectively known as diversity indices (Sodhi & Ehrlich, 2010).

Those indices are often used in order to estimate values for variation among species in these systems and thus obtain substantial values for the biodiversity within a chosen site or sample (Hill et al., 2011). While some diversity indices tend treating all species living in a certain habitat as equal, other index exclusively treat only certain species in the same habitat, depending on what is of relevance for the chosen study in question

(Ricotta, 2004). Example of diversity indices, which treat all species living within the same area as equal in a certain biotic community, is the

Shannon-Wiener's ($H' = -\Sigma(n_i/N) * \log(n_i/N)$)

where n_i is the abundance of the i-th species in an area and N the total number of said species living in the same area (Oksanen, 2015). Generally seen as a sophisticated form of simple diversity indices measuring species and habitat richness, which sometimes could be described as the "most intuitively simple measures of diversity (Hill et al., 2011).Akin to the basic measures for species richness, which tend weighing all species equally with no concern about their functional or phylogenetic differences and properties, Shannon-Wiener's is designed to measure α-diversity (Sodhi & Ehrlich, 2010); which in turn is defined as diversity within one habitat; also known as point diversity (Rosenzweig, 1995).

2.7 Anthropogenic Impacts

The primary contemporary drivers of tropical forest biodiversity loss include direct effects of human activities such as habitat destruction and fragmentation (land-use change), invasive species and over-exploitation, as well as indirect effects of human activities such as climate change (Millennium Ecosystem Assessment, 2005). The relative impacts of these threats vary among the world's major tropical forest regions (Corlett & Primack, 2008). Primary drivers may also induce secondary effects, for example, altered disturbance dynamics (Barlow & Peres, 2004).

The following are the four major anthropogenic drivers of tropical biodiversity loss, focusing on their effects at the species level;

2.7.1 Deforestation and fragmentation

Land-use change is thought to have the greatest impact on biodiversity in tropical forests (Sala et. al, 2000). Forest clearance destroys the habitat and generally causes a decline in forest species abundance and diversity, particularly for species that are restricted in range.

Diverse taxa show different and often variable responses (Barlowet et. al, 2007). Following deforestation, the new habitat will determine biodiversity. For example, secondary forest regenerating after the natural forest has been cleared may never reach the same species richness and composition as primary forest (Chazdon, 2008). Apart from destroying habitat, forest clearance can fragment the remaining forest, leaving areas of forest that are too small for some species to persist, or too far apart for other species to move between (Fahrig, 2003), resulting in a long process of decay in residual diversity from the remaining habitat (Krausset et. al, 2010). Edge effects on fragments also affect species richness and composition (Ewers & Didham, 2006).

2.7.2 Over-exploitation

Over-exploitation of a particular species or group of species can result in that species, or group of species, being driven to local or even global extinction. It differs from the other drivers of biodiversity loss discussed here in specifically targeting individual species. The most well-known examples of overexploitation of tropical forest species involve large mammals for bush-meat (Milner-Gulland e.t al, 2003), and tropical hardwoods for timber (Asner et. al, 2005). A less well-known example is that of Chamaedorea palms (xate´) in Central America, whose leaves are harvested for the floricultural industry (Bridgewater et. al, 2006).

In general human activities tend to affect any of three major aspects of forests:

(i) The total area of forest remaining – many of man's activities remove forest cover either temporarily or permanently. Some forest types may disappear locally, and reduction in the total amount of habitat is a significant pressure on some forest species that can lead to local extinction.

(ii) The configuration of remaining forest cover – reduction in forest area is often accompanied by division of remaining forest cover into fragments, rather than continuous blocks. Forest biodiversity is affected by the consequent local reduction in habitat area, by the exposure of forest edges to new environmental and biotic influences and by isolation from other forest areas.

(iii) The structure and composition of remaining forest – some human activities alter canopy structure, or focus disproportionately on particular species and specific components of their populations.

Each day humans use 40,000 species, most of which go totally unnoticed (Eldredge, 2000). Even though only a minority of humans realizes it, biodiversity provides humans with food, water, oxygen, energy, and detoxification of waste, stabilization of earth's climate, medicine, opportunities for recreation and tourism, and many more things (Secretariat, 2000). Simply put, there would be no population of humans without biodiversity.

There is no clear way of determining the total impact that humans are making on biodiversity; however, it is obvious that many actions by humans are causing a decrease in biodiversity. To determine the total impact that humans are making on a given environment, the area of productive land and water needed to produce the item that is being consumed and the need to account for the waste being generated by humanity must all be taken into account according to management and production practices in use during that time (Wackernagel et al., 2002).

The Convention of Biological Diversity states that there are both indirect and direct human drivers. Some of the indirect human drivers are demographic, economic, sociopolitical, scientific and technological, and cultural and religious factors. Some of the direct human drivers are changes in local land use and land cover, species introductions or removals, external inputs, harvesting, air and water pollution, and climate change (Climate, 2005).

The population of humans is, what many consider, the root of the biodiversity problem (Eldredge, 2000). The number of humans on earth, as of August 2018, exceeds 7.63 billion people, and this number is continuing to grow each day (*worldpopulationreview.com*). The increase in human inhabitants causes a problem because with it comes a need to convert natural habitats to land for human use.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter gives information on the research methodology that was used in this study. They include; research design, study area, target population, sampling procedure, sampling methods, and data collection methods and instruments and data analysis.

Research methodology is the systematic way of solving a research problem using specific methods to obtain results capable of being evaluated (Kothari, 2004). This being a quantitative study, different ecological variables were assessed to determine the anthropogenic impacts on the ecological integrity of Nairobi City Park and findings will assist in deriving conclusions that would give appropriate recommendations for improved park management.

3.2 Research Design

This *ex-post facto* research design was used. This was found to be appropriate for this study in that the dependent variable ecological integrity had already occurred and no manipulation was needed.

3.3 Study Site

As previously described, the park consists of conserved/forest and open/recreational area. The study was undertaken in the conserved/forest area measuring 33 hectares. Ecological data was collected from this area, starting from less dense area bordering the recreational area towards the dense forest. The study area as located in Figure 3.1.

Figure 3.1: Photograph showing Nairobi City Park and its Environs

3.4 Sampling Procedure

A stratified random sampling method was used to collect both social and ecological data. The park was stratified into three strata or zones depicting the proximity to human activity. These zones were classified as near (areas adjacent to recreational areas) mid (areas between recreational areas and deep forest) and far (deep forest area) as shown in Figure 3.2. Systematic sampling was used to lay quadrant plots and transect lines away from each other at intervals of 100 meters and sampling points were at 25m intervals along the transect line.

Figure 3.2: Three stratum for the Nairobi City Park: the outer, middle and inner area all used for data collection

3.5 Sample Size

A sample is the proportion of the population selected for the study or investigation. The sample size for the ecological measurements was determined using the formula of

3.6 Data Collection and Recording Tools

This study collected both primary and secondary data. Primary data as the main source of data was collected in the conserved area of the park while secondary data was obtained from the literature review.

3.6.1 Data Collection Methods

This study applied the use of transect lines and intensive sample quadrant plots (Barnett, 2004), placed along the transect lines systematically.

The transect lines measured 100 meters long and placed 100 meters apart. The sample plots measured 20 meters by 5metres.

A total of 38 sample plots were used to collect data.

The details on tree variables collected is summarized below:

(i) Tree species identification and nomenclature

Trees and their species were identified and recorded in the 100m2 quadrat plots. The nomenclature of the species were counterchecked against international plant names index (www.ipni.org).

(ii) Tree physical attributes

The relationship between trunk diameter and diameter at breast height (DBH) and tree height (H) is the most commonly used measurement of tree size. The allometric relationship of DBH and H among individuals at a particular point in time has long been used to describe the strategies of tree species. (Lida et. al, 2011). Tree DBH and H of all trees in the quadrant plots were collected and recorded.

(iii)Vegetation ground cover

One of the most important characteristics used as an indicator of the status and condition of the forest ecosystem is vegetation cover. Vegetation cover is used to characterize forest vegetation (Kastumpy, 1993). Human influence has over time greatly influenced the ground vegetation of ecosystems. In this study, quantitative data was collected along transect lines and the cover estimated as the proportion of the ground covered by the herbaceous species. Qualitative data was also observed. This observation supplemented the field measurements.

(iv) Tree damage

Approximately half of the tropical forest that was present at the beginning of the twentieth century has already disappeared, with peak deforestation in the 1980s and 1990s (FAO, 2008). The primary contemporary drivers of tropical forest biodiversity loss include direct effects of human activities (Millennium ecosystem assessment, 2005). These influences result in tree damages that include deforestation that results to stumping and debarking. Tree damage was recorded along transect lines and the resultant damages of stumps and debarks recorded.

(v) Number of people visiting the conserved area of the park

Nairobi City Park receives visitors on a daily basis into the park for different recreational purposes. Of these visits, some humans further go into the conserved area of the park. During data collection, the number of people passing through the forest was recorded on the different day. These days represented a picture of the ideal normal situation.

3.6.2 Recording Tools

a) Photographs

Photographs were used to capture highly imaginable records of the users' behavior within the physical settings of the public space and features of the physical environment pertinent to the park's use.

3.7 Validity and Reliability

To enhance validity and reliability of data the samples were collected from different parts in NCP's conserved area with an aim of eliminating location bias that may compromise the reliability and validity of the results.

3.8 Data Processing and Analysis

Data collected was processed and analysed using various statistical methods.

Appendix d shows the objective of the study, its variables and the statistical method used.

Table 3.1: Summary of Analytical Procedures

Study Objectives	Variables Involved	Statistical Method Used
To determine plant species composition of herbaceous and woody plants within the three strata (the outer, middle and the inner areas) within the NCP	Species type and number	Descriptive and inferential statistics
To determine the ground cover of the conserved area of the NCP	Cover assessment	Descriptive and inferential statistics
To assess plant species diversity in the three strata (the outer, middle and the inner areas) within the NCP	Number and species	Descriptive and inferential statistics
To describe tree physical attributes (height, diameter, stumps, and debarking) in the conserved area of NCP	Number and characteristics (height, diameter, stumps, and debarking of trees)	Descriptive and inferential statistics
To determine the average number of human beings who traverse through the conserved area of the NCP	Number	Descriptive and inferential statistics
To Determine the extent of human impact on the trees found within the NCP	Number of people and damage index	Descriptive and inferential statistics

CHAPTER FOUR

RESULTS AND FINDINGS

4.1 Introduction

This chapter presents results and their interpretation on the anthropogenic influences on the ecological integrity of the NCP. The chapter is divided into the following sections: (i) plant species composition in the three strata within the NCP, (ii) Ground cover of the NCP, (iii) plant species diversity within the NCP, (iv) tree physical attributes within the NCP conserved area, (v) number of people accessing NCP conserved area, (vi) human impact on the NCP vegetation resources.

4.2 Plant Species Composition within the NCP's Three Strata

The first objective of this study was to determine the plant species composition of herbaceous and woody plants within Nairobi City Park. The plant species that were found in the NCP within the different strata (the outer, middle and the inner core areas) the type of plant growth habit (whether tree, shrub or herbaceous), plant family were noted from random located transect lines and intensive sample quadrant plots placed along the transect line systematically during the data collection. The data were then analysed and presented in a Table 4.1.

The study recorded 62 plant species belonging to 33 families as shown in Table 4.1. The relative abundance of plant species ranges from 1.6 to 8.0. Plant families that were highly represented in the study area was Mimosaceae (8.06), followed by Euphorbiaceae and Myrtaceae both with a relative abundance of 6.45.

Table 4.1: Woody Plant Families and Number of Species Represented and their Relative Abundance in NCP

Family	Number of Species	Relative Abundance
Mimosaceae	5	8.065
Euphorbiaceae	4	6.452
Myrtaceae	4	6.452
Apocynaceae	3	4.839
Caesalpiniaceae	3	4.839
Meliaceae	3	4.839
Moraceae	3	4.839
Palmae	3	4.839
Aloaceae	2	3.226
Anacardiaceae	2	3.226
Bignoniaceae	2	3.226
Caesalpiniaceae	2	3.226
Combretaceae	2	3.226
Flaourtiaceae	2	3.226
Loganiaceae	2	3.226
Oleaceae	2	3.226
Papilionaceae	2	3.226
Rosaceae	2	3.226
Araucariaceae	1	1.613
Asparagaceae	1	1.613
Asteraceae	1	1.613
Burseraceae	1	1.613
Cannabaceae	1	1.613
Casuarinaceae	1	1.613
Ebenaceae	1	1.613
Fabaceae	1	1.613
Lauraceae	1	1.613
Poaceae	1	1.613
Podocarpaceae	1	1.613
Proteaceae	1	1.613
Rubiaceae	1	1.613
Rutaceae	1	1.613
33	62	100.000

4.2.1 Woody Plant Species within the Outer Stratum of NCP

The relative abundance for the outer stratum was determined and the results are presented in Table 6.3 (in Appendix D) and Figure 4.1

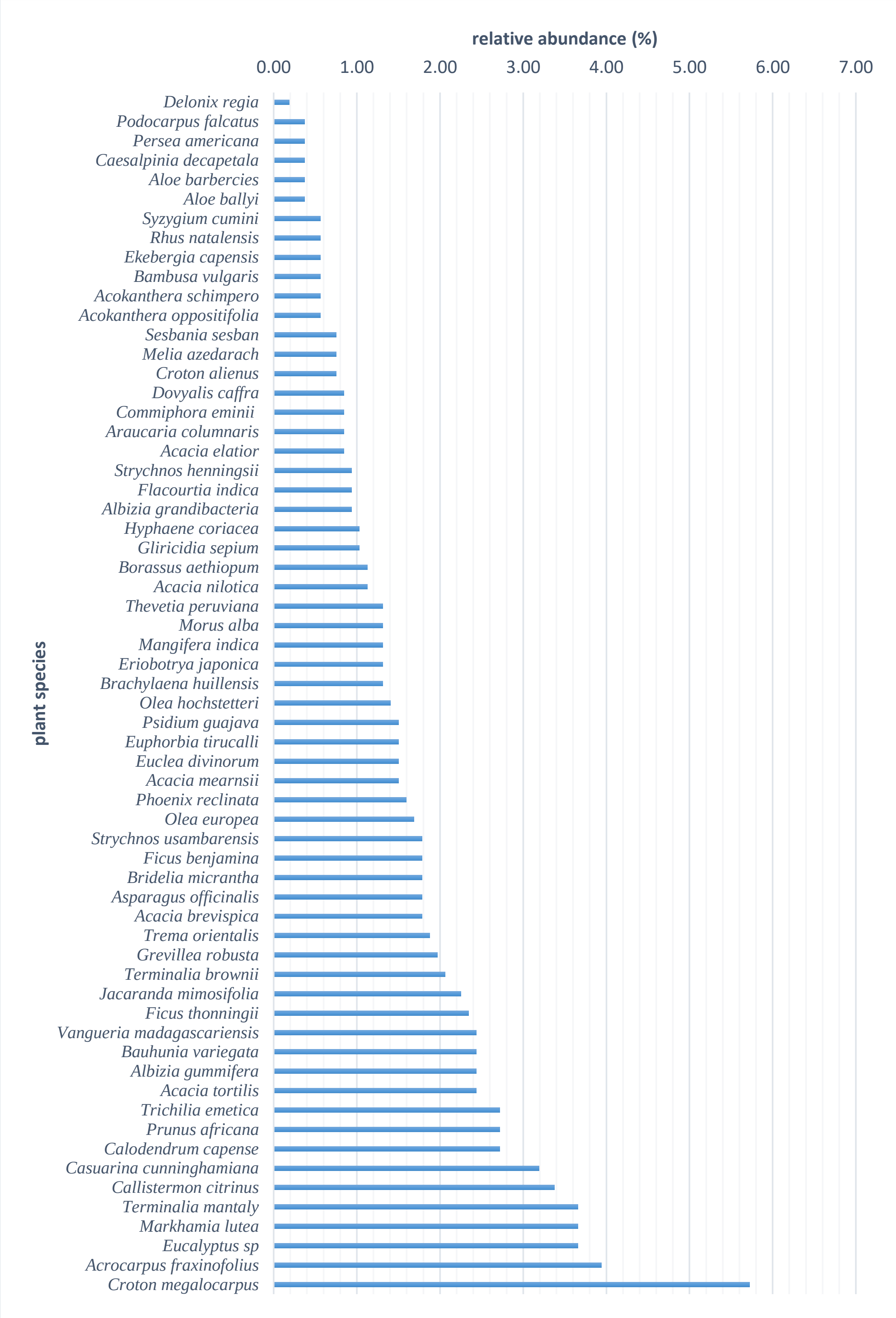

Figure 4.1 species abundance in the outer stratum of NCP

The woody plant species identified in the outer stratum were noted and are presented in a species composition Table 6.3 (Appendix D) and in Figure 4.1.

The outer stratum of the NCP consisted of 62 species, belonging to 33 families were recorded in this area which next to the more accessible outer area to the visitors to park. The relative abundance of the woody plant species ranged from 0.19 to 5.72 %. The plant species the highest relative abundance was *Croton megalocarpus* (5.72 %) followed by *Acrocarpus fraxinifolius* (3.94 %) and *Eucalyptus sp.* (3.66 %). The woody plant species richness was 1066. This area of the park had the lowest species richness than the other two stratum in the NCP.

4.2.2 Woody Plant Species within the Middle Stratum of NCP

The relative abundance for the outer stratum was determined and the results are presented in Table 6.4 (in Appendix D) and Figure 4.2

The middle stratum of the NCP consisted of 62 species, belonging to 33 families were recorded in this area which was more accessible to the visitors to park. The relative abundance of the woody plant species ranged from 0.08 to 5.44 %. The plant species the highest relative abundance was *Croton megalocarpus* (5.44 %) followed by *Magnifera indica* (4.18 %) and *Callistemon citrinus* (4.10 %). The woody plant species richness was 1195. The amount of species richness found in this stratum was in between the other two stratum.

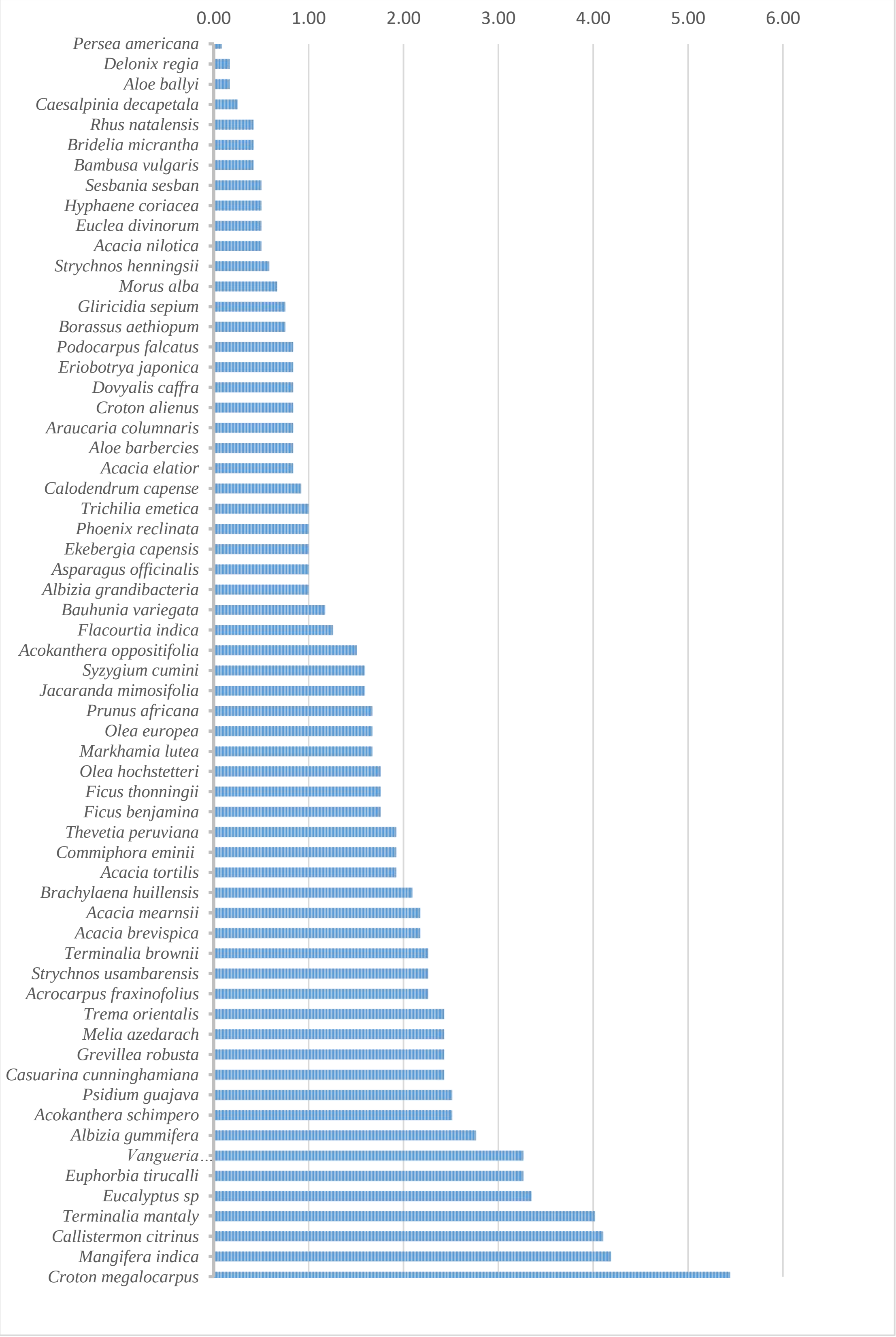

Figure 4.2 Species abundance in the middle stratum of NCP

4.2.3 Woody Plant Species within the Inner Core Stratum of NCP

The relative abundance for the outer stratum was determined and the results are presented in Table 6.5 (in Appendix D) and Figure 4.3.

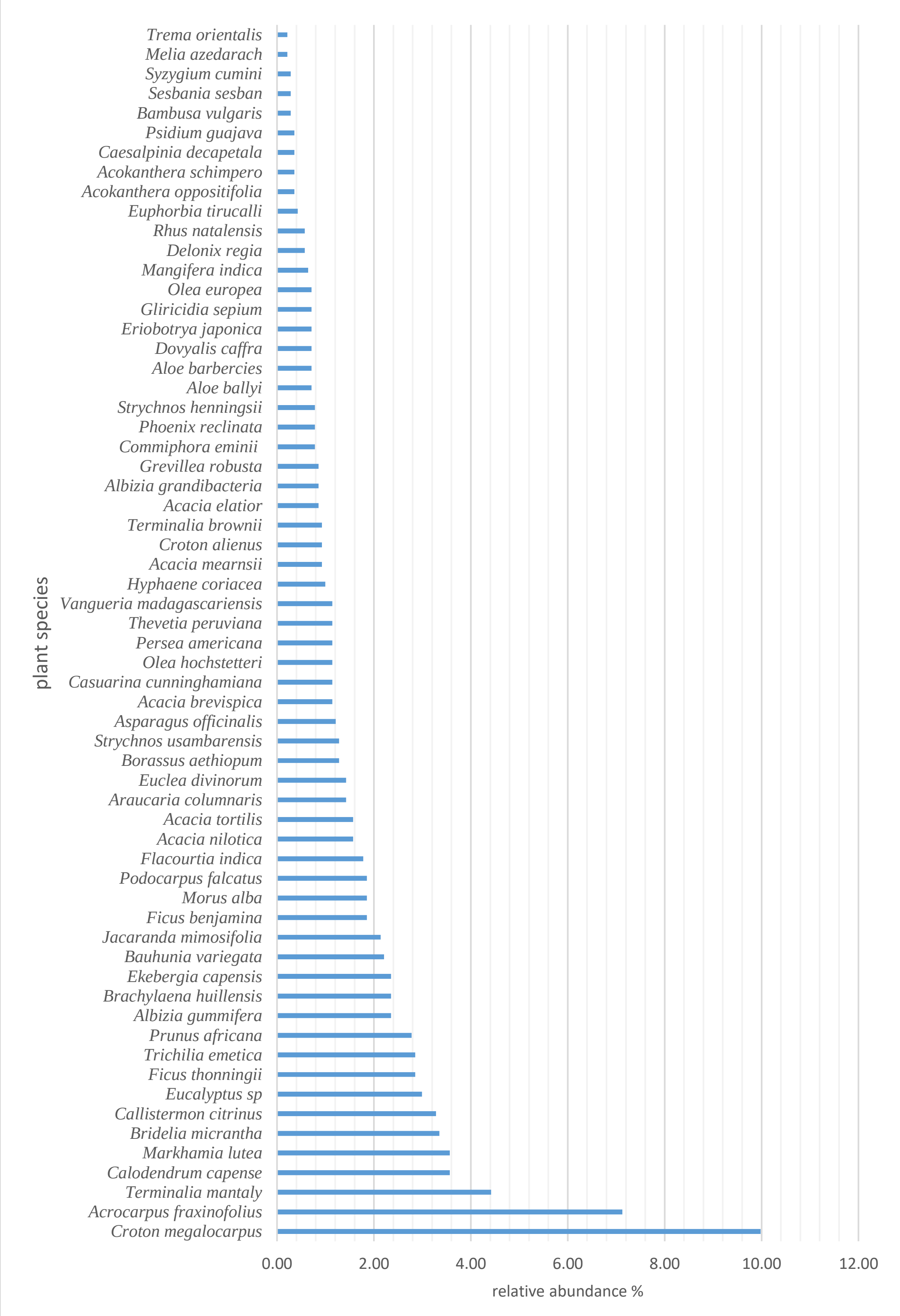

Figure 4.3 Species abundance in the Inner core stratum of NCP

The inner core stratum of the NCP consisted of 62 species, belonging to 33 families were recorded in this area which was less accessible to the visitors coming to the park. The relative abundance of the woody plant species ranged from 0.21 to 9.98 %. The plant species the highest relative abundance was *Croton megalocarpus* (9.98 %) followed by *Acrocarpus fraxinifolius* (7.13 %) and *Terminalia mantaly* (4.42 %). The woody plant species richness was 1403. This section of the park had the highest species richness than the other two areas found in the NCP.

4.2.4 Mean Differences in Plants Species in the Outer, Middle and Inner core Stratum of the NCP

The species richness for the three areas (outer, middle and inner core strata) were found to be different outer (1066), middle (1195) and central (1403). A mean comparison was performed using ANOVA to determine if statistical significant differences in the species richness and abundance existed in the three strata of the NCP. The results are given in Table 4.2.

Table 4.2: ANOVA Table

Species Richness	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	932.656	2	466.328	1.662	.193
Within Groups	51340.484	183	280.549		
Total	52273.140	185			

The results of Table 4.2 indicate that the differences in the species richness of the three strata were not significantly different statistically $F (2, 183) = 1.662$, $p > 0.05$).

4.3 Ground Cover of the Three Strata in NCP

The second objective of this study was to determine the ground cover of the different strata (outer, middle and inner core) of the MCP. The step point method was used to determine cover within each stratum.

4.3.1 Ground Cover for the Outer Stratum within the NCP

The ground cover data was analysed to determine the cover by vegetation and the bare area, the results are shown in Table 4.3.

Table 4.3 Ground Cover for the Outer Stratum in NCP

Plant Species	Total Number of Hits in the Quadrants	Percent over	Percent Species Composition
Grasses			
Brachiaria ruziziensis	29	7.10	17.22
Hyparrhenia rufa	33	7.14	13.86
Imperata cylindrica	29	6.27	12.18
Pennisetum clandestinum	32	6.92	13.44
Panicum maximum	31	6.71	13.02
Paspalum vaginatum	47	10.17	19.74
Forbs/Herbs			
Achyranthes aspera	12	2.59	5.04
Hypoestes verticillaris	13	2.81	5.46
Total Vegetation	238	51.51	100
Litter/mulch	51	11.03	
Bare ground	173	37.44	
Total	462	100	

The ground cover for the outer area of the NCP was found to be 51.5 % covered with vegetation, 11 % dead plant materials (litter or mulch), and 37.4 % was bare. The proportion of the area that was without vegetation (bare) was high an indicator of degradation. The plant species that were highly represented in the area were *Paspalum vaginatum* (19.7 %) and *Brachiaria ruziziensis* (17.2 %). The herbs and forbs were the least represented with *Achyranthes aspera* (2.5 %) and *Hypoestes verticillaris* (2.8 %).

4.3.2 Ground Cover for the Middle Stratum in the NCP

The ground cover data was analysed to determine the area under cover of vegetation and bare areas, the results are shown in Table 4.4.

Table 4.4: Ground Cover for the Middle Stratum in the NCP

Plant Species	Total Number Of Hits In The Quadrants	Percent Cover	Percent Species Composition
Grasses			
Brachiaria ruziziensis	122	15.84	22.46
Hyparrhenia rufa	50	6.49	9.20
Imperata cylindrica	56	7.27	10.31
Pennisetum clandestinum	113	14.67	20.81
Panicum maximum	39	5.06	7.18
Paspalum vaginatum	120	15.58	22.09
Forbs/Herbs			
Achyranthes aspera	15	1.94	2.76
Hypoestes verticillaris	28	3.63	5.15
Total Vegetation	543	70.51	100
Litter/Mulch	71	9.22	
Bare ground	156	20.26	
Total Cover	770		

The ground cover for the middle area of the NCP was found to be 70.5 % covered with vegetation, 9.2 % dead plant materials (litter or mulch), and 20.2 % was bare. The proportion of the area that was without vegetation (bare) was high an indicator of degradation. The plant species that were highly represented in the area were *Paspalum vaginatum* (22 %) and *Brachiaria ruziziensis* (22.4 %) and *Pennisetum clandestinum* (20.8%). The herbs and forbs were the least represented with *Achyranthes aspera* (1.9 %) and *Hypoestes verticillaris* (3.6 %).

4.3.3 Ground Cover for the Inner Core Stratum in NCP

The ground cover data was analysed to determine the area under cover of vegetation and bare areas, the results are shown in Table 4.5.

Table 4.5: Ground Cover for the Inner Core Stratum in the NCP

Plant Species	Total Number Of Hits In The Quadrants	Percent Over	Percent Species Composition
Grasses			
Brachiaria ruziziensis	447	20.15	24.33
Hyparrhenia rufa	134	6.04	7.29
Imperata cylindrica	317	14.29	17.26
Pennisetum clandestinum	320	14.43	17.42
Panicum maximum	48	2.16	2.61
Paspalum vaginatum	538	24.26	29.29
Forbs/Herbs			
Achyranthes aspera	20	0.90	1.09
Hypoestes verticillaris	13	0.59	0.71
Total Vegetation	1837	82.82	100.00
Litter/Mulch	300	13.53	
Bare ground	81	3.65	
Total Cover	2218	100.00	

The ground cover for the inner core area of the NCP was found to be 82.8 % covered with vegetation, 13.5 % dead plant materials (litter or mulch), and 3.6 % was bare. The proportion of the area that was without vegetation (bare) was low an indicator of good condition of the ecological resources. The plant species that were highly represented in the area were *Paspalum vaginatum* (29.2 %) and *Brachiaria ruziziensis* (24.3 %) and *Pennisetum clandestinum* (17.4 %). The herbs and forbs were the least represented with *Achyranthes aspera* (0.9 %) and *Hypoestes verticillaris* (0.59 %).

4.4 Plant Species Diversity of the Three Strata within the NCP

The third objective of this study was to assess the plant species diversity within each of the three strata found within the NCP. The Shannon-Wiener diversity index (H') was used to assess the plant species diversity in each stratum of the park.

4.4.1 Woody Plant Species Diversity in the Outer Stratum of the NCP

The plant species biodiversity (*H'*) for the Outer habitat of the NCP was determined and the results are presented in Table 6.8. (in Appendix F).

The results (Table 6.8) indicate that this habitat had in total 62 species belonging to nine (33) families. The species diversity was found to be (*H'*= -1.602). The index was slightly above the average, indicating that the diversity was affected.

4.4.2 Woody Plant Species Diversity in the Middle Stratum of the NCP

The plant species biodiversity (*H'*) for the middle habitat of the NCP was determined and the results are presented in Table 6.9. (in Appendix F).

The results (Table 6.9) indicate that this habitat had in total 62 species belonging to nine (33) families. The species diversity was found to be (*H'*= -1.691). The index was above average, indicating that the diversity was slightly affected.

The Biodiversity index ranges between 1 and 3 (below 1 is low and above 2 is high plant diversity).

4.4.3 Woody Plant Species Diversity in the Inner Core Stratum of the NCP

The plant species biodiversity (*H'*) for the central habitat was determined and the results are presented in Table 6.10. (in Appendix F).

The results (Table 6.10) indicate that this habitat had in total 62 species belonging to nine (33) families. The species diversity was found to be (*H'*= -1.702). The index was slightly above the average, indicating that the diversity was affected.

4.4.4 Comparison of the Plant Species Diversity in the Three Strata of NCP

The results for the plant diversity for the NCP is shown in Table 6.7 (appendix F) show the plant diversity in NCP to be (H'= -1.707), this is termed as medium. The plant diversity in the three strata varied slightly from each other as shown in Figure 4.4.

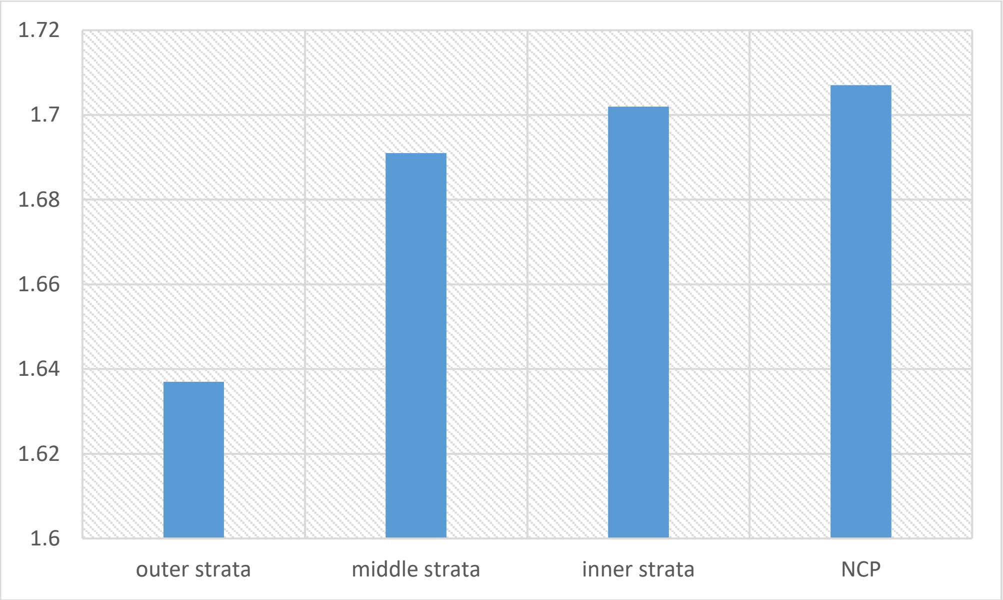

Figure 4.4: Plant species diversity in the three strata and the NCP

The comparison (Figure 4.4) shows that the outer stratum had the lowest plant diversity, followed by the middle and finally the inner part of the NCP. These variations can be related to human activities, which tends to reduce as you move towards the inner core of the Park.

4.4 Tree Physical Attributes in NCP

The fourth objective of this study sought to ascertain tree physical attributes that the trees in the park possess. The four attributes identified were: stem diameter at breast height (DBH), tree height, tree stumps and debarking. The tree attributes were measured on tree samples selected at random along transect lines and the data was then analysed.

4.4.1 Diameter and Height of Trees in the Outer, Middle and Inner Core Strata of the NCP

The tree heights were measured in meters and the DBH were measured in cm and the means were calculated and are shown in Figure 4.5.

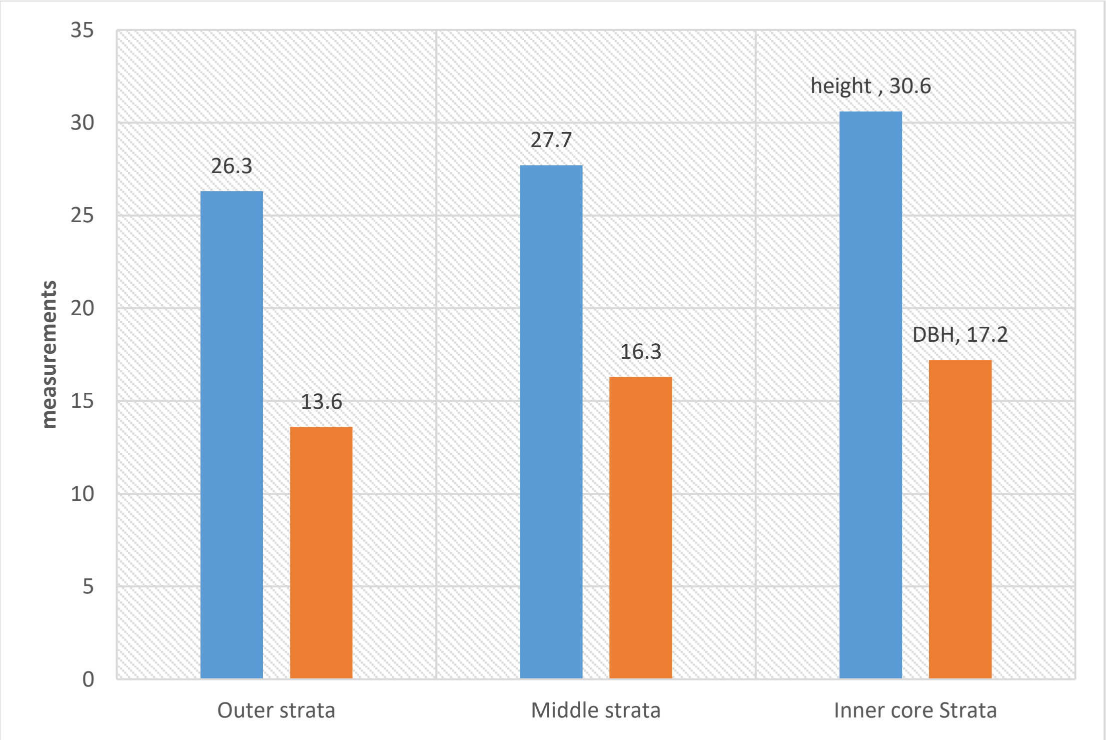

Figure 4.5 shows the variations of tree diameter and height in the three strata

The diameter of trees and the tree height showed an increasing pattern from the outer Strata to the centre. The tree heights means in were 26.3, 27.7 and 30.6 m for the outer, middle and centre areas respectively. The mean diameter of the trees were 13.6, 16.3, and 17.2 cm for the outer, middle and centre areas respectively. The outer strata had the lowest figures indicating a heavy influence of human activities. The trees are younger (with small diameters and low heights) indicating a population of regenerating trees.

4.4.2 Tree Stumps and Debarking

The number of tree stumps were counted on four different transect running from the outer to the inner core strata of NCP. The number of stumps in each stratum were added together and a mean calculated, the results are shown in Table 4.6

Table 4.6: Number of Tree Stumps Counted in the Three Strata in the NCP

	Transects					
Strata	**A**	**B**	**C**	**D**	**Total**	**Mean**
Outer	6	1	14	20	41	10.25
Middle	3	2	2	6	13	3.25
Inner core	0	0	0	2	2	0.5

A declining trend was observed in the number of tree stumps encountered as you move from the outer stratum to the centre (or innermost stratum). The mean number of the stumps for the outer stratum was 10.25, while the middle stratum was 3.25 and the inner core was 0.5. The number of tree stumps an indicator of the number of trees harvested from the area was higher in the outer stratum than the inner core stratum.

The number of tree that were debarked (debarking) were also counted on four different transect running from the outer to the inner core strata of NCP. The number of debarked trees in each stratum were added together and a mean calculated, the results are shown in Table 4.7.

Table 4.7: Number of Debarked Trees Counted in the Three Strata in NCP

	Transect					
Strata	**A**	**B**	**C**	**D**	**Total**	**Mean**
Outer	12	0	10	16	38	9.5
Middle	5	0	12	6	23	5.75
Inner core	3	1	1	3	8	2

The outer stratum had more trees debarked than the inner core stratum due to its accessibility by visitors as it borders the recreation area and the roads. The mean number of debarked trees counted for the outer stratum was 9.5, while the middle stratum was 5.75 and the inner core was 2. The number of debarked trees is an indicator of the extent of human activities in the NCP.

4.5 Number of People Traversing the Three Stratum within the NCP

The fifth objective of this study was to determine the number of people traversing the different areas of the NCP.

The number of people visiting the different areas of the park were counted for 11 days for a period of one month at different days of week. The total number counted was determined and a mean calculated for each of the three strata and the results are shown in Table 4.8.

The average number of people visiting the different areas of the MCP is shown to decrease as one moves from the outer stratum going in to the inner core of the park. The outer core area of the park had 26 people, while the middle area had 12 and the inner core had 3 people.

Table 4.8: Number of People Traversing the Different parts of the NCP

		Strata		
Sample	Day of Week	Outer	Middle	Inner core
Week 1	Monday	26	10	5
	Friday	15	9	2
	Saturday	31	19	10
Week 2	Monday	16	6	0
	Saturday	19	5	2
Week 3	Monday	16	10	3
	Friday	26	9	3
	Saturday	40	19	2
	Sunday	33	14	1
Week 4	Saturday	29	15	6
	Sunday	30	13	4
Total		281	129	38
Mean		25.55	11.73	3.45

An ANOVA was run to determine the mean differences of the number of people visiting the three strata (outer, middle and inner core) of the NCP. The results are shown in Table 4.9.

Table 4.9: ANOVA Table for Mean Comparisons Showing the F-test

Park Visitors	Sum of Squares	df	Mean Square	F	p
Between Groups	2740.424	2	1370.212	42.746	0.001
Within Groups	961.636	30	32.055		
Total	3702.061	32			

The *F*-test (Table 4.9) results indicate that there was a statistically significant difference in the number of people visiting the three strata, $F(2,30) = 42.74$, $p < 0.001$). We can therefore conclude that statistically significant differences do exist in the number of people visiting the three strata (outer, middle and inner core) in NCP.

A post hoc test was then conducted to determine the means that were statistically significant different from the others. Post hoc analysis was performed using Bonferroni post hoc tests. The comparison of the mean pairs for outer stratum (I) and other strata (J), the 95 % confidence interval for the difference between group I and J, statistical significance value (*p* value) and standard error are given in Table 4.10.

Table 4.10: Pairwise Comparisons for the Outer Stratum and Other Strata

Comparison between outer stratum (I) and other strata (J)	Mean Difference (I-J)	Std. Error	p.	95% Confidence Interval	
				Lower Bound	Upper Bound
Middle	13.818	2.414	0.001	7.70	19.94
Inner	22.091	2.414	0.001	15.97	28.21

The mean comparison results for the mean pairs in Table 4.10, indicate that the contribution of two mean pairs (outer and middle, outer and inner core) were statistically ($p < 0.05$) significantly different from each other.

In comparing the mean differences for outer stratum and middle stratum, the outer stratum had statistically significantly higher mean differences 13.18 (95% CI, 7.7 to 19.9), $p < 0.001$) than the medium stratum. The mean differences between outer and inner core stratum, outer stratum had statistically significant higher difference 22.09 (95% CI, 15.9 to 28.2) than the inner core stratum. This implies that outer stratum had higher number of humans visiting the stratum than the other two strata (middle and inner core) and these differences were statistically significant ($p < 0.05$).

4.6 Extent of Human Impact on the Ecological Integrity of the NCP

The sixth objective of this study sought to determine the extent of human activities on the ecological integrity of the NCP.

4.6.1 Extent of Human Activities in the NCP

The independent variable for this study was the intensity of human activities within the NCP, which have an impact on the ecological resources within the park. The variable was operationalized as an index that combined three indicators that include: (i) number of people traversing the NCP as they cause trampling, (ii) number of cut stumps, signifying extractive use, (iii) number of debarked trees, signifying destructive use in the NCP. The indicators were then summed together to form the index of intensity of human activities in the NCP, whose descriptive statistics and frequency distributions are presented in Table 4.11.

Table 4.11: Index of Intensity of Human Activities in the Park

Categories	Frequency	Percent
Below 10	10	30.3
11-20	7	21.2
21-30	5	15.2
31-40	4	12.1
41-50	4	12.1
Above 51	3	9.1
Total	33	100.0

Mean 24±3.04, median 19, mode 4.5, SD 17.47, min 2.50, max 60

The index of intensity of human activities in the NCP had a mean of 24±3.04 (SD 17.47) and ranged between 2.50 and 60 (1 being low intensity and 60 high intensity). The category that was highly (30.3 %) represented is the group with an index of below 10.

4.6.2 Intensity of Human Activities in the Three Strata of NCP

The study determined the intensity of human activities in the three strata (outer, middle and inner core) of NCP. The intensity of the human activities in the three strata were found to be different, with the outer stratum having a higher intensity (45.54), followed by middle stratum (20.72) and finally the inner core with (5.95). These differences in the intensity of human activities are shown in Table 4.12.

Table 4.12: Intensity of Human Activities in the Three Strata in the NCP

Strata	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Outer	11	45.54	8.140	2.454	35.00	60.00
Middle	11	20.72	4.7132	1.421	14.00	28.00
Inner core	11	5.95	2.769	.835	2.50	12.50
Total	33	24.07	17.471	3.041	2.50	60.00

A mean comparison was done using a one way ANOVA. The results of the mean comparison are shown in Table 4.13.

Table 4.13: ANOVA Table for Mean Comparisons Showing the F-test

Intensity of Human Activities	Sum of Squares	df	Mean Square	F	p
Between Groups	8805.924	2	4402.962	137.358	0.001
Within Groups	961.636	30	32.055		
Total	9767.561	32			

The *F*-test results (Table 4.13) indicates that there was a statistically significant difference in the intensity of human activities the three strata, $F(2,30) = 137.35$, $p < 0.001$). We can therefore conclude that statistically significant differences do exist in the intensity of human activities in the three strata (outer, middle and inner core) in NCP.

A post hoc test was then conducted to determine the means that were statistically significant different from the others. Post hoc analysis was performed using Bonferroni post hoc tests. The comparison of the mean pairs for outer stratum (I) and other strata (J), the 95 % confidence interval for the difference between group I and J, statistical significance value (*p* value) and standard error are given in Table 4.14.

Table 4.14: Pairwise Comparisons for the Outer Stratum and Other Strata

Comparison between Outer stratum (I) and other strata (J)	Mean Difference (I-J)	Std. Error	p	95% Confidence Interval	
				Lower Bound	Upper Bound
Middle	24.81	2.414	0.001	18.69	30.93
Inner core	39.59	2.414	0.001	33.46	45.71

The mean comparison results for the mean pairs in Table 4.14, indicate that the contribution of two mean pairs (outer and middle, outer and inner core) were statistically ($p< 0.05$) significantly different from each other.

In comparing the mean differences for outer stratum and middle stratum, the outer stratum had statistically significantly higher mean differences 24.81 (95% CI, 18.6 to 30.9), $p < 0.001$) than the medium stratum. The mean differences between outer and inner core stratum, outer stratum had statistically significant higher difference 39.59 (95% CI, 33.4 to 45.72) than the inner core stratum. This implies that outer stratum experienced a higher intensity of human activities in the stratum than the other two strata (middle and inner core) and these differences were statistically significant ($p< 0.001$).

4.6.3 Ecological Integrity of the NCP

The dependent variable for this study was the ecological integrity of the NCP. This variable was operationalized as an index that involved three indicators. The indicators used to describe ecological integrity were: (i) species richness in the park, (ii) plant species diversity (H'), and (iii) ground cover. These indicators were measured using ecological techniques and their values were added together to form the index of ecological integrity for NCP. The resulting index, its descriptive statistics, and frequency distribution are shown in Table 4.15.

Table 4.15: Descriptive Statistics and Frequency Distributions of Ecological Integrity Index for NCP

Index Categories	Frequency	Percent
Below 1119	11	33.3
1120-1267	11	33.3
1268-1487	11	33.3
Total	33	100.0

Mean 1291±26.7, median 1267, mode 1119, SD 153.7, min 1119, max 1487

The Ecological Integrity Index (EII) for the Nairobi city park had a mean of 1291±26.7 (SD 153.7). The index ranged from lowest (1119) indicating a low integrity to the highest (1487) indicating a high integrity meaning the ecological components were intact and functioning properly, which is the ultimate required level. For when the components are functioning properly the system (park) would be able to provide the required ecosystem services to the people.

4.6.4 Determining the Impact of Anthropogenic Activities on the Ecological Integrity of the NCP

The impact of anthropogenic destruction on the integrity of the NCP was determined by the use of simple linear regression. The ecological integrity of NCP was the dependent variable, while the intensity of human activities was the independent variable. The test for significance of whether the overall regression model is a good fit for the data was performed using the F test. The ANOVA table showing the F-ratio and significance levels is shown in Table 4.16.

Table 4.16: ANOVA Table for the Regression Testing the Fit of the Model

Model	Sum of Squares	df	Mean Square	F	p
Regression	637088.547	1	637088.547	166.132	.001[b]
Residual	118880.017	31	3834.839		
Total	755968.564	32			

a. Dependent Variable: ecological integrity
b. Predictors: (Constant), intensity of human activities

The overall regression model equation was found to be a good fit for the data. The independent variable (intensity of human activities) statistically significantly predicted the dependent variable, ecological integrity of NCP (F (1, 31) = 166.13, p < .001). The regression model is a good fit of the data.

To determine how well the regression model fits the data. The results of the regression model are shown in Table 4.17.

Table 4.17: Regression Model Summary for Intensity of Human Activities and Ecological Integrity of NCP

R	R Square	Adjusted R Square	Std. Error of the Estimate
.918[a]	.843	.838	61.92608

The quality of the prediction of the dependent variable was measured using R^2 (coefficient of determination), which shows the proportion of variation accounted for by the regression model. The model indicates an adjusted R^2 value of 0.843, meaning that the independent variable intensity of human activities explained approximately 84.3 % of the variation in the dependent variable ecological integrity of NCP. The regression coefficients of the model showing the beta, t, and the tolerance levels is shown in Table 4.18.

Table 4.18: Regression Coefficients for Intensity of Human Activities and Ecological Integrity of NCP

	Unstandardized Coefficients		Standardized Coefficients			Collinearity statistics
Model	B	Std. Error	Beta	t	p	VIF
(Constant)	1485.72	18.541		80.130	.001	
Intensity of human activities	-8.076	.627	-.918	-12.89	.001	1.000

The regression analysis shows that the intensity of human activities had negative impact on the ecological integrity of the park. The results (Table 4.18) show that the intensity of human activities have a negative statistical significant influence ($\beta = -.918$, t = -12.89, $p < 0.001$) on the ecological integrity of the NCP. It can therefore be concluded that as the human activities in the park intensify the ecological integrity of the park decreases (or is affected negatively).

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the findings, their discussion, conclusions and recommendations.

5.2 Discussion

The study findings for this study are discussed based on the specific objectives stated in section 1.4 of this thesis.

5.2.1 Plant Species Composition in Nairobi City Park

The Nairobi City Park was found to have 62 plant species belonging to 33 families and a species richness ranging from 1066 to 1403 species. In comparison to other dry forests in the tropics, this could be termed as medium range (McLaren, McDonald, Hall & Healey, 2005). In ecological studies, the properties that explains the relationship between communities are the species richness, diversity and distribution. Comparison of each type of community can be made by comparing their diversity indices. These diversity indices are the measurement to describe general properties of communities (Abdul Razak, Mohamed, Alona, Omar, & Misman, 2019).

a rich plant species composition. The high species composition is typical of can be due to the ecological conditions of the area and introduction of some plant species in the recreation area. A common introduced grass species is the *Paspalum vaginatum* common in all areas of the park. The different types of species are an important ecological tool and form the habitat of the park.

The Mimosacae family made up of mostly tropical and sub-tropical trees and shrubs is the most abundant family in the park because of the climatic and environmental location of Nairobi City Park. The family is mostly known for its importance for medicinal purposes using its barks. Caesalpiniaceae family is also abundant with 5 species identified. This family is mostly found in tropical and sub-tropical; areas. Its economic importance ranges from food, medicine, fiber, dye, tanning and ornamentals. This varied importance of these plant species make them susceptible to human exploitation because they satisfy their needs.

5.2.2 Ground Cover of the Nairobi City Park

Based on the measurement of ground vegetation cover, results reveal *Paspalum vaginatum* grass is widely spread through the edge of the forest. This attributed to the fact that it is used in the recreational area of the park for beautification purposes thus the spread into the forest. Congo grass is also spread and is considered an invasive species. Litter in the forest also covers a huge percentage of the ground cover. This is due to the heavy presence of human traversing through the park using existing trails as such they leave litter in the park. Other ground covers include, forbs and herbs although they occupy a minimal area. Natural vegetation cover is severely affected by droughts (Choubin, Soleimani, Pirnia, Sajedi-Hosseini,. Alilou, Rahmati, Melesse, Singh, & Shahabi, 2019) and can therefore be used to assess the ecological integrity and vegetation changes of an ecosystem.

5.2.3 Woody Plant Species Diversity in Nairobi City Park

The plant species diversity in the three strata was found to be highest in the inner core stratum (H’ 1.702) followed by the middle stratum (H’ 1.691) and finally the outer stratum (H’1.637). The measurement of plant diversity using the Shannon-Weiner diversity index (H’) ranges between -1 and -3, any measurement above -2 is high and any measurement below -1 is low or poor. Biodiversity has been recognized as one of the key components of environmental sustainability. Multispecies biodiversity indices illustrate prevailingly negative trends in the state of nature as a result of human induced pressures, especially land cover change. Biodiversity loss is therefore not decoupled from socioeconomic progress (Vačkář, Brink, Loh, Baillie, Reyers, 2012). Studies have shown that in urban forestry the emphasis on diversity is more important than on the status of the native (indigenous) plant species, the ecological integrity of the park can be enhanced by the diversity of foreign plant species and not the reference to the native species (Conway, Almas & Coore 2019). It was observed that the highest biodiversity was in the inner core strata followed by the middle strata. The difference in biodiversity was not significant. The study reported species diversity in a range between 1.00 and 2.7 from heavily and least distributed parts respectively. The diversity indices (with a range between 1.63-1.70) obtained in the study indicate that Nairobi city park is a moderately rich in plant species ecosystem. This diversity accounted for both abundance and evenness of the species present in the forest. The diversity index obtained showed that the forest ecosystem of Nairobi City Park has diverse communities and are distributed in the park.

5.2.4 Tree Physical Attributes in the Nairobi City Park

On tree physical attributes, the tree diameters and heights were ranging in close measure. The diameter measurements were between 26cm and 31cm. while, the heights of the trees were between 13m and 18m. DBH distribution of trees indicates an absence of larger diameter trees in the forest stand. The absence of larger stem diameter trees (DBH > 80 cm) suggests larger trees have been logged (Vačkář, Brink, Loh, Baillie, & Reyers, 2012). This is unfortunate because large diameter trees represent key structures of forest ecosystems. Large diameter trees are mainly mature trees and ultimately responsible for reproduction, regeneration, succession, dynamics and diversity in forests stands. The number of tree stumps and debarks showed evidence of human influence on tree species in the forest. The stamps and barks were plenty in number in the near strata. This could be attributed to the fact that the near strata is easily accessible by humans as compared to the other strata thus the high probability for trees in the near strata to be exploited. McLaren et al., (2005) pointed out that an inverse J-shaped distribution curve in plant populations indicates an active regeneration. It is anticipated that under improved conservation management, the forest may recover from its disturbed conditions through naturally regenerating indigenous plant species.

5.2.5 Number of Humans Visiting the Conserved Area of Nairobi City Park

Human activities at the local level directly affects land use/cover types in specific areas (Geist & Lambin, 2002). The relationship between number of people visiting the conserved area of Nairobi City Park and the level of stumping and debarking shows there was a strong relationship. Through the correlation value .749 on stumping and .889 on debarking obtained, it can be stated that there was a positive and significant relationship of the two. This indicated that humans utilize the forest resources in the conserved area for their own personal use as such they interfere with the proper functioning of the forest ecosystem.

5.2.6 The Impact of the Intensity of Human Activities on the Ecological Integrity of the Nairobi City Park

The intensity of human activities in the park has negative impacts on the ecological integrity of the NCP. Ecological integrity is a concept that is used in assessing the impact of anthropogenic activities on ecological resources (LaPaix, Freedman, Patriquin, 2009). The method of assessment involves the use of ecological indicators that are measured and then related to existing known values or used in a comparative manner (Ordóñez, & Duinker (2012). This index can be developed further for use in assessing ecological resources spanning many regions (Reza & Abdullah, 2011) and in urban areas (Cortinovis & Geneletti, 2018). were assessed by use of ecological indicators, which are used to the and the comparative evaluation of the three strata that had different human influences. Assessment using ecological indicators has been recommended and used by different authors

5.3 Conclusions

The following conclusions were made from this study:

(i) The NCP was found to have a rich plant species composition with 62 plant species divided into 33 families. Plant species richness and relative abundance varied within the three strata (outer, middle and inner core), with the outer stratum having lower species richness and abundance compared to the other two strata.

(ii) Ground cover varied significantly within the three strata of the NCP. Plant cover was 51.5 % in the outer stratum, 70.5 % in the middle stratum and 82.8 % in the inner core stratum.

(iii) Plant species diversity was found to be at above the mean (1.5) on a scale of 1-3 (I being low and 3 being high).

(iv) Tree characteristics in the park showed signs of consumptive use these included debarking, cut stumps and low DBH and tree height.

(v) The number of people visiting the three strata varied significantly with the outer stratum having more than the inner core.

(vi) The intensity of human activities was found to have a negative impact on the ecological integrity of NCP.

5.4 Recommendations

From the findings of this study, it is recommended that;

(i) Increase the biodiversity in the Park. This can be accomplished by planting indigenous tree and grass species.

(ii) Reduce bare areas in the park by: (i) all visitors to the park to use the designated foot paths and strictly avoid walking away from the foot paths, (ii) planting tree and grass species adopted to the area.

(iii) Training of the visitors to the NCP on the importance of all ecological resources (soil, vegetation, animals) and how to conserve them and their roles when visiting the park. This will reduce the human impact on the NCP.

(iv) The park planning team needs to embark on park interpretation activities to enhance learning experience of the people visiting the park. This will need signs to be put up, identification of plant species and creation of nature trail within the park, a museum housing artifacts and stuffed animals from the park could also be created.

(v) The NCP ecosystem if it maintained intact the managers of the park can apply for funding from international organizations dealing with carbon trade.

(vi) Kenya forest service together with the Nairobi county government to find a lasting solution of fencing off the conserved area of the park to prevent humans from accessing the forest in order to protect the biodiversity in the park.

(vii) Research finding be used to enhance the protection of Nairobi City Park's ecological integrity.

5.5 Recommendation for Further Studies

(i) An assessment of the NCP ecological resources using remote sensing and GIS.

(ii) Trend studies to determine the trends in the ecological resources of NCP.

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APPENDICES

Appendix A: Location and Neighbourhood

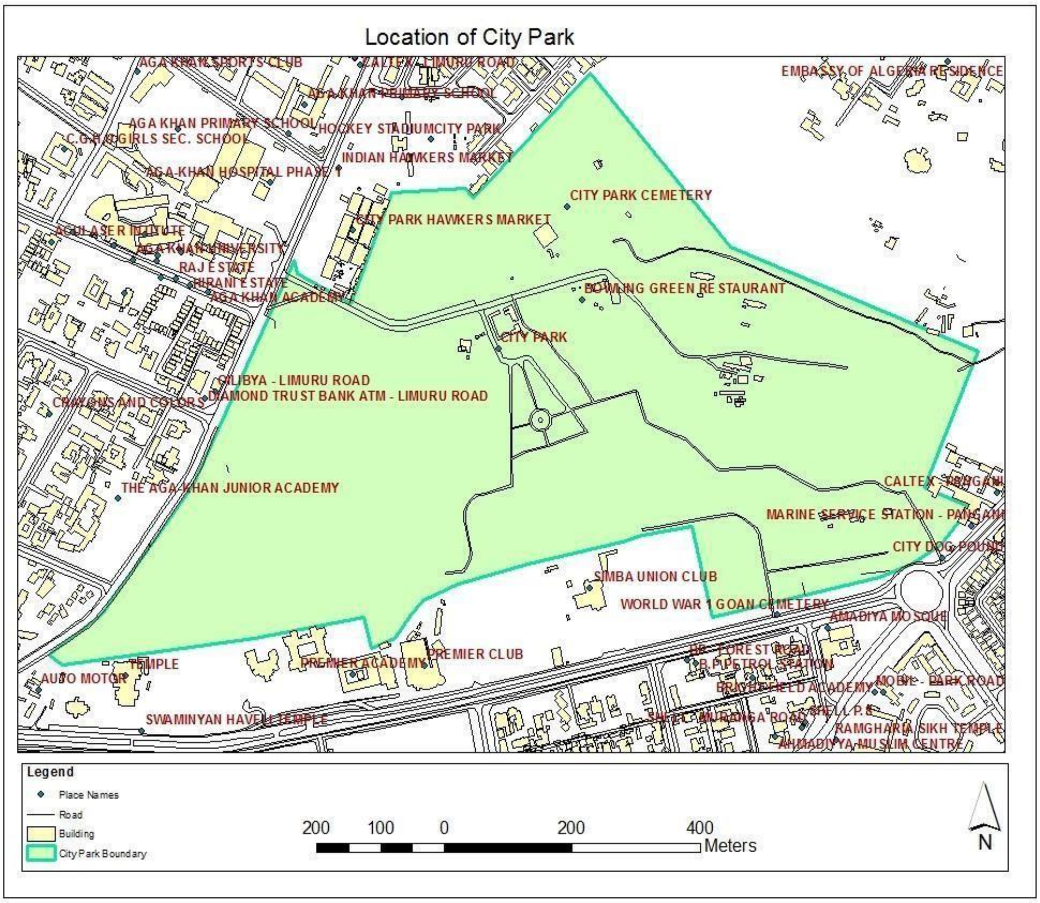

Figure 6.1: Map of Nairobi City County showing Location of Nairobi City Park

Appendix B: Map of NCP Showing the Different Uses of the Park

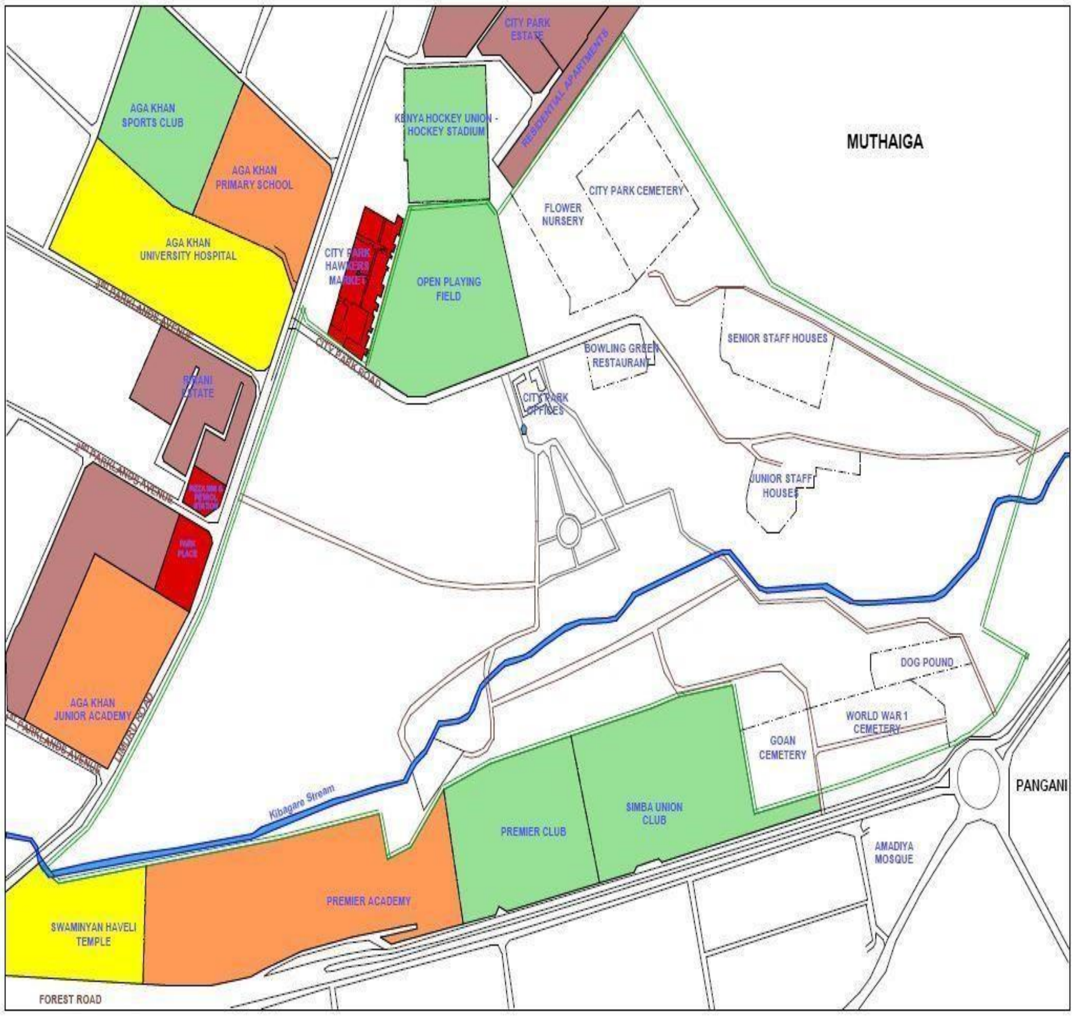

Figure 6.2: Map of Nairobi City Park Neighbourhood Uses

Appendix C: Protocols Used During Data Collection

Table 6.1 Plant Species Checklist

No.	Species	occurrence	Occurrence in strata		
			Outer	Middle	Central
1					
2					

Table 6.2: Ground Cover Assessment Form

Species	Number Of Hits In The plots	Percent Cover	Percentage Vegetation Cover

Appendix D: Field Results on Plant Species Composition

Table 6.3 Plant Species Composition in the Outer Stratum

Plant species	Number	Relative Abundance
Acacia brevispica	26	2.176
Acacia elatior	10	0.837
Acacia mearnsii	26	2.176
Acacia nilotica	6	0.502
Acacia tortilis	23	1.925
Acokanthera oppositifolia	18	1.506
Acokanthera schimpero	30	2.510
Acrocarpus fraxinofolius	27	2.259
Albizia grandibacteria	12	1.004
Albizia gummifera	33	2.762
Aloe ballyi	2	0.167
Aloe barbercies	10	0.837
Araucaria columnaris	10	0.837
Asparagus officinalis	12	1.004
Bambusa vulgaris	5	0.418
Bauhunia variegata	14	1.172
Borassus aethiopum	9	0.753
Brachylaena huillensis	25	2.092
Bridelia micrantha	5	0.418
Caesalpinia decapetala	3	0.251
Callistermon citrinus	49	4.100
Calodendrum capense	11	0.921
Casuarina cunninghamiana	29	2.427
Commiphora eminii	23	1.925
Croton alienus	10	0.837
Croton megalocarpus	65	5.439
Delonix regia	2	0.167
Dovyalis caffra	10	0.837
Ekebergia capensis	12	1.004
Eriobotrya japonica	10	0.837
Eucalyptus sp	40	3.347
Euclea divinorum	6	0.502
Euphorbia tirucalli	39	3.264
Ficus benjamina	21	1.757
Ficus thonningii	21	1.757
Flacourtia indica	15	1.255
Gliricidia sepium	9	0.753
Grevillea robusta	29	2.427

Hyphaene coriacea	6	0.502
Jacaranda mimosifolia	19	1.590
Mangifera indica	50	4.184
Markhamia lutea	20	1.674
Melia azedarach	29	2.427
Morus alba	8	0.669
Olea europea	20	1.674
Olea hochstetteri	21	1.757
Persea americana	1	0.084
Phoenix reclinata	12	1.004
Podocarpus falcatus	10	0.837
Prunus africana	20	1.674
Psidium guajava	30	2.510
Rhus natalensis	5	0.418
Sesbania sesban	6	0.502
Strychnos henningsii	7	0.586
Strychnos usambarensis	27	2.259
Syzygium cumini	19	1.590
Terminalia brownii	27	2.259
Terminalia mantaly	48	4.017
Thevetia peruviana	23	1.925
Trema orientalis	29	2.427
Trichilia emetica	12	1.004
Vangueria madagascariensis	39	3.264
	1195	100.

Table 6.4: Plant Species Composition found in the Middle Stratum of NCP

Plant Species Name	Number of Species	Relative Abundance
Acacia brevispica	19	1.78
Acacia elatior	9	0.84
Acacia mearnsii	16	1.50
Acacia nilotica	12	1.13
Acacia tortilis	26	2.44
Acokanthera oppositifolia	6	0.56
Acokanthera schimpero	6	0.56
Acrocarpus fraxinofolius	42	3.94
Albizia grandibacteria	10	0.94
Albizia gummifera	26	2.44
Aloe ballyi	4	0.38
Aloe barbercies	4	0.38
Araucaria columnaris	9	0.84
Asparagus officinalis	19	1.78
Bambusa vulgaris	6	0.56
Bauhunia variegata	26	2.44
Borassus aethiopum	12	1.13
Brachylaena huillensis	14	1.31
Bridelia micrantha	19	1.78
Caesalpinia decapetala	4	0.38
Callistermon citrinus	36	3.38
Calodendrum capense	29	2.72
Casuarina cunninghamiana	34	3.19
Commiphora eminii	9	0.84
Croton alienus	8	0.75
Croton megalocarpus	61	5.72
Delonix regia	2	0.19
Dovyalis caffra	9	0.84
Ekebergia capensis	6	0.56
Eriobotrya japonica	14	1.31
Eucalyptus sp	39	3.66
Euclea divinorum	16	1.50
Euphorbia tirucalli	16	1.50
Ficus benjamina	19	1.78
Ficus thonningii	25	2.35
Flacourtia indica	10	0.94
Gliricidia sepium	11	1.03
Grevillea robusta	21	1.97
Hyphaene coriacea	11	1.03

Jacaranda mimosifolia	24	2.25
Mangifera indica	14	1.31
Markhamia lutea	39	3.66
Melia azedarach	8	0.75
Morus alba	14	1.31
Olea europea	18	1.69
Olea hochstetteri	15	1.41
Persea americana	4	0.38
Phoenix reclinata	17	1.59
Podocarpus falcatus	4	0.38
Prunus africana	29	2.72
Psidium guajava	16	1.50
Rhus natalensis	6	0.56
Sesbania sesban	8	0.75
Strychnos henningsii	10	0.94
Strychnos usambarensis	19	1.78
Syzygium cumini	6	0.56
Terminalia brownii	22	2.06
Terminalia mantaly	39	3.66
Thevetia peruviana	14	1.31
Trema orientalis	20	1.88
Trichilia emetica	29	2.72
Vangueria madagascariensis	26	2.44
	1066	100.00

Table 6.5: Plant Species Composition for the Inner Core Stratum of the NCP

Plant Species	Number counted	Relative Abundance
Acacia brevispica	16	1.14
Acacia elatior	12	0.86
Acacia mearnsii	13	0.93
Acacia nilotica	22	1.57
Acacia tortilis	22	1.57
Acokanthera oppositifolia	5	0.36
Acokanthera schimpero	5	0.36
Acrocarpus fraxinofolius	100	7.13
Albizia grandibacteria	12	0.86
Albizia gummifera	33	2.35
Aloe ballyi	10	0.71
Aloe barbercies	10	0.71
Araucaria columnaris	20	1.43
Asparagus officinalis	17	1.21
Bambusa vulgaris	4	0.29
Bauhunia variegata	31	2.21
Borassus aethiopum	18	1.28
Brachylaena huillensis	33	2.35
Bridelia micrantha	47	3.35
Caesalpinia decapetala	5	0.36
Callistermon citrinus	46	3.28
Calodendrum capense	50	3.56
Casuarina cunninghamiana	16	1.14
Commiphora eminii	11	0.78
Croton alienus	13	0.93
Croton megalocarpus	140	9.98
Delonix regia	8	0.57
Dovyalis caffra	10	0.71
Ekebergia capensis	33	2.35
Eriobotrya japonica	10	0.71
Eucalyptus sp	42	2.99
Euclea divinorum	20	1.43
Euphorbia tirucalli	6	0.43
Ficus benjamina	26	1.85
Ficus thonningii	40	2.85
Flacourtia indica	25	1.78
Gliricidia sepium	10	0.71
Grevillea robusta	12	0.86
Hyphaene coriacea	14	1.00
Jacaranda mimosifolia	30	2.14

Mangifera indica	9	0.64
Markhamia lutea	50	3.56
Melia azedarach	3	0.21
Morus alba	26	1.85
Olea europea	10	0.71
Olea hochstetteri	16	1.14
Persea americana	16	1.14
Phoenix reclinata	11	0.78
Podocarpus falcatus	26	1.85
Prunus africana	39	2.78
Psidium guajava	5	0.36
Rhus natalensis	8	0.57
Sesbania sesban	4	0.29
Strychnos henningsii	11	0.78
Strychnos usambarensis	18	1.28
Syzygium cumini	4	0.29
Terminalia brownii	13	0.93
Terminalia mantaly	62	4.42
Thevetia peruviana	16	1.14
Trema orientalis	3	0.21
Trichilia emetica	40	2.85
Vangueria madagascariensis	16	1.14
	1403	100.00

Appendix E: Families Composition and Nomenclature
Table 6.6: Plant Species Composition

	Family	Number of Species	Total Number of Species Occurrence in each Stratum		
			Outer	Middle	Centre
1.	Aloaceae	2	12	8	20
2.	Anacardiaceae	2	50	14	9
3.	Apocynaceae	3	48	12	10
4.	Araucariaceae	1	10	9	20
5.	Asparagaceae	1	12	19	17
6.	Bignoniaceae	2	39	63	80
7.	Burseraceae	1	23	9	11
8.	Caesalpiniaceae	5	58	84	186
9.	Cannabaceae	1	29	20	3
10.	Casuarinaceae	1	29	34	16
11.	Combretaceae	2	75	61	75
12.	Compositae	1	25	14	33
13.	Ebenaceae	1	6	16	20
14.	Euphorbiaceae	3	114	99	159
15.	Fabaceae	1	43	26	33
16.	Flaourtiaceae	2	25	19	35
17.	Gramineae	1	5	6	4
18.	Lauraceae	1	1	4	16
19.	Loganiaceae	2	34	29	29
20.	Meliaceae	3	53	43	83
21.	Mimosaceae	5	101	82	120
22.	Moraceae	3	50	58	92
23.	Myrtaceae	4	138	109	96
24.	Oleaceae	2	41	46	26
25.	Palmae	3	32	40	43
26.	Papilionaceae	2	15	19	14
27.	Podocarpaceae	1	10	4	26
28.	Proteaceae	1	33	21	12
29.	Rosaceae	2	34	43	49
30.	Rubiaceae	2	39	26	16
31.	Rutaceae	1	11	29	50
	TOTAL	62	1195	1066	1403

Appendix F: Plant Diversity of strata 1

Table 6.7: Plant Species Diversity in the Outer Stratum of NCP

No.	Species	Number counted	*Pi* (number counted/ total number)	*Log Pi*	*Pi*Loge Pi*
1	*Acacia brevispica*	26	0.021	-1.662	-0.036
2	*Acacia elatior*	10	0.008	-2.077	-0.017
3	*Acacia mearnsii*	26	0.021	-1.662	-0.036
4	*Acacia nilotica*	6	0.005	-2.299	-0.011
5	*Acacia tortilis*	23	0.019	-1.715	-0.03
6	*Acokanthera oppositifolia*	18	0.015	-1.822	-0.027
7	*Acokanthera schimpero*	30	0.025	-1.600	-0.040
8	*Acrocarpus fraxinofolius*	27	0.022	-1.646	-0.037
9	*Albizia grandibacteria*	12	0.010	-1.998	-0.020
10	*Albizia gummifera*	33	0.027	-1.558	-0.043
11	*Aloe ballyi*	2	0.001	-2.776	-0.004
12	*Aloe barbercies*	10	0.008	-2.077	-0.017
13	*Araucaria columnaris*	10	0.008	-2.077	-0.017
14	*Asparagus officinalis*	12	0.010	-1.998	-0.020
15	*Bambusa vulgaris*	5	0.004	-2.378	-0.01
16	*Bauhunia variegata*	14	0.011	-1.931	-0.022
17	*Borassus aethiopum*	9	0.007	-2.123	-0.016
18	*Brachylaena huillensis*	25	0.020	-1.679	-0.035
19	*Brideli amicrantha*	5	0.004	-2.378	-0.01
20	*Caesalpinia decapetala*	3	0.002	-2.600	-0.006
21	*Callistermon citrinus*	49	0.041	-1.387	-0.056
22	*Calodendrum capense*	11	0.009	-2.03	-0.018
23	*Casuarina cunninghamiana*	29	0.024	-1.615	-0.039
24	*Commiphora eminii*	23	0.019	-1.715	-0.033
25	*Croton alienus*	10	0.008	-2.077	-0.017
26	*Croton megalocarpus*	65	0.054	-1.264	-0.068
27	*Delonix regia*	2	0.001	-2.776	-0.004
28	*Dovyalis caffra*	10	0.008	-2.077	-0.017
29	*Ekebergia capensis*	12	0.010	-1.998	-0.020
30	*Eriobotrya japonica*	10	0.008	-2.077	-0.017
31	*Eucalyptus sp*	40	0.033	-1.475	-0.049
32	*Euclea divinorum*	6	0.005	-2.299	-0.011
33	*Euphorbia tirucalli*	39	0.032	-1.486	-0.048

34	*Ficus benjamina*	21	0.017	-1.755	-0.030
35	*Ficus thonningii*	21	0.017	-1.755	-0.030
36	*Flacourtia indica*	15	0.012	-1.901	-0.023
37	*Gliricidia sepium*	9	0.007	-2.123	-0.016
38	*Grevillea robusta*	29	0.024	-1.615	-0.039
39	*Hyphaene coriacea*	6	0.005	-2.299	-0.011
40	*Jacaranda mimosifolia*	19	0.015	-1.798	-0.028
41	*Mangifera indica*	50	0.041	-1.378	-0.057
42	*Markhamia lutea*	20	0.016	-1.776	-0.029
43	*Melia azedarach*	29	0.024	-1.615	-0.039
44	*Morus alba*	8	0.006	-2.174	-0.014
45	*Olea europea*	20	0.016	-1.776	-0.029
46	*Olea hochstetteri*	21	0.017	-1.755	-0.030
47	*Persea americana*	1	0.0008	-3.077	-0.002
48	*Phoenix reclinata*	12	0.010	-1.998	-0.020
49	*Podocarpus falcatus*	10	0.008	-2.077	-0.017
50	*Prunus africana*	20	0.016	-1.776	-0.029
51	*Psidium guajava*	30	0.025	-1.600	-0.040
52	*Rhus natalensis*	5	0.004	-2.378	-0.01
53	*Sesbania sesban*	6	0.005	-2.299	-0.011
54	*Strychno shenningsii*	7	0.005	-2.232	-0.013
55	*Strychnosus ambarensis*	27	0.022	-1.646	-0.037
56	*Syzygium cumini*	19	0.015	-1.798	-0.028
57	*Termina liabrownii*	27	0.022	-1.646	-0.037
58	*Terminalia mantaly*	48	0.040	-1.396	-0.056
59	*Thevetia peruviana*	23	0.019	-1.715	-0.033
60	*Trema orientalis*	29	0.024	-1.615	-0.039
61	*Trichilia emetica*	12	0.010	-1.998	-0.020
62	*Vangueria madagascariensis*	39	0.032	-1.486	-0.048
		1195	1	-118.8	-1.691

Table 6.8: Plant Species Diversity in the Middle Stratum of NCP

No.	Species	Number counted	Pi (number counted / total number)	Log Pi	Pi*LogePi
1	*Acacia brevispica*	19	0.017	-1.749	-0.031
2	*Acacia elatior*	9	0.008	-2.073	-0.017
3	*Acacia mearnsii*	16	0.015	-1.823	-0.027
4	*Acacia nilotica*	12	0.011	-1.948	-0.021
5	*Acacia tortilis*	26	0.024	-1.612	-0.039
6	*Acokanthera oppositifolia*	6	0.005	-2.249	-0.012
7	*Acokanthera schimpero*	6	0.005	-2.249	-0.012
8	*Acrocarpus fraxinofolius*	42	0.039	-1.404	-0.055
9	*Albizia grandibacteria*	10	0.009	-2.027	-0.019
10	*Albizia gummifera*	26	0.024	-1.612	-0.039
11	*Aloe ballyi*	4	0.003	-2.425	-0.009
12	*Aloe barbercies*	4	0.003	-2.425	-0.009
13	*Araucaria columnaris*	9	0.008	-2.073	-0.017
14	*Asparagus officinalis*	19	0.017	-1.749	-0.031
15	*Bambusa vulgaris*	6	0.005	-2.249	-0.012
16	*Bauhunia variegata*	26	0.024	-1.612	-0.039
17	*Borassus aethiopum*	12	0.011	-1.948	-0.021
18	*Brachylaena huillensis*	14	0.013	-1.881	-0.0247
19	*Bridelia micrantha*	19	0.017	-1.749	-0.031
20	*Caesalpinia decapetala*	4	0.003	-2.425	-0.009
21	*Callistermon citrinus*	36	0.033	-1.471	-0.0497
22	*Calodendrum capense*	29	0.027	-1.565	-0.042
23	*Casuarina cunninghamiana*	34	0.031	-1.496	-0.047
24	*Commiphora eminii*	9	0.008	-2.073	-0.017
25	*Croton alienus*	8	0.00	-2.124	-0.015
26	*Croton megalocarpus*	61	0.057	-1.242	-0.071
27	*Delonix regia*	2	0.001	-2.726	-0.005
28	*Dovyalis caffra*	9	0.008	-2.073	-0.017
29	*Ekebergia capensis*	6	0.005	-2.249	-0.012
30	*Eriobotrya japonica*	14	0.013	-1.881	-0.024
31	*Eucalyptus sp*	39	0.036	-1.436	-0.052
32	*Euclea divinorum*	16	0.015	-1.823	-0.027
33	*Euphorbia tirucalli*	16	0.015	-1.823	-0.027
34	*Ficus benjamina*	19	0.017	-1.749	-0.031
35	*Ficus thonningii*	25	0.023	-1.629	-0.038
36	*Flacourtia indica*	10	0.009	-2.027	-0.019
37	*Gliricidia sepium*	11	0.010	-1.986	-0.020

38	*Grevillea robusta*	21	0.019	-1.705	-0.033
39	*Hyphaene coriacea*	11	0.010	-1.986	-0.020
40	*Jacaranda mimosifolia*	24	0.022	-1.647	-0.037
41	*Mangifera indica*	14	0.013	-1.881	-0.024
42	*Markhamia lutea*	39	0.036	-1.436	-0.052
43	*Melia azedarach*	8	0.007	-2.124	-0.015
44	*Morus alba*	14	0.013	-1.881	-0.024
45	*Olea europea*	18	0.016	-1.772	-0.029
46	*Olea hochstetteri*	15	0.014	-1.851	-0.026
47	*Persea americana*	4	0.003	-2.425	-0.009
48	*Phoenix reclinata*	17	0.015	-1.797	-0.028
49	*Podocarpus falcatus*	4	0.003	-2.425	-0.009
50	*Prunus africana*	29	0.027	-1.565	-0.042
51	*Psidium guajava*	16	0.015	-1.823	-0.027
52	*Rhus natalensis*	6	0.005	-2.249	-0.012
53	*Sesbania sesban*	8	0.007	-2.124	-0.015
54	*Strychnos henningsii*	10	0.009	-2.027	-0.019
55	*Strychnos usambarensis*	19	0.017	-1.749	-0.031
56	*Syzygium cumini*	6	0.005	-2.249	-0.012
57	*Terminalia brownii*	22	0.020	-1.685	-0.034
58	*Terminalia mantaly*	39	0.036	-1.436	-0.052
59	*Thevetia peruviana*	14	0.013	-1.881	-0.024
60	*Trema orientalis*	20	0.018	-1.726	-0.032
61	*Trichilia emetica*	29	0.027	-1.56	-0.042
62	*Vangueria madagascariensis*	26	0.024	-1.612	-0.039
		1066	1	-117.31	-1.702

Table 6.9: Plant Species Diversity in the Central Stratum of NCP

No.	Species	Number counted	*Pi* (number counted/total number)	*Log Pi*	*Pi*LogePi*
1	*Acacia brevispica*	16	0.011	-1.942	-0.022
2	*Acacia elatior*	12	0.008	-2.067	-0.017
3	*Acacia mearnsii*	13	0.009	-2.033	-0.018
4	*Acacia nilotica*	22	0.015	-1.804	-0.028
5	*Acacia tortilis*	22	0.015	-1.804	-0.028
6	*Acokanthera oppositifolia*	5	0.003	-2.448	-0.008
7	*Acokanthera schimpero*	5	0.003	-2.448	-0.008
8	*Acrocarpus fraxinofolius*	100	0.071	-1.147	-0.081
9	*Albiziagrandi bacteria*	12	0.008	-2.067	-0.017
10	*Albizia gummifera*	33	0.023	-1.628	-0.038
11	*Aloe ballyi*	10	0.007	-2.147	-0.015
12	*Aloe barbercies*	10	0.007	-2.147	-0.0153
13	*Araucaria columnaris*	20	0.014	-1.84	-0.026
14	*Asparagus officinalis*	17	0.012	-1.916	-0.023
15	*Bambusa vulgaris*	4	0.002	-2.545	-0.0073
16	*Bauhunia variegata*	31	0.022	-1.655	-0.036
17	*Borassus aethiopum*	18	0.012	-1.891	-0.024
18	*Brachylaena huillensis*	33	0.023	-1.628	-0.038
19	*Brideliamicrantha*	47	0.033	-1.475	-0.049
20	*Caesalpinia decapetala*	5	0.003	-2.448	-0.008
21	*Callistermon citrinus*	46	0.032	-1.484	-0.048
22	*Calodendrum capense*	50	0.035	-1.448	-0.051
23	*Casuarinacunninghamiana*	16	0.011	-1.942	-0.022
24	*Commiphoraeminii*	11	0.007	-2.105	-0.016
25	*Croton alienus*	13	0.009	-2.033	-0.018
26	*Croton megalocarpus*	140	0.099	-1.000	-0.099
27	*Delonixregia*	8	0.005	-2.244	-0.012
28	*Dovyaliscaffra*	10	0.007	-2.147	-0.015
29	*Ekebergiacapensis*	33	0.023	-1.628	-0.038
30	*Eriobotrya japonica*	10	0.007	-2.147	-0.015
31	*Eucalyptus sp*	42	0.029	-1.523	-0.045
32	*Eucleadivinorum*	20	0.014	-1.846	-0.026
33	*Euphorbia tirucalli*	6	0.004	-2.368	-0.010
34	*Ficusbenjamina*	26	0.018	-1.732	-0.032
35	*Ficusthonningii*	40	0.028	-1.545	-0.044
36	*Flacourtiaindica*	25	0.017	-1.749	-0.031
37	*Gliricidiasepium*	10	0.007	-2.147	-0.015

38	*Grevillearobusta*	12	0.008	-2.067	-0.017
39	*Hyphaenecoriacea*	14	0.009	-2.000	-0.02
40	*Jacaranda mimosifolia*	30	0.021	-1.669	-0.035
41	*Mangiferaindica*	9	0.006	-2.192	-0.014
42	*Markhamialutea*	50	0.035	-1.448	-0.051
43	*Meliaazedarach*	3	0.002	-2.669	-0.005
44	*Morus alba*	26	0.018	-1.732	-0.032
45	*Oleaeuropea*	10	0.007	-2.147	-0.015
46	*Oleahochstetteri*	16	0.011	-1.942	-0.022
47	*Perseaamericana*	16	0.011	-1.942	-0.022
48	*Phoenix reclinata*	11	0.007	-2.105	-0.016
49	*Podocarpusfalcatus*	26	0.018	-1.732	-0.032
50	*Prunusafricana*	39	0.027	-1.556	-0.043
51	*Psidiumguajava*	5	0.003	-2.448	-0.008
52	*Rhusnatalensis*	8	0.005	-2.244	-0.012
53	*Sesbaniasesban*	4	0.002	-2.545	-0.007
54	*Strychnoshenningsii*	11	0.007	-2.105	-0.016
55	*Strychnosusambarensis*	18	0.012	-1.891	-0.024
56	*Syzygiumcumini*	4	0.002	-2.545	-0.007
57	*Terminaliabrownii*	13	0.009	-2.033	-0.018
58	*Terminaliamantaly*	62	0.044	-1.354	-0.059
59	*Thevetiaperuviana*	16	0.011	-1.942	-0.022
60	*Tremaorientalis*	3	0.002	-2.669	-0.005
61	*Trichiliaemetica*	40	0.028	-1.545	-0.044
62	*Vangueriamadagascariensis*	16	0.011	-1.942	-0.022
		1403	1	-120.66	-1.637

Table 6.10: Plant Species Diversity of the NCP

n	Species	Number counted	*Pi* (number counted/ total number)	*Log Pi*	*Pi*LogePi*
1	*Acacia brevispica*	61	0.016	-1.778	-0.029
2	*Acacia elatior*	31	0.008	-2.072	-0.017
3	*Acacia mearnsii*	55	0.015	-1.823	-0.027
4	*Acacia nilotica*	40	0.010	-1.961	-0.021
5	*Acacia tortilis*	71	0.019	-1.712	-0.033
6	*Acokanthera oppositifolia*	29	0.007	-2.101	-0.016
7	*Acokanthera schimpero*	41	0.011	-1.951	-0.021
8	*Acrocarpus fraxinofolius*	169	0.046	-1.336	-0.061
9	*Albizia grandibacteria*	34	0.009	-2.032	-0.018
10	*Albizia gummifera*	92	0.025	-1.600	-0.040
11	*Aloe ballyi*	16	0.004	-2.359	-0.010
12	*Aloe barbercies*	24	0.006	-2.183	-0.014
13	*Araucaria columnaris*	39	0.010	-1.972	-0.021
14	*Asparagus officinalis*	48	0.013	-1.882	-0.024
15	*Bambusa vulgaris*	15	0.004	-2.387	-0.009
16	*Bauhunia variegata*	71	0.019	-1.712	-0.033
17	*Borassus aethiopum*	39	0.010	-1.972	-0.021
18	*Brachylaena huillensis*	72	0.019	-1.706	-0.033
19	*Bridelia micrantha*	71	0.019	-1.712	-0.033
20	*Caesalpinia decapetala*	12	0.003	-2.484	-0.008
21	*Callistermon citrinus*	131	0.035	-1.446	-0.051
22	*Calodendrum capense*	90	0.024	-1.609	-0.039
23	*Casuarina cunninghamiana*	79	0.021	-1.666	-0.035
24	*Commiphora eminii*	43	0.011	-1.930	-0.022
25	*Croton alienus*	31	0.008	-2.072	-0.017
26	*Croton megalocarpus*	266	0.072	-1.139	-0.082
27	*Delonixregia*	12	0.003	-2.484	-0.008
28	*Dovyaliscaffra*	29	0.007	-2.101	-0.016
29	*Ekebergia capensis*	51	0.013	-1.856	-0.025
30	*Eriobotrya japonica*	34	0.009	-2.032	-0.018
31	*Eucalyptus sp*	121	0.033	-1.481	-0.048
32	*Eucleadivinorum*	42	0.011	-1.940	-0.022
33	*Euphorbia tirucalli*	61	0.016	-1.778	-0.029
34	*Ficus benjamina*	66	0.018	-1.744	-0.031

35	*Ficus thonningii*	86	0.023	-1.629	-0.038
36	*Flacourtia indica*	50	0.013	-1.864	-0.025
37	*Gliricidia sepium*	30	0.008	-2.086	-0.017
38	*Grevillea robusta*	62	0.016	-1.771	-0.03
39	*Hyphaene coriacea*	31	0.008	-2.072	-0.017
40	*Jacaranda mimosifolia*	73	0.019	-1.700	-0.033
41	*Mangifera indica*	73	0.019	-1.700	-0.033
42	*Markhamia lutea*	109	0.029	-1.526	-0.045
43	*Melia azedarach*	40	0.010	-1.961	-0.021
44	*Morus alba*	48	0.013	-1.888	-0.024
45	*Olea europea*	48	0.013	-1.888	-0.024
46	*Olea hochstetteri*	52	0.014	-1.847	-0.026
47	*Perseaamericana*	21	0.005	-2.241	-0.012
48	*reclinata*	40	0.010	-1.961	-0.021
49	*Podocarpus falcatus*	40	0.010	-1.961	-0.021
50	*Prunus africana*	88	0.024	-1.619	-0.038
51	*Psidium guajava*	51	0.013	-1.856	-0.025
52	*Rhus natalensis*	19	0.005	-2.285	-0.011
53	*Sesbania sesban*	18	0.004	-2.308	-0.011
54	*Strychnos henningsii*	28	0.007	-2.116	-0.016
55	*Strychnosus ambarensis*	64	0.017	-1.757	-0.030
56	*Syzygium cumini*	29	0.007	-2.101	-0.016
57	*Terminalia brownii*	62	0.016	-1.771	-0.03
58	*Terminalia mantaly*	149	0.040	-1.390	-0.056
59	*Thevetia peruviana*	53	0.014	-1.836	-0.026
60	*Tremaorientalis*	52	0.014	-1.847	-0.026
61	*Trichiliaemetica*	81	0.022	-1.655	-0.036
62	*Vangueria madagascariensis*	81	0.022	-1.655	-0.036
		3664	1	-116.33	-1.707

Appendix G: Field Photos

A cut stump

A foot path in the Nairobi city park

The forest (inner area) in the Nairobi city Park

The recreation area (outer area) of the Nairobi city park

A path in the Nairobi city park forest

A debarked tree in the Nairobi city park

Appendix F: Research Permit from NACOSTI

NATIONAL COMMISSION FOR SCIENCE,
TECHNOLOGY AND INNOVATION

Telephone +254-20-2213471,
2241349,3310571,2219420
Fax: 254-20-318245,318249
Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref No **NACOSTI/P/18/13211/24181**

Date: **28th August, 2018**

Harriet Chepkemboi Maiyo
Africa Nazarene University
P.O. Box 53067-00200
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"An assessment on the anthropogenic influence on ecological integrity of Nairobi City Park,"*** I am pleased to inform you that you have been authorized to undertake research in **Nairobi County** for the period ending **9th August, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Nairobi County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nairobi County.

The County Director of Education
Nairobi County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified

Appendix G: ANU Letter of Thesis Approval

AFRICA NAZARENE
UNIVERSITY

19th June, 2018

RE: TO WHOM IT MAY CONCERN

Maiyo Chepkemoi Harriet 17J03EMEV002 is a bonafide student at Africa Nazarene University. He/She has finished his/her course work and has defended his/her thesis proposal ***entitled "An assessment of the anthropogenic influences on ecological integrity of Nairobi city park.***

Any assistance accorded to him/her to facilitate data collection and finish his/her thesis is highly welcomed.

Prof. Rodney Reed
Deputy Vice Chancellor, Academic Affairs

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