BITUMEN SEEPAGE AND ITS EFFECTS ON BIODIVERSITY IN ONDO STATE, NIGERIA

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CERTIFICATION

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DEDICATION

This work is dedicated to the glory of almighty God without who this study might not have been possible.

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ABSTRACT

Biodiversity enhances capacity of ecosystems to provide food resources and sequestration services of pollutants in soil and water. Bitumen seepage could impact negatively on soil and vegetation, thereby reducing their value. Information on the impact of bitumen seepage on the abundance of biodiversity in Nigeria is scanty. In this study, effects of bitumen seepage on biodiversity were therefore investigated.

The study was conducted in bitumen belt of Ondo state for three years, with and without evidence of bitumen seepage in Ode-Irele and Ebute-Irele respectively. Composite samples of soil and foliar tissues of six most commonly occurring plants: *Panicum laxum, Panicum maximum, Lycopodium cernuum, Calopogonium mucunoides, Pteridium aquilinium and Centrosema molle* were collected from experimental sites and analysed for presence of heavy metals (copper, zinc, lead, chromium, cadmium, nickel and arsenic) using standard procedure. Water samples at depth of 30 cm midstream were collected for physicochemical analysis: (sulphate, Chemical Oxygen Demand (COD) and turbidity analysis) using standard methods. Vegetation cover was sampled using 5m x 5m sample plots for trees ($\geq$10 cm diameter at breast height) and shrubs, while 1m x 1m sub-plot was used for herbs. Point count and line transect methods were used to enumerate birds and other wild animals respectively. Flora and fauna diversities on experimental sites in wet and dry seasons were assessed using Shannon-Wiener (H^1) and Simpson (D) indices. Data were analysed using descriptive statistics and t-test at p=0.05.

In soil, significantly lower values of copper (139.6 ± 73.8mg/kg) and zinc (219.7 ± 106.1mg/kg) were in polluted sites compared with values in control. In foliar tissues, higher levels of lead (4.0 ± 0.8mg/kg); chromium (11.9 ± 1.9mg/kg); cadmium (2.2 ± 3.4mg/kg); nickel (21.2 ± 3.0mg/kg); and arsenic (0.4 ± 0.3mg/kg) were average values found in combinations of all the plants considered namely *P. laxum, P. maximum, L. cernuum, C. mucunoides, P. aquilinium and C. molle* in seepage sites compared with values in control. Water on seepage site had significantly higher values of sulphate (6.0 ± 0.8mg/L), COD (553.6 ± 343.7mg/L), and turbidity (19.3 ± 12.0 NTU) than those in control. Number of different species of shrubs (797.0 ± 198.6/ha), herbs (29999.9 ± 5798.8/ha), birds (14.2 ± 9.3/ha), and terrestrial wildlife (60.3 ± 11.6/ha) in seepage site were significantly lower than that in control [(2799.8 ± 1195.9/ha), (69977.8 ± 18298.9/ha), (49.6 ± 15.6/ha) and (140.3±32.6/ha) respectively].

Raphia longiflora (H^1=0.33, D=0.01), *Chromolaena odorata* (H^1=0.52, D=0.05), *Ageratum conyzoides* (H^1=0.44, D=0.02), *Cinnamopteryx castaneofuscus* (H^1=0.56, D=0.06) and A*chatina spp* (H^1=0.68, D=0.18) had highest abundance in the study area. Seasonal abundance of herbs (541,666.7 ± 409899.9/ha), birds (166.4 ± 60.4/ha), and other wild animals (336.7 ± 223.9/ha) on experimental sites in wet season was significantly higher than that of dry season.

At the end of the three years study, heavy metals in plants and pollutants in water were high in bitumen seepage area. There were declines in diversities of birds, other wild animals and flora caused by bitumen seepage.

Keywords: Bitumen seepage, Flora and fauna, Diversity, Foliar tissues, Physicochemical, Pollution.

Word - count: 488.

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Glossary

IUCN. International Union for the Conservation of Nature

EIA. Environmental Impact Assessment

FF. Farm Fallow

HF. Island of High Forest

AF. Arable Farmland

RH. Riparian Habitat

PF. Plantation Farmland

UA. Urban Arboreta

FEPA. Federal Environmental Protection Agency

WHO. World Health Organisation

FMNAR. Federal Ministry of Agriculture and Natural Resources

TSS. Total Suspended Solids

TDS. Total Dissolved Solids

DO. Dissolved Oxygen

COD. Chemical Oxygen Demand

BOD. Biochemical Oxygen Demand

CHAPTER ONE

1.0: INTRODUCTION

1.1: Biodiversity and Ecosystem in Crisis

The elaborate network of animals, plants and the places where they live on the planet are facing a serious crisis in biodiversity. The rates at which animal and plant species are becoming extinct, and the pace in which natural environments are being destroyed, are increasing every day. This beautiful, complex natural diversity underpins all life on the planet, and its escalating loss is a serious threat to humans and our way of life, now and in the future (Nature.com 2009).

Human interventions are altering the capacity of ecosystems to provide their resources (e.g. freshwater, food, pharmaceutical products, timber, paper and fibre) and services (e.g. purification of air, water, soil, sequestration of pollutants, climate stability (both global CO_2 sequestration and local), pollination, and prevention of erosion, recycling nutrients and providing fertile soils) (Nature.com 2009).

Ecosystem disruption can have impact on health in a variety of ways and through complex pathways. The types of health effects experienced are determined by the degree to which local population depend on ecosystem services, and factors such as poverty which affect vulnerability to changes in elements like access to food and water. Well managed natural resources are crucial to sustainable development, supporting peaceful communities, encouraging well-balanced economic growth and helping reduce poverty (WHO, 2010).

1.2: What Is IUCN Doing About It?

IUCN's work on biodiversity includes comprehensive research on the status of biodiversity and thousands of individual animal and plant species; action to protect specific species; managing and restoring natural areas, national parks and other protected areas; and promoting the sustainable use of natural resources.

IUCN also provides the knowledge, standards and tools for biodiversity conservation for governments, community organizations, the United Nations and business.

Biodiversity, as the backbone of all life on earth and the core of what IUCN does, is also the basis for four other areas of work: climate change, energy, livelihood and economics.

1.3: The Oil Sands Region of Nigeria and Bitumen Extraction

The Nigerian bitumen deposit put at 42.74 billion metric tones is the second largest in the world, and the projected revenue from this deposit is put at about $10 billon annually (ERA, 2003). The oil sands region of Nigeria is located in a belt, which stretches East-West for over 120km, with outcrops exposed over a 6km region across Edo, Ondo, Ogun, and Lagos states. This region contains the world's second largest reserves of bitumen oil, in the form of tar-sand or bitumen after Canada (ERA, 2003). The Nigerian government gave two companies - Bitumen Exploration and Exploitation Company (Nigeria) Limited (BEECON) and NISSANDS (Nigeria) Limited - till the end of July, 2003 to commence exploration of the country's vast bitumen deposit. These companies, BEECON and NISSANDS were granted rights to begin exploration in blocks 307B and 307C located in the coastal areas of Ondo state. The operations of the two firms are expected to affect close to a hundred communities inhabited predominantly by farmers and fisher-folks; people whose sources of livelihood are closely tied to the environment. In a brazen demonstration of government's determination for the commencement of bitumen exploitation, President Olusegun Obasanjo on March 17, 2003, travelled to Ode-Irele, one of the bitumen-bearing communities to perform the "ground-breaking" ceremony (ERA, 2003). Biodiversity is tied closely to the pattern and distribution of natural and man-made processes (predominately farming systems and fire), that is responsible for the present arrangement of vegetation types in the region.

Oil Sands projects are of two main types — surface mines and in-situ production. Where bitumen occurs near the surface (at less than 40 metres depth) the resource will be extracted from surface mines. Bitumen occurring at depths greater than 40 metres will be pumped out through wells by injection of high-pressure steam (in-situ production). Surface mining projects are large open pits accompanied by tailing ponds and a processing plant. In-situ projects consist of well pads, roads and pipelines. Within in-situ project areas, the forested portion of the landscape is largely retained (Sherrington, 2005).

Bitumen Extraction

The type of oil found in the oil sands deposits, termed bitumen, is heavy and viscous and cannot be easily extracted. The most common form of in-situ extraction is called Steam Assisted Gravity Drain (SAGD). Using the SAGD process, two horizontal wells are placed near the bottom of the bitumen formation. The top horizontal well is used to inject high-pressure steam, which rises to form a high-temperature steam chamber above the well. Within the steam chamber the bitumen is liquefied and then flows by gravity to the lower well where it is collected, along with the condensed water.

Deep oil sands extraction requires the development of a dense network of roads, pipelines, wellpads and processing facilities. A typical deep oil sands project will clear 8% of the forest in a lease. The surface disturbance associated with deep oil sands development is many times greater than the disturbance associated with conventional oil or gas fields, to which in - situ is often compared (fact sheet, 2006).

1.4: Distribution of Biodiversity

Selection bias continues to bedevil modern estimates of biodiversity. Nevertheless, biodiversity is not distributed evenly on earth. It is consistently richer in the tropics and in other localized regions. Flora and fauna diversity depends on climate, altitude, soils and the presence of other species. In the year 2006 large numbers of the earth's species were formally classified as rare, endangered or threatened species. Moreover, many scientists have estimated that there are millions more species actually endangered which have not yet been formally recognized. About 40 percent of the 40,177 species assessed using the IUCN Red List criteria, are now listed as threatened species with extinction - a total of 16,119 species (IUCN, 2008).

1.5: Human Benefits of Biodiversity Conservation

There are many ethical and philosophical positions in nature and our relationship with them. Some positions, for example, would argue that nature has value beyond any that humans hold for it. Others would argue that nature is only important to the extent that it can be used for human activity. Therefore, humans relate with nature in a variety of ways. One commonly used categorisation of biodiversity values to human beings breaks down biodiversity into ecosystem services, biological resources and social benefits, (Furze *et al*, 1996).

Biodiversity also supports a number of natural ecosystem processes and services (Springerlink, 2009). Some ecosystem services that benefit society are air quality, climate (both global CO_2 sequestration and local), water purification, pollination, and prevention of erosion. Non-material benefits that are obtained from ecosystems include spiritual and aesthetic values, knowledge systems and the value of education (Nature.com, 2009).

Agriculture

The economic value of the reservoir of genetic traits present in wild varieties and traditionally grown landraces is extremely important in improving crop performance. Crop diversity is also necessary to help the system recover when the dominant crop type is attacked by a disease: Monoculture, the lack of biodiversity, was a contributing factor to several agricultural disasters in history. Higher biodiversity also controls the spread of certain diseases as pathogens will need to adapt to infect different species. Biodiversity provides food for humans (Furze *et al*, 1996). Although about 80 percent of our food supply comes from just 20 kinds of plants. Humans use at least 40,000 species of plants and animals a day. Many people around the world depend on these species for their food, shelter, and clothing. There is untapped potential for increasing the range of food products suitable for human consumption, provided the high present extinction rate can be stopped (Wilson, 2002).

Human Health

The relevance of biodiversity to human health is becoming a major international political issue, as scientific evidence builds on the global health implications of biodiversity loss. Some of the health issues influenced by biodiversity include dietary health and nutrition security, infectious diseases, medical science and medicinal resources, social and psychological health (Fuller *et al*, 2007; WHO, 1993) and spiritual well-being. Biodiversity is also known to have an important role in reducing disaster risk, and in post-disaster relief and recovery efforts (COHAB, 2009).

One of the key health issues associated with biodiversity is that of drug discovery and the availability of medicinal resources (Muhammad and Amusa, 2005; CMO Compass, 2006, Odugbemi *et al*, 2007).

Business and Industry

A wide range of industrial materials are derived directly from biological resources. These include building materials, fibers, dyes, resirubber and oil (Holding- Anyonge and Roshetko, 2003; Vantomme, 2003). There is enormous potential for further research into sustainably utilizing materials from a wider diversity of organisms. In addition, biodiversity and the ecosystem goods and services it provides are considered to be fundamental to healthy economic systems (FONAFIFO, 2000; Alexander *et al*, 2002; Landell and Porras, 2002). The degree to which biodiversity supports business varies between regions and between economic sectors, however, the importance of biodiversity to issues of resource security (water quantity and quality, timber, paper and fibre, food and medicinal resources etc) are increasingly recognized as universal. As a result, the loss of biodiversity is increasingly recognized as a significant risk factor in business development and a threat to long term economic sustainability.

Other Ecological Services

Biodiversity provides many ecosystem services that are often not readily visible. It plays a part in regulating the chemistry of our atmosphere and water supply. Thus it is directly involved in water purification, recycling nutrients and providing fertile soils (IUCN, 2009). The stability of ecosystem is also related to biodiversity, with higher biodiversity producing greater stability over time, reducing the chance that ecosystem services will be disrupted as a result of disturbances such as extreme weather events or human exploitation.

Leisure, Cultural and Aesthetic Value

Many people derive value from biodiversity through leisure activities such as hiking, birdwatching or natural history study. Biodiversity has inspired musicians, painters, sculptors, writers and other artists (Diamond, 1989). Many cultural groups view themselves as an integral part of the natural world and show respect for other living organisms. Popular activities such as gardening, caring for aquariums and collecting wild fruits and vegetables are all strongly dependent on biodiversity. Philosophically it could be argued that biodiversity has intrinsic aesthetic and spiritual value to mankind *in and of itself* (Diamond, 1989).

Uses of Soil

Soil is used in agriculture, where it serves as the primary nutrient base for plants. The types of soil used in agriculture (among other things, such as the purported level of moisture in the soil) vary with respect to the species of plants that are cultivated (Wikipedia, 2010).

Soil material is a critical component in the mining and construction industries. Soil serves as a foundation for most construction projects. Massive volumes of soil can be involved in surface mining, road building and dam construction. Soil resources are critical to the environment, as well as to food and fiber production. Soil provides minerals and water to plants. Soil absorbs rainwater and releases it later, thus preventing floods and drought. Soil cleans the water as it percolates. Soil is the habitat for many organisms: the major part of known and unknown biodiversity is in the soil, in the form of invertebrates (earthworms, woodlice, millipedes, centipedes, snails, slugs, mites, nematodes, protists), bacteria, archaea, fungi and algae; and most organisms living above ground have part of them (plants) or spend part of their life cycle (insects) below ground. Above-ground and below-ground biodiversities are tightly interconnected (Ponge, 2003; De Deyn *et al*, 2005) making soil protection of paramount importance for any restoration or conservation plan.

Waste management often has a soil component. Septic drain fields treat septic tank effluent using aerobic soil processes. Landfills also use soil for daily cover.
Both animals and humans in many cultures occasionally consume soil. It has been shown that some monkeys consume soil, together with their preferred food (tree foliage and fruits), in order to alleviate tannin toxicity, (Setz *et al*, 1999).
Soils filter, purify water and affect its chemistry. Rain water and pooled water from ponds, lakes and rivers percolate through the soil horizons and the upper rock strata; thus becoming groundwater. The high concentration of heavy metals (lead, zinc, cadmium), in soils is reflected by higher concentrations of metals in plants, and consequently in animal and human bodies. The ability of some plants to absorb and accumulate these heavy metals makes them useful as indicators of environmental pollution. Thus, they can be recommended as indicators for determination of

pollution levels of the environment, (Buszewski *et al*, 2000). Excess nutrients (nitrates, sulfates, phosphates) are filtered out by the soil, (Maximilian *et al*, 2009). Soil organisms metabolize them or immobilize them in their biomass and necromass, (Diplock *et al*, 2009), thereby incorporating them into stable humus. The physical integrity of soil is also a prerequisite for avoiding landslides in rugged landscapes, (Khalil *et al*, 2003).

1.6: Major Threats to Biodiversity Conservation

During the last century, erosion of biodiversity was increasingly observed. Studies showed that 30% of all natural species will be extinct by 2050. Of these, about one eighth of the known plant species are threatened with extinction (IUCN, 2008). Some estimates put the loss at up to 140,000 species per year (based on Species-area theory) and subject to discussion (Pimm *et al*, 1995). This figure indicates unsustainable ecological practices, because only a small number of species come into being each year. Almost all scientists acknowledge that the rate of species loss is greater now than at any time in human history, with extinctions occurring at rates hundreds of times higher than background extinction rates.

The factors that threaten biodiversity have been variously categorized. Jared Diamond describes an "Evil Quartet" of habitat destruction, overkill, introduced species, and secondary extensions. Wilson (2002) prefers the acronym HIPPO, which stands for Habitat destruction, Invasive species, Pollution, Human OverPopulation, and Overharvesting. The most authoritative classification in use today is that of IUCN’s Classification of Direct Threats[1] adopted by most major international conservation organizations such as the US Nature Conservancy, the World Wildlife Fund, Conservation International, and Birdlife International.

According to Bagheera (2010), rapid human population growth in Africa is creating severe impacts on wildlife. Africa’s population growth, along with Asia’s, is the fastest on the planet. While the average number of children per woman worldwide is three, in Africa it is six. The continent’s population in 1994 was 700 million and growing by 3 percent a year, enough to double in just 23 years.

Land Degradation

Land degradation is a human-induced or natural process which impairs the capacity of land to function. Soils are the critical component in land degradation when it involves acidification, contamination, desertification, erosion or salination.

Soil contamination at low levels prior to bitumen development can be said to be within soil capacity to treat and assimilate. Many waste treatment processes rely on this treatment capacity. Exceeding treatment capacity especially during and after bitumen development can damage soil biota and limit soil function.

Destruction of Habitat

The habitat of any given species is considered its preferred area or territory. Many processes associated with human habitation in an area cause loss of this area and the decrease in the carrying capacity of the land for that species. In many cases these changes in land use cause a patchy break-up of the wild landscape. Agricultural land frequently displays this type of extremely fragmented or relictual habitat. However, the most important and large scale cause of habitat fragmentation is the expansion and intensification of human land use (Wang *et al*, 2003; and; Odugbemi, 2008). Habitat fragmentation has three major components: namely loss of the original habitat, reduction in habitat patch size and increasing isolation of habitat patches, all of which contribute to a decrease in species diversity (Andren, 1994).

There are systematic relationships between the area of a habitat and the number of species it can support, with greater sensitivity to reduction in habitat area for species of larger body size and for those living at lower latitudes or in forests or oceans (Drakare *et al*, 2006). Some characterize loss of biodiversity not as ecosystem degradation but by conversion to trivial standardized ecosystems (e.g., monoculture following deforestation) (Schrag *et al*, 2009).

Climate Change

The recent phenomenon of global warming is also considered to be a major threat to global biodiversity. Studies clearly reveal that soil moisture, average temperature changes, frequency and abundance of precipitation are all persistent physical patterns that do not reveal in their pronounced abruptness or accelerating rate any natural trend. Furthermore there is now a scientific consensus that the heat absorbed by the oceans will continue to affect the planet for some decades to come. Those influences are most likely to accelerate, if present trends continue, after 2050, (Siry, 2007).

Water Pollution

Water Pollution can come from migration of contaminants released at the surface or leaking from an underground structure which will flow down through the ground under the influence of gravity. Some hydrocarbons will be adsorbed onto soil particles and retained in soil pores. On encountering ground water, the liquid will typically spread out on the surface of the water and migrate laterally, prefentially in the direction of ground water flow. The volatile components will diffuse into the overlying soil and migrate as a vapour from ahead of the free product.
Water resources will be affected by primary contamination when improperly treated wastes are dumped into water ways and by secondary contamination when there is surface runoff into the water. This has the potential to increase the levels of heavy metals and some water physical, chemical and biological parameters beyond critical limits, such that this will present health risk to biodiversity that depend on the water resource.

Toxicity of Heavy Metals in Soil and Accumulation in Plants

A number of heavy metals which are toxic are released into the environmnent and contribute to a variety of effects on living organisms in food chain (Dembitsky, 2003). All plants have the ability to accumulate essential metals (Ca, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Se, V and Zn) from the soil solution. Plants need different concentrations for growth and development. This ability also allows plants to accumulate other non- essential metals (Al, As, Au, Cd, Cr, Hg, Pb, Pd, Pt, Sb, Te, TI and U) which have no known biological function (Djimgova and Kuleff, 2000). Heavy metals such as cadmium, copper, lead, chromium, zinc, and nickel are important environmental pollutants (United States Environmental Protection Agency, 1997).

The high concentration of heavy metals in soils could be reflected by their higher concentrations in plants. Through the food chain, these metals may consequently get to animal and human bodies (Buszewski *et al*, 2000). The ability of some plants to absorb and accumulate xenobiotics, therefore, makes them useful as indicators of environmental pollution. The study of excessive concentrations of pollutants in biological matrices has been reported in numerous publications (Pandolfini *et al*, 1997; Namiesnik *et al*, 2000).

Other threats to biodiversity conservation include:

- **Exotic Species**
- **Genetic Pollution**
- **Hybridization and Genetics**
- **Chains of Extinction**

An interesting point is that evolved DNA embodies knowledge, and therefore destroying a species resembles burning a book, with the caveat that the book is of uncertain depth and importance and may in fact be best used as fuel. Due to the fact that we know but a portion of the organisms in the biosphere, we do not have a complete understanding of the workings of our environment. To make matters worse, we are wiping out these species against an unprecedented rate. This means that even before a new species has had the chance of being studied and classified, it may already be extinct.

1.7: Conserving Biodiversity

The conservation of biological diversity is a global priority in strategic conservation plans that are designed to engage public policy and concerns affecting local, regional and global scales of communities, ecosystems, and cultures. Conserving biodiversity and action plans identify ways of sustaining human well-being and global economics, including natural capital, market capital, and ecosystem services (Luck *et al*, 2003).

Means

One of the strategies involves placing a monetary value on biodiversity through biodiversity banking. Other approaches are the creation of gene banks, as well as the creation of gene banks that have the intention of growing the indigenous species for reintroduction to the ecosystem (e.g. via tree nurseries) (Holding-Anyonge and Roshetko, 2003). The eradication of exotic species is also an important method to preserve the local biodiversity. Exotic species that have become a pest can be identified using taxonomy and can then be eradicated. Other measures contributing to the preservation of biodiversity include: the reduction of pesticide use and/or a switching to organic pesticides (Freemark and Boutin, 1995). Finally, if the continued preservation of native organisms in an area can be guaranteed, efforts can be made in trying to reintroduce eliminated native species back into the environment. This can be done by first determining which species were indigenous to the area, and then reintroducing them. This determination can be done using databases collected prior to bitumen development.

Plant Species for Enhancing Wildlife Habitat Values

Improved habitat management for wild vertebrate animals and birds, which encourages the growth of vigorous climax or sub-climax plant complexes, are beneficial to the wild animals and birds. The variety of herbs, shrubs and trees frequently resulting from such management is consistent with maintaining proper soil moisture conditions, and also provides the seasonal food and cover requirements for the wild species. Diversified plant complexes also decrease the potential for competition between the various wild animal and bird species. For the purposes of this research, however, certain suggestions with general application will be summarized:

Taller herbs provide better cover for wildlife than short herbs; Native plant species are an essential item for the survival of many wild species; Vigorous, palatable shrubs are especially required for the proper nutrition of dry season big animals and are used extensively by upland game birds during all seasons of the year for food and cover; Wildlife reacts favourably to a diversification of plant communities and species that provide a maximum variety of food and cover choices within a minimum area; Residual native herbs and shrubs found in fence rows, on ditch banks, and within waste areas well interspersed with cultivated land frequently mean the difference between no wildlife and abundant wildlife on agricultural lands and; Many plant species useful in meeting food and cover needs of wildlife can also be employed in conservation plantings for soil and water conservation or simply to attract wildlife or enhance wildlife habitat on the farm or forest.

Creating Bird and Animal Habitats through Planting and Harvesting

Planting herbs, shrubs and native tree plants on large tracts of land helps create welcoming habitat for game birds. Plantings that are strong enough to withstand dry season are especially effective.

1.8: Regulatory context for Environmental Impact Assessments, EIAs, in Nigeria

The biodiversity component of EIAs for oil sand projects evaluates the potential impacts to biodiversity (among many other disciplines) on a project-by-project basis using biodiversity indicators. In Nigeria, the relevant law that deals with a major project such as bitumen mining is contained in the Environmental Impact Assessment Decree No 86 of 1992 (Abimbola, 2000).

In fact, under Nigeria's EIA Decree, which came into effect on December 10, 1992, the objectives expected from the survey are:

- To establish **before a decision is taken** by any person, authority, corporate body or unincorporated body including the government of the federal, state or local governments intending to undertake or authorize the undertaking of any activity whether such may likely or to a significant extent affect the environment or have environmental effects, shall first be taken into account.
- To promote the implementation of appropriate policy on all federal lands (however acquired), states and local government areas, consistent with all laws and decision making process through which the goal and objective in paragraphs (a) of the section of the Decree must be realized; and
- To encourage the development of procedures for information exchange, notification and consultation between organs and persons when **proposed activities** are likely to have significant environmental effects on boundary of bordering or trans- state or on the environment of bordering towns and villages.

In addition to these, the EIA Decree also places restriction on the execution of public or private projects without prior consideration of the environmental impacts.

Furthermore, the Decree in section 13 has made reference to a mandatory study list whereby any activity on the mandatory study list must undergo an EIA. Thus, when a project is described on the mandatory study list or is referred to mediation or a review panel, no federal, state or local government or any of their authority or agency is permitted to exercise any power or perform any duty or function that would permit the project to be carried out until the agency has taken a course of action or decision or issued an action or decision or issued an order that the project could be carried out, with or without conditions.

Specifically, projects listed under the mandatory study activities include agricultural projects, with specified criteria, airport construction, drainage and irrigation projects, land reclamation projects, fisheries projects, forestry and housing projects.

Also included are the construction of different industries, be they chemical, petrochemical, non-ferrous, non-metallic, iron and steel, shipyard, pulp and paper industries, as well as the construction of infrastructure like hospitals, industrial estates, expressways, national highways, new townships and ports.

The list also name mining activities, ore processing and sand dredging involving an area of 50 hectares or more.

In the petroleum sector, we have oil and gas field development projects, offshore pipeline construction, construction of oil refineries, construction of oil and gas separation process, handling and storage facilities and storage depots.

But, the EIA Decree, for instance, has also made provision for interested groups - be they government agencies, members of the public, experts in any relevant discipline and interested groups – to make comments on the possible impacts such activities can have on the environment.

In practice, however, even where an EIA is done, members of the community are usually unaware that they are required to express their comments on the **proposed activity**, until such a project is eventually executed.

It is pertinent to note, that, conducting an EIA does not imply that a project will automatically be abandoned or that approval for such a project will be withdrawn for such a project without any impact on the environment, what is important, in fact is to look for ways and means of reducing the possible impacts of such a project. Where, however, the negative effect of such a project far outweighs its advantages, it may be advisable to consider other alternatives.

The relationship among stakeholders, the regulatory body and the EIA practitioners (environmental consultants) add value to the EIA process through ensuring that terms of reference evolve to reflect issues affecting biodiversity as identified by stakeholders in the Oil Sands region. In the future, stakeholders may identify biodiversity components that are currently not measured, for instance, invertebrate species, to be incorporated into baseline data collection, and then evaluated in the biodiversity assessment.

1.9: Statement of the Problem

For over a decade now, there has been continuous effort by bitumen-producing countries of the world to encourage and foster the use of heavy oils and tar sands, a resource that is now considered the most important source of hydrocarbon for the century. Since the price of crude oil has become unstable, the need for the development of alternative and / or additional sources of energy has become urgent.

Before minerals such as bitumen, can become useful items, they must undergo three stages of development; exploration, mining, and processing. These different stages of mineral development could exert some adverse and negative effects on the environment, particularly soil and water pollution. The most obvious effect of this is on soil and vegetation, which could either suffer total or partial degradation. Indirectly, destruction of vegetation will lead to modification of the natural environment which could have devastating effect on habitat, the relative abundance of species, and in some cases lead to extinction. More obviously, forests are eliminated along with food and shelter needed by wildlife, causing changes in composition of wildlife and other biodiversity resources.

1.10: Justification for the Study

Whatever the impact that bitumen may have on the environment, basically because of the economic consideration, it has to be mined. The methods recommended for the exploitation and mining of bitumen: Geological mapping, surface geophysical method especially seismic survey and, drilling and coring (Ako, 1990; Coker, 1990), open cast or surface-mining, mine-assisted (underground drilling shafts tunnels) and in-situ technologies (Coker, 1990); will not but have some disruption and destruction tendencies such as pollution, vegetation removal, and ecological disturbances which may lead to decline in diversity of plant and animal species.

Most studies in Nigeria have focussed on the impact of crude oil contamination. Until now, few study has focused on – toxicological effects of the physical and chemical properties of soil and water due to bitumen pollution; relationships between the physical and chemical properties of bitumen, water, soil and plants following bitumen pollution; the diversity of plants and the various associated habitats; the diversity and use of habitats by birds and terrestrial wildlife, and their population trend; impact assessment of proposed bitumen development on biodiversity resources in Ondo State.

This study is thus of great relevance as it focuses on the possible impacts of bitumen seepage on some biodiversity that could be used as baseline data for formulating good management plan during the exploitation of bitumen.

1.11: Significance of the Study

The great extinction of biodiversity that started at the end of the last century has almost come to fulfilment during the last decades. It is the largest biological drama the earth has seen since the eradication of the cretaceous giant lizards and their environments. The consequences are partly economic, but, also aesthetic and ethical in character.

Man's growing awareness of the magnitudes of these problems has generated worldwide concern and a general willingness to combat further destruction. In order to capture the state of the biodiversity resources, and to be able to use this to give; economically rational mitigations with regards to the restoration of the environments to its original state during and after Bitumen mining, one step is to oversee the battlefield – to survey it in broad lines. The other, partly simultaneously, is to take action, which is, however, beyond the scope of this research: each action requires data that have to be collected by directed survey and enquiries. This will assist on how to adequately assess some of the various factors that are necessary for the sustainability of biodiversity resources. This will enhance understanding of interactions that are likely to be affected.

To survive the pressures of environmental protections and conservation, natural environments must be justifiable in both "biological and socio-economic terms." With all these, there is need for advance planning and foresight to be brought into the picture of bitumen development in Ondo-State through Environmental Impact Assessment of biodiversity.

1.12: Objectives of the Study

Main objectives

The main purpose of this study is to establish the sensitivities of biodiversity resources and services to habitat changes that may be induced by Bitumen seepage.

Specific Objectives

a) To generate baseline data on the physico-chemical parameters of soil contaminated with bitumen.
b) To generate baseline data on the physico-chemical parameters of water contaminated with bitumen.
c) To investigate relations between contents of metals in soil and their accumulation in part of plants.
d) To generate baseline data on plants, birds and animals prior to bitumen development.
e) To appraise the effect of a loss in primary producer on some higher forms of biodiversity.

1.13: Scope and Limitation of Study

The scope of study shall be limited to:

- Areas of seepage where exploratory activities have been previously carried out by a mining company, and a control site within Irele Local Government of Ondo State.
- Evaluation of the effect of environmental pollution in the study area using the present physico-chemical characteristics of soil, plants and water polluted with bitumen.
- Determination of relative abundance, richness, and composition of plants and animals within the study area.
- Evaluation of the potential impacts to biodiversity using biodiversity indicators that looks at the direct effects on habitat from project development.

1.14: Definition of Terms

Biodiversity: is an umbrella term for the degree of nature's variety. It encompasses all species of plants, animals, soil, water and micro-organisms and the ecosystems and ecological processes of which they are part. Biodiversity can be seen as a measure of nature and its diversity, rather than an entity in itself, and is usually measured at three levels- genes, species and ecosystems (McNeely *et al*, 1990).

Biodiversity is the variety of life: the different plants, animals and micro-organisms, their genes and the ecosystems of which they are a part. It is home to more than one million species of plants and animals, many of which are found nowhere else in the world (Wikipedia, (2012).

Ecosystem: A system that includes all living organisms (biotic factors) in an area as well as its physical environment (abiotic factors) functioning together as a unit (Dictionary.com, 2008).

Also, an ecosystem is made up of plants, animals, microorganisms, soil, rocks, minerals, water sources and the local atmosphere interacting with one another (Dictionary.com, 2008).

Ecosystem services: ecosystem services are broad natural systems and functions. They provide and regulate water resources, the soil, nutrient storage and cycling, pollution breakdown and absorption, and other functions such as climate stability and recovery from unpredictable events, (Furze *et al*, 1996). Ecosystem services are indispensable to the wellbeing of all people, everywhere in the world. They include provisioning, regulating, and cultural services that directly affect people, and supporting services needed to maintain the other services. From the availability of adequate food and water, to disease regulation of vectors, pests, and pathogens, human health and well-being depends on these services and conditions from the natural environment. Biodiversity underlies all ecosystem services (WHO, 2010).

Biodiversity Resources and Services: Resources and services that exists not as a result of human production (directly or indirectly) but that occur naturally. These may include landscape, habitats or natural systems, and components of such systems, including species and populations. Raw materials that are - part of, or produced by such systems as air, water, and soil are also environmental resources and services.

Bitumen: This is a term that denotes hydrocarbon that is essentially immobile at reservoir conditions. In its raw state, bitumen is a sticky, viscous and black substance.

Tar Sand: This is composed of sand, heavy oil and clays that are rich in minerals and water. The heavy oil in tar sand is called bitumen. In this brief, bitumen and tar sands are used interchangeably.

Bitumen/Tar sand of Nigeria has the following physico-chemical properties (Oluwole *et al*, 1985);

Elemental composition - Carbon (85.7%); Hydrogen (10.77%); Nitrogen (0.5%); Chlorine (0.1%); Oxygen (1.72%);

Calorific value (44283Kj/Kg):

Metals:

Carbon (88.2ppm/wt); Fe (812.9ppm/wt); Potasium (12.0ppm/wt); Magnesium (8.7ppm/wt); Sodium (13.0ppm/wt); Nickel (35.3ppm/wt) and; Vanadium (32.5 ppm/wt).

Compound classes (% wt of bitumen):

Saturates (23.4);

Aromatics (13.5);

Total Hydrocarbon:

Saturates + Aromatics (36.9)

Resins (42.2)

Asphaltenes 21.9

Resins + Asphaltenes (64.1)

Tree: a woody perennial plant that reaches a mature height of 24m (except genetic dwarfs) and has a well – defined crown shape. Sometimes there is no clear – cut distinction between small tree and a large shrub.

Shrub: a perennial woody plant less than 10m tall, and having several stems arising at a point near the ground. It may be deciduous or evergreen. At the end of the growing season there is no die back of the aerial parts.

Herb: any flowering plant except those developing persistent woody bases and stems above ground.

CHAPTER TWO

2.0: LITERATURE REVIEW

2.1: Global and Contemporary Uses and Values of Biodiversity Resources and Services

McNeely *et al* (1990) reported that biodiversity is the variety of life: the different plants, animals and micro-organisms, their genes and the ecosystems of which they are a part. It is home to more than one million species of plants and animals, many of which are found nowhere else in the world. Biodiversity is the variation of life forms within a given ecosystem, biome, or for the entire Earth. Biodiversity is often used as a measure of the health of biological systems. The biodiversity found on Earth today consists of many millions of distinct biological species, which is the product of nearly 3.5 billion years of evolution. Biological diversity" or "biodiversity" can have many interpretations and it is most commonly used to replace the more clearly defined and long established terms, species diversity and species richness. Biologists most often define biodiversity as the "totality of genes, species, and ecosystems of a region". An advantage of this definition is that it seems to describe most circumstances and present a unified view of the traditional three levels at which biological variety has been identified:

- Genetic diversity
- Species diversity
- Ecosystem diversity

An explicit definition consistent with this interpretation was first given in a paper by Bruce A. Wilcox commissioned by the International Union for the Conservation of Nature and Natural Resources (IUCN) for the 1982 World National Parks Conference in Bali (Wilcox, 1982). The definition Wilcox gave is "Biological diversity is the variety of life forms...at all levels of biological systems (i.e., molecular, organismic, population, species and ecosystem)..." Subsequently, the 1992 United Nations Earth Summit in Rio de Janeiro defined "biological diversity" as "the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". This is, in fact, the closest thing to a single legally accepted definition of biodiversity, since it is the definition adopted by the United Nations Convention on Biological Diversity.

Diamond (1989) reported that many wildlife species have spiritual significance in different cultures around the world, and they and their products may be used as sacred objects in religious rituals. For example, eagles, hawks and their feathers have great cultural and spiritual value to Native Americans as religious objects.

Diamond (1989) concluded that, fuelled by media coverage and inclusion of conservation education in early school curriculum, Wildlife tourism and Ecotourism has fast become a popular industry generating substantial income for developing nations with rich wildlife especially Africa and India. This ever growing and ever becoming more popular form of tourism is providing the much needed incentive for poor nations to conserve their rich wildlife heritage and its habitat.

Olowokudejo (1992) reported that although virtually everyone on earth benefits from medicinal plants, it is the financially poorest who are typically most dependent on medicinal plants- culturally, and for their medicines and income.

WHO (1993) reported that a large portion of the world population (more than 85%) especially in developing countries depend on traditional systems of medicine for treatment of a variety of diseases. This has been attributed to inaccessibility of modern drugs to many people in the rural areas, and the economic factor.

Elliot and Mwangi, 1998, reported that the potentially largest source of benefits to rural people from wildlife is wildlife based tourisms, including trophy hunting. For example in 1996, trophy hunting alone contributed US $225 million to the economies of South Africa, the United Republic of Tanzania, Zambia and Zimbabwe.

Caspary (1999) revealed that bush meat is an important source of human benefits. The actual amount of bush meat being harvested is difficult to quantify because the harvest is mostly informal and illegal, but it is clearly enormous. In Cote d' Ivoire, for instance, it was estimated that in 1996 around 120,000 tonnes of wild meat was harvested by over a million hunters. This was more than twice the yearly production of meat from domestic livestock, and its market value of around US$150, million represented 1.4 percent of the gross national product.

Alexander *et al* (2002) revealed that in the Pacific Northwest as many as 36 species of mushroom are gathered and traded, but porcini (*Boletus edulus*). Chanterelles (*Chanterullus spp*), lobster, mushroom (*Hypomyces lactiflorum*) morels (*Morchella spp*), truffles (*Tuber spp*) and American matsutake (*Tricholoma magnivelare*) make up the bulk of the industry. The estimated size of the wild mushroom market in the states of Washington, Oregon and Idaho in the United States evolved from US $ 21.5 million in 1985 to $ 41.1 million in 1992.

Laird and Pierce (2002) reported that the world market for herbal remedies in 1999 was calculated to be worth US$19.4 billion, with Europe in the lead (US$6.7billion), followed by Asia (US$5.1 billion), North America (US$4.0 billion), Japan (US$2.2 billion), and then the rest of world (US$1.4 billion).

Schippmann *et al* (2002) reported that in terms of the number of species individually targeted, the use of plants as medicines represents by far the biggest human use of the natural world. Plants provide the predominant ingredients of medicines in most medical traditions. There is, however, no reliable figure for the total of medicinal plants on earth, and numbers and percentages for countries and regions vary greatly.

Holding- Anyonge and Roshetko (2003) reported that farmers plant or conserve trees on their farms for a variety of products and services – not only timber, but also fuel-wood, fruits, vegetables, fodder, medicines, resins, shade (for livestock or under-storey crops) and soil and water conservation. Timber may be a secondary product, harvested only after the tree has served its primary production or service role. In small-scale systems in developing countries, timber production is generally not intensive, once trees are planted – there is little proactive management – fertilizer application, thinning, pruning and weeding. If these activities are undertaken they are usually intended to benefit agricultural crops.

Vantomme (2003) confirmed that the many and often conflicting demands from different user groups for forest products (timber and a variety of non-wood forest products including also floral greens, natural honey, berries and medicinal plants) create a great challenge and demand for conflict – management arrangement and innovative forest management and policies at all levels, from landowners, municipalities, user groups and non-governmental organizations to concerned state and federal agencies. In view of the high financial states of several of the uses involved, administrators in the region are hastening to fine-tune forest policy and regulations governing access and user rights and to promote forest management that accommodate a wide range of forest uses.

WHO (2003) also enunciated that there is an increased interest in alternative therapies globally and a consistent increase in the use of plant derived products as they are convenient alternatives, or complimentary to the use of orthodox or synthetic drugs.

Deug and Graham (2004) concluded that this is due in part to adverse effects of conventional drugs, the drift towards consuming natural products as opposed to synthetics, as well as the increasing awareness of the beneficial effects of natural products and high inflation in the Third World, (Jacobs *et al*, 2001).

Muhammad and Amusa (2005) reported that in North- Western Nigeria, the roots and leaves of *Senna occidentalis* have been used in the treatment of malaria. Other plants used include: *Anogeissus leiocarpa* (bark), *Daniella oliveri* (bark), *Momordica balsamia* (leaves) and *Azadiratcha indica* (leaves, stem and bark).

Togola *et al* (2005) reported that the infusion of the leaves and shoots of *Heliotropium indicum* are used in treating rashes. Infusion of the flowers taken in small doses regulates menstruation, while large doses can induce abortion. The juice from the leaves is antiseptic and anti-inflammatory, and is effective in the treatment of wounds, sores, boils and pimples.

Hassan *et al* (2006) reported that, in Montana country, wildlife has been an essential part of human culture for at least 12,000 years. Prehistoric occupants hunted wild animals for food, and used the by-products for clothing, shelter, and tools. Beginning with the white man’s culture, about 160 years ago, beaver pelts were important in commerce and were an inducement to the exploration and settlement of the mountains west. Later, in the gold rush days following 1860, wild animals were a major, and frequently only, source of subsistence food. In modern times, game has become a major recreational, aesthetic and economic asset to Montana.

Bamaiyi *et al* (2006) reported that seed oil of *Khaya senegalensis* significantly reduced *C. maculatus* emergence of F1 and F2 progeny, although reduction in oviposition was not significantly reduced. There was no significant difference between K. Senegalensis and pirimphos-methyl EC for all the parameters measured.

The extract of *Lactuca taraxacifolia* (dried leaves) in saline has been demonstrated to exhibit anti-viral activity. In western Nigeria, the juice from squeezed leaves is used as eye drops to treat eye inflammation, (Obi *et al*, 2006).

Ukaga *et al* (2006) carried out a comparative study of anti-malarial herbs used by traditional healers in two villages in Imo state. The water extract of roots and leaves of *Uvaria chemae*, *Strophantus hispidus*, and *Acioa barteria* were tested in Umuneke Ugiri. In the other village, Odummara Obiorodo, a concoction called Agbo iba which consisted of the leaves of *Citrus sinensis*, *Mangifera indica*, *Carica papaya*, *Vernonia amygdalina*, *Psidium guajava*, *Ocimum gratissimum*, *Cymbopogon citriatus*, *Azadiratcha indica* and seeds of *Citrus aurantifolia* brought about 100% parasitemia clearance among patients that returned for evaluation when compared to 69% clearance in those from Umuneke Ugiri.

Agra *et al* (2007) reported that in Brazil, a decoction of the leaves of *Ageratum conyzoides* has been found useful in the treatment of ovarian inflammation, amenorrhea dysmenorrhea, rheumatism and diarrhoea. An infusion of the whole plant has been found to give relief from intestinal pains, anorexia and arthritis.

In Nigeria, the whole plant, leaves and roots are used in treating ulcers, wounds, gonorrhoea, craw-craw, emetic skin diseases, gastro-intestinal disturbances and sleeping sickness. The leaf extract is used as an eye wash and optical brightener. In south-wesstern Nigeria where a lot of studies have been carried out the use of barks, roots, leaves or whole plants of *Morinda lucida*, *Enanthia chlorantha*, *Alstonia boonei*, *Azadiratcha indica*, *Khaya grandifolia*, *Citrus medica* have been used in treating malaria, (Odugbemi, 2006).

2.2: Physico-chemical properties of Soil

Ravina and Markus (1975) evaluated the influence of high exchangeable potassium percent (EPP) on the physical condition of the soil and on growth is, assuming the possibility of its improving the structure of the soil. A greenhouse experiment with a grumusol of different levels of EPP was conducted. The mechanical and physical properties of the different EPP soils were not significantly different. With increasing

EPP, there is a change in the c-spacing of the clay, showing that part of the smectites is transformed into mixed layered clay. A marked rise in the yield with increasing percentage of exchangeable potassium in the soil was found. There is a significant interaction between the exchangeable potassium and the uptake of magnesium and phosphorus, which decreases with increasing EPP.

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Foth (1984) reported that Humus formation is a process dependent on the amount of plant material added each year and the type of base soil; both are affected by climate and the type of organisms present. Soils with humus can vary in nitrogen content but have 3 to 6 percent nitrogen typically; humus, as a reserve of nitrogen and phosphorus, is a vital component affecting soil fertility.

Amadi *et al* (1993) reported increases in the cations of soils treated with crude oil.

Bärlocher and Corkum (2003) studied mass losses of oak leaves in microcosms, where numbers of aquatic hyphomycete species (1–5) and nutrient concentrations (2 levels each of N, P, and Ca) were varied. Species numbers, species identities, N, P and N×P interactions all had significant effects on leaf mass loss, but the magnitude of the effect was greater for N and P than for species numbers. Mass loss in multicultures was greater than predicted from average contributions of the component species in single cultures. This may have been due to sampling effects or niche complementarities.

Bever *et al* (1997) reported that although its importance for plant mineral nutrition and nutrient cycling has long been recognized, the soil community has rarely been integrated into dynamical frameworks of plant populations, in spite of abundant evidence for its involvement. Specifically, diversity can be maintained between locally homogeneous patches when positive feedback and dispersal occur at local scales. Using a simple experimental protocol, substantial negative feedback on plant growth through the soil community have been found, suggesting that it may be involved in the maintenance of plant species diversity. The importance of the soil community in other areas of plant ecology and evolution was discussed, including the suggestion that interactions with the soil community may be involved in the maintenance of sexual or asexual reproductive systems.

Agro/Hort 100 (2001) reported that all living organisms are sensitive to pH. The plant roots will not function optimally in soils outside a specific pH range unique to that organism. If the pH of the soil is extreme either alkaline or acid, the plant will die. Soil microorganisms, insects, and other animals present in the rhizosphere are equally sensitive to pH. Alkaline soils have pH 7.5 - 8.5. Acidic soils have pH 4 - 6.5. Soils with pH values outside these ranges are usually toxic to most plants. Soil pH can be altered by amendments. Increasing organic matter will decrease pH (increase acidity). Lime can be added to increase pH (increase alkalinity). Certain fertilizers are delivered as acidic or basic solutions. These will also alter soil pH.

Reid and Dirou (2004) reported that a soil test gives snapshot of some of the nutrients in soil and helps decide which ones to add to make soil more productive. However, it is not a magic formula, and test results need to be considered together with plant tissue tests, and farm's cropping, pasture and fertiliser history. Preferred level of **pH** is ($CaCl_2$): 5.0–5.5. When soil pH is measured in a solution of $CaCl_2$, the pH is 0.5–0.8 lower than if measured in water. **Cation exchange capacity** (**CEC**): CEC is a measure of the ability of the soil to hold the nutrients calcium, magnesium and potassium. Good fertile soils with high clay content and moderate to high organic matter levels usually have a cation exchange capacity of 10 or higher. Preferred level of CEC is above 10. **Exchangeable cations**: The major cations are calcium, magnesium, potassium, sodium and aluminium. These are held in the soil by organic matter and clay. If soil test report does not give percentages, this can be calculated by dividing the quantity of each cation (the meq figure) by the CEC figure, and multiplying the result by 100. Sometimes the level of hydrogen cations is reported, but this should not be added to your total CEC. If any other cations are reported, such as manganese, this may indicate a toxicity problem. High levels of aluminium are toxic to some plants, and this situation is usually associated with more acidic soils.

High sodium levels can indicate sodicity problems (i.e. soil structure problems), or salinity problems. When your soil test report gives quantities in parts per million (ppm), you can use the conversions in table 2.2 to obtain meq figures. **Calcium/magnesium ratio**: Preferred level is above 3. If the figure is below 2, it is more difficult for plants to take up potassium, and there can be problems with soil structure breaking down due to dispersion. Phosphorus**:** Because phosphorus tends to tie up with aluminium and iron and become unavailable to plants in acid soils, it is important to keep your pH at around 5 if your soil is to benefit from phosphorus. **Nitrate nitrogen**: Agronomists generally like to see a level of 10 mg/kg or more in pasture soils, and a level greater than 20 mg/kg in horticultural crops. **Conductivity (salt):** Preferred level is below 0.15 dS/m ($EC_{1:5}$). Electrical conductivity is a measure of salts in the soil. A productive soil's conductivity should be below 0.15 dS/m (decisiemens per metre). Plants vary in their reaction to salt stress, from 'sensitive' to 'tolerant', and the degree of reaction is less in clay soils than in sandy soils. For this reason, soils affected by salt should also have a saturation conductivity test (EC_{se}). However, these results should not be compared with $EC_{1:5}$ figures. Salinity problems can be caused by too much fertiliser, salty irrigation water or saline ground water. Salts can be leached out with rainfall or low salinity irrigation water without affecting soil pH. Because of its high rainfall, the North Coast generally does not have a great problem with soil salinity except in some low, poorly draining soils close to tidal rivers. **Organic carbon:** Preferred level is above 2%. Organic carbon is a measure of the organic matter in the soil. It includes undecomposed plant litter, soil organisms and humus. Soil organic carbon stores important nutrients, stabilises soil structure and feeds soil microbes. If soil organic carbon is declining over time, then consider practices such as green manure crops, minimum tillage, mulching or strategic grazing.

The physical integrity of soil is also a prerequisite for avoiding landslides in rugged landscapes, (Khalil *et al*, 2003).

TFREC (2004) reported that "Soils are complex mixtures of minerals, organic compounds, and living organisms that interact continuously in response to natural and imposed biological, chemical, and physical forces." Within Ecosystems soil is a medium for plant growth and crop production; primary cleansing and recycling medium; source material for construction and medicinal products; sustain biological activity, diversity, and production; and Store and cycle nutrients and other elements.

Low C: N ratios (<25:1) are indicative of mineralization and rapid rates of decomposition; High C: N ratios (>25:1) indicate immobilization and slower decomposition rates; Soil pH **a**ffects availability of plant nutrients (in general, optimal pH is from 5.5-7.5). Low pH soils (<6.0) results in an increase in Al; Aluminum is toxic to plants; Affects the availability of toxic metals, which is generally more available in acidic soils; Affects the activity of soil microorganisms, thus affecting nutrient cycling and disease risk. CEC is a measure of the quantity of cations that can be adsorbed and held by a soil. CEC is dependent upon the amount of organic matter and clay in soils and on the types of clay. In general, the higher OM and clay content, the higher the CEC. Beneficial impacts of SOM on soil properties: Physical - stabilizes soil structure, improves water holding characteristics, and lowers bulk density, dark color may alter thermal properties; Chemical - higher CEC, acts as a pH buffer, ties up metals, interacts with xenobiotics; Biological - supplies energy and body-building constituents for soil organisms, increases microbial populations and their activities, source and sink for nutrients, ecosystem resilience, affects soil enzymes.

De Deyn (2005) reported that soil resources are critical to the environment, as well as to food and fiber production. Soil provides minerals and water to plants. Soil absorbs rainwater and releases it later, thus preventing floods and drought. Soil cleans the water as it percolates. Soil is the habitat for many organisms: the major part of known and unknown biodiversity is in the soil, in the form of invertebrates (earthworms, woodlice, millipedes, centipedes, snails, slugs, mites, springtails, enchytraeids, nematodes, protists), bacteria, archaea, fungi and algae; and most organisms living above ground have part of them (plants) or spend part of their life cycle (insects) belowground. Above-ground and below-ground biodiversities are tightly interconnected, making soil protection of paramount importance for any restoration or conservation plan.

Lafleur *et al* (2005) reported that through nest building and foraging activities, ants alter physical properties and nutritional status of soils through structural modifications and nutrient accumulation. In turn, these alterations may enhance soil quality for plant growth. This study examined the effect of the invasive red imported fire ant, Solenopsis invicta Buren, on soil properties and plant growth. In our greenhouse study, ant activity decreased soil pH and increased phosphorus (P^{+}) and potassium (K^+) in the soil. They collected soil from within and adjacent to randomly selected nests in two common habitats of Louisiana – longleaf-pine (*Pinus palustris*) forests and longleaf-pine plantations. After physical and chemical properties were measured, *Gardenia japonicus* seedlings were planted in the soil to determine growth rate. In comparison to adjacent soil, ant nest soils from both habitats were lower in moisture content and bulk density and higher in $NH4^+$. Ant nest soils were also higher in Ca^{2+}, Mg^{2+}, K^+ and Na^+ than in adjacent soils in longleaf-pine forests. *G. japonicus* seedlings grown in nest soil from pine forests were an average of three times taller than those grown in adjacent soil, and those from pine plantations were twice as tall as those grown in adjacent soils. These results suggest that invasive fire ants alter the physical and chemical properties of the soil. These soil modifications enhance plant growth since NH_4^+, a nutrient that limits growth has been increased.

Nnaji *et al* (2005) reported that high concentration of Ca^{2+}, Mg^{2+} and trace elements in soil is attributable to rapid decay and mineralization of organic and mineral materials in the soil.

AgSource (2006) reported that soil cations become increasingly more soluble and plant available as the exchangeable % increases. The goal is to maintain adequate amounts of nutrients for plant uptake while nutrient minimizing leaching loss. Optimum base saturation percentages recommended are: Na, <10%, K, 2-7%, Mg, 13.9% and Ca, 65-75%.

Dawit *et al* (2007) reported that humus also absorbs water, acting as a moisture reserve, that plants can utilize; it also expands and shrinks between dry and wet states, providing pore spaces. Humus is less stable than other soil constituents, because it is affected by microbial decomposition, and over time its concentration decreases without the addition of new organic matter.

Claudia *et al*, (2008) further confirmed that excess nutrients filtered out by the soil, or metabolized were incorporated into stable humus.

Diplock *et al*, (2009) confirmed that soil organisms metabolize excess nutrients or immobilize them in their biomass and necromass.

Maximilian *et al* (2009) reported that excess nutrients (nitrates, sulfates, phosphates) are filtered out by the soil.

Dick (2009) reported that cation ratios can help in identifying soil structure problems, and are a great tool for identifying problems. Research on Ca: Mg ratio was often based on total calcium and magnesium levels in a soil. The Mehlic 3 method of testing does not relate to the 'functional' fraction of calcium and magnesium in the soil, i.e. that proportion actively being exchanged between soil colloids, soil solution, plant roots, microbes etc. A better way to truly determine Ca:Mg ratio would be to measure the soluble cations in the soil and take plant tissue samples. This would help to better determine a true plant available ratio. It is also important to point out that using Ca/Mg Ratios in isolation (without taking into account ppms) can lead to erroneous interpretations, calcium and magnesium levels can both be low, yet have an ideal ratio; or both can be high, yet have an ideal ratio. Ca:Mg ratio of 4:1 to 7:1 offers a soil with better structure, better aeration, and better productivity. Calcium is the element that causes the soil particles to move apart for aeration and drainage. Magnesium makes the particles stick together. High Mg soils cause potassium and calcium deficiency in plants. Soils with high magnesium tend to have poor structure. Typically these soils will have more sodium cations attached to the clay as well. Having high magnesium and sodium causes the clay particles to disperse when wet and set like concrete when dry. The magnesium ions sitting on the clay surfaces have a 50% greater hydrated radius than calcium which causes these soils to absorb more water. This excess water tends to weaken the forces that hold soil particles to together resulting in less aggregate stability and greater dispersion of soil particles reducing infiltration rates and hydraulic conductivity (drainage). These soils tend to swell when wet and become very hard when dry, often forming a hard surface crust and becoming very difficult to till. Soils containing greater than 300 ppm of ammonium acetate extractable magnesium are considered high as well as soils with base saturations greater than 15%. Soils that are saturated with magnesium can also show low potassium levels as of less than 100 ppm.

Haman and Izuno (2009) reported that Water is essential in the plant environment for a number of reasons. Water transports minerals through the soil to the roots where they are absorbed by the plant. Water is also the principal medium for the chemical and biochemical processes that support plant metabolism. Sandy soils consist mainly of large mineral particles with very small percentages of clay, silt, and organic matter. In sandy soils there are many more large pores than in clayey soils. In addition the total volume of pores in sandy soils is significantly smaller than in clayey soils (30 to 40% for sandy soils as compared to 40 to 60% for clayey soils). As a result, much less water can be stored in sandy soil than in the clayey soil. A significant number of the pores in sandy soils are large enough to drain within the first 24 hours due to gravity and this portion of water is lost from the system before plants can use it.

2.3: Physicochemical Characteristics of Water

Adegoke-Anthony and Adedokun (1990) reported that due to the relatively impermeable nature of the surficial material such as shales and clays in the bitumen belt of Ondo State, it is unlikely that a general unconfined water table condition would exist except in the occasional thin layers of sand where such have contact with nearby streams. As a result, the most visible evidence of groundwater in the northern part of the tar sand area is in the form of sprigs. All the springs are clean, odourless and clear, and they serve as good drinking water supply for the people in the area in which they are found. Discharge measurements of springs covering both the dry and rainy season reflect the response of the springs to seasonal variations. Discharges values were high during the rainy season and low during the dry season).

Kakulu and Osibanjo (1991) reported that high total suspended solids levels also increases turbidity in water which prevents light from reaching aquatic plants and animals.

APHA (1992) reported that by a similar action to that of Ca, Mg imparts hardness to water. This may be reduced by chemical softening or by ion exchange.

Ansa – Asare (1992) reported that the pH of natural water determines the solubility and chemical forms of most substances in water. High levels of total dissolved solids limit the industrial and agricultural use of water.

Ademoroti (1996) reported that Biological oxygen demand (BOD) measure the amount of oxygen requires by bacteria for breaking down to simpler substances the decomposable organic matter present in any water, wastewater or treated effluent.

Electrical conductivity of water is a useful and easy indicator of its salinity or total salt content. Wastewater effluents often contain high amounts of dissolved salts from domestic sewage. High salt concentrations in waste effluents however, can increase the salinity of the receiving water, which may result in adverse ecological effects on aquatic biota (Ademoroti, 1996).

Adeyinka (1996) reported that whenever industrial wastewater is discharged into a body of surface water, care must be taken to avoid damaging any sensitive ecosystem and to ensure that no long term accumulation of pollutants occurs in the sediments and that the overall use of the water in question is not impaired. Untreated or incompletely treated industrial wastewater contains algae materials, non – biodegradable organic matter, heavy metals and other toxicants that deteriorate the receiving stream.

DWAF (1996) reported that high or low pH values in a river have been reported to affect aquatic life and alter toxicity of other pollutant in one form or the other. Low pH values in a river for examples impair recreational uses of water and affect aquatic life. A decrease in pH values could also decrease the solubility of certain essential element such as selenium, while at the same time low pH increases the solubility of many other elements such as Al, B, Cu, Cd, Hg, Mn and Fe. It was further confirmed that BOD is also taken as a measure of the concentration of organic matter present in any water. The greater the decomposable matter present, the greater the oxygen demand and the greater the BOD values (APHA 1992).

Speijer (1996) reported that many workers have been reported to have potential health risk from nitrate in drinking water above threshold of 45 mg/l, which may give rise to a condition known as methaemoglobinemia in infants and pregnant women.

Chapman (1997) reported that the DO is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as the self purification capacity of the water body. The standard for sustaining aquatic life is stipulated at 5mg/l a concentration below this value adversely affects aquatic biological life, while concentration below 2mg/l may lead to death for most fishes.

Horsfall and Spiff (1998) reported that non-biodegradable pollutants are those that cannot be broken down by micro-organisms and hence persist in the environment and become toxic to life e.g. heavy metals such as Hg, Pb, Cd, Cr, V, etc and compounds like DOT, HCFC, CFC, pesticides etc. They accumulate in living tissue and proceed along the food chain and could result in the death of organisms.

Morrison *et al* (2001) reported that wastewater discharge from sewage and industries are major component of water pollution, contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to a destabilized aquatic ecosystem.

Emoyan *et al* (2005) determined the concentration of Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb) and Zinc (Zn) which may affect human health and the "health" of the aquatic ecosystem in the River Ijana Ekpan, using a pye unicam Atomic Absorption Spectrometry SP model 2900. The level of heavy metal in the study area varied between Cd (0.010 ± 0.004mgl^{-1}) and (0.100 ±0.014mg1^{-1}); Cr (0.037 ± 0.006mg1^{-1}) and (0.067 ± 0.020mg1^{-1}), Cu (0.020 ± 0.004mg1^{-1}) and (0.050 ± 0.029mg1^{-1}); Fe (0.046 ± 0.007 mg1^{-1}) and (0.229 ± 0.008mg1^{-1}); Ni (0.030 ± 0.004mg1^{-1}) and (0.080 ± 0.010mg1^{-1}); Pb (0.025 ± 0.006mg1^{-1}) and (0.058 ± 0.008mg1^{-1}) and Zn (0.088 ± 0.012mg1^{-1}) and (0.122 ± 0.007mg1^{-1}). The concentration of these parameters of pollution contained in the study area (SS_1–SS_3) indicated that the River is fairly polluted. The possible sources of these parameters of pollution are diverse: originating from anthropogenic / natural and point sources.

Kocak *et al* (2005) reported that heavy metals are present in food in very minute quantities; the existence is due to their role in body metabolism, it has been establish that whatever is taken as food might cause metabolic disturbance if it does not contain the permissible upper and lower limits of heavy metals. Thus, both deficiency and excess of essential micro-nutrients (iron, zinc and chromium) may produce undesirable effects

Tepe *et al* (2005) reported that a dissolved oxygen concentration above 5mg/l is adequate enough to support aquatic life.

Benson *et al* (2007) determined trace metals concentrations in surface water, sediment and water lily (*Nymphaea lotus*) samples from the banks of Calabar River, a major tributary of Cross River Estuary, Nigeria. The results revealed average concentrations 0.017, 0.010, 37.08 and 0.025 mg/l, respectively, for As, Cd, Fe and Pb in surface water samples, which exceeded Federal Environmental Protection Agency (FEPA) maximum guideline values. Elevated levels of heavy metals (As, 1.251 mg/kg; Cd, 0.038 mg/kg; Co, 0.509 mg/kg; Cu, 3.78 mg/kg; Fe, 35.48 mg/kg;

Mn, 10.72 mg/kg; Ni, 0.732 mg/kg; Pb, 1.355 mg/kg; V, 0.427 mg/kg; and Zn, 8.665 mg/kg) in sediment samples indicated anthropogenic influences while, measured concentrations in *N. lotus* were typical of a growing plant.

Akan (2008) reported that Wastewater and vegetable samples were collected from the Jakara wastewater channel near the Airport Road Bridge, Kano metropolis. Samples were collected between the periods of November 2007 to May 2008 to determine the following parameters, pH, temperature, turbidity, chemical oxygen demand (COD), Biological oxygen demand (BOD), dissolved oxygen (DO), conductivity, total dissolved solid (TDS), total suspended solid (TSS), sulphate, nitrate, nitrite and phosphate. In addition, metals (copper, cobalt, chromium, iron, manganese, magnesium, nickel, cadmium, lead, sodium, potassium and calcium were determined. Levels of pH, conductivity, temperature, nitrate, nitrite, sulphate, phosphate, TSS, TDS, DO, BOD and COD were higher than the maximum permissible limits set by Federal Environmental Protection Agencies (FEPA) Nigeria. The concentrations of the metals in the wastewater and vegetable samples were higher than limits set by WHO and the maximum contaminant levels (MCL). The high concentration of metals in the vegetable samples suggests that the wastewater used for the irrigation of these vegetables within the study area can be classified as polluted and thus unfit for irrigation of crops. Thus, the wastewater around the Jakara channel is highly polluted. Domestic and industrial waste should be properly disposed and or recycled. Relevant agencies should make continuous effort to control, regulate and educate populace on indiscriminate waste disposal from domestic and industries within the study area.

Israel *et al* (2008) analyzed effluents and soil samples where sediments from the treated effluents are dumped for physicochemical properties, metallic and non-metallic ions. These parameters were compared with established international standard (FEPA). Effluents were classified as process waste water (PWW), clarified water (CW), and final discharge (FD). The petrochemical effluents contained very high concentration of TDS (284.00±014 mg/L) and significant concentrations of TSS (78.89±0.01 mg/L), COD (30.10±0.02 mg/L), DO (13.20±0.01 mg/L), BOD (6.12±0.00 mg/L), PO4 3- (4.34±0.00 mg/L), SO4 2- (3.59±0.00 mg/L), Cl- (55.52±0.01 mg/L) and NO3 - (8.40±0.01 mg/L). Low concentrations of iron, zinc, copper, cadmium, lead, nickel and cobalt was also observed. Some heavy metals were not detected at all in some of the effluent samples analyzed. Apart from temperature and total dissolved solid TDS, all the other parameters were below FEPA effluent limitations for guidelines for Petroleum Refinery, Fuel/Gasoline oil category in Nigeria.

Trivedi *et al* (2009) investigated physico-chemical parameters of water samples of Ganga River at Kanpur. The observed values of different physico-chemical like pH, temperature, turbidity, Total Hardness (TH), Iron, Chloride, Total Dissolved Solids (TDS), Ca^{+2}, $SO4^{-2}$, $NO3^{-}$, F^{-1}, Total Alkalinity (TA), Oxygen Consumption (OC), Suspended Solids (SS) of water samples were compared with standard values recommended by World Health Organisation (WHO). It was found that significant correlation holds for TA with Cl-, Mg^{+2}, Ca^{+2}, TH, TDS, Fluoride and OC. A significant negative correlation was found between SS with Chloride, Mg+2, TDS, fluoride and OC. All the physico-chemical parameters are within the highest desirable or maximum permissible limit set by WHO except turbidity which was high, while $NO3^{-}$, Cl^{-1} and F^{-1} are less than the values prescribed by WHO.

2.4: Bitumen-Polluted Soil, Heavy Metals in Plants and Land Rehabilitation: Impacts and Interactions

Gudin and Syratt (1975) enunciated the incorporation of hydrocarbon material into soil causes an increase in microbial oxygen uptake. Competition between micro-organism and higher plants for available soil Nitrogen also occurs. It was proposed that rehabilitation of oil spill sites includes aeration of soil, addition of nitrogen and seeding with leguminous species in order rapidly to establish a mantle of vegetation.

Odu (1978) encapsulated that in oil-polluted soils treated with (NH4) SO4 and with nutrient elements with and without enhanced aeration, there was no significant difference in oil degradation in soil with or without enhanced aeration, nor in soils treated with and without (NH4)2 SO4 and / or nutrients after 4 weeks incubation. After 12 weeks, oil degradation was significantly higher (P = 0.05) in the (NH4)2 SO4 and nutrient treated soils in comparison to the untreated soils and in soils with enhanced aeration in comparison to the undisturbed soil, at the 5% oil pollution level.

Gildon and Tinker, 1983 reported that the degree of infection of onions with the vesicular-arbuscular mycorrhizal fungus Glomus mosseae was strongly reduced by additions of zinc, copper, nickel or cadmium to the soil medium, and could be completely elimited by heavy rates of application. A split pot experiment was used to show that zinc translocated within the plant from other roots was effective in decreasing infection levels. Despite this, clover plants growing on areas which had been heavily contaminated with metal were found to be strongly infected with mycorrhizal fungi. A comparison of G. mosseae isolated from these plants with the isolate used at Rothamsted showed the former to be much more tolerant of zinc and cadmium in the soil. There was some indication that mycorrhizal infection, particularly with the tolerant isolate, could protect plants against the effects of heavy metal additions. These infections might be very important in revegetation of polluted sites.

Ekweozor (1990) chronicled the problems associated with processing of bitumen from oil sands to include presence of trace metals, including vanadium, nickel and iron as well as suspended clay particles. These tend to corrode equipment and foul up the catalysts. Also, high resin plus asphaltene contents lead to deleterious consequence, mainly coke and polymer deposition. On the positive, though, is the fact that the almost-complete absence of n-alkanes from the Nigerian bitumen means relatively large proportion of naphthenic and aromatic hydrocarbons.

Clemente *et al* (1991) reported that organic materials promoted fixation of heavy metals in a mine soil contaminated with mineral suphides in Aznalcolar, Spain.

Glass (1995) reported that toxic metal pollution of waters and soil is a major environmental problem, and most conventional remediation approaches do not provide acceptable solutions. The use of specially selected and engineered metal accumulating plants for environmental clean-up is an emerging technology called phyto remediation. Three subjects of this technology are applicable to toxic metal remediation: phyto extraction – the use of metal accumulating plants to remove toxic metals from soil; rhizofiltration- the use of plant roots to remove toxic metals from polluted waters; and phyto stabilisation- the use of plants to eliminate the bio availability of toxic metals in soils. Biological mechanisms of toxic metal uptake, translocation and resistance as well as strategies for improving phyto remediation are also discussed.

Ademoroti (1996) showed that vegetables accumulate considerable amount of heavy metals especially Pb, Cr, Cu, Zn in roots and leaves.

Ekundayo and Fagbami (1996) reported that soil organic matter reduces availability of heavy metals by chelation.

El-Gendi *et al* (1997) reported the use of treated drainage water for enhancing these micronutrients in soils. But, higher concentrations in the plough layer suggest that most arable plants may get these micronutrients by interception and mass flow while tree crops may suffer deficiencies due to inadequacy in the deeper horizons.

Amusan *et al* (1999) studied plant uptake of heavy metals on a similar site at University of Ife garbage dump and found out that Pb uptake by water leaf (*Talinum triangulare*), okra (*Albelmuscus esculentus*) increased in leaves and roots of water leaf and in the fruit of okra relative to those grown in the non-dump sites

Kashem and Singh (1999) conducted a study to investigate the heavy metal contamination of soil and vegetation in the vicinity of industries around Dhaka city in Bangladesh. Categorically soils, grass (Cynoden doctylon L), water hyacinth (Eichhornia crassipes L), rice (Oryza sative L), and arum (Alocasia esculenta L) were collected from tannery, ceramic, textile dying and sulphuric acid producing industrial sites. The concentrations of total Cd, Cu, Mn, Ni, Pb and Zn ranged from 0.1–1.8, 28–217, 106–577, 25–112, 17–99 and 53–477 mg kg^{-1} soil, respectively among the industrial sites. The concentrations of some heavy metals ranged from background levels to levels in excess of tolerable limits in agricultural soils. The concentrations of total Cu, Mn, Ni, Pb and Zn decreased with increasing distance from the disposal points of the tannery and the textile dying industries. Cadmium, Cu, Mn, Ni, Pb and Zn showed highly significant ($p < 0.01$) positive correlations with their total and DTPA-extractable contents in soils. The concentrations of most heavy metals were also higher in the vegetation samples of tannery area and the content of Pb (13–45 mg kg^{-1}) in grass samples exceeded the toxic limit. In correlation matrix, plant concentrations of Cu, Mn, Pb and Zn were significantly correlated with their total and extractable contents in soils.

Santamaria *et al* (1999) shows that the heavy metals content of various parts of plant differs, the researchers reported that in vegetables organs the concentrations of heavy metals are in the order of leaf> stem> root> tuber> bulb> fruit> seed.

Buszewski *et al* (2000) reported that the high concentration of heavy metals in soils is reflected by higher concentrations of metals in plants, and consequently in animal and human bodies. The ability of some plants to absorb and accumulate xenobiotics makes them useful as indicators of environmental pollution. Accumulate metals (heavy metals and macroelements) in assimilation organs and roots. Thus, they can be recommended as indicators for determination of pollution levels of the environment. The metal concentrations in soils of the measured area (Toruii, Poland) did not exceed the limited values recommended by the Polish Standards for agricultural soils [22]. Lower amounts of heavy metals in soil samples taken in spring were observed. The contents of metals in examined plants (grasses, mosses, pine needles) were lower than permitted concentrations, except lead in grasses and mosses. Generally, the concentration of metals decreased with increasing distance from the pollutant emission sources. Grasses do absorb the contaminants during their relatively short vegetation period, *i.e.* spring-autumn. The concentrations of heavy metals in grasses were proportional to those in soil. For that reason they are very good instruments - biosensors - for observation of the trends in soil composition of pollutants.

Arambarri *et al* (2000) reported that superficial soil and grass samples from 13 locations affected by several anthropogenic sources (mining, metal factory, traffic emissions) were collected in Gipuzkoa, northern Spain. The more labile metal fractions, the mobile (extracted by 0.01 mol l^{-1} $CaCl_2$) and the mobilisable (extracted by 0.005 mol l^{-1} DTPA), were evaluated using a short sequential procedure with two steps. From the results a short-medium term potential lability of Cd, Cu, Zn and Pb can be concluded. The labile levels were compared with the results obtained using the Tessier sequential procedure. Factor analysis was used to check the associations between the total metal contents in soil and grass, as well as between the levels of the different sequential fractions and the total content in grass. Cd, Cu and Zn labile levels were related to total metal grass contents indicating its suitability for the availability studies in polluted soil–plant system.

Kinigoma (2001) examined the effect of drilling fluid additives on the Soku oil fields environment. Soil and reserve pits in various locations were assessed for some physico-chemical characteristics and heavy metal content using standard methods for water and wastewater analysis. Plant growth and other biomass were also assessed. The result showed that the levels of most physiochemical characteristics are generally within the limits of guidelines by regulatory authorities. However, trace metal levels are generally below toxic levels, except Fe, Ca and Mg, which were higher than recommended values. These high values of Fe, Ca and Mg (17.70-220.2; 11.03-296.80; and 12.62-75.71 ppm) respectively are characteristic of the Niger Delta Swamp soils. Also a poor plant growth was observed in the immediate vicinity of location of drilling operations, an indication of the toxic effect of drilling fluids on the environment. During the drilling operation of oil and gas, drilling fluid and cuttings and other waste materials generated in the process must be properly disposed. The drilling fluid, which consists of diverse chemical components, is used in the drilling operation in order to achieve specific purpose at a given site. It is pumped and recirculated through the borehole to serve several drilling operations purposes. The drill cuttings from the borehole are inert fragments of rocks and fine solids penetrated while drilling a hole and brought to the surface by drilling fluid.

Lombi *et al* (2001) conducted a pot experiment to compare two strategies of phytoremediations: natural phyto-extraction using Zn and Cd hyper accumulator, *Thlapsi caerulescens* J presl and C presl vs. chemically enhanced phytoextraction using maize (*Zea mays*) treated with ethylenediaminetetraacetiacid (EDTA). The study used an industrially contaminated soil and an agricultural soil contaminated with metals from sewage sludge. Three crops of *T. Caerulescens* grown over 391 days removed more than 8mg kg^{-1} Cd and 200mg kg^{-1} Zn from the industrially contaminated soil, representing 43 and 7% of the two metals in the soil. In contrast, the high concentration of Cu in the agricultural soil severely reduced the growth of *T. Caerulescens*, thus limiting its phyto extraction potentials. The EDTA treatment greatly increased the solubility of heavy metals in both soils, but this did not result in large increase in metal concentrations in the maize shoots. Phyto extraction of Cd and Zn by maize + EDTA was much smaller than by *T. Caerulescens* from the industrially contaminated soil, and was either smaller (Cd) or similar (Zn) from the agricultural soil. After EDTA treatment, soluble heavy metals in soil pore water occurred mainly as metal-EDTA complexes, which were persistent for several weeks. High concentration of heavy metals in soil pore water after EDTA treatment could pose an environmental risk in the form of ground water contamination.

Ma *et al* (2001) discovered the ability of the Chinese brack fern, P. Vittata to hyper accumulate arsenic. In a field test, the ferns were planted at a wood-preserving site containing soil contaminated with arsenic from 18.8 to 1,603 parts per million arsenic and they accumulated from 3,281 to 4,980 parts per million arsenic in their tissues.

Demrba (2003) sampled toxic metal levels in selected samples of various biomass types—wood, wood bark, fruit shell, mushroom, and lichen—were determined. The samples were analyzed by atomic absorption spectrophotometrically for their toxic metal elements: As, Cd, Cr, Cu, Pb, and Hg. The maximum levels of As, Cd, Cr, Cu, Pb, and Hg were 4.118 mg/kg in beech trunk wood ash, 3.926 mg/kg in Cladonia rangiformis, 15.057 mg/kg in Lactarius piperatus, 92.488 mg/kg in Amanita muscaria, 40.832 mg/kg in beech trunk bark ash, and 0.718 mg/kg in Cladonia rangiformis, respectively, in all the samples. The problem of uptake and accumulation of these elements has environmental and toxicological aspects as well. Air toxic emissions during biomass combustion were typically very low and often near or below detection limits.

Schmidt (2003) reported that for heavy metal – contaminated agricultural land, low – cost, plant – based phyto extraction measures can be a key element for a new land management strategy. When agents are applied into the soil, the solubility of heavy metals and their subsequent accumulation by plants can be increased, and therefore, phyto extraction enhanced. An overview is given of the state of the art of enhancing heavy metal solubility in soils, increasing the heavy metal accumulation of several high –biomass – yielding and metal – tolerant plants and the effect of these measures on the risk of heavy metal leaching. Several organic as well as inorganic agents can effectively and specifically increase solubility and, therefore, accumulation of heavy metals by several plant species. Crops like willow (*Salix viminalis*), Indian mustard (*Brassica juncea*), corn (*Zea mays*), and Sunflower (*Helianthus annuus*) show high tolerance to heavy metals and are therefore, to an extent able to use the surpluses that originate from soil manipulation. More than 100-fold increases of lead concentrations in the biomass of crops were reported, when ethylenediaminetetraaceticacid (EDTA) was applied to contaminated soils. Uranium concentrations could be strongly increased when citric acid was applied. Cadmium and Zinc concentrations could be enhanced by inorganic agents like elemental sulphur or ammonium sulphate. However, leaching of heavy metals due to increased mobility in soils cannot be excluded. Thus, implementation on the field scale must consider measures to minimize leaching. So, the application of more than 1g EDTA kg-1 becomes inefficient as lead concentration in crops is not enhanced and leaching rate increases. Moreover, for large-scale applications, agricultural measures as placement of agents, dosage splitting, the kind and amount of agents applied, and the soil properties are important factors governing plant growth, heavy metal concentrations, and leaching rates. Effective prevention of leaching, breeding of new plant varieties, and use of the contaminated biomass (e.g., as bio fuels) will be crucial for the acceptance and the economic breakthrough of enhanced phyto extraction.

Lindsay *et al* (2003) reported that transgenic Indian mustard (*Brassica juncea*) plants over producing the enzymes Y-glutamylcysteine synthetase (ECS) or glutathione synthetase (GS) were shown previously to have increased levels of metal-binding thiol peptides phytochelatins and glutathione, and enhanced Cd tolerance and accumulation. These results were obtained with a solution culture. To better examine the phyto remediation potential of these transgenics, a green house experiment was performed in which the transgenics were grown on metal-contaminated soil collected from a USEPA superfund site near Leadville, Colorado. A grass mixture used for revegetation of the site was included for comparism. The ECS and GS transgenics accumulated significantly ($P<0.05$) more metal in their shoot than wild type (WT) Indian mustard, while the APS plants did not. Of the six metals tested, the ECS and GS transgenics accumulated 1.5-fold more Cd, and 1.5- to 2-fold more Zn, compared with wild-type Indian mustard. Furthermore, the ECS transgenics accumulated 2.4- to 3-fold more Cr, Cu, and Pb, relative to WT. The grass mixture accumulated significantly less metal than Indian mustard: approximately 2-fold less Cd, Cu, Mn and Zn, and 5.7-fold less Pb than WT Indian mustard or an unplanted control. While WT did not remove more metal than the unplanted control for any of the metals tested, all three types of transgenics significantly soli metal concentration, and remove between 6% (Zn) and 25% (Cd) of the soil metal. This study was the first to demonstrate enhanced phytoextraction potential of transgenic plants using polluted soil. The results confirm the importance of metal-binding peptides for plant metal accumulation and show that results from hydroponic systems have value as an indicator for phyto remediation potential.

Hough *et al* (2004) performed a risk assessment of metal exposure to population subgroups living on, and growing food on, urban sites. They modeled uptake of cadmium, copper, nickel, lead, and zinc for a selection of commonly grown allotment and garden vegetables. Generalized linear cross-validation showed that final predictions of Cd, Cu, Ni, and Zn content of food crops were satisfactory, whereas the Pb uptake models were less robust. Predicted concentrations of metals in the vegetables were used to assess the risk of exposure to human populations from homegrown food sources. Risks from other exposure pathways (consumption of commercially produced foodstuffs, dust inhalation, and soil ingestion) were also estimated. These models were applied to a geochemical database of an urban conurbation in the West Midlands, United Kingdom. Risk, defined as a "hazard index," was mapped for three population subgroups: average person, highly exposed person, and the highly exposed infant (assumed to be a 2-year-old child). The results showed that food grown on 92% of the urban area presented minimal risk to the average person subgroup. However, more vulnerable population subgroups (highly exposed person and the highly exposed infant) were subject to hazard index values greater than unity. This study highlights the importance of site-specific risk assessment and the "suitable for use" approach to urban redevelopment.

Howari *et al* (2004) drew attention to heavy metal contamination associated with highways or motorways which has risen in the last decades because of the associated health hazards and risks. The present study analysed the metal content in soil samples of one of the main highways along the western part of the Jordanian border, the North Shuna–Dead Sea–Aqaba Highway. The metals analysed were Pb, Zn, Cd, Co and Ni. In the samples collected, the recorded average concentrations were as follows: 40 ppm for Ni, 5 ppm for Cd, 79 ppm for Zn, 79 ppm for Pb, and 25 ppm for Co. The average concentrations of Cd, Pb, and Co are higher than the average natural background values of heavy metals. The geo-accumulation index of these metals in the soils under study indicated that they are uncontaminated with Ni, Zn, and Co and moderately contaminated with Cd and Pb. In all of the investigated locations, the study found that concentrations decreased with depth. The cluster statistical analyses and pollution load index were used to relate pollution to land use or highway conditions. Two main trends were identified: (i) higher concentrations were located near intersections close to the urban areas in the Jordan Valley, in association with junctions controlled by traffic lights and check points; and (ii) lower concentrations were found to the southwest in areas of mainly barren landscape close to the Dead Sea and Aqaba.

Kuzovkina *et al* (2004) reported that cadmium is not an essential element for plant metabolism and can be strongly phytotoxic, causing rapid death.

Melegy and Paces (2004) reported that heavy metals in different environmental compartments can be hazardous to ecosystems. Budgets of Cd, Pb and Zn in small ecosystems of the Shubra El-Kheima area in Egypt are presented. The budgets are not in steady state because they change with time. So the concentrations of the metals are a function of time. The critical loads of heavy metals to soils can be calculated from an inventory of inputs and outputs of the trace components in the catchment area. Critical time is an important parameter for critical load evaluation because it can indicate which of the heavy metals may be the most acute threat to the soils. Egyptian soil in the Shubra El-Kheima area seems to be in danger of heavy metal pollution by Zn, Cd and Pb. The calculated critical loads and their exceedances are approximate indicators of the hazards in the soil system. The critical time is a warning signal to initiate an environmental evaluation of possible pollution hazards.

TFREC (2004) reported that Seeds and fruits have lower concentrations than do leaves, stems, or roots. Roots and tubers have highest concentrations, with the skin having higher concentrations than does the inner flesh. Tree fruits contain very low Pb and As concentrations.

Adeyeye *et al* (2005) reported that Levels of iron, zinc, manganese, copper, tin, aluminium, magnesium, sodium, potassium, lead, arsenic, chromium, cadmium, titanium and calcium were determined in cocoa seeds shell ash, liquid effluent, soil sediments and associated plants (kokoyam and cassava parts) using an atomic absorption spectrophotometer from a cocoa processing industry located at Akure along the Akure-Owo express road, Ondo State, Nigeria. The soil sediments metals were more highly concentrated than the corresponding values in the liquid effluent; both samples showed evidence of metal bioaccumulation. The toxic trace metals determined were mostly above the permissible safe levels. Plants should not be planted along the effluent channel to avoid plant bioaccumulation of toxic metals.

Adebiyi *et al* (2005) seperated bituminous sands from south-western Nigeria into water and sand fractions, and these were analysed for their physico-chemical properties and trace-metal contents to evaluate their potential environmental hazards. The samples were obtained from five different locations (Ilubirin, Agbabu, Mile 2, Olowo-Irele, and Loda) in Ondo State, south-western Nigeria. The water content was extracted using Dean and Stark apparatus, while the sands were collected as left-over from the thimble. The trace metal content was determined using total X-ray fluorescence (TXRF) spectrometry. The physico-chemical parameters (conductivity, pH, total alkalinity, total acidity, salinity, colour, organic matter, Cl^-) were determined using standard analytical methods. Copper, Cr, Zn, and As, which are known to be toxic metals, were highly enriched (enrichment factor, EF>10) in the sand fraction samples, while comparison of some of the physico-chemical parameter values of the water and sand fractions with recommended standards showed that the values of some of the parameters were relatively high. These values indicate their potential environmental hazards. This calls for proper management of the tailings that will be produced during the exploitation of the bituminous sands. Analysis of certified IAEA standard reference material (IAEA-soil-7) was carried out to ensure accuracy and precision of the TXRF technique.

Asaah *et al* (2005) carried out Partial extraction on thirty-three (33) soil samples collected from the Bassa industrial zone 1 of Douala, Cameroon. From the samples analyzed the following metal concentrations (range) were obtained (in ppm): Ag (0–1.3), As (0–64), Cd (0–7.3), Co (0–31), Cr (34–423), Cu (12–909), Mn (55–3282), Mo (0–81.6), Ni (9–284), Pb (0–3320), Sb (0–30), Sc (0.6–7.5), V (26110), Zn (30–3782), and Fe (in wt %) (1.50–47.31). Results obtained reveal background and anomalous populations for most of the metals except Sc and V, which only have background populations. Multi-element geochemical anomalies occur within the vicinity of industries, waste dump sites, metal workshops, and mechanical workshops. *R*-mode factor analysis reveals three element associations and two singular elements (As, Cd) accounting for 94% of the total data variance. The three associations are: Ag–Cu–Cr–Fe–Mn–Mo–Ni–Sb; Co–Cu–Pb–Sb–Zn; and Sc–V. The geoaccumulation indices show that soils in the Bassa industrial zone are moderately to very highly pollute. These metal-laden soils constitute a major health risk to the local population and a cause for concern. This study successfully relates the concentration and distribution of toxic metals in the soils of the Bassa industrial zone to urban effluents generated mainly from industrial activities.

Audu and Lawal (2005) reported that the high concentrations of heavy metals in plants could be attributed to the use of untreated wastewater by farmers for the irrigation of vegetables.

Available phosphorus had significant (*P*=0.05) negative relationship with all heavy metals, implying unavailability of phosphorus in soils affected by wastewater. Abundance of Fe in these soils increases phosphate sorption (Giesler *et al*., 2005).

Anikwe and Nwobodo (2006) have reported high level of heavy metals (Pb, Fe, Cu and Zn) in their study of the long term effects of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, South eastern part of Nigeria.

Karkhanis *et al* (2005) conducted an experiment on rhizofilteration in a greenhouse, usingpistia, duckweed and water hyacinth (eichornia crassipes) to remediate aquatic environment contaminated by coal ash containing heavy metals. Rhizofilteration of coal ash started from 0, 5, 10, 20, 30, and 40%. Simultaneously the physicochemical parameters of leachate were analysed and results showed that pitia has high potential capacity of uptake of the heavy metals (Zn, Cr and Cu) and duckweed also showed good potential for uptake of these metals next to pistia. Rhizofilteration of Zn and Cu in case of water hyacinth was lower as compared to pistia and duckweed. This result shows that pistia/duckweed/water hyacinth can be good accumulators of heavy metals in aquatic environment.

Meers *et al* (2005) proposed Phytoextraction as an alternative remediation technology for soils polluted with heavy metals or radionuclides, but is generally conceived as too slow working. Enhancing the accumulation of trace pollutants in harvestable plant tissues is a prerequisite for the technology to be practically applicable. The chelating aminopolycarboxylic acid, ethylene diamine tetraacetate (EDTA), has been found to enhance shoot accumulation of heavy metals. However, the use of EDTA in phytoextraction may not be suitable due to its high environmental persistence, which may lead to groundwater contamination. This paper aims to assess whether ethylene diamine disuccinate (EDDS), a biodegradable chelator, can be used for enhanced phytoextraction purposes. A laboratory experiment was conducted to examine mobilisation of Cd, Cu, Cr, Ni, Pb and Zn into the soil solution upon application of EDTA or EDDS. The longevity of the induced mobilisation was monitored for a period of 40 days after application. Estimated effect half lives ranged between 3.8 and 7.5 days for EDDS, depending on the applied dose. The minimum observed effect half life of EDTA was 36 days, while for the highest applied dose no decrease was observed throughout the 40 day period of the mobilisation experiment. Performance of EDTA and EDDS for phytoextraction was evaluated by application to *Helianthus annuus*. Two other potential chelators, known for their biodegradability in comparison to EDTA, were tested in the plant experiment: nitrilo acetic acid (NTA) and citric acid. Uptake of heavy metals was higher in EDDS-treated pots than in EDTA-treated pots. The effects were still considered insufficiently high to consider efficient remediation. This may be partly due to the choice of timing for application of the soil amendment. Fixing the time of application at an earlier point before harvest may yield better results. NTA and citric acid induced no significant effects on heavy metal uptake.

Soltan *et al* (2005) reported that in soils unaffected by wastewater, greater concentrations of heavy metals were noticed, suggesting possibility of fallen forms of these metals on the soils unaffected by wastewater. This could be due to proximity of sources of the wastewater to the study site in soils proximal to a ferrosilicon production factory at Edfu, Aswan in Egypt.

Nickel in small amounts is essential for maintaining proper health in animals and humans (Egyptian Environmental Affair Agency, 1996), while in concentrations of $2.03\times10{-}6$ mg/kg or less it may not have adverse health effects (Soltan *et al.*, 2005).

Carrasqueros Durán *et al.* (2006) reported that vermicompost is effective in the removal of heavy metals in soil.

Desrosiers *et al* (2006) reported that photocatalytic process as a method of heavy metal removal from soil is expensive.

Gueu *et al.* (2006) suggested hulls of palm tree for bioremediation.

Ita *et al* (2006) analysed Fruiting bodies of ten mushroom species (edible & non-edible) for their heavy metals content. Results indicated that the concentration of heavy metals accumulated by the mushrooms were species-dependent. *Formes applanatus* had the highest concentration of Zn and Cu, while the levels of Pb and Cd were highest in the non-edible species of *Paragyrodon sphaerosporus*. Iron was highly accumulated by *Polyporus frondosis* with a maximum value of 731.6 ± 13.2 mg kg-1 DM. The heavy metal accumulating potential of the mushrooms generally decreased in the trend: Fe > Zn > Cu > Mn > Pb > Cd. However, the levels in all the edible species (*Polyporus frondosis, Armillariella mellea, Pleurotus sapidus, Polyporus sulphureus, and Pleurotus ostreatus*) did not exceed the stipulated FAO/WHO (1976) dietary standards.

Sun *et al* (2006) reported that the concentrations of Cu, Zn, Pb and Cd in soils near a lead–zinc mine located in Shangyu, Zhejiang Province, China, were determined and their toxicity was assessed using the toxicity characteristic leaching procedure (TCLP) developed by the United States Environmental Protection Agency. The TCLP method is a currently recognized international method for evaluation of heavy metal pollution in soils. The available levels of Cu, Zn, Pb and Cd were 8.2–36, 23–143, 6.4–1367 and 0.41–2.2 mg kg^{-1}, respectively, while the international standards were 15, 25, 5 and 0.5 mg kg^{-1}, respectively. Soils around the mine were more polluted with Zn and Pb, followed by Cd and Cu. Moreover, the levels of heavy metals in the soils extracted by TCLP indicated that extraction fluid 2 was more effective than extraction fluid 1 in extracting the heavy metals from the polluted soils and there was a positive correlation between fluids 1 and 2. Available heavy metal contents determined by TCLP were correlated with soil total heavy metal contents.

Akaninwor *et al* (2007) evaluated the concentrations of selected heavy metals and physico-chemical characteristics of effluents from a beverage company in Rivers State, Nigeria and those of the receiving Woji River to ascertain the efficiency of the company's waste treatment processes. The results showed that the contents of Mg in downstream water samples differed significantly ($p< 0.05$) from those of upstream and effluent samples with a value of 80.8mg/l. However, the concentration of Na^+ in the upstream samples far exceeded those of other samples with a mean value of 791mg/l. The concentrations of Cd, Pb and Cr fell below detection limit of 0.001mg/l for all samples. Also, the levels of Fe, Zn, and Mn were low with Fe having the highest concentration of 2.10mg/l (downstream and treated effluent samples, respectively). The pH of the samples was generally alkaline, except the upstream samples that gave a pH value of 6.89. The dissolved Oxygen contents of all the samples fell below FEPA limit of 10mg/l. However, the highest chemical oxygen demand concentration of 93.7mg/l was obtained in the untreated effluent sample. The mean ammonia concentration of the untreated sample was much higher than those of the treated with a value of 50.0mg/l. Also, total dissolved solid content of the untreated sample fell far above those of the treated sample. In general, whereas the concentrations of nutrient metals were higher in the treated samples, the contents of the physico-chemical parameters in the treated samples fell far below those of the untreated samples. These findings suggest that the treatment system adopted by the beverage company is efficient for effluent treatment as the values fell within the natural background levels.

Isildak *et al* (2007) studied some heavy metal uptake in mushroom species; their metal content in soil substrate and the relation in between metal concentration in mushroom and soil were investigated. Mushroom species and soil in which mushroom species were grown were collected from Tokat region of Turkey. Six different mushroom species and their underlying soil (0-10 cm layer) samples were analyzed for some heavy metals (Cu, Pb, Fe, Zn, Cd, Mn, Ni, Cr and Co). The analysis was performed with an atomic absorption spectrometer. The results indicate that in general, heavy metal contents in all mushroom species were lower than the underlying soil substrates except for some mushroom species. The results obtained from the analyses of mushroom and underlying soil samples were evaluated using linear correlation analysis and concentration factors to identify the metal accumulation of mushrooms.

Obasohan (2007) assessed and monitored the concentrations of Cu, Mn, Zn, Cd, Cr, Ni and Pb in the gills, offal, muscle and liver of a commercially important mudfish (*Parachanna obscura*) from Ogba River, Benin City, Nigeria between January and December, 2005. The same metals were also determined in the water of the river. The results revealed that the concentrations of all the metals in the tissues (offal, gills, muscle and liver) were higher than the concentrations of the metals in water and indicated bioaccumulation. The concentrations of all the metals in water were below WHO and FEPA recommended limits and suggested that the water of Ogba River was suitable for drinking, but the concentrations of Cu, Mn, Cr, Ni and Pb in all fish tissues exceeded these limits and indicated that the fishes of Ogba River, as far as these metals were concerned, were unfit for human consumption. Consequently, close monitoring of metals pollution and the consumption of the fishes of Ogba River is recommended with a view to minimizing the risks to health of the population that depend on the river for their water and fish supply.

Ra *et al* (2007) reported that soils affected by wastewater treatment plant activity exhibited significant toxicity on Daphnia magna and Selenastrum capricornutum growing within Youngsan River watershed in Soul, Korea

Akeredolu (2008) investigated the concentration of heavy metals in surface water of bitumen seepage areas of Ondo state, Nigeria. Results revealed the following mean values: Fe for dry season 0.67mg/l was greater than that of dry season 0.33mg/l; Pb 0.38mg/l in the wet season was greater than 0.22mg/l in the dry season; Cr value 0.20mg/l in the wet season was lower than 0.35mg/l in the dry season. Zn in the wet season 0.12 mg/l was lower compared to that of dry season, 0.15mg/l; Cd 0.10 in the wet season was greater than 0.09mg/l in the dry season. Cu 0.50mg/l in the wet season was lower compared to 0.52mg/l in the dry season. It was found that Mn, Zn, Cu, Cr, Cd, Pb varied significantly between locations, but not significant for seasons. Fe, Pb and Cr were found to be higher than standard limits. Mn, Zn and Cu are lower compared to standard limits, while Cd is within desirable permissible limit.

Chhotu and Fulekar (2009) reported that the current remediation technique of heavy metal from contaminated soil-water are expensive, time consuming and environmentally destructive. Unlike organic compounds, metals cannot degrade, and therefore effective cleanup requires their immobilisation to reduce or remove toxicity. In recent years, scientists and engineers have started to generate cost effective technologies that include use of microorganisms/biomass or live plants to clean polluted areas. Phytoremediation is an emerging technology for cleaning up contaminated sites, which is cost effective, and has aesthetic advantages and long term applicability. It is best applied at sites with shallow contamination of organic, nutrient or metal pollutants that are amenable to one of the five applications; phytotransformation, rhizosphere bioremediation, phytostabilisation, phytoextraction and rhizofiltration. The technology involves efficient use of plants to remove, detoxify or immobilize environmental contaminants in a growth matrix (soil, water or sediments) through the natural, biological, chemical or physical activities or processes of the plants.

Onweremadu (2008) investigated selected properties of soils affected by wastewater and its relationship with some heavy metals. A free survey technique involving target sampling was used in siting soil profile pits. Soil samples were collected based on horizon differentiation and analyzed using routine and special analytical techniques. Soil data were subjected to correlation analysis using SAS program. Results show that all heavy metals studied had values above critical limits in the polluted soils using known standards and that these biotoxic metals decreased with soil depths.

Highly significant (P=0.01 and 0.05) relationships were established between investigated heavy metals and some soil properties, especially soil pH and organic matter. Further studies involving more edaphic properties, biotoxic metals and their bioaccessibility in crops growing on wastewater soils will surely enhance knowledge and management of these highly anthropogenically influenced soils of the study site.

Arao *et al* (2009) reported that rice consumption is a major source of cadmium and arsenic for the population of Asia. They investigated the effects of water management in rice paddy on levels of cadmium and arsenic in Japanese rice grains. Flooding increased arsenic concentrations in rice grains, whereas aerobic treatment increased the concentration of cadmium. Flooding for 3 weeks before and after heading was most effective in reducing grain cadmium concentrations, but this treatment increased the arsenic concentration considerably, whereas aerobic treatment during the same period was effective in reducing arsenic concentrations but increased the cadmium concentration markedly. Flooding treatment after heading was found to be more effective than flooding treatment before heading in reducing rice grain cadmium without a concomitant increase in total arsenic levels, although it increased inorganic arsenic levels. Concentrations of dimethylarsinic acid (DMA) in grain were very low under aerobic conditions but increased under flooded conditions. DMA accounted for 3−52% of the total arsenic concentration in grain grown in soil with a lower arsenic concentration and 10−80% in soil with a higher arsenic concentration. A possible explanation for the accumulation of DMA in rice grains is that DMA translocates from shoots/roots to the grains more readily than does inorganic arsenic.

Adewole (2009) investigated the hydrocarbon and toxic metal contents of the bitumen-impacted soil, sediment and water samples within the Ogun block aspect of Nigerian bitumen belt. The aim was to determine the level of induced pollution on the immediate environments directly under the influence of the oil tar seepage. The results indicate exceptionally high concentration of both total hydrocarbon and polynuclear aromatic hydrocarbons in all types of samples in varying degrees (i.e., sediment > soil > water) when compared to the standard values. These obtained values depict pollution which may be induced on animals and humans interacting with each of these micro environments. It is anticipated that proper management of the bitumen seeps in the study areas at present and effective planning of its exploitation in future will reduce to the barest minimum all its diverse but serious effects on the biota.

Chen *et al* (2009) collected Cu, Ni, Cd, Hg, As, and Pb contents in wild edible mushrooms from three different sites in China and determined them by atomic absorption spectrometry and atomic fluorescence spectrometry. All element concentrations were determined on a dry weight basis. A total of 11 species was studied, five being from the urban area and six from rural areas in China. The As content in the mushrooms ranged from 0.44 to 1.48 mg/kg. The highest As content was seen in *Macrolepiota crustosa* from the urban area, and the lowest in *Russula virescens* from rural areas. A high Ni concentration (1.35 mg/kg) was found in *Calvatia craniiformis* from the urban area. The lowest Ni level was 0.11 mg/kg, for the species *R. virescens* and *Cantharellus cibarius*. The Cu content ranged from 39.0 to 181.5 mg/kg. The highest Cu content was seen in *Agaricus silvaticus* and the lowest in *C. cibarius*. The Pb content ranged from 1.9 to 10.8 mg/kg. The highest Pb value was found in *C. craniiformis.* The Cd content ranged from 0.4 to 91.8 mg/kg. The highest Cd value was found in *M. crustosa.* The Hg content ranged from 0.28 to 3.92 mg/kg. The highest Hg level was found in *Agaricus* species. The levels of the heavy metals Cd, Pb, and Hg in the studied mushroom species from urban area can be considered high. The metal-to-metal correlation analysis supported they were the same source of contamination. High automobile traffic was identified as the most likely source of the contamination. Based upon the present safety standards, consumption of those mushrooms that grow in the polluted urban area should be avoided.

Mathur and Yadav (2009) defined Phytoextraction as an ecofriendly technology through which plants are used for removing heavy metal contaminant from polluted sites. The effective implementation of this cost effective emerging technology requires a conceptual insight of soil and plant processes that control the uptake of targeted contaminant from the problematic area. Most of the current research deals with the plants grown in heavy metal contaminated soils and analyzed experimentally to determine their capacity to remove them from the soil. However, the prediction of the metal uptake by plants through mathematical modeling has received very little attention so far due to the complexity of the soil-plant-atmosphere continuum. In this study, a mathematical model is developed to investigate the removal of a heavy metal, lead (Pb), by maize at different growth stages of the plant. The model comprised of two parts: (1) moisture flow prediction and (2) contaminant uptake simulation. The first part predicts the actual water uptake by plant and computes the hydraulic regime of the soil profile for different moisture conditions. Through the second part of the model, the lead extraction kinetics is simulated using the water uptake data and plant root biomass accumulation. The model yields a set of partial differential equations which are solved numerically by the finite difference technique for varying boundary conditions. The moisture flow simulation is validated using the literature of field data for maize and the metal extraction simulation is performed based on this prediction for a characteristic example to remediate a lead contaminated site.

2.5: Migration of contaminants

Department of Environment (2009) reported that the migration of contaminants is dependent upon their physical and/or chemical characteristics and upon the hydro-geological and geochemical characteristics of the site. Low viscosity liquid and gaseous hydrocarbons are highly mobile and may migrate from point sources to contaminate a wide area. Unless trapped in impermeable strata or in existing infrastructure, the gaseous substances will have evaporated fairly rapidly from their original point of deposition or disposal. Viscous liquids and semi-solid tars are less mobile, but also flow and therefore may have migrated. Liquids released at the surface or leaking from an underground structure will flow down through the ground under the influence of gravity. Some hydrocarbons will be adsorbed onto soil particles and retained in soil pores. On encountering ground water, the liquid will typically spread out on the surface of the water and migrate laterally, preferentially in the direction of ground water flow. The volatile components will diffuse into the overlying soil and migrate as a vapour from ahead of the free product. Vapour emission from contaminated land could accumulate in poorly ventilated spaces and present a health and explosion hazard. Insoluble liquids which are denser than water will sink through the groundwater until they encounter an impermeable barrier, where they will spread out and possibly continue to migrate in the direction of groundwater flow. Soluble components (such as phenols) will dissolve in the groundwater and migrate in the direction of groundwater flow. Soluble inorganic contaminants deposited on the surface or in the unsaturated zone may be leached by rainwater infiltration and also enter underlying groundwater. Metal contamination is likely to be localised. The movement of metals through the soil is reduced by the presence of organic matter and by solubility limitations. However, low PH conditions caused by the presence of mineral acids could enhance the mobility of some metals. Metals attenuated in soils at, or close to the surface may be transported by wind action. Mineral acids will migrate within soil-water. The buffering capacity of most soils will neutralise acidity to some degree. However, soluble mineral acid anaions, such as nitrate or chloride, can migrate freely through the soil. Generally, the higher the organic matter and particularly clay content of the soil the greater the degree of adsorption of organic compounds and hence the lower their mobility. The greatest degree of contamination migration will occur in coarse-grained sands and gravels with little organic content. Some organic contaminants will biodegrade naturally in soils, although the rate of degradation will depend upon the environmental conditions. However, asbestos, metals and most other inorganic contaminants are not biodegradeable. Wind dispersal of contaminated soil may be a further transport mechanism where there is gross surface contamination by some of the less mobile contaminants, particularly metals and asbestos. PCBs are highly persistent and fat soluble, possibly leading to accumulation in food chains.

2.6: Habitat Degradation and Threats to Biodiversity Conservation

Plants

Bever *et al* (1997) reported that although its importance for plant mineral nutrition and nutrient cycling has long been recognized; the soil community has rarely been integrated into dynamical frameworks of plant populations, in spite of abundant evidence for its involvement. The concept of feedback may provide theoretical and experimental tools for investigating the importance of the soil community in the population ecology and evolution of plants. A mathematical model demonstrates the potential for two divergent dynamics, with positive feedback leading to the loss of diversity at a local scale and negative feedback leading to its maintenance. A linear contrast of the growth of plants in association with their own soil communities compared to the growth of plants in association with each others' soil communities can be used to differentiate between these possibilities in empirical studies. Spatially explicit computer simulations demonstrate that the dynamics of a spatially structured community, as the soil community is likely to be, can differ from those predicted for a well-mixed population. Specifically, diversity can be maintained between locally homogeneous patches when positive feedback and dispersal occur at local scales. Using a simple experimental protocol, substantial negative feedback on plant growth was found through the soil community, suggesting that it may be involved in the maintenance of plant species diversity. It was suggested that interactions with the soil community may be involved in the maintenance of sexual or asexual reproductive systems.

Young *et al* (1996) reported that habitat fragmentation reduces the size and increases the spatial isolation of plant populations. Initial predictions have been that such changes will be accompanied by an erosion of genetic variation and increased inter-population genetic divergence due to increased random genetic drift, elevated inbreeding and reduced gene flow. Results of recent empirical studies suggest that while genetic variation may decrease with reduced remnant population size, not all fragmentation events lead to genetic losses and different types of genetic variation (e.g. allozyme and quantitative variation) may respond differently. In some circumstances, fragmentation actually appears to increase gene flow among remnant populations, breaking down local genetic structure.

Soladoye and Olowokudejo (1999) reported that harvests to meet the demand for a growing number of medicinal species are in many cases exceeding sustainable levels. If these trends are allowed to continue, many medicinal plants which are chemical factories of almost limitless potential are at a risk and may become extinct before they are even described scientifically.

Fragmentation from agriculture and urbanization reduces the size of habitat patches, and isolates them from each other, which could affect the species found in the remaining fragments (Johnson, 2000).

Kahmen and Poschlod (2000) screened four isozymes to study the genetic variation of the populations. The results of the study suggest that small populations of plants exhibit a reduced reproductive success which could not be attributed to genetic erosion. It might be attributed to the longevity of the clonal *A. montana* that the genetic structure of the populations examined has remained unaffected by the habitat fragmentation so far. In addition, gene flow has probably still been taking place between the fragmented populations. Possibly, the reduced reproductive success of plants in the small populations was caused by missing availability of cross-compatible pollen because of a reduced set of S-alleles due to genetic drift. Furthermore, environmental maternal effects may have played an important role in reproduction and germinability.

Ghersa *et al* (2002) reported that information on the geographical distribution of plant invasion has been recorded in detail in some areas of the world; however, in large regions such as South America there are a few, if any, records of the spread of alien plants and invasive species and even less information about their effects on ecosystems at different levels of organization. This study examines the extent to which woody species introduced during the last centuries are invading the Rolling Pampa (which is typical of the entire region of the Argentina pampas) and discusses whether this invasion is related to the species' genetics or to environmental factors. All woody species were surveyed along landscape corridors (highways and intersecting secondary dirt roads and streams), as well as in farmed fields under three different tillage systems: zero tillage in the entire field for all crops in the rotation (where tillage was replaced by a presowing herbicide application), zero tillage for selected crops, and conventional tillage. Landscape corridors along the roads had been invaded by 40 woody species (mostly trees). On the farmed land, fields under the zero tillage farming system were invaded by seven woody species (three tree species and four shrubs). With zero tillage for select crops only, woody species richness was reduced to three (one tree and two shrub species). In the conventional tillage, there were only three invading species, all shrubs. In both the roadside and riparian corridors, the species with the highest constancy values were *Gleditsia triacanthos* L., *Morus alba* L., and *Melia azedarach* L. In both types of zero tillage farmed fields, *M. alba* was absent, but *G. triacanthos* and *M. azedarach* remained the species with the highest constancy values. Both genetic and ecological factors were important determinants for the invasion of the pampas by woody species. The woody invasion process has reached a point at which the Pampean grasslands on the better-drained soils will no longer be restored to a grassland biome without human intervention.

FOSA (2003) reported that currently in Africa, forests and forestry confronts a number of problems, including a rapid decline in forest cover, loss of biological diversity and a variety of unsustainable uses that cast uncertainty on the future flows of goods and services.

Land areas with higher degrees of urbanization are known to have increased numbers of woody and invasive species. Furthermore, increased woody vegetation is known to correlate with decreased density of native grassland bird species (Chapman and Reich 2007).

Jacquemyn *et al* (2007) reported that in much of Western Europe, orchid species have suffered dramatic declines in abundance, whereas the remaining populations often tend to be small and isolated, occur in ecologically marginal habitats and may show decreased reproductive output due to altered pollinator interactions or the absence of specialized pollinators. Furthermore, small and isolated populations were expected to suffer from genetic erosion and increasing genetic divergence among populations, through the effects of random genetic drift, increased levels of inbreeding and reduced gene flow, potentially leading to reduced possibilities of population recovery in the future. In this study, genetic diversity and fitness variation were studied in nine fragmented populations of the food deceptive orchid *Orchis purpurea*. Within-population genetic diversity and among-population differentiation were investigated using dominant AFLP markers. All studied populations were relatively small (range 12–302; mean: 90 individual species/ population). Despite their small size, genetic diversity within populations was rather high (mean gene diversity H_j: 0.21, range: 0.15–0.27) and genetic differentiation among populations was not higher than that typically observed in deceptive orchids ($F_{ST} = 0.09$). Nevertheless, Mantel tests showed a positive correlation between geographical and genetic distances indicating limited gene flow among populations. Fruit set, on the other hand, was very low (average fruit set: 5.5%), suggesting strong pollinator limitation, which, in turn, resulted in very low recruitment rates (average seedling recruitment per flowering individual: 0.12). Both measures significantly increased with increasing population size, indicating that a certain threshold value (>50 flowering individuals) has to be reached to produce a sizeable number of fruits and seedlings. These results suggested that although deceptive pollination clearly results in a fitness cost, it may serve as an effective means to maintain high gene diversity within and to counter high genetic differentiation among small orchid populations. From a genetic point of view, results further suggest that small populations of orchid species should not be neglected as they may harbour as much genetic diversity as large populations.

John (2008) reported that, fragments of habitat are often viewed as islands and are managed as such; however, habitat fragmentation includes a wide range of spatial patterns of environments that may occur on many spatial scales. Fragments exist in a complex landscape mosaic, and dynamics within a fragment are affected by external factors that vary as the mosaic structure changes. The simple analogy of fragments to islands, therefore, is unsatisfactory. Understanding how birds respond to these complexities of fragmentation requires mechanistic studies focused on habitat selection and movement behaviour. Conservation efforts must be based on viewing fragmentation as a range of conditions that occurs in a landscape mosaic and management should be directed toward the mosaics rather than focusing solely on reserves.

Lawton-Rauh (2008) reported that demographic processes modulate genome-wide levels and patterns of genetic variation via impacting effective population size independently of natural selection. Such processes include the perturbation of population distributions from external events shaping habitat landscape and internal factors shaping the probability of contemporaneous alleles in a population (coalescence). Several patterns have recently emerged: spatial and temporal heterogeneity in population structure have different influences on the persistence of new mutations and genetic variation, multi-locus analyses indicate that gene flow continues to occur during speciation and the incorporation of demographic processes into models of molecular evolution and association genetics approaches has improved statistical power to detect deviations from neutral-equilibrium expectations and decreased false positive rates.

Odugbemi (2008) reported that the most serious proximate threats to biodiversity are habitat loss, habitat degradation, intensive cultivation, population pressure and over-exploitation. Within the last 30 years, it is believed that about 43% of the forest ecosystem has been lost through human activities, upsurge in human numbers and consumption patterns. There has also been a significant increase of 84,762km2 of the total rain-fed agricultural areas of the country cleared for intensive, extensive and flood agriculture. A total area of about 5,981km2 was also cleared for the establishment of plantation trees crops, forest trees, and irrigation and livestock projects.

Vamosi *et al* (2008) reported that the analysis of the phylogenetic structure of communities can help reveal contemporary ecological interactions, as well as link community ecology with biogeography and the study of character evolution. The number of studies employing this broad approach has increased to the point where comparison of their results can now be used to highlight successes and deficiencies in the approach, and to detect emerging patterns in community organization. They reviewed studies of the phylogenetic structure of communities of different major taxa and trophic levels, across different spatial and phylogenetic scales, and using different metrics and null models. Twenty-three of 39 studies (59%) find evidence for phylogenetic clustering in contemporary communities, but terrestrial and/or plant systems are heavily over-represented among published studies. Experimental investigations, although uncommon at present, hold promise for unravelling mechanisms underlying the phylogenetic community structure patterns observed in community surveys. They discussed the relationship between metrics of phylogenetic clustering and tree balance and explore the various emerging biases in taxonomy and pitfalls of scale. Finally, they looked beyond one-dimensional metrics of phylogenetic structure towards multivariate descriptors that better capture the variety of ecological behaviours likely to be exhibited in communities of species with hundreds of millions of years of independent evolution.

Corenblit *et al* (2009) reported that riparian systems provide diverse landforms, habitats and resources for animals and plants. Certain organisms, defined as 'ecosystem engineers', significantly create and modify the physical components of riparian systems. Many studies have highlighted such engineering effects by animals on riparian systems, but the identification and understanding of the effects and responses of plants within fluvial corridors have emerged only recently. The modulation of matter, resources and energy flows by engineering plants helps establish characteristic sequences of fluvial landform creation and maintenance associated with synergetic ecological successions. They related this process to the concept of niche construction, developed mainly by evolutionary biologists.

Young and Metzler (2010) reported that one plant that is adapted to the rainforest is the fern leaf. The fern leaf is adapted to the rainforest because it lives on the rainforest floor and doesn’t get much sunlight. Because it lives on the ground, not only does it not get a lot of sunlight it does not receive a lot of rainwater since the canopy absorbs much of it. So its roots have adapted by anchoring the plant to the ground and saving the little water it receives. It also leans towards the sunlight that comes through the canopy. One animal that is adapted to the rainforest is the howler monkey. It has many adoptions to the rainforest that help it with its everyday life. One adaptation is its long tail that allows them to hang a great distance down from branches where it lives. Their hands with opposable thumbs allow them to climb trees easier and to grab food. Their black fur also helps hide them in the trees where they live.

Birds

Soule *et al* (1992) reported that the effects of fragmentation in a scrub habitat in California on three taxa (plants, birds, and rodents) are concordant. Extinctions within the habitat remnants occur quickly and the sequence of species disappearances of birds and rodents is predictable based on population density in undisturbed habitat. Distance effects on species diversity were weak to non-existent, and habitat area effects were strong. Edge effects and cumulative habitat loss following isolation of the remnants were correlated with loss of species diversity. Recolonization in these taxa occurs rarely. Rodents appeared to be extremely susceptible to extinction. Small, old patches retain a predictable subset of bird and rodent species, reinforcing the principle that larger reserves are generally superior.

Graham and Des Granges (1993) revealed that farming practices have a direct effect on birds breeding in monoculture farms of corn, wheat, soybeans and legumes, (and dairy farms with its associated crops of pastures, hay, clover, barley and oats); intensive farming leads to nests being over run by farm machineries.

Boutin *et al* (1994) confirmed that farming practices also destroy many habitats used extensively by birds that are located on the margins of cultivated areas. The elimination of farm woodlots is generally associated with a reduction in species abundance and richness. The physical aspects of cash crops are similar regardless of the crop: bare earth with scattered seedlings, growing more or less densely depending on the crop. This may limit frequentation by birds, which probably find more insects and plant food in fodder crops and pastures land, where the vegetation provides habitats for insects and protection from predators. In addition, minimal amounts of pesticides are used on forage crops and pasture land in comparison to cash crops, which helps to maintain a greater diversity of vegetation in adjacent habitats and thus probably helps to improve wildlife habitats.

Schroeder *et al* (1992) observed the same phenomenon when the margins between cultivated fields (shelterbelts, hedgerows, e.t.c.) extensively used by farmland species are eliminated.

Herkert (1994) studied the influence of area and vegetation structure on breeding bird communities associated with 24 Illinois grassland fragments (0.5-600 ha) between 1987 and 1989 to document the effects of habitat fragmentation in a severely fragmented mid-western landscape. Fragment area strongly influenced bird communities within grasslands and accounted for a high percentage of the variation in mean breeding bird species richness among fragments ($R^2 = 0.84$). Breeding bird species richness patterns within 4.5-ha subsections of these grasslands also significantly increased with fragment size. Eight of the 15 (53%) most common bird species had distributions among fragments that were significantly influenced by habitat area, whereas six species (40%) had distributions within fragments that were significantly influenced by vegetation structure only. The Dickcissel (*Spiza americana*) was the only species with a distribution within fragments that was not significantly associated with either habitat area or vegetation structure. Four groups of birds were identified by an analysis of habitat area and vegetation structure preferences of individual species: area-sensitive species (5 species), edge species (3), vegetation-restricted species (6), and the Dickcissel. Estimates of minimal area requirements for the five area-sensitive species ranged from 5 to 55 ha. Discriminant analyses of habitat suitability within fragments suggested that the absence of area-sensitive grassland bird species from some small fragments may result, in part, from limited habitat availability. All five area-sensitive species, however, also regularly avoided structurally suitable habitat on small grassland fragments. As a result of the considerable extent to which native and, more recently, agricultural grasslands have declined in the Midwest, habitat fragmentation is likely to have caused mid-western grassland bird declines, especially for area-sensitive species.

The lack of woody cover limits habitability for game birds on Conservation Reserve Program acreages in northwest Texas (Lutz *et al*, 1994).

Freemark and Boutin (1995) revealed that herbicide spray drift plays a role in reducing the diversity of vegetation in habitats near cultivated fields, which affect birds' food sources and reproduction.

Lawton *et al* (1998) reported that, despite concern about the effects of tropical forest disturbance and clearance on biodiversity, data on impacts, particularly on invertebrates, remain scarce. They reported a taxonomically diverse inventory on the impacts of tropical forest modification at one locality. They also examined a gradient from near-primary, through old-growth secondary and plantation forests to complete clearance, for eight animal groups (birds, butterflies, flying beetles, canopy beetles, canopy ants, leaf-litter ants, termites and soil nematodes) in the Mbalmayo Forest Reserve, south-central Cameroon. Although species richness generally declined with increasing disturbance, no one group serves as a good indicator taxon for changes in the species richness of other groups. Species replacement from site to site (turnover) along the gradient also differs between taxonomic groups. The proportion of 'morphospecies' that cannot be assigned to named species and the number of 'scientist-hours' required to process samples both increase dramatically for smaller-bodied taxa. Data from these eight groups indicate the huge scale of the biological effort required to provide inventories of tropical diversity, and to measure the impacts of tropical forest modification and clearance.

Richard and Thomas (2001) reported that abundances of forest birds in an unfragmented, undisturbed, and relatively mature temperate deciduous forest at the Hubbard Brook Experimental Forest, New Hampshire, changed markedly between 1969 and 1998. Total numbers of birds (all species combined) declined from 210–220 individuals/10 ha. Of the 24 regularly occurring species, 12 decreased significantly (four to local extinction), three increased significantly, and nine remained relatively constant in abundance. Nine of the 12 declining species were Neotropical migrants. Most species exhibited similar trends on Breeding Bird Survey (BBS) routes in New Hampshire during the same 30 year period and on three replicate study sites in nearby sections of the White Mountains from 1986–1998. Probable causes of trends were diverse and differed among species. Most could be accounted for by individual species' responses to events occurring primarily in the local breeding area. The most important local factor affecting bird abundance was temporal change in forest vegetation structure, resulting from natural forest succession and local disturbances.

Findings from this study demonstrated that major changes in bird abundances occur over time even in undisturbed and relatively mature forests, and illustrate the need for considering habitat requirements of individual species and how habitat suitability changes over time when trying to assess the causes of their long-term population trends. The results also imply that any conclusions about the effects of other factors affecting forest bird abundances, such as increased nest predation or brood parasitism associated with habitat fragmentation, must also account for successional changes that may be affecting habitat suitability.

Duffy (2002) reported that proposed links between biodiversity and ecosystem processes have generated intense interest and controversy in recent years. Several considerations suggest that changing diversity in multi-level food webs can have important ecosystem effects that can be qualitatively different than those mediated by plants. First, extinctions tend to be biased by trophic level: higher-level consumers are less diverse, less abundant, and under stronger anthropogenic pressure on average than wild plants, and thus face greater risk of extinction. Second, unlike plants, consumers often have impacts on ecosystems disproportionate to their abundance. Thus, an early consequence of declining diversity will often be skewed trophic structure, potentially reducing top-down influence. Third, where predators remain abundant, declining diversity at lower trophic levels may change effectiveness of predation and penetrance of trophic cascades by reducing trait diversity and the potential for compensation among species within a level. The mostly indirect evidence available provides some support for this prediction. Yet effects of changing animal diversity on functional processes have rarely been tested experimentally. Evaluating impacts of biodiversity loss on ecosystem function requires expanding the scope of current experimental research to multi-level food webs.

Urbanization and agriculture both have impacts on natural landscapes; however, urbanization generally has a more permanent and damaging effect than agriculture (McKinney, 2002).

Martins *et al* (2003) used a latitudinal approach to explore the effects of disturbance on birds, but specific attention was paid to whether natural geographically-based variation in the forest ecosystem might have been a major contributory factor equal to, or greater than, effects of disturbance. Bird census data were collected from two Indonesian islands, Sumba and Buru. On Sumba the differences between habitat types in terms of species richness, species accumulation rates, and numbers of birds were swamped by simple site differences between the forest blocks sampled. On Buru, disturbed areas were more diverse than mature forest but it was still not possible to discount the effects of natural variation between forest areas. Although the islands support bird faunas which are rather similar in size and origin, local species diversities and abundances were significantly greater on Sumba.

Blair (2004) revealed that species richness and diversity of birds increase at moderate levels of urbanization, and decrease with high levels of development.

Fernandez *et al* (2004) reported that during the past century, the Pampas meadowlark *Sturnella defilippii* underwent a severe population drop and now, it is confined mostly to southern Pampas's grasslands. They analyzed the habitat and landscape characteristics associated to the presence of reproductive groups of Pampas meadowlarks in this area. During the 1999 breeding season, 89 randomly stratified selected points were surveyed where they noted the presence/absence of Pampas's meadowlarks. For each point they estimated seven habitat variables related to vegetation cover and six landscape variables derived from different maps. They found 11 groups of displaying males, nine of them on natural grassland plots. Multivariate analyses indicate that field type and vegetation cover are the main factors associated to the presence of Pampas meadowlark. Reproductive groups were found preferentially at natural grasslands with high vegetation cover. Habitat loss and intensive grazing of fields appear to be the main factors associated to their sharp population decline and distribution retraction.

Brenda (2005) reported that several varieties of birds, insects, and small mammals were at home in grasslands, prairies, and young forests. These include pheasant, quail, Ruffed Grouse, and American Woodcock, all sought-after game birds. When large tracts of land were planted in row crops, which did not produce desirable cover, populations of these birds and animals leave the area. When suburban housing communities replace farms, swaths of green lawns accented with mulched flower beds replace native grasses, and small woody plants. Suburban lawn care usually entails the use of quantities of fertilizer, herbicides, and insecticides designed to protect manicured landscapes. The resulting environment is pretty in the eyes of the homeowners, but it is unsuitable for birds seeking cover and food. Young forests provide prime habitat for upland game birds. In the natural environment, major vegetative disturbances occur regularly. Prairie fires and forest fires burn acres of grasses and timber, returning these areas to new growth. Windstorms knock down trees. Flooding and droughts are events that affect habitat significantly. However, human intervention has limited these natural major vegetative disturbances. More and more land has become farmland, built-up areas, or managed forests.

Mike *et al* (2007) reported that understanding the relationships between environmental fluctuations, population dynamics and species interactions in natural communities is of vital theoretical and practical importance. This knowledge is essential in assessing extinction risks in communities that are, for example, pressed by changing environmental conditions and increasing exploitation. Findings indicated that abundance rank, the form of population dynamics, and the colour of environmental variation interact in affecting species extinction risk. These interactions are further modified by inter-specific interactions within competitive communities as the interactions filter and modulate the environmental noise.

Qiuxiang *et al* (2008) analyzed a bird community in a secondary forest and the results showed that the magpie was one of the key groups in the secondary forest. The key group is identified based on the nests used by other birds at a rate of 25%–40.17%. The size of the community is different and the number of these key groups is not certain.

Wiens (2008) reported that fragments of habitat are often viewed as islands and are managed as such; however, habitat fragmentation includes a wide range of spatial patterns of environments that may occur on many spatial scales. Fragments exist in a complex landscape mosaic, and dynamics within a fragment are affected by external factors that vary as the mosaic structure changes. The simple analogy of fragments to islands, therefore, is unsatisfactory. Understanding how birds respond to these complexities of fragmentation requires mechanistic studies focused on habitat selection and movement behaviour. Conservation efforts must be based on viewing fragmentation as a range of conditions that occurs in a landscape mosaic and management should be directed toward the mosaics rather than focusing solely on reserves.

José *et al* (2009) reported that population growth and human development result in biodiversity loss and biological homogenization not only in developed countries, but increasingly in the less developed countries as well. In those countries, where urbanization and agricultural intensification occur at a faster rate than in developed countries, habitat degradation appears to be the leading cause of wildlife loss. During the breeding seasons of 2002–2005, road surveys were conducted across five biomes of Argentina to detect variations in raptor community attributes as potential indicators of broad scale habitat degradation. Abundance of individuals, richness and diversity of species were calculated to assess the effects of habitat transformation and patch size on these community attributes. Raptor communities strongly varied in relation to habitat transformations, with lower abundance of individuals, richness and diversity of species in more transformed landscapes. Small patches of natural vegetation and locations in which natural and cultivated lands were interspersed showed lower richness and diversity of raptors than large patches. Fragmentation was the main cause of reductions in abundance of individuals. Although the relative contribution of two estimates of habitat degradation to abundance, richness and diversity of raptors varied among biomes, these community attributes proved useful as predictors of habitat degradation. This was especially true in habitats where raptor communities are more complex although overall patterns remained constant across biomes, from forests to deserts. Taking into account current trends of habitat transformation (drastic increments in monocultures, urban areas, and habitat patchiness), the conservation of raptor communities in these biomes could be seriously compromised. In terms of species-specific responses of raptors to habitat degradation, a rapid process of homogenization can be expected, resulting in only a few winner species within a general scenario of losers.

Schrag *et al* (2009) reported that land use drive biodiversity patterns at large scales. Changes in the variable conversion of land to agriculture, will lead to broad-scale changes in species patterns at regional scales. In countries with developing economies, conversion of land to monocultures of highly valuable crops, such as soybeans, is already occurring and is expected to increase in the future. Monitoring this change, as well as its impacts on important indicator species, such as birds, will provide insight into the rate and direction of these important changes. Data from the first four years of a long-term monitoring program was used to relate broad-scale patterns in land-use change to bird species richness and composition across land-use gradients in central Argentina. Results suggest that species richness is positively correlated with cover of native vegetation and negatively correlated with agricultural use. Canonical correspondence analysis results show that raptors are found mainly in areas of agricultural use and, therefore, may be more vulnerable to agricultural practices and pesticide use. The results of this study suggest that continued conversion of native ecosystems to annual crops may lead to decreased overall richness of avifauna and possible important changes in species composition.

Birdlife International (2010) reported that the most important threats to the world's birds are the spread of agriculture (significantly affecting 73% of Threatened bird species) and human use of biological resources, either through direct exploitation of bird populations or from the indirect impacts on bird populations of forest logging (which combined affect 71% of birds). These threats are the main drivers behind habitat degradation and conversion which are influencing 95% of Globally Threatened Bird populations. Invasive species (especially predators) also threaten nearly a third of Globally Threatened Birds. Increasing problems are being caused by human disturbance, incidental mortality (notably the drowning of seabirds in long line fisheries) and environmental pollution (on land, in wetlands and seas, and in the air), with human-induced climate change having serious longer term consequences for the world's birds. For further information see State of the world's birds 2004.

Animals

Steffan-Dewenter and Tscharntke (1999) reported that the destruction and fragmentation of natural habitats is the major reason for the decreasing biodiversity in the agricultural landscape. Loss of populations may negatively affect biotic interactions and ecosystem stability. The hypothesis that habitat fragmentation affects bee populations and thereby disrupts plant-pollinator interactions was tested. Mean body size of flower-visiting wild bees was larger on isolated than on non-isolated habitat islands emphasizing the positive correlation of body size and foraging distance. Abundance of flower-visiting honeybees depended on the distance from the nearest apiary. Abundance of other flower visitors such as hover flies did not change with increasing isolation. Number of seeds per fruit and per plant decreased significantly with increasing distance from the nearest grassland for both mustard and radish. Mean seed set per plant was halved at a distance of approximately 1000 m for mustard and at 250 m for radish. In accordance with expectations, seed set per plant was positively correlated with the number of flower-visiting bees. They found no evidence for resource limitation in the case of mustard and only marginal effects for radish. They concluded that habitat connectivity is essential to maintain not only abundant and diverse bee communities, but also plant-pollinator interactions in economically important crops and endangered wild plants.

Dunne *et al* (2002) reported that food-web structure mediates dramatic effects of biodiversity loss including secondary and `cascading' extinctions. These effects were studied by simulating primary species loss in 16 food webs from terrestrial and aquatic ecosystems and measuring robustness in terms of the secondary extinctions that followed. As observed in other networks, food webs were more robust to random removal of species than to selective removal of species with the most trophic links to other species. More surprisingly, robustness increases with food-web connectance but appears independent of species richness and omnivory. In particular, food webs experience `rivet-like' thresholds past which they display extreme sensitivity to removal of highly connected species. Higher connectance delays the onset of this threshold. Removing species with few trophic connections generally has little effect though there are several striking exceptions. These findings emphasize how the *number* of species removed affects ecosystems differently depending on the trophic *functions* of species removed.

Urbanization can potentially impact the function of a native grassland ecosystem in many ways. Habitats can become fragmented into smaller parcels, water and nutrient cycles may be disturbed, and plant and animal communities may be altered (Alberti *et al*. 2003).

Krauss *et al* (2003) reported that habitat area was the most important predictor of butterfly community structure and influenced habitat specialists more than habitat generalists. In contrast expectations, habitat isolation had no effect as most butterflies could cope with the degree of isolation in the study region. Landscape diversity appeared to be important for generalist butterflies only.

Wang *et al* (2003) reported that wildlife habitat pattern is affected by natural and human disturbance. The area of suitable habitat (SD > or = 0.35) was becoming smaller and more fragmented, with a deteriorated quality. It was proved that spatial diversity index could reflect the habitat suitability of wildlife, and describes the habitat spatial pattern explicitly. This study would provide a scientific basis for protecting wild animals and their habitats.

Attum *et al* (2006) reported the impact of human-induced desertification on the species richness, abundance, and composition of sand dune flora and herpetofauna of North Sinai, Egypt. The hypothesis was that degraded habitats would have reduced vegetation complexity, richness, and abundance, and consequently lower reptile species richness and abundance. It was also hypothesized that desert lizards would not follow the typical generalist/specialist responses to habitat degradation found in other biomes. Instead, it was predicted that because vegetation loss intensifies the environmental extremity of deserts, those species specialized for open and sandy environments would be more likely to persist in desertified habitats than would desert generalists. Results showed that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species. However, protected sites did have significantly higher percent vegetation cover and height. Habitat protection clearly had strong effects on the reptile community as species richness and abundances were significantly higher in protected sites. The composition of the reptile community between protected and unprotected sites differed significantly. Contrary to past studies in other environments, desert generalist species were not able to persist in degraded sites and were only found in protected sites. Specialist species were ubiquitous in that they occurred in both areas protected and unprotected from vegetation loss. They proposed that the effects of disturbance on species composition (specialists or generalists) depend on whether the disturbance exacerbates or reduces environmental harshness and the conditions that favour specialization. In extreme environments, specialist and generalist responses to habitat degradation are opposite to that of more productive environments.

Keller and Schradin (2008) reported that the hotspots of biodiversity are important areas in facilitating an understanding of species richness and its maintenance. Herbivores can increase plant richness by reducing dominant plant species thus providing space for subdominant species. As small mammals are abundant in the Succulent Karoo and therefore might affect plant richness by means of herbivory, it was tested if this mechanism might exist in the Succulent Karoo in southern Africa, a biodiversity hotspot due to its extraordinary plant richness. At ten ecologically different study sites, plant and small mammal richness and diversity were measured, and 11 abiotic factors including soil composition, altitude and rainfall were determined. They found positive correlations between plant richness and the number of small mammal species. A general linear model revealed that the number of small mammal species was more important than abiotic factors in explaining variation in plant richness. To test whether small mammals might directly influence plant richness, they studied the influence of the bush-Karoo rat *Otomys unisulcatus*, a central place forager, on the plant community. The immediate surroundings of occupied *O. unisulcatus* nests showed significantly higher plant richness than control areas. It was concluded that small mammals can have a positive effect on plant richness in the Succulent Karoo. While experimental data are needed to support these correlative results, the results of the study indicated that areas of high small mammal richness should be included in conservation programs of the Succulent Karoo.

Allendorf *et al* (2008) reported that human harvest of animals in the wild occurs in terrestrial and aquatic habitats throughout the world and is often intense. Harvest has the potential to cause three types of genetic change: alteration of population subdivision, loss of genetic variation, and selective genetic changes. To sustain the productivity of harvested populations, it is crucial to incorporate genetic considerations into management. Nevertheless, it is not necessary to disentangle genetic and environmental causes of phenotypic changes to develop management plans for individual species. They gave recommendations, recognizing that some genetic change due to harvest is inevitable. Management plans should be developed by applying basic genetic principles combined with molecular genetic monitoring to minimize harmful genetic change.

Green *et al* (2008) reported that the influence of keystone consumers on community structure is frequently context-dependent; the same species plays a central organising role in some situations, but not others. On Christmas Island, in the Indian Ocean, a single species of omnivorous land crab, *Gecarcoidea natalis*, dominates the forest floor across intact rainforest. It was hypothesised that this consumer plays a key role in regulating seedling recruitment and in controlling litter dynamics on the island, independent of the type of vegetation in which it occurred. Surveys across island rainforest showed that seedlings of species susceptible to predation by land crabs are consistently rare. Abundance and diversity of these species were negatively correlated to red crab abundance. Although red land crabs may be important determinants of seedling recruitment to the over-storey, differences in over-storey and seedling composition at the sites suggests that recruitment of vulnerable trees still occurs at a temporal scale exceeding that of this study. These "windows" of recruitment may be related to infrequent events that reduce the effects of land crabs. Results suggest that unlike the context dependence of most keystone consumers in continental systems, a single consumer, the red land crab, consistently controls the dynamics of seedling recruitment across this island rainforest.

Odugbemi (2008) reported that the most serious proximate threats to biodiversity are habitat loss, habitat degradation, intensive cultivation, population pressure and over-exploitation. Within the last 30 years, it is believed that about 43% of the forest ecosystem has been lost through human activities, upsurge in human numbers and consumption patterns. There has also been a significant increase of 84,762km2 of the total rain-fed agricultural areas of the country cleared for intensive, extensive and flood agriculture. A total area of about 5,981km2 was also cleared for the establishment of plantation trees crops, forest trees, and irrigation and livestock projects.

Haddad *et al* (2009) reported that plant diversity is predicted to be positively linked to the diversity of herbivores and predators in a food web. Yet, the relationship between plant and animal diversity is explained by a variety of competing hypotheses, with mixed empirical results for each hypothesis. They sampled arthropods for over a decade in an experiment that manipulated the number of grassland plant species. It was found that herbivore and predator species richness were strongly, positively related to plant species richness, and that these relationships were caused by different mechanisms at herbivore and predator trophic levels. Even more dramatic was the threefold increase, from low- to high-plant species richness, in abundances of predatory and parasitoid arthropods relative to their herbivorous prey. Results demonstrated that, over the long term, the loss of plant species propagates through food webs, greatly decreasing arthropod species richness, shifting a predator-dominated trophic structure to being herbivore dominated, and likely impacting ecosystem functioning and services.

Young and Metzler (2010) reported that one plant that is adapted to the rainforest is the fern leaf. The fern leaf is adapted to the rainforest because it lives on the rainforest floor and doesn't get much sunlight. Because it lives on the ground, not only does it not get a lot of sunlight it does not receive a lot of rainwater since the canopy absorbs much of it. So its roots have adapted by anchoring the plant to the ground and saving the little water it receives. It also leans towards the sunlight that comes through the canopy. One animal that is adapted to the rainforest is the howler monkey. It has many adoptions to the rainforest that help it with its everyday life. One adaptation is its long tail that allows them to hang a great distance down from branches where it lives. Their hands with opposable thumbs allow them to climb trees easier and to grab food. Their black fur also helps hide them in the trees where they live.

2.7: Approaches to Managing Biodiversity

Andren (1994) reported that, habitat fragmentation implies a loss of habitat, reduced patch size and an increasing distance between patches, but also an increase of new habitat. Simulations of patterns and geometry of landscapes with decreasing proportions of the suitable habitat give rise to the prediction that the effect of habitat fragmentation on, e.g., population size of a species would be primarily through habitat loss in landscape with a high proportion of suitable habitat. However, as the proportion of suitable habitat decreases in the landscape, area and isolation effects start influencing the population size of the species. Hence, the relative importance of pure habitat loss, patch size and isolation are expected to differ at different degrees of habitat fragmentation.

Bever *et al* (1997) reported that although its importance for plant mineral nutrition and nutrient cycling has long been recognized, the soil community has rarely been integrated into dynamical frameworks of plant populations, in spite of abundant evidence for its involvement. The concept of feedback may provide theoretical and experimental tools for investigating the importance of the soil community in the population ecology and evolution of plants. A mathematical model demonstrates the potential for two divergent dynamics, with positive feedback leading to the loss of diversity at a local scale and negative feedback leading to its maintenance. A linear contrast of the growth of plants in association with their own soil communities compared to the growth of plants in association with each others' soil communities can be used to differentiate between these possibilities in empirical studies. Spatially explicit computer simulations demonstrate that the dynamics of a spatially structured community, as the soil community is likely to be, can differ from those predicted for a well-mixed population. Specifically, diversity can be maintained between locally homogeneous patches when positive feedback and dispersal occur at local scales.

Using a simple experimental protocol, substantial negative feedback on plant growth through the soil community have been found, suggesting that it may be involved in the maintenance of plant species diversity. The importance of the soil community in other areas of plant ecology and evolution was discussed, including the suggestion that interactions with the soil community may be involved in the maintenance of sexual or asexual reproductive systems.

Young and Metzler (2010) reported that every second a Tropical Rainforest is being either burned down, or bulldozed down. The reason they are burned down because people “need” the wood for different reasons: for paper, for construction and etc. They go through the rainforests and take plants that they believe contain medicinal value but if it doesn’t contain any it was just a waste of plant. Many animals have their habitat destroyed when people come in and cut down the trees. This is becoming an increasing problem; many animals are losing not just their habitat but their existence.

2.8: Habitat Management Methods

Plants

Freemark *et al* (1991) reported that the presence of a well-developed shrub or tree stratum in habitats next to farm fields plays a role in increasing habitat spatial heterogeneity and the ability of the habitat to support a greater variety of farmland birds. The presence of a variety of habitats (drainage ditches, old fields, hedgerow, small woodlots, and isolated trees) other than strictly agricultural habitats helps to increase species diversity in agricultural areas.

Dewees and Saxena, 1997, reported that trees on farms have long been recognized as protecting and often enhancing soil fertility, assisting in soil and water conservation and providing fodder, fuel-wood and construction materials for rural households. They also help maintain biodiversity (by diversifying plant cover and providing habitat for other plants and animals) and enhance landscape. In addition, commercial production of timbers on farms in the tropics, either as scattered trees or as small scale woodlands is a potentially important elements of farm livelihoods.

Holding-Anyonge and Roshetko (2003) revealed that, traditionally, farmers have grown trees using local seed sources to provide products and services that support their livelihood needs and are known to be compatible with the annual crop and livestock components of their farming systems.

Roshetko (2001) revealed that the use of improved germsplasm and improved varieties, provenances and clones could raise the profitability of small holder production of tree products including timber. Yet farmers have little access to quality germplasm of either indigenous or exotic tree species. In most cases quality seed sources of indigenous species have not been identified and farmers have limited experience with proper seed collection and management techniques. The supplies of quality exotic germplasm are usually limited and restricted to government and industrial use.

Liu (2003) enunciated that China has recently taken major steps to give communities and private sector greater freedom to manage forests for a profit. To meet their objectives, the plans stress the need to strengthen market-based instruments (e.g. auction) and to provide incentives to encourage the private sector or individual farmers to participate in the restoration, protection, and management of degraded land.

Adekunle and Olagoke (2008) investigated tree species diversity, biovolume and forest stand structure in natural forest ecosystem located around some selected communities in the bitumen-producing area of Ondo state, Nigeria. The results of the study revealed that there were ninety nine (99) tropical hardwood timber species (range: 21 to 48 species per selected forest). These species were distributed among twenty nine (29) families. While *Funtumia elastica* has the highest population distribution across the selected communities' forest, Euphorbiaceae was the dominant family in the entire area. Although there was a moderate variation in the biodiversity indices among the selected communities' forest, the Shannon-Weiner diversity index of $H^1 = 4.02$ and species evenness of $E = 0.88$ were obtained for the entire study area. Tree density summing up to 2,740 trees/6 ha varied moderately, with a range of 361–609 tree/ha, among the communities. Though most of the trees encountered belonged to the lowest diameter size class, the mean basal area and biovolume were 26.69 m^2/ha and 262.36 m^3/ha respectively.

Diniz *et al* (2010) reported that anthropogenic changes in the landscape result in an environmental mosaic with serious consequences for biodiversity. The aim of the present study was to assess the effects of the anthropogenic changes on Asteraceae richness and abundance, and to evaluate the consequences for the richness of Tephritidae assemblages in five sampling sites, with three sampled habitats in each: cerrado (Brazilian savanna), eucalyptus stands and pasture. Sampling was carried out in 15 random transects (cerrados and one pasture) and in 30 transects (eucalyptus stands and the remaining pastures). Composition, species richness and insect abundance in each habitat type was estimated by sampling the flower heads for each species of host plant, collected by four people for 1h. Differences in mean abundance of plant population between habitats and sites were tested by two-way ANOVA. Differences in plant species richness between habitats and sites and effects of habitat, site and host plant richness on insect richness were tested using a generalized linear model with Poisson errors. Within each sampling site, cerrados showed higher species richness of Asteraceae than pastures and eucalyptus stands. There were also significant differences in plant richness among sites. Mean population abundance values were significantly different among habitats, but not among sites. Increased host plant richness led to significant insect species richness. There were no additional significant effects of habitat on insect richness. Therefore, anthropogenic alterations in landscape determined the impoverishment of plant assemblages and therefore of insect assemblages, because of the positive relationship between host plant richness and insect richness.

Birds

Peter *et al* (1994) used multiple and logistic regression analysis to study the breeding-area requirements of 10 species of grassland and early-successional birds at 90 grassland-barren sites in Maine. The incidence of six of the species was clearly sensitive to the area of grassland. Upland Sandpipers, the species with the largest area requirements, were infrequent at sites of less than 50 ha and reached 50% incidence at those of about 200 ha. Grasshopper Sparrows reached 50% incidence at about 100 ha, Vesper Sparrows at about 20 ha, and Savannah Sparrows at about 10 ha. Incidence for three edge species, Brown Thrasher, Common Yellowthroat, and Song Sparrow, was negatively correlated with open area, and incidence for Field Sparrows was not strongly influenced by grassland size. These results indicate that grasslands need to be approximately 200 ha in area if they are to be likely to support a diverse grassland bird fauna. However, large grasslands or grassland-barrens are rare; random samples indicated that in Maine only 1% of hayfields and only 8% of grassland-barrens were more than 64 ha in area. Conservation efforts seeking to protect habitat for rare grassland birds need to consider sites of at least 100 ha--and preferably 200 ha--in size, and these are notably rare in Maine and probably throughout New England and eastern North America. Airports provide some of the last extensive patches of grassland habitat in the northeast. To maintain viable populations of area-sensitive grassland birds, management of these sites for nesting birds will become increasingly important.

To evaluate habitat use by birds, 20- minutes birds point count to a radius of 30 meters was carried out in each of the habitats. All species heard or seen within each habitat (of 30 m-radiuses) were then recorded as described by Benoit *et al*, 1996.

Unique methods for cryptic bird species such as early morning/late evening display flight counts for long-tailed nightjar as described by Innes *et al*, 2004, or call-counting for nocturnal species such as owls was used where these or other cryptic species are present. All the identification for bird species followed the Birds of the West African Town and Garden by Elgood, 1982.

Guthery and Rollins (1997) reported that Brush is an essential habitat component for most species of upland game birds. In areas where brush becomes too dense, brush sculpting can be used to enhance habitability via increasing the interspersion of cover types. Mechanical methods of brush control are generally preferred because of the selectivity afforded and the soil disturbance that results from clearing. Prescribed burning, while useful, is generally overrated as a brush management tool relative to game bird habitat management, at least in the western half of Texas. The manager's objective should be to maximize the amount of "useable space" available to the target species of game bird. In general, the manager has a good deal of latitude in selecting a brush management pattern that will maximize the average density of a particular game bird species. Habitats have a property which we shall call "slack:" Many different arrangements of habitat objects, such as treated and untreated stands of brush, are equally valuable to a particular species of game bird.

Laiolo P. (2002) analysed bird community-habitat relationships during the breeding period in a managed broad-leaved forest of north-western Italy (a newly established nature reserve). Species richness, diversity, biomass and abundance of some ecological groups of birds were analysed with respect to habitat variables, summarising habitat structure, canopy and understorey floral composition. Two major patterns of relationships among bird and habitat were traced: the first involved changes in tree structure during their growth (canopy height and diameter of the dominant tree), the second was related to characteristics associated with floral richness. Bird diversity, species richness, the amount of hole nesters, of trunk and ground feeders were positively associated with stands age. The abundance of some groups of birds was positively related to plant species richness: understorey species richness influenced shrub feeders, shrub nesters and edge species; canopy species richness affected trunk feeders. Canopy species richness also affected bird diversity, richness, biomass, abundance of hole nesters, trunk feeders and forest interior species.

Ives and Carpenter (2007) reported that understanding the relationship between diversity and stability requires knowledge of how species interact with each other and how each is affected by the environment. The relationship is also complex, because the concept of stability is multifaceted; different types of stability describing different properties of ecosystems lead to multiple diversity-stability relationships. A growing number of empirical studies demonstrate positive diversity-stability relationships. These studies, however, have emphasized only a few types of stability, and they rarely uncover the mechanisms responsible for stability. Because anthropogenic changes often affect stability and diversity simultaneously, diversity-stability relationships cannot be understood outside the context of the environmental drivers affecting both. This shifts attention away from diversity-stability relationships toward the multiple factors, including diversity, that dictate the stability of ecosystems.

Williams and Middleton (2007) demonstrated that within-year climatic variability, particularly rainfall seasonality, is the most significant variable explaining spatial patterns of bird abundance in Australian tropical rainforest. The likely mechanism causing this pattern is a resource bottleneck (insects, nectar, and fruit) during the dry season that limits the population size of many species. The patterns support both the diversity–climatic– stability hypothesis and the species–energy hypothesis but clearly show that seasonality in energy availability may be a more significant factor than annual totals or means. An index of dry season severity is proposed that quantifies the combined effect of the degree of dryness and the duration of the dry season. They suggested that the predicted increases in seasonality due to global climate change could produce significant declines in bird abundance, further exacerbating the impacts of decreased range size, increased fragmentation, and decreased population size likely to occur as a result of increasing temperature. They suggested that increasing climatic seasonality due to global climate change has the potential to have significant negative impacts on tropical biodiversity.

Somerfield *et al* (2008) reported that, indices are used to quantify change in environment by reducing aspects of environmental complexity to numbers. Biodiversity indices are typically calculated using the numbers of species and their relative abundances. A recent advance has been the development of additional measures of diversity, such as phylogenetic diversity, based on relationships between organisms. The emerging paradigms of the importance of biodiversity to ecosystem services and the ecosystem approach to fishery management could be well served by the development of indicators of ecosystem functioning. They discussed how relatedness measures may be adapted to quantify aspects of community structure of relevance to ecosystem functioning, by combining information on species' occurrence, life history, and ecological traits. They presented an index that reflects average functional distinctness within assemblages. The approach was illustrated using North Sea fish. Results reveal that average functional distinctness is not independent of taxonomic distinctness. This was expected, but the weakness of the relationship suggests that both indices may prove useful, because they are not constrained to convey the same information about samples. Both indices are shown to be weakly related to species richness, which was not expected. This is a consequence of differences in the frequency of occurrence among species.

Seymour and Dean, (2010) reported that land use management practices often change habitat structure, which in turn influence diversity and the composition of floral and faunal assemblages. In the southern Kalahari, southern Africa, heavy grazing after above-average rainfall has lead to bush thickening, and widespread use of arboricides and/or removal of large trees for firewood has also impacted habitat structure. At sites near Kimberley, in South Africa, the effects of these changes on bird species richness and which aspects of habitat structure most influenced bird assemblage diversity and composition was investigated. They also investigated correlations between bird life history traits and habitat characteristics using RLQ analysis. Bird species richness and abundance were both explained by vertical habitat heterogeneity and density of woody species between the heights of 0–2 m, with bird species richness also explained by the density of woody species at heights above 6 m. Large trees within bush-thickened areas dampened the effects of bush thickening on bird assemblages by enabling certain species to persist, consistent with the idea that large trees are keystone structures. Smaller insectivorous gleaners, ball- and cup-nesters, birds with parts of their range extending into arid areas and birds with long-wavelength plumage (i.e. red, orange or yellow plumage) dominated bush-thickened habitats. Seed-eaters, burrow- and ground-nesters, bark-foragers, birds that perch and sally, or perch and swoop to the ground, were all negatively associated with bush thickening. Cavity-nesters, bark-foragers, hawkers, frugivores, birds that perch and sally and species with iridescent plumage were negatively affected by the loss of large trees. Of the common species analysed, nearly 40% of species had life history traits tied to large trees; and 68% had traits negatively associated with bush thickening and removal of large trees together, suggesting that where these changes in habitat occur simultaneously, bird diversity will be strongly affected.

Kokiso (2012) investigated avian diversity in hedgerows at Angacha, in the Kembatta zone, Ethiopia. Diversity and preferences of birds to hedgerow types varied in relation to their vegetation composition and structure. Five endemic species, i.e., Rüppel's BlackChat (*Cossyfa semirufa*), the White-cheeked Turaco (*Tauraco leucotis*), the Banded Barbet (*Lybius undatus*), the Abyssinian Oriole (*Oriolus monacha*) and the Wattled Ibis (*Bostrychia carucullatta*) were recorded in the thickhedgerow type. Thickness, height and width of hedgerows affected the diversity, distribution and habitat preference of birds. Thickhedgerow types showed the highest avian species diversity, richness and similarity. There was a high correlation between the hedgerow diversity and its bird diversity, which was directly associated with habitat quality. Bird species diversity and preference for hedgerow types require important conservation and management priorities. High species richness was observed in thickhedgerows. Species richness in the three types of hedgerows ranged from 5 to 22 during dry season and from 6 to 24 during the wet season. There were variations in the bird species richness among hedgerow types ($t = 3.361$, $p < 0.05$) but not between seasons. The highest species diversity was obtained in the thickhedgerow type. Compared with other hedgerow types, thickhedgerows harbored high endemism. Species similarity was high between thin and thickhedgerow types followed by open and thin types during both dry and wet seasons. The least similarity was observed between open and thicktypes.

The distribution of avian species among the hedgerow types were 22.2% in open hedgerows, 55.5% in thin hedgerows and 88.9% in thickhedgerows. The highest preference was observed for the thickhedgerow type. Relative abundance varied during dry and wet seasons for different hedgerow types.

Animals

Presence or absence of fauna resources can be established using hunters' in-depth interview or ethnographic interviews as described by Taylor and Bodgen Cited in Minichiello *et al* (1990).

Indirect estimate of animal abundance through population indices in habitats can also be used to enumerate terrestrial wildlife, because, direct observation of animal population is not suitable for West and Central African rain forests. Indices to population trends are easier to obtain and normally sufficient for management and research purposes (Lancia *et al*, 1994).

Assumptions of Population Indices

The theory of population indices depends on the following basic assumptions as outlined by Anderson, 1991:

- Good sampling practice spaced over time to permit a useful analysis is based on sampling in space and time of extraneous factors.
- The use of indices postulates that index value is simply proportional to true population density.
- Indices of population indicate trends from year to year and from habitat to habitat.
- Trend data indicate whether populations are increasing, decreasing, or stable in a habitat.

Vonesh (2001) compared species richness and habitat correlates of leaf-litter herpetofaunal abundance in undisturbed and selectively logged forests, and an abandoned pine plantation in Kibale National Park, Uganda. Result shows that assemblage composition was most similar at logged and unlogged sites. The logged forest herpetofauna had higher species richness and abundance than the unlogged forest, but diversity was greater in the unlogged forest due to greater evenness. In contrast, the pine plantation site had the highest richness, abundance, and evenness of the three study sites, but species composition was distinct from the other areas. Herpetofaunal densities were significantly lower in all three areas during the dry season than in the wet season. During the dry season, soil moisture, litter mass, topography, shrub cover, and number of fallen logs were significant positive predictors of herpetofaunal presence in litter plots, but only soil moisture was significant in the wet season.

Tattersall *et al* (2002) reported that farmland is readily divisible into linear habitats such as hedges, and non-linear habitats such as fields and woodlots. They investigated whether the linear or non-linear character of habitat patches, mediated by edge effects, has an impact on the abundance, diversity and richness of the small mammal communities that live within and between them. In particular, they hypothesized, first, that edge effects cause narrow linear habitats to be avoided by specialists such as the bank vole *Clethrionomys glareolus*, but not by generalists such as the wood mouse *Apodemus sylvaticus*; secondly, that edge effects lead to specialists being present in atypical habitat, through excursions at the interface between two habitats. There was no evidence that specialists avoided linear habitats. Indeed, the field boundary was the most species-rich habitat surveyed, and bank voles were more abundant in linear hedgerow than in non-linear woodland. Bank voles were present in linear set-aside and in the crop edge, but never in non-linear blocks of set-aside or crop, implying that they diffused out of the hedgerow into the adjacent habitats. There was no evidence of an effect of habitat linearity on field voles Microtus agrestis, wood mice or common shrews Sorex araneus. Their results suggest that on uncropped land such as set-aside, the linear or non-linear character of habitats will make little difference to small mammal abundance and diversity. They advocated similar assessments for other taxa so that the effects of farm management and habitat configuration on biodiversity can be understood more fully.

Pablo *et al* (2006) evaluated the temporal and spatial patterns of abundance and the amount of damage caused by gall-inducing insects (GII) in deciduous and riparian habitats in a seasonal tropical dry forest in Mexico. Abundance and leaf damage by GII were greater in deciduous than in riparian habitats during the wet season. For each GII species that occurred in both habitats, host plant species supported greater abundance and leaf damage by GII in deciduous habitats during the wet season. These results indicated a greater association of GII species with host plants in deciduous than in riparian habitats during the wet season. In riparian habitats, 11 plant species (61.1%) had greater density of GII in the dry than in the wet season. Similarly, leaf damage by GII was significantly greater in the dry than in the wet season in riparian habitats for 12 plant species (66.7%). Dry forest plants of riparian habitats presented two peaks of leaf-flushing: GII colonized leaves produced in the first peak at the beginning of the wet season, and accumulated or recolonized leaves in the second peak at the beginning of the dry season. The levels of leaf damage by GII detected in this study in the rainy season were considerably higher than those obtained for folivorous insects in other Neotropical forests, suggesting that this GII guild might have an important impact on their host plant species in this tropical community. Alexandra (2007) reported that habitat had a significant effect on butterfly abundance in both the lower traps and the upper traps. Lower riparian forest traps had a significantly lower abundance than any of the other habitats. The observed abundances for the lower traps in the recovering pastureland, secondary forest, and bamboo forest were not significantly different from each other. For the upper traps, the riparian forest butterfly abundance was only significantly lower than the secondary forest abundance. Unlike the lower traps, the upper bamboo forest trap abundance was not significantly different from the riparian forest abundance; similarly to the lower traps, the bamboo site abundance was not significantly different from the observed secondary forest abundance.

Barlow *et al* (2007) reported that in general, habitat quality appeared to be more important than the surrounding landscape in determining butterfly community structure. However, the community structure of the strong-flying Charaxinae was related to the amount of primary forest in surrounding landscape. There was very poor congruence between the response patterns of richness and abundance among different butterfly subfamilies. There was a significant interaction between habitat and season based on richness and abundance metrics, although not based on community structure. Secondary forest exhibited higher observed richness than primary forest in the peak of the dry-season, but not at other times of the year. This observation could explain the lack of consensus in previous studies, as those reporting higher richness in secondary forest only sampled during the dry-season.

2.9: Bitumen Occurrence, Development Method and Effects on the Environment

Adegoke, 2000, reported that Tar sands or bituminous sands have been known to occur in Okitipupa and Ijebu-ode Provinces since the beginning of the 20th century. The seepages were locally used –for painting and waterproofing. The recorded occurrences were along an East-West (120 km) belt that stretches from Ijebu-Ode in Ogun State to Akotogbo and Siluko areas in Ondo and Edo States respectively. The outcrop belt is about 4-6km wide. He also confirmed that Gulf Oil Corporation, Pittsburg Crokett & Wescott 1954) examined 15 samples of bituminous sand samples from Aye and, Ode-lrele areas of Ondo State.

It is known from the report on the geotechnical investigations of the Ondo State bituminous sands that the bituminous sands are overlain with overburden varying between 0m amd 50m thick, and therefore, the tar sands in much of the area can be won by open cast mining (Adegoke-Anthony and Adedokun, 1990).

Coker, 1990, confirmed the similarity of grain/ water relationship of both the Nigerian and Canadian oil sands, which makes it characteristically easy to derive comparative studies on processing of Nigerian Bitumen Deposit. He safely deduced that Nigerian Oil Sand Deposits will be developed and exploited along the lines of development Technologies in Canada in three phases: surface mining for deposits occurring from the surface to within less than 50m; mine-assisted (underground drilling shaft tunnels) for oil sands at depths between 50m and 300m of overburden; and in-situ technologies for oil sands and heavy oils at depths in excess of 300m.

Ako, 1990, chronicles bitumen exploratory activities as: geological mapping, surface geophysical method, topographic survey, drilling and coring, and geophysical borehole logging, for detailed sub surface mapping of the bitumen impregnated beds.

Adekoya, 1995, reported that Nigeria is endowed with abundant mineral resources, which have contributed immensely to the national socio-economic deve1opment. Before the minerals could make such contributions, they have to undergo three stages of development, viz, exploration, mining and -processing. The three stages of mineral development have, however, caused different types of environmental damage, which include: ecological disturbance, destruction of natural flora and fauna, pollution of air, land and water, geological hazards due to instability of soil and rock masses, landscape degradation and radiation hazards.

Anderson, 1991, reviewed the studies of the petroleum industry's land-use activities in Canada, which showed that, habitat alteration affected wildlife in various ways. Hunted big game avoided roadways more than did unhunted species. Animals are adapted to stationary disturbances, such as a drilling rig, much more readily than to moving disturbances, such as traffic on a road. Animals with smaller home ranges were more tolerant of disturbances, and migratory or nomadic species were less tolerant than resident species.

Odiete, 1999, enumerated some anthropogenic activities that disrupt the ecosystem to include solid mineral mining, crude oil and gas development, and production and pipelines laying, terminals and depots for crude oil and refined products, the consequence of which are: destruction 'of cash crops and economic trees, deforestation, disruption, destruction of homeland, dispossession of land owners, farmers and fishermen; landscape degradation and depletion of natural resources. He stressed further that, through habitat destruction and modification, virtually any form of sustained human activity results in some modifications of the natural environment, which will affect the relative abundance of species, and in some extreme cases lead to extinction as a result of the habitat becoming unsuitable for the species, or the habitat becoming fragmented.

CHAPTER THREE

3.0: MATERIALS AND METHODS

3.1: Study Area

The study area is Ode-Irele in Ondo State of Nigeria. It is located in the Southern fringe of the state between Longitudes 04^0 47^1 E to 05^0 10^1 E, and Latitudes 06^0 16^1N to 06^0 40^1 N, (fig 3.1 and 3.2). The area falls within the Tropical Rainforest ecological zone. Ode-Irele forest area was selected because a Bitumen mining Company, Jerex Energy, Canada, Carried out a preliminary geological mapping and investigation along the Bitumen belt between October 1995 and 1998. The activities of this energy company confirmed the presence of Bitumen seepage (plates 3.1 and 3.2) in Ode-Irele forest area. This occasioned the setting up of Bitumen Project Implementation Committee in August, 2000 and eventual flag off by president olusegun Obasanjo (plate 3.3).

3.2: The Data Types

The research data were of three types;

- Laboratory analysis
- Ecological survey
- Desk review

Desk Review

Desk review was used for mining condition.

3.3: Evaluation of Physico-Chemical Parameters of Soil

Composite samples of soil were collected at Loda (S1), Ludasa (S2), Petu (S3) and Lofo (S4) the seepage sites and Ebute-Irele (S0) the control site which is about 12km away for analysis of physico-chemical parameters. Samples of surface soil were collected using auger.

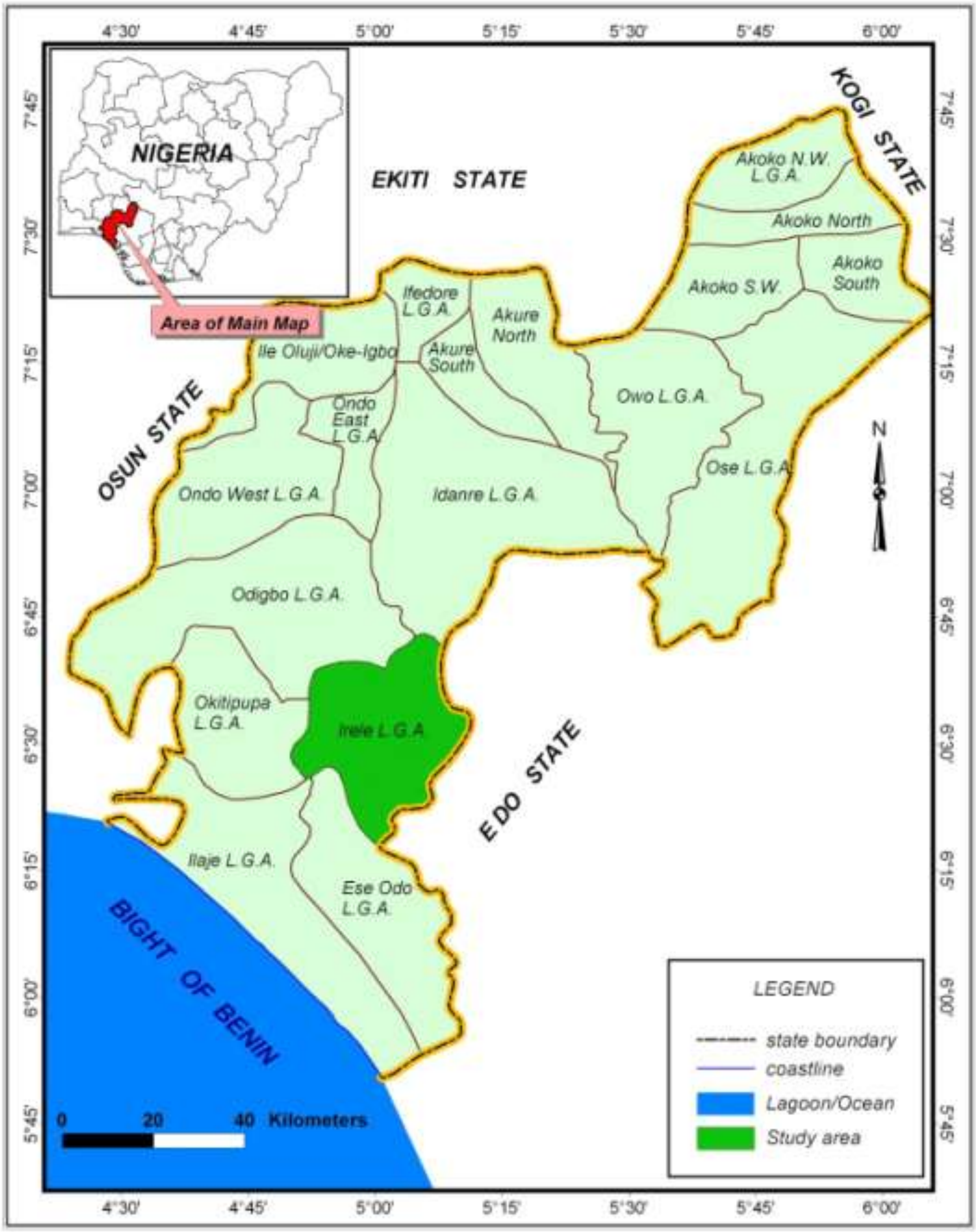

Fig 3.1: Map of Nigeria showing Ondo-State and Irele Local Government Area

Source: Ondo State Survey, 2008

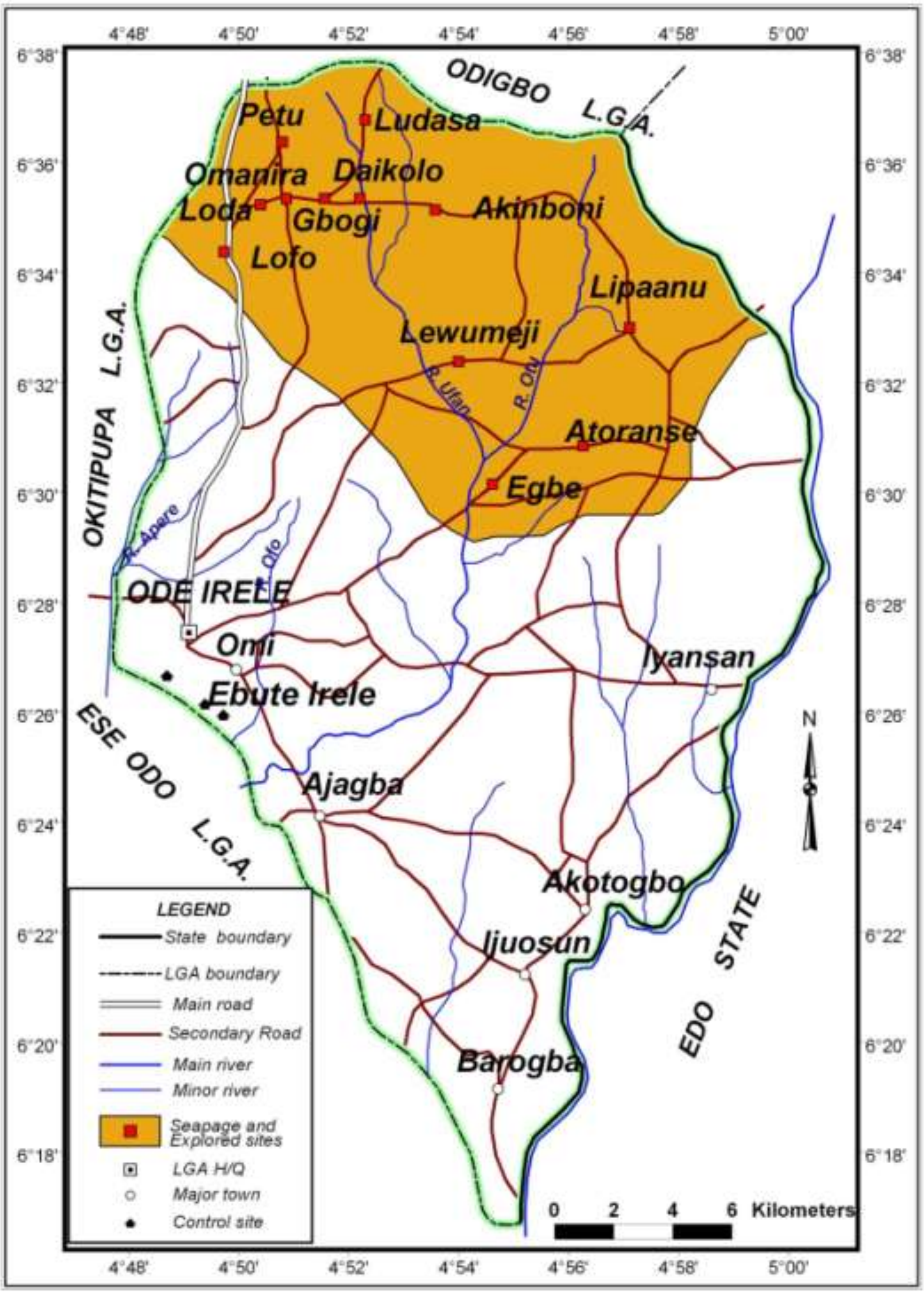

Fig 3.2: Map of Irele Local Government Showing Bitumen Exploration Sites

Source: Ondo State Survey, 2008

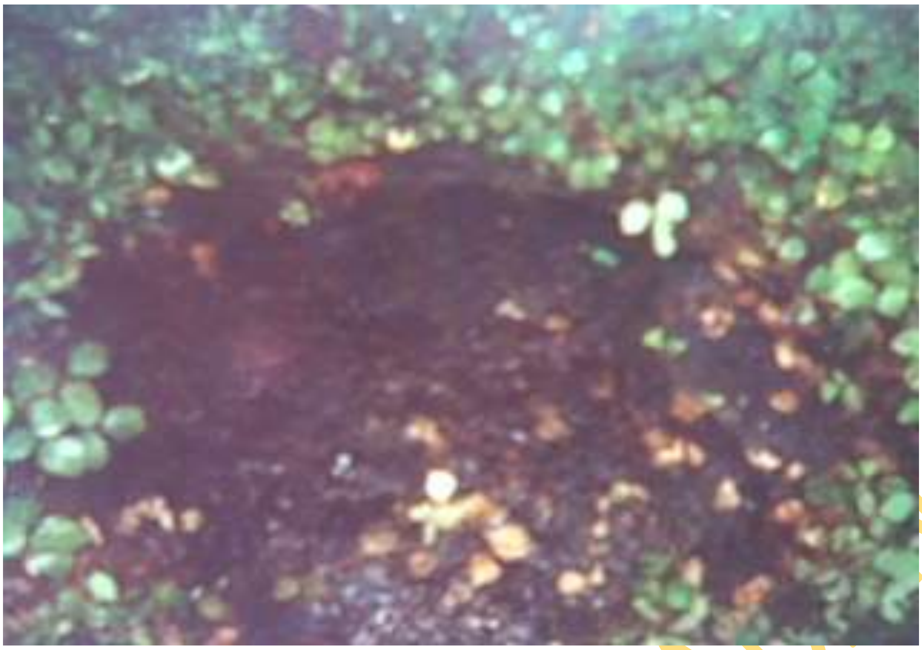

Plate 3.1: Seepage of Bitumen at Ludasa Village, Irele, Ondo-State

Plate 3.2: Sign-Post by Federal Ministry of Solid Minerals on Bitumen Contract at Ludasa Village, Irele, Ondo State

Plate 3.3: Plaque of the Official Flag-Off Of Nigeria’ s Commercial Bitumen Project at Gbeleju-Loda, Irele, Ondo-State

3.4: Evaluation of Physico-Chemical Parameters of water

Composite samples of water were also collected at Loda (S1), Ludasa (S2), Petu (S3) and Lofo (S4) the seepage sites and Ebute-Irele (S0) the control site which is about 12km away for analysis of physico-chemical parameters. Water was collected to a depth of 30cm midstream.

3.5: Evaluation of Heavy Metals in Plants

1m^2 frame quadrant was used to sample vegetation on bitumen seepage and explored sites, and control sites. This was used in assessing the percent cover of various groups of plants on polluted and unpolluted soils. Two criteria were used in selecting plants for analysis: plants with more than 5% coverage were selected; plants that were common to seepage and explored sites even though they had less than 5% coverage were also selected. This is to investigate the levels of bio-accumulation of heavy metals of the flora of Bitumen contaminated sites.

3.6: Soil Particle-size Analysis by Bouyoucos (hydrometer) Method

Soil particle-size analysis followed Bouycous hydrometer method by Bouycous (1951).

3.7: Organic Matter Determination

Determination of organic carbon followed wet oxidation method by Walkey and black (1934).

3.8: Soil PH Determination by Glass Electrode PH Meter

Determination of soil pH followed glass electrode pH meter method described by Bates (1954).

3.9: Determination of Nitrogen by Regular Micro K jeidal Method

Soil nitrogen was determined using regular micro Kjeidal described by Jackson (1962).

3.10: Determination of Available Phosphorus in Soil and Water

Available phosphorus was determined using ascorbic acid blue colour method as described by Murphy and Riley (1962).

3.11: Determination of Exchangeable Acidity Using KCl Extraction Method

Exchangeable acidity was determined using KCl Extraction Method as described by Moleon (1965).

3.12: Determination of Cation Exchange Capacity, CEC, by Direct Cation Saturation

CEC was determined using direct saturation method described by Kanchiro and Sherman (1967).

3.13: Determination of Available Phosphorus in Soil and Water

Available phosphorus was determined using ascorbic acid blue colour method as described by Murphy and Riley (1962).

3.14: Determination of Sulphur and Sulphate in Water

Sulphur and sulphate were determined using turbidimetric method.

3.15: Determination of Nitrate and ammonia in Water Extracts

Nitrate and ammonia in water extracts were determined using Brucine colorimetric method as described by Greweling and Peech (1968).

3.16: Measurement of Electrical Conductivity in Water

Electrical Conductivity of water was determined using Wheatstone bridge arrangement.

3.17: Determination of Acidity of Water Samples

Acidity of Water Samples was determined by titrating water with NaOH using phenolphthalein and methyl orange indicators as described by American Public Health Association and American Water Works (1946).

3.18: Determinations of Carbonate and Bicarbonate (alkalinity) in Water Samples

Carbonate and bicarbonate (alkalinity) were determined by titrating water with H_2SO_4 using phenolphthalein and methyl orange indicators as described by American Public Healyh Association and American Water Works (1946).

3.19: Chloride Determination

Chloride was determined by titrating it with $AgNO_3$ using potassium mercury (ii) thiocyanate method as described by American Public Health Association and American Water Works (1946).

3.20: Determination of Oxygen Balance, Biochemical Oxygen Demand and Chemical Oxygen Demand in Water

Oxygen Balance, Biochemical Oxygen Demand and Chemical Oxygen Demand in Water were determined using the methods described in water analysis by atomic absorption and flame emission spectroscopy by American society, Washington D.C. (1968).

3.21: Conductivity Test for Salt Concentration in Water

Conductivity Test for Salt Concentration in Water to determine total dissolved solid was carried out using the method described by the United State Department of agriculture, USDA (1969).

3.22: Determination of Water pH

Surface water pH was determined using pH meter.

3.23. Determination of Micro Nutrients - Fe, Mn, Cu, Pb, Cd, Cr, Ni, V, Zn and As in Soil, Water and Plant Extracts

Micro Nutrients, Fe, Mn, Cu, Pb, Cd, Cr, Ni, V, Zn and As were determined using atomic absorption spectrometer as described by Perkin-Elmer (1968).

3.24: Determination of Mg in Soil Extracts, Water and Plant Digest

Mg in plant Digest and Soil Extracts was determined by the use of atomic absorption Spectrometry as described by Perkin-Elmer (1968).

3.25: Colorimetric Determination of Al in Soil, Water and Plant Extracts

Determination of Al in soil, water and Plant Extracts was carried out using colorimetric method as described by Black (1965).

3.26: Vegetation Survey of Baseline Site

The vegetation cover of baseline site was sampled using 5x5-M quadrants at specific habitats in the study sites. Records were then taken of the plants occurring in the quadrants. The vegetation morphology was surveyed in terms of:

Composition (i.e. the number, richness and diversity of constituent plant species);

Layering (i.e. changes in structural components in terms of – tree cover (plants with 10 dbh), shrub cover (plants up to 2m in heigtht) and herb cover (plants less than 2m).

However, 1-m^2 sub-plot was used to survey herb cover within each of the 5x5 – m quadrant. For each chosen quadrant, all the plant species were as far as possible identified and listed. Those that could not be immediately identified with certainty were collected, labelled, subsequently pressed, and taken home for identification. All the identification for tree species followed Keay (1989) and odugbemi (2008); that of shrubs followed that of Agyakwa (1987) and Odugbemi (2008); while that of herbs followed Odugbemi (2008) and Akobundu and Agyakwa (1987). The habitats considered for vegetation sampling included:

- Fallow Land, FL
- High Forest (islands), HF
- Arable Farmland (edge), AF
- Riparian Habitat, RH
- Cashcrop Farmland, CF
- Urban Arboreta, UA

3.27: Assessment of Birds Conposition

To assess birds composition, 20- minutes birds point count to a radius of 30 meters and unique methods for cryptic bird species such as early morning/late evening display flight counts for long-tailed nightjar was carried out in each of the habitats stated below.

The habitats considered are:

- Fallow Land, FL

- High Forest (islands), HF
- Arable Farmland (edge), AF
- Riparian Habitat, RH
- Cashcrop Farmland, CF
- Urban Arboreta, UA

Visits to each habitat were replicated three times each in both the dry seasons and the raining season, thus making a total of six replicates per habitat.

3.28: Assessment of Animal Composition

Indirect estimate of animal abundance through population indices in the habitats was used to enumerate terrestrial wildlife, because, direct observation of animal population is not suitable for West and Central African rain forests. Indices to population trends are easier to obtain and normally sufficient for management and research purposes.

This involved a survey/census of mammals, reptiles and amphibians along transects of 50x10 meters in the study areas. Direct count method, using a pair of binoculars, was employed for the census of the animals which readily offered themselves for observation. The presence of some of the animals was ascertained by probing such humid habitat like logs, heaps of dead decaying leaves, forest undergrowths, ponds and burrows. Thus, all sighted, captured or dislodged animals were identified, often on the spot, to possible taxonomic levels using field guides and keys. The indirect method which makes use of evidence of animal's presence was used for species which do not offer themselves readily for observation. Signs of animal presence such as burrows, faecal pellets, hairs, foot prints or tracks plate, sloughed skin, devoured food (cassava, yam, oil palm nuts, etc) as well as vocalization, skeleton/carcass and trampled grass were of immense use in the course of the investigation.

3.29: Assessment of Faunal Resources Diversity

Measurement of diversity was used to compare the species composition of animal resources in the study area. Comparisons were made for animal and bird, and plant communities between dry and raining seasons.

Shannon – Weiner and Simpson Diversity Indicesa were used for the comparison.

Shannon –Weiner Index

$$H^1 = \sum_{X=1}^{s} Pi \, Log_e \, Pi$$

Where:

Pi = proportion of the community belonging to the i^{th} species

s =- Number of species

Log_e = Natural log.

N.B: A useful reference in diversity calculations is the maximum diversity possible with a given number of individuals and species.

Simpson Diversity Index

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Where:

N = Number of individuals of all species

n = number of individual of a species

3.30: Biodiversity Assessment Process

The ecosystem-level indicators (Table 3.1) were assessed to determine how well they related to ecological function (flows of animals, plants) and structure (the relationship of species and abiotic components to landscape composition and arrangement) as described by (Olson, 2001).

The ecosystem level looks at plant community species diversity, occurrence of rare species, and habitat specificity of species.

Vegetation types represent the basic units of landscape structure for project-specific biodiversity assessment. The plants and vertebrate species occurring in each vegetation type were used to determine whether a high, moderate or low level of biodiversity is present relative to other vegetation types as described by Sherrington, 2005. This ecosystem-level information is translated to the landscape level by using indicator measures on the ranked vegetation types to predict changes in the arrangement of these types as could be occasioned by bitumen development.

Selection of Key Issues and Questions

The key issues identified by Sustainable Ecosystem Working Group, SEWG, Alberta, Canada, relating to biodiversity conservation goals in the region, which are formulated into key questions were used in the biodiversity assessment. These key questions were addressed in the EIA to determine the direction, magnitude, duration or active disturbance, frequency, and reversibility of individual effects in relation to the project. There are two levels of biodiversity assessment: landscape and ecosystem.

Application of Indicators

Agreed biodiversity indicators developed by Olson, 2001, which relate to the key issues and questions and which enabled assessments to be focused to address these, were applied. The ecosystem-level indicators (Table 3.1) were assessed to determine how well they related to ecological function (flows of animals and plants) and structure (the relationship of species and abiotic components to landscape composition and arrangement) (Olson, 2001). The ecosystem level looks at plant community species diversity, occurrence of rare species, and habitat specificity of species.

Vegetation types represent the basic units of landscape structure for project-specific biodiversity assessment. The plants and vertebrate species occurring in each vegetation type were used to determine whether a high, moderate or low level of biodiversity is present relative to other vegetation types as described by Sherrington, 2005.

Metrics for Assessing Probable Effects

The relative abundance and richness of trees, shrubs, herbs, birds and animals were assessed on per hectare basis. This is to ascertain the probable effect of the proposed project development on the broad taxonomic assemblages of biodiversity. The probable number of the assemblages that are present in each of the ecosystems per hectare will, therefore, represent the number that will be affected in each of the ecosystems for every hectare that is lost to the project development.

Table 3.1: Selected Biodiversity Measures

Level	indicator measures
Ecosystem level	Abundance of vegetation types: uniqueness of regional vegetation classes based on relative abundance in RSA
	Total species richness: total number of vascular (eg, herbs and shrubs) and non-vascular plant species (eg bryophytes and lichens), terrestrial vertebrates in each vegetation type
	Species overlap: proportion (%) of plant species and terrestrial vertebrate species shared with other vegetation types (>4 habitats shared)
	Rare species potential: potential for ecosystems to support listed plant species and wildlife species of special concern
	Structural complexity: measure of the number of layers comprising each vegetation type
	The number and distribution of native and non-native plant species

Source: Olson, 2001

Process and Rationale Used To Select Biotic and Abiotic Indicators for Biodiversity within Selected Taxonomic Groups

Biotic indicators for biodiversity in each of the following assemblages: trees, shrubs, herbs, birds and animals were selected on the basis of their occurrence in 50% of the habitats sampled. Abiotic indicators for biodiversity in soils were selected based on the ecosystem services that they give in terms of - provision and regulation of water resources, the soil, nutrient storage and cycling, pollution breakdown and absorption, and other functions such as climate stability and recovery from unpredictable events, as described by Furze *et al*, 1996.

3.31: Analytical Techniques

The data collected were subjected to descriptive statistics, Completely Randomized Design (CRD), t-test for independent samples and coefficient of rank correlation.

The descriptive statistics used are percentage, arithmetic mean, standard deviation (SD).

Mean = $\frac{\sum X}{N}$

Where: $\sum X$ = Summation of values

N = number of items in the set

Standard Deviation (S.D.) = $\sqrt{\frac{(\sum X_i - X)^2}{n-1}}$

Where:

Xi = values in a data

X = mean values in a data

n=number of elements in a sample test.

$\sum$ = Summation

Completely Randomized Design

The analysis of this design is based on the linear model below:

$Yij = \mu + T_i + eij$

μ = unknown constant, the population mean common to all treatments

Tj = Effect of jth treatment

eij = Error term

Yij = value of any observation

T-test for independent samples

The computation of t-statistic under this approach is given as:

$$t = \frac{X_A - X_B}{\sqrt{\frac{S^2 (n_A + n_B)}{(n_A)(n_B)}}} \quad \text{.................... equation 1}$$

Where,

X_A and X_B = arithmetic means for groups A and B

n_A and n_B = number of observations in groups A and B (note that n_A and n_B do not have to be the same)

S^2 = pooled within-group variance (for independent samples with equal variance)

S^2 is computed as follows:

$$S^2 = \frac{SSA + SSB}{(nA - 1) + (nB - 1)} \quad \text{.................... equation 2}$$

Where,

$$SS_A = \sum X^2{}_A - \frac{(\sum X_A)^2}{n_A} \quad \text{.................... equation 3}$$

$$SS_B = \sum X^2{}_B - \frac{(\sum X_B)^2}{n_B} \quad \text{.................... equation 4}$$

Correlation

The rank correlation denoted by r_s is given by:

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)}$$

Where:

d= difference between paired ranks

n= number of ranks

CHAPTER FOUR

4.0: RESULTS

4.1.1: Relationships between Chemical Properties of Bituminous Tar and Associated Surface Soil of Ondo State Bitumen Belt

Chemical Properties of Bituminous Tar and associated surface soil are presented in Table 4.1. The result shows that: $_{p}H$ (KCl), $_{p}H$ (H_2O), available Phosphorus, exchangeable bases and base saturation of the bituminous tar did not vary remarkably from that of the associated surface soil ($P>0.05$).

Organic carbon (109.1±8.1mg/kg), Total Nitrogen (27.4±3.3mg/kg), Exchangeable Acidity, EA, (59.4±2.6meq/100g) and Cation Exchange Capacity, C.E.C, (60.0±0.2meq/100g) of bituminous tar were significantly higher than 20.8±27.2mg/kg, 9.9±0.3mg/kg, 2.1±1.3meq/100g and 4.3±1.8meq/100g in the associated surface soil ($P<0.05$) (appendix 1).

4.1.2: Relationship between the Physical Properties of Bituminous Tar and Associated Surface Soil of Ondo State Bitumen Belt

Physical properties of bituminous tar and associated surface soil are presented in Table 4.2. The mean proportion of sand in both tar and sand was found to be the highest, followed respectively by gravel, silt and clay. The result shows that sand components of tar (957.5±7.8g/kg) is significantly higher than that of associated surface soil (892.0±0.0g/kg), while silt (27.0±9.9g/kg) is significantly lower in tar than associated surface soil (94.0±0.0g/kg) ($P<0.05$). But, each of Clay and gravel content of tar and soil are not remarkably different from one another (appendix 2).

4.1.3: Chemical Characteristics of Soils in Ondo State Bitumen Belt

The relationship between the chemical properties of soils in Bitumen seepage and control sites is presented in Tables 4.3. The results show that: Organic Carbon, Available phosphorus, calcium, magnesium, sodium, and potassium of soils in seepage and control sites are not significantly different from one another ($P>0.05$) (appendix 3). Total nitrogen, (9.9±1.9mg/kg); exchangeable acidity, (1.9±0.9meq/100gm); and CEC, (4.3±1.0meq/100gm) were significantly higher in seepage soils than 3.8meq/100g, 0.4 meq/100gm and 2.5meq/100gm respectively in the control sites. pH (H_2O) (4.3±0.7) and PH (KCl) (3.1±0.8) of seepage soil was significantly lower than 5.8±0.2 and 3.9±0.2 respectively in the control (appendix). pH, Available phosphorus, potasium, magnesium, calcium, sodium, exchangeable acidity and CEC were found to be lower than optimum recommended rates, while organic carbon and nitrogen were found to be higher than than optimum recommended rates (table 4.4).

4.1.4: Relationship between Heavy Metals in Bituminous Tar and Seepage Surface Soils of Ondo State Bitumen Belt

Comparison of heavy metals in bituminous tar and associated surface soils in seepage site is presented in table 4.5. The result shows that the values of Mn, (805.0±136.1mg/kg), and Fe, (990.3±115.3mg/kg) are significantly higher in surface soil than 610.0±140.0mg/kg and 760.0±160.0mg/kg respectively in bituminous tar. But, Cu, (139.6±73.5mg/kg) and Zn, (219.7±105.4mg/kg) are significantly lower in surface soil than 200.0±20.0mg/kg and 250.0±50.0mg/kg in tar. However**,** Pb, Ni, As, Cr, V and Cd in bituminous tar and associated surface soils in seepage sites are not significantly different from one another ($P>0.05$) (appendix 4).

4.1.5: Trace Heavy Metals in Surface Soil in Bitumen Seepage and Control Sites

The result of trace heavy metal in bitumen seepage soil in table 4.6 shows that the values of Mn, (805.0±136.09mg/kg), Cu, (140.0±73.5mg/kg), and Zn, (220.0±105.4mg/kg) in bitumen seepage sites were significantly lower in seepage sites than 1129.5±208.4mg/kg, 297.5±25.3mg/kg, and 370.3±24.5mg/kg respectively in control (Appendix 5). Fe, (990.3±115.3mg/kg) was, however, significantly higher in seepage sites than 300.0±84.2mg/kg in control ($P<0.05$).

The mean values for Pb, Ni, As, Cr, and V in seepage sites were however not significantly different from that of the control ($P>0.05$).

Table 4.1. Relative Proportions of Chemical Properties of Bituminous Tar and Associated surface soil of Ondo State Bitumen Belt

Parameter	Soil					Bituminous Tar		
	S 1	S 2	S 3	S 4	Mean	T 1	T 2	Mean
pH (H2O)	5.0	3.6	3.2	5.4	4.3	2.6	3.4	2.8
pH(KCl)	2.1	4.1	4.5	1.7	3.1	2.7	2.9	3.0
Org Carbon (mg/kg)	1.5	40.0	41.0	1.7	20.8*	103.4	114.8	109.1*
Total N(mg/kg)	10.1	9.7	9.6	10.2	9.9*	25.1	29.7	27.4*
Av P(mg/kg)	0.8	0.1	0.8	0.03	0.4	0.7	1.0	0.8
Ca (meq/100g)	1.5	1.0	1.0	1.6	1.3	1.3	1.4	1.3
Mg (meq/100g)	0.8	0.7	0.6	0.9	0.7	0.7	0.9	0.8
Na (meq/100g)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
K (meq/100g)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ex Ac (me(meq/100g)q/100g)	3.0	1.2	0.8	3.4	2.1*	57.6	61.2	59.4*
CEC(meq/100g)	5.6	3.1	2.5	6.2	4.3*	59.8	60.1	60.0*
Base Sat(meq/100g)	460.4	611.7	640.0	428.1	536.1	367.9	854.7	611.3

NB: Marked mean values are significant at $P < 0.05$

Table 4.2. Relative Proportions of Physical Properties of Bituminous Tar and Associated Surface Soil of Ondo State Bitumen Belt

Source	Parameter (g/kg)			
	Sand	Silt	Clay	Gravel
Tar 1	952	34	14	105.1
Tar 2	963	20	17	126.2
Mean	957.5*	27.0*	15.5	115.7
Soil 1	892.0	94.0	14.0	99.8
Soil 2	892.0	94.0	14.0	165.9
Mean	892.0*	94.0*	14.0	132.9

NB: Marked mean values are significant at $P < 0.05$

Table 4.3. Chemical Characteristics of Surface Soils in Bitumen Seepage and Control Sites of Ondo State Bitumen Belt

Parameter	Seepage Site (S)					Control Site (C)				
	S 1	S 2	S 3	S 4	Mean	C1	C2	C3	C4	Mean
pH (H_2O)	5.0	3.6	3.2	5.4	4.3*	5.8	6.1	5.5	5.8	5.8*
pH(KCl)	2.1	4.1	4.5	1.7	3.1*	3.9	3.7	4.1	3.9	3.9*
Org Carbon(mg/kg)	1.5	40.0	41.0	1.7	20.8	15.8	18.0	13.4	15.6	15.7
Total N(mg/kg)	10.1	9.7	9.6	10.2	9.9*	3.9	3.3	4.3	3.7	3.8*
Av P(mg/kg)	0.8	0.1	0.8	0.03	0.4	0.1	0.1	0.1	0.1	0.1
Ca (meq/100g)	1.5	1.0	1.0	1.6	1.3	1.2	1.2	1.2	1.2	1.2
Mg(meq/100g)	0.8	0.7	0.6	0.9	0.7	0.8	0.6	0.6	0.8	0.7
Na (meq/100g)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
K (meq/100g)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ex Ac(meq/100g)	3.0	1.2	0.8	3.4	2.1*	0.4	0.4	0.4	0.4	0.4*
CEC(meq/100g)	5.6	3.1	2.5	6.2	4.3*	2.6	2.4	2.5	2.5	2.5*
Base Sat(meq/100g)	460.4	611.7	644.0	428.1	536.1	838.0	843.2	880.0	801.2	840.6

NB: Marked mean values are significant at $P < 0.05$

Table 4.4. Optimum Range of Soils Chemical Characteristics

Element/	Optimum range	Source	Present study		
			Bitumen belt	Control site	Tar
PH(kcl)	6.0-7.0	Sideman and Coleman (2010)	3.1	3.9	3.0
Org. C	2.0%	FAO	20.8	15.7	109.1
N	0.2%	FMNAR	9.9	3.8	27.4
Av. P	9.07-18.14kg	Sideman and Coleman (2010)	0.4	0.1	0.8
K	3.5-5.0(meq/100 g)	Sideman and Coleson (2010)	0.16	0.2	0.2
Mg	10-25(meq/100g)	,,	0.74	0.7	0.8
Ca	60-80(meq/100g)	,,	1.25	1.2	1.3
Na	<10%	Ag Source, 2006	0.08	0.1	0.1
Ex Acidity	<10(meq/100 g)	Sideman and Coleman, 2010	2.10	0.40	59.4
CEC	8.0-16.0meq/100 gm	FAO	4.3	2.5	60.0

Source: Ag Source, 2006, FAO, FEPA, FMNAR, Sideman and Coleman, 2010

Table 4.5. Trace Heavy Metals in Bituminous Tar and Seepage Surface Soils of Ondo State Bitumen Belt

Location	Level (mg/kg)									
	Mn	Fe	Cu	Zn	Pb	Ni	As	Cr	V	Cd
Soil 1	730.0	970.0	200.0	290.0	10.0	10.0	5.0	10.0	8.0	3.0
Soil 2	820.0	1000.0	200.0	270.0	10.0	20.0	5.0	9.0	8.0	3.0
Soil 3	680.0	860.0	50.0	60.0	4.0	2.0	3.0	10.0	9.0	1.0
Soil 4	990.0	1140.0	110.0	240.0	10.0	20.0	6.0	10.0	7.0	3.0
Mean	805.0*	990.3*	139.6*	219.7*	8.5	13.1	5.0	10.0	7.7	2.5
Tar 1	711.0	867.0	209.0	278.0	69.0	10.9	4.9	12.8	6.9	3.8
Tar 2	513.0	654.0	176.0	210.5	87.0	13.5	4.3	9.2	5.1	3.4
Mean	760.5*	760.0*	200.0*	250.0*	10.0	10.0	10.0	10.0	6.0	3.6

NB: Marked mean values are significant at $P < 0.05$

Table 4.6: Trace Heavy Metals in the Bitumen Seepage Surface Soils and Control

Location	Level (mg/kg)									
	Mn	Fe	Cu	Zn	Pb	Ni	As	Cr	V	Cd
Seepage 1	730.0	970.0	200.0	290.0	10.0	10.0	5.0	10.0	8.0	3.0
Seepage 2	820.0	1000.0	200.0	270.0	10.0	20.0	5.0	9.0	8.0	3.0
Seepage 3	680.0	860.0	50.0	60.0	4.0	2.0	3.0	10.0	9.0	1.0
Seepage 4	990.0	1140.0	110.0	240.0	10.0	20.0	6.0	10.0	7.0	3.0
Mean	805*.0	990.3*	139.6*	219.7*	8.5	13.1	4.0	10.3	7.7	2.6
Control 1	1210.0	320.0	330.0	370.0	10.0	10.0	5.0	9.0	8.9	38.0
Control 2	890.0	200.0	310.0	340.0	10.0	10.0	6.0	10.0	9.0	4.0
Control 3	1370.0	400.0	290.0	400.0	10.0	10.0	4.0	10.0	8.7	4.0
Control 4	10.50.0	270.0	270.0	370.0	10.0	10.0	5.0	10.0	9.0	3.9
Mean	1129.5*	298.0*	300.0*	370.0*	10.0	10.0	5.0	10.0	9.0	4.0

NB: Marked mean values are significant at $P < 0.05$

4.2.1: Relationships among Physico-Chemical Parameters of Water in Ondo State Bitumen Belt

Linear association that exist among physical, chemical and Biochemical parameters of surface water is shown in Table 4.7. The result shows the following positive associations:

$BiCO_3$

The level of $BiCO_3$ ranges from 18.30 to 20.60mg/l across all locations in the Bitumen Belt (appendix 6). $BiCO_3$ in Water is positively correlated with each of S, SO_4, NO_3, alkalinity, Total Dissolved Solute, TDS, Total Suspended Solute, TSS, Turbidity, Conductivity, Chemical Oxygen Demand, COD, and Biological Oxygen Demand, BOD. As the levels of these parameters rise in water, so also did that of $BiCO_3$. However, the correlation between $BiCO_3$, and alkalinity was found to be significant ($P<0.05$).

Chloride

The level of Cl^- concentration in water ranges between 18.00 and 25.20mg/l (appendix 6). The association between chloride and Dissolved Oxygen, DO, was also found to be significant ($p<0.05$). The levels of the two parameters in water were found to rise and fall together.

Sulphur

Sulphur level in water across the bitumen belt ranges between 11.42 and 21.56mg/l (appendix 6). The following parameters in water – SO_4, NH3, NO3, and alkalinity also; TDS, TSS, Turbidity, Temperature, Conductivity, COD and BOD have positive association with sulphur. Sulphur level in water along with each of the parameters rises and falls together. The rise and fall in the levels of S and SO_4 in water is, however, more significant than those of others ($P<0.05$).

SO_4

The amount of SO_4 across all locations ranges between 5.31 and 7.11mg/l (appendix 6). SO_4 level in water across the bitumen belt is positively correlated with the levels of NH_3, NO_3, alkalinity, TDS, TSS, Turbidity, Temperature, Conductivity, COD and BOD. The levels of each of the parameters in water positively influence SO_4 presence.

NH_3

The level of NH_3 across the bitumen belt ranges between 5.60 and 46.30 mg/l. NH_3 was found to increase or decrease steadily with increasing or decreasing levels of NO_3, alkalinity, turbidity and temperature.

NO_3

The Level of NO_3 in water ranges between 9.60 and 46.20mg/l. It was also found to be positively associated with levels of alkalinity, TDS, turbidity, temperature, Conductivity, COD and BOD. NO_3 level present in water of the bitumen belt rises and falls with increasing and decreasing levels of the mentioned parameters. The association between NO_3 and COD was, however, found to be significant, ($P<0.05$).

Alkalinity

The level of alkalinity of water across all locations ranges between 2.40 and 13.00mg/l (appendix 6). Alkalinity in water also positively correlates with levels of TDS, TSS, turbidity, conductivity, COD and BOD. The relationship between alkalinity and each of COD and BOD was, however found to be significant, ($P<0.05$).

TDS

Levels of TSS, turbidity, conductivity, COD and BOD were found to positively influence an increase or decrease of TDS level in water across the Bitumen belt. The level of TDS in all locations fluctuates between 0.08 and 0.14mg/l.

TSS

Turbidity, Conductivity, DO, COD and PH levels of water also, are positively correlated with the amount of TSS in water, the level of TSS value ranges between 0.09 and 0.14mg/l.

Turbidity

Increase and or decrease in temperature, conductivity, COD, BOD and PH also affect rises and fall of turbidity. The value ranges between 1.86 and 28.62mg/l (appendix 6). The positive association of turbidity and conductivity was, however, found to be significant ($P<0.05$).

Temperature

Temperature level of water also positively correlates with the levels of conductivity, COD and BOD. Temperature level across all locations fluctuates between 26.80 and 27.60^{0}C (appendix 7).

Conductivity

The levels of COD, BOD and PH were found to be positively associated with the level of conductivity, with correlation between conductivity and COD being significant ($P<0.05$). Conductivity of water across all locations was found to range between 196.00 and 705.00ds/cm^3.

DO

DO level also positively correlates with that of PH. The level of DO and PH in water were seen to rise and fall together. DO levels across all locations fluctuate with values ranging between 2.70 and 6.90mg/l (appendix 8).

COD

COD level also decreases and increases with falls and rises in the levels of BOD and PH. But, the association between COD and BOD was found to be significant ($p<0.05$). COD level across the bitumen belt ranges between 112.40 and 878.50mg/l.

The result also shows the following negative associations:

$BiCO_3$

$BiCO_3$ level in water across the Bitumen Belt is negatively correlated with each of the following parameters – Cl^-,S^- , NH_3, Temperature, dissolved oxygen, and PH. As $BiCO_3$ level rises, those of S, NH_3, Temperature, dissolved oxygen, and PH decreases. But, level of $BiCO_3$ dropped with increasing level of Cl^-.

Chloride

Cl^- level in water of the bitumen belt was also found to be negatively correlated with each of S, SO_4, NH_3, NO_3, alkalinity, TDS, TSS, Turbidity, Temperature, Conductivity, COD, BOD, DO and PH. The association between Cl- and each of NO_3, BOD and DO are significant. Cl^- level increased with decreasing levels of S, SO_4, NH_3, NO_3, alkalinity, TDS, TSS while the level decreased with increasing quantity of Temperature and Conductivity.

Sulphur

Sulphur with each of DO and PH were also found to be negatively correlated. As sulphur increases, levels of DO and PH in water were seen to drop.

Sulphate

Sulphate with each of DO and PH were also found to be negatively correlated. As sulphate level increases in water, PH dropped. As SO_4 level dropped, DO level increased and vice versa.

Nitrate

Nitrate, NO_3 was found to be negatively correlated with each of DO, TDS and PH. The relationship between NO_3 and DO was, however, found to be significant. As NO_3 level increased in water, levels of DO, TDS and PH were seen to decrease.

Alkalinity

The association between alkalinity and each of DO and PH was found to be negative, but the association with DO is significant ($p<0.05$). As the levels of DO and PH rises in water, alkalinity level declined.

Total Dissolved Solute

Total dissolved solute TDS, in water was found to be negatively correlated with each of Temperature, DO and PH. The association between TDS and DO was, however found to be significant ($P<0.05$). As the levels of temperature, DO and PH rises in water that of TDS was found to drop.

Total Suspended Solute

Total suspended solute, TSS, was negatively correlated with each of $NH_{3,}$ $NO_{3,}$ Temperature and BOD. TSS level was found to fall with increasing quantities of $NH_{3,}$ NO_3, Temperature and BOD.

Dissolved Oxygen

Dissolved oxygen, DO, shows negative correlation with each of $NH_{3,}$ Turbidity, Temperature, conductivity and COD. The association between DO and COD was, however found to be significant ($P<0.05$). DO level rises with decreasing levels of $NH_{3,}$ and turbidity.

pH

PH in water was also seen to have negative correlation with each of Temperature and BOD. As the levels of the two rises, that of PH decreases. PH levels across the Bitumen Belt fluctuate between 4.95 and 6.37.

Seepage sites had significantly highest values of Sulphur, 17.65±2.82mg/l; Sulphate, 5.99±0.78mg/l; Chemical Oxygen Demand 553.58±343.68mg/l, and Turbidity, 19.27±11.97NTU in surface water than 11.42±2.82mg/l, 3.77±0.78mg/l, 116.70±8.59mg/l and 2.34±0.43mg/l respectively in control ($p<0.05$) (Appendix 6).

Other parameters such as $BiCO_3$, NH_3, NO_3, alkalinity BOD, temperature and conductivity though are having higher values in seepage site than in the control (table 4.8), the difference was not significant. Also, Cl, pH, DO and TDS were found to be higher in the control, but, the difference is not remarkable over that of the seepage site (appendix 9).

4.2.2: Associations among Trace Heavy Metals of Water in Ondo State Bitumen Belt

Result of trace heavy metals in surface water of bitumen seepage and control sites (table 4.9) shows that they are not significantly different (appendix 10). Linear associations that exist among trace heavy metals of water in the bitumen are presented in Table 4.10. The result shows the following positive associations:

Iron

The level of Iron, Fe in water is positively correlated with the levels of each of copper, Cu, Manganese, Mn, Lead, Pb, Chromium, Cr, Nickel, Ni, Vanadium, V, and Zinc, Zn. The association between Fe and Cu was, however, found to be significant ($P<0.05$). The level of the two heavy metals rises and falls together.

Copper

Cu level was also found to be positively correlated with the levels of each of Mn, Pb, Cr, Ni, V and Zn. As the levels of each of the heavy metals increases, so does that of Cu.

Manganese

Mn level also rises and falls with respective increasing and decreasing levels of Pb, Cr, Ni, V and Zn. The positive association between Mn and V was found to be significant, ($P<0.05$).

Lead

Ni and V levels in water were found to positively influence the level of Pb.

Chromium

Levels of Cd, Ni, V, As and Zn also positively affect the level of Cr in water. The levels of each of the heavy metals rise and fall with rises and fall in chromium level.

Cadmium

As and Zn levels in water positively affect the level of Cd in water. The levels of the heavy metals rise and fall together.

Table 4.7. Correlations among Physical, Chemical and Biochemical Parameters of Water in Ondo State Bitumen Belt

Variable	Physical, Chemical and Biochemical Characteristics									
	$BiCO_3$	Cl	S	SO_4	NH_3	NO_3	DO	COD	BOD	PH
$BiCO_3$	1.0	-0.5	0.8	0.8	-0.3	0.5	-0.7	0.7	0.7	-0.6
Cl	-0.5	1.0	-0.6	-0.5	-0.5	-0.9*	0.9*	-0.9	-0.9*	-0.2
S	0.8	-0.6	1.0	1.0*	0.2	0.8	-0.8	0.8	0.8	-0.5
SO_4	0.8	-0.5	1.0*	1.0	0.1	0.7	-0.7	0.8	0.8	-0.4
NH_3	-0.3	-0.5	0.2	0.1	1.0	0.6	-0.4	0.4	0.5	0.5
NO_3	0.5	-0.9*	0.8	0.7	0.6	1.0	-1.0*	0.9*	1.0*	-0.0
Alkal.	0.9*	-0.8	0.9	0.8	0.1	0.8	-0.9*	0.9*	0.9*	-0.3
TDS	1.0*	-0.4	0.8	0.8	-0.4	0.4	-0.6	0.6	0.6	-0.7
TSS	0.4	-0.0	0.1	0.3	-0.4	-0.2	0.0	0.3	-0.0	0.1
Turbidity	0.3	-0.7	0.6	0.7	0.6	0.7	-0.6	0.9	0.7	0.4
Temp.	-0.1	-0.1	0.5	0.4	0.5	0.4	-0.3	0.2	0.4	-0.4
Conductivity	0.6	-0.8	0.8	0.8	0.5	0.8	-0.8	1.0*	0.9	0.1
DO	-0.7	0.9*	-0.8	-0.7	-0.4	-1.0*	1.0	-0.9*	-1.0*	0.1
COD	0.7	-0.9	0.8	0.8	0.4	0.9*	-0.9*	1.0	0.9*	0.0
BOD	0.7	0.9*	0.8	0.8	0.5	1.0	-1.0*	0.9*	1.0	-0.2
pH	-0.6	-0.2	-0.5	-0.4	0.5	-0.0	0.1	0.0	-0.2	1.0
	Alkal.	TDS	TSS	Turbidity	Temp	conductivity				
$BiCO_3$	1.0	1.0*	0.4	0.3	-0.1	0.6				
Cl	-0.8	-0.4	-0.0	-0.7	-0.1	-0.8				
S	0.9	0.8	0.1	0.6	0.5	0.8				
SO_4	0.8	0.8	0.3	0.7	0.4	0.8				
NH_3	0.1	-0.4	-0.4	0.6	0.5	0.5				
NO3	0.8	0.4	-0.2	0.7	0.4	0.8				
Alkalinity	1.0	0.9	0.3	0.6	0.1	0.8				
TDS	0.9	1.0	0.4	0.2	-0.0	0.5				

TSS	0.3	0.4	1.0	0.4	-0.6	0.4
Turbidity	0.6	0.2	0.4	1.0	0.1	0.9*
Temp	0.1	-0.0	-0.6	0.1	1.0	0.2
Conductivity	0.8	0.5	0.4	0.9*	0.2	1.0
DO	-0.9*	-0.6	0.0	-0.6	-0.3	-0.8
COD	0.9*	0.6	0.3	0.9	0.2	1.0*
BOD	0.9*	0.6	-0.0	0.7	0.4	0.9
PH	-0.3	-0.7	0.1	0.4	-0.4	0.1

NB: Marked correlations are significant at $P < 0.05$

Table 4.8: Physico-chemical Parameters of Water in Seepage and Control Sites

Parameter	Seepage site					Control site				
	S 1	S 2	S 3	S 4	Mean	C 1	C 2	C 3	C 4	Mean
CO_3 (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
$BiCO_3$(mg/l)	18.3	18.3	48.8	20.4	20.6	17.4	19.2	16.9	19.7	18.3
Cl (mg/l)	25.2	18.0	18.0	22.8	21.0	22.4	208	21.0	22.2	21.6
S (mg/l)	16.1	17.8	21.6	15.2	17.7*	9.1	13.7	10.0	12.8	11.4*
SO_4(mg/l)	5.3	5.9	7.1	5.7	6.0*	3.1	4.5	3.1	4.5	3.8*
NH_3(mg/l)	5.6	46.3	4.2	8.8	16.2	5.2	7.0	6.2	6.0	6.1
NO_3(mg/l)	9.6	51.3	46.2	10.6	29.4	9.0	13.4	10.1	12.3	11.2
Alkalinity (mg/l)	2.4	7.0	13.0	4.5	6.7	2.0	3.6	3.6	2.1	2.8
TDS(mg/l)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TSS(mg/l)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Turbidity	1.9	28.6	24.9	24.9	19.3	2.0	2.6	2.8	1.9	2.3
Temperature (^oC)	27.6	27.6	26.9	26.9	227.3	26.4	27.2	26.6	27.0	26.8
Conductivity	196.0	627.0	535.0	535.0	515.8	190.0	216.0	186.0	220.0	203.0
DO(mg/l)	7.3	3.6	2.7	6.9	5.1	6.4	7.0	5.6	7.8	6.7
COD(mg/l)	112.4	765.6	878.5	457.8	553..6*	122.9	108.2	125.2	110.5	116..7*
BOD(mg/l)	61.3	498.2	586.0	86.4	308.0	72.2	52.8	79.6	60.2	66.2
pH	5.0	6..5	5.0	6.4	5.7	6.4	6.0	6.1	6.3	6.2

NB: Marked mean values are significant at $P < 0.05$

Nickel

The association between Nickel and each of V, As and Zn was also found to be positive.

Arsenic

As and Zn level were found to rise and fall together in water.

The result further reveals the following negative associations:

Arsenic

The levels of Fe, Cu, Mn and Pb have negative correlations with that of As. As the levels of each of the heavy metals rises, the level of As falls and vice versa.

Cadmium

The level of Cd also shows negative association with each of Fe, Cu, Mn, Pb, Ni and V. The association between Cd and Pb was, however, found to be significant ($p<0.05$).

Lead

The levels of each of Cr and Zn also rise with decreasing level of Pb in water.

Copper and Zinc

Cu and Zn were also found to be negatively correlated. As the level of Cu increases in water, that of zinc decreases, and vice versa.

4.2.3: Associations among Trace Heavy Metals and Macro Heavy of Water in Ondo State Bitumen Belt

The linear relationship that exists among trace heavy metals and macro heavy metals (table 4.11) present in surface water across the bitumen belt is presented in table 4.12. The result shows the following positive correlations. The levels of macro heavy metals in seepage site and control were found not to significantly different from one another (appendix 11).

Iron

Iron level present in water of the bitumen belt was found to positively correlate with each of Ca, Mg, K, Na, P, and N. As the levels of these elements rise or fall in water, so did that of Fe. There was, however, a significant association between Fe and Na ($p<0.05$).

Table 4.9: Available Trace Heavy Metals in Surface Water in Seepage and Control Sites

Location	Elements (mg/kg)									
	Mn	Fe	Cu	Zn	Pb	Cr	Cd	Ni	V	As
S1	12.2	2.2	0.6	1.5	0.06	0.06	0.03	0.4	0.3	0.01
S2	9.9	1.8	0.7	1.5	0.04	0.05	0.02	0.4	0.4	0.01
S3	16.2	2.2	0.6	1.6	0.005	0.02	0.02	0.4	0.3	0.02
S4	9.8	2.0	1.3	1.5	0.04	0.06	0.03	0.4	0.4	0.01
Mean	12.0	2.1	0.7	1.5	0.04	0.05	0.03	0.4	0.3	0.01
C1	11.2	2.0	0.6	2.0	0.04	0.06	0.03	0.3	0.3	0.02
C2	12.0	1.9	0.5	1.6	0.03	0.07	0.03	0.2	0.4	0.01
C3	13.3	2.2	0.7	1.8	0.05	0.08	0.02	0.4	0.3	0.01
C4	9.9	2.3	0.6	1.2	0.04	0.07	0.03	0.3	0.3	0.01
Mean	12.0	2.0	0.7	1.5	0.04	0.07	0.03	0.3	0.3	0.01

Table 4.10. Heavy Metals in Surface Water of Ondo State Bitumen Belt: Impacts and Interaction

	Fe	Cu	Mn	Pb	Cr	Cd	Ni	V	As	Zn
Fe	1.0	0.8*	0.8	0.6	0.0	-0.7	0.2	0.4	-0.4	0.3
Cu	0.8*	1.0	0.6	0.5	0.2	-0.6	0.4	0.2	-0.2	0.3
Mn	0.8	0.6	1.0	0.6	0.4	-0.7	0.6	0.9*	-0.1	0.3
Pb	0.6	0.5	0.6	1.0	-0.3	-1.0*	0.3	0.4	-0.8	-0.5
Cr	0.0	0.2	0.4	-0.3	1.0	0.1	0.8	0.6	0.8	0.6
Cd	-0.7	-0.6	-0.7	-1.0*	0.1	1.0	-0.4	-0.4	0.7	0.4
Ni	0.2	0.4	0.6	0.3	0.8	-0.4	1.0	0.8	0.3	0.2
V	0.4	0.2	0.9*	0.4	0.6	-0.4	0.8	1.0	0.2	0.2
As	-0.4	-0.2	-0.1	-0.8	0.8	0.7	0.3	0.2	1.0	0.7
Zn	0.3	0.3	0.2	-0.5	0.6	0.4	0.2	0.2	0.7	1.0

NB: marked correlations are significant at $P < 0.05$

Copper

Copper level present in water also positively correlates with those of Na and P. Increases or decreases in the level of the two macro nutrients leads to rises or falls of Cu level in water.

Manganese

The level of Mn in water was also found to rise or fall with increase or decrease in the levels of Ca, Mg, K, Na, P and N.

Lead

There is a positive relationship between the level of Pb in water and those of Ca, Na, P and N.

Cadmium

The relationship between Cd and each of Ca, Mg, K and N was found to be positive.

Nickel

There is also a positive association between Ni and each of Na and P

Vanadium

The levels of Cd, Mg, K, Na, Ca and N were also found to be positively correlated with that of vanadium.

Arsenic

Mg and K level in water were found to increase or decrease with rises and falls in the level of As.

Zinc

The amount of Zn also rises and falls with increase or decrease in the levels of Ca, Mg, K and Na.

Calcium

Ca level and those of Mg, K and N were found to rise and fall together. The association between Ca and Mg was, however, found to be significant.

Magnesium

Levels of K, Na and N were found to have positive association with that of Mg. The amount of Mg in water rises or falls with increases or decreases in the amount of each of the nutrients.

Potassium

Na and N levels present in water were also found to rise and fall with increase and decrease in the level of potassium. The association between potassium and Nitrogen is, however, significant ($p<0.05$).

Sodium

Na was also found to fluctuate positively with changes in the levels of P, N and Cr.

The result also reveals the following negative associations:

Copper

Cu level present in surface water across the bitumen belt was found to decrease as the levels of Ca, Mg, K and N increases, and vice versa.

Lead

Mg and K levels were found to have negative associations with that of Pb.

Chromium

The levels of each of Ca, Mg, K, P and N were also found to increase with decrease in the level of Cr, and vice versa.

Cadmium

Negative association was discovered to exist between Cd, and each of Na and P.

Arsenic

Negative correlation was also found to exist between As and each of Ca, Na, P and N.

Zinc

The level of N was also found to decrease as the level of Zn rises in water.

Calcium

Calcium level decreases with increases in the levels of Na and P

Phosphorus

The levels of Mg, K, N, V and Zn were found to negatively influence the amount of P in water across the bitumen belt.

4.3.1: Investigation of the Flora of Bitumen Contaminated Sites of Ondo State Bitumen Belt

Observations on the flora of bitumen seepage area and areas subjected to bitumen exploration were carried out (tables 4.13 and 4.14). The result shows that *Panicum laxum* (plate 4.4) is the most abundant on outcrop sites with 56.5 % composition. This is respectively followed by *Lycopodium cernuum*, 28.9% (plate 4.1), *Calopogonium mucunoide*, 8.3% (plate 4.1), *Centrosema molle* 3.1%, *Diodea scandens*, 1.6% and *Chromolaena odorata*, 1.2%, while *Combretum mucronatum* has the least composition of 0.4%. On exploratory site, *Lycopodium ceernum* has the highest percentage composition of 43.7. This is followed by *Pteridium aquilinium*, 18.6% (plate 4.2), *Panicum maximum*, 17.8% (plate 4.3), *Panicum laxum*, 9.5% (plate 4.4), *Centrosema molle*, 5.8%, *Calopogonium mucunoide*, 2.5%, *while the least is recorded for Diodea scandens*, 2.1%.

4.3.2: Percent Composition of Flora Families on Seepage and Exploration Sites of Ondo State Bitumen Belt

Table 4.15 shows the percent composition of flora families on both seepage and exploration sites. The result shows that, on seepage soils, Graminae has the highest composition of 58.1%, followed respectively by Lycopodiaceae, 28.8%, Leguminosae, 11.5%, and Compositae, 1.2%, while Combretaceae has the least composition of 0.4%. On exploration soils, Lycopodiaceae has the highest composition of 43.7%, followed respectively by Graminae, 27.3%, Dennstaedtiaceae, 18.6%, and Leguminosae, 8.3%, while Rubiaceae family has the least composition of 2.1%.

Table 4.11. Available Macro Heavy Metals in Surface Water

Location	Elements (mg/kg)			
	Ca	Mg	K	Na
S1	132.0	54.0	2.0	4.0
S2	145.0	60.0	3.0	4.0
S3	136.0	55.0	3.0	4.0
S4	152.0	62.0	4.0	4.1
Mean	141.3	57.8	3.0	4.0
Control 1	125.0	55.0	3.0	4.0
Control 2	145.0	51.0	5.0	5.0
Control 3	121.0	50.0	4.0	3.0
Control 4	149.0	56.0	4.0	4.0
Mean	135.0	53.0	4.0	4.0

Table 4.12: Correlations among Trace Heavy Metals and Macro Heavy Metals in Water of Ondo State Bitumen Belt

		Elements (mg/kg)				
	Ca	Mg	K	Na	P	N
Fe	0.2	0.1	0.1	0.8*	0.3	0.2
Cu	-0.3	-0.4	-0.4	0.7	0.5	-0.2
Mn	0.2	0.1	0.0	0.8	0.2	0.2
Pb	0.1	-0.3	-0.2	0.5	0.8	0.1
Cr	-0.6	-0.2	-0.3	0.3	-0.2	-0.3
Cd	0.1	0.4	0.3	-0.6	-0.8	0.0
Ni	-0.6	-0.4	-0.4	0.5	0.3	-0.3
V	0.1	0.3	0.2	0.6	-0.1	0.3
As	-0.3	0.2	0.0	-0.1	-0.7	-0.2
Zn	0.0	0.3	0.1	0.3	-0.6	-0.1
Ca	1.0	0.9*	0.7	-0.0	-0.5	0.6
Mg	0.9*	1.0	0.9*	0.1	-0.8	0.7
K	0.7	0.9*	1.0	0.3	-0.5	0.9*
Na	-0.0	0.1	0.3	1.0	0.3	0.4
P	-0.5	-0.8	-0.5	0.3	1.0	-0.2
N	0.6	0.7	0.9*	0.4	-0.2	1.0

NB: marked correlations are significant at $P < 0.05$

Table 4.13: Plant Species at Sites Contaminated with Bitumen in Ondo State Bitumen Belt

Location	Main plant species	Family	Number/m^2
Seepage sites			
	Panicum laxum	Graminae	143
	Chromolaena odorata	Compositae	3
	Combretum mucronatum	Combretaceae	1
	Lycopodium cernuum	Lycopodiaceae	73
	Calopogonium mucunoides	Leguminosae	21
	Panicum laxum	Graminae	88
	Panicum maximum	Graminae	4
	Centrosema molle	Leguminosae	8
Exploration sites			
	Panicum maximum	Graminae	43
	Centrosema molle	Leguminosae	14
	Pteridium aquilinium	Dennstaedtiaceae	45
	Lycopodium cernuum	Lycopodiaceae	106
	Panicum laxum	Graminae	23
	Panicum maximum	Graminae	23
	Calopogonium mucunoides	Leguminosae	6
	Diodea scandens	Rubiaceae	5

Table 4.14: Percentage Composition of Various Plants on Bitumen Contaminated Soils in Ondo State Bitumen Belt

Main plant species	Seepage site	Explored site
	Composition (%)	
Panicum laxum	56.5	9.5
Chromolaena odorata	1.2	-
Combretum mucronatum	0.4	-
Lycopodium cernuum	28.9	43.7
Calopogonium mucunoides	8.3	2.5
Diodea scandens	-	2.1
Centrosema molle	3.1	5.8
Panicum maximum	1.6	17.8
Pteridium aquilinium	-	18.6

Table 4.15. Percent Composition of Various Families of Plants on Bitumen Contaminated Soils of Ondo State Bitumen Belt

Families	Seepage sites	Exploration sites
	Composition (%)	
Graminae	56.5	27.3
Leguminosae	11.5	8.3
Compositae	1.2	-
Combretaceae	0.4	-
Lycopodaceae	28.8	43.7
Rubiaceae	1.6	2.1
Dennstaedtiaceae	-	18.6

Plate 4.1: *Lycopodium cernuum* and *Calopogonium mucunoides* growing on Bitumen Seepage Soil

Plate 4.2: ***Pteridium aquilinum*** **growing on Bitumen Explored Soil**

Plate 4.3: ***Panicum maximum*** **growing on Bitumen Explored Soil**

Plate 4.4: ***Panicum laxum*** **growing on Bitumen Explored Soil**

4.3.3: Available Trace Heavy Metals in Plants Growing On Bitumen Explored Soil, Seepage Soil and Control Site of Ondo State Bitumen Belt

Comparison of the mean amount of available trace heavy metals in plants growing on exploratory, seepage and control soils is shown in table 4.16. The results show that the means of all the heavy metals – Fe, Cu, Mn, Pb, Cd, Cr, Ni, V, Zn and As in the plants in the three sites are not significantly different from one another (P>0.05) (appendices 12, 13 and 14).

Iron (Fe)

In bitumen explored soil, out of the six plants found in the site, *Centrosema molle* was found to accumulate the highest amount of Fe, 1111.5mg/kg, followed by *Panicum laxum,* 1030.6mg/kg, *Pteridium aquilinum,* 895.8mg/kg, *Lycopodium cernuum,* 810.5mg/kg, *Calopogonium mucunoide,* 732.9mg/kg, and *Panicum maximum,* 688.3mg/kg.

In the bitumen seepage site, out of the three plants found, *Panicum laxum* accumulated the highest amount of Fe, 1075.0mg/kg followed *by Lycopodium cernuum,* 834.2mg/kg and *Calopogonium mucunoide,* 755.6mg/kg.

In the control site, *Panicum maximum* was found to have the highest level of Fe, 997.5mg/kg, followed by *Centrosema molle*, 981.1mg/kg, *Calopogonium mucunoide*, 931.5mg/kg, while *Panicum laxum* has the least amount of Fe, 815.6mg/kg.

Copper (Cu)

Centrosema molle was also found to accumulate the highest amount of Cu in the explored soil, 48.6mg/kg, followed respectively by *Panicum laxum,* 46.7mg/kg, *Pteridium aquilinium,* 41.3mg/kg, *Calopogonium mucunoide,* 39.9mg/kg, *Lycopodium cernuum,* 36.8mg/kg, and *Panicum maximum,* 24.0mg/kg.

In the seepage site, *Panicum laxum* also accumulated the highest amount of Cu, 43.8 mg/kg, followed by *Calopogonium mucunoide,* 30.6mg/kg and *Lycopodium cernuum,* 27.9mg/kg, respectively.

Cu level in the control site was found to be highest in *Centrosema molle*, 43.6mg/kg, and followed by *Calopogonium mucunoide*, 43.2mg/kg, *Panicum maximum*, 42.8mg/kg, and *Panicum laxum*, 36.6mg/kg.

Manganese (Mn)

The highest amount of Mn was accumulated by *Panicum laxum* in the explored site 716.5mg/kg, followed respectively by *Centrosema molle*, 698.7mg/kg, *Lycopodium cernuum*, 550.7mg/kg, *Calopogonium mucunoide*, 510.8mg/kg, *Pteridium aquilinum* 510.8mg/kg and *Panicum maximum*, 435.2mg/kg.

In the seepage site, *Panicum laxum* was found to accumulate the highest amount of Mn, 698.0mg/kg, followed by *Lycopodium cernuum*, 472.9mg/kg, and *Calopogonium mucunoide*, 432.8mg/kg.

In the control site, Mn level was found to be highest for *Centrosema molle* 609.2mg/kg, followed by *Panicum maximum*, 587.4mg/kg, *Calopogonium mucunoide*, 581.6mg/kg, and least in *Panicum laxum*, 511.5mg/kg.

Lead (Pb)

In the explored site, the highest amount of Pb was found to be accumulated by *Centrosema pubescens*, 4.0mg/kg, followed by *Panicum maximum*, 3.2mg/kg, *Calopogonium mucunoide*, 3.1mg/kg, *Pteridium aquilinum*, 2.9mg/kg, *Lycopodium cernuum*, 2.8mg/kg, *and Panicum laxum*, 2.5mg/kg.

The highest amount of Pb was, however, accumulated by *Calopogonium mucunoide* in the seepage site, 4.7mg/kg, followed by *Lycopodium cernuum*, 4.2mg/kg and *Panicum laxum*, 3.1mg/kg respectively.

Calopogonium mucunoide was found to have the highest amount of Pb, 3.9mg/kg, in the control site, followed by *Centrosema molle*, 3.6mg/kg, *Panicum maximum*, 3.4mg/kg, while *Panicum laxum* has the least amount, 2.8mg/kg.

Cadmium (Cd)

The highest level of Cd in the explored soil was found to accumulate in *Pteridium aquilinum*, 0.6mg/kg, followed respectively by *Panicum laxum*, 0.5mg/kg, *Centrosema molle*, 0.4mg/kg, *Panicum maximum* and *Lycopodium cernuum*, 0.3mg/kg each, and *Calopogonium mucunoide*, 0.10mg/kg.

In the seepage site, *Lycopodium cernuum* was found to accumulate the highest amount of Cd, 6.1mg/kg, followed respectively by *Calopogonium mucunoide*, 0.4mg/kg and *Panicum laxum*, 0.1mg/kg.

Pb level was found to be highest in *Calopogonium mucunoide*, 0.7mg/kg, in the control site, followed by *Panicum maximum*, 0.5mg/kg, and *Centrosema molle*, 0.3mg/kg , with the least level occurring in *Panicum laxum*, 0.2mg/kg.

Chromium (Cr)

In the bitumen explored site, *Panicum laxum* accumulated the highest amount of Cr, 13.2mg/kg, followed respectively by *Centrosema molle*, 12.9mg/kg, *Lycopodium cernuum*, 12.6mg/kg, *Calopogonium mucunoide* and *Panicum Maximum*, 9.8mg/kg each, and *Pteridium aqquilinum*, 8.5mg/kg.

In the seepage site, the highest amount of Cr was found in *Panicum laxum*, 14.0mg/kg, followed by *Calopogonium mucunoide*, 11.3mg/kg and *Lycopodium cernuum*, 10.4mg/kg.

Cr was found to accumulate most in *Centrosema molle*, 12.6mg/kg, in the control site, followed respectively by *Panicum maximum*, 11.7mg/kg, *Calopogonium mucunoide*, 10.6mg/kg, with the least in *Panicum laxum*, 10.5mg/kg.

Nickel (Ni)

Lycopodium cernuum was found to accumulate the highest level of Ni, 21.3mg/kg, in the explored site, followed respectively by *Centrosema molle*, 16.7mg/kg, *Calopogonium mucunoide*, 15.2mg/kg, *Panicum laxum*, 13.3mg/kg, *Pteridium aquilinum*, 12.8mg/kg, and *Panicum maximum*, 11.9mg/kg.

In the seepage site, Ni accumulates most in *Lycopodium cernuum*, 24.4mg/kg, followed by *Panicum laxum*, 20.6mg/kg, and *Calopogonium mucunoide*, 18.6mg/kg.

Ni was found to accumulate most in *Calopogonium mucunoide*, 21.5mg/kg, in the control site followed by *Centrosema molle*, 20.6mg/kg, and *Panicum maximum*, 16.5mg/kg, while the least occurred in *Panicum laxum*, 14.9mg/kg.

Vanadium (V)

In the explored site, *Calopogonium mucunoide* has the highest level of V, 8.6mg/kg, followed by *Panicum laxum*, 8.2mg/kg, *Panicum maximum*, 8.1mg/kg, *Pteridium aquilinum* and *Lycopodium cernuum*, 7.9mg/kg each, while the least was found in *Centrosema molle*, 6.9mg/kg.

In the seepage site, *Calopogonium mucunoide* has the highest level of V, 11.5mg/kg, followed respectively by *Lycopodium cernuum*, 6.5mg/kg and *Panicum laxum*, 5.6mg/kg.

In the control site, the highest level of V, 10.5mg/kg, was found in *Panicum maximum* followed by *Calopogonium mucunoide*, 9.8mg/kg, and *Centrosema molle*, 9.3mg/kg, while the least was found in *Panicum laxum*, 7.8mg/kg.

Arsenic, (As)

In the explored site, *Pteridium aquilinum* has the highest level of As, 0.60mg/kg, followed respectively by *Panicum maximum* and *Lycopodium cernuum*, 0.mg/kg each, while the trio of *Calopogonium mucunoide*, *Centrosema molle* and *Panicum laxum* has the least, 0.3mg/kg each.

In the seepage soil, the highest level of As was found in *Lycopodium cernuum*, 0.6mg/kg, followed by *Panicum laxum*, 0.5mg/kg, while *Calopogonium mucunoide* has a comparatively lower level of 0.1mg/kg.

The highest amount of As was found to accumulate in *Panicum laxum*, 0.5mg/kg, in the control site followed by *Calopogonium mucunoide* and *Centrosema molle*, 0.3mg/kg each, with the least level, 0.2mg/kg, occurring in *Panicum maximum*.

Zinc (Zn)

In the explored site, the highest level of Zn was found in *Centrosema molle* and *Panicum laxum*, 93.2mg/kg each, followed by *Pteridium aquilinum*, 90.3mg/kg, *Calopogonium mucunoide*, 89.3mg/kg, *Panicum maximum*, 81.1mg/kg, and *Lycopodium cernuum*, 71.5mg/kg.

In the seepage site, *Panicum laxum* accumulate the highest level of Zn, 86.5mg/kg, followed by *Lycopodium cernuum*, 79.9mg/kg, and *Calopogonium mucunoide*, 65.1mg/kg.

Calopogonium mucunoide was found to have the highest level of Zn, 73.3mg/kg, in the control site. This is followed by *Panicum maximum*, 72.4mg/kg and *Panicum laxum*, 69.5mg/kg, while the least was found in *Centrosema molle*, 55.6mg/kg.

4.3.4: Available Macro Heavy Metals in Plants on Bitumen Seepage Soil, Explored Soil and Control Site of Ondo State Bitumen Belt

Comparison of the mean amount of available macro elements in plants on bitumen explored, seepage and control soils is shown in table 4.17. The result shows that the means of all the elements – Ca, Mg, Na, K, P and N are not significantly different from one another in all sites ($P>0.05$) (Appendices 15, 16 and 17).

Calcium, Ca

In the bitumen explored site, the highest amount of Ca was found in *Pteridium aquilinum*, 16493.2mg/kg. This was followed by *Panicum laxum*, 11857.9mg/kg, *Centrosema molle*, 11826.5mg/kg, *Panicum maximum*, 9874.3mg/kg, *Lycopodium cernuum*, 9763.2mg/kg, with the least occurring in *Calopogonium mucunoide*, 9743.2mg/kg.

In the outcrop site, *Lycopodium cernuum* was found to accumulate the highest amount of Ca, 16118.2mg/kg, followed by *Calopogonium mucunoide*, 16101.1mg/kg, with the least found in *Panicum laxum*, 13047.2mg/kg.

In the control site, *Panicum laxum* accumulate the highest amount of Ca, 14173.3mg/kg. This is followed by *P. maximum*, 13348.1mg/kg, and *Calopogonium mucunoide*, 12974.3mg/kg, while the least occurred in *Centrosema molle*, 11786.5mg/kg.

Magnessium, Mg

Available Mg was found to accumulate most in *Centrosema molle*, 9173.1mg/kg, in explored site, followed by *Pteridium aquilinum*, 9.047.1mg/kg, *Panicum laxum*, 7508.1mg/kg, *Calopogonium mucunoide*, 6511.7mg/kg, *Panicum maximum*, 6252.9mg/kg, with the least occurring in *Lycopodium cernuum*, 6118.9mg/kg.

The level of available Mg in the seepage site was highest in *Calopogonium mucunoide*, 9274.1mg/kg. This is followed by *Lycopodium cernuum*, 8871.1mg/kg, with the least occurring in *Panicum laxum*, 8674.3mg/kg.

In the control site, the highest level of Mg was found in *Panicum laxum*, 8605.1mg/kg. This is followed by *Calopogonium mucunoide*, 8493.3mg/kg, *Panicum maximum*, 8197.7mg/kg, while the least occurred in *Centrosema molle*, 7419.8mg/kg.

Potassium, K

Centrosema molle was found to have the highest amount of K, 60.0mg/kg in the bitumen explored site. This is followed by *Panicum laxum*, 57.0mg/kg, *Pteridium aquilinum*, 54.8mg/kg, *Calopogonium mucunoide*, 44.1mg/kg, *Lycopodium cernuum*, 44.0mg/kg, with the least occurring in *Panicum maximum*, 43.9mg/kg.

The highest level of K was found to accumulate most in *Panicum laxum*, 61.2mg/kg, in the outcrop site, while the duo of *Calopogonium mucunoide* and *Lycopodium cernuum* have the least level of available K, 48.0mg/kg each.

In the control site, K was found to accumulate most in *Calopogonium mucunoide*, 56.1mg/kg, followed by *Panicum maximum*, 54.7mg/kg, *Panicum laxum*, 53.9mg/kg, with the least occurring in *Centrosema molle*, 49.8mg/kg.

Sodium, Na

In the explored site, the highest amount of Na was found in *Panicum laxum*, 221.7mg/kg. This is followed by *Centrosema molle*, 23.1mg/kg, *Lycopodium cernuum*, and *Pteridium aquilinum*, 19.7mg/kg each, and *Calopogonium mucunoide*, 18.1mg/kg, with the least occurring in *Panicum maximum*, 17.2mg/kg.

Na was found to accumulate most in *Panicum laxum*, 23.1mg/kg, in the outcrop site. This is respectively followed by *Lycopodium cernuum*, 20.4mg/kg, and *Calopogonium mucunoide*, 18.7mg/kg.

In the control site, *Panicum maximum* was found to contain the highest amount of Na, 22.2mg/kg, followed by *Calopogonium mucunoide*, 21.7mg/kg, *Panicum laxum*, 21.1mg/kg, with the least occurring in *Centrosema molle*, 20.1mg/kg.

Phosphorus, P

In the explored site, *Centrosema molle* and *Panicum maximum* were found to contain the highest level of available P, 70.0mg/kg each. These are followed by *Calopogonium mucunoide*, 60.0mg/kg, *Panicum laxum* and *Lycopodium cernuum*, 40.0mg/kg each, while the least occurred in *Pteridium aquilinum*, 30.0mg/kg.

In the outcrop site, *Lycopodium cernuum* accumulated the greatest amount of available P, 150.0mg/kg followed by *Calopogonium mucunoide*, 80.0mg/kg, while the least occurred in *Panicum laxum*, 50.0mg/kg.

In the control site, the highest level of available P was found in *Calopogonium mucunoide*, 180.0mg/kg, followed by *Panicum laxum*, 80.0mg/kg, with the least occurring in *Panicum maximum* and *Centrosema molle*, 60.0mg/kg each.

Nitrogen, N

In the explored site, the highest level of N made available to plants was found in *Centrosema molle*, 22000.0mg/kg. This is followed by *Panicum maximum*, 21000.0mg/kg, *Lycopodium cernuum*, 17200.0mg/kg, *Panicum laxum*, 17100.0mg/kg, *Calopogonium mucunoide*, 15200.0mg/kg, with the least occurring in *Pteridium aquilinum*, 14700.0mg/kg.

Calopogonium mucunoide was found to accumulate the highest level of available N in the outcrop site, 22700.0mg/kg. This is followed by *Lycopodium cernuum*, 18600.0mg/kg, while the least occurred in *Panicum laxum*, 17400.0mg/kg.

In the control site, N level was highest in *Calopogonium mucunoide*, 22700.0mg/kg, followed by *Panicum laxum*, 21800.0mg/kg, and *Panicum maximum*, 17500.0mg/kg, while the least level was found in *Centrosema molle*, 16900.0mg/kg.

Table 4.16: Available Trace Heavy Metals in Plants on Bitumen Explored, Seepage and Control Soils

Plants	**Elements (mg/kg)**									
	Fe	Cu	Mn	Pb	Cr	Cd	Ni	V	As	Zn
Explored Site										
Calopogonium mucunoides	730	40	511	3.1	9.8	0.1	15.2	8.6	0.3	89.3
Centrosema pubescens	1120	49	700	4.0	12.9	0.4	16.7	6.9	0.3	93.2
Panicum maximum	690	24	440	3.7	9.8	0.3	11.9	8.1	0.4	81.1
Pteridium aquilinium	896	41	510	2.9	8.9	0.6	12.8	7.9	0.6	90.3
Panicum laxum	1030	47	720	2.5	13.2	0.5	13.3	8.2	0.3	93.2
Lycopodium ceernum	810	37	550	2.8	12.6	0.3	21.3	7.9	0.4	71.5
Mean										
Seepage Site										
Calopogonium mucunoides	760.0	30.0	433.0	4.7	11.3	0.4	19.0	11.5	0.1	65.1
Panicum laxum	10 80.0	40.0	700.0	3.1	14.0	0.1	21.0	5.8	0.5	86.5
Lycopodium ceernum	830.0	29.0	470.0	4.2	10.4	6.1	24.4	6.9	0.6	79.9
Mean										
Control Site										
Calopogonium mucunoides	932	43.20	582	3.9	10.6	0.7	21.5	9.8	0.3	73.3
Panicum maximum	998	43	587	3.4	11.7	0.5	16.5	10.5	0.2	72.4
Centrosema pubescens	981	44	609	3.6	12.6	0.3	20.6	9.3	0.3	55.6
Panicum laxum	816	37	512	2.8	10.5	0.2	14.9	7.8	0.5	69.5
Mean										

Table 4.17: Available Macro Heavy Metals in Plants on Bitumen Explored, Seepage and Control Soils

Plants	**Elements(g/kg)**					
	Ca	Mg	K	Na	P	N
Explored Site						
Calopogonium mucunoides	9743.0	6512.0	44.0	18.0	60.0	15200.0
Centrosema pubescens	11827.0	9173.0	60.0	23.0	70.0	22000.0
Panicum maximum	9874.0	6253.0	44.0	17.0	70.0	21000.0
Pteridium aquilinium	16493.0	9047.0	55.0	20.0	30.0	14700.0
Panicum laxum	11858.0	7508.0	57.0	222.0	40.0	17100.0
Lycopodium ceernum	9763.0	6119.0	44.0	20.0	40.0	17200.0
Mean						
Seepage site						
Calopogonium mucunoides	16101.0	9274	48	19	80	22700
Panicum laxum	13047.0	8674	61	23	50	17400
Lycopodium ceernum	16118.0	8871	48	20	150	18600
Mean						
Control Site						
Calopogonium mucunoides	12974.0	8943.0	56.0	22.0	180.0	22700
Panicum maximum	13348.0	8198.0	55.0	22.0	60.0	17500
Centrosema pubescens	11787.0	7420.0	50.0	20.0	60.0	16900
Panicum laxum	14173.0	8605.0	54.0	21.0	80.0	21800
Mean						

4.4.1: Effect of Habitat changes on Tree Composition of Ondo State Bitumen Belt

Effect of habitat changes on Tree composition of the Bitumen Belt is presented in Table 4.18. The result shows, that, the total number of individual trees, i.e, abundance, and number of different species of trees per unit area, i.e, richness in all the habitats are significantly affected by habitat type ($P<0.05$) (appendix 17). Seasonal changes was however found not to have any significant effect on the total number of trees and different types of species in the entire habitats ($P>0.05$) (appendix 20). Also, the interaction of habitat type and season has no significant effect on the tree composition of the Bitumen Belt ($P>0.05$).

The mean abundance of trees censused in each quadrant in all the habitats ranges between two and 18 per 25m^2. Cashcrop Farmland was found to contain an average of two individuals trees, Urban Arboreta (four individual trees), Island of High Forest (four individuals trees), Riparian Habitat (eight individual trees), Fallow Land (16 individual trees), and Arable Farmland(18 individual trees).

On the mean species richness, Arable Farmland has the highest species richness of nine per unit area. This is followed repectively by Fallow Land (eight species), Riparian Habitat (seven species), Island of High forest High Forest (four species), Urban Arboreta (three species), while Cashcrop Farmland has the least species richness of one.

Test of significant difference (appendix 19) reveals that, the abundance of trees for Cashcrop Farmland, Urban Arboreta and Island of High Forest are not significantly different from one another. Also, that of Urban Arboreta, Island of High Forest and Riparian Habitat was found not to be significantly different. Those in Fallow Land and Arable Farmland are also not significantly different from one another. Also, test of significant difference shows that, the tree species richness in Cashcrop Farmland differ significantly from those of the other habitats. Urban Arboreta and Island of High forest are, however, not significantly different from one another. Island of High Forest and Riparian Habitat are also not significantly different from one another. So also are Fallow Land and Arable Farmlands.

Table 4.18. Effect of Habitat Changes on Tree Composition of Ondo State Bitumen Belt

Variable	FL		HF		AF		RH		CF		UA	
	D	W	D	W	D	W	D	W	D	W	D	W
Abundance of trees/25m^2	17	16	4	4	18	18	9	8	1	3	5	4
Richness of tree species/25m^2	9	8	4	4	10	9	7	7	1	1	4	3

AF= Arable Farmland, FL= Fallow Land, RH= Riparian Habitat, HF= Island of High Forest, CF= Cashcrop Farm, UA= Urban Arboreta

4.4.2: Effect of Habitat Changes on Shrub Composition of Ondo State Bitumen Belt

The effect of habitat changes on the composition of shrub species is presented in table 4.19. The result shows that the total number of shrubs, i.e, abundance, and number of different species of shrubs, i.e, richness are significantly affected by habitat type ($P<0.05$) (appendix 21). Although seasonal variation significantly influenced the total number of shrubs ($P<0.05$), it did not have any significant effect on the species richness of shrubs ($P>0.05$). Abundance of shrubs was significantly higher in the wet than dry season (Appendix 24). The interaction of habitat type and season was also found not to have any significant effect on total number of shrubs and species richness of shrubs ($P>0.05$).

Arable Farmland has the highest species abundance. This is followed respectively by Urban Arboreta, Island of High Forest, Cashcrop Farmland and Fallow Land. Riparian Habitat, however, has the least abundance of shrubs per unit area. On species richness, High Forest has the highest density followed by Arable Farmland, Fallow Land and Urban Arboreta, while the least is recorded for Riparian Habitat and Cashcrop Farmland.

Test of significant difference reveals that, for total number of shrubs (appendix 22), Riparian Habitat, Cashcrop Farmland, Urban Arboreta and Fallow Land are not significantly different from one another ($P>0.05$). Also, Fallow Land and Arable Farmland are not significantly different from one another ($P>0.05$). On richness of shrubs, Riparian Habitat and Fallow Land were found not to be significantly different ($P>0.05$). The trio of Fallow Land, Cashcrop Farmland and Island of High Forest were found not to be significantly different from one another ($P>0.05$). Also, Cashcrop Farmland, Island of High forest and Urban Arboreta are not significantly different from one another ($P>0.05$) (appendix 23).

4.4.3: Effect of Habitat and Seasonal Changes on Composition of Herbs in Ondo State Bitumen Belt

The relative abundance of herbaceous species, i.e, abundance, and number of species, i.e, richness across the six habitats is presented in Table 4.20. The result shows that, the total number of individuals in each quadrant of $1m^2$ and number of different species are significantly affected by habitat type and season, as well as interaction between them ($P<0.05$) (appendix 25). The mean number of herbs in each quadrant ranges between seven and 64. Island of High forest, with seven herbs per unit area, has the least number of individual plants followed by Fallow Land (11), Urban Arboreta (36), Riparian Habitat (50), Arable Farmland (62) and Cashcrop Farmland (64). Wet season has a significant higher number of individual herbs (54) than that of dry season, 23, ($P<0.05$) (appendices 26 and 27).

Test of significant difference shows that the total number of individual herbs in each quadrant is not significantly different between Island of High Forest and Fallow Land. Also, Arable Farmlands and Cashcrop Farmland are not significantly different from one another. But, Urban Arboreta and Riparian Habitat are significantly different from one another and from other habitats, $P>0.05$ (appendix 26).

Futhermore, the mean number of different species of herbs censused in each quadrant was found to be significantly affected by habitat type and seasonal variation ($P<0.05$). Interaction of the two also significantly affect the species richness of the herbs, $P<0.05$, (appendix 26). Mean number of different species censused in each quadrant ranges between four and 11. The least mean number of species (four) was recorded for Island of High Forest. This is followed by Fallow Land (Five), Cashcrop Farmland, Urban Arboreta and Riparian Habitat (7 each) and Arable Farmland (11). The number of different herb species in the wet season (8) is significantly higher than that of the dry season (5) ($P<0.05$).

Test of significant difference (appendix 26) among the habitats reveals that, the number of different species of herbs is not significantly different between Island of High Forest and Fallow land. Cashcrop Farmland, Urban Arboreta and Riparian Habitat were also found not to be significantly different from one another. But, Arable Farmland is significantly different from the others.

In addition, test of significant difference on the interaction of habitat type and season on number of different herb species shows that, Islands of High Forest (dry), Islands of High Forest (wet), Fallow Land (wet) and Urban Arboreta (dry) are not significantly different from one another. Also, Island of High Forest (wet), Urban Arboreta (dry), Cashcrop Farmland (dry) and Fallow Land (dry) are not significantly different from one another. So also, are Fallow Land (wet), Urban Arboreta (dry), Cashcrop Farmland (dry) and Fallow Land (dry). Likewise, Urban Arboreta (dry), Cashcrop Farmland (dry), fallow Land (dry) and Riparian Habitat (dry) are not significantly different from one another. The trio of Fallow Land (dry), Riparian Habitat (dry) and Arable Farmland (dry) are not signnificantlydifferent from one another. So also, are Riparian Habitat (dry), Arable Farmland (dry), Cashcrop Farmland (wet), and Riparian Habitat (wet). It was also found that, Cashcrop Farmland (wet), Riparian Habitat (wet) and Urban Arboreta are not significantly different from one another, while Arable Farmland (wet) is significantly higher than all others (appendix 26).

Also, test of significant difference of the interaction of habitat type and seasons on total number of individual herbs proved, that, Islands of High Forest (dry), Islands of High Forest (wet), Fallow Land (wet and dry), Arable Farmland (dry) are not significantly different from one another. Also, Fallow Land (wet), Fallow Land (dry) are not significantly different from one another. In addition, Arable Farmland (dry), Urban Arboreta (dry) and Cashcrop Farmland (dry) are not significantly different from one another. It was also found, that, Urban Arboreta (dry), Cashcrop Farmland (dry), and Riparian Habitats (dry) are not significantly different. As it was discovered that, Urban Arboreta (wet) and Riparian Habitat (wet) are not different, so also - Cashcrop Farmland (wet) and Arable Farmland (wet) are also not significantly different from one another (appendix 26).

4.4.4: Distribution of Native and Non-Native Tree Species in Ondo State Bitumen Belt

The number and distribution of native and non-native tree species in tables 4.21 and 4.22 respectively shows that 81 plant species are native to the bitumen belt, while 16 are non-natives. Out of the 82 native tree species, 37 species are found in Fallow Land, 32 in High Forest, 38 in Arable Farmland, 17 in Riparian Habitat, three in Cashcrop Farmland and 9 in Urban Arboreta. Also, out of the 15 non-native tree species, three are found in Arable Farmland, one in Cashcrop Farmland and 14 in Urban Arboreta. In natural forest, *Raphia longflora*, H^1=0.333, D=0.009074 is the most abundant naturally growing trees. Among planted crops, *Theobroma cacao*, H^1=0.69, D=0.26 is the most abundant.

Table 4.19: Effect of Habitat Changes on Shrub Composition in Ondo State Bitumen Belt

Variable	FL		HF		AF		RH		CF		UA	
	D	W	D	W	D	W	D	W	D	W	D	W
Abundance of Shrubs/25m^2	18	26	31	30	31	49	17	21	27	31	27	43
Richness of shrub species/25m^2	6	8	10	8	8	9	5	6	6	6	6	7

AF= Arable Farmland, FL= Fallow Land, RH= Riparian Habitat, HF= Island of High Forest, CF= Cashcrop Farm, UA= Urban Arboreta

Table 4.20: Effect of Habitat and Seasonal Changes on Composition of Herbs in Ondo State Bitumen Belt

Variable	FL		HF		A F		RH		CF		UA	
	D	W	D	W	D	W	D	W	D	W	D	W
Abundance of Species	12	11	7	7	19	105	41	59	33	95	25	48
Richness of species	6	4	3	4	7	14	6	8	5	8	5	9

AF= Arable Farmland, FL= Fallow Land, RH= Riparian Habitat, HF= Island of High Forest, CF= Cashcrop Farm, UA= Urban Arboreta

4.4.5: Distribution of Native Shrub Species in Ondo State Bitumen Belt

The number and distribution of native species of shrubs (table 4.23) shows that 63 species of native shrubs belonging to 31 families are found in the bitumen belt. Arable Farmland and Riparian Habitat were found to have the highest number of different shrub species of 30 each, followed by island of High Forest, 28 species, Fallow Land, 26 species, while Cashcrop Farmland and Urban Arboreta both have the least number of species of 25 each (table 4.30). The most abundant shrub specie is *Chromolaena odorata*, H^1=0.52, D=0.045799, followed by *Anthonotha macrophyla*, H1=0.41, D=0.022022.

4.4.6: Distribution of Native Herb Species in Ondo State Bitumen Belt

The number and distribution of native species of herbs in table 4.24 shows that 130 native species are associated with the bitumen belt. Out of this number, 52 species are associated with Arable Farmland, 43 with Urban Arboreta, 36 with Riparian Habitat, 33 with Cashcrop Farmland, 30 with Fallow Land and 15 with island of High Forest. The most abundant herbaceous specie is *Ageratum conyzoide*, H^1=0.44, D=0.024765.

4.4.7: Distribution of Non- Native Herb Species in Ondo State Bitumen Belt

The number and distribution of non- native herbs in table 4.25 shows that six species are non-native to the bitumen belt. Out of these, two species are associated with Arable Farmland, two also with Urban Arboreta, four with Cashcrop Farmland, and two with Riparian Habitat. The non-native herb species are *Euphorbia hyssopifolia, Pepperomia pelucida, Mimosa invisa, Sesamum indicum Blumea aurita, Richardia brasiliensis* and *Gomphrena celosoides.*

4.4.8: Potential of Ecosystem to Support Plant Species of Special Concern in Ondo State Bitumen Belt

The study area was found to contain 11 rare or endangered plant species (table 4.26). Plants for traditional, medical and cultural practices were found to be abundant in the various habitats in this order - arable farmland>urban arboreta> fallow land>high forest, cashcrop farmland>riparian habitat (table 4.27).

Table 4.21: Native Tree Species of Ondo State Bitumen Belt

S/No	Local Name	*Scientific Name*	Family	Uses	Habitats where found	H^1	D
1	Okikan aja	*Pseudospondias microcarpa*	Anarcardiaceae		HF	0.00	0.00
2	Ekikan	*Spondias mombim*	,,	TMC	FL,AF,UA	0.230	0.00435
3	Ako-araasa	*Bridelia atroviridis*	Euphorbiaceae		FL,HF,AF	0.148	0.000869
4	Araasa	*Bridelia micrantha*	,,	TMC	FF,AF,RH	0.150	0.000605
5	Odogbo	*Anthostema aubreyanum*	,,		AF	0.086	0.000115
6	Akika igba	*Discoglypremma caloneura*	,,	TMC	CF	0.00	0.00
7	Agbabu	*Gilbertiodendron deweverei*	Leguminosae: caesalpiniodae		RH	0.00	0.00
8	Mahogany	*Khaya ivoriense*	Meliaceae	TMC	CF	0.00	0.00
9	Urere	*Carapa procera*	,,	TMC	FL	0.00	0.00
10	Ijebo	*Entandrophragma cylindricum*	,,	TMC	HF,AF	0.086	0.000115
11	Akoko igbo	*Lovoa trichiloides*	,,	TMC	FL,AF	0.118	0.000435
12	Akomu	*Pycnanthus angolensis*	Myristicaceae	TMC	FL,HF,RH	0.00	0.00
13	Oropa	*Staudtia stipitata*	,,	TMC	HF	0.00	0.00
14	Awun	*Alstonia boonei*	Apocynaceae	TMC	FL,AF	0.097	0.000195
15	Roba dudu	*Funtumia elastic*	,,	TMC	FL,AF	0.163	0.000869
16	Akata	*Funtumia Africana*	,,	TMC	FL,AF	0.086	0.001165

17	Opepe	*Nauclea diderichii*	Rubiaceae	TMC	FL,HF,AF	0.086	0.001165
18	Adagbon	*Pausinistalia johimbe*	,,		AF	0.086	0.001165
19	Ako idagbon	*P. talbotii*	,,		HF,RH	0.00	0.00
20	Abura	*Mitragyna ledermannii*	,,		RH	0.204	0.000363
21	Oruwo	*Morinda lucida*	,,	TMC	FL	0.163	0.000165
22	Ako adindin	*Zygium guineense*	Leg: caesalpinoideae		FL,AF	0.224	0.002912
23	Abo adindin	*Zygium sp.*	,,		FL,AF	0.196	0.001941
24	Apa	*Afzelia Africana*	,,	TMC	FL,HF,AF	0.00	0.00
25	Ayan	*Afzelia bipidensis*	,,		HF	0.00	0.00
26	Erun	*Erythrophleum ivoriense*	,,		FL,AF	0.086	0.000115
27	Apado	*Berlinia coriacea*	,,		RH	0.204	0.00182
28	Eru	*Pachylesma tessmannii*	,,		FL,AF	0.118	0.000435
29	Erun obo	*Erythrophleum suaveolens*	,,	TMC	FL,HF	0.00	0.00
30	Ayie	*Albizia glaberrima*	Leg: mimosoideae		FL,AF	0.196	0.001941
31	Ayinreta	*Albizia zygia*	,,	TMC	FL,AF	0.118	0.000435
32	Apasa	*Pentaclethra microphyla*	,,		FL,AF	0.132	0.000582
33	Agboin	*Piptadeniastrum africanum*	,,	TMC	FL,HF,AF	0.086	0.000115
34	Olisan	*Cylodiscus*	,,	TMC	RH	0.204	0.00181

		gabunensis					3
35	Ayinre bonabona	*Albizia adanthiafolia*	,,	TMC	AF, FL	0.412	0.01970
36	Ekki	*Lophira alata*	Ochnaceae	TMC	HF,AF	0.191	0.00116 1
37	Utako	*Strombosia pustulata*	Olacaceae		HF,AF	0.191	0.00116 1
38	Utako-pupa	*S. grandifolia*	,,		HF	0.00	0.00
39	Ata	*Fagara zanthoxyloides*	Rutaceae	TMC	FL	0.132	0.00058 2
40	Afara-funfun	*Terminalia superb*	,,	TMC	HF	0.00	0.00
41	Afara-dudu	*T. ivoriense*	,,		HF	0.191	0.00116 1
42	Iroko	*Milicia excels*	Moraceae	TMC	HF	0.00	0.00
43	Ewupin	*Ficus exasperate*	,,	TMC	FL,AF,UA	0.148	0.00086 9
44	Oropa	*F. mucoso*	,,	TMC	FL	0.097	0.00019 4
45	Opoto	*F. capensis*	,,	TMC	FL	0.132	0.00058 2
46	Ibisere	*Myrantheus aboreus*	,,	TMC	FL	0.00	0.00
47	Aworiwo	*Cola lauriflora*	Boraginaceae	TMC	RH	0.204	0.00181 5
48	Oma	*Cordia millenii*	,,	TMC	HF	0.191	0.00116 1
49	Omodon	*Cordia platythyrsa*	,,		FL,AF	0.132	0.00058 2
50	Ofun	*Mansonia altissima*	,,	TMC	HF	0.00	0.00
51	Aye	*Sterculia*	,,		HF,AF	0.191	0.00116

		rhinopetala					1
52	Arere	*Triplochyton scleroxylon*	,,		HF	0.191	0.001161
53	Obi-edun	*Cola millenii*	,,	TMC	FL	0.097	0.000194
54	Tutumese	*Octobolus spectabilis*	,,		FL,AF,UA	0.171	0.000850
55	Obi gbanja	*Cola acuminate*	,,	TMC	CF,UA	0.530	0.045161
56	Obi abata	*Cola nitida*	,,	TMC	CF,UA	0.442	0.021505
57	Owewe	*Cola verticilata*	,,		FL	0.097	0.000194
58	Isin	*Blighia unijugata*	Sapindaceae	TMC	FL,AF	0.097	0.000194
59	Ponpola	*Bombax buonopozenze*	Bombacaceae	TMC	HF	0.00	0.00
60	Awori	*Rhodonagphalon breviscupe*	,,		FL,AF	0.148	0.000869
61	Egungun	*Ceiba petandra*	,,	TMC	FL,HF,AF	0.00	0.00
62	Opepe ira	*Nesorgodonia papaverifera*	Sterculaceae	TMC	RH	0.150	0.000605
63	Ghoofun	*Phoenix reclinata*	Palmae		HF	0.00	0.00
64	Ope	*Elaeis guineensis*	,,	TMC	FL,AF,RH, CF,UA	0.318	0.006452
65	Agbon	*Cocos nucifera*	,,	TMC	UA	0.00	0.00
66	Ope odo	*Raphia longiflora*	,,		RH	0.333	0.009074
67	Aworo	*Buchlolzia coriacea*	Moringaceae	TMC	FL,HF,AF, RH	0.251	0.003630
68	Oro	*Irvingia gabonensis*	Irvingaceae	TMC	HF	0.191	0.001161
69	Odudu	*Klainedoxa*	,,	TMC	HF,AF	0.00	0.00

		gabonensis					
70	Agbalumo	*Chrysophylum albidum*	Sapotaceae	TMC	UA	0.00	0.00
71	Awonrinwon	*Chrysobalamus icaco*	Chrysobalanaceae		FL,HF,AF, RH	0.204	0.001815
72	Otu	*Homalium letestui*	Samydaceae		FL,HF,AF, RH	0.150	0.000605
73	Akoko	*Newbouldia laevis*	Bignoniaceae	TMC	UA	0.230	0.002510
74	Pandoro	*Kigelia Africana*	Bignoniaceae	TMC	AF	0.00	0.00
75	Ajeleera	*Barteria nigrita*	Passifloraceae		AF	0.086	0.000115
76	Saposapo	*Anthocleista djalonensis*	Loganiaceae	TMC	AF	0.148	0.000869
77	Sapo	*Anthocleista liebrechsiana*	,,	TMC	RH	0.150	0.000605
78	Sokusogho	*Vernonia conferta*	Compositae		RH	0.00	0.00
79	Okilolo	*Symphonia globulifera*	Guttiferae		RH	0.204	0.001815
80	Ojia	*Daniella ogea*	Leg: caesalpinioidae		FL	0.00	0.00
81	Akolodo	*Brachystegia eurycoma*	Leguminosae: caesalpiniodae		RH	0.150	0.000605
82	Ehinawosin	*Monodora tenuifolia*	Annonaceae	TMC	AF	0.086	0.000115

Table 4.22: Distribution of Non-Native Tree Species in Ondo State Bitumen Belt

S/ No	*Local Name*	*Scientific Name*	Family	Uses	Habitats where found	H^1	D
1	*Kaju*	*Anarcardium occidentale*	Anarcardiaceae	TMC	UA	0.171	0.000850
2	*Mangoro*	*Mangifera indica*	Anarcardiaceae	TMC	UA	0.00	0.00
3	*Ajekofole*	*Croton zambesicus*	Euphorbiaceae	TMC	AF,UA	0.00	0.00
4	*Igi tiiki*	*Tectona grandis*	Verbenaceae	TMC	UA	0.230	0.002510
5	*Igi melaina*	*Gmelina arborea*	Verbenaceae	TMC	UA	0.00	0.00
6	*Gofa*	*Psidium guajava*	Myrtaceae	TMC	AF,UA	0.00	0.00
7	*Osan*	*Citrus sinensis*	Rutaceae	TMC	UA	0.00	0.00
8	*Tanjarini*	*C. reticulata*	,,		UA	0.00	0.00
9	*Orombo were*	*C. aurantifolia*	,,	TMC	UA	0.00	0.00
10	*Dongoyaro*	*Azadiratcha indica*	Meliaceae	TMC	UA	0.171	0.000850
11	*Paroba*	*Hevea brasilliensis*	Rubiaceae		AF	0.148	0.000869
12	*Ogede wewe*	*Musa sapientus*	Musaceae	TMC	UA	0.372	0.012755
13	*Ogede agbagba*	*M. parasidiaca*	,,	TMC	UA	0.410	0.017857
14	*Koko*	*Theobroma cacao*	Sterculaceae	TMC	CF,UA	0.693	0.258065
15	*Ibepe*	*Carica papaya*	Caricaceae	TMC	UA	0.171	0.000850
16	*Igi furutu*	*Terminalia cattapa*	Combretaceae	TMC	UA	0.171	0.000850

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Table 4.23: Distribution of Native Shrub Species of Ondo State Bitumen Belt

S/No	Local Name	*Scientific Name*	Family	Uses	Habitats where Found	H^1	D
1	Ege	*Manniophyton fulvum*	Malvaceae	TMC	FL,HF,AF, RH,CF,UA	0.145	0.0007997
2	Furu	*Abutilon mauritianum*	,,	TMC	UA	0.102	0.000167
3	*Ipa*	*Alchornea cordifolia*	,,	TMC	FL,HF,AF, CF,UA	0.253	0.002506
4	*Ijan/pe pe*	*Alchornea laxiflora*	,,	TMC	FL,HF,AF, CF,UA	0.301	0.007574
5	*Arunfof o*	*Cassia hirsuta*	,,		FL,RH,CF, UA	0.313	0.008521
6		*Cassia occidentalis*	,,		UA	0.194	0.002005
7		*Crudia klainel*	,,		RH	0.208	0.002357
8	*Ilasa-omode*	*Urena lobata*	,,	TMC	AF,UA	0.250	0.004344
9	*Iseketu*	*Sida acuta*	,,	TMC	AF,CF,UA	0.325	0.009524
10	*Iso Obo*	*S. cordifolia*	,,	TMC	CF,UA	0.194	0.002005
11	*Akintol a*	*Chromolaena odorata*	Asteraceae	TMC	FL,AF,RH, CF,UA	0.523	0.045799
12	Abare	*Anthonotha macrophylla*	Leg: caesalpinoid eae		FL,AF	0.423	0.022022
13	*Omu-Aja*	*Cnestis ferruginea*	Cleomaceae	TMC	FL,HF,AF, RH,CF,UA	0.218	0.002799
14		*Combretum hispidum*	Combretace ae		FL,HF,AF, RH	0.204	0.002288
15	*Okan*	*Combretum racemosum*	,,	TMC	HF	0.204	0.002288
16		*Combretum*	,,		FL, HF	0.224	0.003921

		zenkeri					
17		*Combretum alnifolia*	,,		AF	0.082	0.000169
18		*Desmodium tortuosum*	Dennstaedtiaceae	TMC	FL,AF,CF, UA	0.115	0.0003998
19	*Awin*	*Dialium guineense*	,,	TMC	HF,AF,RH, UA	0.180	0.001634
20		*Hippocratea pallens*	Hippocrataceae		AF,UA	0.141	0.000844
21	*Gbegbe*	*Icacina tricantha*	Icacinaceae	TMC	FL,HF,AF, RH,CF,UA	0.447	0.026174
22		*Ludwigia abyssinica*	Loganiaceae		CF	0.174	0.002068
23	*Oju-Eja*	*Mallotus oppositifolius*	Euphorbiaceae	TMC	FL,HF,RH, CF,UA	0.347	0.011438
24		*Neoboutinia velutina*	,,		RH,CF	0.079	0.0001120 .
25	*Osunsun-iro*	*Dryeptis chevailieri*	,,	TMC	HF,RH,UA	0.180	0.001634
26		*Dryeptis gilgiana*	,,		HF,RH	0.230	0.003142
27		*Mareya micrantha*	,,		FL,RH	0.260	0.005050
28	*Ido-apata*	*Microdesmus puberula*	,,	TMC	FL	0.355	0.012128
29	*Lapalapa*	*Jatropha curcas*	,,	TMC	UA	0.207	0.002506
30	*Igba-yinrin elegun*	*Solanum torvum*	Solanaceae	TMC	UA.	0.140	0.000835
31		*Starchytarpheta cayennensis*	Sphenocleaceae		AF,RH,CF, UA	0.291	0.006754
32	*Abiko*	*Triumpheta*	Tiliaceae	TMC	FL,AF,CF,	0.082	0.000167

		cordifolia			UA		
33		*T. rhomboids*	,,		AF,UA	0.082	0.000167
34	*Atori*	*Glyphia brevis*	,,	TMC	FL,HF,RH, CF	0.244	0.003922
35	*Lakolako*	*Grewia sp.*	,,	TMC	UA	0.00	0.00
36	*Ewe-epo*	*Walthera indica*	Sterculiaceae	TMC	AF,RH,UA	0.103	0.000338
37		*Cola heterophyla*	,,		AF	0.00	0.00
38	*Olododo*	*Heistera parviflora*	Olacaceae		FL,HF,RH	0.186	0.001683
39	*Arogbo dogbo*	*Aptandra zenkeri*	,,		FL,HF,AF, RH,CF	0.158	0.001182
40	*Igbere*	*Uvariodendron mirabile*	Annonaceae		HF,RH	0.078	0.000109
41		*U. augustifolium*	,,		HF	0.078	0.000109
42		*Uvariopsis bakeriana*	,,		HF,RH	0.158	0.001182*
43	*Ewe-igbale*	*Moringa oleifera*	Moringaceae	TMC	FL,RH	0.115	0.0003998
44		*Oncoba spinosa*	Flacourtiaceae	TMC	FL,HF,AF, RH,CF	0.122	0.000563
45		*Dovyalis zenkeri*	,,		HF,CF	0.158	0.001089
46		*Ochna multiflora*	Ochnaceae		RH	0.136*	
47	*Irosun-igbo*	*Napoleona imperialis*	Lecythidaceae	TMC	FL,HF,AF, RH	0.079	0.000673
48		*Dichapetalum floribundum*	Chailletiaceae		FL,HF,AF	0.115	0.0003998
49		*D. giuneense*	,,		FL,HF,AF, RH	0.218	0.002799
50	*Gbengb*	*Pterocarpus*	Papilionace	TMC	RH	0.161	0.001122

	e	*santalinoides*	ae				
51	*Irosun*	*Baphia nitida*	,,	TMC	FL,HF,AF, RH,CF	0.186	0.001683
52	*Urohun dudu*	*Baphia pubescens*	,,	TMC	HF,AF	0.141	0.000844
53		*Bielschmedia mannii*	Lauraceae		HF	0.106	0.000109
54	*Ewe asaju*	*Blepharis maderaspatensis*	Acanthaceae	TMC	FL,RH,CF	0.145	0.000654
55		*Indigofera hirsutum*	Fabaceae		AF,RH,CF, UA	0.174	0.001559
56		*Mimosa invisa*	Mimosaceae		AF	0.00	0.00
57	*Pako-Ijebu*	*Massularia acuminate*	Rubiaceae	TMC	FL,AF,CF	0.174	0.001477
58	*Ajo*	*Sphenocentrum jollyanum*	Menispermaceae	TMC	FL,HF	0.158	0.001089
59	*Ewuro*	*Vernonia amygdalina*	Compositae	TMC	UA	0.082	0.000167
60	*Orogbo*	*Garcinia kola*	Guttiferae	TMC	UA	0.00	0.00
61		*Clerodendron umbellatum*	Verbenaceae	TMC	AF	0.103	0.000338
62		*Zehneria cappilitaceae*	,,	.	AF	0.082	0.000169
63	*Atori*	*Carpolobia lutea*	Polygalaceae	TMC	AF,CF	0.128	0.000591

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Table 4.24: Checklist of Native Herb Species in Ondo State Bitumen Belt

S/No	Local Name	Scientific Name	Family	Uses	Habitats	H[1]	D
1	*Rekureku*	*Althenanthera sessilis*	Amaranthaceae	TMC	RH	0.118	0.000584
2		*Funaria hygrometrica*	Musciceae		HF	0.150	0.000605
3		*Diplazium sammatii*	Athyraceae		RH, CF, FL, HF	0.254	0.003630
4		*Ipomea aquatica*	Convolvulaceae		RH	0.099	0.000364
5		*Marchantia sp.*	Marchantiaceae		HF	0.204	0.001815
6	*Imu*	*Drynaria laurentii*	Polypodiaceae	TMC	HF	0.254	0.003630
7		*Fiurenia ciliaris*	Cyperaceae		RH	0.155	0.001181
8		*F. umbellata*	,,		RH		
9	*Lei*	*Kilinga bulbosa*	,,		AF, UA,RH	0.141	0.000922
10	*Eru-lefi*	*K. erecta*	,,		UA,CF	0.107	0.000430
11		*k. squamulata*	,,		RH	0.118	0.000364
12		*Mariscus longibracteatus*	,,		UA,RH	0.099	0.000364
13	*Ikeregun*	*M. alternifolius*	,,	TMC	AF,UA,CF,FL	0.367	0.014043
14		*M. flabelliformis*	,,		AF,UA,CF	0.193	0.002150
15		*Cyperus rotundus*	,,		AF,UA	0.107	0.000442
16	*Ofio*	*C.*	,,	TMC	AF,UA	0.143	0.000958

		esculentus					
17		*Rhyncospora corymbosa*	,,		RH	0.145	0.001013
18	*Labelabe*	*Scleria naumaniama*	,,		AF,CF,FL,HF	0.00	0.00
19		*Dissotis rotundifolia*	Melastomaceae	TMC	RH	0.171	0.001558
20		*D. erecta*	,,		RH	0.138	0.000857
21		*Ludwigia decurens*	Onagracceae		RH	0.187	0.001986
22		*Acroceras zizanoides*	Poaceae		RH,CF	0.216	0.002979
23		*Echinochloa pyramidalis*	,,		RH	0.110	0.000467
24		*Leersia hexandra*	,,	TMC	RH	0.128	0.000714
25		*Panicum laxum*	,,		AF,RH,FL	0.230	0.003583
26		*P. maximum*	,,		UA	0.193	0.002150
27		*Andropogon tectorum*	,,		AF,CF	0.043	0.000037
28	*Idi*	*Axonopus compressus*	,,		AF,UA,CF,FL	0.401	0.018809
29		*Bracharia deflexa*	,,		AF	0.043	0.000037
30		*Cynodon plectostachyum*	,,		UA	0.039	0.000020
31		*Leptochloa caerulensis*	,,		UA	0.039	0.000020
32		*Chloris pilosa*	,,		AF,UA	0.193	0.002150
33		*Dactyloctenium aegyptium*	,,		AF,UA	0.094	0.000307

34	*Ese-Kanna kanna*	*Eleusine indica*	,,	TMC	AF,UA	0.078	0.000184
35		*Eragrostis tenella*	,,		AF,UA	0.078	0.000184
36		*Oplismenus bumannii*	,,		AF,CF	0.271	0.005759
37		*Spermacoce verticilata*	Rubiaceae		UA,CF	0.133	0.000780
38		*Paspalum conjugatum*	Poaceae		RH,CF	0.070	0.000142
39		*P. orbiculare*	,,		AF,RH	0.079	0.000195
40		*Perotis indica*	,,		AF,RH,FL	0.161	0.001363
41		*Setaria barbata*	,,		AF,RH	0.161	0.001363
42		*Polygonum lanigerum*	Polygonaceae		RH		
43		*P. salicifolium*	,,		RH		
44		*Pentodon pentandrus*	Rubiaceae		AF,RH	0.125	0.000676
45		*Diodea scandens*	,,		UA,CF,FL	0.107	0.000430
46		*Mitrocarpus villosus*	,,		UA	0.00	0.00
47		*Melochia corchorifolia*	Sterculaceae		RH,CF	0.128	0.000714
48		*Clappertonia ficifolia*	Tiliaceae	TMC	RH	0.079	0.000195
49	*Ahon-Ekun/Irun mu Arugbo*	*Acanthus montanus*	Acanthaceae	TMC	CF	0.082*	
50	*Ekere*	*Hypoestis*	,,	TMC	AF,FL	0.043	0.000037

		verticilaris					
51	*Aboro*	*Achyranthes aspera*	Amaranthaceae	TMC	UA,RH, CF	0.224	0.003277
52	*Tete-elegun*	*Amaranthus spinosus*	,,	TMC	UA	0.054	0.000061
53		*Celosia trygina*	,,	TMC	CF,FL	0.110	0.000274
54	*Arehin-posun/saw ere pepe*	*Cyathula prostrata*	,,	TMC	UA,FL	0.054	0.000061
55	*Emima-Agbo*	*Pupalia lappacea*	,,	TMC	CF,FL	0.059	0.000085
56	*Imi-Esu*	*Ageratum conyzoides*	Asteraceae	TMC	AF,FL	0.437	0.024765
58	*Yunyun*	*Aspilia Africana*	,,	TMC	AF,CF,F L	0.281	0.005746
59	*Abere oloko*	*Bidens pilosa*	,,	TMC	AF	0.043	0.000037
60	*Efo-odu*	*Solanum nigrum*	Solanaceae	TMC	FL	0.189	0.001642
61		*Acalypha ciliate*	Euphorbiaceae		UA	0.039	0.000020
62		*Cyperus difformis*	Cyperaceae		RH	0.161	0.001363
63		*Pycreus lanceolatus*	,,		RH	0.128	0.000714
64	*Awerepepe*	*Spilanthes filicaulis*	Asteraceae	TMC	AF,CF	0.191	0.002101
65	*Odundun-owo*	*Emilia coccinea*	,,	TMC	AF,CF,F L	0.238	0.003915
66	*Olowo-jeja*	*Erigeron floribundus*	,,		AF	0.043	0.000037
67		*Lactuca*	,,		AF,UA	0.098	0.000344

		taraxacifolia					
68	*Abo-yunyun*	*Melanthera scandens*	,,	TMC	CF,FL	0.032	0.000014
69	*Aluganbi*	*Synedrella nodiflora*	,,	TMC	AF,UA,RH,FL	0.189	0.001642
70	*Igbalode*	*Tridax procumbens*	,,	TMC	AF,FL	0.152	0.000821
71		*Vernonia cinnerea*	,,	TMC	UA	0.082	0.000205
72	*Apari-Igun*	*Heliotropium indicum*	Boraginaceae	TMC	UA	0.107	0.000430
73	*Adimeru*	*Euphorbia heterophyla*	Euphorbiaceae	TMC	AF	0.107	0.000442
74		*Heliotropium ovalifolium*	Boraginaceae		FL	0.253	0.004104
75	*Ekuya*	*Cleome viscose*	Cleomaceae		UA	0.00	0.00
76		*Hewittia sublobata*	Convolvulaceae		AF,CF,FL	0.152	0.000821
77	*Ewe gboro*	*Ipomea asarifolia*	,,	TMC	RH	0.047	0.000026
78	*Alukerese*	*Involucrata*	,,	TMC	AF,UA	0.078	0.000184
79	*Atewogba*	*Mauritiania*	,,	TMC	AF,CF	0.046	0.000043
80		*Triloba*	,,		AF,FL	0.032	0.000012
81	*Kankan oyinbo*	*Luffa aegyptica*	Cucurbitaceae		UA	0.00	0.00
82	*Emi-ile/oro-elewe*	*Euphorbia hirta*	Euphorbiaceae	TMC	CF	0.00	0.00
83	*Eyin-olobe*	*Phylanthus amarus*	,,	TMC	UA	0.039	0.000020

84	*Saworo/ala tunse*	*Crotalaria retusa*	Fabaceae	TMC	AF,FL	0.151	0.001118
85		*Desmodium scorpiurus*	,,		UA,CF,FL	0.120	0.000573
86		*Setaria longiseta*	Poaceae		AF,CF	0.046	0.000043
87		*Hyptis lanceolata*	Lamiaceae		AF,RH	0.032	0.000012
88	*Agberulori /iku-ekun*	*Leonotis nepetifolia*	,,	TMC	AF	0.032	0.000012
89		*Platostoma africanum*	,,		AF,UA	0.00	0.00
90	*Olojongbo du/iro Opolo*	*Solenostemon monostachyus*	,,	TMC	AF,UA	0.125	0.000676
91	*Aparan*	*Spigelia anthelma*	Loganiaceae	TMC	CF	0.193	0.002170
92	*Lobiiri*	*Asystasia gangetica*	Acanthaceae	TMC	UA,CF	0.092	0.000298
93	*Mesenmesen*	*Scoparia dulcis*	Scrophulaceae	TMC	UA	0.690	0.000123
94	*Ilasa-omode/ilasa Agbonrin*	*Urena lobata*	Malvaceae	TMC	UA,CF	0.046	0.001597
95	*Jogbo*	*Hyptis suaveolens*	Lamiaceae	TMC	AF	0.107	0.000442
96		*Zonia latifolia*	Fabaceae		UA	0.094	0.000307
97		*Boerhavia coccinea*	Nytaginaceae		UA	0.690	0.000123
98	*Etiponla pupa/etipaile*	*B. diffusa*	,,	TMC	UA	0.131	0.000737
99	*Papas an*	*Portulaca*	Portulacaceae	TMC	UA	0.00	0.00

		oleracea					
100	*Ahon ounde/idinle*	*P. quadrifida*	,,		UA	0.120	0.000573
101	*Koropo*	*Physalis angulata*	Solanaceae	TMC	AF	0.032	0.000012
102		*P. micrantha*	,,		FL	0.110	0.000274
103	*Ipe-Erin*	*Fluerya aestuans*	Urticaceae	TMC	UA,RH	0.118	0.000584
104		*F. ovalifolia*	,,		CF	0.046	0.000043
105		*Pouzolzia guineensis*	,,		AF	0.125	0.000676
106		*Aneilema aequinoctiale*	Commelinaceae		RH	0.238	0.003895
107		*A .beniniense*	,,		AF,CF	0.150	0.001106
108		*Commelina benghalensis*	,,		UA,RH,FL	0.238	0.003895
109	*Itopere*	*C. diffusa*	,,	TMC	AF,UA,CF	0.238	0.003915
110		*C. erecta*	,,		RH	0.214	0.002726
111	*Jagborokun*	*Pallisota hirsute*	,,	TMC	AF	0.043	0.000037
112		*Smilax krausiana*	Smilacaceae	TMC	AF	0.032	0.000012
113		*Pteridium sp.*	Athyraceae		HF,FL	0.293	0.006050
114		*Dryopteris filix*	,,		HF,FL	0.254	0.003630
116		*Sporobolus pyramidalis*	Poaceae		CF	0.082	0.000213
117	*Apalofa*	*Calopogonium mucunoide*	Leguminosae	TMC	AF,CF	0.116	0.000553
118	*Ewa ahun*	*Centrosema*	,,	TMC	AF,CF	0.033	0.000014

		pubescens					
119	*Oko-esin/ponripon-omi*	*Setaria megaphyla*	Poaceae	TMC	CF,HF	0.204	0.001815
120	*Iramu/oworo*	*Nephrolepsis bisserata*	Athyraceae	TMC	HF	0.204	0.001815
121		*Selaginella sp.*	Sellaginelaceae		HF	0.293	0.006050
122		*Pteridium sp.*	Athyraceae		HF	0.293	0.006050
123		*Platycerium stemaria*	,,		FL,HF	0.221	0.002736
124		*Spagnum sp.*	Musciceae		HF	0.00	0.00
125		*Polytrichum sp.*	,,		HF	0.510	0.039927
126	*Ewe-eeran*	*Thaumatococcus danieli*	Marantaceae	TMC	HF	0.150	0.000605
127	*agunmana*	*Culcasia scandens*	Araceae	TMC	HF	0.204	0.001815
128		*Pegularia daemia*	Asclepiadaceae		RH	0.079	0.000195
129		*Canna indica*	Cannaceae	TMC	RH	0.110	0.000467
130		*Celtis sp.*	Ulmaceae		AF	0.078	0.000184

Table 4.25: Checklist of Non-Native Herb Species in Ondo State Bitumen Belt

S/No	*Scientific Name*	Family	Uses	Habitats	H^1	D
1	*Euphorbia hyssopifolia*	Euphorbiaceae		AF, UA, CF	0.272	0.005652
2	*Pepperomia pelucida*	Piperaceae	TMC	UA	0.254	0.004731
3	*Caladium bicolor*			UA,CF	0.046	0.001597
4	*Sesamum indicum*	Pedaliaceae	TMC	CF	0.092	0.000298
5	*Blumea aurita*	Asteraceae	TMC	RH	0.138	0.000130
6	*Richardia brasiliensis*	Rubiaceae		AF	0.098	0.000344

4.4.9: Ecosystem Plant Key Indicators of Ondo State Bitumen Belt

Table 4.28 shows that, 14 tree species, *Spondias mombim, Bridelia atroviridis, Bridelia micrantha, Pycnanthus angolensis, Nauclea diderichii, Afzelia africana, Piptadeniastrum africanum, Ficus exasperata, Octobolus spectabilis, Cola acuminata, Elaeis guineensis, Buchlolzia coriacea, Chrysobalamus icaco,* and *Homalium letestui* were found to occur in at least three habitats out of the six habitats. Species overlap of shrubs in the bitumen belt shows that 27 shrub species were found to occur in at least three out of the six habitats sampled (table 4.29). The species that overlap in the bitumen belt include *Manniophyton fulvum, Alchornea cordifolia, Alchornea laxiflora, Casia hirsuta, Sida acuta, Chromolaena odorata,* and *Cnestis ferruginea.* Others include *Desmodium tortuosum, Dialium guineense, Icacina tricantha, Mallotus oppositifolius, Dryeptes chevailieri, Starchytarpheta cayennensis, Triumpheta cordifolia, Glyphia brevis, Walthera indica, Heistera parviflora, Aptandra zenkeri* and *Oncoba spinosa. Napoleona imperialis, Dichapetalum floribundum, Dichapetalum guineense, Baphia nitida, Blepharis maderaspatensis, Indigofera hirsutum, Massularia acuminata,* and *Combretum hispidum* were also found to overlap in at least three habitats out of the six habitats. 21 of the 27 shrub species were found to be associated with each of Fallow Land and Riparian habitat, 20 each with Arable Farmland and Cashcrop Farmland, and 16 each with island of High Forest and Urban Arboreta.

Table 4.30 shows the number of herbs that overlap in the habitats sampled. Out of the 134 herb species encountered in all the six habitats, the following 18 herb species were found to occur in at least three habitats - *Diplazium samattii, Mariscus alternifolius, Scleiria naumaniama, Axonopus compressus, Synedrella nodiflora, Kylinga bulbosa, Mariscus flabelliformis, Panicum maximum, Perotis indica, Diodea scandens, Achyranrhes aspera, Aspilia africana, Hewitia sublobata, Emilia coccinea, Desmodium scorpiurus, Euphorbia hyssopifolia, Commelina benghalensis* and *C. diffusa*.

Table 4.26: Rare, Threatened and Endangered Plant Species and Provenances of Ondo State Bitumen Belt

Family	Species	Status	Threats
Boraginaceae	*Cordia milleni*	Rare	Forest clearance and utilisation for timber and medicinal purposes
Irvingiaceae	*Irvingia gabonensis*	In danger of genetic erosion	Logging operations and settlement
Meliaceae	*Entandrophragma angolense*	Threatened. Severe genetic erosion	Commercial exploitation
,,	*Lovoa trichiloides*	Priority for in situ and ex situ conservation. Threatened by over exploitation	Logging
,,	*Khaya senegalensis*	Genetic erosion	Exploitation for timber
Moraceae	*Milicia excelsa*	Widespread but threatened in some areas	Extensive logging
Sterculiaceae	*Nesogordonia papaverifera*	Endangered in some parts of its range and subject to genetic improverishment in outlaying populations	Logging
,,	*Triplochiton scleroxylon*	Priority for in situ and ex situ conservation. Threatened by over exploitation	Logging
Combretaceae	*Terminalia ivoriense*	,,	,,
,,	*Terminalia superb*	,,	,,
Araceae	*Caladium bicolour*	Rare	

Table 4.27: Potential of Habitats to Support Plants for Traditional, Medicinal and Cultural Purposes (TMC) of Ondo State Bitumen Belt

Plants for TMC	Arable Farmland	Fallow Land	High Forest	Riparian Habitat	Cashcrop Forest	Urban Arboreta
Trees/Habitat	23	25	19	11	3	22
Shrubs/Habitat	18	20	15	15	18	20
Herbs/Habitat	24	13	5	10	19	21
Mean	22	19	13	12	13	21

Table 4.28: Tree Species Shared Among Various Habitats of Ondo State Bitumen Belt

S/No	Family	*Scientific Name*	Habitats where found
1	Anarcardiaceae	*Spondias mombim*	FL, AF, UA
2	Euphorbiaceae	*Bridelia atroviridis*	FL, HF, AF
3	,,	*Bridelia micrantha*	FL,AF, RH
4	Myristicaceae	*Pycnanthus angolensis*	FL, HF, AF
5	Apocynaceae	*Nauclea diderichii*	FL,HF,AF
6	Caesalpinaceae	*Afzelia Africana*	FL,HF,AF
7	Mimosacaceae	*Piptadeniastrum africanum*	FL,HF, AF,RH
8	Moraceae	*Ficus exasperate*	FL, AF, UA
9	Boraginaceae	*Octobolus spectabilis*	FL, AF, UA
10	,,	*Cola acuminate*	RH,CF,UA
11	Palmae	*Elaeis guineensis*	FL, AF,RH,CF,UA
12	Moringaceae	*Buchlolzia coriacea*	FL,HF,AF,RH
13	Chrysobalanaceae	*Chrysobalamus icaco*	HF,AF,RH
14	Samydaceae	*Homalium letestui*	FL,HF,AF,RH

Table 4.29: Species Overlap of Shrubs in Ondo State Bitumen Belt

S/No	*Scientific Name*	Family	Habitats Where Found
1	*Manniophyton fulvum*	Malvaeceae	FL,HF,AF,RH,CF,UA
2	*Alchornea cordifolia*	,,	FL,AF,RH,CF,UA
3	*Alchornea laxiflora*	,,	FL,HF,AF,CF,UA
4	*Casia hirsute*	,,	FL,RH,CF,UA
5	*Sida acuta*	,,	AF,CF,UA
6	*Chromolaena odorata*	Asteraceae	FL,AF,RH,CF,UA
7	*Cnestis ferruginea*	Cleomaceae	FL,HF,AF,RH,CF,UA
8	*Desmodium tortuosum*	Dennstaedtiaceae	FL,AF,CF,UA
9	*Dialium guineense*	,,	HF,AF,RH,UA
10	*Icacina tricantha*	Icacinaceae	FL,HF,AF,RH,CF,UA
11	*Mallotus oppositifolius*	Euphorbiaceae	FL,HF,RH,CF,UA
12	*Dryeptes chevailieri*	,,	AF,HF,RH,CF,UA
13	*Starchytarpheta cayennensis*	Sphenocleaceae	AF,RH,CF,UA
14	*Triumpheta cordifolia*	Tiliaceae	FL,AF,CF,UA
15	*Glyphia brevis*	,,	FL,HF,RH,CF
16	*Walthera indica*	Sterculiaceae	AF,RH,UA
17	*Heistera parviflora*	Olacaceae	FL,HF,RH
18	*Aptandra zenkeri*	,,	FL,HF,AF,RH,CF
19	*Oncoba spinosa*	Flacourtiaceae	FL,HF,AF,RH,CF
20	*Napoleona imperialis*	Lecythidaceae	FL,HF,AF,RH
21	*Dichapetalum floribundum*	Chailletiaceae	FL,HF,AF
22	*Dichapetalum guineense*	,,	FL,HF,AF,RH
23	*Baphia nitida*	Papilionaceae	FL,HF,AF,RH,CF
24	*Blepharis maderaspatensis*	Acanthaceae	FL,RH,CF
25	*Indigofera hirsutum*	Fabaceae	AF,RH,CF,UA
26	*Massularia acuminate*	Rubiaceae	FL,HF,PF
27	*Combretum hispidum*	Combretaceae	FL,HF,AF,RH

Table 4.30: Herbaceous Species Overlap of Ondo State Bitumen Belt

S/No	*Scientific Name*	Family	Habitat
1	*Diplazium samattii*	Athyraceae	RH,CF,FL,HF
2	*Mariscus alternifolius*	Cyperaceae	AF,UA,CF,FL
3	*Scleria naumaniama*	Cyperaceae	AF,CF,FL,HF
4	*Axonopus compressus*	Poaceae	AF,UA,CF,FL
5	*Synedrella nodiflora*	Asteraceae	AF,UA,RH,FL
6	*Kylinga bulbosa*	Cyperaceae	AF,UA,RH
7	*Mariscus flabelliformis*	Cyperaceae	AF,UA,CF
8	*Panicum maximum*	Poaceae	AF,RH,FL
9	*Perotis indica*	Poaceae	AF,RH,FL
10	*Diodea scandens*	Rubiaceae	UA,CF,FL
11	*Achyranrhes aspera*	Amaranthaceae	UA,RH,FL
12	*Aspilia Africana*	Asteraceae	AF,CF,FL
13	*Hewitia sublobata*	Convolvulaceae	AF,CF,FL
14	*Emilia coccinea*	Asteraceae	AF,CF,FL
15	*Desmodium scorpiurus*	Fabaceae	UA,CF,FL
16	*Euphorbia hyssopifolia*	Euphorbiaceae	AF,UA,CF
17	*Commelina benghalensis*	Commelinnaceae	UA,RH,FL
18	*C. diffusa*	Commelinnaceae	AF,UA,CF

4.5.0: Bird Species Typical of Ondo State Bitumen Belt

The total number of individual birds, i.e, abundance, and number of different species, i.e, richness typical of the bitumen belt are presented in Table 4.31. The result indicates that the number of individual birds and number of species encountered in each quadrant per habitat type significantly differ from one another, ($P<0.05$), (appendix 28). These two parameters were also found to be significantly affected by season ($P<0.05$). Interaction of habitat type and season, however, had no significant impact on the number of individual birds and number of species ($P>0.05$).

The mean number of individual birds in each quadrant across the various habitats for both dry and wet seasons ranges between 27 and 63. Urban Arboreta had the highest number of 63, followed by Arable Farmland (59), Riparian Habitat (51), Fallow Land (29), and Island of High Forest (28) while Cashcrop Farmland has the least species density of, 27/2829m^2.

Test of significant difference (appendix 29) shows that the total number of individuals in Cashcrop Farm, Islands of High Forest and Fallow Land are not significantly different from one another. Riparian Habitat, Arable Farmland, and Urban Arboreta are also found not to be significantly different from one another. The number of individual birds in the dry season (38) was also found to be significantly lower than that of the wet season (47) ($p<0.05$).

As regards the mean number of different species of birds in each quadrant, Cashcrop Farmland (11 species) was found to be significantly lower than the other habitats. Farm Fallow (14 Species), Islands of High Forest (14 Species) and Arable Farmland (15 Species) are not significantly different from one another. Arable Farmland (15 Species) and Urban Arboreta (16 Species) are also not significantly different in terms of number of different species. While Urban Arboreta (16 Species) and Riparian Habitat (17 Species), are also found not to be significantly different from one another. The effect of seasonal variations was found to be more favourable to the richness of species during the wet season (15 Species) than the dry season (14 Species) (appendix 30).

4.5.1: Species Composition of Birds in Fallow Land of Ondo State Bitumen Belt

The diversity of birds' species in fallow land is presented in Table 4.32. Diversity index, however, shows that, Purple glossy starling, *lamprocolius purpureus* and village weaver, *Plesiositagra cucullatus* have the highest species diversity (H^1 = 0.192, D=0.00402 each), followed by yellow white – eye, *Zosterops senegalensis* (H^1

= 0.179, D=0.00329). Green Wood Hoopoe, *Phoeniculus erythrorhyncus*; Broad – billed roller, *Eurystomus afer*; Brown Barbler, *Turdoides plebeja*; Common bulbul, *Pycnonotus barbatus* and Red – headed malimbe, *Malimbus rubricolis* (H^1 = 0.151, D=0.00204 each) are also highly diversified.

13 birds in this habitat have the lowest diversity index of 0. Among these are Pigmy kingfisher, *Ispidina picta*; Senegal kingfisher, *Halcyon senegalensis*, yellow – fronted Tinker bird, *Pogoniulus chrysoconus*; Gabon woodpecker, *Dendropicos goertae*; Spectacled flycatcher, *Platysteria cyanea*, Chestnut- and -black starling, *Onychognatus fulgidus* and Bell shrike, *Laniurus ferrugineus*.

4.5.2: Species Diversity of Birds in Fallow Land of Ondo State Bitumen Belt

The phylogenetic diversity of birds in fallow land is presented in fig 4. This habitat was found to be associated with 27 different families of birds. Accipitridae has the highest number of different bird species (6 Spp.), followed by Prionopidae and ploceidae (5 Species each), Columbidae, Alcedinidae, Picidae and Nectarinidae (4 Species each). Families such as Strigidae, Micropodidae, Coracidae, Phoeniculidae, Bucerotidae, Meropidae, Timalidae, Turdidae, Dicruridae, Oriolidae, Corvidae, Zosteropidae and Fringilidae, however, have the least numbers of species per family.

On the number of individuals that make up each family, Ploceidae has the highest (29 individuals), followed by Accipitridae (22 individuals), Sturnidae (14 individuals), Nectarinidae (13 individuals), Pycnonotidae (12 individuals), Columbidae and Zosteropidae (10 individuals each). The family that, however, have the least number of individual is Fringilidae, (1 individual). It is however remarkable to see some families with one species each having high number of individuals. Such families include: Coracidae (eight), Phoeniculidae (eight) Timalidae (eight), Micropididae (seven), Musophagidae (seven), Meropidae (six) Turdidae and Corvidae (five).

4.5.3: Percentage Composition of Birds Families in Fallow Land of Ondo State Bitumen Belt

The percentage composition of birds in fallow land is shown in fig 4.6. Ploceidae family was found to have the highest composition of 12.6%, followed by Accipitridae, 9.6%, Sturnidae, 6.1%, Prionopidae and Nectarinidae (5.7% each). Among the 27 families that were censused in farm fallow habitat, Fringilidae has the least percentage composition (0.4%).

Table 4.31: Total Number and Number of Different Species of Birds of Ondo State Bitumen Belt

Variable	F	L	H	F	A	F	R	H	C	F	U	A
	D	W	D	W	D	W	D	W	D	W	D	W
Abundance of Birds/2829m^2	24	34	24	31	55	62	46	55	23	31	56	69
Richness of Bird Species/2829 m^2	12	15	14	15	15	15	17	18	10	11	16	17

N.B: FL=Fallow Land, HF= Islands of High Forest, AF=Arable Farmland, RH=Riparian Habitat, CF=Cashcrop Farmland, UA=Urban Arboreta.

Table 4.32: Species Composition of Birds in Fallow Land of Ondo State Bitumen Belt

S/No	Common Name	*Scientific Name*	Family	Dry	Rain	Total	H^1	D
1	Black kite	*Milvus migrans*	Accipitridae	1	2	3	0.070	0.00022
2	Black-shouldered kite	*Elaneus caerulens*	"	2	2	4	0.088	0.00044
3	Africa hawk Eagle	*Hieraaetus spilogaster*	"	2	2	4	0.088	0.00044
4	Ayres hawk Eagle	*Hieraaetus dubius*	"	1	2	3	0.070	0.00022
5	Casins hawk Eagle	*Spizaetus africanus*	"	1	3	4	0.088	0.00044
6	Lizzard buzzard	*Kaupifalco monogrammicus*	"	2	2	4	0.088	0.00044
7	Green fruit Pigeon	*Treron australls*	Columbidae	-	2	2	0.050	0.00007
8	Red -eyed turtle Dove	*Streptopelia semi torquata*	"	1	1	2	0.050	0.00007
9	Red -billed wood Dove	*Tutur afer*	"	2	3	5	0.105	0.00073
10	Grey plantain-eater	*Crinifer piscator*	Musophagidae	3	4	7	0.150	0.00153
11	Levaillant Cuckoo	*Climator levaillanti*	Cuculidae	1	1	2	0.050	0.00007
12	Didric	*Lampromorpha*	"	1	1	2	0.050	0.00007

	Cuckoo	*caprius*						
13	Senegal Coucal	*Centropus senegalensis*	"	1	2	3	0.070	0.00022
14	Akin eagle Owl	*Bubo leucostictus*	Strigidae	2	2	4	0.088	0.00044
15	Palm swift	*Cysiurus parvus*	Micropididae	3	4	7	0.150	0.00153
16	Broad billed roller	*Eurystormus afer*	Coracidae	4	4	8	0.151	0.00204
17	Green wood Hoopoe	*Phoeniculus erythrorhyncus*	Phoeniculidae	3	5	8	0.151	0.00204
18	African pied Hornbill	*Tockus fasciatus*	Bucerotidae	4	3	7	0.150	0.00153
19	Pigmy kingfisher	*Ispidina picta*	Alcedinidae	1	-	1	0	0.00000
20	Striped kingfisher	*Halcyon chelicuti*	"	1	-	1	0	0.00000
21	Senegal kingfisher	*Halcyon senegalensis*	"	1	-	1	0	0.00000
22	Blue breasted kingfisher	*Halcyon malimbicus*	"	-	1	1	0	0.00000
23	Laughing Dove	*Stigmatopelia senegalensis*	Columbidae	-	1	1	0	0.00000
24	White-throated bee eater	*Aerops albicolis*	Meropidae	4	2	6	0.121	0.00110
25	Tooth -billed barbet	*Pogornornis bidendatus*	Capitonidae	1	4	5	0.105	0.00073
26	Yellow-	*Pogoniulus*	"	1	-	1	0	0.00000

	fronted tinker bird	*chrysoconus*						
27	Grey wood pecker	*Dendropicos goertae*	Picidae	1	1	2	0.050	0.00007
28	Gabon wood pecker	*Dendropicos gabonensis*	"	-	1	1	0	0.00000
29	Cardinal woodpecker	*Dendropicos fuscescens*	"	1	-	1	0	0.00000
30	Fire- bellied wood pecker	*Dendropicos pyrrhogaster*	"	1	1	2	0.050	0.00007
31	Brown barbler	*Turdoides plebeja*	Timalidae	3	5	8	0.150	0.00204
32	Common bulbul	*Pycnonotus barbatus*	Pycnonotidae	4	4	8	0.150	0.00204
33	Yellow-throated leaf love	*Pyrrhurus Flavicollis*	"	2	2	4	0.088	0.00044
34	Striped fly catcher	*Muscicapa striata*	Muscicapidae	1	-	1	0	0.00000
35	Spectacled flycatcher	*Platysteira cyanea*	"	-	1	1	0	0.00000
36	Grey -backed paradise fly catcher	*Tchitrea smithii*	"	1	2	3	0.070	0.00022
37	Snowy-headed robin chat	*Cossypha niveicapilla*	Turdidae	2	3	5	0.105	0.00073
38	Willow warbler	*Phylloscopus trochilus*	Sylvildae	3	-	3	0.070	0.00022
39	White -bellied	*Sylvietha*	"	1	2	3	0.070	0.00022

	crombec	*flaviventris*						
40	Grey -backed Camaroptera	*Camaroptera brevicaudata*	"	1	1	2	0.050	0.00007
41	Velvet-mantled Drongo	*Dicrurus adsimilis*	Dicruridae	1	2	3	0.070	0.00022
42	Fiscal Shrike	*Lanius collaris*	Prionopidae	1	2	3	0.070	0.00022
43	Puff back Shrike	*Dryoscopics gambensis*	"	2	2	4	0.088	0.00044
44	Gonolek	*Laniurus barbatus*	"	1	1	2	0.050	0.00007
45	Bush Shrike	*Tchagra senegala*	"	1	2	3	0.070	0.00022
46	Black-winged Oriole	*Oriolus nigripennis*	Oriolidae	1	1	2	0.050	0.00007
47	Pied Crow	*Corvus albus*	Corvidae	2	3	5	0.105	0.00073
48	Violet-backed Starling	*Cinnyricinclus leucogaster*	Sturnidae	2	-	2	0.050	0.00007
49	Purple- glossy Starling	*Lamprocolius purpureus*	"	8	3	11	0.192	0.00402
50	Chestnut-winged Starling	*Onychognatus fulgidus*	"	1	-	1	0	0.00000
51	Bell Shrike	*Laniurus ferrugineus*	Prionopidae	1	-	1	0	0.00000
52	Yellow white-eye	*Zosterops senegalensis*	Zesteropidae	4	6	10	0.179	0.00329
53	Splendid	*Cynnyris*	Nectarinida	1	2	3	0.070	0.00022

	Sunbird	*coccinigaster*	e					
54	Olive-bellied Sunbird	*Cynnyris chloropygius*	“	2	1	3	0.070	0.00022
55	Green-headed Sunbird	*Cyanomitra verticallis*	“	2	2	4	0.088	0.00044
56	Collard Sunbird	*Anthreptis collaris*	“	1	2	3	0.070	0.00022
57	Grey-headed Sparrow	*Passer griseus*	Fringilidae	-	1	1	0	0.00000
58	Chestnut-&-black weaver	*Cinnamopteryx castaneofuscus*	Ploceidae	2	2	4	0.088	0.00044
59	Village weaver	*Plesiositagra cucullatus*	“	4	7	11	0.192	0.00402
60	Spec. Weaver	*Hyphanturgus brachypterus*	“	1	3	4	0.088	0.00044
61	Red-headed Malimbe	*Malimbus rubricollis*	“	4	4	8	0.151	0.00204
62	Grey-crowned negro Finch	*Nigrita canicapilla*	Ploceidae	1	1	2	0.050	0.00007

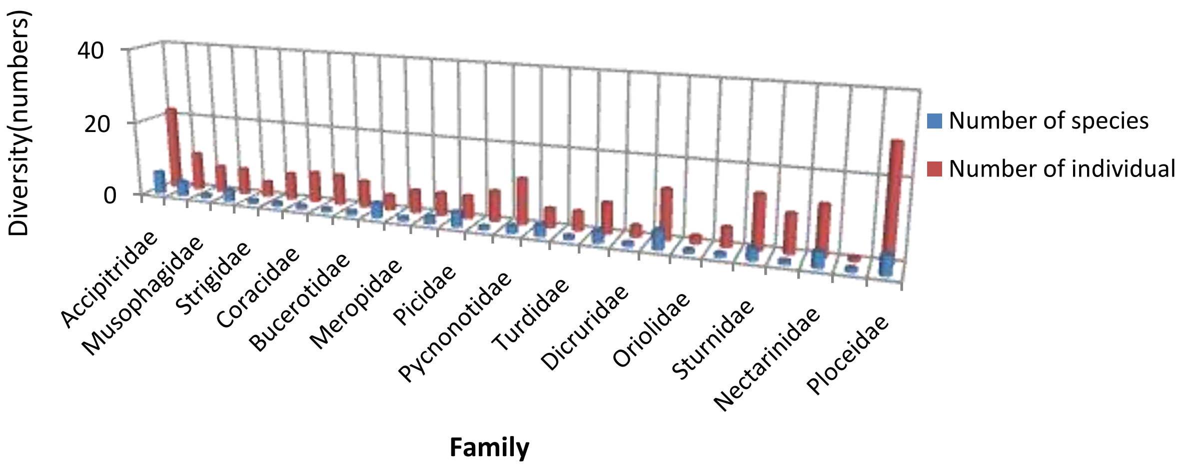

Fig 4.1: Species Diversity of Birds in Fallow Land 0f Ondo State Bitumen Belt

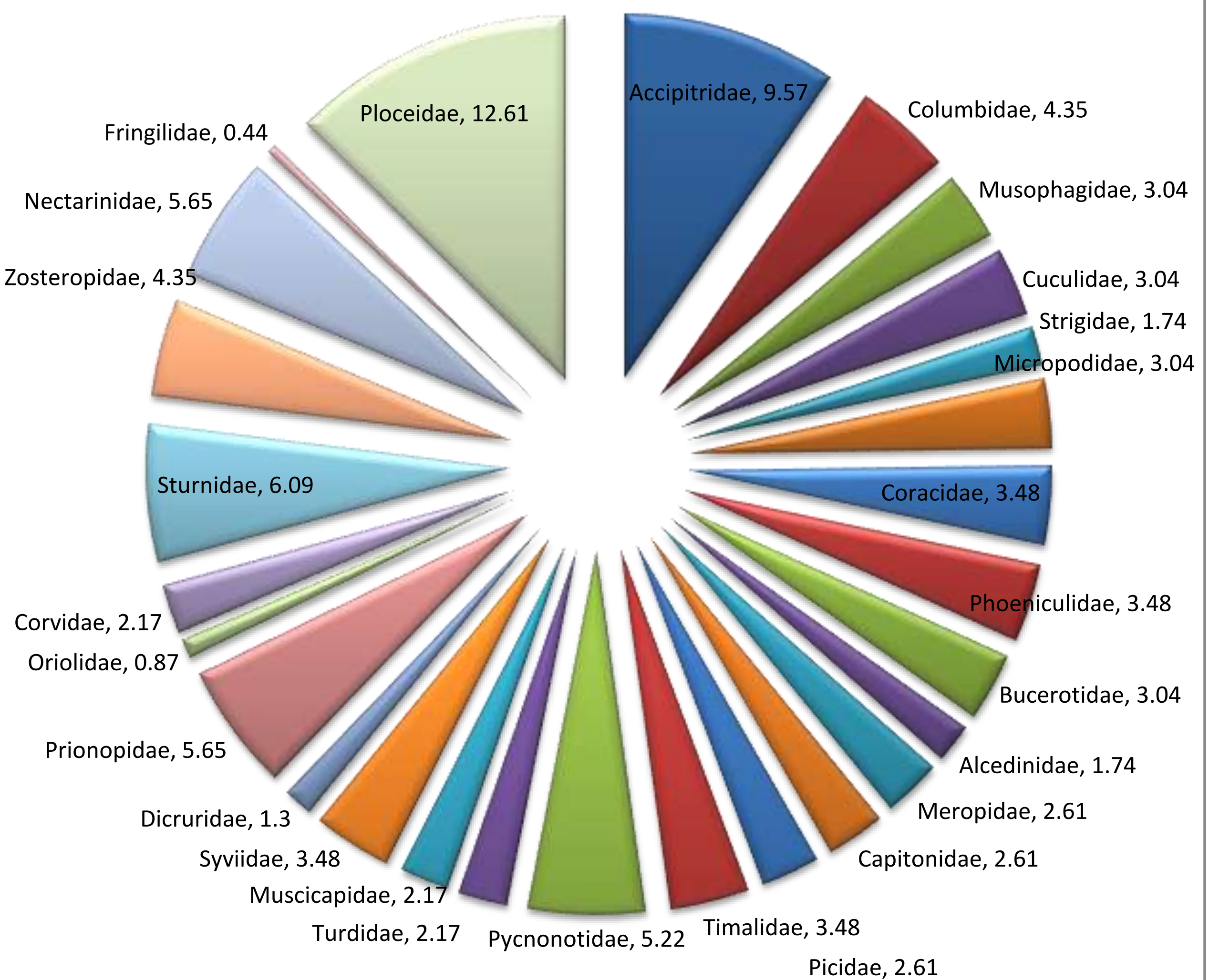

Fig 4.2: Percentage Composition of Birds in Fallow Land of Ondo State Bitumen Belt

4.5.4: Species Composition of Birds in Islands of High Forest of Ondo State Bitumen Belt

Table 4.33 shows the species composition of birds characterised Islands of high forest. The composition of bird species was found to be highest for Chestnut –and- black weaver, *Cinnamopteryx castaneofuscus* (H^1 = 0.220, D=0.00310). This is respectively followed by village weaver, *Plesiositagra cucullatus* (H^1 = 0.205, D=0.00253), Yellow white -eye, *Zosterops senegalensis* (H^1 = 0.189, D=0.00203), Puff -back shrike, *Dryoscopus gambensis* (H^1 = 0.157, D=0.00118), Pied crow, *Corvus albus* (H^1= 0.157, D=0.00118), Palm swift, *Capsiurus parvus* (H^1 = 0.173, D=0.00158), Allied hornbill, *Tockus fasciatus* and palm bulbul, (H^1 = 0.139, D=0.00084 each). While red – eyed turtle Dove, *Streptopelia semitorquata*, Pigmy kingfisher, *Ispidina picta*, Striped kingfisher, *Halcyon chelicuti*, white- throated bee -eater, *Aerops albicolis*, Grey -backed camaroptera, *Camaroptera brevicaudata*, chestnut -and -winged starling, *Onychognatus fulgidus* ,and grey- headed sparrow, *Passer grisseus* were found to have the least species diversity (H^1 = 0 each).

4.5.5: Species Diversity of Birds in Islands of High Forest of Ondo State Bitumen Belt

The species diversity of Birds in Islands of High Forest habitat is shown in fig 4.7. Among the 26 families and 53 different species found in this habitat, Accipitridae has the highest phylogenetic diversity with nine species and 30 individuals. Ploceidae (4 Species, 25 individuals), Nectarinidae (4 species, 16 individuals), Alcedinidae (4 species, 7 individuals), Pycnonotidae (3 species, 16 individuals), Cuculidae (3 species, 10 individuals), and Columbidae (3 species, 16 individuals) also have very high phylogenetic diversity. Two families -Meropidae and Sylviidae, however, have the least number of species and individuals (one, one each).

4.5.6: Percentage Composition of Birds in Islands of High Forest of Ondo State Bitumen Belt

Fig 4.8 shows the percentage composition of birds in Islands of High Forest. Among the family groups, composition is highest for Accipitridae (16.0%). Ploceidae (13.0%) also have higher percentage composition. These are followed by pycnonotidae (8.0%), Picidae, 7%, Nectarinidae (6.0%), Cuculidae, Columbidae and Zosteropidae (5.0% each), Micropodidae and Alcedinidae (4.0%) each. The quadruplets of meropidae, Sylviidae, Sturnidae and Fringilidae, however, have the least percentage composition of 1% each.

Table 4.33: Species Composition of Birds in Islands of High Forest of Ondo State Bitumen Belt

S/No	Common Name	*Scientific Name*	Family	Dry	Wet	Total	H[1]	D
1	Black kite	*Milvus migrans*	Accipitridae	3	2	5	0.121	0.00056
2	Black - shouldered kite	*Elaneus caerulens*	"	2	2	4	0.101	0.00034
3	African hawk Eagle	*Hieraaetus spilogaster*	"	2	2	4	0.101	0.00034
4	Ayres hawk Eagle	*Hieraaetus dubius*	"	2	2	4	0.101	0.00034
5	Harrier hawk	*Polybroides typus*	"	1	1	2	0.058	0.00006
6	African long tail hawk	*Urotriochis macrourus*	"	1	1	2	0.058	0.00006
7	Casins hawk Eagle	*Spizaetus africanus*	"	2	2	4	0.101	0.00034
8	Lizard buzzard	*Kaupifalco monogrammicus*	"	1	1	2	0.058	0.00006
9	Shikra	*Accipiter badius*	"	1	2	3	0.081	0.00017
10	Red- eyed turtle dove	*Streptopelia semitorquata*	Columbidae	1	-	1	0	0.00000
11	Red- billed wood dove	*Tutur afer*	"	2	2	4	0.101	0.00034
12	Green fruit pigeon	*Treron australis*	"	2	2	4	0.101	0.00034
13	Grey plantain-eater	*Crinifer piscator*	Musophagidae	2	3	5	0.121	0.00056

14	Grey Parrot	*Psittacus erithracus*	Picidae	2	3	5	0.121	0.00056
15	Yellow-bellied Parrot	*Poicephalus senegalus*	"	5	-	5	0.121	0.00056
16	Levaillant cuckoo	*Climator levaillanti*	Cuculidae	2	2	4	0.101	0.00034
17	Didric cuckoo	*Lampromorpha caprius*	"	1	2	3	0.081	0.00017
18	Senegal coucal	*Centropus senegalensis*	"	1	2	3	0.081	0.00017
19	Akin Eagle Owl	*Bubo leucostictus*	Strigidae	1	2	3	0.081	0.00017
20	Palm Swift	*Cypsiurus parvus*	Micropodidae	3	5	8	0.173	0.00158
21	Broad-billed Roller	*Eurystomus afer*	Coracidae	2	3	5	0.121	0.00056
22	Green wood Hoopoe	*Phoeniculus erythrorhyncus*	Phoeniculidae	3	-	3	0.081	0.00017
23	African pied Hornbill	*Tockus fasciatus*	Bucerotidae	3	3	6	0.139	0.00084
24	Pigmy kingfisher	*Ispidina picta*	Alcedinidae	1	-	1	0	0.00000
25	Striped kingfisher	*Halcyon Chelicuti*	"	-	1	1	0	0.00000
26	Senegal kingfisfer	*Halcyon senegalensis*	"	1	2	3	0.081	0.00017
27	Blue-breasted kingfisher	*Halcyon malimbicus*	"	1	1	2	0.033	0.00006
28	White - throated bee eater	*Aerops albicollis*	Meropidae	-	1	1	0	0.00000

29	Tooth -billed barbet	*Pogonornis bidendatus*	Capitonidae	1	1	2	0.033	0.00006
30	Yellow - fronted Tinker bird	*Pogoniulus chrysoconus*	"	1	1	2	0.033	0.00006
31	Grey Woodpecker	*Dendropicos goertae*	Picidae	1	1	2	0.033	0.00006
32	Fire-bellied Woodpecker	*Dendropicos pyrrhogaster*	"	1	1	2	0.033	0.00006
33	Common bulbul	*Pycnonotus barbatus*	Pycnonotidae	2	3	5	0.121	0.00056
34	Palm bulbul		"	2	4	6	0.139	0.00084
35	Yellow - throated leaf love	*Pyrrhurus flavicollis*	"	2	3	5	0.121	0.00056
36	Spectacled fly catcher	*Platysteiira cyanea*	Muscicapidae	1	1	2	0.033	0.00006
37	Grey backed paradise fly catcher	*Tchitrea smithii*	"	1	2	3	0.081	0.00017
38	Grey backed camaroptera	*Camaroptera brevicaudata*	Sylvidae	-	1	1	0	0.00000
39	Velvet-mantled Drongo	*Dicrurus modestus*	Dicruridae	1	1	2	0.033	0.00006
40	Puff- back shrike	*Dryoscopus gambensis*	Prionopidae	3	4	7	0.157	0.00118
41	Black-winged oriole	*Oriolus nigripennis*	Oriolidae	2	-	2	0.033	0.00006
42	Pied crow	*Corvus albus*	Corvidae	3	4	7	0.157	0.00118
43	Chestnut-winged starling	*Onychognathus fulgidus*	Sturnidae	1	-	1	0	0.00000

44	Yellow white eye	*Zosterops senegalensis*	Zosteropidae	4	5	9	0.189	0.00203
45	Splendid sunbird	*Cynnyris coccinigaster*	Nectarinidae	1	2	3	0.081	0.00017
46	Olive- bellied sunbird	*Cynnyris chloropygius*	"	1	1	2	0.033	0.00006
47	Green - headed sunbird	*Cyanomitra verticallis*	"	2	2	4	0.101	0.00034
48	Collared sunbird	*Anthreptes collaris*	"	1	1	2	0.033	0.00006
49	Grey- headed sparrow	*Passer grisseus*	Fringilidae	-	1	1	0	0.00000
50	Chestnut - &black weaver	*Cinnamopteryx castaneofuscus*	Ploceidae	3	8	11	0.220	0.00310
51	Village weaver	*Plasiositagra cucullatus*	"	3	7	10	0.205	0.00253
52	Red- headed malimbe	*Malimbus rubricollis*	"	-	2	2	0.033	0.00006
53	Grey- crowned negro finch	*Nigritha canicapilla*	,,	1	1	2	0.033	0.00006

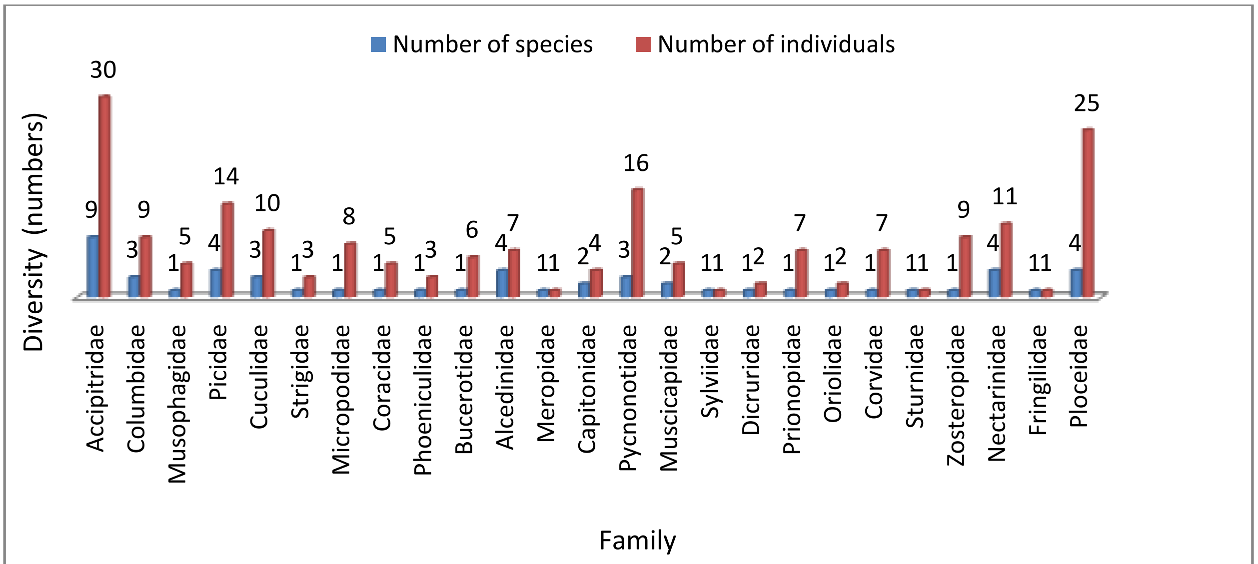

Fig 4.3: Species Diversity of Birds in Islands of High Forest of Ondo State Bitumen Belt

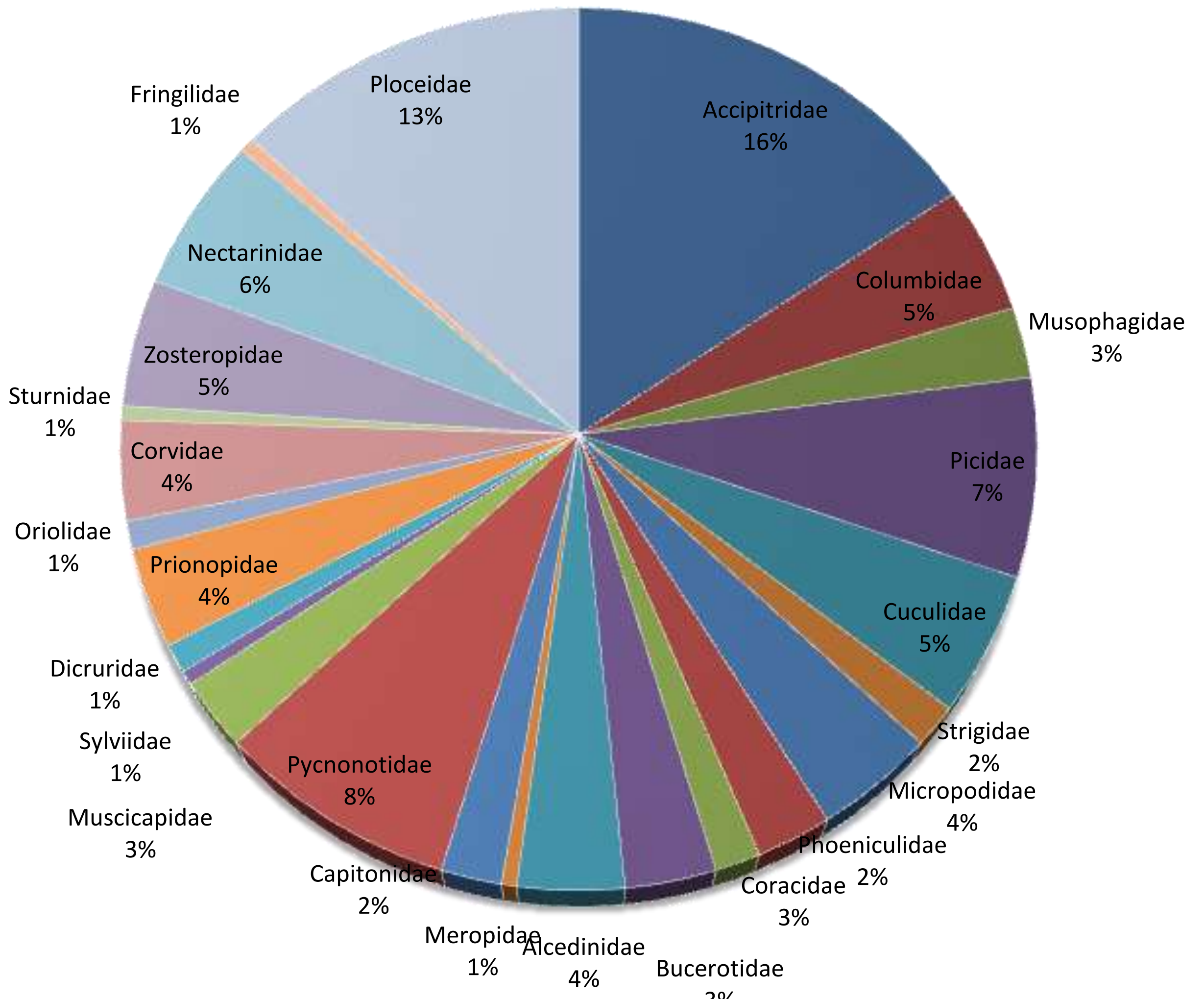

Fig 4.4: Percentage Composition of Birds in Islands of High Forest of Ondo State Bitumen Belt

4.5.7: Species Composition of Birds in Arable Farmlands of Ondo State Bitumen Belt

Table 4.34 shows the composition of bird species in Arable farmlands. The result shows that, village weaver, *Plesiositagra cucullatus* (H^1 = 0.472, D=0.03210) is the most abundant in this habitat. This is followed by Chestnut -and -black weaver, *Cinnamopteryx castaneofuscus* (H^1 = 0.339, D=0.01112). Birds with comparatively high species diversity also include Red – headed Dioch, *Quelea erythrops* (H^1 = 0.237, D=0.00387), violet backed starling, *Cinnyricinclus leucogaster* (H^1 = 0.178, D=0.00176), European wheat –ear, *Oenanthe oenanthe* and Red- faced grass warbler, *Cisticola erythrops (*Shannon = 0.137 each, D=0.00085), African pied -wagtail, *Motacilla* aguimp, Yellow wagtail, *Budytes flavus*, Purple – glossy starling, *Lamprocolius purpureus* and bronze Manikin, *Spermestes cucullatus* (H^1 = 9072.19, D=0.00058 each). Also, white – throated bee – eater, *Aerops albicolis* (H^1 = 0.109, D=0.00046), Grey plantain – eater, *Crinifer piscicator* and Kurrichane Thrush, *Turdus libonyanus* (H1 = 0.099, D=0.00036 each), African hawk Eagle, *Hieraaetus spilogaster*, Green wood hoopoe, *Phoeniculus erythrorhyncus* (H^1 = 0.089, D=0.00027 each), Black kite, *Milvus migrans*, Tooth- billed Barbet, *Pogonornis bidentatus*, Common bulbul, *Pycnonotus barbatus* and Pied crow, *Corvus albus* (H^1 = 0.079, D=0.00019 each) are high in species diversity in farmlands. However, the trio of spotted flycatcher, *Muscicapa striata*, willow warbler, *Phylloscopus trochilus* and green -headed sunbird, *Cyanomitra verticallis* have the least diversity index of 0.

4.5.8: Species Diversity of Birds in Arable farmlands of Ondo State Bitumen Belt

Phylogenetic characterisation of birds in Arable farmlands is presented in fig 4.9. The result shows that Ploceidae has the highest distribution, with eight species and 160 individuals. Families of Motacillidae (4 species, 29 individuals), Sylviidae (4 species, 20 individuals), Columbidae (4 species, 14 individuals), Nectarinidae (4 species, 14 individuals), Alcedinidae (4 Species, 13 individuals), Turdidae (three species, 22 individuals), and Accipitridae (three species, 15 individuals) are well represented phylogenetically in farmlands. At the other extreme of phylogenetic diversity of Arable farmland birds are Phoeniculidae, Capitonidae, Pycnonotidae, Corvidae, Coracidae, Bucerotidae, Fringilidae, Dicruridae, and Picidae, with one specie and varying numbers of individuals.

4.5.9: Percentage Composition of Birds in Arable Farmlands of Ondo State Bitumen Belt

Fig 4.10 shows the percentage composition of birds in Arable farmlands. The result indicates that, Ploceidae has the highest percentage composition of 40.6%. This is followed by Motacillidae (7.4%). The families of Sturnidae (6.9%), Turdidae (5.6%), and Sylviidae (5.1%) also have high percentage composition. Families of Accipitridae (3.8%), Columbidae and Nectarinidae (3.6% each) are also well represented in this habitat. Picidae, however, has the lowest percentage distribution of 0.5%.

4.5.10: Species Composition of Birds in Cashcrop Farmland of Ondo State Bitumen Belt

The species composition of birds in cashcrop farmland is presented in Table 4.35. Chestnut and black weaver, *Cinnamopteryx castaneofuscus*, (H^1 = 0.368, D=0.01367) is the most abundant in this habitat. This is followed respectively by Bronze manikin, *Spermestes cucullatus* (H^1 = 0.352, D=0.01196), Rufous – faced grass warblers, *Cisticola erythrops* (H^1 = 0.320, D=0.00889), Grey plantain eater, *Crinifer piscator*, kurrichane thrush, *Turdus libonyanus*, Casins hawk eagle, *Spizaetus africanus* (H^1=0.206, D=0.00239 each), African hawk Eagle, *Hieraaetus Spilogaster*, Green wood hoopoe, *Phoeniculus erythrorhyncus* and common bulbul, *Pycnonotus barbatus* (H^1 = 0.160, D=0.00114 each) all have high species diversity. The following birds on the other hand, have 0 species diversity – cardinal wood pecker, *Dendropicos fuscescens*, Whinchat, *saxcola rubeira* and chestnut -winged Starling, *Onychognatus fulgidus*.

4.5.11: Species Diversity of Birds in Cashcrop Farmlands of Ondo State Bitumen Belt

The family distribution of birds in cashcrop farmlands is shown in fig 4.11. A total of 29 different species of birds were found to make use of this habitat. Among the families, Accipitridae has six different species with 24 individuals. This is followed by Ploceidae (three Spp, 35 individuals), Sylviidae (two Spp., 17 individuals), prionopidae (two Spp., 35 individuals), Sylviidae (two Spp., 17 individuals), Motacillidae and turdidae (two Spp., eight individuals each), and picidae (two Spp., three individuals). On the other hand, the family of sturnidae has the least number of specie of one, and one individual.

4.5.12: Percentage Composition of Birds Families in Cashcrop Farmlands of Ondo State Bitumen Belt

The percentage composition of cashcrop farmland birds is presented in fig 4.12. Ploceidae and Accipitridae families are comparatively higher (26.3% and 18.0% respectively) than others. These are followed by Sylviidae (12.8%), Motacillidae and Turdidae (6.0% each), Musophagidae and prionopidae (5.3% each). The family of Sturnidae, however, has the least composition of 0.8%.

4.5.13: Species Composition of Birds in Riparian Habitat of Ondo State Bitumen Belt

Table 4.36 shows the species composition of birds in Riparian habitat. The result depicts that 47 bird species frequent riparian habitat. The composition of the birds in the habitat was found to be highest for Chestnut –and- black weaver, *Cinnamopteryx castaneofuscus* (H^1=0.557, D=0.05942). This is followed by violet – backed Starling, *Cynnyricinclus leucogaster* (H^1 =0.244, D=0.00414) and white throated bee – eater, *Merops albicolis* (H^1 = 0.152, D=0.00110 each). Grey parrot, *Psittacus erithacus* , green wood hoopoe, *Cinniricinclus erythrorhyncus* and pied crow, *Corvus albus* all have a higher family diversity index (H^1 = 0.139, D=0.00085 each). Also, green fruit Pigeon, *Treron australis*, common Bulbul, *Pycnonotus barbatus* and yellow white-eye, *Zosterops senegalensis* all have high species composition (H^1=0.111, D=0.00046 each). Broad-billed Roller, *Eurystomus afer*, African hawk Eagle, *Hieraaetus spilogaster*, brown barbler, *Turdoides plebeja*, Bell Shrike, *Laniurus ferrugineus*, grey-headed Sparrow, *Passer grisseus*, are all close in terms of species composition (H^1=0.096, D=0.00030 each). 12 species comprising of black Kite, *Milvus migrans*, African long tail hawk, *Urotriochus macrourus*, Lizard buzzard, *Kaupifalco monogrammicus*, Pel's fishing Owl, *Scotopelia peli*, pigmy Kingfisher, *Ispidina picta*, blue-breasted Kingfisher, *Halcion malimbicus*, palm Bulbul, *Thescelocichla leucopleura*, snowy-headed robin Chat, *Cossypha niveicapilla*, puff-back Shrike, *Dryoscopus gambensis*, Gonolek, *Laniurus barbatus*, purple-glossy Starling, *Lamprocolius purpureus*, green-headed Sunbird, *Cyanomitra verticallis* were found to be associated with this habitat (H^1=0.080, D=0.00018 each). Birds with the least diversity, however, are African monkey Eagle, *Stephanoctus coronatus*, and grey – backed camaroptera, *Camaroptera brevicaudata* (H^1= 0 each).

Table 4.34: Species Composition of Birds in Arable Farmlands of Ondo State Bitumen Belt

S/No	Common Name	*Scientific Name*	Family	Dry	Wet	Total	H^1	D
1	Black Kite	*Milvus migrans*	Accipitridae	3	3	6	0.079	0.00019
2	African Hawk eagle	*Hieraaetus spilogaster*	Accipitridae	3	4	7	0.089	0.00027
3	Shikra	*Accipiter badius*	Accipitridae	1	1	2	0.032	0.00001
4	Red -Eye Turtle Dove	*Streptopelia semitorquota*	Columbidae	2	2	4	0.057	0.00008
5	Laughing Dove	*Stigmatopelia senegalensis*	Columbidae	2	2	4	0.057	0.00008
6	Red- billed wood dove	*Turtur afer*	Columbidae	2	2	4	0.057	0.00008
7	Green fruit pigeon	*Treron australis*	Columbidae	1	1	2	0.032	0.00001
8	Grey plantain – eater	*Crinifer piscicator*	Musophagidae	4	4	8	0.099	0.00036
9	Levaillant cuckoo	*Climator Levaillanti*	Cuculidae	2	1	3	0.045	0.00004
10	Didric Cuckoo	*Lampromorpha caprius*	Cuculidae	1	1	2	0.032	0.00001
11	Broad -billed roller	*Eurystomus afer*	Coracidae	1	4	5	0.068	0.00013
12	Green wood hoopoe	*Phoeniculus erythrorhyncus*	Phoeniculidae	3	4	7	0.089	0.00027
13	African pied hornbill	*Tockus fasciatus*	Bucerotidae	2	3	5	0.068	0.00013
14	Pigmy	*Ispidina picta*	Alcedinidae	1	2	3	0.045	0.00004

	kingfisher							
15	Striped Kingfisher	*Halcyon chelicuti*	Alcedinidae	1	2	3	0.045	0.00004
16	Senegal Kingfisher	*Halcyon senegalensis*	Alcedinidae	1	3	4	0.057	0.00008
17	Blue breasted kingfisher	*Halcyon malimbicus*	Alcedinidae	1	2	3	0.045	0.00004
18	White-throated bee eater	*Aerops albicollis*	Meropidae	4	5	9	0.109	0.00046
19	Tooth-billed barbet	*Pogonornis bidendatus*	Capitonidae	3	3	6	0.079	0.00019
20	Fire- bellied woodpecker	*Dendropicos pyrrhogaster*	Picidae	1	1	2	0.032	0.00001
21	African pied wagtail	*Motacilla aguimp*	Motacillidae	5	5	10	0.118	0.00058
22	Yellow wagtail	*Budytes flavus*	Motacillidae	7	3	10	0.118	0.00058
23	P. B. Pipit	*Anthus leucophrys*	Motacillidae	3	2	5	0.068	0.00013
24	Y. T. Long claw	*Macronyx croceus*	Motacillidae	2	2	4	0.057	0.00008
25	Common bulbul	*Pycnonotus barbatus*	Pycnonotidae	3	3	6	0.079	0.00019
26	Spotted flycatcher	*Muscicapa striata*	Muscicapidae	1	-	1	0	0.00000
27	Grey-backed paradise flycatcher	*Tchitrea smithii*	Muscicapidae	2	2	4	0.057	0.00008
28	European wheat ear	*Oenanthe oenanthe*	Turdidae	6	6	12	0.137	0.00085

29	Kurrichane thrush	*Turdus libonyanus*	Turdidae	3	5	8	0.099	0.00036
30	Whinchat	*Saxcola rubeila*	Turdidae	2	-	2	0.032	0.00001
31	Willow warbler	*Phylloscopus trochilus*	Sylviidae	1	-	1	0	0.00000
32	White-bellied crombec	*Sylvietta flaviventris*	Sylviidae	1	2	3	0.045	0.00004
33	Grey-backed camaroptera	*Camaroptera Brevica-Udata*	Sylvidae	3	1	4	0.057	0.00008
34	Red- faced grass warbler	*Cisticola erythrops*	Sylviidae	6	6	12	0.137	0.00085
35	Rufuos - faced grass warbler	*Dicrurus adsimilis*	Dicruridae	2	2	4	0.057	0.00008
36	Gonolek	*Laniurus barbatus*	Prionopidae	1	2	3	0.045	0.00004
37	Bush shrike	*Tchagra senegala*	Prionopidae	2	2	4	0.057	0.00008
38	Pied crow	*Corvus albus*	Corvidae	2	4	6	0.079	0.00019
39	Violet-backed starling	*Cinnyricinclus Leucogaster*	Sturnidae	12	5	17	0.178	0.00176
40	Purple-glossy starling	*Lamprocolius purpureus*	Sturnidae	4	6	10	0.118	0.00058
41	Splendid sunbird	*Cynnyris coccinigaster*	Nectarinidae	2	2	4	0.057	0.00008
42	Olive-bellied	*Cynnyris chloropygius*	Nectarinidae	3	2	5	0.068	0.00013

	sunbird							
43	Green-headed sunbird	*Cyanomitra verticallis*	Nectarinidae	1	-	1	0	0.00000
44	Collared sunbird	*Anthreptes collaris*	Nectarinidae	2	2	4	0.057	0.00008
45	Grey-headed sparrow	*Passer grisseus*	Frimgilidae	3	2	5	0.068	0.00013
46	Chestnut - and -black weaver	*Cinnamopteryx castaneofuscus*	Ploceidae	13	29	42	0.339	0.01112
47	Village weaver	*Plesiositagra cucullatus*	Ploceidae	30	41	71	0.472	0.03210
48	Spec. Weaver	*Hyphanturgus brachypterus*	Ploceidae	-	3	3	0.045	0.00004
49	Red- headed malimbe	*Malimbus rubricollis*	Ploceidae	-	2	2	0.032	0.00001
50	Red- headed dioch	*Quelea erythrops*	Ploceidae	13	12	25	0.237	0.00387
51	Bronze manikin	*Spermestes cucullatus*	Ploceidae	5	5	10	0.118	0.00058
52	Grey - crowned negro finch	*Nigrita canicapilla*	Ploceidae	2	-	2	0.032	0.00001
53	Pin -tailed whydah	*Vidua macroura*	Ploceidae	2	3	5	0.068	0.00013

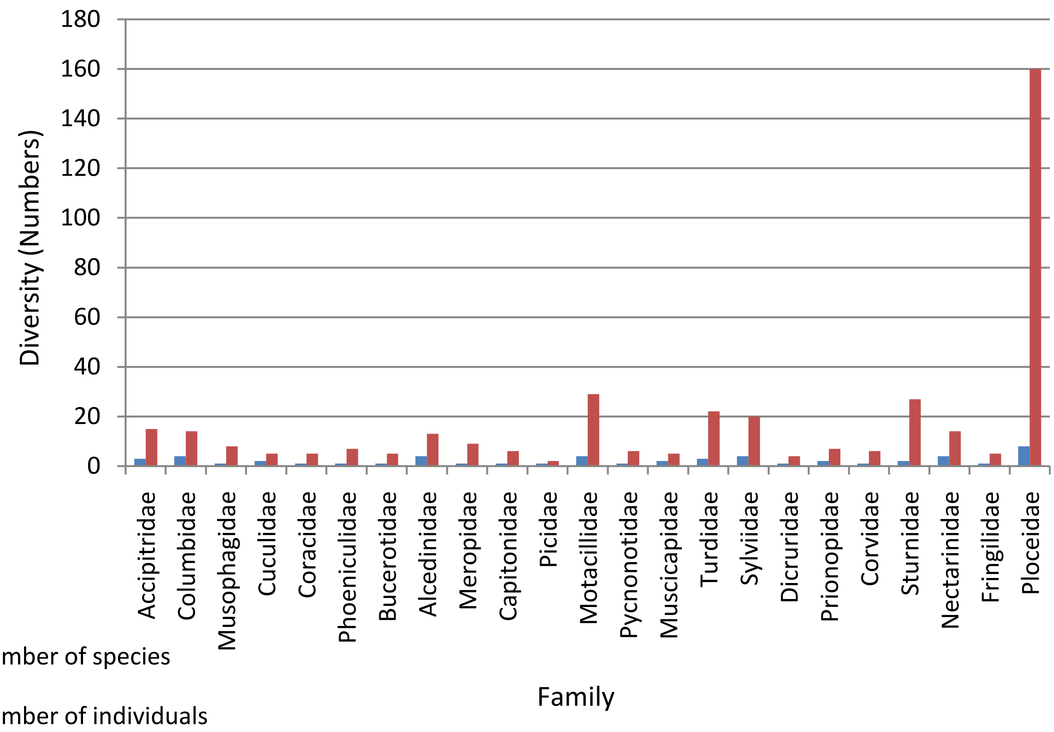

Fig 4.5: Species Diversity of Birds in Arable Farmland of Ondo State Bitumen Belt

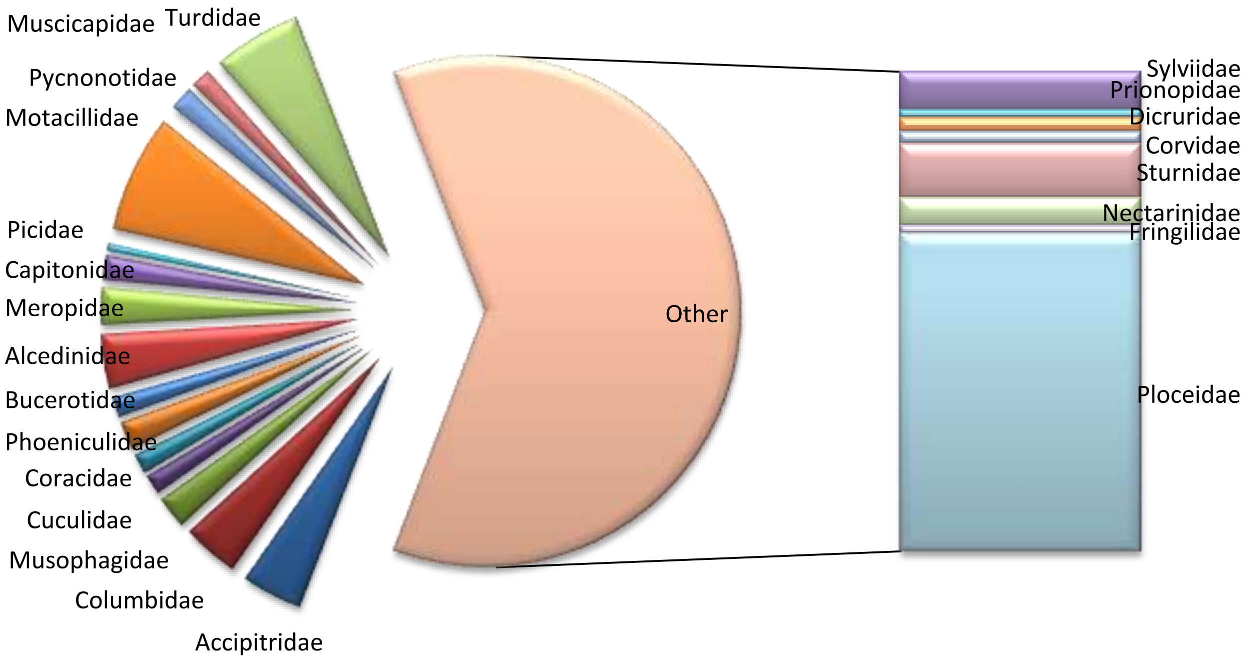

Fig 4.6: Percentage Distribution of Birds in Arable Farmland of Ondo State Bitumen Belt

Table 4.35: Species Composition of Birds in Cashcrop Farmland of Ondo State Bitumen Belt

S/No	Common Name	*Scientific Name*	Family	Dry	Wet	Total	H^1	D
1	Black Kite	*Milvus migrans*	Accipitridae	1	3	4	0.135	0.00068
2	Afr. Hawk Eagle	*Hieraaetus spilogaster*	,,	2	3	5	0.160	0.00114
3	Ayres Hawk Eagle	*H. dubius*	,,	2	2	4	0.135	0.00068
4	Casins Hawk Eagle	*Spizaetus africanus*	,,	3	4	7	0.206	0.00239
5	Lizard Buzzard	*Kaupifalco monogrammicus*	,,	1	1	2	0.078	0.00011
6	Shikra	*Accipiter badius*	,,	1	1	2	0.078	0.00011
7	Grey plantain eater	*Crinifer piscator*	Musophagidae	3	4	7	0.206	0.00239
8	Levaillant Cuckoo	*Climator levaillanti*	Cuculidae	1	1	2	0.078	0.00011
9	Didric Cuckoo	*Lampromorpha caprius*	,,	1	2	3	0.108	0.00034
10	G. W. Hoopoe	*Phoeniculus erythrorhyncus*	Phoeniculidae	2	3	5	0.160	0.00114
11	W. T. Bee-Eater	*Aerops albicolis*	Meropidae	1	3	4	0.135	0.00068
12	Y.F. Tinker bird	*Pogoniulus chrysoconus*	Capitonidae	1	1	2	0.078	0.00011
13	Cardinal Woodpecker	*Dendropicos fuscecens*	Picidae	1		1	0	0.00000
14	Fire-bellied	*D.*	,,	1	1	2	0.078	0.00011

	Woodpecker	*Pyrrhogaster*						
15	Plain-backed Pipit	*Anthus leucophrus*	Motacillidae	2	2	4	0.135	0.00068
16	Y. T. Long claw	*Macroneux croceus*	,,	2	2	4	0.135	0.00068
17	Common Bulbul	*Pycnonotus barbatus*	Pycnonotidae	1	4	5	0.160	0.00114
18	K. Thrush	*Turdus libonyanus*	Turdidae	3	4	7	0.206	0.00239
19	Whinchat	*Saxcola rubeira*	,,	1		1	0	0.00000
20	G.B. Camaroptera	*Camaroptera brevicaudata*	Sylviidae	2	2	4	0.135	0.00068
21	R.F. Grass warbler	*Cisticola erythrops*	,,	6	7	13	0.320	0.00889
22	Bush Shrike	*Tchagra senegala*	Prionopidae	1	2	3	0.108	0.00034
23	C.W. Starling	*Onychognatus fulgidus*	Sturnidae	1		1	0	0.0000
24	Bell Shrike	*Laniarus ferrugineus*	Prionopidae	2	2	4	0.135	0.00068
25	O.B. Sunbird	*Cynniris chloropygius*	Nectarinidae	1	1	2	0.078	0.00011
26	C.B. Weaver	*Cinnamopteryx castaneofuscus*	Ploceidae	6	10	16	0.368	0.01367
27	R.H. Malimbe	*Malinbus rubricolis*	,,	1	3	4	0.135	0.00068
28	Bronze Manikin	*Spermestes cucullatus*	,,	6	9	15	0.352	0.01196

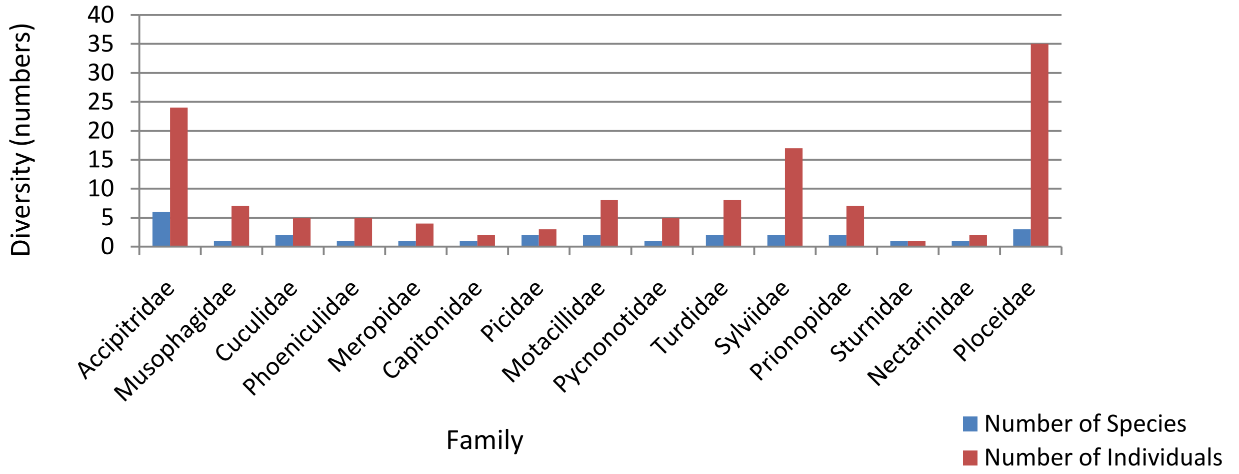

Fig 4.7: Species Diversity of Birds in Cashcrop Farmlands of Ondo State Bitumen Belt

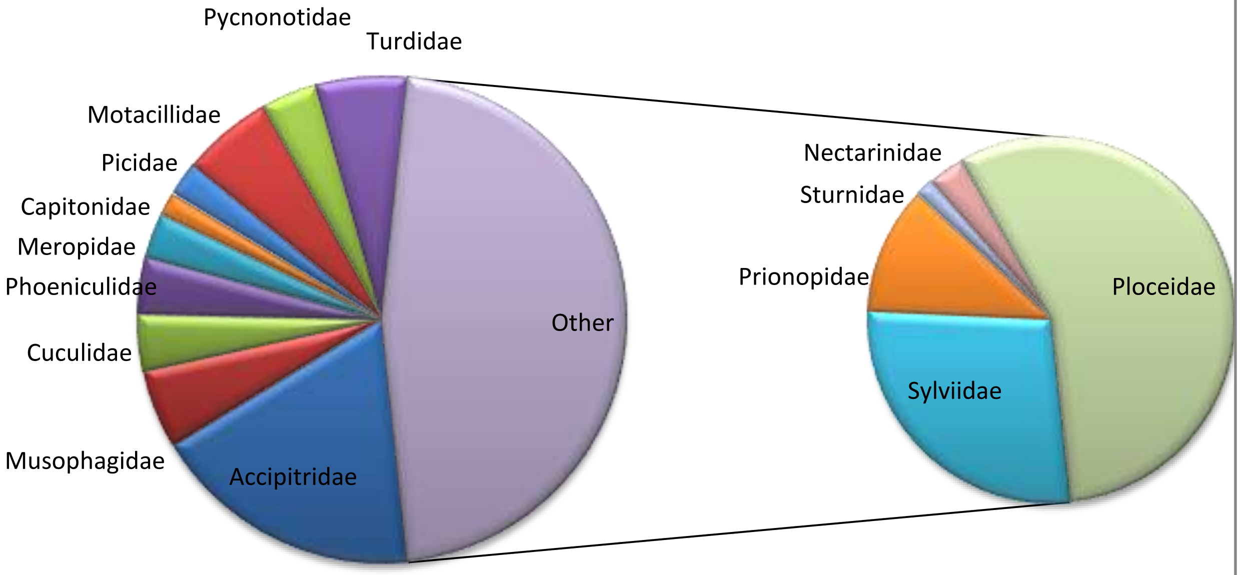

Fig 4.8: Percentage composition of Birds in Cashcrop Farmlands of Ondo State Bitumen Belt

4.5.14: Species Diversity of Birds in Riparian Habitat of Ondo State Bitumen Belt

The diversity of birds is shown in fig 4.13. This habitat was found to be associated with 24 families composed of 48 different species. Among the families, Accipitridae has the highest phylogenetic diversity of six species with 21 individuals. This is followed by ploceidae (four Spp., 71 individuals), Columbidae (four Spp., 14 individuals), Prionopidae (3 Spp., 13 individuals), Alcedinidae (three Spp., 11 individuals), Nectarinidae (three Spp., nine individuals) and Cuculidae (three Spp., seven individuals). Sturnidae, Pycnonotidae, Picidae, Muscicapidae and Capitonidae are represented by two families each with decreasing numbers of individuals. Sylviidae family, however, has the least phylogenetic diversity, as it was found to be composed of one species, and one individual in this habitat.

4.5.15: Percentage Composition of Birds Families in Riparian Habitat of Ondo State Bitumen Belt

The percentage composition of birds in Riparian habitat is represented in fig 4.14. Among the 24 families of birds found to be using this habitat, Ploceidae has the highest percentage composition (27.6%). This is followed by Accipitridae and Sturnidae (8.2% each), Columbidae (5.5%), Prionopidae (5.1%), Sylviidae, however, has the least percentage composition of 0.4%.

4.5.16: Species Composition of Birds in Urban Arboreta of Ondo State Bitumen Belt

Species composition of birds in Urban Arboreta is presented in Table 4.37. A total of 56 species were found to be making use of urban arboreta. Among these, species composition is highest for Chestnut- and -black weaver, *Cinnamopteryx castaneofuscus* (H^1 = 0.433, D=0.02400), followed by Cattle Egret, *Bulbucus ibis* (H^1 =0.247, D=0.00441), European Swallow, *Hirundo rustica* (H^1 =0.204, D=0.00258), Red – headed Dioch, *Queela erythrops* (Shannon = 0.189, D=0.00207), Little African swift, *Colletoptera affinis* (H^1=0.148, D=0.00106), Palm swift, *Cypsiurus parvus*, Rufous – chested swallow, *Hirundo semirufa* and Bronze manikin, *Spermestes Cucullatus* (H^1=0.139, D=0.00090 each), Yellow-wagtail, *Budytes flavus*, and violet-back Starling, *Cinnyricinclus leucogaster* (H^1=0.121, D=0.00061 each), Kurrichane thrush, *Turdus libonyanus*, and Ayres hawk Eagle, *Hieraaetus dubius* (H^1=0.101, D=0.00038 each). The following birds, however, have the least species composition:- Tooth – billed barbet, *Pogonorius bidentatus*, spotted flycatcher, *Muscicapa striata* and Laughing Dove, *Stigmatopelia senegalensis*(H^1=0 each).

Table 4.36: Species Composition of Birds in Riparian Habitat of Ondo State Bitumen Belt

S/No	Common Name	*Scientific Name*	Family	Dry	Wet	Total	H^1	D
1	Black kite	*Milvus migrans*	Accipitridae	1	3	4	0.080	0.00018
2	African hawk eagle	*Hieraaetus spilogaster*	,,	2	3	5	0.096	0.00030
2	Afr. Long tail hawk	*Urotriochus macrourus*	,,	2	2	4	0.080	0.00018
3	Casins hawk Eagle	*Spizaetus africanus*	,,	1	2	3	0.064	0.00009
4	Lizard buzzard	*Kaupifalco monogrammicus*	,,	2	2	4	0.080	0.00018
5	African Monkey Eagle	*Stephanoetus coronatus*	,,	1		1	0	0.00000
6	Red -eyed Turtle Dove	*Streptopelia semitorquata*	Columbidae	2	1	3	0.064	0.00009
7	Laughing Dove	*Stigmatopelia Senegalensis*	Columbidae	2	1	3	0.064	0.00009
8	Red -billed wood Dove	*Tutur afer*	Columbidae	1	1	2	0.048	0.00003
9	Green fruit Pigeon	*Treron australis*	Columbidae	3	3	6	0.111	0.00046
10	Grey	*Psittacus*	Picidae	4	4	8	0.139	0.00085

	Parrot	*erithacus*						
11	Levaillant Cuckoo	*Climator levaillanti*	Cuculidae	1	1	2	0.048	0.00003
12	Didric Cuckoo	*Lampromorpha caprius*	Cucilidae	2	-	2	0.048	0.00003
13	Senegal Coucal	*Centropus senegalensis*	Cucilidae	2	1	3	0.064	0.00009
14	Long-tailed night jar	*Scotornis climacurus*	Caprimulgidae	1	2	3	0.064	0.00009
15	Pel's fishing owl	*Scotopelia peli*	Strigidae	2	2	4	0.080	0.00018
16	Broad - billed roller	*Eurystomus afer*	Coracidae	2	3	5	0.096	0.00030
17	Green wood hoopoe	*Phoeniculus erythrorhyncus*	Phoeniculidae	2	6	8	0.139	0.00085
18	Pigmy kingfisher	*Ispidina picta*	Alcedinidae	2	2	4	0.080	0.00018
19	Senegal kingfisher	*Halcyon senegalensis*	Alcedinidae	2	1	3	0.064	0.00009
20	Blue-breasted kingfisher	*Halcyon malimbicus*	Alcedinidae	2	2	4	0.080	0.00018
22	Tooth-billed barbet	*Pogonornis bidentatus*	Capitonidae	1	1	2	0.048	0.00003
23	Yellow - fronted tinker bird	*Pogoniulus Chrysoconus*	Capitonidae	1	1	2	0.048	0.00003

24	Grey wood pecker	*Dendropicos goertae*	Picidae	1	1	2	0.048	0.00003
25	Brown barbler	*Turdoides plebeja*	Timalidae	5	-	5	0.096	0.00030
26	Common bulbul	*Pycnonotus barbatus*	Pycnonotidae	3	3	6	0.111	0.00046
27	Palm bulbul	*Thescelocichla leucpleura*	Pycnonotidae	1	3	4	0.080	0.00018
28	Spectacle d flycatcher	*Platysteira cyanea*	Muscicapidae	1	1	2	0.048	0.00003
29	Grey - backed paradise fly catcher	*Tchitrea smithii*	Muscicapidae	1	2	3	0.064	0.00009
30	Snowy-headed robin chat	*Cossyypha niveicapilla*	Turdidae	2	2	4	0.080	0.00018
31	Grey-backed camaropt era	*Camaroptera brevicaudata*	Sylviidae	1	-	1	0	0.00000
32	Puff back shrike	*Dryoscopus gambensis*	Prionopidae	2	2	4	0.080	0.00018
33	Gonolek	*Laniarus barbatus*	Prionopidae	2	2	4	0.080	0.00018
34	Bell shrike	*Laniarus ferrugineus*	Prionopidae	2	3	5	0.096	0.00030
35	Black-winged oriole	*Oriolus nigripennis*	Oriolidae	1	2	3	0.064	0.00009

36	Pied crow	*Corvus albus*	Corvidae	2	6	8	0.139	0.00085
37	Violet-backed Starling	*Cinniricinclus leucogaster*	Sturnidae	12	5	17	0.244	0.00414
38	Purple glossy Starling	*Lamprocolius purpureus*	,,	4		4	0.080	0.00018
39	Yellow white eye	*Zosterops senegalensis*	Zosteropidae	3	3	6	0.111	0.00046
40	Splendid Sunbird	*Cynniris coccinigaster*	Nectarinidae	1	1	2	0.048	0.00003
41	O.B. Sunbird	*C. chloropygius*	,,	1	2	3	0.064	0.00009
42	G. H. Sunbird	*Cyanomitra verticallis*	,,	2	2	4	0.080	0.00018
43	G.H. Sparrow	*Passer grisseus*	Fringilidae	2	3	5	0.096	0.00030
44	C & B Weaver	*Cinnamopteryx castaneofuscus*	Ploceidae	35	28	63	0.557	0.05942
45	Spec. Weaver	*Hyphanturgus brachypterus*	,,	2		2	0.048	0.00003
46	R.H. Malimbe	*Malimbus rubricollis*	,,	3		3	0.064	0.00009
47	G.C. N. Finch	*Nigrita canicapilla*	,,	1	2	3	0.064	0.00009
48	White-throated bee-eater	*Aerops albicolis*	Meropidae	5	4	9	0.152	0.00110

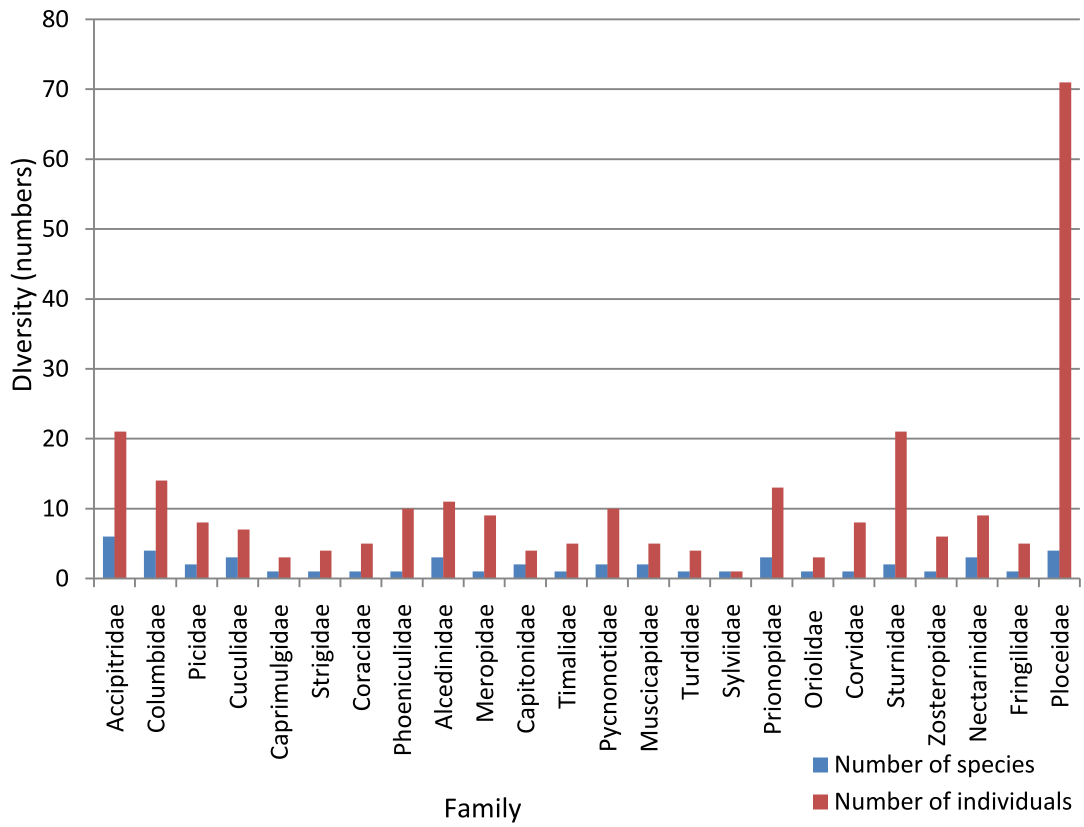

Fig 4.9: Species Diversity of Birds in Riparian Habitat of Ondo State Bitumen Belt

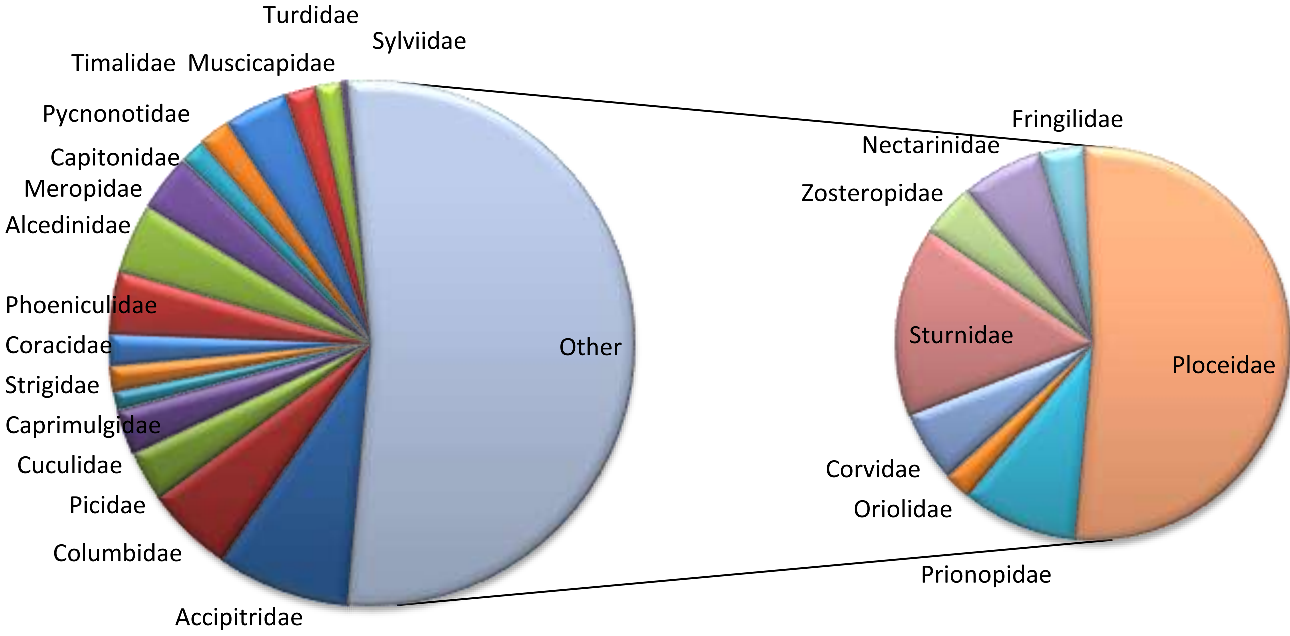

Fig 4.10: Percentage Composition of Riparian Birds Families of Ondo State Bitumen Belt

Table 4.37: Species Composition of Birds in Urban Arboreta of Ondo State Bitumen Belt

S/No	Common Name	*Scientific Name*	Family	Dry	Rain	Total	H^1	D
1	Black kite	*Milvus migrans*	Accipitridae	2	1	3	0.045	0.00004
2	African hawk eagle	*Hieraaetus Spilogaster*	"	2	2	4	0.058	0.00008
3	Ayres hawk eagle	*Hieraaetus dubius*	"	4	4	8	0.101	0.00038
4	Lizard buzzard	*Kaupifalco monogrammicus*	"	1	1	2	0.033	0.00001
5	Shikra	*Accipiter badius*	"	1	2	3	0.048	0.00004
6	Red- eyed turtle Dove	*Streptopelia Semitorquata*	Columbidae	2	2	4	0.058	0.00008
7	Red- billed wood Dove	*Tutur afer*	"	2	1	3	0.048	0.00004
8	Grey plantain eater	*Crinifer piscator*	Musophagidae	3	5	8	0.101	0.00038
9	Levaillant cuckoo	*Climator levaillanti*	Cuculidae	1	2	3	0.048	0.00004
10	Senegal coucal	*Centropus sennegalensis*	"	1	2	3	0.048	0.00004
11	Little African swift	*Colletoptera affinis*	Micropodidae	4	9	13	0.148	0.00106
12	Palm swift	*Cypsiurus parvus*	Micropodidae	5	8	12	0.139	0.00090
13	Pigmy	*Ispidina picta*	Alcedinidae	-	2	2	0.033	0.00001

	kingfisher							
14	Senegal kingfisher	*Halcyon senegalensis*	“	1	2	3	0.048	0.00004
15	Stripped kingfisher	*Halcyon Chelicuti*	“	2	2	4	0.058	0.00008
16	Blue - breasted kingfisher	*Halcyon malimbicus*	“	1	2	3	0.048	0.00004
17	White-throated bee eater	*Aerops albicollis*	Meropidae	4	2	6	0.080	0.00020
18	Tooth - billed barbet	*Pogonornis bidentatus*	Capitonidae	1	-	1	0	0.00000
19	Africa pied wagtail	*Motacilla aguimp*	Motacilidae	5	4	9	0.111	0.00049
20	Yellow wagtail	*Budytes flavus*	Motacilidae	6	4	10	0.121	0.00061
21	Plain-backed pipit	*Anthus leucophrys*	Motacilidae	3	6	9	0.111	0.00049
22	Yellow-throated-long claw	*Macronxy Croceus*	Motacilidae	2	2	4	0.058	0.00008
23	Common bulbul	*Pycnonotus barbartus*	Pycnonotidae	4	3	7	0.091	0.00028
24	Spotted flycatcuer	*Muscicapa striata*	Muscicapidae	1	-	1	0	0.00000
25	Grey-backed	*Tchitrea smitihii*	Muscicapidae	1	2	3	0.048	0.00004

	paradise fly-catcher							
26	European wheat ear	*Oenanthe oenanthe*	Turdidae	4	-	4	0.058	0.00008
27	Laughing dove	*Stigmatopelia Senegalensis*	Columbidae	1	-	1	0	0.00000
28	Cattle egret	*Bubulcus ibis*	Ardeidae	12	14	26	0.247	0.00441
29	Kurrichane thrush	*Turdus libonyanus*	Turdidae	3	5	8	0.101	0.00038
30	Whin chat	*Saxcola rubeira*	Turdidae	2	-	2	0.033	0.00001
31	Snowy - headed robin chat	*Cossypha niveicapilla*	Turdidae	2	-	2	0.033	0.00001
32	Willow warbler	*Phylloscopus trochilus*	Sylviidae	1	1	2	0.033	0.00001
33	White-bellied crombec	*Sylvietha flaviventris*	Sylviidae	1	1	2	0.033	0.00001
34	Grey - backed camaroptera	*Camaroptera brevicaudata*	Sylviidae	1	1	2	0.033	0.00001
35	Rufous - faced grass warbler	*Cisticola erythrops*	Sylviidae	6	5	11	0.130	0.00075
36	Rufous-chested swallow	*Hirundo semirufa*	Hirundidae	6	6	12	0.139	0.00090
37	European swallow	*Hirundo rustica*	Hirundidae	11	9	20	0.204	0.00258

38	Velvet - mantled Drongo	*Dicrurus adsimilis*	Dicruridae	2	1	3	0.048	0.00004
39	Fiscal Shrike	*Lanius collaris*	Prionopidae	2	2	4	0.058	0.00008
40	Bush Shrike	*Tchagra senegala*	Prionopidae	-	2	2	0.033	0.00001
41	Pied crow	*Corvus albus*	Corvidae	5	3	8	0.101	0.00038
42	Violet - backed Starling	*Cinnyricinclus leucogaster*	Sturnidae	6	4	10	0.121	0.00061
43	Purple-glossy Starling	*Lamprocolius purpureus*	Sturnidae	2	3	5	0.059	0.00014
44	Chestnut - winged Starling	*Onychognathus Fulgidus*	Sturnidae	1	3	4	0.058	0.00008
45	Bell Shrike	*Laniarus ferrigineus*	Prionopidae	-	2	2	0.033	0.00001
46	Splendid Sunbird	*Cynnyris coccinigaster*	Nectarinidae	1	2	3	0.048	0.00004
47	Olive - bellied Sunbird	*Cynnyris chloropygius*	Nectarinidae	2	2	4	0.058	0.00008
48	Green-headed Sunbird	*Cyanomitra verticallis*	Nectarinidae	2	2	4	0.058	0.00008
49	Collared Sunbird	*Arthreptes collaris*	Nectarinidae	2	2	4	0.058	0.00008
50	Grey- -	*Passer grisseus*	Fringilidae	3	5	8	0.101	0.00038

	headed Sparrow							
51	C & B weaver	*Cinnamomopteryx castaneofuscus*	Ploceidae	31	30	60	0.433	0.02400
52	Spectacled weaver	*Hyphanturgus brachypterus*	Ploceidae	3	5	8	0.101	0.00038
53	Red-headed Dioch	*Quelea erythrops*	Ploceidae	6	12	18	0.189	0.00207
54	Bronze Manikin	*Spermestes cucullatus*	Ploceidae	4	8	12	0.139	0.00090
55	Grey-crowned negro Finch	*Nigrita canicapilla*	Ploceidae	1	1	2	0.033	0.00001
56	Pin -tailed Whydah	*Vidua macroura*	Ploceidae	-	4	4	0.058	0.00008

4.5.17: Species Diversity of Birds in Urban Arboreta of Ondo State Bitumen Belt

Fig 4.15 shows the species diversity of birds among 23 families. The result shows that, Ploceidae family has six species and 104 individual birds. This is closely followed by Accipitridae (5 species, 20 individuals). Other birds with high species diversity include Motacillidae (4 species, 32 individuals), Sylviidae (4 species, 17 individuals), Turdidae (4 species, 16 individuals), Nectarinidae (4 species, 15 individuals) and Sturnidae (3 species, 19 individuals). Capitonidae, however, has the least number of species and individuals (one, one).

4.5.18: Percentage Composition of Birds Families in Urban Arboreta of Ondo State Bitumen Belt

Fig 4.16 shows the percentage composition of birds in urban arboreta. The result reveals that, the family of Ploceidae has the highest composition of 27.0%. This is followed by Motacillidae and Hirundidae, (8.3% each). Families with high percentage composition also include Micropodidae (6.5%), Accipitridae (5.2%), Sturnidae (5.0%), Sylviidae (4.4%), Turdidae (4.2%), and Nectarinidae (3.9%). While the least composition of, 0.3%, is recorded for Capitonidae.

4.6.0: Relative Abundance of Animals in Ondo State Bitumen Belt

Relative abundance of animals in the Bitumen belt is shown in Table 4.38. The results shows that the number of individual animals, abundance, and species richness censured in the various habitats significantly differ from one another (P<0.05). The effect of seasonal variation on number of individual animals and number of different species is also significant (P<0.05). Interaction of the habitat and seasons, however, had no significant effect on these two parameters (P>0.05) (appendix 32).

The abundance of animals in each transect ranges between six and 26. Islands of High Forest have the highest total number of animals, 26, followed by Riparian Habitat, 25, Fallow Land, 13. While the duo of Arable Farmland and Cashcrop Farmland has eight individuals each, with Urban Arboreta recording the least species abundance. Wet season has mean number of 20 as against dry season, which are 16 (Table 4.38).

Least Significant Difference, LSD, Test for species abundance in each quadrant shows that, the six habitats are significantly different from one another, with the exception of Arable Farmland and Cashcrop Farmland which are not significantly different. LSD test for seasonal variations also shows that the mean number of individual animals encountered during dry, 16, and wet, 20, seasons are significantly different from one another (appendix 33).

Also, the mean number of different species of animals (species richness) found within some of the different habitats differs significantly from one another. The mean number of different species of animals ranges between 4 and 9. Islands of High Forest, Arable Farmland, Fallow Land and Riparian Habitat has the highest number of species per unit area, (eight species each), Cashcrop Farmland has six species, while Urban Arboreta has the least species richness. Test of significant difference shows that, Arable Farmland, Fallow Land and Riparian Habitat are not significantly different from one another in term of the number of different species (appendix 33). The number of different species found during dry, 6, and wet, 8, seasons also differ significantly from one another ($p<0.05$) (appendices 33 and 34).

4.6.1: Species Composition of Animals in Fallow Land of Ondo State Bitumen Belt

Table 4.39 shows the species Composition of animals in Fallow Land. The result shows that species composition was highest for Giant forest Squirrel, *Potozerus strangeri* (H^1 = 0.322, D=0.00820). This is respectively followed by Orange – headed squirrel, *Funiusciurus anchrythrus* (H^1= 0.284, D=0.00546), small land snail, *Achachatina marginata* (H^1=0.242, D=0.00328), brush tail porcupine, *Artherius africanus*, Black rat, *Rattus rattus*, Emin`s giant rat, *Cricetomys emini*, Climbing mouse, *Dendromys mystacalis*, Black mamba, *Dendroaspis polylepis*, and Royal Python, *Python regius* (H^1 = 0.196, D=0.00164 each). The remaining species of animals have the same least diversity index (H^1 = 0.144, D=0.00055 each).

4.6.2: Species Diversity of Animals in Fallow Land of Ondo State Bitumen Belt

The phylogenetic diversity of birds in Fallow Land is presented in fig 4.17. It is shown in the result that, of the eigth orders of animals in this habitat, Rodentia has the highest number of different species with 29 individual animals. Squamata also has high species diversity, as five different species with 12 individuals were censured in this habitat. Carnivora and Primata have two species with four individuals each, Mollusca, two species and six individuals. While Insectivora has the least species diversity, as it is represented in this habitat with one species and two individuals.

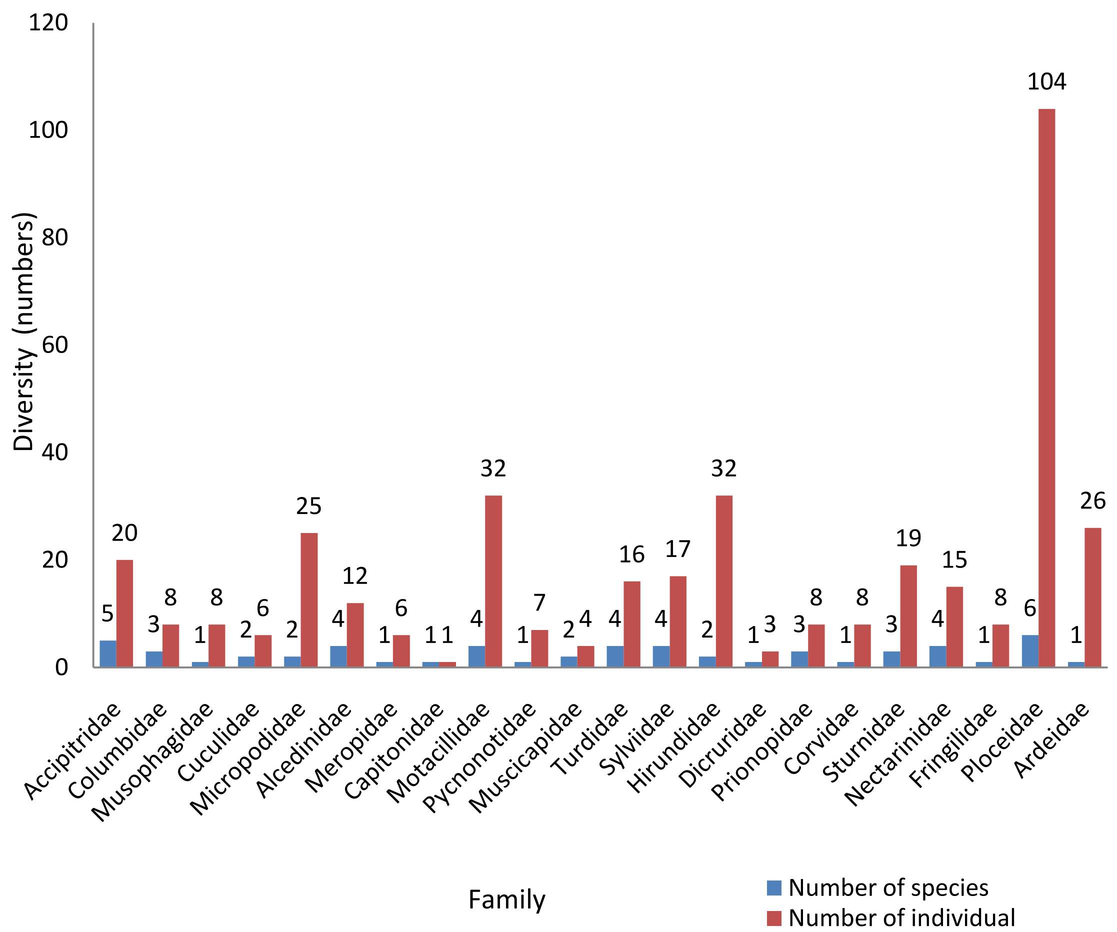

Fig 4.11: Species Diversity of Birds in Urban Arboreta of Ondo State Bitumen Belt

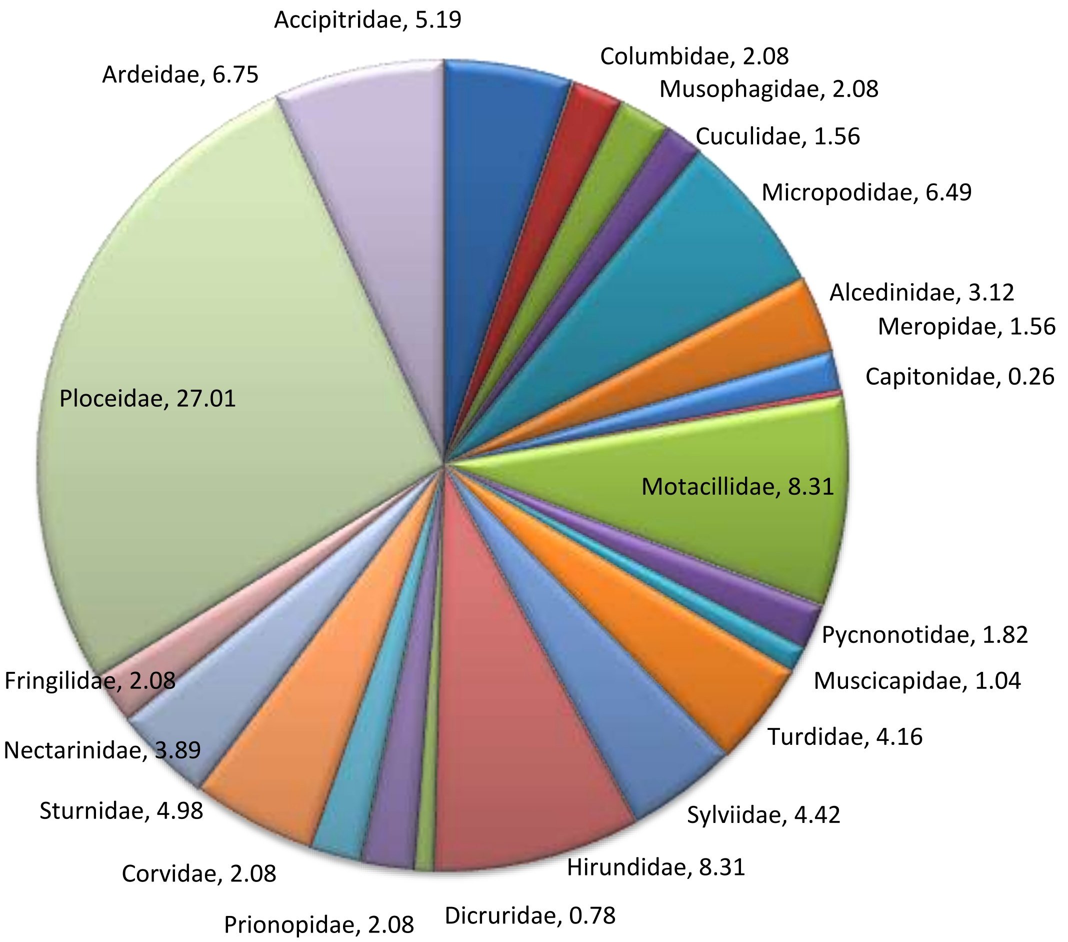

Fig 4.12: Percentage Composition of Birds in Urban Arboreta of Ondo State Bitumen Belt

Table 4.38: Relative Abundance of Animals in Ondo State Bitumen Belt

Variable	AF		FF		RH		HF		CF		UA	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Abundance of Animals/500m^2	6	10	12	14	25	26	17	35	6	9	5	7
Richness of Animal Species/500m^2	8	8	7	9	8	8	7	9	4	7	3	5

AF= Arable Farmland, FL= Fallow Land, RH= Riparian Habitat, HF= Islands of High Forest, CF= Cashcrop Farmland, UA= Urban Arboreta

Table 4.39: Species Composition of Animals in Fallow Land of Ondo State Bitumen Belt

S/No	Animal	*Scientific Name*	Order	Dry	Rain	Total	H^1	D
1	Brush tail porcupine	*Artheriurus africanus*	Rodentia	2	1	3	0.196	0.00164
2	Black rat	*Rattus rattus*	Rodentia	2	1	3	0.196	0.00164
3	Flying squirrel	*Anomalorus beecrofti*	Rodentia	1	1	2	0.144	0.00055
4	Giant forest squirrel	*Potoxerus stranger*	Rodentia	3	3	6	0.322	0.00820
5	Orange headed squirrel	*Funniusciurus anchrythrus*	Rodentia	3	2	5	0.284	0.00546
6	Emin`s giant rat	*Cricetomys emini*	Rodentia	1	2	3	0.196	0.00164
7	African giant rat	*Cricetomys gambianus*	Rodentia	2	2	4	0.242	0.00328
8	Climbing mouse	*Dendromys mystacalis*	Rodentia	2	1	3	0.196	0.00164
9	Cusimanse mongoose	*Crossarchus obscures*	Carnivora	1	1	2	0.144	0.00055
10	Forest genet	*Geneta poensis*	Carnivora	1	1	2	0.144	0.00055
11	Cane rat	*Thryonomys swinderianus*	Rodentia	2	2	4	0.242	0.00328
12	Dwarf galago	*Galagoides demidovii*	Primata	1	1	2	0.144	0.00055
13	Long tailed musk shrew	*Crocidura dolichura*	Insectivora	1	1	2	0.144	0.00055
14	Potto	*Perididictus potto*	Primata	1	1	2	0.144	0.00055

15	Green mamba	*Dendroaspis viridis*	Squamata	1	1	2	0.144	0.00055
16	Black mamba	*Dendroaspis polylepis*	Squamata	1	2	3	0.196	0.00164
17	Gaboon Viper	*Bitis gabonica*	Squamata	1	1	2	0.144	0.00055
18	African Python	*Python sebae*	Squamata	1	1	2	0.144	0.00055
19	Royal python	*Python regius*	Squamata	1	2	3	0.196	0.00164
20	Giant land snail	*Achachatina marginata*	Mollusca	1	1	2	0.144	0.00055
21	Small land snail	*Achatina sp*	,,	1	3	4	0.242	0.00328

4.6.3: Percentage Composition of Animals in Fallow Land of Ondo State Bitumen Belt

Fig 4.18 shows the percentage composition of animals in Fallow Land. The result reveals that, Rodentia has the highest percentage composition (51.0%), Squamata follows, with composition of 19.0%. The composition of Mollusca is also high (9.0%), while the trio of Carnivora, Hyracoidea and Primata has the same percentage composition of 6.0% each. Insectivora, however, has the least percentage composition (3.0%).

4.6.4: Species Composition of Animals in Arable Farmland of Ondo State Bitumen Belt

Species composition of animals in Arable farmland is shown in Table 4.40. The result shows that 21 species were censused in Arable farmland. Small land snail, *Achatina sp* was found to have the highest diversity index (H^1=0.683, D=0.18484). This is closely followed by medium land snail, *Achatina achatina* (H^1=0.336, D=0.01027), Climbing mouse, *Dendromys mystacalis* (H^1 = 0.245, D=0.00392), giant land Snail, *Achachatina marginata* (H^1 = 0.191, D=0.00187), Giant rat, *Cricetomys gambianus* and Bush buck, *Tragelaphus niger* (H^1 = 0.162, D=0.00112 each). The least diversity index is however recorded for spitting Cobra, *Naja nigricollis*.

4.6.5: Species Diversity of Animals in Arable Farmland of Ondo State Bitumen Belt

The phylogenetic diversity of animals in Arable farmland is presented in fig 4.19. The result shows that, 6 orders of animals are associated with this habitat. Rodentia was found to have the highest number of species, eigth, with 23 numbers of individual animals. Carnivora also shows high diversity (4 Species, 8 individuals), Mollusca, (three species, 61 individuals). While the least diversity value was recorded for Insectivora as it has one species and two individuals.

4.6.6: Percentage Composition of Animals in Arable Farmland of Ondo State Bitumen Belt

Percentage Composition of animal order in Arable farmland is presented in fig 4.20. The result shows that percentage composition was highest in Mollusca (58.0%). This is followed respectively by Rodentia (22.0%), Carnivora (7.0%), Artiodactyla (6.0%), and squamata (5.0%), while Insectivora has the least percentage composition of 2.0%.

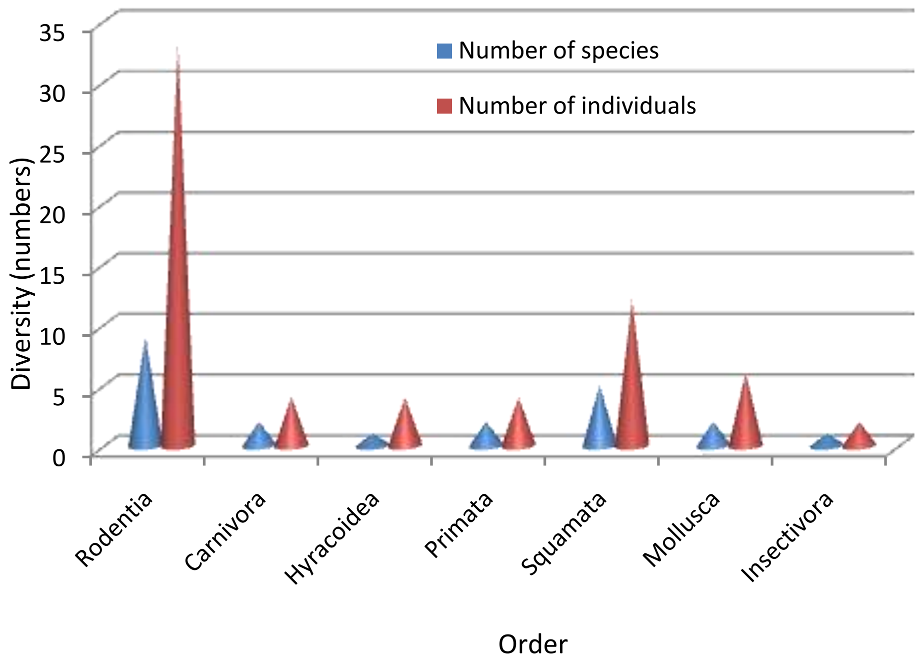

Fig 4.13: Species Diversity of Animals in Fallow Land of Ondo State Bitumen Belt

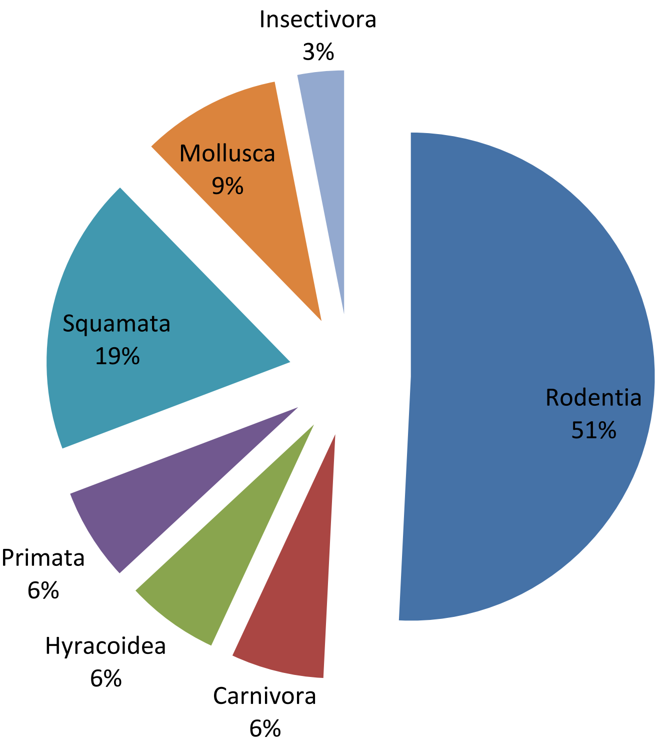

Fig 4.14: Percentage Composition of Animals in Fallow Land of Ondo State Bitumen Belt

Table 4.40: Species Composition of Animals in Arable Farmland of Ondo State Bitumen Belt

S/No	Animal	*Scientific Name*	Order	Dry	Rain	Total	H^1	D
1	Ground squirrel	*Xerups erythropus*	Rodentia	1	1	2	0.095	0.00019
2	Brush tail porcupine	*Artheriurus africanus*	Rodentia	1	1	2	0.095	0.00019
3	Cane rat	*Thryonomys swinderianus*	Rodentia	1	1	2	0.095	0.00019
4	Stripped grass mouse	*Lemniscomus barbarus*	Rodentia	1	1	2	0.095	0.00019
5	Black rat	*Rattus rattus*	Rodentia	1	1	2	0.095	0.00019
6	Rusty bellied rat	*Lophuromys sikapusi*	Rodentia	1	1	2	0.095	0.00019
7	Giant rat	*Cricetomys gambianus*	Rodentia	2	2	4	0.162	0.00112
8	Climbing mouse	*Dendromys mystacalis*	Rodentia	4	3	7	0.245	0.00392
9	African wild cat	*Felis libyca*	Carnivora	1	1	2	0.095	0.00019
10	Cusimanse mongoose	*Crossarchus obscurus*	Carnivora	1	1	2	0.095	0.00019
11	African Civet	*Civettictis civetta*	Carnivora	1	1	2	0.095	0.00019
12	Forest genet	*Geneta poensis*	Carnivora	1	1	2	0.095	0.00019
13	Bush buck	*Tragelaphus niger*	Artiodactyla	2	2	4	0.162	0.00112
14	Black dulker	*Cephalophus niger*	Artiodactyla	1	1	2	0.095	0.00019

15	Long tailed musk shrew	*Crocidura dolichura*	Insectivora	1	1	2	0.095	0.00019
16	Black mamba	*Dendroaspis polylepis*	Squamata	1	1	2	0.095	0.00019
17	Spitting cobra	*Naja nigricollis*	Squamata	1		1	0	0.00000
18	Royal python	*Python regius*	Squamata	1	1	2	0.095	0.00019
19	Giant land snail	*Achachatina marginata*	Mollusca	2	3	5	0.191	0.00187
20	Medium land snail	*Achatina achatina*	,,	4	7	11	0.336	0.01027
21	Small land snail	*Achatina sp*	,,	8	37	45	0.683	0.18484

4.6.7: Species Composition of Animals in Riparian Habitat of Ondo State Bitumen Belt

Table 4.41 shows the species composition of animals in Riparian habitat. It is revealed in the result that 24 species were censused. Among these species, composition is highest for small land snail, *Achachartina sp* and white – throated guenon, *Cercopithecus erythrogaster* (H1=0.379, D=0.01500). This is followed repectively by Dwarf guenon, *Corcopithecus talapoin* (H^1 = 0.363, D=0.01312), white – nosed guenon, *Cercopithecus petaurista* (H^1=0.330, D=0.00975). Other animals with high species composition include Baboon, *Papio Anubis* (H^1 = 0.235, D=0.00350), Two species of Python were, however, found to have the least percentage composition in the habitat, (H^1=0.000, D=0.000 each).

4.6.8: Species Diversity of Animals in Riparian Habitat of Ondo State Bitumen Belt

Species diversity of animals in Riparian habitat is presented in fig 4.21. The result reveals that, among the eight orders found in this habitat, Artiodactyla has the highest diversity (7 species, 17 individuals). This is followed by Primata (6 species, 62 individuals), and Mollusca (three species, 25 individuals). Rodentia, Testudina, and squamata have two species each, but with respective number of individuals of 11, six and two. Crocodila, however, have one specie with two individuals.

4.6.9: Percentage Composition of Animals in Riparian Habitat of Ondo State Bitumen Belt

Percentage composition of animals in Riparian habitat is presented in fig 4.22. The result shows, that, Primata has the highest composition (49.0%), followed by Mollusca, 20.0%, Artiodactyla, (13.0%), Rodentia, 9.0%, Testudina has 5.0% composition, while Hyracoidea, Squamata and Crocodila have the same composition of (1.0% each) in this habitat.

4.6.10: Species Composition of Animals in Islands of High Forest of Ondo State Bitumen Belt

Table 4.42 shows the species composition of animals in Islands of High Forest. The result shows, that, Giant land snail, *Achachatina marginata* is the most abundant (H^1 = 0.669, D=). Other animals with high composition include Porcupine, *Artheriurus africanus* (H^1 = 0.274, D=0.00513), Giant forest squirrel, *Potoxerus strangeri*, Black

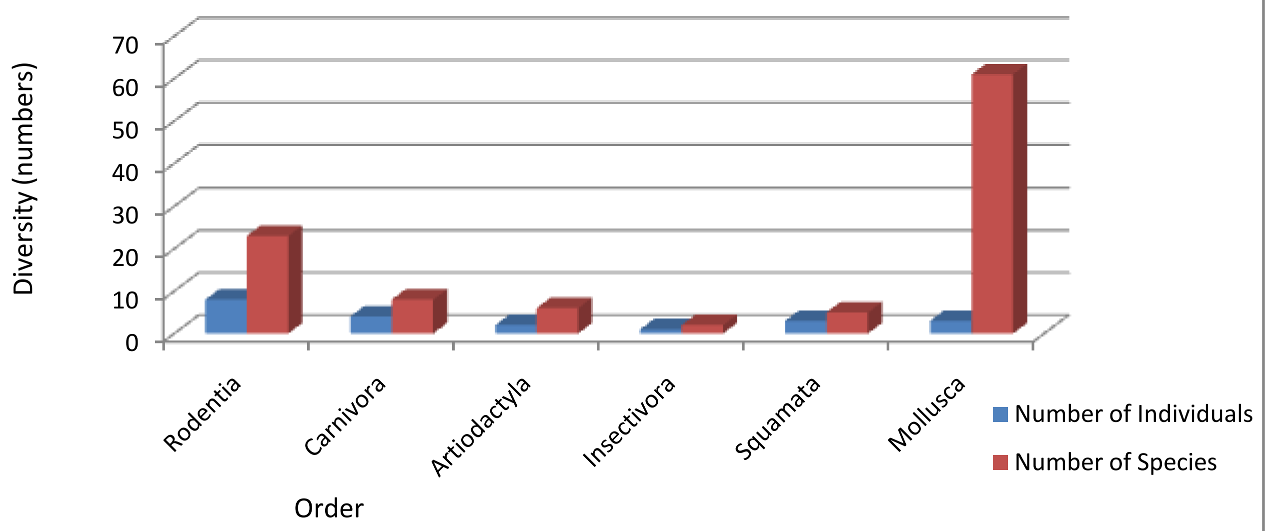

Fig 4.15: Species Diversity of Animals in Arable Farmland of Ondo State Bitumen Belt

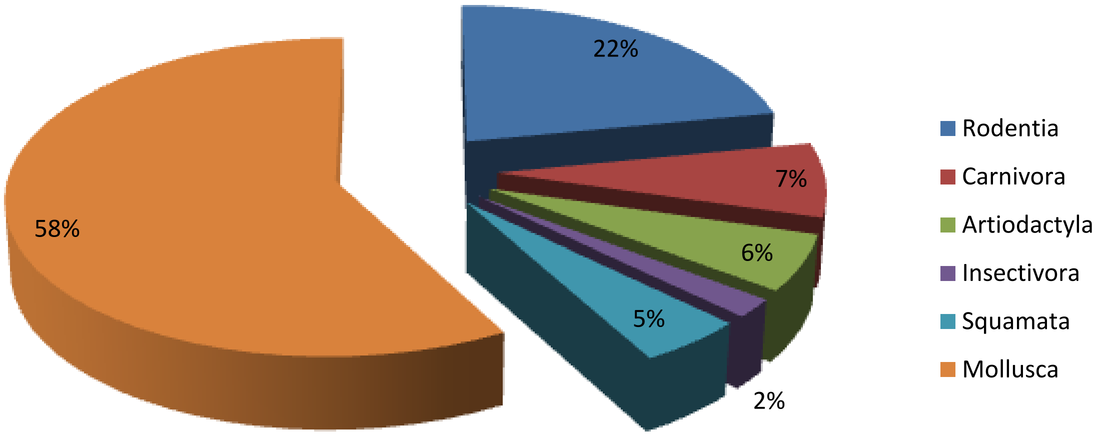

Fig 4.16: Percentage Composition of Animals in Arable Farmland of Ondo State Bitumen Belt

Table 4.41: Species Composition of Animals in Riparian Habitat of Ondo State Bitumen Belt

S/No	Animal	*Scientifiic Name*	Order	Dry	Wet	Total	H^1	D
1	Giant forest squirrel	*Potoxerus stranger*	Rodentia	3	4	7	0.213	0.00262
2	Orange-headed squirrel	*Funiusciurus anchrythrus*	,,	2	2	4	0.140	0.00075
3	Tree hyrax	*Dendrohyrax dorsalis*	Hyracoidea	2		2	0.081	0.00012
4	Red river hog	*Potamochoerus aethiopicus*	Artiodactyla	1	3	4	0.140	0.00075
5	Bush buck	*Tragelaphus niger*	Artiodactyla	1	1	2	0.081	0.00012
6	Maxwell duiker	*Cephalophus maxwelli*	Artiodactyla	1	2	3	0.024	0.00037
7	Black duiker	*Cephalophus niger*	Artiodactyla	1	1	2	0.081	0.00012
8	Buffalo	*Syncerus cafer*	Artiodactyla	1	1	2	0.081	0.00012
9	Red - flanked duiker	*Cephalophus rufilatus*	Artiodactyla	1	1	2	0.081	0.00012
10	Water buck	*Kobus ellipsiprymmus*	Artiodactyla	1	1	2	0.081	0.00012
11	White-throated guenon	*Cercopithecus erythrogaster*	Primata	9	7	16	0.379	0.01500
12	Swamp monkey	*C. nigroviridis*	Primata	4	3	7	0.213	0.00262
13	White-nosed guenon	*C. petaurista*	Primata	5	8	13	0.330	0.00975

14	Dwarf guenon	*C. talapoin*	Primata	8	7	15	0.363	0.01312
15	Baboon	*Papio Anubis*	Primata	3	5	8	0.235	0.00350
16	Potto	*Perididictus potto*	Primata	2	1	3	0.024	0.00037
16	African Python	*Python sebae*	Squamata	1		1	0.000	0.00000
17	Python	*Python sp.*	Squamata		1	1	0.000	0.00000
18	Aligator	*Alligator Sp.*	Crocodila	1	1	2	0.081	0.00012
19	Tortoise	*Testudo sp.*	Testudina	2	2	4	0.140	0.00075
20	Turtle	*Kinostermon subrurum*	Testudina	2		2	0.081	0.00012
22	Giant land Snail	*Achachatina marginata*	Mollusca	3	3	6	0.190	0.00187
23	Medium land snail	*Achatina achatina*	,,	3		3	0.024	0.00037
24	Small land snail	*Achatina sp*	,,	6	10	16	0.379	0.01500

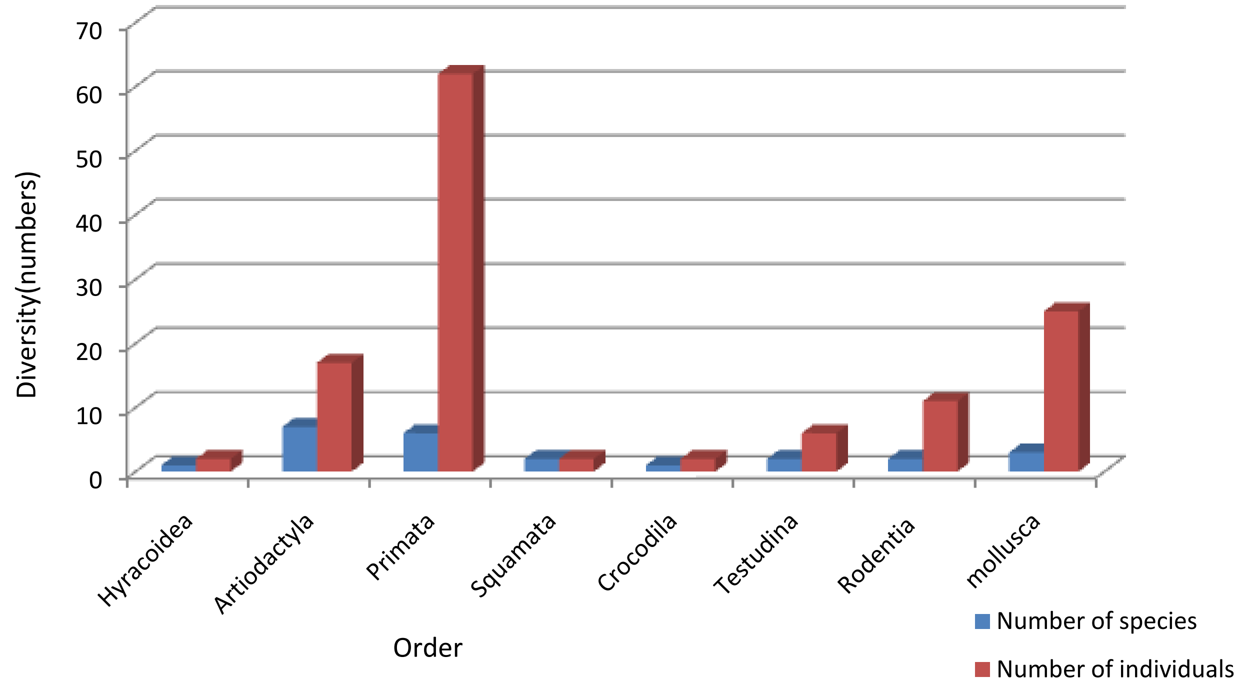

Fig 4.17: Species Diversity of Animals in Riparian Habitat of Ondo State Bitumen Belt

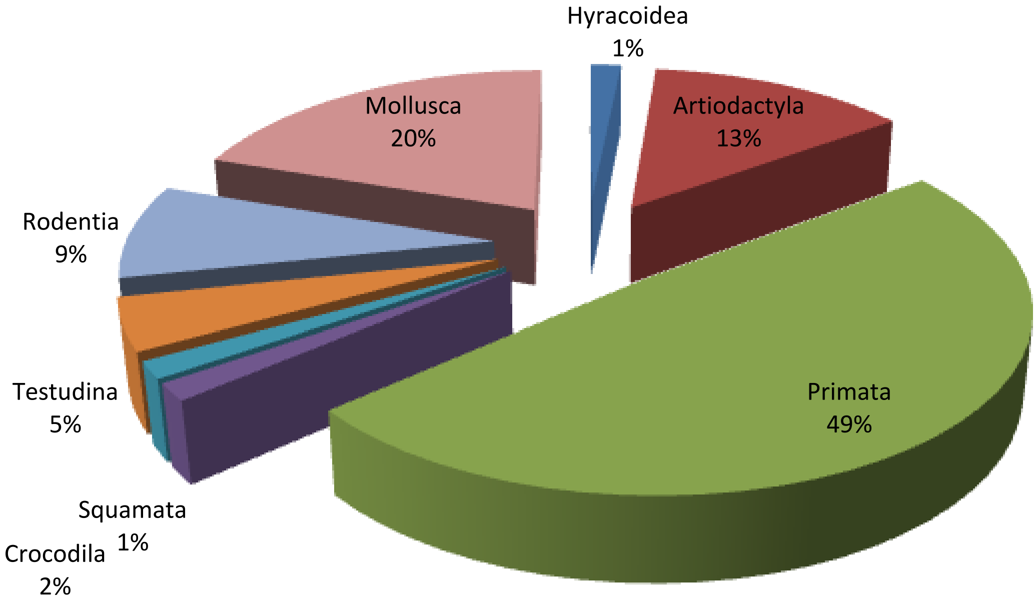

Fig 4.18: Percentage Composition of Animals in Riparian Habitat of Ondo State Bitumen Belt

Table 4.42: Species Composition of Animals in Islands of High Forest of Ondo State Bitumen Belt

S/No	Animal	Scientific Name	Family	Dry	Rain	Total	H[1]	D
1	Tree Hyrax	*Dendrohyrax dorsalis*	Hyracoidea	1	2	3	0.165	0.00103
2	Porcupine	*Artheriurus africanus*	Rodentia	3	3	6	0.274	0.00513
3	Flying squirrel	*Anomalorus beecroftii*	"	1	1	2	0.121	0.00034
4	Giant forest squirrel	*Potoxerus stranger*	"	2	2	4	0.204	0.00205
5	Orange headed squirrel	*Funiuscriurus anchrythrus*	"	1	2	3	0.165	0.00103
6	Giant rat	*Cricetomys gambianus*	"	1	1	2	0.121	0.00034
7	Tree pangolin	*Manis tricuspis*	Pholidota	1	1	2	0.121	0.00034
8	Wild pig	*Potamochoerus aethiopicus*	Artiodactyla	1	2	3	0.165	0.00103
9	Bush buck	*Tragelaphus niger*	"	1	1	2	0.121	0.00034
10	Maxwell duiker	*Cephalophus maxwelli*	"	1	2	3	0.165	0.00103
11	Black duiker	*Cephalophus niger*	"	2	2	4	0.204	0.00205
12	African Python	*Python sebae*	Squamata	1	1	2	0.121	0.00034
13	Royal python	*Python regius*	"	1	2	3	0.165	0.00103
14	African Tree Viper	*Atheris squamigera*	Viperidae	1	3	4	0.204	0.00205
15	Tortoise	*Testudo sp.*	Testudina	1	3	4	0.204	0.00205
16	Giant land snail	*Achachatina marginata*	Mollusca	10	20	30	0.669	0.14867

duiker, *Cephalophus niger*, African Tree Viper, *Atheris squamigera* and Tortoise, *Testudo sp.*, (H^1 = 0.204, D=0.00205 each). Among animals with the least species composition are Flying squirrel, *Anomalurus beecrofti*, Giant rat, *Cricetomys gambianus*, Tree pangolin, *Manis triscupis*, Bush buck, *Tragilaphus niger* and, Royal python, *Python regius* (H^1 = 0.165, D=0.00034 each).

4.6.11: Species Diversity of Animals in Islands of High Forest of Ondo State Bitumen Belt

Fig 4.23 shows the species diversity of animals found in Islands of High Forest. The result shows that eight orders were found in the habitat. Among these orders, Rodentia has the highest number of species. It has five different species with 17 individuals, while Artiodactyla has four species with 12 individuals, and Squamata has two species with five individuals. However, Mollusca are represented with one species and 30 individuals. Viperidae and Testudina have one species and four individuals each, while Hyracoidea has one species and three individuals. The order with the least species diversity however, is Pholidota.

4.6.12: Percentage Composition of Animals in Islands of High Forest of Ondo State Bitumen Belt

The result in fig 4.24 shows that Mollusca are the order of animals mostly encountered in Islands of high forest with a percentage composition of 39.0%. This is followed by Rodentia, 22.0%, and then Artiodactyla, 16.0%. Squamata has a percentage composition of 6.%, while crocodila and testudina have 5.2% each, and Hyracoidea is composed of 4.0%. Pholidota, however, has the least percentage composition in this habitat, 3.0%.

4.6.13: Species Composition of Animals in Cashcrop Farmland of Ondo State Bitumen Belt

The species composition of animals in Cashcrop Farmland is shown in table 4.43. The result reveals that, black rat, *Rattus rattus* and small land snail, *Achatina sp* has the highest species diversity (H^1=0.357, D= 0.01203each). This is followed by respecticely by giant land snail, *Achachatina marginata* (H1=0.307, D=0.00748) and giant forest squirrel, *Potoxerus strangeri*, (H^1=0.280, D=0.00561). Other animals with high diversity include giant rat, *Cricetomys gambianus*, and dwarf guenon, *Cercopithecus talapoin* (H^1=0.251, D=0.00401 each), orange-headed tree squirrel, *Funiusciurus anchrythrus*, African Civet, *Civettictis civetta* and black duiker, *Cephalophus niger* (H^1=0.220, D=0.00267 each), and cane rat, *Thryonomys swinderianus* (H^1=0.187, D=0.00160). While the trio of stripped grass mouse, *Lemniscomys barbarus*, viper, *Bitis gabonica* and royal python, *Python regius* have the least diversity (H^1=0.000, D=0.000).

4.6.14: Species Diversity of Animals in Cashcrop Farmland of Ondo State Bitumen Belt

Species diversity of animals in Cashcrop Farmland is presented in fig 4.25. The result reveals that, Rodentia has the highest number of species and individuals (eight species and 38 individuals). This is followed by Squamata (4 species and eight individuals), and Mollusca (three species and 22 individuals). Artiodactyla is represented in this habitat by two species and seven individuals, while Carnivora has one species and five individuals. Viperidae has the least number of species and individual.

4.6.15: Percentage Composition of Animals in Cashcrop Farmland of Ondo State Bitumen Belt

The percentage composition of animals in Cashcrop Farmland is presented in fig 4.26. The result reveals that Rodentia has the highest percentage composition, 44.0%. This is followed respectively by Mollusca, 25.0%, Squamata, 9.0%, Artiodactyla, 8.0%, and Primata, 7.0% and Carnivora, 6.0%. The least percentage composition was however recorded for Viperidae, 1.0%.

4.6.16: Species Composition of Animals in Urban Arboreta of Ondo State Bitumen Belt

Species composition of animals in Urban Arboreta is presented in table 4.44. The result shows that medium land snail, *Achatina achatina* is the most abundant in this habitat, (H^1=0.570, D=0.61620). This is respectively followed by small land snail, *Achatina sp* (H^1=0.482, D=0.03279), Giant Rat, *Cricetomys gambianus*, (H^1=0.461, D=0.02811), ground Squirrel, *Xerops erythropus*, (H^1=0.340, D=0.01009), Black Rat, *Rattus rattus* and Cane Rat, *Thryonomys swinderianus* also have a high diversity (H^1=0.279, D=0.00541 each). The least species composition was, however, recorded for Stipped grass Mouse, *Lemniscomys barbarus*, Black Mamba, *Dendroaspis polylepis*., Cobra, *Naja nigricollis*,Viper, *Bitis gabonica*, Dwarf Galago, *Galagoides demidovii* (H^1=0.000, D=0.000).

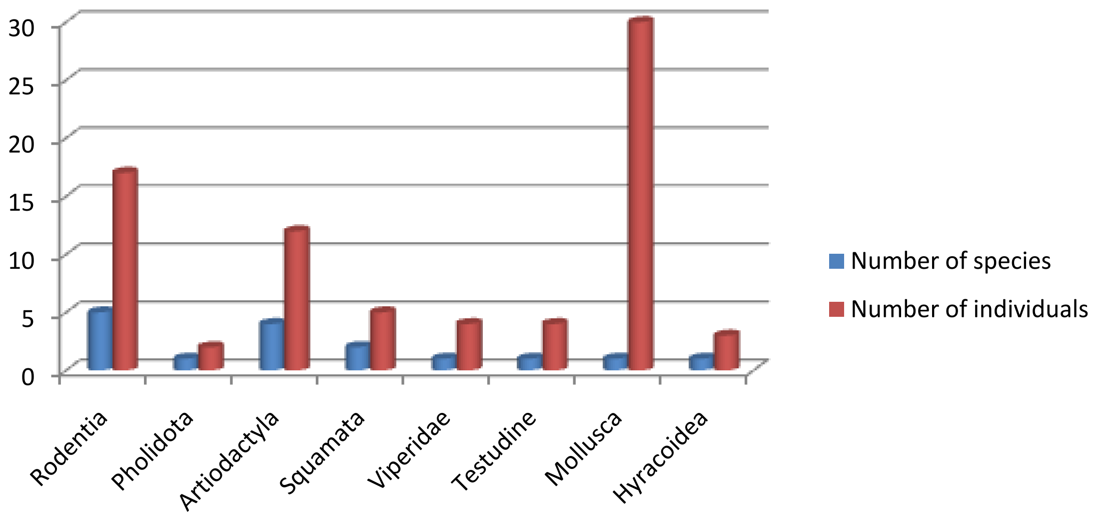

Fig 4. 19. Species Diversity of Animals in Islands of High Forest

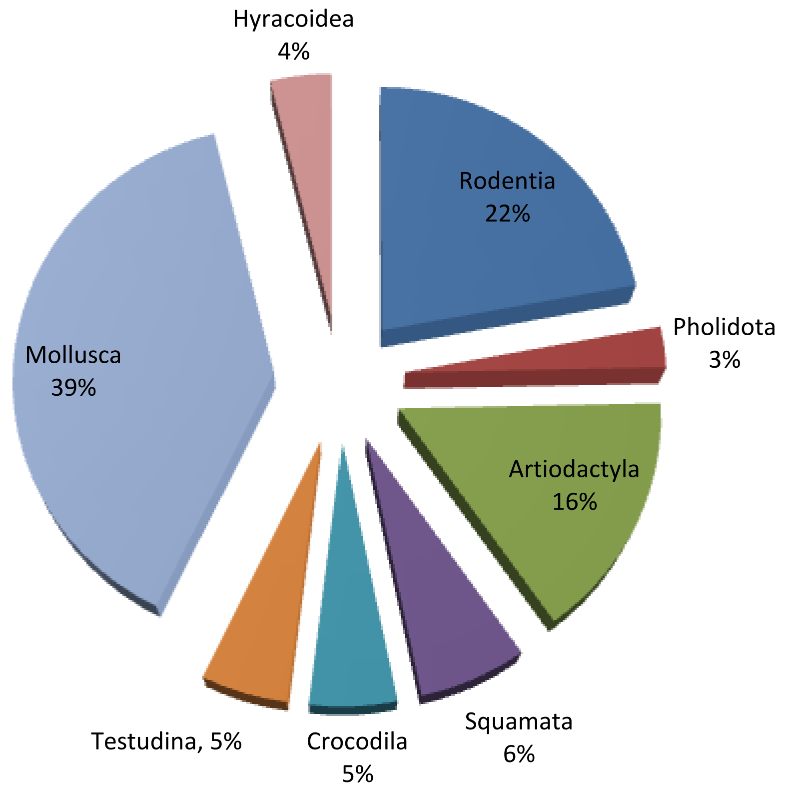

Fig 4.20: Percentage Composition of Animals in Islands of High Forest of Ondo State Bitumen Belt

Table 4.43: Species Composition of Animals in Cashcrop Farmland of Ondo State Bitumen Belt

S/no	Common Name	*Scientific Name*	Order	Dry	Wet	Total	H^1	D
1	Porcupine	*Artheriurus africanus*	Rodentia	2	1	3	0.150	0.00080
2	Stripped grass mouse	*Lemniscomys barbarus*	,,		1	1	0	0.00000
3	Black rat	*Rattus rattus*	,,	4	6	10	0.357	0.01203
4	Giant forest Squirrel	*Potoxerus strangeri*	,,	5	2	7	0.280	0.00561
5	Orange-headed tree Squirrel	*Funiusciurus anchrythrus*	,,	3	2	5	0.220	0.00267
6	Giant Rat	*Cricetomis gambianus*	,,	2	4	6	0.251	0.00401
7	Cane Rat	*Thryonomys swinderianus*	,,	3	1	4	0.187	0.00160
8	Climbing Mouse	*Dendromys mystacalis*	,,		2	2	0.110	0.00027
9	African Civet	*Civettictis civetta*	Carnivora	2	3	5	0.220	0.00267
10	Black Duiker	*Cephalophus niger*	Artiodactila	1	4	5	0.220	0.00267
11	Eland	*Taurotragus sp.*	,,	2		2	0.110	0.00027
12	Dwarf Guenon	*Cercopithecus talapoin*	Primata		6	6	0.251	0.00401
13	Gaboon Viper	*Bitis gabonica*	Viperadae		1	1	0	0.00000
14	Royal	*Python regius*	Squamata		1	1	0	0.00000

	Python							
15	African Python	*Python sebae*	,,	2		2	0.110	0.00027
16	Cobra	*Naja nigricollis*	,,		3	3	0.150	0.00080
17	Black Mamba	*Dendroaspis polylepis*	,,	1	1	2	0.110	0.00027
18	Giant land Snail	*Achachatina marginata*	Mollusca	4	4	8	0.307	0.00748
19	Medium land snail	*Achatina achatina*	,,	1	3	4	0.187	0.00160
20	Small land snail	*Achatina sp*	,,	3	7	10	0.357	0.01203

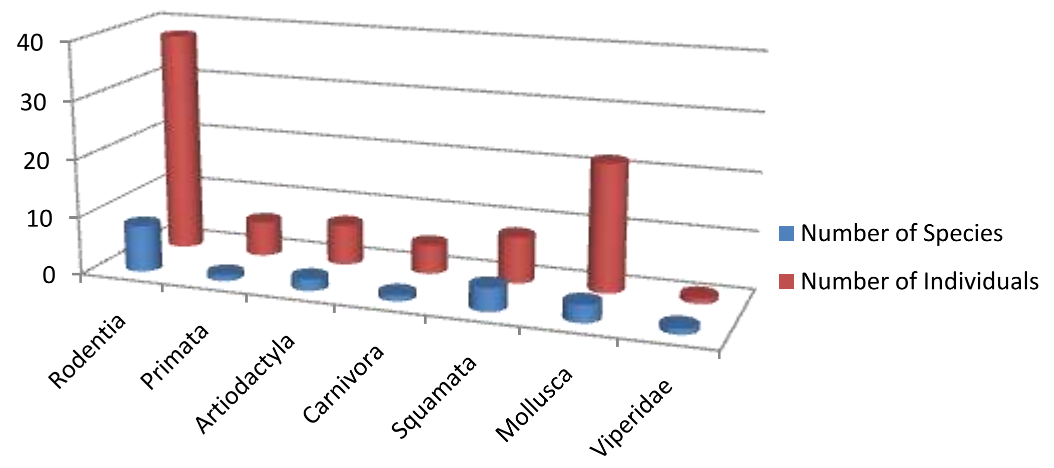

Fig 4.21: Species Diversity of Animals in Cashcrop Farmland of Ondo State Bitumen Belt

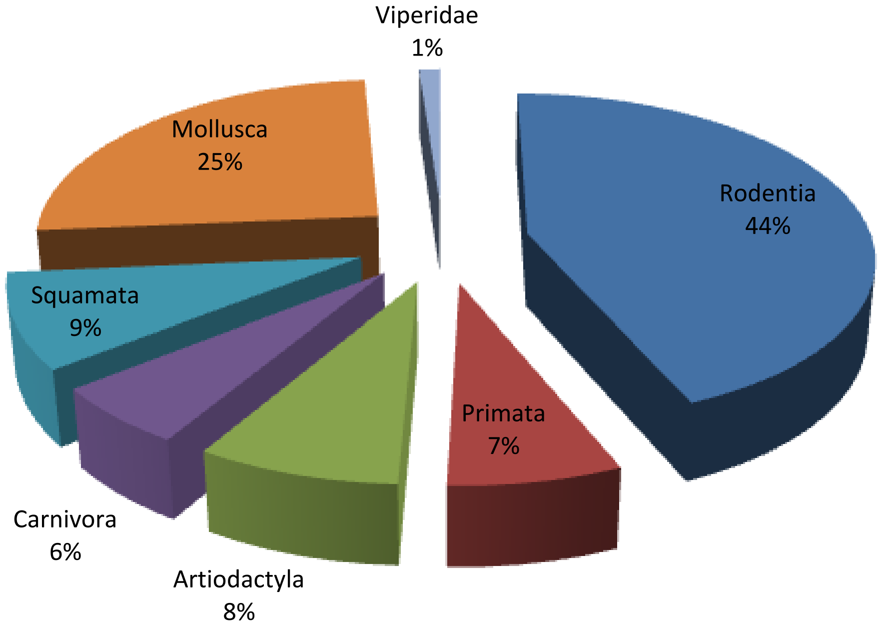

Fig 4.22: Species Diversity of Animals in Cashcrop Farmland of Ondo State Bitumen Belt

Table 4.44: Species Composition of Animals in Urban Arboreta of Ondo State Bitumen Belt

S/No	Common Name	*Scientific Name*	Family	Dry	Wet	Total	H^1	D
1	Giant Rat	*Cricetomis gambianus*	Rodentia	4	9	13	0.461	0.02811
2	Ground Squirrel	*Xerops erythropus*	,,	5	3	8	0.340	0.01009
3	Black Rat	*Rattus rattus*	,,	4	2	6	0.279	0.00541
4	Stripped grass Mouse	*Lemniscomys barbarous*	,,		1	1	0	0.00000
5	Cane Rat	*Thryonomys swinderianus*	,,	2	4	6	0.279	0.00541
6	Black Mamba	*Dendroaspis polylepis*	Squamata		1	1	0	0.00000
7	Cobra	*Naja nigricollis*	,,	1		1	0	0.00000
8	GaboonViper	*Bitis gabonica*	Viperidae		1	1	0	0.00000
9	Giant land snail	*Achachatina marginata*	Mollusca	1	3	4	0.413	0.00216
10	Medium land snail	*Achatina achatina*	,,	8	11	19	0.570	0.06162
11	Small land snail	*Achatina sp*	,,	6	8	14	0.482	0.03279
12	Dwarf Galago	*Galagoides demidovii*	Primata	1		1	0	0.00000

4.6.17: Species Diversity of Animals in Urban Arboreta of Ondo State Bitumen Belt

Species diversity of animals in Urban Arboreta is presented in fig 4.27. The result reveals that Rodentia has the highest diversity with five species and 34 individuals, followed respectively by Squamata, two species and two individuals, Mollusca, three species and 37 individuals, while Primata and Viperidae have one species each and one individual.

4.6.18: Percentage Composition of Animals in Urban Arboreta of Ondo State Bitumen Belt

Percentage composition of animals in urban Arboreta is given in fig 4.28. The result shows that Mollusca, has the highest composition of 35.0%, followed respectively by Rodentia 42.0% , and Squamata, 31.0%, while the least composition of 1.0% each was recorded for Primata and Viperidae.

4.7: Distribution of Native and Non-Native Bird Species of Ondo State Bitumen Belt

The number and distribution of native bird species in table 4.45 shows that 78 bird species (some in plates 4.5- 4.10) are native to the bitumen belt. Out of this, 57 are distributed over Fallow Land, 54 over High forest, 52 over Arable Farmland, 49 over Urban Arboreta, 48 over Riparian Habitat and 26 over Cashcrop Farmland.

Number and distribution of non-native bird species in table 4.45 shows that seven non-native bird species (on in plate 4.11) are associated with the bitumen belt. Out of this, seven species are distributed over Urban Arboreta, five over Arable Farmland, three over Fallow Land, and one each over High Forest, Riparian Habitat and Cashcrop Farmland.

4.8: Distribution of Native Animal Species of Ondo State Bitumen Belt

45 animal species (some in plates 4.12 – 4.24) belonging to 11 families are native to the bitumen belt (table 4.46). Out of these, 20 species are found in FL, 20 in AF, 24 in RH, 19 in HF, 20 in CF, and 12 in UA.

4.9: Animals and Birds of Special Concern in Ondo State Bitumen Belt

Five birds and ten animals are rare, threatened or endangered in their range in the bitumen belt (tables 4.47).

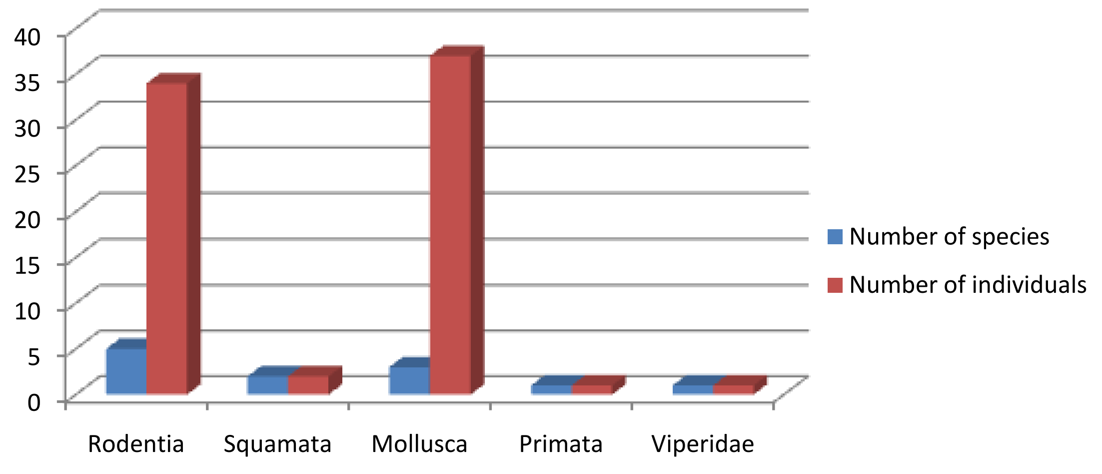

Fig 4.23: Species Diversity of Animals in Urban Arboreta of Ondo State Bitumen Belt

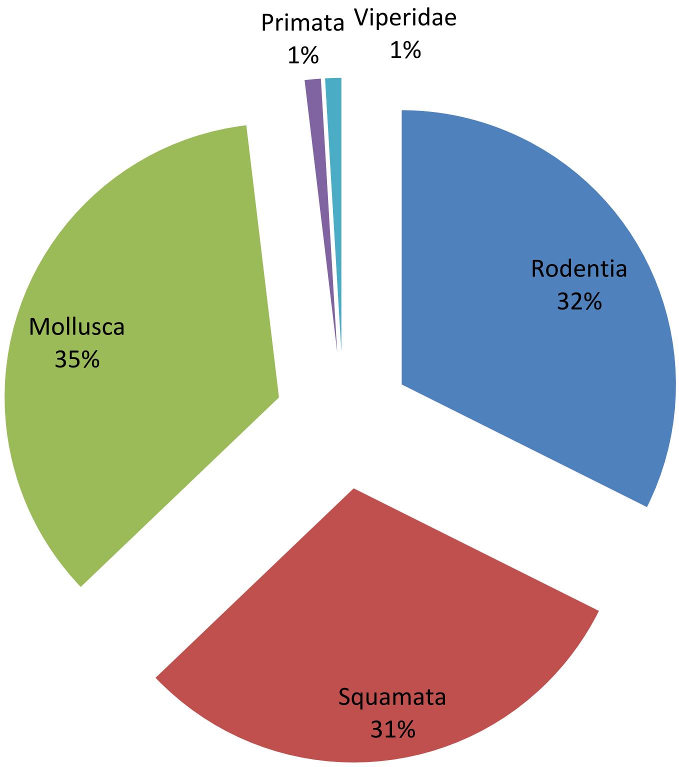

Fig 4.24: Percentage Composition of Animals in Urban Arboreta of Ondo State bitumen belt

Table 4.45: Native and Non Native Bird Species of Ondo State Bitumen Belt

S/No	Local Name	Scientific Name	Family	Habitat where Found
		Native		
		Native Species		
1	Black Kite	*Milvus migrans*	Accipitridae	FL,HF,AF,RH,CF,UA
2	Black-shouldered Kite	*Elaneus caerulens*	,,	FL,HF
3	Afrcan Hawk Eagle	*Hieraaetus Spilogaster*	,,	FL,HF,AF,RH,CF,UA
4	Ayres Hawk Eagle	*Hieraaetus dubius*	,,	FL,HF,CF,UA
5	Casins Hawk Eagle	*Spizaetus africanus*	,,	FL,HF,RH,CF
6	Lizard Buzzard	*Kaupifalco monogrammicus*	,,	FL,HF,AF,RH,CF,UA
7	Harrier Hawk	*Polybroides typus*	,,	HF
8	African long-tail Hawk	*Urotriochis macrourus*	,,	HF,RH
9	African Monkey Eagle	*Stephanoetus coronatus*	,,	RH
10	Shikra	*Accipiter badius*	,,	HF,AF,CF,UA
11	Red-Eyed Turtle Dove	*Streptopelia Semitorquata*	Columbidae	FL,HF,AF,RH,UA
12	Laughing Dove	*Stigmatopelia Senegalensis*	,,	FL,AF,RH,UA
13	Red-billed Wood Dove	*Tutur afer*	,,	FL,HF,AF,RH,UA
14	Green Fruit Pigeon	*Treron australis*	,,	FL,HF,AF,RH
15	Grey Plantain Eater	*Crinifer piscator*	Musophagidae	FL,HF,AF,CF,UA
16	Grey Parrot	*Psittacus erithracus*	Picidae	HF,RH
17	Yellow-bellied	*Poicephalus*	,,	HF,AF

	Parrot	*senegalus*		
18	Levailant Cuckoo	*Climator levaillanti*	Cuculidae	FL,HF,AF,RH,UA,CF
19	Didrick Cuckoo	*Lampromorpha caprius*	,,	FL,HF,AF,RH,CF
20	Senegal Coucal	*Centropus sennegalensis*	,,	FL,HF,RH,UA
21	Long-tailed Night Jar	*Scotornis climacurus*	Caprimulgidae	RH
22	Akin Eagle owl	*Bubo leucostictus*	Strigidae	FL,HF,RH
23	Pel's fishing Owl	*Scotopelia peli*	,,	HF,AF
24	Little African Swift	*Colletoptera affinis*	Micropodidae	UA
25	Palm Swift	*Cypsiurus parvus*	,,	FL,HF,AF,RH,CF,UA
26	Broad-billed Roller	*Eurystomus afer*	Coracidae	FL,HF,AF,RH
27	Green wood hoopoe	*Phoeniculus erythrorhyncus*	Phoeniculidae	FL,HF,AF,RH,CF
28	African pied Hornbill	*Tockus fasciatus*	Bucerotidae	FL,HF,AF,RH
29	Pigmy Kingfisher	*Ispidina picta*	Alcedinidae	FL,HF,AF,RH,UA
30	Stripped Kingfisher	*Halcyon Chelicuti*	,,	FL,HF,AF,UA
31	Senegal Kingfisher	*Halcyon senegalensis*	,,	FL,HF,AF,RH.UA
32	Blue-breasted Kingfisher	*Halcyon malimbicus*	,,	FL,HF,AF,RH.UA
33	Tooth-billed Barbet	*Pogonornis bidentatus*	Capitonidae	FL,HF,AF,RH,CF,UA
34	Yellow-fronted Tinker Bird	*Pogoniulus chrysoconus*	,,	UA,HF,RH,CF

35	Grey Wood-pecker	*Dendropicos goertae*	Picidae	FL,HF,RH
36	Gabon Woodpecker	*Dendropicos gabonensis*	,,	FL
37	Cardinal woodpecker	*Dendropicos fuscecens*	,,	FL,CF
38	Fire-bellied Woodpecker	*Dendropicos pyrrhogaster*	,,	FL,HF,AF,CF
39	African Pied Wagtail	*Motacilla aguimp*	Motacilidae	AF,UA
40	Plain-backed Pipit	*Anthus leucophrys*	,,	AF,CF,UA
41	Yellow-throated long-claw	*Macronxy Croceus*	,,	AF,CF,UA
42	Brown Barbler		Timalidae	FL,RH
43	Common Bulbul	*Pycnonotus barbartus*	Pycnonotidae	FL,HF,AF,RH,CF,UA
44	Palm Bulbul		,,	HF,RH
45	Yellow-throated leaf-love	*Pyrrhurus flavicollis*	,,	FL,HF
46	Spectacled Flycatcher	*Platysteiira cyanea*	Muscicapidae	FL,HF,RH
47	G.B.P. Flycatcher	*Tchitrea smithii*	,,	FL,HF,AF,RH,UA
48	Kurrichane Thrush	*Turdus libonyanus*	Turdidae	AF,CF,UA
49	Snowy-headed Robin Chat	*Cossypha niveicapilla*	,,	FL,RH,UA
50	White-bellied Crombec	*Sylvietha flaviventris*	Sylviidae	FL,AF,UA
51	Grey-backed Camaropera	*Camaroptera brevicaudata*	,,	FL,HF,AF,RH,CF,UA
52	Rufuos-faced	*Cisticola erythrops*	,,	AF,CF,UA

	Grass Warbler			
53	Rufuos-chested Swallow	*Hirundo semirufa*	Hirundidae	UA
54	Velvet-mantled Drongo	*Dicrurus adsimilis*	Dicruridae	FL,HF,AF,UA
55	Fiscal Shrike	*Lanius collaris*	Prionopidae	FL,UA
56	Puff-backed Shrike	*Dryoscopus gambensis*	,,	FL,HF,RH
57	Gonolek	*Laniarus barbatus*	,,	FL,AF,
58	Bush Shrike	*Tchagra senegala*	,,	FL,AF,CF,UA
59	Oriole	*Oriolus nigripennis*	Oriolidae	FL,HF,RH
60	Pied Crow	*Corvus albus*	Corvidae	FL,HF,AF,RH,UA
61	Violet-backed Starling	*Cinnyricinclus leucogaster*	Sturnidae	FL,AF,RH,UA
62	Purple-glossy Starling	*Lamprocolius purpureus*	,,	FL,AF,RH,UA
63	Chestnut-winged Starling	*Onychognathus Fulgidus*	,,	FL,HF,CF,UA
64	Bell Shrike	*Laniarus ferrigineus*	Prionopidae	FL,HF,AF,RH,CF,UA
65	Yellow white-eye	*Zosterops senegalensis*	Zosteropidae	FL,HF,RH
66	Splendid Sunbird	*Cynnyris coccinigaster*	Nectarinidae	FL,HF,AF,RH,UA
67	Olive-bellied Sunbird	*Cynnyris chloropygius*	,,	FL,HF,AF,RH,CF,UA
68	Green-headed Sunbird	*Cyanomitra verticallis*	,,	FL,HF,AF,RH,UA
69	Collard Sunbird	*Arthreptes collaris*	,,	FL,HF,AF,UA
70	Grey-headed Sparrow	*Passer grisseus*	Fringilidae	FL,HF,AF,RH,UA
71	Chestnut and black Weaver	*Cinnamomopteryx castaneofuscus*	Sturnidae	FL,HF.AF,RH,CF,UA
72	Village Weaver	*Plasiositagra*	Ploceidae	FL,HF,AF,

		cucullatus		
73	Spectacled Weaver	*Hyphanturgus brachypterus*	,,	FL,AF,RH,UA
74	Red-headed Malimbe	*Malimbus rubricollis*	,,	FL,HF,AF,RH,CF
75	Red-headed Dioch	*Quelea erythrops*	,,	AF,UA
76	Bronze Manikin	*Spermestes cucullatus*	,,	AF,CF,UA
77	Grey-crowned Negro Finch	*Nigrita canicapilla*	,,	FL,HF,AF,RH,UA
78	Pin-tailed Whydah	*Vidua macroura*	,,	AF,UA
		Non-Native		
1	Cattle Egret	*Bubulcus ibis*	Ardeidae	UA
2	White-throated Bee-eater	*Aerops albicollis*	Meropidae	FL,HF,AF,RH,CF,UA
3	Yellow wagtail	*Budytes flavus*	Motacilidae	AF,UA
4	Spotted Flycatcher	*Muscicapa striata*	Muscicapidae	FL,AF,UA
5	European Wheatear	*Oenanthe oenanthe*	Turdidae	AF,UA
6	Willow warbler	*Phylloscopus trochilus*	Sylviidae	FL,AF,UA
7	European Swallow	*Hirundo rustica*	Hirundidae	UA

Plate 4.5: Red-Headed Malimbe, *Malimbus rubricollis* Found in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.6: Grey Parrot, *Psittacus erithracus* Found in Ondo State Bitumen Belt

Conservation Status- Threatened

Plate 4.7. White-Throated Bee-Eater, *Aerops albicolis* Found in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.8: African Pied Hornbill, *Tockus fasciatus* Found in Ondo State Bitumen Belt

Conservation Status- Threatened

Plate 4.9: Grey-Headed Sparrow, *Passer grisseus* Found in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.10: Pin-tailed Whydah, *Vidua macroura* Found in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.11: European Swallow, *Hirundo rustica* Found in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Table 4.46: Native Animal Species in Ondo State Bitumen Belt

S/No	Common Name	Scientific Name	Order	Habitats where found
1	Ground squirrel	*Xerups erythropus*	Rodentia	AF,UA
2	Porcupine	*Artheriurus africanus*	Rodentia	Fl,AF,HF,CF
3	Cane rat	*Thryonomys swinderianus*	Rodentia	FL,AF,CF,UA
4	Stripped grass mouse	*Lemniscomys barbarus*	,,	AF,CF,UA
5	Rusty bellied rat	*Lophuromys sikapusi*	,,	AF
6	Black rat	*Rattus rattus*	Rodentia	FL,AF,CF,UA
7	Flying squirrel	*Anomalorus beecrofti*	,,	FL,HF
8	G.F. Squirrel	*Potoxerus strangeri*	,,	FL,RH,HF,CF
9	O. H. Squirrel	*Funniusciurus anchrythrus*	,,	FL,RH,HF,CF
10	Emin,s giant rat	*Cricetomys emini*	,,	FL
11	Giant rat	*Cricetomys gambianus*	,,	FL,AF,HF,CF,UA
12	Climbing mouse	*Dendromys mystacalis*	,,	FL,AF,CF
13	Tree pangolin	*Manis tricuspis*	Pholidota	HF
14	Wild cat	*Xerups erythropus*	Carnivora	AF
15	Cusimanse mongoose	*Crossarchus obscures*	,,	FL,AF
16	Civet	*Civettictis civetta*	,,	FL,AF,CF
17	Forest genet	*Geneta poensis*	,,	FL,AF
18	Tree hyrax	*Dendrohyrax dorsalis*	Hyracoidea	RH,HF
19	Wild pig	*Potamochoerus aethiopicus*	Artiodactyla	RH,HF
20	Bush buck	*Tragelaphus niger*	Artiodactyla	AF,RH,HF
21	Maxwel duiker	*Cephalophus maxwelli*	,,	RH,HF
22	Black duiker	*Cephalophus niger*	,,	FL,AF,RH,HF,CF

23	R. F. Duiker	*Cephalophus rufilatus*	,,	RH
24	Water buck	*Kobus ellipsiprymmus*	,,	RH
25	Eland	*Taurotragus sp.*	,,	CF
	Buffalo	*Syncerus cafer*	,,	RH
25	Shrew	*Crocidura dolichura*	Insectivora	FL,AF
26	Dwarf galago	*Galagoides demidovii*	Primata	FL,UA
27	W. T. Guenon	*Cercopithecus erythrogaster*	,,	RH
28	Swamp monkey	*C. nigroviridis*	,,	RH
29	Anubis baboon	*Papio Anubis*	,,	RH
30	Potto	*Perididictus potto*	,,	FL
31	Dwarf guenon	*C. Talapoin*	,,	RH,CF
32	W. N. Guenon	*C. Petaurista*	,,	RH
33	Green mamba	*Dendroaspis viridis*	Squamata	FL
34	Black mamba	*Dendroaspis polylepis*	,,	FL,AF,CF,UA
35	Viper	*Bitis gabonica*	,,	FL,CF,UA
36	Python	*Python sp.*	,,	FL,RH,HF,CF
37	Royal python	*Python regius*	,,	FL,AF,HF,CF
38	African Python	*Python sebae*	,,	RH
39	Cobra	*Naja nigricollis*	,,	AF,CF,UA
40	Alligator	*Alligator Sp.*	Crocodila	RH, HF
41	Tortoise	*Testudo sp.*	Testudina	RH,HF
42	Turtle	*Kinostermon subrurum*	,,	RH
43	Giant land snail	*Achachartina marginata*	Molusca	FL,AF,HF,RH,CF,UA
44	Medium land snail	*Achatina achartina*	,,	AF,RH,CF,UA
45	Small land snail	*Achatina sp*	,,	AF,FL,RH,CF,UA

Plate 4.12: Head of Black Mamba, *Dendroaspis polylepis* Killed in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN2.3)

Plate 4.13: Green Mamba, *Dendroaspis viridis* Killed in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.14: Royal Python, *Python regius* Killed in Ondo State Bitumen Belt

Conservation Status- Not Evaluated (CITES appendix ii)

Plate 4.15: Grass Mouse, *Xerups erythropus* With a Suckling Babe Killed in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.17: Gaboon Viper, *Bitis gabonica* Killed in Ondo State Bitumen Belt

Conservation Status- Vulnerable (IUCN 3.1)

Plate 4.18: Side View of African Civet, *Civettictis civetta* Killed in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.19: Dwarf Galago, *Galagoides demidovii* Found in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.20: Flying Squirrel, *Anomalorus beecrofti* Killed in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.21: Baboon, *Papio Anubis* Found in Ondo State Bitumen Belt Conservation Status- least Concern (IUCN 3.1)

(a)

Plate 4.22: White Throated Guenon, *Cercopithecus erythrogaster* Found in Ondo State Bitumen Belt

Conservation Status- Endangered

Plate 4.22: Maxwell's Duiker, *Cephalophus maxwelli* Killed in Ondo State Bitumen Belt

Conservation Status- least Concern (IUCN 3.1)

Plate 4.23: Giant Land Snail, *Achachartina marginata* in its Natural Habitat Found in Ondo State Bitumen Belt

Conservation Status- Not listed

Plate 4.24: Medium Land Snail, *Achatina achatina* Found in Ondo State Bitumen Belt

Conservation Status- Not listed

Table 4.47: Rare, Threatened and Endangered Species of Birds and Animaks in Ondo State Bitumen Belt

Family	Species	Status	Threat
		Birds	
Strigidae	*Bubo leucostictus*	Rare	Habitat degradation and human interference
Accipitridae	*Spizaetus africanus*	Threatened	Habitat decreasing via tree felling and human interference
,,	*Urotriochis macrourus*	Rare	Destruction of primary habitat
Bucerotidae	*Tockus fasciatus*	Threatened	Destruction of primary habitat
Picidae	*Psittacus erithracus*	Endangered	Destruction of primary habitat
		Animals	
Pholidota	*Manis tricuspis*	Endangered	Destruction of primary habitat
Artiodactyla	*Taurotragus sp.*	,,	Destruction of primary habitat
Artiodactyla	*Kobus ellipsiprymmus*	Threatened	Destruction of primary habitat
Primata	*Cercopithecus erythrogaster*	,,	Destruction of primary habitat
Mollusca	*Achachartina sp*	Threatened	Destruction of primary habitat
Insectivora	*Crocidura dolichura*	Endangered	Destruction of primary habitat
Rodentia	*Dendromys mystacalis*	,,	Destruction of primary habitat
Testudina	*Testudo sp.*	Threatened	Collection and sale, pollution of freshwater
,,	*Kinostermon subrurum*	,,	Food and trade, draining of wetland
Crocodila	*Alligator sp*		Loss of wetland habitat

4.10: Animal and Bird Ecosystem Key Indicators of Ondo State Bitumen Belt

Species overlap of birds in the bitumen belt shows that 59 bird species were found to overlap in the belt (table 4.48). Out of this, 52 birds are distributed over Fallow Land, 47 over Arable Farmland, 45 over High Forest, 44 over Urban Arboreta, 43 over Riparian Habitat and 25 over Cashcrop Farmland.

Animal species overlap in the bitumen belt indicates that 12 animal species overlap in at least three habitats out of the six habitats sampled (table 4.49). The animals that overlap include - *Artheriurus africanus*, *Thryonomys swinderianus*, *Lemniscomus barbarus*, *Potoxerus strangeri*, *Funiuscriurus anchrythrus*, *Cricetomys gambianus*, *Tragelaphus niger*, *Cephalophus niger*, *Dendroaspis sp.*, *Python regius*, *Python sp.*, and *Achachartina marginata*. 10 of the 12 animal species are distributed over Cashcrop Farmland, nine each in Arable farmland and High Forest, eight in Fallow Land, while Urban Arboreta and Riparian Habitat have five animal species distributed over them.

4.11: Ranking of Ecological Unit for Biodiversity Abundance Potential in Baseline Site of Ondo State Bitumen Belt

The relative abundance of plant and animal species in each ecosite (table 4.50) was discovered to be highest in arable farmlands, followed respectively by Riparian Habitat, RH, Urban Arboreta, UA, Cashcrop Farmlands, CF, islands of High Forest, HF and Fallow Land, FL.

4.12: Ranking of Ecological Unit for Biodiversity Richness of Biological Resources in Study Site of Ondo State Bitumen Belt

The observed and estimated species richness for each ecosite phase is expected to follow this trend-AF>RH>FL, HF>UA>CF (table 4.52).

4.13: Ranking of Ecological Unit for Diversity of Biological Resources in Study Site of Ondo State Bitumen Belt

The diversity of biological resources in table 4.51 reveals that biota in the various habitats are diversified in this order- AF>FL>RH, UA>HF>CF.

Table 4.48: Species Overlap of Birds in Ondo State Bitumen Belt

S/No	Local Name	Scientific Name	Family	Habitat Where Found
1	Black Kite	*Milvus migrans*	Accipitridae	FL,HF,AF,RH,CF,UA
2	African Hawk Eagle	*Hieraaetus spilogaster*	,,	FL,HF,AF,RH,CF,UA
3	Ayres Hawk Eagle	*Hieraaetus dubius*	,,	FL,HF,CF,UA
4	Casins Hawk Eagle	*Spizaetus africanus*	,,	FL,HF,RH,CF
5	Lizard Buzzard	*Kaupifalco monogrammicus*	,,	FL,HF,AF,RH,CF,UA
6	Shikra	*Accipiter badius*	,,	HF,AF,CF,UA
7	Red-Eyed Turtle Dove	*Streptopelia semitorquata*	Columbidae	FL,HF,AF,RH,UA
8	Laughing Dove	*Stigmatopelia senegalensis*	,,	FL,AF,RH,UA
9	Red-billed Wood Dove	*Tutur afer*	,,	FL,HF,AF,RH,UA
10	Green Fruit Pigeon	*Treron australis*	,,	FL,HF,AF,RH
11	Grey Plantain Eater	*Crinifer piscator*	Musophagidae	FL,HF,AF,CF,UA
12	Levailant Cuckoo	*Climator levaillanti*	Cuculidae	FL,HF,,AF,RH,UA,CF
13	Didrick Cuckoo	*Lampromorpha caprius*	,,	FL,HF,AF,RH,CF
14	Senegal Coucal	*Centropus senegalensis*	,,	FL,HF,RH,UA
15	Akin Eagle owl	*Bubo leucostictus*	Strigidae	FL,HF,RH
16	Palm Swift	*Cypsiurus parvus*	Micropodidae	FL,HF,AF,RH,CF,UA
17	Broad-billed Roller	*Eurystomus afer*	Coracidae	FL,HF,AF,RH

18	Green wood hoopoe	*Phoeniculus erythrorhyncus*	Phoeniculidae	FL,HF,AF,RH,CF
19	Allied Hornbill	*Lophocerus semifasciatus*	Bucerotidae	FL,HF,AF,RH,CF
20	Pigmy Kingfisher	*Ispidina picta*	Alcedinidae	FL,HF,AF,RH,UA
2	Stripped Kingfisher	*Halcyon Chelicuti*	,,	FL,HF,AF,UA
22	Senegal Kingfisher	*Halcyon senegalensis*	,,	FL,HF,AF,RH,UA
23	Blue-breasted Kingfisher	*Halcyon malimbicus*	,,	FL,HF,AF,RH,UA
24	White-throated Bee-eater	*Aerops albicollis*	Meropidae	FL,HF,AF,RH,CF,UA
25	Tooth-billed Barbet	*Pogonornis bidendatus*	Capitonidae	FL,HF,AF,RH,UA
26	Grey Wood-pecker	*Dendropicos goertae*	Picidae	FL,HF,RH
27	Plain-backed Pipit	*Anthus leucophrys*	Motacillidae	AF,CF,UA
28	Yellow-throated long-claw	*Macronyx croceus*	,,	AF,CF,UA
29	Common Bulbul	*Pycnonotus barbatus*	Pycnonotidae	FL,HF,AF,RH,CF,UA
30	Spectacled Flycatcher	*Platysteiira cyanea*	Muscicapidae	FL,HF,RH
31	G.B.P. Flycatcher	*Tchitrea smithii*	,,	FL,HF,AF,RH,UA
32	Kurrichane Thrush	*Turdus libonyanus*	Turdidae	AF,CF,UA
33	Whinchat	*Saxcola rubeila*	,,	AF,CF,UA
34	Snowy-headed Robin Chat	*Cossypha niveicapilla*	,,	FL,RH,UA

35	Willow warbler	*Phylloscopus trochilus*	Sylviidae	FL,AF,UA
36	White-bellied Crombec	*Sylvietha flaviventris*	,,	FL,AF,UA
37	Grey-backed Camaropera	*Camaroptera brevicaudata*	,,	FL,HF,AF,RH,CF,UA
38	Rufuos-faced Grass Warbler	*Dicrurus adsimilis*	Dicruridae	AF,CF,UA
39	Velvet-mantled Drongo	*Dicrurus modestus*	,,	FL,HF,AF,UA
40	Puff-backed Shrike	*Dryoscopus gambensis*	Prionopidae	FL,HF,RH
41	Bush Shrike	*Tchagra senegala*	,,	FL,HF,RH
42	Oriole	*Oriolus nigripennis*	Oriolidae	FL,HF,RH
43	Pied Crow	*Corvus albus*	Corvidae	FL,HF,AF,RH,UA
44	Violet-backed Starling	*Cinnyricinclus leucogaster*	Sturnidae	FL,AF,RH,UA
45	Purple-glossy Starling	*Lamprocolius purpureus*	,,	FL,AF,RH,UA
46	Chest-nut Winged Starling	*Onychognathus fulgidus*	,,	FL,HF,CF,UA
47	Bell Shrike	*Laniarus ferrugineus*	Prionopidae	FL,HF,RH,CF,UA
48	Yellow white-eye	*Zosterops senegalensis*	Zosteropidae	FL,HF,RH
49	Splendid Sunbird	*Cynnyris coccinigaster*	Nectarinidae	FL,HF,AF,RH,UA
50	Olive-bellied Sunbird	*Cynnyris chloropygius*	,,	FL,HF,AF,RH,CF,UA
51	Green-headed Sunbird	*Cyanomitra verticallis*	,,	FL,HF,AF,RH,UA
52	Collard Sunbird	*Anthreptes collaris*	,,	FL,HF,AF,UA
53	Grey-headed Sparrow	*Passer grisseus*	Fringilidae	FL,HF,AF,RH,UA

54	Chestnut and black Weaver	*Cinnamopteryx castaneofuscus*	Ploceidae	FL,HF,AF,RH,CF,UA
55	Village Weaver	*Plasiositagra cucullatus*	,,	FL.HF,AF
56	Spectacled Weaver	*Hyphanturgus brachypterus*	,,	FF,AF,RH,UA
57	Red-headed Malimbe	*Malimbus rubricollis*	,,	FL,HF,AF,RH,CF
58	Bronze Manikin	*Spermestes cucullatus*	,,	AF,CF,UA
59	Grey-crowned Negro Finch	*Nigritha canicapilla*	,,	FL,HF,AF,RH,UA

Table 4.49: Animal Species Overlap of Ondo State Bitumen Belt

S/No	Scientific Name	Order	Habitats where Found
1	*Artheriurus africanus*	Rodentia	AF,FL,HF,CF
2	*Thryonomys swinderianus*	,,	AF,CF,UA
3	*Lemniscomus barbarous*	,,	AF,CF,UA
4	*Potoxerus stranger*	,,	FL,RH,HF,CF
5	*Funiuscriurus anchrythrus*	,,	FL,RH,HF,CF
6	*Cricetomys gambianus*	,,	AF,FL,HF,CF,UA
7	*Tragelaphus niger*	Artiodactyla	AF,RH,HF
8	*Cephalophus niger*	,,	AF,RH,HF,CF
9	*Dendroaspis sp.*	Squamata	AF,FL,CF
10	*Python regius*	,,	AF,FL,HF,UA
11	*Python sebae.*	,,	FL,HF,CF
12	*Achachartina marginata*	Mollusca	AF,FL,RH,HF,CF,UA

Table 4.50: Relative Abundance of Biodiversity Species in Study Site of Ondo State Bitumen Belt

Biodiversity	CF	AF	RH	UA	FL	HF
Herbs/Habitat	64	62	50	36	7	7
Shrubs/Habitat	29	47	19	35	22	31
Trees/Habitat	2	18	8	4	16	4
Mean for vegetation	33	42	26	25	15	14
Animals/Habitat	8	8	25	6	13	26
Birds/Habitat	27	59	51	63	29	28
Overall mean	26	39	31	29	17	19

Mean for vegetation=AF>CF>RH>UA>FL>HF,

Overall mean=AF>RH>UA>CF>HF>FL

AF= Arable Farmland, CF=Cashcrop Farmland, RH=Riparian Habitat, UA=Urban Arboreta, FL, Fallow Land, HF= Islands of High Forest

Table 4.51: Diversity of Biota in Study Site of Ondo State Bitumen Belt

BD	CF	AF	RH	UA	FL	HF
Herbs/Habitat	37	53	34	46	30	16
Shrubs/Habitat	25	30	31	25	26	27
Trees/Habitat	4	41	22	24	40	33
Animals/Habitat	20	21	24	12	21	16
Birds/Habitat	28	53	47	53	62	53
Mean	23	40	32	32	36	29

AF= Arable Farmland, CF=Cashcrop Farmland, RH=Riparian Habitat, UA=Urban Arboreta, FL=Fallow Land, HF= Islands of High Forest

Table 4.52: Richness of Biodiversity in Study Site of Ondo State Bitumen Belt

Taxa	CF		AF		RH		UA		FL	
	OB/m^2	ES/ha	OB/m^2	ES/ha	OB/m^2	ES/ha	OB/m^2	ES/ha	OB/m^2	ES/ha
Herbs	6	60000	10	100000	7	70000	7	70000	5	50000
Shrubs	/25m^2	Per ha	/25m^2	Per/ha	/25 m^2	Per ha	/25m^2	Per ha	/25 m^2	Per ha
	6	2400	8	3200	6	2400	7	2800	7	2800
Trees	/25m^2	Per ha	/25m^2	Per/ha	/25 m^2	Per ha	/25m^2	Per ha	/25 m^2	Per ha
	1	400	10	4000	6	2400	3	1200	8	3200
Animals	/500m^2	Per ha	/500m^2	Per ha	/500m^2	Per ha	/500m^2	Per ha	/500m^2	Per ha
	6	120	8	160	8	160	4	80	8	160
Birds	/2828m^2	Per ha	/2828m^2	Per ha	/2828m^2	Per ha	/2828m^2	Per ha	/2828m^2	Per ha
	11	39	15	53	17	60	16	57	14	50
Mean	6	12592	10	21483	7	15004	7	14827	5	11242

N.B: OB=observed species richness, ES=estimated species richness

AF= Arable Farmland, CF=Cashcrop Farmland, RH=Riparian Habitat, UA=Urban Arboreta, FL=Fallow Land, HF= Islands of High Forest

4.14: Biodiversity on Study Sites That Are Representative of the Proposed Reclamation Ecosites of Ondo State Bitumen Belt

The measurable levels of abundance, richness and diversity of biological forms in the following baseline sites: plantation farmlands, arable farmlands (edges), riparian habitats, urban arboreta, farm fallow and islands of high forest (table 4.53) is expected to follow this trend- AF>RH>UA>FL>HF>CF representing the levels of biodiversity expected in the reclamation ecosites.

4.15: Abundance of Biodiversity in Bitumen Seepage sites and Control

The result of relative abundance of biodiversity in bitumen seepage sites and control is presented in table 4.54. The result reveals that, abundance of each of animals and herbs is not significantly different between bitumen seepage sites and that of control. However, abundance for birds, trees and shrubs are significantly higher in the control site than those of seepage sites (appendix 35).

4.16: Richness of Biodiversity on Bitumen Seepage sites and Control

The result of richness of biodiversity (Appendix 36) in bitumen seepage sites and control is presented in table 4.55. The result shows that the mean values for each of birds, animals, trees, shrubs and herbs are lower relative to that in the control. Richness for birds, animals, shrubs and herbs were, however, found to be significantly higher in the control site than those of the seepage sites.

Table 4.53: Biodiversity on Study Sites of Ondo State Bitumen Belt

Taxa	CF	AF	RH	UA	FL	HF
Abundance/Habitat	26	39	31	29	17	19
Richness/Habitat	6	10	9	7	8	8
Diversity/Habitat	23	40	32	32	36	29
Mean	18	30	24	23	20	19

AF= Arable Farmland, CF=Cashcrop Farmland, RH=Riparian Habitat, UA=Urban Arboreta, FL=Fallow Land, HF= Islands of High Forest

Table 4.54: Relative Abundance of Biodiversity in Seepage and Control Site

Biota	**Mean**	
	Seepage Site	Control site
Bird/Ha	64.0*	134.5 *
Animal/Ha	160.0	200.0
Trees/Ha	789.9 *	2775.2 *
Shrubs/Ha	2396.8 *	12388.9 *
Herbs/Ha	429999.8	349999.7

NB: Marked mean values are significant at $P < 0.05$

Table 4.55: Richness of Biodiversity in Seepage and Control Site

Biota	Mean	
	Seepage site	Control Site
Bird/Ha	14.2*	49.6*
Animal/Ha	60.3*	140.3*
Trees/Ha	800.2	1999.0
Shrubs/Ha	797.0*	2799.8*
Herbs/Ha	29999.9*	69977.8*

NB: Marked mean values are significant at P < 0.05

CHAPTER FIVE

5.0: DISCUSSION

5.1.1.1: Baseline Information and Environmental Impact Assessment, EIA, of Chemical Properties of Tar and Soil of Ondo State Bitumen Belt

The result of chemical Properties of Bituminous Tar and associated surface soil shows that: pH (KCl), pH (H_2O), Available Phosphorus, Exchangeable bases and Base saturation of the bituminous tar did not vary remarkably from that of the associated surface soil. But P, Mg and base saturation were higher in tar than that of surface soil. Organic carbon, Total Nitrogen, Exchangeable Acidity, EA, and Cation Exchange Capacity, C.E.C, of bituminous tar were significantly higher than that of the associated surface soil ($P<0.05$). This could be attributed to the activities of soil organisms in metabolizing excess nutrients or immobilizing them in their biomass and necromass as the rep[orted by Diplock *et al*, (2009), which is further confirmed by Nnaji *et al* (2005) that high concentration of Ca^{2+}, Mg^{2+} and trace elements in soil is attributable to rapid decay and mineralization of organic and mineral materials in the soil. This process may be partly responsible for the formation of bitumen. This view is supported by the finding of (Haman and Izuno, 2009) that the frequent addition of easily decomposable organic residues leads to the synthesis of complex organic compounds.

The pH (KCl) of the bituminous tar which is lower than that of associated surface soil is a pointer to the possibility of the tar not being the source of the low pH in the soil. The high pH could possibly have come from high Mg soils as noted in the finding of Dick (2009).

The amount of organic carbon in both bituminous tar and associated surface soil is far above the optimum range as described by Sideman and Coleman (2010). But the difference in the amount of organic carbon as reflected in a statistically higher amount in bituminous tar over that of the associated surface soil is a pointer to a possible mineralization and rapid rates of decomposition of organic residues in the formation of bitumen. This view is supported by the finding of (Haman and Izuno, 2009) that the frequent addition of easily decomposable organic residues leads to the synthesis of complex organic compounds.

The higher amount of nitrogen in bituminous tar in comparison with the associated surface soil and significantly higher value of nitrogen in bitumen seepage sites over that of the control site could be as a result of mineralization, decomposition and bio-accumulation of organic residues in the formation of bitumen. This view is supported by the finding of (Haman and Izuno, 2009) that the frequent addition of easily decomposable organic residues leads to the synthesis of complex organic compounds.

The insignificant differences in the levels of available phosphorus, and exchangeable bases (Ca^{2+} Mg^{2+} k^{+} and Na^{+}) in both bituminous tar and associated surface soil is an indication of the effect of very high amount of organic matter on the availability of nutrients especially phosphorus for plant growth through its mineralization by soil micro-organisms as indicated in the findings of Reid and Dirou (2004). Likewise, the abundance of Fe in these soils could have also increased phosphate sorption as found in the earlier work of Giesler *et al*. (2005).

The significantly higher amount of CEC in bituminous tar over that of the associated surface soil points to a possible bio-accumulation of CEC from the surface soil to the tar since CEC is dependent upon the amount of organic matter as reported by TFREC (2004).

5.1.1.2: Relationship between the Physical Properties of Bituminous Tar and Associated Surface Soil: Environmental Impacts Assessment

With the relative size distribution of sand (892.00g/kg), silt (94.00g/kg) and clay (14.00g/kg) (4.2), the soil of the bitumen belt can therefore, be classified as sandy-loam.

The lower clay content of the soils is an indication that the soil is in low CEC. Reid and Dirou (2004) confirmed that good fertile soils with high clay content usually have a CEC of 10 or higher.

The greater proportion of sandy particles and gravels over that of silt and clay as found in the bitumen belt is an indication of the ability of the soil in this area to drain away water after heavy rainfall that is typical of the tropical rainforest. This agreed with findings of Haman and Izuno (2009) that in sandy soils there are many more large pores than in clayey soils. In addition the total volume of pores in sandy soils is significantly smaller than in clayey soils (30 to 40% for sandy soils as compared to 40 to 60% for clayey soils). As a result, much less water can be stored in sandy soil than in the clayey soil. It is also important to realize that a significant number of the pores in sandy soils are large enough to drain within the first 24 hours due to gravity and this portion of water is lost from the system before plants can use it.

The significantly higher amount of sand particles found in bituminous tar over that of the associated surface soil is an indication that sand is a component of bitumen. Also, the insignificant difference in the levels of clay particles found in tar-sand and associated surface soil is a reflection of the presence of suspended clay particles which is a problem that is associated with oil sand processing as described by Ekweozor (1990).

Also, the smaller amount of clay particles compared to the rest of the physical properties of soil shows that the CEC of the soil is lower than the required level. Findings of TFREC (2004) revealed that CEC is dependent upon the amount of organic matter and clay in soils and on the types of clay. In general, the higher OM and clay content, the higher the CEC.

5.1.1.3: Chemical Properties of surface soils in Bitumen Seepage and Control Sites: Environmental Impacts Assessment

The relationship between the chemical properties of soils in Bitumen seepage and control sites shows that: Organic Carbon, Available phosphorus, calcium, magnesium, sodium, and potassium of soils in seepage and control sites are not significantly different from one another. Total nitrogen, exchangeable acidity, and CEC were significantly higher in seepage soils than that in the control sites. pH (H_2O) and PH (KCl) of seepage soil was significantly lower than that of the control.

Soil pH

The lower pH is possibly due to increasing organic carbon. According to Agro/Hort 100 (2001) increasing organic matter will decrease pH (increase acidity) and that all living organisms are sensitive to pH. The plant roots will not function optimally in soils outside a specific pH range unique to that organism. If the pH of the soil is extremely either alkaline or acidic, the plant will die. Soil microorganisms, insects, and other animals present in the rhizosphere are equally sensitive to pH. Alkaline soils have pH 7.5 - 8.5. Acidic soils have pH 4 - 6.5. Soils with pH values outside these ranges are usually toxic to most plants.

Soil pH and Plant Growth

The pH of soil in seepage site as measured in KCl and water was found to be lower than that of the control. However, the pH of the two sites which is not even up to the optimal level points to a possible increase in leaching as a result of hydrophobic action as reported by Agbogidi *et al* (2005). This may possibly reduce available plant nutrients; increase the concentration of toxic metals which are generally more available in acidic soils. The low soil pH could also affect the activities of soil micro organisms, thus affecting nutrient cycling and disease risk. This agreed with the finding of TFREC (2004) that low pH soils (<6.0) results in an increase in Al; Aluminum which is toxic to plants; Affects the availability of toxic metals, which is generally more available in acidic soils; Affects the activity of soil microorganisms, thus affecting nutrient cycling and disease risk. The pH of the soil is generally lower than the optimum recommended by Sideman and Coleman (2010). This is an indication that the soil is acidic.

Organic Carbon, Nitrogen and Other Available Nutrients: Impacts and Interaction

Organic carbon which is a measure of the organic matter in the soil across the bitumen belt was found to be higher than the critical level recommended by FEPA which is 2.0%. This could be ascribed to the ability of soil organic carbon in storing important nutrients, stabilising soil structure and feeding soil microbes as reported in the finding Reid and Dirou (2004).

Organic Matter and Availability of Nutrients for Plant Growth

The level of organic carbon in seepage site was higher than that of control, but the difference was not significant. Organic matter has both a direct and indirect effect on the availability of nutrients for plant growth. In addition to serving as a source of N, P, through its mineralization by soil microorganisms, organic matter could also have influenced the supply of nutrients from other sources (for example, organic matter is required as an energy source for N-fixing bacteria, as reported by Wikipedia (2010).

Effect of Organic Matter on Soil Physical Condition, Soil Erosion and Soil Buffering and Exchange Capacity

Humus has a profound effect on the structure of many soils. Aeration, water-holding capacity and permeability are all favourably affected by humus. The frequent addition of easily decomposable organic residues leads to the synthesis of complex organic compounds that bind soil particles into structural units called aggregates. These aggregates help to maintain a loose, open, granular condition. Water is better able to infiltrate and percolate downward through the soil, thereby preventing erosion, and aeration is highly enhanced (Haman and Izuno, 2009).

The organic carbon content of seepage soil is higher than FEPA critical limit of 2.0, but not significantly different from that of control. Organic matter has the tendency to contribute to plant growth through its effect on the physical, chemical, and biological properties of the soil. According to Reid and Dirou (2004) nutritionally, it could serve as a source of N and P for plant growth, biologically it possibly could affect the activities of microflora and microfaunal organisms and, physically and physico-chemically, it possibly would not only have promoted good soil structure, thereby improving tilth, but could also improve aeration and retention of moisture and increase the buffering and exchange capacity of soils.

Nitrogen

Nitrogen content of soil across the bitumen belt which was found to be higher than the critical level recommended by FMNAR (0.2%), 10 mg/kg or more in pasture soils, and a level greater than 20 mg/kg in horticultural crops (Reid and Dirou, 2004) can be ascribed to the high abundance of nitrogen fixing plants found in the study area, and the rapid rate of mineralization of organic matter. TFREC (2004) confirmed that each year, about 1 to 4% of nutrients in the soil organic matter are released through microbial transformations to become available to plants. Release is highest under warm, moist conditions. Thus, the release of N into the soil could have been favoured by the high temperature and rainfall typical of the bitumen belt. The higher amount of nitrogen in bitumen seepage sites over that of the control site could be as a result of mineralization, decomposition and bio-accumulation of organic residues in the formation of bitumen. This view is supported by the finding of (Haman and Izuno, 2009) that the frequent addition of easily decomposable organic residues leads to the synthesis of complex organic compounds.

C: N Ratio

The low C: N ratios, 4:1, in the bitumen belt are indicative of increased mineralization and rapid rates of decomposition of organic residues as reported by (TFREC, 2004).

Available Phosphorus, Calcium, Magnesium, Sodium and Potassium

Available P which was found to be lower than the optimum level, 20-100mg/kg (FEPA), is in contrast with the finding of Nnaji *et al* (2005) that rapid decomposition of organic residues leads to the release of nutrient, particularly P for the use of plants. Available phosphorus is also lower than the optimal level of between 9.07-18.14kg as recommended by Sideman and Coleman (2010).

Na^+ and K^+ are within the optimum recommended rates of <10% by Agsource (2006) and 3.5-5.0meq/100g by Sideman and Coleman (2010) respectively in the bitumen belt as well as the control site is in tandem with the finding of Agbogidi *et al* (2005) in which it was reported that low K^+ and Na^+ of soil may be due to nutrient immobilisation consequent on the formation of complexes in soil after degradation and uptake.

Ca^{2+} in soils as a % of CEC is below the optimum range, while Mg^{2+} is higher than the optimum, but Na^+ and K^+ are within the optimum range. The implication of this on nutrient availability is that Ca^{2+} will not be made readily available for plant uptake, while nutrient loss through leaching will be increased in the bitumen belt as described by AgSource (2006). Ca^{2+} which was found to be below the optimal level of between 60-80meq/100g is an indication that the soil is fragile. This is in agreement with the finding of Nnaji *et al* (2005) that high concentration of calcium in soil is attributable to rapid decay and mineralization of organic materials in the soil.

Mg^{2+} is lower than the optimum level of 10-25meq/100g as recommended by Sideman and Coleman (2010). This can result into K^+ and Ca^{2+} defficiency.

The insignificant differences in the levels of available phosphorus, and exchangeable bases (Ca^{2+} Mg^{2+} k^+ and Na^{+}) in surface soil in seepage sites and control site is an indication of the effect of very high amount of organic matter on the availability of nutrients especially phosphorus for plant growth through its mineralization by soil micro-organisms as indicated in the findings of Reid and Dirou (2004). Likewise, the abundance of Fe in these soils could have also increased phosphate sorption as found in the earlier work of Giesler *et al*., 2005.

The low Ca:Mg ratio in the soils of the bitumen belt which falls below 4:1-7:1 is a reflection of the high amount of Mg in the soils. However, it is only if the figure is below 2, that it is more difficult for plants to take up potassium, and there can be problems with soil structure breaking down due to dispersion as reported by Reid and Dirou (2004). Ca:Mg in soils which was found to be below the optimum will make it difficult for plants to take up K^+ and there can be problems with soil structure breaking down due to dispersion (Haman and Izuno, 2009).

Dick (2009) confirmed that high Mg soils cause potassium and calcium deficiency in plants. Soils with high magnesium tend to have poor structure. Typically these soils will have more sodium cations attached to the clay as well. Having high magnesium and sodium causes the clay particles to disperse when wet and set like concrete when dry. However, the frequent addition of easily decomposable organic residues as manifested in the huge amount of organic carbon in the soil could have led to the synthesis of complex organic compounds of exchangeable bases that could have helped in ameliorating the negative effect of high Mg in the soil. Ravina and Markus (1975) confirmed that there is a significant interaction between the exchangeable potassium and the uptake of magnesium and phosphorus. Maximilian *et al* (2009) reported that excess nutrients (nitrates, sulfates, phosphates) are filtered out by the soil. Claudia *et al*, (2008) further confirmed that excess nutrients filtered out by the soil, or metabolized were incorporated into stable humus.

Exchangeable Acidity

Exchangeable Acidity of soils was also found to be below optimum level of <10meq/100g recommended by sideman and Coleman (2010). The significantly higher level of acidity in bituminous tar over its associated soil, and between surface soil in seepage sites and control is a pointer to the fact that the tar could be a possible source of acidity unto the surrounding surface soil.

Cation Exchange Capacity

The CEC of the surface soil of 4.33meq/100gm in the bitumen belt which was found to be near the optimum range of 5meq/100gm (Sideman and Coleman, 2010), but lower than FAO recommended value of 8.0-16.0meq/100g soil is a reflection of the poor ability of the soil to hold the nutrients: calcium, magnesium and potassium. In the findings of Reid and Dirou (2004) good fertile soils with high clay content and moderate to high organic matter levels usually have a cation exchange capacity of 10 or higher. This view is supported by the findings of TFREC (2004) in which it was reported that CEC is a measure of the quantity of cations that can be adsorbed and held by a soil and that CEC is dependent upon the amount of organic matter and clay in soils and on the types of clay. In general, the higher OM and clay content, the higher the CEC.

Notwithstanding the very high amount of organic matter in the soil of the study area, the CEC is still very low. This is an indication of the smaller amount of clay particles in the soil, which possibly gave a counter action on the ability of the organic matter to increase the soil CEC.

However, the significantly higher value of CEC in bitumen seepage sites over that of the control site shows that higher amount of organic carbon could also have influenced the supply of nutrients from other sources (for example, organic matter is required as an energy source for N-fixing bacteria, as reported by Wikipedia (2010).

5.1.1.4: The Suitability and Availability of Soils within the Project Area for Reclamation

Even though the soil could be said to be fragile due to high acidic nature, low Ca^{2+}, low Ca:Mg ratio, low CEC and low clay, the high amount of organic carbon, nitrogen, and low C:N ratio still make the soil suitable for reclamation within the proposed project area. This is in agreement with the findings of Dick (2009) that cation ratios can help in identifying soil strucrure problems.

5.1.1.5: Heavy Metals in Bituminous Tar and Seepage Surface Soils: Impact and Interaction

The insignificantly different levels of Mn, Fe, Cu, Zn, Pb, Ni, As, Cr and Cd in bituminous tar and associated surface soils in seepage site point to the fact that bituminous tar and the associated surface soil already contained the heavy metals in appreciable quantities. The seepages of bitumen could have been the point source of heavy metals contamination of soils in the site (Citation). Ekweozor (1990) chronicled the problems associated with processing of bitumen from oil sands to include presence of trace metals, including vanadium, nickel and iron as well as suspended clay particles. Howari *et al* (2004) also drew attention to heavy metal contamination associated with highways or motorways which has risen in the last decades because of the associated health hazards and risks. Two main trends were identified: (i) higher concentrations were located near intersections close to the urban areas in the Jordan Valley, in association with junctions controlled by traffic lights and check points; and (ii) lower concentrations were found to the southwest in areas of mainly barren landscape close to the Dead Sea and Aqaba.

5.1.1.6: Trace Heavy Metals in Surface Soil of Bitumen Seepage and Control Sites: Impacts and Interaction

The significantly lower values of Mn, Cu, and Zn in seepage soils when compared with those of the control sites are pointers to the ability of plants growing naturally on bitumen polluted soils to extract the metals from the soil. This is in agreement with the finding of Chhotu and Fulekar (2009) that unlike organic compounds, metals cannot degrade, and therefore effective cleanup requires their immobilisation to reduce or remove toxicity. The technology involves efficient use of plants to remove, detoxify or immobilize environmental contaminants in a growth matrix (soil, water or sediments) through the natural, biological, chemical or physical activities or processes of the plants.

While the significantly higher value of Fe in seepage soil over that of the control points to the high toxic level of the heavy metal in the soil of the seepage sites. This agreed with the finding of Adebiyi *et al* (2005) that trace metals which are toxic were highly enriched in the sand fraction of bitumen.

The mean values for Pb, Ni, As, Cr, V and Zn in seepage sites were however not significantly different from that of the control. This agreed with the finding of Buszewski *et a*l (2000), that the metal concentrations in soils of measured area did not exceed recommended levels.

5.1.1.7: Summary of Potential Impacts of Bitumen Seepage on Soil

The low pH of soil in the bitumen belt makes the soil to be acidic and prone to leaching and other soil problems.

Low Ca^{2+} as a percentage of CEC in soil will contribute to nutrient leaching.

Lower Ca: Mg ratio will reduce soil structural agregation, aeration and productivity.

Low CEC is an indicator of the poor ability of soil to hold nutrients.

Lower amount of clay will contribute to the poor CEC of the soil.

While the significantly higher value of Fe in seepage soil over that of the control points to the high toxic level of the heavy metal in the soil of the seepage sites.

Decreases and increases in nutrients can affect the amount of primary production as well as the types of plants that grow with subsequent effect on animals. The successful reproduction of plants and animals depends on the physical and chemical regimes of their environment.

Mitigation

The low pH, low Ca^{2+} , low CEC and lower amount of clay in soil indicates soil problems and should be strictly monitored.

Fe level in the soil should be under constant monitoring.

Plants that can accumulate heavy metals should be used to remediate bitumen polluted soil.

Chemical amendment of polluted soil should be carried out.

Bioremediation of soil should also be taken into account to clean up derelict soil.

To avoid serious leaching, soil management programmes should include addition of liming materials.

The overburden should be stockpiled for use in future reclamation.

Air sparging should be carried out to agitate liquid contaminant for easy clean-up.

Vegetation clearing and soil disturbance should be reduced to the barest minimum.

Exposed land area and duration of exposure should be minimised.

Improved management can limit erosion by using techniques like limiting disturbance during construction.

Construction during erosion prone periods should be avoided.

Proper backfilling and revegetation of all excavated areas and trenches should be ensured.

5.2.1: Physico-Chemical parameters of Water in the Bitumen Belt: Assessment of Potential Impacts

The significantly highest mean values of Sulphur, Sulphate, Chemical Oxygen Demand and Turbidity in surface water of bitumen seepage site over that of control shows that the parameters in water could have been generated from bitumen seepages.

The positive and negative correlation that holds between the physico-chemical parameters of surface water in the bitumen belt agreed with the finding of Trivedi *et al* (2009).

Bicarbonate, $BiCO_3$

The level of $BiCO_3$ ranges from 18.3 to 20.6mg/l across all locations in the Bitumen Belt.

Chloride, Cl^-

The level of Cl^- concentration in surface water ranges between 18.00 and 25.20mg/l. Cl^- falls below FEPA and WHO recommended standard of 200mg/l, and FAO toxicity level of 200-500mg/l. Cl^- falls below FEPA and WHO recommended standard of 200mg/l, and FAO toxicity level of 200-500mg/l, and so poses no potential environmental hazard.

Sulphur

Sulphur level in surface water across the bitumen belt ranges between 11.42 and 21.56mg/l, and is higher than WHO limit of 0.2mg/l, for discharge into surface water. Sulphur in the form of sulphide which is higher than WHO limilt (500mg/l) for discharge into surface water could be ascribed to runoff from bitumen seepages and exploratory activities. This is so because the level in the seepage site is higher than that of the control. This could have toxicological effect on biodiversity.

Sulphate, SO_4

The amount of SO_4 across all locations ranges between 5.31 and 7.11mg/l, and the values are lower than WHO limit of 500mg/l, for discharge into surface water. SO_4 also falls below FEPA recommended standard of 50mg/l and WHO (250mg/l). This implie that even with the attendant significant increment of the parameter in the study area over that of control, the amount of SO_4 that is leached into aquatic environment is not enough to cause any potential hazard to biodiversity.

Nitrate, NO_3

The lower range of NO_3 in surface water of the bitumen belt, 9.60, falls below FEPA and WHO recommended standard, while the upper range, 46.20mg/l, is higher than FEPA, but lower than WHO recommended standard of 50mg/l. Speijer (1996) reported that many workers have been reported to have potential health risk from nitrate in drinking water above threshold of 45 mg/l, which may give rise to a condition known as methaemoglobinemia in infants and pregnant women. Toxic level of NO_3 recorded in seepage site could not have come from bitumen seepage alone since its level is not significantly different from that of the control. NO_3 are components of agricultural fertilizers commonly used by farmers in the bitumen belt. NO_3 from fertilizers and bitumen seepages may have been leached into the soil and river bodies and thus may have contributed to the significant concentrations observed in this study. The upper range of NO_3 found in this belt could pose a potential environmental hazard to biodiversity.

Ammonia, NH_3

The high levels of NH_3 across the bitumen belt ranges between 5.60 and 46.30 mg/l which are higher than the amount recommended by Osibanjo (1986) but lower than 200mg/l that is recommended per body weight. The toxic level of NH_3 is possibly a reflection of the high rate of organic decomposition in the study area, since its level is not significantly different from that of the control. This could have toxicological effect on biodiversity.

Alkalinity

The level of alkalinity of water across all locations ranges between 2.40 and 13.00mg/l.

Total Dissolved Solids, TDS

The levels of TDS in all locations across the bitumen belt fluctuate between 0.08 and 0.14mg/l, which all fall far below the FEPA recommended standard of 2000mg/l. The low level of TDS is an indication that TDS in the aquatic environment across the bitumen belt does not pose any potential threat to biodiversity. This low level is in contrast with the finding of Israel *et al* (2008) that petrochemical effluents contained very high concentration of TDS. Akan (2008) also confirmed that TDS of soils irrigated with wastewater was higher than the maximum permissible limits set by Federal Environmental Protection Agencies (FEPA), Nigeria.

Total Suspended Solids, TSS

TSS which value ranges between 0.09 and 0.14mg/l, falls below FEPA recommended standard of 30mg/l. Low level of TSS in aquatic medium imply that TSS in the bitumen belt does not at present pose any potential environmental harzard to biodiversity. This low level is in contrast with the finding of Israel *et al* (2008) that petrochemical effluents contained significant concentrations of TSS.

Turbidity

Turbidity value ranges between 1.86 and 28.62 NTU. The lower range is below what is recommended by FMENV/DPR, but the upper range is higher than the guide level of 10NTU. High turbidity level in water though prevents light from reaching aquatic plants and animals (Kakulu and Osibanjo, 1991), points to the ability of the aquatic medium to protect micro-organisms from the effects of disinfectants. Level of turbidity is significantly higher in seepage site than that of control. This could be ascribed to runoff from bitumen seepages and exploratory activities.

Temperature

Temperature level in surface water across all locations which fluctuates between 26.80 and 27.60^{0}C falls below FEPA recommended standard of 30.00^{0}C and 35^{0}C as recommended by the Department of Petroleum Resources (DPR). Lower temperature level in aquatic medium is a reflection of its inability to enhance the growth of micro-organisms. But, the lower temperature may have reduced taste, odour, colour and corrosion problems. No wonder the surface water in this belt was discovered to be very clean and is mostly used for all sorts of domestic utilities by the aborigines.

Electrical Conductivity

The electrical conductivity of surface water across all locations which ranges between 196.00 and 705.00Ns/cm is lower than WHO recommended level of 2000Ns/cm. Wastewater effluents often contain high amounts of dissolved salts from domestic sewage. High salt concentrations in waste effluents however, can increase the salinity of the receiving water, which may result in adverse ecological effects on aquatic biota (Ademoroti, 1996). The water in the study area is low in electrical conductivity. Low electrical conductivity of surface water in the bitumen belt could, therefore, pose no potential environmental threat to biodiversity. Electrical conductivity of water according to Ademoroti (1996) is a useful and easy indicator of its salinity or total salt content. High amounts of dissolved salts in bitumen seepage site over that of the control which is, however, not significant could have come from domestic sewage. High salt concentrations in waste effluents however, can increase the salinity of the receiving water, which may result in adverse ecological effects on aquatic biota (Akan, 2008).

Dissolved Oxygen, DO

DO levels which is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as the self purification capacity of water body (Chapman, 1997) across all locations fluctuate with values ranging from 2.70 to 6.90mg/l, and falls below FEPA recommended standard of 20mg/l. DO level which falls below FEPA recommended standard and whch is lower than that of control site points to greater amount of decomposable matter that possibly have been discharged into the aquatic medium from anthropogenic sources which could have resulted in the greater amount of oxygen demand thereby making DO to be exceedingly low. This is in contrast with the finding of Israel *et al* (2008) that petrochemical effluent contained significant concentration of DO. This is further confirmed by Morrison *et al* (2001) that wastewater discharge from sewage and industries are major component of water pollution, contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to a destabilized aquatic ecosystem.

Chemical Oxygen Demand, COD

COD level across the bitumen belt ranges between 112.40 and 878.50mg/l and is higher than FEPA recommended level of 40.00mg/l. COD which is a measure of biochemical activities taking place in aquatic medium, and which is very high in this area could have been generated from bitumen seepage since the level is highest at seepage site than that of control site. This could be a source of potential environmental pollution. A high BOD value usually suggests more waste products or pollutants are present according to report from Israel *et al* (2008).

Biochemical Oxygen Demand, BOD

BOD levels which range between 61.30 and 586.00mg/l across the bitumen belt is far above the FEPA recommended standard of 10.00mg/l. BOD is the measurement of the dissolved oxygen used by microorganism in the biological oxidation of organic matter. The BOD level of surface water across the bitumen belt prior to development is higher than FEPA recommended values, it could then be deduced that BOD in this area could therefore be a source of threat to biodiversity resources and services. The level of BOD which is insignificantly higher in seepage site over that of control shows that the toxic level could have come only from bitumen seepage. This is in agreement with the finding of Israel *et al* (2008) that petrochemical effluent contained significant concentration of COD. Akan (20080 also confirmed that COD of soils irrigated with wastewater was higher than the maximum permissible limits set by FEPA.

The significant association between DO and BOD ($P<0.05$) in this study is a further confirmation of the findings of DWAF (1996), that BOD is also taken as a measure of the concentration of organic matter present in any water. The greater the decomposable matter present, the greater the oxygen demand and the greater the BOD values.

pH

The lower range of pH levels across the Bitumen Belt, 4.95 falls below FEPA recommended standard, while the upper range of 6.37, is higher than FEPA recommended level of 6-9. Most desirable limit by WHO is 7-8.5. Ansa – Asare (1992) reported that the pH of natural water determines the solubility and chemical forms of most substances in water. High levels of total dissolved solids limit the industrial and agricultural use of water.

The negative correlation between PH and BOD and temperature is a reflection of the ability of pH to determine the solubility and chemical forms of most substances in water as reported by Ansa – Asare (1992). The upper range of pH that is higher than FEPA recommended level could limit the industrial and agricultural use of water. DWAF (1996) reported that high or low pH values in a river affect aquatic life and alter toxicity of other pollutants in one form or the other. Low pH values in a river for example could impair recreational uses of water and affect aquatic life.

5.2.2: Trace Heavy Metals in Surface Water

Manganese, Mn

Manganese level across all locations sampled ranges between 9.80 and 16.20mg/l. The range of Mn values is higher than WHO (2003) limitation guideline of 0.20mg/l. This contrasted with the finding of Akeredolu (2008) that Mn was lower compared to standard limits,

Iron, Fe

Iron level across all location in the bitumen belt ranges between 1.80 and 2.20mg/l, and is lower than WHO (2003) limitation guideline of 5.00mg/l and FEPA, 1991 limitation guideline of 20.00mg/l. Kinigoma (2001) reported toxic level of Fe which were higher than recommended values. This contrasted with the finding of Akeredolu (2008) that Fe was found to be higher than standard limits.

Copper, Cu

Copper level across the bitumen belt ranges between 0.60m and 0.70mg/l. This range of values though a little higher than WHO (2003) limitation guideline of 0.20mg/l, is lower than FEPA limitation guideline of 1.50mg/l. This agreed with the finding of Akeredolu (2008) that Cu was lower compared to standard limits.

Zinc, Zn

Zinc level varies between 1.50mg and 1.70mg/l. The range of values falls below WHO and FEPA limitation guideline of 2.00mg/l. This agreed with the finding of Akeredolu (2008) that Zn was lower compared to standard limits.

Lead, Pb

Lead level varies between 0.005 and 0.05mg/l. These values fall far below WHO and FEPA limitation guideline value of 5.00mg/l. This is in tandem with the work of Israel *et al* (2008) in which low concentrations of lead was also observed from the treated effluents which were dumped for physicochemical properties, metallic and non-metallic ions analysis. This is however in contrast with the finding of Akeredolu (2008) Pb was found to be higher than standard limits.

Chromium, Cr

The range of values for chromium across all locations varied between 0.02 and 0.07mg/kg. These values are higher than FEPA detection limit of 0.01mg/l. This agreed with the finding of Akeredolu (2008) that Cr was found to be higher than standard limits.

Cadmium, Cd

The range of values for cadmium varies between 0.02 and 0.03mg/l. These values are higher than WHO limitation guideline of 0.01mg/l, but lower than FEPA limitation guideline of 1.00mg/l. This agreed with the finding of Akeredolu (2008) that Cd is within desirable permissible limit.

Nickel, Ni

The range of values for nickel varies between 0.004 and 0.40mg/l. These values though higher than WHO, 2003 limitation guideline of 0.23mg/l, is lower than 1.00mg/l as recommended by FEPA. Ekweozor (1990) chronicled the problems associated with processing of bitumen from oil sands to include presence of trace metals, including nickel

Vanadium, V

Vanadium level across the bitumen belt ranges between 0.03 and 0.40mg/kg. Ekweozor (1990) chronicled the problems associated with processing of bitumen from oil sands to include presence of trace metals, including vanadium. The lower range is lower than 0.1mg/kg recommended by MESD (2003), while the upper range is higher than the permissible limit.

Arsenic, As

Arsenic level which ranges between 0.01 and 0.02mg/kg is higher than FEPA limitation guideline of 0.01mg/l. Adebiyi *et al* (2005) confirmed that As which was known to be toxic metals, was highly enriched (enrichment factor, EF>10) in the water fraction samples of bituminous sands from south-western Nigeria.

5.2.3: Potential Impacts of the Project on Heavy Metals of Surface Water Quality

A large number of factors and geological conditions could have influenced the correlations between different pairs of physicochemical parameters of water samples directly or indirectly. Some of the physicochemical parameters such as Cl^-, SO_4, TDS, TSS, temperature and conductivity are within desirable or maximum permissible limits. Others such as sulphur, NO_3, NH_3, turbidity, dissolved oxygen, COD and BOD are however higher than permissible limits.

The toxic levels of Mn, Cu, Cr, Cd, Ni, V and As that is found in the surface water of the bitumen belt could be ascribed to the ability of low water pH in this area to possibly increase the solubility of many elements as reported by DWAF (1996). The high concentration of these elements in surface water across the bitumen belt could, therefore pose a potential environmental hazard to biodiversity as reported by Benson *et al* (2007). The toxic level of Fe and Pb however contrasted with the finding of Akeredolu (2008) that Fe, Pb and Cr were found to be higher than standard limits. Mn, Zn and Cu are lower compared to standard limits, while Cd is within desirable permissible limit.

Low levels of Fe, Zn and Pb in surface water of the bitumen belt may not pose any potential danger to biodiversity. This is against the finding of Benson *et al*, 2007, that Fe in surface water samples exceeded Federal Environmental Protection Agency

(FEPA) maximum guideline values. The low concentration of Fe, Zn and Pb in some locations in the bitumen belt could be ascribed to the low pH value of the water in those areas that possibly caused a decrease in the solubility of the elements as found by DWAF, 1996.

5.2.4: Project Components That May Influence Surface Water Quality: Impact Assessment

Project components that may impact surface water include-

Surface Runoff or Groundwater Discharge; Oil spills; Bitumen Extraction:

During bitumen extraction, the mined ore will be crushed, mixed with water for slurring, transported and conditioned in a pipeline, and fed to a bitumen-extraction facility. The bitumen will be separated as froth – a mixture of bitumen, water and solids. The froth will be further treated in a froth treatment plant to produce bitumen for sale. Effluents from the separation process will cause pollution of surface water from surface runoff and groundwater due to leaks in underground storage tanks.

5.2.5: Significance of Any Impacts on Water Quality and Implications to Aquatic Resources

The following negative impacts will also take place in surface water bodies:

Vegetation loss due to mining will result into increased runoff, thereby increasing the suspended solids in streams.

Deforestation along with water will increase water yield, as the flow pattern of rivers is expected to change when the surrounding vegetation is removed.

Water quality and quantity will be reduced due to non-vegetated catchments with deposition of soil particles in water column and the resuspension of bottom sediments taking place.

There will also be generation of silt at banks of creeks.

Leakages, spills and discharges of bitumen oil, grease and effluents will also cause a reduction in water quality.

Some minerals may even form complex interactions, with prolonged exposure for wildlife.

Increase in turbidity due to exposure of soil surface run-offs carrying sediment will cause alteration in drainage pattern due to changes in topography and improper re-instatement.

Reduction in water quality may reduce growth and cause reproductive failure in aquatic vertebrates.

5.2.6: Effect of Changes in Surface Runoff or Groundwater Discharge on Water Quality in Surface Water Bodies

Water Pollution can come from migration of contaminants. Liquids released at the surface or leaking from an underground structure will flow down through the ground under the influence of gravity. Some hydrocarbons will be adsorbed onto soil particles and retained in soil pores. On encountering ground water, the liquid will typically spread out on the surface of the water and migrate laterally, preferentially in the direction of ground water flow. The volatile components will diffuse into the overlying soil and migrate as a vapour from ahead of the free product. Vapour emission from contaminated land could accumulate in poorly ventilated spaces and present a health and explosion hazard. Insoluble liquids which are denser than water will sink through the groundwater until they encounter an impermeable barrier, where they will spread out and possibly continue to migrate in the direction of groundwater flow. Soluble components (such as phenols) will dissolve in the groundwater and migrate in the direction of groundwater flow. Soluble inorganic contaminants deposited on the surface or in the unsaturated zone may be leached by rainwater infiltration and also enter underlying groundwater (Department of Environment, 2009).

5.2.7: Summary of Potential Impacts on Surface Water

Once the bitumen is mined, separating bitumen from the sand/fines commonly involves the use of significant volumes of water.

Water resources will be affected by primary contamination when improperly treated wastes are dumped into water ways and by secondary contamination when there is surface runoff into the water.

Critical level of sulphur in surface water could be toxic to biodiversity.

Critical level of nitrate in water could pose a potential health risk in drinking water to inhabitants of local community, and environmental hazard to biodiversity.

The high level of NH_3 in surface water, which is a reflection of the high rate of organic decomposition in the study area, could make it a source of health hazard to people and biodiversity.

High turbidity level in water which could, however, protect micro-organisms from the effects of disinfectants could also cause bacterial growth. Soil runoff will potentially increase turbidity, thereby reducing the amount of light and oxygen available to aquatic life, and destroying the habitats for many species.

Dissolved oxygen could have been used by organic wastes, and this may pose health risk such that fish and other invertebrate organisms cannot survive.

COD which is a measure of biochemical activities taking place in aquatic medium, and which is above critical level in this area could be a source of potential environmental hazard to biodiversity.

High BOD in this area could be a source of threat to environmental resources and services.

Low pH values in the aquatic medium could impair recreational uses of water and affect aquatic life. The decrease in pH values could also decrease the solubility of certain essential element, while at the same time low pH could cause increases in the solubility of many other elements such as Al, Cu, Cd, Mn and Fe.

Critical levels of Mn, Cr, Cd, Ni and As in surface water could make the water to be toxic and unsafe for biodiversity and human.

Mitigation

Some of the physicochemical parameters such as Cl^-, SO_4, TDS, TSS, temperature and conductivity are within desirable or maximum permissible limits. Others such as sulphur, NO_3, NH_3, turbidity, dissolved oxygen, COD and BOD are however higher than permissible limits. These ones should be monitored before, during and after bitumen mining.

The toxic levels of Mn, Cu, Cr, Cd, Ni, V and As that is found in the surface water of the bitumen belt should also be monitored.

Water quality changes over time, so interpreting data based on one or two Smples is not enough. More extensive samplings should be carried out to provide additional information.

Rhizofilteration should be employed to remove toxic trace heavy metals from water bodies.

Water used in bitumen separation must be recycled to minimize the make-up water demand.

Water for depressurising must be treated/re-cycled for process re-use, or piped for deep well disposal, as applicable.

In terms of groundwater, water wells should be typically constructed using engineered stainless steel wells screens or machine-perforated liners, and can include soil or bedrock completions.

Industry-standard testing methods should be used to establish the long-term deliverability of the wells. Groundwater monitoring programs are to be implemented to prevent over-exploitation of the resource and to minimize the potential for impact to existing users. Routine well maintenance programs should be implemented to ensure an uninterrupted delivery of source water. New source water wells should be added to ensure adequate back-up supply/capacity.

There must be a federal water pollution control act as a major stimulus to improvement of water resources.

Water cleanup efforts should be directed towards prevention of pollution rather than working on the receiving bodies of water.

Wastewater should be treated on site before they are discharged into water bodies.

Water quality standards should be established for all wastewater discharges, prior to commencement of bitumen development.

Ensure that sewage treatment plants are built, throughout the duration of site preparation, construction and preparation.

Contaminated run- off or drainage water should be controlled by containment, throughout the duration of site preparation, construction and preparation.

Oil spills and leaks should be minimised by adherence to good housekeeping and good work practices, throughout the duration of site preparation, construction and preparation.

As much as possible, excavation should be carried out during the dry season or provision made for silt traps to control impact on water system.

Proper re-instatement procedures should be undertaken after backfilling exercise to maintain existing drainage pattern.

Tailings: At the time of mine closure, tailings impoundments contain huge volumes of water in storage. Such water must be released in a controlled manner, such that the quantity, duration and quality of the release falls within the range as could be specified in the project approval.

Technologies should be evaluated to minimize the volume of tailings produced.

5.3.1: Trace Heavy Metals in Plants on Explored, Seepage and Control Sites: Phytoextraction Potential

Iron, Fe

The mean amount of Fe in plants growing on explored, seepage and control sites falls far above what is recommended as the permissible limit by FAO, 5.0mg/kg. This implies that the plants on these sites are capable of accumulating very high amount of Fe. This is in contrast with the finding of Ita *et al* (2006) Fe levels in edible mushroom species (*Polyporus frondosis, Armillariella mellea, Pleurotus sapidus, Polyporus sulphureus, and Pleurotus ostreatus*) did not exceed the stipulated FAO/WHO (1976) dietary standards.

Copper, CU

The mean level of Cu in plants in the explored, seepage and control which is found to be higher than FEPA and WHO limitation guide level of 3.0mg/kg is an indication that the plants are capable of accumulating high level of Cu. This agreed with the finding of Adebiyi *et al* (2005) that Copper, which is known to be toxic metal was highly enriched (enrichment factor, EF>10) in the sand fraction samples of ondo state bituminous sands indicating its potential environmental hazards. This, however, is in contrast with the finding of Ita *et al* (2006) Cu levels in edible mushroom species (*Polyporus frondosis, Armillariella mellea, Pleurotus sapidus, Polyporus sulphureus, and Pleurotus ostreatus*) did not exceed the stipulated FAO/WHO (1976) dietary standards.

Manganese, Mn

The mean level of Mn in plants in the explored, seepage and control sites which is found to be higher than FEPA and WHO limitation guide level of 0.5mg/kg is an indication that the plants are capable of accumulating high level of Mn. This is in contrast with the finding of Ita *et al* (2006) that Mn level in edible mushroom species (*Polyporus frondosis, Armillariella mellea, Pleurotus sapidus, Polyporus sulphureus, and Pleurotus ostreatus*) did not exceed the stipulated FAO/WHO (1976) dietary standards.

Lead, Pb

The mean level of Pb in plants in the explored, seepage and control sites which is found to be higher than FEPA and WHO limitation guide level of 2.0mg/kg is an indication that the plants are capable of accumulating high level of Pb. This is in contrast with the finding of Ita *et al* (2006) Pb level in edible mushroom species (*Polyporus frondosis, Armillariella mellea, Pleurotus sapidus, Polyporus sulphureus, and Pleurotus ostreatus*) did not exceed the stipulated FAO/WHO (1976) dietary standards.

Cadmium, Cd

The mean level of Cd in plants on surface soil of bitumen explored, seepage and control sites which is found to be lower than FEPA and WHO limitation guide level of 2.0mg/kg is an indication that the metal may not be a source of potential threat to plants growing on bitumen polluted soil. The lower level of Cd in the plants on these sites which value is also lower than FEPA and WHO guideline level could be ascribed to the immobility of the metal in the soil. This possibly accounted for the small level of the metal that was accumulated by the plants on these sites. This view is supported by the findings of Akaninwor *et al* (2007) that the concentrations of Cd, Pb and Cr fell below detection limit of 0.001mg/l for all samples characteristics of effluents from a beverage company in Rivers State, Nigeria. This also agreed with the finding of Ita *et al* (2006) Cd level in edible mushroom species (*Polyporus frondosis, Armillariella mellea, Pleurotus sapidus, Polyporus sulphureus, and Pleurotus ostreatus*) did not exceed the stipulated FAO/WHO (1976) dietary standards.

Chromium, Cr

The mean level of Cr in plants in the explored, seepage and control sites which is found to be higher than FEPA and WHO limitation guide level of 0.15mg/kg is an indication that the plants are capable of accumulating high level of Cr. This agreed with the finding of Adebiyi *et al* (2005) that Cr, which is known to be toxic metal was highly enriched (enrichment factor, EF>10) in the sand fraction samples of ondo state bituminous sands indicating its potential environmental hazards.

Nickel, Ni

The mean level of Ni in plants in the explored, seepage and control sites which is found to be higher than FEPA and WHO limitation guide level of 0.5mg/kg is an indication that the plants are capable of accumulating high level of Ni. Report from Hough *et al* (2004) that Ni content of food crops was satisfactory.

Arsenic, As

The mean level of As in plants in bitumen explored, seepage and control sites is within the preferred level of <20mg/kg, as recommended by Reid and Dirou, 2004. This low level of As is an indication that the metal does not pose any environmental threat to plants growing on the soil. This finding is in contrast to the finding of Adebiyi *et al* (2005), that As, which is known to be a toxic metal, is highly enriched (enrichment factor, EF>10) in the sand fraction samples, in the bituminous sands from south-western Nigeria. Ma *et al* (2001) discovered the ability of the Chinese brack fern, P. Vittata to hyper accumulate arsenic.

Zinc, Zn

The mean level of Zn in plants in the explored, seepage and control sites which is found to be higher than FEPA and WHO limitation guide level of 75mg/kg and 10-75mg/kg respectively is an indication that the plants are capable of accumulating high level of Zn. This agreed with the finding of Adebiyi *et al* (2005) that Zn, which is known to be toxic metal was highly enriched (enrichment factor, EF>10) in the sand fraction samples of ondo state bituminous sands indicating its potential environmental hazards.This contrasted with finding of Ita *et al* (2006) Zn in edible mushroom species (*Polyporus frondosis, Armillariella mellea, Pleurotus sapidus, Polyporus sulphureus, and Pleurotus ostreatus*) did not exceed the stipulated FAO/WHO (1976) dietary standards.

The high levels of Fe, Cu, Mn, Pb, Cr, Ni and Zn found in plants growing in the bitumen belt is a reflection of the toxicological levels of the metals in the soil. This agreed with the Findings of Adebiyi *et al* (2005), that Copper, Cr, Zn, and As, which are known to be toxic metals, were highly enriched (enrichment factor, EF>10) in the sand fraction samples, in the bituminous sands from south-western Nigeria. The toxicological effect of Zn on plants is further confirmed by Burd *et al* (2000), that plant growth was inhibited by the presence of added Zn Ni and Pb. Asaah *et al*, 2005 confirmed that Mn-laden soils constitute a major health risk to the local population and a cause for concern.

But the ability of the plants on the bitumen impregnated and polluted soils to accumulate high level of metals points to the fact that the plants on these sites can be used for the phytoextractio and remediation of the heavy metals. This is in agreement with the findings of Buszewski *et al*, 2000 that the high concentration of heavy metals in soils is reflected by higher concentrations of metals in plants, and consequently in animal and human bodies. The ability of some plants to absorb and accumulate xenobiotics makes them useful as indicators of environmental pollution. Thus, they can be recommended as indicators for determination of pollution levels of the environment. Adewole (2009) confirmed the toxic metal contents of the bitumen-impacted soil and pollution level which may be induced on animals and humans interacting with each of these micro environments. In the report of Glass (1995), toxic metal pollution of waters and soil is a major environmental problem, and most conventional remediation approaches do not provide acceptable solutions. He therefore recommended phyto extraction – the use of metal accumulating plants to remove toxic metals from soil; rhizofiltration- the use of plant roots to remove toxic metals from polluted waters; and phyto stabilisation- the use of plants to eliminate the bio availability of toxic metals in soils.

Predicted concentrations of metals in the plants can be used to assess the risk of exposure to biodiversity populations from bitumen pollution.

5.3.2: Available Macro Heavy Metals in Plants on Bitumen Explored Soil and Control Site

Calcium and Magnesium

The true available Ca:Mg ratio in plants, 2:1, which is not all that different from the soluble Ca:Mg ratio in soil substrate in the bitumen belt, 2:1, will make it increasingly more easy for plants to take up potassium, which is in agreement with the findings of Reid and Dirou (2004). Dick (2009) however reported that cation ratios can help in identifying soil structure problems, and are a great tool for identifying problems, and that a better way to truly determine Ca:Mg ratio would be to measure the soluble cations in the soil and take plant tissue samples. This would help to better determine a true plant available ratio. (Ca, 915088.8mg/kg), (Mg, 8939.8mg/kg) in seepage soil were found to be higher than 75-200 and 50-150 repective permissible limits set by WHO. This is in contrast with the finding of Kinigoma (2001) who examined the effect of drilling fluid additives on the Soku oil fields environment and found that the levels of most physiochemical characteristics especially Ca and Mg were generally within the limits of guidelines by regulatory authorities.

Sodium

The range of Na in plants on bitumen explored, outcrop and control sites ranges between 20.7mg/kg and 53.30mg/kg. This level is within allowable limit of 200mg/kg set by WHO (1996).

Potassium

The values of potassium across the bitumen belt is higher than FAO (1996) permissible limit of <2. The sorption of the amount of available K in plants in bitumen explored seepage and control sites is possibly enhanced due to the optimum Ca: Mg ratio of the soils. According to the report from Agronomy Guide (2010) potassium deficiency is characterized by reduced plant growth and a yellowing and/or burning of leaf edges. Since potassium is mobile in the plant, the symptoms appear on the older leaves first.

Phosphorus

The amount of P made available for plant use in bitumen explored, seepage and control sites shows that the lower range is a little higher than what is required for tree crops, while the upper range is suitable for vegetable production, as established by Reid and Dirou (2004).

Nitrogen

The range of nitrogen in plants on bitumen explored, seepage and control sites is far above what is preferred by agronomists (10.00 mg/kg) or more in pasture soils, and a little greater than 20.00 mg/kg in horticultural crops, as established by Reid and Dirou (2004). The range is also greater than the value (25mg/kg) regarded as not objectionable by MESD (2003). This makes the plants growing especially on the explored and outcrop soils to be suitable for the remediation of heavy metals. This agreed with the early work of Gudin and Syratt (1975), that the incorporation of hydrocarbon material into soil causes an increase in microbial oxygen uptake. Competition between micro-organism and higher plants for available soil Nitrogen also occurs. It was proposed that rehabilitation of oil spill sites includes aeration of soil, addition of nitrogen and seeding with leguminous species in order rapidly to establish a mantle of vegetation. Nitrogen value was

5.3.3: Biomonitoring in Brief

Highest mean levels of lead, Chromium, Cadmium, Nickel, and Arsenic that were recorded in combinations of *Panicum laxum, Panicum maximum, Lycopodium cernuum, Calopogonium mucunoides, Pteridium aquilinium and Centrosema pubescens* that were found growing naturally in seepage site over that of control site makes the plants useful indicators of environmental pollution. The ability of these plants to absorb and accumulate the heavy metals, therefore, makes them useful as indicators of environmental pollution. Monitoring of the presence or absence of these plant ecotypes and/or plant species further makes them useful as indicator plants. For this reason they are very good instruments - biosensors - for observation of the trends in soil composition of pollutants. This is in agreement with the findings of Schmidt (2003), Meers *et al* (2005) and Chhotu and Fulekar (2009) that for heavy metal – contaminated land, low – cost, plant – based phyto extraction measures can be a key element for a new land management strategy and as an alternative remediation technology.

5.4.1: Effect of Habitat changes on Tree Composition of Ondo State Bitumen Belt

Effect of habitat changes on Tree composition of the Bitumen Belt shows that the abundance and number richness in all the habitats are significantly affected by habitat type. Seasonal changes were however found not to have any significant effect on the total number of trees and different types of species in the entire habitats. Also, the interaction of habitat type and season has no significant effect on the tree composition of the Bitumen Belt.

On abundance, cashcrop farmland was found to have the least followed in ascending order by Urban Arboreta and Island of High Forest, Riparian Habitat, Fallow Land and Arable Farmland. This agreed with the finding of Attum *et al* (2006) that areas protected from vegetation loss (such as Riparian Habitat which is a naturally protected area) did not have significantly higher vegetation richness or abundance except for only a few species. Pablo *et al* (2006) equally reported similar result on low abundance in Riparian Habitat.

On species richness, Arable Farmland has the highest species richness followed respectively by Fallow Land, Riparian Habitat, island of High forest, Urban Arboreta and Cashcrop Farmland. This agreed with the finding of Attum *et al* (2006) that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species.

5.4.2: Effect of Habitat Changes on Shrub Composition of Ondo State Bitumen Belt

The effect of habitat changes on the composition of shrub species shows that the abundance and richness are significantly affected by habitat type. Although seasonal variation significantly influenced the total number of shrubs, it did not have any significant effect on the number of different species of shrubs. This agreed with the finding of Vonesh (2001) that Herpetofaunal densities were significantly lower during the dry season than in the wet season.

The interaction of habitat type and season was also found not to have any significant effect on abundance and species richness of shrubs. This disagreed with the finding of

Barlow *et al* (2007) that there was a significant interaction between habitat and season based on richness and abundance metrics, although not based on community structure.

Arable Farmland has the highest species abundance. This is followed respectively by Urban Arboreta, Island of High Forest, Cashcrop Farmland and Fallow Land. Riparian Habitat, however, has the least abundance of shrubs species. This agreed with the finding of Attum *et al* (2006) that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species. Pablo *et al* (2006) equally reported similar result on low abundance in Riparian Habitat.

On species richness, High Forest has the highest density followed by Arable Farmland, Fallow Land and Urban Arboreta, while the least is recorded for Riparian Habitat and Cashcrop Farmland. Highest species richness in High forest could be traced to the finding of Attum *et al* (2006) that protected sites did have significantly higher percent vegetation cover and height. Pablo *et al* (2006) also reported low species richness.

5.4.3: Effect of Habitat and Seasonal Changes on Composition of Herbs in Ondo State Bitumen Belt

The relative abundance and species richness of herbaceous plants across the six habitats shows that the total number of individuals is significantly affected by habitat type and season, as well as interaction between them. For abundance of herbs, Island of High forest has the least abundance followed in ascending order by Fallow Land, Urban Arboreta, Riparian Habitat, Arable Farmland and Cashcrop Farmland. Wet season has a significant higher abundance over that of dry season. This agreed with the finding of Attum *et al* (2006) that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species. However, protected sites did have significantly higher percent vegetation cover and height

Futhermore, the species richness of herbs censused are found to be significantly affected by habitat type and seasonal variation. Interaction of the two also significantly affects the species richness of the herbs. This agreed with the finding of Barlow *et al* (2007) that there was a significant interaction between habitat and season based on richness and abundance metrics, although not based on community structure.

The least species richness was recorded for Island of High Forest. This is followed in ascending order by Fallow Land, Cashcrop Farmland, Urban Arboreta and Riparian Habitat, and Arable Farmland. This agreed with the finding of Attum *et al* (2006) that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species. Corenblit *et al* (2009) also confirmed it that riparian systems provide diverse landforms, habitats and resources for plants.

The herb species richness in the wet season is significantly higher than that of the dry season. Kokiso (2012) reported increased species richness in wet season over that of dry season.

5.4.4: Amount of Vegetation to Be Affected in Ondo State Bitumen Belt: Environmental Impact Assessment of Vegetation Cover

The vegetation of the study area is tropical rainforest. Generally, this ecological zone is made up of mixtures of trees, shrubs and herbs.

For every hectare of Arable Farmland cleared, 4000 trees will be lost, while 3200 trees will be lost in Fallow Land, 2400 in Riparian Habitat, 1600 in High Forest and 1200 in Urban Arboreta, and 1200 in Cashcrop Farmland; 3200 shrubs in AF, 2800 in UA, 3600 in High Forest, 2400 in Cashcrop Farmland, 2800 in Fallow Land and 2400 in Riparian Habitat; 60000 herbs in Cashcrop Farmland, 100000 in Arable Farmland, 70000 each in Riparian Habitat and Urban Arboreta, 50000 in Fallow Land, and 30000 in High Forest. Report from FOSA (2003) showed that currently in Africa, forests and forestry confronts a number of problems, including a rapid decline in forest cover, loss of biological diversity and a variety of unsustainable uses that cast uncertainty on the future flows of goods and services.

A total of 82 tree plant species from 29 families which are natives and 16 non-natives belonging to ten families in the bitumen belt may be lost to bitumen mining. Out of the 82 native tree species, 37 species are found in Fallow Land, 32 in High Forest, 38 in Arable Farmland, 17 in Riparian Habitat, three in Cashcrop Farmland and 9 in Urban Arboreta. Also, out of the 15 non-native tree species, three are found in Arable Farmland, one in Cashcrop Farmland and 14 in Urban Arboreta. Holding-Anyonge and Roshetko (2003) revealed that, traditionally, farmers have grown trees using local seed sources to provide products and services that support their livelihood needs and are known to be compatible with the annual crop and livestock components of their farming systems. Report from Ghersa *et al* (2002), however, indicated that the woody invasion process has reached a point at which the Pampean grasslands on the better-drained soils will no longer be restored to a grassland biome without human intervention. Land areas with higher degrees of urbanization are known to have increased numbers of woody and invasive species. Furthermore, increased woody vegetation is known to correlate with decreased density of native grassland bird species (Chapman and Reich 2007).

A total of 63 species of native shrubs belonging to 31 families will be adversely affected in the bitumen belt. Out of these, Arable farmland and Riparian habitat were found to have the highest number of different shrub species of 30 each, followed by High Forest, 28 species, Fallow Land, 26 species, while Cashcrop Farmland and Urban Arboreta both have the least number of species of 25 each. Odugbemi (2008) reported that the most serious proximate threats to biodiversity are habitat loss, habitat degradation, intensive cultivation, population pressure and over-exploitation, with large area being also cleared for the establishment of plantation trees crops, forest trees, and irrigation and livestock projects.
A total of 130 native herb species belonging to 36 families that are associated with the bitumen belt may be lost to mining of the solid mineral. Out of this number, 51 species are associated with Arable Farmland, 43 with Urban Arboreta, 35 with Riparian Habitat, 33 with Cashcrop Farmland, 30 with Fallow Land and 15 with High Forest. Six species from six families are non-native to the bitumen belt. Out of these, two species each are associated with Arable Farmland and Urban Arboreta, three with Cashcrop Farmland, and two with Riparian Habitat. Findings from Young *et al* (1996) revealed that habitat fragmentation reduces the size and increases the spatial isolation of plant populations.

The significantly higher abundance of trees and shrubs in the control site over those of seepage sites and the lower mean values of richness for trees, shrubs and herbs in seepage sites relative to that in the control are pointers to the devastating effect that bitumen mining will impact on plant abundance.

5.4.5: Potential Effect of Bitumen Development on Plant Species of Special Concern

The study area is known to contain 11 rare, threatened or endangered plant species. The varieties of rare, threatened or endangered plant species that are associated with the primary forest will decline and may even result into outright extinction, which represent the irreversible loss of unique resources of unusual value in the matter of their potential economic applications. This agreed with the ecosystem-level biodiversity indicators that are used to measure ecosystem function which indirectly include the occurrence of listed (rare) plants as described by Olson (2001).

5.4.6: Potential of Habitats to Support Plants for Traditional, Medicinal and Cultural Purposes (TMC) of Ondo State Bitumen Belt

The increased interest in alternative therapies globally and a consistent increase in the use of plant derived products as they are convenient alternatives, or complimentary to the use of orthodox or synthetic drugs has been reported by many researchers- Laird and Pierce, 2002, Schippmann *et al*, 2002, WHO, 2003, Deug and Graham, 2004, Muhammad and Amusa, 2005, Togola *et al*, 2005, Bamaiyi *et al*, 2006, Obi *et al*, 2006a, Ukaga, *et al*, 2006, Odugbemi, 2007, Agra *et al*, 2007, and Ofuya *et al*, 2007.

5.4.7: Impact of Bitumen Mining On Permanent Changes to Vegetation and Wetland Communities

Changes to vegetation:

A central question directly related to changes in landscape structure, is whether or not the reclaimed mines will support a comparable level of biodiversity to that existing prior to disturbance. Biodiversity of the baseline vegetation classes compared to the vegetation types after reclamation and closure will change where forest areas are reclaimed to non- forest areas such as swamps, riparian areas and marshes

Surface mining of bitumen will lead to loss of vegetation. 14 tree species: *Spondias mombim, Bridelia atroviridis, Bridelia micrantha, Pycnanthus angolensis, Nauclea diderichii, Afzelia africana, Piptadeniastrum africanum, Ficus exasperata, Octobolus spectabilis, Cola acuminata, Elaeis guineensis, Buchlolzia coriacea, Chrysobalamus icaco,* and *Homalium letestui* have been identified as tree key indicator species, because they were found to occur in at least three habitats out of the six habitats censured, that is, they are plant species with frequencies of occurrence in 50% and above of the habitats in this vegetational zone along the proposed bitumen belt; 27 shrub species have also been identified as key indicators.The shrub species that overlap in the bitumen belt include *Manniophyton fulvum, Alchornea cordifolia, Alchornea laxiflora*, *Casia hirsuta, Sida acuta, Chromolaena odorata*, and *Cnestis ferruginea.* Others include *Desmodium tortuosum, Dialium guineense, Icacina tricantha, Mallotus oppositifolius, Dryeptes chevailieri*, *Starchytarpheta cayennensis, Triumpheta cordifolia, Glyphia brevis, Walthera indica, Heistera parviflora, Aptandra zenkeri* and *Oncoba spinosa. Napoleona imperialis, Dichapetalum floribundum, Dichapetalum guineense, Baphia nitida, Blepharis maderaspatensis, Indigofera hirsutum, Massularia acuminata,* and *Combretum hispidum* were also found to overlap in at least three habitats out of the six habitats. 21 of the 27 shrub species were found to be associated with Fallow Land, 21 also with Riparian habitat, 20 each with Arable Farmland and Cashcrop Farmland, and 16 each with High Forest and Urban Arboreta: Out of the 136 herb species encountered in all the six habitats, the following 18 herb species were found to occur in at least three habitats –

Diplazium samattii, Mariscus alternifolius, Scleria naumaniama, Axonopus compressus, Synedrella nodiflora, Kylinga bulbosa, Mariscus flabelliformis, Panicum maximum, Perotis indica, Diodea scandens, Achyranrhes aspera, Aspilia Africana, Hewitia sublobata, Emilia coccinea, Desmodium scorpiurus, Euphorbia hyssopifolia, Commelina benghalensis and *C. Diffusa*, thus making percentage species overlap to be 13.43%. These herbaceous species are therefore identified as key ecological indicators. Thus, the key indicator species will be mostly affected by the surface excavation of bitumen because of their ecological spread over the bitumen belt. Six habitats- where the trees are found will also be seriously destroyed as described by Olson (2001).

Open cast mining of bitumen will lead to deforestation (clearing of tall trees) due to vegetation removal.

Vegetation removal will lead to loss of species diversity of forest capability due to forest fragmentation.

There may be extinction of plant species as ecosystems decreases in stability.

Extinction of species due to reduction in ecosystem complexity may contribute to the collapse of global ecosystem.

There may be a resultant effect of reduction in pollution and absorption capacity of natural systems.

Reduction in pollution and absorption capacity of natural systems may lead to increased mortality rates as a result of growing environmental degradation, which may aid the emergence of new diseases and the resurgence of old ones.

Bitumen seepage and mining will also lead to disruption, destruction and fragmentation of wetlands.

Disturbance, an event that significantly alters the pattern of variation in the structure or function of a system, and fragmentation, the breaking up of a habitat and ecosystem into smaller parcels are processes that cause land transformations, an important process in landscapes as development occurs. An important consequence of repeated, random clearing (whether by natural disturbance or human activity) is that contiguous cover can break down into isolated patches, especially when the area cleared exceeds critical level.

The destruction of the habitats, especially Riparian Habitat will affect the ability of watersheds to store and release water. The quantity of water will be reduced particularly during the dry season, while during the raining season; the quality of water will be negatively affected due to runoff. Vegetation removal will also make the volume of water to temporarily swell up, particularly during the raining season, thus, causing intense flooding from precipitation, and gradually the volume of water in the non-vegetated catchments will start to decrease. Deforestation along with water increase water yield, as the flow pattern of rivers change when the surrounding vegetation is removed as reported by Wittenberg and Sivapalan (1999) and most notably stream flow recession is more gradual with the absence of vegetation.

High Mg cation in soils in the bitumen belt may result into potassium and calcium deficiency in soils. Soils with high magnesium tend to have poor structure. Typically these soils will have more sodium cations attached to the clay as well. Having high magnesium and sodium causes the clay particles to disperse when wet and set like concrete when dry. The magnesium ions sitting on the clay surfaces have a 50%

greater hydrated radius than calcium which causes these soils to absorb more water. This excess water tends to weaken the forces that hold soil particles together resulting in less aggregate stability and greater dispersion of soil particles reducing infiltration rates and hydraulic conductivity (drainage) (Dick, 2009). This will therefore increase the erosion potential of the bitumen belt.

5.4.8: Effects of Vegetation Removal on Recreation, Aboriginal, and Other Uses

Loss of vegetation will cause landscape degradation which will affect the pristine beauty of the environment, and loss of recreational potential. This agreed with the finding of Odugbemi (2008) that the most serious proximate threats to biodiversity are habitat loss, habitat degradation, intensive cultivation, population pressure and over-exploitation.

Aboriginal people will be forcibly moved from their ancestral homes and cultural ties will be severed. The continued degradation of the environment will lead to loss of arable farmlands. This will cause severe unemployment problems, while rural poverty will be deepened. *Then, there will be widespread and intense social tensions.* Plants for traditional, medical and cultural practices will be seriously affected in the various habitats in this order - arable farmland>urban arboreta> fallow land>high forest, cashcrop farmland>riparian habitat.

5.4.9: Expected Timelines for Establishment and Recovery of Vegetative Communities and the Expected Differences in the Resulting Vegetative Community Structures

Establishment and recovery of vegetative communities is expected to take place immediately an area has been mined. But, erosion of genetic variation and increased inter-population genetic divergence due to increased random genetic drift, elevated inbreeding and reduced gene flow is expected to be reflected in the resulting vegetative community structures, because of the reduced size and spatial isolation of plant populations (Young *et al* 1996). This is in agreement with the finding of Kahmen and Poschlod (2000) that small populations of plants exhibit a reduced reproductive success which could not be attributed to genetic erosion.

Dynamics of a well-mixed population of vegetative communities prior to bitumen mining is likely to be different from those predicted for a spatially structured community as could be brought about by mining activities.

Bitumen seepage could have a major impact on the ecosystem into which it is released. The seepages could destroy plants through contamination of groundwater and soils. This coupled with the attending exploratory activities will create patches of habitats which will drive away animals and birds from their original habitats. This agreed with the finding of John (2008) that fragments of habitat are often viewed as islands and are managed as such; however, habitat fragmentation includes a wide range of spatial patterns of environments that may occur on many spatial scales. Fragments exist in a complex landscape mosaic, and dynamics within a fragment are affected by external factors that vary as the mosaic structure changes. Conservation efforts must be based on viewing fragmentation as a range of conditions that occurs in a landscape mosaic and management should be directed toward the mosaics rather than focusing solely on reserves. The changes that are made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people. These problems, unless addressed, will substantially diminish the benefits that future generations can obtain from ecosystems. The challenge of reversing the degradation of ecosystem while meeting increasing demands for services should be taken as a matter of serious concern. The bottom line is that human actions are depleting Earth’s natural capital, putting such strain on the environment that the ability of the planet’s ecosystems to sustain future generations can no longer be taken for granted.

5.4.10: Impact of Any Loss of Wetlands and Effect on Land Use, Fragmentation and Biodiversity

Wetland communities have an unusually large concentration of wildlife species which utilise these areas for either part or all of their activities. Corenblit *et al* (2009) reported that riparian systems provide diverse landforms, habitats and resources for animals and plants. Certain organisms, defined as 'ecosystem engineers', significantly create and modify the physical components of riparian systems.

Another serious effect of mining is loss of wetland habitat for wildlife. Vegetation changes that will occur when mining will be taking place will affect wetland habitat structure as well as the food supply for animals. The flowering and growth cycles of plants can be altered by the various construction activities associated with bitumen mining. Corenblit *et al* (2009) reported that riparian systems provide diverse landforms, habitats and resources for animals and plants. Certain organisms, defined as 'ecosystem engineers', significantly create and modify the physical components of riparian systems.

Studies have shown that the decline of wildlife diversity and abundance has been the result of wetland loss (Anderson, 1991).

The disruption, destruction and fragmentation of habitats and wetlands will also cause landscape degradation and loss in aesthetic value of the environment, thus limiting the recreational use of biodiversity resources and services. This agreed with the finding of Odugbemi (2008) that the most serious proximate threats to biodiversity are habitat loss, habitat degradation, intensive cultivation, population pressure and over-exploitation. Corenblit *et al* (2009) reported that riparian systems provide diverse landforms, habitats and resources for animals and plants. Certain organisms, defined as 'ecosystem engineers', significantly create and modify the physical components of riparian systems.
Variety of plant species associated with the primary wetland habitats will decline.

Mitigation

The vegetative communities so removed by soil stripping should be replanted especially with a ground cover of native plant species (on which native wildlife largely depend) using indigenous seed germplasm prior to and after commencement of mining and soon after the soil has been back - filled.

Time frame between clearing, exploitation and backfilling/revegetation should be reduced.

One of the strategies of conserving biodiversity involves placing a monetary value on biodiversity through biodiversity banking.

Botanical gardens, test plantations, and banks of seeds and plant tissue of native species in particular must be maintained in order to have diversity of plants in the wild, with the intention of growing the indigenous species for reintroduction to the ecosystem (e.g. via tree nurseries).

Ecosites that support rare species of plants should be identified and left undeveloped.

The eradication of exotic species is also an important method to preserve the local biodiversity. Exotic species that have become a pest can be identified using taxonomy and can then be eradicated.

Efforts should be made in trying to reintroduce eliminated native species back into the environment. This can be done by first determining which species were indigenous to the area, and then reintroducing them. This determination can be done using databases collected prior to bitumen development.

Rehabilitation of oil spill sites should include seeding with leguminous species in order rapidly to establish a mantle of vegetation.

The following recommendations are essential to minimize the risk to the forest posed by poorly managed deep oil sands development:

Plan should be developed for the oil sands region that describes the landscape objectives that will be met through the oil sands lease allocation and regulatory approval processes.

Proposed lease sales and project approvals should be suspended until the plan is in place.

New interconnected protected areas representative of the forested region as conservation offset measure should be established.

Quantitative limits must be established on cumulative industrial disturbances and precautionary standards for wildlife habitat, water use and release, and watershed integrity to ensure that forest values are protected.

Land management planning standard must be established to guide the development of operating plans for all resource companies working in a given management area.

Mining companies must be required to implement “best practices” to minimize environmental damage from in-situ development.

Market-based instruments (e.g. auction) should be strengthened to provide incentives to encourage the private sector or individual farmers to participate in the restoration, protection, and management of degraded land.

Decommissioning and Abandonment Phase

The mining company/ies should:

- Re-vegetate all bare areas and restore site to original land use.
- Restore land to original form as much as possible and return to indigenes.
- Return land to indigenes for other land-use.

5.5.1: Effect of Habitat Changes on Birds Composition

The reult of abundance and species richness typical of the bitumen belt indicates that they differ significantly per habitat. This agreed with the finding of Kokiso (2012) that there were variations in the bird species richness among hedgerow types. Abundance was also found to be significantly affected by season ($P<0.05$). This agreed with the finding of Kokiso (2012) that relative abundance varied during dry and wet seasons for different hedgerow types. Richness was also found to be significantly affected by season. This is in contrast with the finding of Kokiso (2012) that there were variations in the bird species richness among hedgerow types but not between seasons. Interaction of habitat type and season, however, had no significant impact on the number of individual birds and number of species. This is in contrast with the finding of Barlow *et al* (2007) that there was a significant interaction between habitat and season based on richness and abundance metrics, although not based on community structure. Williams and Middleton (2007) demonstrated that within-year climatic variability, particularly rainfall seasonality, is the most significant variable explaining spatial patterns of bird abundance in. tropical rainforest. The likely mechanism causing this pattern is a resource bottleneck (insects, nectar, and fruit) during the dry season that limits the population size of many species. They suggested that increasing climatic seasonality due to global climate change has the potential to have significant negative impacts on tropical biodiversity.

5.5.2: Abundance of Birds

For the abundance of birds across the various habitats for both dry and wet seasons, Urban Arboreta had the highest abundance followed respectively by Arable Farmland, Riparian Habitat, Fallow Land, Island of High Forest and Cashcrop Farmland. This agreed with the finding of Seymour and Dean, (2010) that bird species richness and abundance were both explained by vertical habitat heterogeneity and density of woody species between the heights of 0–2 m, with bird species richness also explained by the density of woody species at heights above 6 m. Large trees within bush-thickened areas dampened the effects of bush thickening on bird assemblages by enabling certain species to persist, consistent with the idea that large trees are keystone structures.

5.5.3: Richness of Birds

Richness of bird species was found to be highest in RH followed respectively by UA, AF, HF, FL and CF. Fallow Land, Islands of High Forest and Arable Farmland are not significantly different from one another. Arable Farmland and Urban Arboreta are also not significantly different. Urban Arboreta and Riparian Habitat are also found not to be significantly different from one another. The higher richness of birds in Riparian habitat could possibly be traced to the finding of Attum *et al* (2006) that protected sites did have significantly higher percent vegetation cover and height. Corenblit *et al* (2009) also have it that riparian systems provide diverse landforms, habitats and resources for animals and plants. Habitat protection clearly had strong effects on the reptile community as species richness and abundances were significantly higher in protected sites. The monoculture nature of cashcrop farmland may be responsible for the low richness as confirmed by Boutin *et al* (1994) that farming practices also destroy many habitats used extensively by birds that are located on the margins of cultivated areas, and the physical aspects of cash crops are similar regardless of the crop: bare earth with scattered seedlings, growing more or less densely depending on the crop. This may limit frequentation by birds, which probably find more insects and plant food in fodder crops and pastures land, where the vegetation provides habitats for insects and protection from predators.

5.5.4: Diversity of Birds

The diversity of birds was found to be highest in FL, Followed by AF, UA, HF, and RH and CF respectively. The preference of habitats in this order could be ascribed to the finding of Kokiso (2012) that thickness of habitats affected the diversity, distribution and habitat preference of birds.

5.5.5: Population Trend and Habitat Selection of Bird Species Typical of the Bitumen Belt

Abundance of bird species in the region was found to follow this trend- UA>AF>RH>FL>HF>CF. The physical aspects of Farm Fallow, FF, High Forest, HF, and Cashcrop Farmland, CF, are similar: low herbaceous abundance, richness and diversity in FL and HF, low herbaceous species richness in CF; low shrub abundance, richness and diversity in FL and CF; low tree species abundance and richness in HF, low tree species richness and diversity in CF. These might have limited frequentation by birds, which probably find more insects and plant food in Urban Arboreta, Arable Farmland and Riparian Habitat, where the vegetation provides habitats for insects and protection from predators as described in the findings of Brenda (2005), in which it was also reported that young forests provide prime habitat for upland game birds, and that in the natural environment, major vegetative disturbances occur regularly. José *et al* (2009) also confirmed that fragmentation as was observed in FL, HF and CF was the main cause of reductions in abundance of individuals. In particular, Boutin *et al* (1994) confirmed that the physical aspects of cash crops are similar regardless of the crop: bare earth with scattered seedlings, growing more or less densely depending on the crop. This may limit frequentation by birds, which probably find more insects and plant food in fodder crops and pastures land, where the vegetation provides habitats for insects and protection from predators. Schroeder *et al* (1992) observed the same phenomenon when the margins between cultivated fields (shelterbelts, hedgerows, e.t.c.) extensively used by farmland species are eliminated.

Species Richness

Richness of bird species was found to follow this trend- RH>UA>AF>FL, HF>CF.

The richness of shrub species in Arable Farmland, AF, and Urban Arboreta, UA, is similar to birds' richness. Richness of shrub species in AF and Riparian Habitat, RH, is also similar. Richness of herbaceous species in AF, RH and UA in relation to the richness of birds is also similar. How these patchy fragments of habitats –AF, UA and RH are able to support a highly rich species of birds could be attributed to a number of factors: According to Wiens (2008), Fragments exist in a complex landscape mosaic, and dynamics within a fragment are affected by external factors that vary as the mosaic structure changes. Understanding how birds respond to these complexities of fragmentation requires mechanistic studies focused on habitat selection and movement behaviour. Conservation efforts must, therefore, be based on viewing fragmentation as a range of conditions that occurs in a landscape mosaic and management should be directed toward the mosaics rather than focusing solely on reserves; Also, Schrag *et al* (2009), confirmed that species richness is positively correlated with cover of native vegetation and that bird species richness follows a gradient of temperature and precipitation with the hottest and wettest areas having the highest predicted species richness.

Species Diversity

The diversity of bird species in the habitats was found to follow this trend- FL>AF, HF, UA>RH>CF.

The diversity of tree species in Arable Farmland and Fallow Land, diversity of herbaceous species in Arable Farmland and Urban Arboreta in relation to bird's diversity in the listed habitats are similar. The factor that possibly accounted for this is the unconscious improved habitat management for birds, which possibly have been brought about by forest fires in AF, FL and UA which according to Martins *et al* (2003), encourages the growth of vigorous climax or sub-climax plant complexes, and are so beneficial to birds. The variety of herbs, shrubs and trees frequently resulting from such management could have been consistent with maintaining proper soil moisture conditions, and also provides the seasonal food and cover requirements for the bird species. Diversified plant complexes also decrease the potential for competition between the various bird species. The relationship of the various classes of birds to each other, and to the plants upon which they feed, may be highly variable and complex.

5.6.1: Relative Abundance of Animals in Ondo State Bitumen Belt

Relative abundance of animals in the Bitumen belt is shown shows that the number of individual animal abundance and species richness censured in the various habitats significantly differ from one another. This agreed with the finding of Kokiso (2012) that there were variations in the bird species richness among hedgerow types. The effect of seasonal variation on number of individual animals and number of different species is also significant. This also agreed with the finding of Kokiso (2012) that relative abundance varied during dry and wet seasons for different hedgerow types. Richness was also found to be significantly affected by season. This is, however, in contrast with the finding of Kokiso (2012) that there were variations in the bird species richness among hedgerow types but not between seasons. Interaction of the habitat and seasons, however, had no significant effect on these two parameters. This contrasted with the finding of Barlow *et al* (2007) that there was a significant interaction between habitat and season based on richness and abundance metrics, although not based on community structure. Williams and Middleton (2007) demonstrated that within-year climatic variability, particularly rainfall seasonality, is the most significant variable explaining spatial patterns of bird abundance in. tropical rainforest. The likely mechanism causing this pattern is a resource bottleneck (insects, nectar, and fruit) during the dry season that limits the population size of many species. They suggested that increasing climatic seasonality due to global climate change has the potential to have significant negative impacts on tropical biodiversity.

5.6.2: Abundance of Animals

The abundance of animals per habitat ranges is highest in Islands of High Forest, followed respectively by Riparian Habitat, Fallow Land, Arable Farmland and Cashcrop Farmland, and with Urban Arboreta. The six habitats are significantly different from one another, with the exception of Arable Farmland and Cashcrop Farmland which are not significantly different. The abundance of animals in this order could be ascribed to height and density of trees which are mostly common in Riparian Habitat and Fallow Land. Although Arable Farmland might not contain densely woody species, but, the ground cover of arable crops has make up for this. This agreed with the finding of Seymour and Dean, (2010) that bird species richness and abundance were both explained by vertical habitat heterogeneity and density of woody species between the heights of 0–2 m, with bird species richness also explained by the density of woody species at heights above 6 m. Large trees within bush-thickened areas dampened the effects of bush thickening on bird assemblages by enabling certain species to persist, consistent with the idea that large trees are keystone structures. Corenblit *et al* (2009) also have it that riparian systems provide diverse landforms, habitats and resources for animals and plants.

The abundance of animals encountered during dry season was significantly lower than that of the season. This disagreed with the finding of Barlow *et al* (2007) that secondary forest exhibited higher observed richness than primary forest only in the peak of the dry-season, but not at other times of the year.

5.6.3: Richness of Animals

Also species richness in some of the different habitats differs significantly from one another. Islands of High Forest, Arable Farmland, Fallow Land and Riparian Habitat have the highest number of species richness followed by Cashcrop Farmland, while Urban Arboreta has the least species richness. What possibly brought this about are the tall trees which are possibly common to all of them. This is in agreement with the finding of Barlow *et al* (2007) reported that secondary forest exhibited higher observed richness than primary forest in the peak of the dry-season, but not at other times of the year.

The species richness found during dry and wet seasons also differ significantly from one another, with the wet season having the higher richness. This disagreed with the finding of Barlow *et al* (2007) that secondary forest exhibited higher observed richness than primary forest in the peak of the dry-season, but not at other times of the year.

5.6.4: Diversty of Animals

The diversity of animals was found to be highest in Riparian Habitat followed respectively by Arable Farmland and Fallow Land, Cashcrop Farmland, High Forest and Urban Arboreta. The preference of habitats in this order particularly for Riparian Habitat could be ascribed to the finding of Kokiso (2012) that thickness of habitats affected the diversity, distribution and habitat preference of birds. The low diversity as found in Island of high forest and urban arboreta which are relictuals of habitats could be traced to the finding of Young *et al* (1996) that habitat fragmentation reduces the size and increases the spatial isolation of plant populations and that genetic variation may decrease with reduced remnant population size.

5.6.5: Population Trend and Habitat Selection of Animal Species Typical Of the Bitumen Belt

Animal Species abundance was found to follow this ranking-HF>RH>FL>CF, AF>UA in the habitats sampled. Animal species richness was also found to follow this trend in the six habitats-AF, RH, FL, HF>CF>UA, while species diversity followed this trend- RH>FL, AF>CF>HF>UA.

In HF, animal species abundance is highest. This could be ascribed to higher abundance and high diversity of shrub species in this habitat. The species diversity of animals found in Islands of High Forest shows that eight orders were found in the habitat. Among these orders, Rodentia has the highest number of species. This supports the finding of Keller and Schradin (2008) that the hotspots of biodiversity are important areas in facilitating an understanding of species richness and its maintenance. Herbivores can increase plant richness by reducing dominant plant species thus providing space for subdominant species. They found positive correlations between plant richness and the number of small mammal species. A general linear model revealed that the number of small mammal species was more important than abiotic factors in explaining variation in plant richness. It was concluded that small mammals can have a positive effect on plant richness in the Succulent Karoo.

In Riparian Habitat, animal species abundance and richness are higher and diversity highest; this could be linked to the high species abundance and richness of trees, high species abundance and higher species richness of herbs in Riparian Habitat. The highest species diversity of animals could be ascribed to the highest species diversity of shrubs in Riparian Habitat. Percentage composition of animals in Riparian Habitat shows that Primata has the highest composition (49.0%). Young and Metzler (2010) confirmed that one animal that is adapted to the rainforest is the howler monkey. It has many adoptions to the rainforest that help it with its everyday life.

The high animal species abundance and high species diversity in Fallow Land could be due to the higher abundance of tree species. This is in line with the finding of Brenda (2005) reported that several varieties of small mammals were at home in young forests.

The high animal species richness and diversity found in edges of Arable Farmland could be ascribed to the highest tree species richness and diversity, shrubs higher species richness and diversity, and herbs higher species abundance and highest diversity. This is in contrast with the finding of Boutin *et al* (1994) that farming practices destroy many habitats used extensively by birds that are located on the margins of cultivated areas. The elimination of farm woodlots is generally associated with a reduction in species abundance and richness.

Schroeder *et al* (1992) observed the same phenomenon when the margins between cultivated fields (shelterbelts, hedgerows, e.t.c.) extensively used by farmland species are eliminated.

The data on animal species abundance, richness and diversity showed that the abundance, richness, and diversity of plant species are very important in supporting abundance, richness and diversity of animal species. This agreed with the findings of Keller and Schradin (2008), Haddad *et al*, (2009), that abundance of small mammals in habitats do have effect on plant richness by means of herbivory, and that the hotspots of biodiversity are important areas in facilitating an understanding of species richness and its maintenance. Herbivores can increase plant richness by reducing dominant plant species thus providing space for subdominant species, and that plant diversity is predicted to be positively linked to the diversity of herbivores and predators in a food web.
The physical aspects of Cashcrop Farmland and Urban Arboreta with regards to species abundance, richness and diversity of trees are the same – lower tree abundance, richness and low diversity in Urban Arboreta, and least tree species abundance, richness and diversity in Cashcrop Farmland.

The significantly lower abundance, richness and diversity of animals recorded for Cashcrop Farmland and Urban Arboreta was probably due to the destruction and fragmentation of natural habitats. The open space created by the low tree species abundance, richness and diversity in Cashcrop Farmland and Urban Arboreta might have limited frequentation by animals, which probably find cover from predators and more plant food in High Forest, Riparian Habitat, Fallow Land and Arable Farmland. Natural and human induced disturbance, as a result of urbanisation and plantation farming could have reduced the area of suitable habitat. This agreed with the findings of Krauss *et al*, 2003, Wang *et al*, 2003, Omar *et al*, 2006, Wulff, 2008 in which they reported that habitat area was the most important predictor of animal community structure, and that the wildlife habitat pattern changes can be caused by natural and human disturbance, with the area of suitable habitat becoming smaller and more fragmented, with a deteriorated quality. They proved that spatial diversity index could reflect the habitat suitability of wildlife, and that degraded habitats reduced vegetation complexity, richness, and abundance, and consequently lower animal species richness and abundance.

5.7: Summary of Potential Impacts on Fauna Resources of Ondo State Bitumen Belt

Bush clearing will cause vegetation removal, and this will result into soil erosion that will further impoverish the soil.

Loss of vegetation will lead to destruction of plant communities.

Loss of vegetation can cause a change in successional stage which will affect wildlife species composition especially small mammals and songbirds.

Strip-mining of bitumen will result into fragmentation of vegetation.

Fragmentation of vegetation will lead to loss and degradation of primary habitats for wildlife, and consequently migration of wildlife.

Fragmentation of tropical forest through changes in the understory vegetation structure will adversely affect forest interior species of animals and birds.

Habitat fragmentation will affect food availability for birds and other wildlife.

Alteration in the micro-climate and physical environment will adversely affect understory birds due to habitat fragmentation.

Surface mining will lead to the disruption, destruction and fragmentation of wetlands used by wildlife.

45 native animal species belonging to 11 families and 78 bird species which are native to the bitumen belt, and seven non-native bird species associated with the bitumen belt will be displaced during bitumen mining.

Disruption of habitats will lead to the invasion of alien species.

Nine animals and five birds that are rare, threatened or endangered in their range in the bitumen belt will decline and may be lost forever if appropriate management measures are not instituted.

58 bird and 12 animal species which were found to overlap in the belt, with frequencies of occurrence in 50% and above of the habitats in this vegetational zone along the proposed bitumen belt, which are key indicator species will be mostly affected by the surface excavation of bitumen because of their ecological spread over the bitumen belt.

Variety of animal and bird species that are associated with the primary forest will decline and may even result into outright extinction which represents the irreversible loss of unique resources of unusual value in the matter of their potential economic applications.

Loss of unique animal and bird species due to habitat alterations will reduce the potential aesthetic and consequently economic applications of the biodiversity for recreation and tourism. Elliot and Mwangi, 1998, confirmed that the potentially largest source of benefits to rural people from wildlife is wildlife based tourisms, including trophy hunting.

Acid precipitation, a secondary pollution, may have direct and indirect effects on terrestrial and aquatic ecosystems such as injury to foliage such that animals are not able to feed well, leaching of nutrients from plants and soil, and elimination of certain plant and animal species.

Acid precipitation can also alter habitats so that new communities develop.

Acid rain will also reduce forest growth, cause erosion of the cuticles of leaves, and leaching of nutrient salts from the soil, all of which will have a long-term effect on wildlife via the food chain.

Changes in water quality resulting from the introduction of toxic materials can affect terrestrial wildlife, when some minerals form complex interactions, with prolonged exposure to wildlife. When these minerals are in excess of the critical limits set by FEPA and WHO, they may result into chronic effects on animal health. But, minimal and tolerable levels which, however, accumulate in the bodies of the animals may result into acute effects.

In some pits, birds and mammals may become stuck in the oily substance and die.

5.8: Human Population and the Availability of Species for Traditional Use in Ondo State Bitumen Belt: Impacts and Interaction

The project is expected to cause human population explosion, because there will be influx of people into the area. This will put pressure on wildlife use;

Population growth will also increase the degree of harassment of wildlife resources;

This will also increase secondary matters such as changes in water quality and quantity due to anthropogenic influences;

Human accessibility to previously remote areas may have significant impact on wildlife species because of great encounters with people.

Creation of access roads during the development process may result into vehicular collision with wildlife. Many animals will perish when roads block traditional movement routes. Also, daily and seasonal movement of animals may be blocked by access routes.

Many of the animals used traditionally for medical purposes will, therefore, decline due to habitat loss and changes in structural composition of forests, avoidance of relictual habitats, road-kills and secondary impacts, as well as non-aboriginal hunting which will put pressure on the availability of animals for traditional use.

5.9: Availability of Species for Traditional Use in Ondo State Bitumen Belt

The elimination of habitats may be associated with a reduction in species abundance and richness with the most important local factor affecting abundance being temporal change in forest vegetation structure, resulting from natural forest succession and local disturbances. The destruction and fragmentation of natural habitats is the major reason for the decreasing biodiversity in the agricultural landscape. Species richness generally declined with increasing disturbance. Loss of populations may negatively affect biotic interactions and ecosystem stability according to the findings of Boutin *et al* (1994), Herkert (1994), Lawton *et a*l (1998), Steffan-Dewenter and Tscharntke' (1999) and, Richard and Thomas (2001). Diamond (1989) confirmed that many wildlife species such as eagles, hawks and their feathers have great cultural and spiritual value and significance to the culture of native people, and they and their products may be used as sacred objects in religious rituals. Bush meat as an important source of human benefits may be harvested through informal and illegal activities, particularly via non-aboriginal hunting pressure, (Caspary, 1999).

Wildlife has been an essential part of human culture for at least 12,000 years. Prehistoric occupants hunted wild animals for food, and used the by-products for clothing, shelter, and tools. In modern times, game has become a major recreational, aesthetic and economic asset, while a large portion of the world population (more than 85%) especially in developing countries depend on traditional systems of medicine for treatment of a variety of diseases. This has been attributed to inaccessibility of modern drugs to many people in the rural areas, and the economic factor (WHO, 1993).

Human harvest of animals in the wild occurs in terrestrial and aquatic habitats throughout the world and is often intense. Harvest has the potential to cause three types of genetic change: alteration of population subdivision, loss of genetic variation, and selective genetic changes, with population growth and human development resulting in biodiversity loss and biological homogenization (Allendorf *et al*, 2008; Jose *et al*, 2009).

Mitigation

Vegetation clearing should be restricted to leased belt and narrow strips needed for development and safety of operations, prior to onset of site preparation.

Alien or exotic animal species should be eliminated from the land by frequent inspection, during operation.

Many species will need to migrate at certain times of the year, requiring a connection to other regions. This would mean that wildlife corridors need to be made. This would still be considerably cheaper and easier than clearing/preserving entirely new areas.

Stress Reduction

Noise should be reduced by developing parks and wilderness areas. In urban areas, parks are usually edge communities.

Plans should be made to extract bitumen from one area before moving to another.

Plans should also be made to reduce use of roads to reduce wildlife stress.

Noise can also be reduced by concentrating activities in one area.

Seismic activity or blasting should be prevented near calving ranges or during raptor nesting.

Plans should be developed to encourage developers to leave raptor nests and other unique wildlife regions isolated.

Understanding how birds respond to complexities of fragmentation requires mechanistic studies focused on habitat selection and movement behaviour. Conservation efforts must, therefore, be based on viewing fragmentation as a range of conditions that occurs in a landscape mosaic and management should be directed toward the mosaics rather than focusing solely on reserves.

Developers, hunters, and landowners should be educated on how they can maximise benefits from wildlife.

Enforce "no hunting of game animals" during site preparatory activities.

Areas that are particularly important to wildlife such as migratory corridors, raptor nesting sites; dry season range should be delineated and marked as critical to wildlife.

To sustain the productivity of displaced populations, it is crucial to incorporate genetic considerations into management. Nevertheless, it is not necessary to disentangle genetic and environmental causes of phenotypic changes to develop management plans for individual species.

Variety of habitats (drainage ditches, old fields, hedgerow, small woodlots, and isolated trees) which helps to increase species diversity should be taken into account during project development phase.

Sensitive habitats such as riparian habitats which are extremely sensitive to alteration because they contain restricted habitats of wildlife species such as **Afr. Long tail hawk, African Monkey Eagle, Pel's fishing owl, Pigmy kingfisher, Red river hog, Water buck, White- throated guenon, Swamp monkey, Dwarf guenon, White-nosed guenon, Baboon, Turtle, Python and Alligator** should be left undeveloped**.**

Very tall trees used by raptors should be left undestroyed.

Tall shrubs used for nesting, source of food and cover by birds should also be left undestroyed.

Excess land take should be avoided and bush clearing minimized during site survey.

Control the suspended particles in the run-offs, and wet grounds to reduce dust.

Time frame between clearing trenching, pipe-laying, and backfilling/revegetation should be reduced.

All bare areas should be re-vegetated and site restored to original land use.

Land should be restored to original form as much as possible and return to indigenes for other land-use.

5.10: Population Trends and Habitat Selection of Bird Species Typical Of the Bitumen Belt

The important factors that possibly influenced the highest abundance and higher richness and diversity of birds in Urban Arboreta were the higher abundance of shrub species and high shrub richness, high herbaceous species richness and higher herbaceous species diversity which are useful in meeting food and cover needs of wildlife and birds especially in the migratory and dry season periods as described in the previous work of Richard and Thomas (2001). Here, taller herbs provide better cover for wildlife than short herbs. The residual native herbs, shrubs and trees found in channels dug at the sides of roads to take away water, fence rows and waste areas in UA possibly contributed to the species abundance, richness and diversity of birds in UA. Also native plant species that are abundant in this habitat are essential items for the survival of many wild species. Vigorous, palatable shrubs are especially required and used extensively by birds during all seasons of the year for food and cover.

Even with the nature of habitat patches and reclictuals that are associated with the urban setup as a result of various developments, bird species abundance, richness and diversity were still higher than the other five habitats. This may be so because Wiens, (2008) reported that fragments of habitat are often viewed as islands and are managed as such; however, habitat fragmentation includes a wide range of spatial patterns of environments that may occur on many spatial scales. Also, wildlife reacts favourably to a diversification of plant communities and species that provide a maximum variety of food and cover choices within a minimum area.

In Arable Farmland, the factors that possibly influenced the higher abundance, high species richness and higher species diversity of birds were the highest abundance, richness and diversity of tree species.

In Riparian Habitat, the factors that possibly accounted for the high abundance and highest species richness of birds were higher abundance and high species richness of tree.

5.11: Population Trend and Habitat Selection of Animal Species Typical Of the Bitumen Belt

In HF, animal species abundance and species richness is highest, while species diversity is high. This could be ascribed to high tree species diversity in the habitat, higher abundance and high diversity of shrub.

In Riparian Habitat, animal species abundance and richness are higher; this could be linked to the high species abundance and richness of trees, high species abundance and higher species richness of herbs in Riparian Habitat. The highest species diversity could be ascribed to the highest species diversity of shrubs in Riparian Habitat.

The high animal species abundance in Fallow land could be due to the higher abundance of tree species.

The high animal species richness and diversity found in Arable Farmland could be ascribed to the highest tree species diversity and richness, shrubs higher species diversity and richness, and herbs higher species abundance and highest diversity.

The data and observation on animal species abundance, richness and diversity showed that the foraging activities of herbivores could have increased plant richness by reducing dominant plant species, thus, providing space for subdominant species as found in the findings of Keller and Schradin (2008), Haddad *et al* (2009) in which they also reported that the hotspots of biodiversity are important areas in facilitating an understanding of species richness and its maintenance.

The physical aspects of Cashcrop Farmland and Urban Arboreta with regards to species abundance, richness and diversity of trees are the same – lower tree abundance, richness and low diversity in Urban Arboreta, and least tree species abundance, richness and diversity in Cashcrop Farmland.

The significantly lower abundance, richness and diversity of animals recorded for Cashcrop Farmland and Urban Arboreta was probably due to the destruction and fragmentation of natural habitats. Loss of populations may have negatively affected biotic interactions and ecosystem stability. The open space created by the low tree species abundance, richness and diversity in Cashcrop Farmland and Urban Arboreta could have limited frequentation by animals, which probably find cover from predators and more plant food in High Forest, Riparian Habitat, Fallow Land and Arable Farmland. Natural and human induced disturbance, as a result of urbanisation and plantation farming could have reduced the area of suitable habitat with the possible effect of habitats becoming smaller and more fragmented as described in the findings of Krauss *et al* (2003), Wang *et al* (2003), Omar *et al* (2006) and Wulff (2008), in which they also reported that habitat area was the most important predictor of animal community structure which have influence on habitat specialists more than habitat generalists, and that the wildlife habitat pattern changes can be caused by natural and human disturbance, with the area of suitable habitat becoming smaller and more fragmented, with a deteriorated quality. They proved that degraded habitats reduced vegetation complexity, richness, and abundance, and consequently lower animal species richness and abundance

5.12: Abundance and Richness of Fauna Resources on Bitumen Seepage sites and Control

Results show that the mean value for the abundance of animals in seepage sites is not significantly different between seepage and the control site, while richness was found to be significantly higher in the control site than those of the seepage sites. Abundance and richness for birds are significantly higher in the control site than those of seepage sites. These are further confirmations of effect of degradation and fragmentation that bitumen mining will have on species abundance and richness of animals.

5.13: Ranking of Ecological Unit for Biodiversity Abundance Potential in Baseline Site of Ondo State Bitumen Belt

The relative abundance of biodiversity in each ecosite was discovered to be highest in arable farmlands, followed respectively by Riparian Habitat, RH, Urban Arboreta, UA, Cashcrop Farmlands, CF, islands of High Forest, HF and Fallow Land, FL. This agreed with the finding of Tattersall *et al* (2002) that farmland is readily divisible into linear habitats such as hedges, and non-linear habitats such as fields and woodlots and that there was no evidence that specialists avoided linear habitats. Result of their study showed that the field boundary was the most species-rich habitat surveyed. Their results suggest that on uncropped land such as set-aside, the linear or non-linear character of habitats will make little difference to small mammal abundance and diversity. Corenblit *et al* (2009) also confirmed it that riparian systems provide diverse landforms, habitats and resources for plants. In the case of UA, Attum *et al* (2006) also found out that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species.

5.14: Ranking of Ecological Unit for Biodiversity Richness of Biological Resources in Baseline Site of Ondo State Bitumen Belt

The observed and estimated species richness for each ecosite phase is expected to follow this trend-AF>RH>FL, HF>UA>CF. This agreed with the finding of Tattersall *et al* (2002) that farmland is readily divisible into linear habitats such as hedges, and non-linear habitats such as fields and woodlots and that there was no evidence that specialists avoided linear habitats. Their result revealed that the field boundary was the most species-rich habitat surveyed. Their results also suggest that on uncropped land such as set-aside, the linear or non-linear character of habitats will make little difference to small mammal abundance and diversity. Corenblit *et al* (2009) also confirmed it that riparian systems provide diverse landforms, habitats and resources for plants. Attum *et al* (2006) also found out that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species.

5.15: Ranking of Ecological Unit for Biodiversity Diversity of Biological Resources in Baseline Site of Ondo State Bitumen Belt

The diversity of biological resources reveals that biota in the various habitats are diversified in this order- AF>FL>RH, UA>HF>CF. This agreed with the finding of Tattersall *et al* (2002) that farmland is readily divisible into linear habitats such as hedges, and non-linear habitats such as fields and woodlots and that there was no evidence that specialists avoided linear habitats. Their finding showed that the field boundary was the most species-rich habitat surveyed. Their results suggest that on uncropped land such as set-aside, the linear or non-linear character of habitats will make little difference to small mammal abundance and diversity. Corenblit *et al* (2009) also confirmed it that riparian systems provide diverse landforms, habitats and resources for plants. Attum *et al* (2006) also found out that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species.

5.16: Biodiversity on Baseline Sites That Are Representative of the Proposed Reclamation Ecosites of Ondo State Bitumen Belt

The measurable levels of abundance, richness and diversity of biological forms in the following baseline sites: plantation farmlands, arable farmlands (edges), riparian habitats, urban arboreta, farm fallow and islands of high forest is expected to follow this trend- AF>RH>UA>FL>HF>CF representing the levels of biodiversity expected in the reclamation ecosites. The case of AF and RH agreed with the finding of Tattersall *et al* (2002) and Corenblit *et al* (2009). In the case of UA, Attum *et al* (2006) found out that areas protected from vegetation loss did not have significantly higher vegetation richness or abundance except for only a few species.

5.17: Potential Effects of Fragmentation on Biodiversity Resources in Ondo State Bitumen Belt; Abundance of Biodiversity in Bitumen Seepage sites and Control

The result of relative abundance of biodiversity in bitumen seepage sites and control reveals that, values for abundance of each of animals and herbs are not significantly different between bitumen seepage sites and that of control. However, abundance for birds, trees and shrubs are significantly higher in the control site than those of seepage sites. Somerfield *et al* (2008) reported that, indices are used to quantify change in environment by reducing aspects of environmental complexity to numbers. Biodiversity indices are typically calculated using the numbers of species and their relative abundances. With this, results of this study agreed with the finding of Young *et al* (1996) that habitat fragmentation reduces the size and increase the spatial isolation of plant populations. Andren (1994) also confirmed that habitat fragmentation implies a loss of habitat, reduced patch size and an increasing distance between patches, but also an increase of new habitat and that as the proportion of suitable habitat decreases in the landscape, area and isolation effects start influencing the population size of the species. Hence, the relative importance of pure habitat loss, patch size and isolation are expected to differ at different degrees of habitat fragmentation. FOSA (2003) reported that currently in Africa, forests and forestry confronts a number of problems, including a rapid decline in forest cover, loss of biological diversity and a variety of unsustainable uses that cast uncertainty on the future flows of goods and services. Diniz *et al* (2010) further confirmed that anthropogenic changes in the landscape result in an environmental mosaic with serious consequences for biodiversity. Therefore, anthropogenic alterations in landscape determined the impoverishment of plant assemblages and therefore of insect assemblages, because of the positive relationship between host plant richness and insect richness. Seymour and Dean, (2010) knocked this fact home that land use management practices often change habitat structure, which in turn influence diversity and the composition of floral and faunal assemblages.

5.18: Potential Effects of Fragmentation on Biodiversity Resources in Ondo State Bitumen Belt; Richness of Biodiversity on Bitumen Seepage sites and Control

The result of richness of biodiversity in bitumen seepage sites and control shows that the mean values for each of birds, animals, trees, shrubs and herbs are lower relative to that in the control. Richness for birds, animals, shrubs and herbs were, however, found to be significantly higher in the control site than those of the seepage sites. This agreed with the finding of Wang *et al* (2003) that wildlife habitat pattern is affected by natural and human disturbance. The result of this study also agreed with the finding of Blair (2004) that species richness and diversity of birds increase at moderate levels of urbanization, and decrease with high levels of development. José *et al* (2009) confirmed that population growth and human development result in biodiversity loss and biological homogenization and that in terms of species-specific responses of biodiversity to habitat degradation, a rapid process of homogenization can be expected, resulting in only a few winner species within a general scenario of losers. Schrag *et al* (2009) also confirmed that land use drive biodiversity patterns at large scales. Changes in the variable conversion of land to agriculture, will lead to broad-scale changes in species patterns at regional scales.

Pollution breakdown and absorption capacity of natural systems will be affected negatively, thereby reducing capacity of biodiversity in dealing with human wastes.

Environmental degradation may result in increased mortality rates which may aid the emergence of new diseases and resurgence of old ones.

Fragmentation of biodiversity may result in unfavourable climate alterations.

Watersheds will be fragmented and their ability to naturally capture, store and release water may be reduced.

Fragmentation may also result in loss of species diversity of forest capability.

It may also create habitat patches that will further reduce the contiguity of habitats, which will reduce seeds dispersal and natural regulation of plant and animal populations.

It may cause landscape degradation and loss in aesthetic values of biodiversity resources and services, thereby reducing the potential for ecological tourism.

Habitat degradation may result into outright extinction of animal and plant species of touristic potential.

Variety of plant and animal species associated with the primary forest may decline and even result into outright extinction which represent irreversible loss of unique resources of unusual value in the matter of their potential economic applications.

Fragmentation may even result in the alteration of the earth' s albedo, and increase carbondioxide in the atmosphere thereby creating green house effect.

Small and isolated populations, which occur in ecologically marginal habitats, may show decreased reproductive output due to altered pollinator interactions or the absence of specialized pollinators.

Small and isolated populations are expected to suffer from genetic erosion and increasing genetic divergence among populations, through the effects of random genetic drift, increased levels of inbreeding and reduced gene flow, potentially leading to reduced possibilities of population recovery in the future.

Habitat fragmentation may reduce the size and increases the spatial isolation of plant populations. Such changes will be accompanied by an erosion of genetic variation and increased inter-population genetic divergence due to increased random genetic drift, elevated inbreeding and reduced gene flow.

Mitigation

10% per year felling regime of vegetation should be carried out, to provide a more sustained income and to ensure that non-timber benefits are retained.

Indigenous seed germplasms should be collected and preserved to be used in the revegetation so as to rapidly restore the environment to its original state.

Wildlife corridors in fragmented habitats should be bridged so as to increase population of biodiversity.

Watersheds, areas that naturally capture, store and release water, because of their richness in biodiversity, and most importantly because of their reduced and patch size should be left unexploited no matter the richness in bitumen.

Because riparian systems provide diverse landforms, habitats and resources for animals and plants, they should be left undeveloped.

Ecologically marginal habitats, because of the small and isolated populations that they contain should as much as possible be left unexploited.

In particular, the country' s environmental laws should be strictly enforced to protect the wetlands.

Deforested land should be reforested immediately before exploitation of any other place.

Regarding environmental restoration, all critical habitats that have been degraded should be rehabilitated to the highest possible level of productivity and biodiversity.

Government should intervene through appropriate legislation to compel mining company to internalise the reparation and replacement costs for environmental damage which will be external to the company.

5.19: Summary and Conclusions

With the relative size distributions of sand in the soil of the bitumen belt, the soil can therefore, be classified as sandy-loam. The lower clay content of the soils is an indication of the low CEC of the soils. The pH, C:N ratio, Ca^{2+}, Ca:Mg ratio, exchangeable acidity and CEC of the soil are generally lower that the optimum recommended rates, an indication that the soil is acidic, and has poor ability to hold nutrients (Ca, Mg and K). Soil acidification degrades land, lowers crop productivity and increases soil vulnerability to contamination and erosion. But, the high rate of mineralization and rapid decomposition of organic matter have possibly compensated for the nutrient loss.

The organic carbon content, nitrogen, phosphorus, Mg^{2+} of the soil in the bitumen belt are higher than FEPA critical limits. Na^{+} and K^{+} are within the optimum required for plant growth.

Low pH, Ca^{2+}, Ca: Mg ratio, CEC and high Mg^{2+} could negatively affect the availability of plant nutrients. But, low C:N ratio, high organic carbon, nitrogen and phosphorus were able to enhance the capacity of soil to sustain plant and animal productivity through rapid decay and mineralization in the soil, which underlies all ecosystems to provide their resources (e.g. freshwater; food; pharmaceutical products; timber; paper; resin and; fibre) and services (e.g. purification of air water, soil; protection of water catchments; preservation of natural scenic beauty; protection of biological resources for conservation, research and scientific purposes; sequestration of pollutants; climate stability (both global CO_2 sequestration and local; pollination; prevention of erosion; recycling nutrients and; providing fertile soils). Nutrients supplied from soil organic matter (OM) decomposition in particular (such as nitrogen) depend more on the rate of OM decomposition than on extractable levels of these nutrients.

Ecological processes influence the extent, distribution and biodiversity of systems. If primary production declines, energy flow to higher trophic level is diminished, potentially compromising the sustainability of animal populations dependent on plants for food. Primary production is influenced by the availability of nutrients. Decreases and increases in nutrients can affect the amount of primary production as well as the types of plants that grow with subsequent effect on animals. The successful reproduction of plants and animals depends on the physical and chemical regimes of their environment, which could be seriously impacted upon by bitumen seepage.

Surface water on which wildlife depends has its lower range of $NO_{3,}$ pH, and turbidity falling below FEPA and WHO recommended standard, while the upper range is higher than FEPA, but, lower than WHO recommended standard. The levels of $NH_{3,}$ COD and BOD, in water across the bitumen belt were found to be higher than recommended levels. The levels of TDS, TSS, temperature, electrical conductivity, and dissolved oxygen in surface water in all locations across the bitumen belt all fell far below the FEPA recommended standard levels. Seepage sites had significantly highest mean values of Sulphur, Sulphate, Chemical Oxygen Demand and Turbidity, in surface water than that of control.

Manganese, copper, chromium, and arsenic levels in surface water across all locations sampled were found to be higher than FEPA and WHO recommended critical levels. Iron, zinc, lead, cadmium, nickel level across all location in the bitumen belt were found to be lower than FEPA and WHO recommended critical levels. Copper, cadmium and nickel were, however, found to be higher than WHO limitation levels. There was high concentration of heavy metals in soils due to bitumen contamination as reflected by higher concentrations of Pb, Cr, Cd, Ni and As in the six most commonly occurring plants - *Panicum laxum, Panicum maximum, Lycopodium cernuum, Calopogonium mucunoides, Pteridium aquilinium and Centrosema molle* on bitumen seepage sites over control site of the study area. The ability of these plants to absorb and accumulate heavy metals makes them useful as indicators of environmental pollution.

This study proves that plants found growing naturally on bitumen contaminated soils accumulate heavy elements in assimilation tissues. Thus, they can be recommended as indicators for determination of pollution levels of the environment. Harvesting the plant shoots can permanently remove these contaminats from the soil, thus cleaning up and helping at the same time to stabilise contaminated environments. This is a fast emerging technlology that is known as phytoextraction. This potential remediation strategy that involves the use of plants to extract heavy metals from contaminated soil can also make use of the plants to cover the soil, and erosion and leaching will thus be reduced. With successive cropping and harvesting of the plants, the level of the contaminants in the soil will be reduced.

The heavy metals could contribute to a variety of toxic effects on biodiversity in food chain through bioaccumulation and bio-magnification. The pollution of soil and water with heavy metals is a major environmental concern today. Metals and other inorganic contaminants are among the most prevalent forms of contamination found around geological areas and from anthropological sources.

In the baseline site, abundance and richness of trees, shrubs, herbs, birds and animal species are significantly affected by habitat type ($P<0.05$). The effect of seasonal variation on abundance and richness of herbs, birds and animals is also significant ($P<0.05$). Interaction of habitat and seasons, however, had no significant effect on abundance and richness of trees, shrubs, birds and animals ($P>0.05$), but, is significant for herbs ($P<0.05$).

Mean population (abundance) for trees, shrubs and birds in bitumen polluted site was significantly lower than control. Mean number of different species (richness) for shrubs herbs, birds, and animals in seepage site were significantly lower than that of control. Loss of original habitat, formation and eventual reduction in habitat patch size and increasing isolation of habitat patches, all of which are consequences of bitumen seepage could have contributed to a decrease in species diversity, abundance and richness. Patch, a term fundamental to landscape eclology is a relatively homogenous area that differs from its surrounding. Patches have a definite shape and spatial configuration, and can be described compositionally by internal variables such as number of trees, number of tree species, or other similar measurements. Decrease in species abundance could also have been brought about by contamination of groundwater and soil through bitumen seepage.

5.20: Recommendations/Management Plans

Mitigation measures which have been should be defined for the identified significant associated and potential impacts based on the following criteria should be enforced:

Prevention - design and management measures for ensuring that significant potential impacts and risks do not occur.

Reduction - Operational and management measures for ensuring that the effects or consequences of those significant associated and potential impacts that cannot be prevented are reduced to a level as low as reasonably practical.

Control - Operational and management measures for ensuring that residual associated impacts are reduced to a level as low as reasonably practical.

Fresh Water Source

Potential water sources must be evaluated with a preferred source for the development. Water storage should also be considered as a potential contingency.

Genetic Change

Some genetic change due to harvest and land degradation is inevitable. Management plans should be developed by applying basic genetic principles combined with molecular genetic monitoring to minimize harmful genetic change.

Consultation Process /Socioeconomic Benefits

Mining company should utilize and build upon socioeconomic information gathered from other operators and industry associations, along with input from public consultation process to assess the socioeconomic impacts and benefits of this project. Benefits are expected to include:

Huge amount of money should be invested to develop the Oil Sands Project (bitumen), which should be largely spent in the bitumen belt, and across Nigeria.

Post-Operation/Mine Reclamation

Mature oil sands projects have immense footprints, and these projects include unique environmental and cultural challenges respecting mine closure, reclamation and abandonment. As such, environmentally acceptable and technically viable programs have to be prepared that address both the operational and post-operational phases of the projects. Long-term implications and impacts on local and regional groundwater resources have to be assessed and quantified, where possible.

Additionally, at the time of mine closure, tailings impoundments contain huge volumes of water in storage. Such water must be released in a controlled manner, such that the quantity, duration and quality of the release falls within the range specified in the project approval. Groundwater monitoring and management programs should be implemented to ensure that when aforementioned occurs, with deviations investigated, they should be mitigated as required.

Reclamation of disturbance to facilitate species movement through key habitat, such as marshes, is a mitigation measure intended to restore species flow essential to ecosystem function and overall biodiversity following project operations. The ecosystem-level biodiversity indicators that are used to measure ecosystem function (such as species flow) indirectly are the diversity and abundance of vascular, non-vascular plants and vertebrates, the occurrence of listed (rare) plants and vertebrates. These indicators are to be measured on reclaimed landscapes in regional monitoring programmers funded by project proponents.

For the reclamation of terrestrial vegetation there should be strategies to attain ranges of biodiversity similar to pre-disturbance values. One approach is that closure landforms should be "spatially variable" such that a range of ecosystems becomes established. Other strategies are preservation of refugia within mining areas and ensuring species native to the area are used in reclamation.

Restoration/Reinstatement

Correct construction techniques should be employed to guard against any longterm restoration problem, i.e. soil erosion. The success of any restoration process is measured by the similarity of the vegetation and firmness of the soil on the restored land to that of its surroundings.

Phyto-Remediation

Mining of bitumen could affect soil, water and plants as well as having longer harmful effects which may reduce biodiversity. The six most commonly occurring plants that were found growing naturally on bitumen seepage site are recommended for soil remediation to return the soil to a condition of ecological stability together with the establishment of plant communities it supports prior to disturbance when bitumen mining eventually commences.

Toxic metals in plants naturally growing on bitumen polluted soil indicate their potential environmental hazards. This calls for proper management of the tailings that will be produced during the exploitation of the bituminous sands.

Predicted concentrations of metals in the plants can be used to assess the risk of exposure to biodiversity populations from bitumen pollution.

Chelation can also be employed to use soil organic matter to reduce availability of heavy metals.

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APPENDICES

Appendix 1. Chemical Properties of Bituminous Tar and Associated surface soil of Ondo State Bitumen Belt

Variable	Mean		t – value	df	P	S. D.	
	Tar	Soil				Tar	Soil
PH (KCL)	3.0	3.1	-0.1	2	0.9	0.6	1.4
PH (H2O)	2.8	4.3	-1.9	2	0.2	0.1	1.1
Org. C(mg/kg)	109.1*	20.8*	4.4*	2*	0.1*	8.1*	27.2*
Total N(mg/kg)	27.4*	9.9*	7.6*	2*	0.0*	3.3*	0.3*
C:N ratio	4:1	2:1					
Av. P(mg/kg)	0.8	0.4	1.0	2	0.4	0.2	0.5
Ca(meq/100g)	1.3	1.3	0.3	2	0.8	0.1	0.4
Mg(meq/100g)	0.8	0.7	0.3	2	0.8	0.1	0.1
Ca:Mg ratio	2:1	2:1					
Na(meq/100g)	0.1	0.1	-1.0	2	0.4	0.0	0.0
K(meq/100g)	0.2	0.2	0.8	2	0.5	0.0	0.0
Ex. Ac(meq/100g)	59.4*	2.1*	28.5*	2*	0.0*	2.6*	1.3*
C.E.C(meq/100 g)	60.0*	4.3*	44.7*	2*	0.0*	0.2*	1.8*
Base Sat(meq/100g)	611.3	536.1	0.3	2	0.8	344.2	107.0

NB: Marked mean values are significant at P < 0.05

Appendix 2. Physical Properties of Bituminous Tar and Associated Surface Soil of Ondo State Bitumen Belt

Variable	Mean (g/kg)		t – value	Df	P	S. D.	
	Tar	Soil				Tar	Soil
Sand	957.5*	892.0*	12.0*	2*	0.0*	7.8*	0.0*
Silt	27.0*	94.0*	-9.61*	2*	0.0*	9.9*	0.0*
Clay	15.5	14.0	1.0	2	0.4	2.1	0.0
Gravel	115.7	132.9	-0.5	2	0.7	14.9	46.7

NB: Marked mean values are significant at P < 0.05

Appendix 3. Chemical Characteristics of Surface Soils in Bitumen Seepage Sites of Ondo State Bitumen Belt

Chemical Property	**Mean**		**t-value**	**df**	**P**	**SD**	
	Seepage Site	Control Site				Seepage site	Control Site
PH(KCl)	3.1	3.9	-1.84	6	0.42	0.8	0.2
PH(H_2O)	4.3*	5.8*	-4.17*	6*	0.04*	0.7*	0.2*
Organic Carbon(mg/kg)	20.8	15.7	0.63	6	0.38	15.8	1.9
Total Nitrogen(mg/kg)	9.9*	3.8*	6.35*	6*	0.13*	1.9*	0.4*
C:N	4:1	4:1					
Phosphorus(mg/kg)	0.4	0.1	1.88	6	0.12	0.3	0.0
Calcium (meq/100g)	1.3	1.2	0.50	6	0.53	0.3	0.0
Magnesium (meq/100g)	0.7	0.7	2.00	6	0.35	0.1	0.1
Ca:Mg ratio	2:1	2:1					
Sodium (meq/100g)	0.1	0.1	0.00	6	1.00	0.0	0.0
Potassium(meq/100g)	0.2	0.2	0.50	6	0.53	0.0	0.0
Exchangeable Acidity(meq/100g)	1.9*	0.4*	3.27*	6*	0.73*	0.9*	0.0*
CEC(meq/100g)	4.3*	2.5*	3.57	6*	0.08*	1.0*	0.1*
Base saturation(meq/100g)	919.6	840.6	2.45	6	0.29	34.8	32.2

NB: Marked mean values are significant at $P < 0.05$

Appendix 4. Heavy Metals in Bituminous Tar and Seepage Surface Soils of Ondo State Bitumen Belt

Variable	Mean(mg/kg)		t- value	df	P	**SD**	
	Surface soil	Bituminous tar				Surface soil	Bituminous tar
Mn	805.0*	610.0*	2.0*	5*	0.1*	136.1*	140.0*
Fe	990.3*	760.0*	2.5*	5*	0.1*	115.3*	160.0*
Cu	139.6*	200.0*	-0.3*	5*	0.8*	73.5*	20.0*
Zn	219.7*	250.0*	0.0*	5*	1.0*	105.4*	50.0*
Pb	8.5	10.0	0.4	5	0.7	3.3	0.0
Ni	13.1	10.0	0.4	5	0.7	8.7	0.0
As	4.0	10.0	-0.1	5	0.9	2.4	0.0
Cr	10.3	10.0	1.9	5	0.1	0.7	0.0

V	7.7	6.0	2.7	5	0.0	1.0	0.0
Cd	2.6	4.0	-0.8	5	0.5	1.1	0.0

NB: Marked mean values are significant at $P < 0.05$

Appendix 5. Trace Heavy Metals in Surface Soil in Bitumen Seepage and Control Sites

HO: there is no significant difference between seepage and control sites

Taxa	**Mean Mg/Kg**		**t-value**	**df**	**P**	**SD**	
	Seepage Site	Control Site				Seepage Site	Control Site
Mn	805.0*	1129.5*	-2.6*	6*	0.1*	136.1*	208.1*
Fe	990.3*	300.0*	8.6*	6*	0.0*	115.3*	84.2*
Cu	139.6*	297.5*	-4.0*	6*	0.0*	73.5*	25.8*
Zn	219.7*	370.3*	-2.9*	6*	0.0*	105.4*	24.5*
Pb	8.5	10.0	-1.0	6	0.8	3.3	0.0
Ni	13.1	10.0	0.7	6	0.3	8.7	0.0
As	4.0	5.0	-0.6	6	0.4	2.4	0.8
Cr	10.3	9.8	0.0	6	1.0	0.7	0.5
V	7.7	8.9	-0.0	6	1.0	1.0	0.1
Cd	2.6	4.0	-1.5	6	0.6	1.1	0.3

Appendix 6: Chemical Characteristics Of Water

Location	CO3 (mg/l)	$BiCO_3$ (mg/l)	Cl^- (mg/l)	S (mg/l)	SO_4 (Mg/l)	NH3 (mg/l)	$NO3^-$ Mg/l)	Alkalinity (mg/l)
S1	NIL	18.3	25.2	16.08	5.31	5.6	9.60	2.40
S2	NIL	18.3	18.0	17.77	5.86	46.3	51.26	7.00
S3	NIL	48.8	18.0	21.56	7.11	4.2	46.20	13.00
S4	NIL	20.4	22.8	15.19	5.66	8.8	10.60	4.50
		20.60	21.00	17.65	5.99	16.23	29.42	6.73
C1	NIL	17.4	22.40	9.13	3.09	5.18	9.01	2.01
C2	NIL	19.20	20.80	13.71	4.45	7.02	13.39	3.59
C3	NIL	16.90	21.00	10.00	3.07	6.21	10.08	3.55
C4	NIL	19.70	22.20	12.84	4.47	5.99	12.32	2.05
Mean		18.3	21.6	11.42	3.77	6.1	11.20	2.80

Appendix 7: Physical Characteristics Of Water

Location	TDS (mg/l)	TSS (mg/l)	Turbidity	Temperature(^{0}C)	Conductivity (ds/m)
S1	0.09	0.09	1.86	27.6	196
S2	0.08	0.09	28.62	27.6	627
S3	0.09	0.14	24.86	26.9	535
S4	0.09	0.14	24.86	26.9	535
Mean	0.10	0.11	19.27	27.33	515.75
C1	0.09	0.11	2.04	26.40	190
C2	0.07	0.09	2.64	27.20	216
C3	0.05	0.08	2.77	26.60	186
C4	0.11	0.12	1.91	27.00	220
Mean	0.08	0.10	2.34	26.8	203

Appendix 8: Biochemical Characteristics of Water

Location	DO(mg/l)	COD(mg/l)	BOD(mg/l)	PH(mg/l)
S1	7.3	112.4	61.3	4.95
S2	3.6	765.6	498.2	6.45
S3	2.7	878.5	586.0	5.00
S4	6.9	457.8	86.4	6.37
Mean	5.13	553.58	307.98	5.69
C1	6.40	122.90	72.20	6.41
C2	7.00	108.20	52.80	5.99
C3	5.56	125.20	79.60	6.10
C4	7.84	110.50	60.20	6.30
Mean	6.7	116.7	66.2	6.20

Appendix 9: Physico-Chemical Parameters of Surface Water in Bitumen Seepage and Control Sites

HO: there is no significant difference between seepage and control sites

Taxa	Mean		t-value	df	P	SD	
	Seepage Site	Control Site				Seepage	Control
BiCO3	20.60	18.30	0.31	6	2.45	14.93	1.36
Cl	21.00	21.60	-0.19	6	2.45	3.60	0.82
S	17.65*	11.42*	3.48*	6*	2.45*	2.82	2.82
SO4	5.99*	3.77*	3.96*	6*	2.45*	0.79	0.78
NH3	16.23	6.10	1.00	6	2.45	20.14	0.76
NO3	29.42	11.2	0.51	6	2.45	22.40	2.01
Alkalinity	6.73	2.80	1.66	6	2.45	4.59	0.89
pH	5.69	6.20	-1.19	6	2.45	0.83	0.19
DO	5.13	6.70	-1.25	6	2.45	2.32	0.96
C O D	553.58*	116.70*	8.02*	6*	2.45*	343.68	8.59

BOD	307.98	66.20	1.77	6	2.45	272.90	11.99
TDS	0.10	0.08	1.43	6	2.45	0.03	0.03
TSS	0.11	0.10	0.67	6	2.45	0.02	0.02
Turbidity	19.27*	2.34*	2.83*	6*	2.45*	11.94	0.43
Temperature	27.33	26.80	1.21	6	2.45	0.34	0.37
Conductivity	515.75	203.00	1.03	6	2.45	224.20	17.47

Appendix 10: Trace Heavy Metals in Surface Water of Bitumen Seepage and Control Sites
HO: there is no significant difference between seepage and control sites

Taxa	**Mean g/kg**		**t-value**	**df**	**P**	**SD**	
	Seepage Site	Control Site				Seepage	Control
Mn	0.0120	0.0120	0.00	6	1.00	2.95	20.92
Fe	0.0021	0.0021	0.00	6	1.00	0.20	0.18
Cu	0.0007	0.0006	1.10	6	0.34	0.06	0.08
Zn	0.0015	0.0017	0.00	6	1.00	0.05	0.42
Pb	0.00004	0.00004	-0.44	6	0.68	0.02	0.01
Cr	0.00005	0.00007	-2.39	6	0.05	0.02	0.01
Cd	0.00003	0.00003	0.00	6	1.00	0.01	0.01
Ni	0.0003	0.0003	0.00	6	1.00	0.00	0.08
V	0.0003	0.0003	-0.57	6	0.58	0.17	0.08
As	0.00001	0.00001	0.00	6	1.00	0.01	0.01

Appendix 11: Available Macro Heavy Metals in Surface Water

Location	**Elements (g/kg)**			
	Ca	Mg	K	Na
S1	0.132	0.054	0.002	0.004
S2	0.145	0.060	0.003	0.004
S3	0.136	0.055	0.003	0.004
S4	0.152	0.062	0.004	0.041
Control 1	0.125	0.055	0.003	0.004
Control 2	0.145	0.051	0.005	0.005
Control 3	0.121	0.050	0.004	0.003
Control 4	0.149	0.056	0.004	0.004
Mean	0.135	0.053	0.004	0.004

Appendix 12: Available Trace Heavy Metals in Plants on Bitumen Exploratory and Seepage Soils in Ondo State Bitumen Belt

Element	Mean(mg/kg)		t-value	df	P	SD	
	Exploratory soils	Seepage soils				Exploratory site	Seepage site

Fe	879.9	888.3	-0.1	7	0.9	167.6	166.4
Cu	39.6	34.1	0.2	7	0.9	8.7	8.5
Mn	570.5	534.8	0.2	7	0.8	112.7	143.4
Pb	3.2	4.0	-1.0	7	0.4	0.5	0.8
Cd	0.4	2.2	-1.4	7	0.2	0.2	3.4
Cr	11.1	11.9	-0.1	7	0.9	2.0	1.9
Ni	15.2	21.2	-2.8	7	0.0	3.5	3.0
V	7.9	7.9	0.3	7	0.8	0.6	3.2
Zn	87.9	77.2	0.1	7	1.0	8.6	11.0
As	0.4	0.4	0.3	7	0.8	0.1	0.3

Appendix 13: Available Trace Heavy Metals in Plants on Bitumen Exploratory Soil and Control Site of Ondo State Bitumen Belt

Element	Mean(mg/kg)		t-value	df	P	SD	
	Exploratory site	Control site				Exploratory site	Control site
Fe	879.9	931.4	-0.5	8	0.7	167.6	82.2
Cu	39.6	41.6	0.5	8	0.6	8.7	3.3
Mn	570.5	572.4	-0.0	8	1.0	112.7	42.2
Pb	3.2	3.4	-0.5	8	0.7	0.5	0.5
Cd	0.4	0.4	0.3	8	0.7	0.2	0.2
Cr	11.1	11.4	-0.2	8	0.9	2.0	1.0
Ni	15.2	18.4	-0.6	8	0.6	3.5	3.2
V	7.9	9.4	-2.1	8	0.1	0.6	1.2
Zn	87.9	67.7	0.1	8	0.9	8.6	8.23
As	0.4	0.3	0.2	8	0.9	0.1	0.6

Appendix 14: Available Trace Heavy Metals in Plants on Bitumen Seepage and Control Soils in Ondo State Bitumen Belt

Element	Mean(mg/kg)		t-value	df	P	SD	
	Seepage site	Control site				Seepage site	Control site

Fe	888.3	931.4	-0.4	5	0.6	166.4	82.2
Cu	34.1	41.6	-1.4	5	0.1	8.5	3.3
Mn	534.8	572.4	-0.6	5	0.4	143.4	42.2
Pb	4.0	3.4	1.1	5	0.3	0.8	0.5
Cd	2.2	0.4	0.9	5	0.1	3.4	0.2
Cr	11.9	11.4	0.4	5	0.6	1.9	1.0
Ni	21.2	18.4	1.0	5	0.0	3.0	3.2
V	7.9	9.4	-1.0	5	0.0	3.2	1.2
Zn	77.2	67.7	1.2	5	0.0	11.0	8.2
As	0.4	0.3	0.6	5	0.4	0.3	0.6

Appendix 15: Available Macro Heavy Metals in Plants around Bitumen Seepage and Exploratory Soils of Ondo State Bitumen Belt

Elements	Mean (mg/Kg)		t-value	df	P	SD	
	Seepage site	Exploratory site				Seepage site	Exploratory site
Ca	15088.8	11593.1	1.0	7	0.3	176.8	26.1
Mg	8939.8	7435.3	1.8	7	0.1	30.6	13.9
Ca:Mg ratio	2:1	2:1					
Na	20.7	53.3	-0.2	7	0.9	0.2	0.2
K	52.4	50.6	-0.5	7	0.7	0.8	0.8
N	19566.7	17866.7	0.1	7	1.0	2.2	3.0
P	93.3	51.7	0.5	7	0.7	0.1	0.0

Appendix 16: Available Macro Elements in Plants on Bitumen Exploratory Soil and Control Site of Ondo State Bitumen Belt

Elements	Mean(mg/Kg)		t-value	df	P	SD	
	Exploratory site	Control site				Exploratory site	Control site
Ca	11593.1	13070.6	-0.6	8	0.6	26.1	13.5
Mg	7435.3	8179.0	-1.0	8	0.4	13.9	5.3
Ca:Mg	2:1	2:1					

ratio							
Na	53.3	21.3	0.3	8	0.8	0.2	0.1
K	50.6	53.6	-0.3	8	0.8	0.8	0.3
P	51.7	99.0	-0.5	8	0.7	3.0	0.1
N	17866.7	19729.0	-0.1	8	1.0	0.0	3.0

Appendix 17: Available Macro Elements in Plants on Bitumen Seepage Soil and Control Site of Ondo State Bitumen Belt

Elements	Mean(mg/Kg)		t-value	df	P	SD	
	Seepage site	Control site				Seepage site	Control site
Ca	15088.8	13070.6	0.5	5	0.7	176.8	13.5
Mg	6336.5	8179.0	1.4	5	0.2	30.6	5.3
Ca:Mg ratio	2:1	2:1					
Na	20.7	21.3	-0.1	5	0.9	0.2	0.1
K	50.6	53.6	-0.2	5	0.9	0.8	0.3
P	52.4	99.0	-0.2	5	0.8	2.2	0.1
N	19233.3	19729.0	-0.1	5	0.9	0.1	3.0

Appendix 18: Anova for Abundance and Richness of Trees in Ondo State Bitumen Belt

HO: There are no significant differences in the total number of trees and number of tree species in the various habitats in **ondo state bitumen belt**

Variable	Effects	df Effect	ms Effect	df Error	ms Error	F	P – level
Abundance of Trees	**Habitat Type**	5*	536.7*	60*	29.06	18.5*	0.0*
	Season	1	0.1	60	29.0	0.0	1.0
	Interaction	5	7.1	60	29.0	0.2	0.9
Richness of Tree species	**Habitat Type**	5*	134.5*	60*	8.1*	16.6*	0.0*
	Season	1	4.0	60	8.1	0.5	0.5
	Interaction	5	1.1	60	8.1	0.1	1.0

Appendix 19: Least significance difference, LSD, Test for Total number of Trees and Number of Tree Species in Ondo State Bitumen Belt

Variable	Habitat	Mean	1	2	3	4
Abundance of Trees	Plantation Farm	3	XXXX			
	Urban Arboreta	4	XXXX	XXXX		
	High Forest	4	XXXX	XXXX		
	Riparian Habitat	8		XXXX		
	Farm Fallow	16			XXXX	
	Arable Farmland	18			XXXX	
Richness of Tree species	Plantation Farm	1	XXXX			
	Urban Arboreta	3		XXXX		
	High Forest	4		XXXX	XXXX	
	Riparian Habitat	6			XXXX	
	Farm Fallow	8				XXXX
	Arable Farmland	10				XXXX

Appendix 20: t-Test for Abundance and Richness of Trees species in Ondo State Bitumen Belt

Abundance/ha	Mean		SD	
	Dry	Wet	Dry	Wet
	3600.0	3533.3	2828.4	2634.1
Richness/ha	Mean		SD	
	Dry	Wet	Dry	Wet
	2333.3	2132.3	1372.1	1147.0

Appendix 21: Anova for Abundance and Richness of Shrubs in Ondo State Bitumen Belt

HO: There are no significant differences in the total number of shrubs and number of shrub species in the various habitats in ondo state bitumen belt

Variable	Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
Abundance of Shrubs/25m^2	Habitat Type	5*	1185.9*	60*	137.8*	8.6*	0.0*
	Season	1*	1233.4*	60*	137.8*	9.0*	0.0*
	Interaction	5	194.5	60	137.8	1.4	0.2
Richness of shrub species/25m^2	Habitat Type	5*	5*	5*	5*	5*	5*
	Season	1	1	1	1	1	1
	Interaction	5	5	5	5	5	5

Appendix 22: LSD Test for Total Number of Shrubs in Ondo State Bitumen Belt

Habitat	Mean	1	2	3	4
Riparian Habitat	18.9	Xxxx			
Farm Fallow	22.3	Xxxx	Xxxx		
Plantation Farmland	29.3		Xxxx	Xxxx	
High Forest	30.7		Xxxx	Xxxx	
Urban Arboreta	35.1			Xxxx	
Arable Farmland	46.9				Xxxx

Appendix 23: LSD Test for Number of Shrub Species in Ondo State Bitumen Belt

Habitat	Mean	1	2	3
Riparian Habitat	6.3	Xxxx		
Plantation Farmland	6.4	Xxxx		
Urban Arboreta	6.6	Xxxx		
Farm Fallow	7.1	Xxxx	xxxx	
Arable Farmland	7.9		xxxx	
High Forest	9.3			Xxxx

Appendix 24: t-test for Effect of Habitat Changes on Shrub Composition in Ondo State Bitumen Belt

Abundance/ha	**Mean**		**SD**	
	Dry	Wet	Dry	Wet
	10066.7	13333.3	2484.1	4238.2
Richness/ha	Mean		SD	
	Dry	Wet	Dry	Wet
	2733.3	2933.3	733.9	484.4

Appendix 25: Anova for Abundance and Richness of Herbs in Ondo State Bitumen Belt

HO: The total number of herbs and number of different species of herbs are not affected by habitat and seasonal changes.

Variable	Effects	df Effect	ms Effect	df Error	ms Error	F	P – Level
Abundance of herbs	Habitat Type	5*	7415.0*	60*	213.1*	34.8*	0.0*
	Seasons	1*	17766.1*	60*	213.1*	83.4*	0.0*
	Interaction	5*	3693.2*	60*	213.1*	17.9*	0.0*
Richness of species	Habitat Type	5*	71.1*	60*	2.5*	28.9*	0.0*
	Season	1*	105.1*	60*	2.5*	42.8*	0.0*
	Interaction	5*	28.7*	60*	2.5*	11.7*	0.0*

Appendix 26: Least significance difference, LSD, Test for Total Number of Herbs in the various habitats in Ondo State Bitumen Belt

(alpha = 0.05)

Variable	Habitat	Mean	1	2	3	4	5	6	7
Abundance of herbs	High Forest	7	XXXX						
	Farm Fallow	11	XXXX						
	Urban Arboreta	36		XXXX					
	Riparian Habitat	50			XXXX				
	Arable Farmland	62				XXXX			
	Plantation Farmland	64				XXXX			
	Season								
Abundance of herbs	Dry	23	XXXX						
	Wet	54		XXXX					
	Interaction								
Abundance of Herbs	High Forest Dry (3)	7	XXXX						
	High Forest Wet (4)	7	XXXX						
	Farm Fallow Wet (2)	11	XXXX	XXXX					
	Farm Fallow Dry (1)	10	XXXX	XXXX					

	Arable Farmland Dry (5)	19	XXXX	XXXX	XXXX				
	Urban Arboreta Dry (11)	25		XXXX	XXXX	XXXX			
	Plantation Farm Dry (9)	33			XXXX	XXXX	XXXX		
	Riparian Habitat Dry (7)	41				XXXX	XXXX		
	Urban Arboreta Wet (12)	48					XXXX	XXXX	
	Riparian Habitat Wet (18)	59						XXXX	
	Plantation Farm Wet (10)	95							XXXX
	Arable Farmland Wet (6)	105							XXXX

Appendix 27: t-test for Effect of Habitat Changes on Herb Composition in Ondo State Bitumen Belt

Abundance/ha	**Mean**		**SD**	
	Dry	Wet	Dry	Wet
	228333.3	541666.7	128098.7	409899.9
Richness/ha	Mean		SD	
	Dry	Wet	Dry	Wet
	53333.3	78333.3	13699.5	37099.5

Appendix 28: Total Number and Number of Different Species of Birds on Baseline Site

HO: The total number of birds and number of different species are not affected by habitat and seasonal changes.

Variable	**Effects**	**df Effect**	**ms Effect**	**df Error**	**ms Error**	**F**	**P - Level**
Abundance of Birds	Habitat Type	5*	3248.53*	60*	257.88 *	12.60 *	0.00*

	Season	1*	1440.06*	60*	257.88 *	5.58*	0.02*
	Interaction	5	13.96	60	257.88	0.05	0.99
Richness of Bird species	Habitat Type	5*	60.56*	60*	3.63*	16.71 *	0.00*
	Season	1*	28.13*	60*	3.63*	7.76*	0.01*
	Interaction	5	2.09	60	3.63	0.58	0.72

Appendix 29: Least significance Difference, LSD Test, for Total Number of Birds

Variable	Habitat	Mean	1	2
Abundance of Birds	Plantation farm	27	XXXX	
	High Forest	28	XXXX	
	Farm Fallow	29	XXXX	
	Riparian Habitat	50		XXXX
	Arable Farmland	58		XXXX
	Urban arboreta	62		XXXX
	Season			
Abundance of Birds	Dry	38	XXXX	
	Wet	47		XXXX

Appendix 30: Least Significance Difference, LSD, Test for number of Different Species of Birds

Variable	Habitat	Mean	1	2	3	4
Richness of species	Plantation Farm	11	XXXX			
	Farm Fallow	14		XXXX		
	High Forest	14		XXXX		
	Arable Farmland	15		XXXX	XXXX	
	Urban Arboreta	16			XXXX	XXXX
	Riparian Habitat	17				XXXX
	Season					
	Dry	14	XXXX			
	Wet	15		XXXX		

Appendix 31: t-Test for Abundance and Richness of Birds species in Ondo State Bitumen Belt

Abundance/ha	**Mean**		**SD**	
	Dry	Wet	Dry	Wet
	134.5	166.4	57.0	60.4
Richness	Mean		SD	

	Dry	Wet	Dry	Wet
	51.3	53.7	9.2	9.7

Appendix 32: Relative Abundance and Richness of Animals As Affected By Habitat and Seasonal Changes on Baseline Site

HO: The Relative Abundance and Richness of Animals Are Not Affected By Seasonal Changes

VARIABLE	EFFECT	df Effect	ms Effect	df Error	ms Error	f	P - Level
Abundance of animals	Habitat	5*	298.72*	12.91*	12.91*	23.14*	0.00*
	seasons	1*	102.08*	12.91*	12.91*	7.91*	0.01*
	Interaction	5	17.03	12.91	12.91	1.32	0.28
Richness of animal species	Habitat	5*	15.80*	40*	1.80*	8.80*	0.000*
	season	1*	17.52*	40*	1.80*	9.76*	0.003*
	interaction	5	1.41	40	1.80	0.78	0.51

Appendix 33: LSD Test for Total Number and Number of Different Species of Animals

Variable	Habitat	Mean	1	2	3	4
richness of animal species	Urban arboreta	4	XXXX			
	Plantation farmland	6		XXXX		
	Arable farmland	8			XXXX	
	Farm fallow	8			XXXX	
	Riparian habitat	8			XXXX	
	High forest	9				XXXX
	Seasons					
	Dry	6	XXXX			
	Wet	8		XXXX		

VARIABLE	Habitat	Mean	1	2	3	4	5
	Urban arboreta	6	XXXX				
	Plantation farmland	8		XXXX			
Abundance of animals	Arable farmland	8		XXXX			
	Farm fallow	13			XXXX		
	Riparian habitat	25				XXXX	
	High forest	26					XXXX
	Seasons						
	Dry	10	XXXX				
	Wet	16		XXXX			

Appendix 34: t-Test for Abundance and Richness of Animal species in Ondo State Bitumen Belt

Abundance/ha	Mean		SD	
	Dry	Wet	Dry	Wet
	236.7	336.7	158.7	223.9
Richness/ha	Mean		SD	
	Dry	Wet	Dry	Wet
	123.3	153.3	42.7	30.1

Appendix 35: Relative Abundance of Biodiversity in Seepage and Control Sites

Biota	Mean		t-value	df	P	SD	
	Seepage Site	Control site				Seepage	Control
Bird/Ha	64.0*	134.5 *	-6.5*	6*	0.0	11.7*	18.3*
Animal/Ha	160.0	200.0	-0.8	6	0.2	68.0	73.0
Trees/Ha	789.9 *	2775.2 *	-5.0*	6*	0.0	327.8*	731.6*
Shrubs/Ha	2396.8 *	12388.9 *	-6.6*	6*	0.0	1611.7*	2591.8*
Herbs/Ha	429999.8	349999.7	-0.7	6	0.4	210000.0	129100.0

Appendix 36: Richness of Biodiversity in Seepage and Control Site

Biota	Mean		t-value	Df	P	SD	
	Seepage site	Control Site				Seepage	Control
Bird/Ha	14.2*	49.6*	-3.9*	6*	0.1*	9.3*	15.6*
Animal/Ha	60.3*	140.3*	-4.4*	6*	0.0*	11.6*	32.6*
Trees/Ha	800.2	1999.0	-0.8	6	0.3	232.0	980.0
Shrubs/Ha	797.0*	2799.8*	-3.6*	6*	0.6*	198.6*	1195.9*
Herbs/Ha	29999.9*	69977.8*	-4.2*	6*	0.0*	5798.8*	18298.9*