Riparian bird diversity of the Ndumo Game Reserve, South Africa

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Abstract

Riparian areas are the ecotones between aquatic and terrestrial landscapes. They are critical areas for biodiversity conservation as they are rich in species diversity. Riparian habitats have more complex vegetation structures, resulting in more heterogeneous habitats. This provides a larger variety of microhabitats, a greater range of microclimates, better hiding places from predators, and generally increased resources, leading to increased bird diversity and intricate community compositions.

Riparian ecosystems create corridors for migrating bird species and serve as corridors to pass through from one habitat to another. They supply nesting habitats during breeding season with abundant food resources. Riparian ecosystems are popular overwintering habitats for birds from adjacent non-riparian areas and have been found to be more species rich than non-riparian habitats.

Vegetation structure plays a role in habitat selection as it affects aspects such as foraging, resting, perching, finding a mate, selecting a nesting site, and successfully breeding and raising offspring. The complex vegetation structures in riparian habitats create favourable conditions and abundant resources for the survival of bird species.

Anthropogenic disturbances affect the integrity of riparian ecosystems and could lead to habitat destruction if not managed. Ndumo Game Reserve is a protected area and because of the different habitat types within riparian areas many species could use these sites as refuge sites during winter.

Change in seasons may affect food availability, influx of competition when migrating species arrive, access to water, as well as the change in vegetation structure as seasons change. Bird species richness and abundance would therefore differ among diverse habitats and over time, and create intricate community structures. This was the subject of this study.

The Phongolo River flowing through Ndumo Game Reserve was chosen as the study area, with five sites comprising of four sub-plots each chosen within the reserve. Four were riverine sites and one was located next to a pan where the river flows into the pan. Riparian forest was the dominant vegetation type with differences between each site in the composition of plant species as well as vegetation structure. One site had visible anthropogenic disturbances, including burnt-down trees and crops growing across the river from the site. Five surveys were undertaken over a period of 10 months, resulting in 100 sub-plot samples. Sampling was done using the point-count method within a radius of 50 m.

Multivariate analyses consisted of indicator analysis, Shannon diversity index and NMS ordinations, as well as PCAs. NMS bi-plots were used to define avian community structures responding to vegetation structure and seasonal changes.

The results showed that species richness, abundance, and diversity differed between the sites. There were more bird species and individual birds at the pan site, but the site that was structurally most diverse also had the highest bird species richness. Feeding and nesting behaviours also affected habitat selection. One of the sites showed anthropogenic disturbances, but it seems the use of larger birds as indicators of disturbance was not sucsessful as there were no clear differences in pattern to distinguish it from the other sites. Birds smaller than one kilogram per individual also did not show any effects of disturbance. It could be that the approach that was followed was not applicable, or ordinations might not be applicable to investigate the effect of disturbances.

It can be deduced that environmental factors such as vegetation structures and seasonality had an effect on the distribution of birds along the riparian corridors of Ndumo Game Reserve, and disturbances do not yet show any effects.

Key words: Birds, Riparian corridors, Ndumo Game Reserve, Vegetation structure, Anthropogenic factors, Seasonal influences, Feeding guilds, Nesting guilds, Habitat selection, Convergent and divergent communities, Community trajectories, Biomass

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Chapter 1: Introduction

1.1. Riparian habitats

Riparian habitats (riparian: of or relating to or located on the banks of a river or a stream) can, *inter alia*, be defined as the aggregation of floral species that depend on a flow of water on or near the surface (Davis, 1977), or the transition zone between the aquatic and terrestrial landscape (Naiman *et al*., 1993), or any area belonging to the bank of a river, and its biotic living communities (Naiman *et al*., 2000).

Many studies have been conducted to improve our understanding of riparian ecosystems (Naiman *et al*., 2000). Species richness and bird abundance are normally greater in riparian areas than in non-riparian areas as a result of aquatic and terrestrial fauna and flora (higher food resources and more complex vegetation structure) along riparian ecosystems contributing towards its complexity and heterogeneity (Whitaker & Montevecchi, 1997; Woinarski *et al*., 2000; Pearson & Manuwal, 2001; Gentry *et al*., 2006; Palmer & Bennett, 2006; Chan *et al*., 2008). The edge effect, where two habitat types meet (aquatic and terrestrial in this case) is characterised by an increase in the richness and abundance of wildlife at the interface (Whitaker & Montevecchi, 1997). Greater amounts of food are available at riparian sites than non-riparian sites; this, coupled with the rich diversity in vegetation structure can lead to enhanced heterogeneity of birds in riparian zones (Murakami & Nakano, 2001).

Riparian ecosystems are increasingly recognised as critical areas for biodiversity conservation, especially in urban environments (Palmer & Bennett, 2006). Riparian ecosystems are the interfaces between terrestrial and freshwater ecosystems and are particularly sensitive to environmental change (Naiman *et al*., 2000). They play an important role in filtering contaminants, buffering landscapes against erosion, and providing habitat for an abundance of individuals of different species (Sabo *et al*., 2005). Riparian plant communities are generally composed of specialized and disturbance-adapted species within a matrix of less-specialized and less-frequently disturbed upland forest (Naiman *et al*., 2000). Characteristics of riparian areas include topography, dendritic structure, high amounts of edge area, and the provision of corridors through the landscape (Palmer & Bennett, 2006).

Riparian ecosystems are particularly important for birds (MacArthur, 1964). It was reported that higher avian abundance were present in habitats with permanent water than those without, and correlations between species diversity and floral height diversity were also noted (MacArthur, 1964). Several studies have highlighted the importance of riparian areas to birds, although the extent of the difference in species richness and diversity compared to adjacent areas may vary with landscape contexts, as well as with variation in characteristics within each riparian zone itself (Woinarski *et al*., 2000).

Riparian ecosystems, or parts thereof, frequently act as longitudinal corridors and habitats for birds (Rosenberg *et al*., 1997). Corridors are passageways for animals between habitat patches where they live and reproduce; corridors themselves are not necessarily used for reproduction (Rosenberg *et al*., 1997), but could be used for reproduction and then considered as habitats (Knopf *et al*., 1988). Corridors are also used for feeding and passing through from one habitat to another (Rosenberg *et al*., 1997), and are critically important in fragmented areas, as birds need to move in and through the corridors to find more intact habitat patches. Because of the different habitat types, riparian areas plays host to a rich variety of faunal and floral species, including bird species. Birds rely on a complex diversity of vegetation structure mixed with the resultant food diversity, to successfully inhabit, breed, and flourish in riparian habitats.

Through river impoundment, water management, and lowering of water tables, the flow variability and fluctuations in channel width have been reduced in many parts of the world. These changes affect riparian biodiversity (Naiman *et al*., 2000). Macro-invertebrates, fishes, amphibians, birds and mammals are all affected by the alterations of riparian plant communities (Naiman *et al*., 2000) as habitats and nutrient availability changes.

Riparian habitats are not necessarily the most abundant habitat type in terms of species richness and resource abundance. No difference was found in either bird species richness or total abundance between riparian habitats and interior fir forest habitats (Whitaker & Montevecchi, 1997). The conflicting results could be ascribed to the fact that most studies compared the differences between riparian habitats and upland forest that might already be altered by anthropogenic activities (Whitaker & Montevecchi, 1997). Riparian habitats are also mostly studied in dryer areas (where upland and riparian habitats often contrasts starkly) and thus the presumption that riparian areas are vastly richer in species diversity may be a problem of scale and subjectivity. According to Whitaker and Montevecchi (1997), the emphasis on protecting riparian habitat is skewed and should be more inclusive of inland forests with similar species richness and composition.

The relative importance of riparian zones to terrestrial wildlife may vary geographically, as bird species richness and abundance in the forests of the Pacific Northwest (26 species) were similar to that of riparian habitats in the same area (22 species) (Pearson & Manuwal, 2001). Riparian habitats may play host to different, not more, species than do non-riparian habitats (Sabo *et al*., 2005).

Palmer and Bennett (2006) found the following in their study on the difference between riparian and non-riparian sites:

- Vegetation structure was more complex in riparian sites and included a mid-storey layer generally missing from non-riparian habitats;
- Floristic composition differed between the two habitats types;
- Riparian sites were substantially richer, abundant and more diverse in terms of bird species than adjacent non-riparian sites; and
- Bird species composition also differed significantly between these habitat types.

Many factors affect riparian habitats, some of which are climate, the local species pool, the hydrological cycle, geo-morphological changes, and disturbance regimes. Disturbances such as floods bring change to rivers and streams, which may have a big influence on fauna and flora of riparian zones. Sediment deposition, nutrient flow, and water levels may influence vegetation, which in turn can influence all other species. Continuous change creates heterogeneous habitats (Whittington *et al*.,

2016) with no specific resource responsible for diverse species richness, but rather a large range of resources working together to create a myriad of habitat opportunities for species. Water may be the only obvious riparian resource used by birds that may otherwise be essentially non-riparian (Woinarski *et al*., 2000).

1.2. Biodiversity

Biological diversity can be described as the variability and viability among living organisms and the ecologically complex habitats in which they occur (Noss, 1990). Three levels of biological diversity can be described: genetic diversity, species diversity and community (ecosystem) diversity (Begon *et al*., 2006). Species diversity includes the entire range of species on earth; genetic diversity is the variation of genes within a species; and community diversity encompasses all the different biological communities together with their associations with the physical environment. While evaluating habitats as measures of diversity causes some problems, similar to genetic diversity being too difficult and costly, species diversity is a generally accepted measure of diversity (Doherty *et al*., 2000). Using the multispecies approach instead of the single species approach gives additional information that a single species approach cannot give, making it a more suitable approach to identifying the different diversities within a landscape.

Different scales will give different impressions of what biodiversity looks like. Smaller scales might give genetic diversity, and larger scales give community diversity, or information on community types, like swamp, desert, and woodlands (Begon *et al*., 2006). Patterns identified at smaller scales might not reflect large-scale patterns and vice versa, and therefore scale is of utmost importance when discussing diversity (Begon *et al*., 2006).

According to Begon *et al*. (2006), four types of factors can affect biodiversity/species richness: geographic factors, factors correlated with latitude, factors that are independent of latitude, and biotic factors.

Nutrients, water, and/or conditions can be limiting factors for plants at the base of the food chain. Change in productivity of primary producers will affect productivity of the surrounding environment, ultimately affecting species richness (Begon *et al*., 2006).

Higher primary productivity results in a wider range of available resources that leads to greater species richness. If a productive environment is/was the result of more abundant resource supplies rather than a greater variety of resources, it might lead to more individuals per species (abundance) rather than more species (Begon *et al*., 2006). Therefore, increased primary productivity might lead to increased species richness (Begon *et al*., 2006). However, primary productivity usually influences species richness in combination with other factors (Begon *et al*., 2006).

As mentioned before, riparian ecosystems are increasingly recognised as critical areas for biodiversity conservation (Palmer & Bennett, 2006). Riparian ecosystems are particularly sensitive to environmental change (Naiman *et al*., 2000) and thus need to be conserved in order to preserve the diverse array of species that make use of riparian habitats. Conservation efforts need to reach beyond species level in order to conserve communities and their habitats too. Managing and conserving different habitats could lead to the conservation and management of the species occupying these habitats. In order to do this it is of paramount importance to understand how biological communities respond to habitat loss and anthropogenic disturbances (Posa & Sodhi, 2006).

Descriptions of vegetation structures and anthropogenic disturbances are required to characterise adequately habitats for conservation. Different bird species associate differently with different habitats and in order to manage habitats more effectively, a better understanding of how biological communities interact with these factors is needed. Conservation strategies can then be implemented using such knowledge to conserve effectively a greater variety of habitats, and therefore a greater variety of bird species (Posa & Sodhi, 2006).

1.3. Birds

Importance of birds:

- Birds are relatively easy to identify, by call, plumage, or both (Bibby *et al*., 1992; Becker, 2003)

- Birds are relatively easy to census as they are well known, easily recognisable, and simpler to locate than many other taxonomic groups (Becker, 2003).
- Bird sampling normally does not involve capture for identification (such as for fish, small mammals or insects) but merely recording, thereby placing very little stress on the animals and environment, apart from observer presence. Bird sampling is also non-destructive and multiple observations can be made of the same individuals over multiple surveys with very little effects caused by the observations itself (Bibby *et al*., 1992).
- Birds can be useful indicators of the state of the environment and are key species for education and public awareness (Bibby *et al*., 1992; Becker, 2003).
- When combined with habitat data, bird studies have a number of different applications. For example, they can be used to predict to effects of land-use (Bibby *et al*., 1992).
- Birds are well-known indicators due to their sensitivity to environmental perturbations, relevance to ecosystem functioning (e.g., pollination and seed dispersal), and relative ease in sampling (Posa & Sodhi, 2006).
- Birds have numerous trophic levels, nesting requirements, population sizes, size differences, and behavioural patterns. Studying combinations of these characteristics provide scientists and the public with insight into the ecologies/ecological niches the birds occupy.
- Some species of birds can be seen as “umbrella” and “keystone” species, and can be used as indicator species to assess environmental conditions (Nilsson & Berggren, 2000).
- Umbrella species can be used to make conservation-related decisions. Protecting umbrella species usually means many other species that make up the ecological community in a habitat are protected indirectly (Begon *et al*., 2006; O’Halloran *et al*., 2002).
- Keystone species are crucial in an ecosystem because of many other species that depend on the keystone species for survival (Begon *et al*., 2006).

- Flagship species are usually well known species, loved by the public, whose conservation is considered important (e.g. birds of prey) (O’Halloran *et al*., 2002; Becker, 2003).
- Birds can be primary consumers (ducks, geese, and doves), secondary consumers (cisticolas, shrikes, flycatchers, and falcons), and even tertiary consumers (falcons, kites, eagles, and vultures) and thus play an important role in the food web (Begon *et al*., 2006).
- Scavengers (vultures and crows) eat dead animal material and keep the environment clean (Begon *et al*., 2006).
- Birds are important for seed dispersal of fruit, playing a vital role in maintaining and restoring many plant communities (Clout & Hay, 1989; O’Halloran *et al*., 2002).
- Some bird species are economically important, e.g. game species like woodcock, grouse, quail, pheasant, and duck.
- Birds attract tourists to bird sanctuaries and game reserves, which may promote job creation and economic growth (Naguran, 2002).
- Some bird species are useful pest controllers, such as insectivores and raptors (Hockey *et al*., 2005).
- Birds are often abundant and rich in diversity, which allows for large amounts of data (Cody, 1981).
- Birds are highly mobile, allowing them to move from unsuitable habitats towards more suitable habitats (Palmer & Bennett, 2006).
- Factors that benefit birds may also have a positive influence on other living organisms (O'Halloran *et al*., 2002).
- Some birds such as scavengers (vultures and crows) eat dead animal material (Begon *et al*., 2006; Hockey *et al*., 2005).
- Birds and mammals are the only true endothermic animal groups. Factors affecting birds may therefore also affect mammals, including humans, more so than many other animal groups.
- Birds are intrinsically significant, as individual species, regardless of their perceived importance under other headings.

1.4. Habitat selection

Birds are highly mobile and therefore capable of searching for the most suitable habitats (note, the habitat does not select the bird, but vice versa). However, birds do not just occur wherever they can. Different species have different habitat needs, requirements, and conditions that have to be met in order to flourish in an environment (Begon *et al*., 2006). Physiological and behavioural ecology affects habitat selection, to the extent that behaviour patterns sometimes keep species from occupying habitats that would otherwise be well-suited.

Cody (1981) identifies three factors that affect habitat selection by birds – vegetation structure, competitors, and productivity. All three must be considered together when making predictions about habitat selection. There are, however, many more factors that act as conditions and constraints, such as microclimate, edges, floristics, food and water availability, nesting suitability, shelter, breeding mates, and other species (Wiens, 1989b; Begon *et al*., 2006). The process of habitat selection is complex and not yet fully understood, despite the subject being intensively studied since the 18th century (Cody, 1981).

Riparian systems are diverse in many ways. Because of this, the birds can rest, forage, breed, and flourish within these habitats. Riparian ecosystems also create corridors for migrating birds (Rosenberg *et al*., 1997). Migrating species do not breed locally, but travel far to find suitable breeding habitats. Riparian areas may provide suitable nesting conditions for many bird species (Knopf *et al*., 1988), but some birds use it as transition zones from one place to another only, a stopover on a long migration journey to feed and rest (Rosenberg *et al*., 1997), or a wintering habitat during non-breeding season. Whenever one habitat has degraded to such an extent that species need to seek alternative habitats, corridors also provide important through-zones find more intact habitat patches.

Vegetation structure plays a role in habitat selection as it affects aspects such as foraging, resting, perching, finding a mate, selecting a nesting site, and successfully breeding and raising offspring. Conditions and resources that are favourable for reproduction and survival are of cardinal importance for the selection of habitat. According to Begon *et al*. (2006), these are usually distributed patchily in both space and time. Spatial scale is of great importance to bird species composition. Because of the different habitat types within riparian areas, and the different vegetation structures, many species select riparian habitats over non-riparian habitats.

Specialist bird species have stricter prerequisites for habitat selection than do generalists. Specialists have limited options because of the restricted niches they can fill. Their ecological niche encompasses their tolerances and requirements (Begon *et al*., 2006), and many birds thrive in riparian habitats as all their needs and requirements are met. These needs pertain to feeding habits, nesting prerequisites and general habitat selection.

Habitats that are more heterogeneous will have more species as they provide a larger variety of microhabitats, a greater range of microclimates, better hiding places from predators, and generally increased resources (Begon *et al*., 2006). Reduction in suitable habitat because of habitat fragmentation influences the integrity of a site. Isolation of habitat patches can increase predation and brood parasitism, and a decrease in migration into a patch can lead to higher probabilities of local extinction (Boulinier *et al*., 1998).

Different species use different size scales to select habitats (Begon *et al*., 2006). African Fish-Eagles would have different requirements for a suitable habitat than would a Paradise Flycatcher. Scale is an important factor in bird habitat selection; scale should therefore be considered when designing management plans for riparian habitats.

1.5. Motivation

Little is known about the floodplain wetlands of the Phongolo River (Dube *et al*., 2015). Few studies have been done to understand the current ecological state and functioning of the floodplain as a whole, as well as the health and diversity of the organisms that inhabit the area. Riparian areas in general have great species richness and a large variety of species, for not only birds, but may also be critically important for conserving and sustaining all the species that inhabit riparian areas. They are however, generally vulnerable to fragmentation and anthropogenic disturbances. Therefore, this study aims to study riparian bird assemblages in the Ndumo Game Reserve.

Ndumo Game Reserve should be conserved because:

- It is the only major floodplain incorporating a series of pans within the borders of South Africa (Cooper, 1980).
- It is the southern distribution limit of several tropical aquatic organisms, notably birds, and is, therefore, of considerable scientific interest (Cooper, 1980).
- It is an important wintering ground for a large number of waterfowl, such as White-faced Duck, White Pelican (of which it is also the only breeding colony in South Africa), and the African Openbill (Heeg & Breen, 1982).

Annual Phongolo flooding supplies enough water to fill the pans, aid in the growth of primary producers (*Potamogeton crispus*) (who depend on floodwaters for enough water to grow), to flush out dissolved salts, and to erase the effects of trampling and grazing. If primary production is reduced, secondary production will be reduced; invertebrates will probably drop in abundance, fish will have less food, hippopotami will abandon the pans if they become too shallow, oligochaete worms and mussels will disappear from the pans if salinities are raised, and the composition of the zooplankton will change markedly (Heeg & Breen, 1982). This will affect birds too, if food becomes scarce, and it might lead to local extinction (Heeg & Breen, 1982).

If development occurs without regard for its impact on the floodplain, eventually the floodplain ecosystem would change to such an extent that it would cease to exist as a functional ecology. The altered flood regimes are already affecting the floodplain and the ever-increasing demands from subsistence agriculture are straining the water supply. Some form of control over its utilization needs to be implemented. A policy to preserve the floodplain in conjunction with agricultural development might help with the conservation of the floodplain and all its ecosystems (Heeg & Breen, 1982).

The Phongolo Floodplain is unique in South Africa, with its natural beauty and many rare species. It has been described as (arguably) one of the most beautiful and interesting conservation areas in South Africa (Heeg & Breen, 1982), it therefore deserves to be preserved for future generations.

1.6. Hypotheses

- Bird variables in and along riparian corridors in Ndumo Game Reserve are affected by vegetation and seasonal influences;
- Riverine bird communities are affected by proximity to large disturbance;
- Larger birds would be more affected by anthropogenic factors than smaller birds.

1.7. Aim

The aim of this project was to conduct an ecological survey to determine the bird biodiversity of sites along the riparian zone in the Ndumo Game Reserve.

1.8. Objectives

- Characterise riparian habitat by vegetation structure;
- Identify temporal and spatial changes in bird diversity;
- Compare the environmental and avian metrics;
- Derive insights into the bird ecology of the study area.
- Investigate whether the human disturbance at one site is affecting bird composition.
- The influence of riparian vegetation structure and species composition on avian assemblages and community structure in the Ndumu Game Reserve

Chapter 2: Literature review

2.1. Maputaland

Maputaland, the traditional name of a natural region in KwaZulu-Natal, South Africa, is unique - rich in biological diversity and abundance. As a result of the variety of ecosystems in this small area, no other area of South Africa possesses such a rich variety of tropical bird species for its size as does Maputaland. This is also the southern end of the great Mozambique Coastal Plain, making it the southernmost distribution of many tropical species (Cooper, 1980). Protected areas such as the Tembe Elephant Park and the Kosi Bay National Park form an ecological link with the iSimangaliso Wetland Park (previously known as the Greater St Lucia Wetland Park) – a World Heritage Site – which lies to the south of Maputaland (Naguran, 2002; Smith *et al*., 2008).

Maputaland is particularly well known for its rich bird diversity, with 57% of southern Africa's total bird species occurring there (Cyrus *et al*., 1980). Many large (>250g), water-associated, colonially nesting bird species do not nest elsewhere in South Africa (Bowker & Downs, 2012). Two particular species, the Pink-backed Pelican and Yellow-billed Stork, do not breed regularly elsewhere in South Africa (Bowker & Downs, 2012). Maputaland provides a range of nesting and feeding sites with its many water bodies of various types.

Precipitation occurs mostly from September to April (Mucina & Rutherford, 2006), with numerous lakes and rivers forming the Phongolo Floodplain. The largest water body is Lake St Lucia, an estuary in excess of 70 km long and 18 km wide, with a surface area of about 417 km^2 (Bowker & Downs, 2012). This lake receives water from several rivers and runs into the sea, resulting in large variations in salinities along its course, with a range of habitats for birds and their prey (Bowker & Downs, 2012).

Maputaland forms part of the Maputaland-Pondoland-Albany biodiversity hotspot (SANBI, 2010) and the South East African Coast Endemic Bird Area (World Wildlife Fund, 2016). Two hundred and thirty of the 2 500 plant species in this hotspot have endemic or near-endemic status (Smith & Leader-Williams, 2006), which makes this area critical for conservation. It also contains the iSimangaliso Wetland Park and World Heritage Site, five RAMSAR sites and nine Important Bird Areas (IBAs), as well as a number of important populations of globally threatened species, such as the Black Rhino and Pel's Fishing-Owl (Smith & Leader-Williams, 2006).

Many of the plant species that occur in Maputaland grow nowhere else in South Africa. This makes the vegetation unique and interesting, creating diverse habitats. Dense thicket vegetation, partially impenetrable in the protected areas, grows where the topography is particularly flat and the soils are poorly drained. It does not grow very tall – 2 to 5 m high – but is rich in diversity, including species such as *Acacia grandicornuta, Gardenia cornuta, Euphorbia grandicornis* and *Pappea capensis*.

The Maputaland Conservation Planning System includes bird species that are listed for conservation. Species with a limited range of occurrence might not be conserved when considering land-cover types alone, and, species with a very large habitat would not benefit from only a patch of habitat being conserved. These two types of species need to be conserved. The bird species, as listed by Smith and Leader-Williams (2006):

- Swamp Nightjar (*Caprimulgus natalensis natalensi*)
- Southern Banded Snake Eagle (*Circaetus fasciolatus*)
- Saddle-billed Stork (*Ephippiorhynchus senegalensis*)
- Cape Vulture (*Gyps coprotheres*)
- Mangrove Kingfisher (*Halcyon senegaloides*)
- Denham's Bustard (*Neotis denhami stanleyi*)
- Pel's Fishing-Owl (*Scotopelia peli*)

Some bird species are so specialised that they are restricted to a specific habitat. Even though most bird species have great mobility and adaptability and can choose their habitat without being restricted to a certain area, it is evident that some species appear to have a distinct preference for a particular ecosystem (Cooper *et al*., 1980). Their niche requirements within the ecosystem are, therefore, of great interest and importance, especially from a conservation point of view. Cooper *et al* (1980) gave a total bird species richness of 462 for Maputaland, which represents 82% of KwaZulu-Natal’s bird species and 56% of South Africa’s total.

2.2. The Phongolo Floodplain

The Phongolo Floodplain occupies the northwestern corner of Maputaland and includes the area of the Makhatini Flats that is flooded by the Phongolo River during summer. During these floods the Phongolo River bursts its banks and inundates 13 000 ha of the flats, which extends at least to the confluence of the Phongolo and Usuthu rivers in the Ndumo Game Reserve (JayWay, 2015). When the river subsides in autumn, water remains in about 25 major and many minor pans, covering a total area of about 2 600 ha. While most of the minor pans dry out during winter, many of the others retain water even in the driest years.

The construction of the Pongolapoort Dam in the Phongolo River was completed in 1973. This dam supplies irrigation water for sugarcane and cotton plantations on the adjacent Makhatini Flats (Dube *et al*., 2015). The current flood management is partly based on the demands of the floodplain communities for their crops and livelihoods. Seventy percent of total flow occurs during the wet period from November to March (mostly October when the dam is, normally, near full). The lowest flow is expected from June to September, accounting for almost 10% of the total flow (Dube *et al*., 2015). Both flows are of lower magnitude than natural flows and some water needs are not satisfied by the current releases. Effects of the controlled release of water on the downstream floodplain ecosystem are still poorly understood (Dube *et al*., 2015).

A certain amount of water is needed to maintain ecological processes in the floodplain, but the environmental flows were not established at the time of dam construction. The practicality of implementing successful flood plans that fulfil all the needs of ecosystems, ecological processes, as well as community needs, remains a challenge (Dube *et al*., 2015). Agricultural development poses a threat to the river and aquatic ecosystems, which, along with the floodplain in general, is already under ecological threat by the artificial flow regimes, including volume, rate, duration and timing of flows, imposed by Pongolapoort Dam management (Heeg & Breen, 1982). The floodplain has become the livelihood of more and more people over the past few years. Human population increases threatens sustainable utilisation of the floodplain, and the population around the Phongolo floodplain has grown from 30 000 to over 186 502 over the past 30 years (Heeg & Breen, 1982; Statistics South Africa, 2011). However, even with all the disturbances present, riverine forests and thickets, floodplain grasslands, numerous lakes, ponds, the river and alluvial savannah all make up the vegetation of the Phongolo Floodplain to create a rich and diverse ecosystem and habitats for numerous kinds of fauna and flora.

The first formal conservation area (Pongola Nature Reserve and floodplain) was proclaimed in 1894, 22 years after the Yellowstone National Park was established in the United States as the world's first national park (Pienaar, 1991). Ndumo Game Reserve's flood basin wetlands were given international conservation status in 1997 (Ramsar site no. 887), according to the RAMSAR agreement (Kabii, 1997; Liebenberg, 2010).

The lower Phongolo is one of the most bio-diverse areas of South Africa, especially its bird component. The coastal plain that starts in Somalia in the north reaches all the way south to the Makhatini Flats that include the lower Phongolo River and provides habitat for many birds, including species that reach their southern limits here. The biggest threats to biodiversity in the region are habitat loss, invasive alien species, and water demand exceeding water availability.

Twenty one percent of water birds in the Phongolo Floodplain feed largely on vertebrates, 47% feed largely on invertebrates (e.g. the African Openbill feed on molluscs), and the remaining 32% feed on plant food (Maclean, 1990). Pans, created when the area is flooded, are temporary inland water bodies and highly productive in terms of phytoplankton and zooplankton. The Phongolo Floodplain hosts vast numbers of phytophagous ducks during winter, switching their feeding in summer to seeds of water lilies, grasses, and sedges.

The drastic seasonal changes (highly seasonal wet/dry phases) necessitate riverine birds to adapt to extreme changes in water levels. At low water, sandbanks, mudflats and/or rocks are exposed. Apart from the limited area of suitable nesting and foraging habitat, the temporary nature of these habitats makes it necessary for the birds to move from high-water regions to low-water regions seasonally (Maclean, 1990).

The floodplain supports a variety of birdlife that utilises it as feeding and/or breeding habitat. The South African Bird Atlas Project data (SABAP1) recorded 46 Red Data species, comprising one endangered, 16 vulnerable and 29 near-threatened. SABAP2 recorded 26 of the 46 Red Data species recorded in SABAP1 (Pearson, 2014). The White Stork, which is not listed, but is protected internationally through the Bonn Convention on Migratory species, was also recorded (Pearson, 2014). However, non-endangered species also play an important role in the dynamics of the floodplain. Cattle Egret (*Bubulcus ibis*) occur in large numbers in the *Phragmites* stands of the floodplain, feeding on terrestrial insects. According to Heeg and Breen (1982) their faeces may play a role in introducing plant nutrients into the system.

A few other bird species that occur in the Phongolo floodplain are: Neergaard's Sunbird (*Nectarinia neergaardi*), Woordward's Batis (*Batis fratrum*), Rudd's Apalis (*Apalis ruddi*), African Broadbill (*Smithornis capensis*), Crowned Eagle (*Stephanoaetus coronatus*), Crested Guineafowl (*Guttera pucherani*), Pink-throated Longclaw (*Macronyx ameliae*), and Southern Banded Snake Eagle (*Circaetus fasciolatus*) (Cooper, 1980).

Vegetation forms the primary energy source which supports the entire food web in all ecosystems and is the base of all these different habitat types. Habitat types are determined by the vegetation types, especially in riparian zones, which in turn are determined by the regional climate, the regional pool of species, and the hydrological, geo-morphological, and disturbance regime (Whittington *et al*., 2016).

The vegetation in the immediate vicinity of the floodplain can be divided into five principal types, namely:

- Sand forest,
- Woodland,
- Acacia tree and bush vegetation,

- Riparian forest and,
- Aquatic and marginal pan vegetation (Heeg & Breen, 1982).

On the eastern side of the Phongolo River, the woodland (on sandy soils) is dominated by *Terminalia sericea*, *Strychnos spinosa* and *Acacia burkei* (Heeg & Breen, 1982). *Combretum zeyheri* is dominant on the western bank in mixed woodland. In the clay and loamy soils on the margins of the floodplain there are *Acacia* trees and bush vegetation, as well as *Spirostachys africana*.

Riparian forest occurs along the banks of the river (Heeg & Breen, 1982). Large stands of *Ficus sycomorus and Rauvolfia caffra* grow along the Phongolo River in Ndumo Game reserve – both species may reach great heights – where it covers 246 ha. Sadly, these communities are extensively cut and burnt for crop lands in other unprotected parts, with only 160 ha remaining recognisable by 1982. Other large trees in this community include *Syzygium guineense* and *Trichilia emetica* (Heeg & Breen, 1982). Species that characterise these communities are; *Ficus sycomorus, Rauvolfia caffra, Trichilia emetica, Dicliptera heterostegia, Entada spicata, Adina microcephala, Syzygium guineense, Setaria chevalieri, Ipomoea digitate, Ageratum conyzoides, Allophyllus decipiens, Grewia caffra, Ficus capreifolia, Kraussia floribunda, Oplismenus hirtellus and Mananthotaxiscaffra*. Two reed communities favour the wettest areas along the floodplain. *Phragmites mauritianus* favours riverbanks, inlet channels, and pan margins where water levels fluctuate, while *Pragmites australis* prefers flat swampy areas. An area of 234 ha is covered by these species, most of which occur in Ndumo Game Reserve (Rogers, 1980).

2.3. Ndumo Game Reserve

Ndumo Game Reserve (26°53’ S; 32°18’ E) is situated in north-eastern KwaZulu-Natal. It is 10 117 ha in extent and proclaimed as a reserve in 1924 by the then Natal Parks Board (Kyle & Marneweck, 1996), with the primary objective of strict protection of wildlife, especially for Nile Hippo (*Hippopotamus amphibious*) (Dube *et al.*, 2015; Whittington *et al*., 2016). RAMSAR status was awarded in 1997 as a Wetland of International Importance (Kyle & Marneweck, 1996; Ramsar, 1997). The area surrounding the Ndumo Game Reserve is communally owned by the Mathenjwa and

Tembe tribes and most of the floodplain upstream is state land (Kyle & Marneweck, 1996). Rural communities surround Ndumo Game Reserve and rely heavily on floodplain ecosystem services (Dube *et al*., 2015), to such an extent that some of the local communities have moved into the eastern side of Ndumo Game Reserve and are using wood for fuel and building, sedges for thatch, and grazing their domesticated animals on floodplain vegetation (personal observation).

When compared with other protected areas, Ndumo Game Reserve is significantly rich and diverse in terms of plant and animal species. The reserve itself plays host to some species of high conservation importance and priority, including White and Black rhinoceros, hippo, crocodiles and a variety of antelope species (Naguran, 2002). Red data herbivores such as Red Duiker and Suni can breed here safely.

Approximately 4 047 ha (40% of the reserve) is covered by pans, rivers and general floodplain during the wet season, while this number shrinks to about 1 518 ha (about 15%) during the dry season (Kyle & Marneweck, 1996) Two red data fish species, the Mozambique Killifish (*Nothobranchius orthonotus*) and the Checked Goby (*Redigobius dewaali*), occur in these pans and rivers in the reserve, as well as ten red data reptiles: Natal Hinged Tortoise (*Kninxys natalensis*), African Rock Python (*Python sebae*), Eastern Wolf Snake (*Lycophidion semiannule*), Variegated Wolf Snake (*Lycophidion variegatum*), Whyte's Water Snake (*Lycodonomorphus whytii obscuventris*), Forest Marsh Snake (*Natriciteres variegata sylvatica*), Mozambique Shovel-snout (*Prosymna janni*), East African Egg Eater (*Dasypeltis medici*), Forest Cobra (*Naja melanoleuca*), and the Nile Crocodile (*Crocodylus niloticus*). Of these Whyte's Water Snake, Forest Marsh Snake, and the Nile Crocodile are wetland dependent species (Kyle & Marneweck, 1996).

Ndumo Game Reserve is visited by a large number of local and overseas tourists each year for its ecotourism attractions. The reserve boasts the largest recorded bird list per hectare in South Africa (Naguran, 2002), about 83% of the Maputaland total (Cyrus, 1980), and is a very popular destination for birdwatchers.

Ndumo Game Reserve is one of two known breeding localities of the African Openbill (*Anastomus lammelligerus*) within the borders of South Africa. The

Phongolo Floodplain is one of the few areas where this rare bird can be regularly seen. Its diet consists mainly of large molluscs (mussels and large snails). This species is dependent on the floodplain for both breeding and feeding (Heeg & Breen, 1982).

Various vegetation communities in Ndumo Game Reserve have been described by Pooley (1978). Along most of the Phongolo River, a fringe of trees up to 35 m tall occurs, with species such as *Ficus sycamorus*, *Rauvolfia caffre,* and *Syzygium guineense* the most abundant. Shorter woody plants, particularly *F. capreifolia,* form extensive fringing communities in certain localities. Trees like *Trichilia emetic*, *Kigelia Africana,* and *Acacia albida* occur on the floodplain itself, and pans are generally surrounded by *Acacia xanthophloea* communities. A dense sward of stoloniferous grasses such as *Cynodon*, *Sporobolus,* and *Digitaria* grow under these trees, next to the pans.

2.4. Riparian bird assemblages/Birds in the Floodplain (and Ndumo)

One hundred and twenty wetland associated species have been recorded in the Ndumo Game Reserve (Kyle & Marneweck, 1996)**,** nineteen of which are Red Data waterbirds: White Pelican (*Pelecanus onocrotalus*) (rare), Pink-backed Pelican (*Pelecanus rufescens*) (rare), Rufous-bellied Heron (*Ardeola rufiventris*) (rare), White-backed Night Heron (*Gorsachius leuconotus*) (indeterminate), Little Bittern (*Ixobrychus minutus*) (rare), White Stork (*Ciconia ciconia*) (rare), Black Stork (*Ciconia nigra*) (indeterminate), Woolly-necked Stork (*Ciconia episcopus*) (rare), African Openbill (*Anastomus lamelligerus*) (rare), Saddle-billed Stork (*Ephippiorhynchus senegalensis*) (rare), Yellow-billed Stork (*Mycteria ibis*) (rare), Greater Flamingo (*Phoenicopterus roseus*) (indeterminate), Lesser Flamingo (*Phoeniconaias minor*) (indeterminate), Pygmy Goose (*Nettapus auritus*) (rare), African Finfoot (*Podica senegalensis*) (indeterminate) Lesser Jacana (*Microparra capensis*) (rare), White-fronted Plover (*Charadrius marginatus*) (rare), Collared Pratincole (*Glareola pratincola*) (rare) and Caspian Tern (*Hydroprogne caspia*) (rare).

As mentioned before, two particular species, the Pink-backed Pelican and Yellow-billed Stork, do not breed regularly elsewhere in South Africa (Bowker & Downs, 2012). White Pelicans that breed at Lake St. Lucia (the only breeding colony in South Africa) frequent the floodplain in Ndumo Game Reserve from time to time and carry food to their young over a distance of 100 km away (Heeg & Breen, 1982). The African Openbill is dependent on the floodplain, as it requires large molluscs in shallow waters to feed.

As many as 8 000 White-faced Duck flock to any individual pan during the peak of the *Potamogeton crispus* growing season where they feed exclusively on the turions of this plant (Heeg & Breen, 1982). This is indicative of the importance of these pans as a winter-feeding ground. The reserve is also an important north/south migration route for migrating waterbirds (Kyle & Marneweck, 1996).

The first breeding colony of Pink-backed Pelicans was discovered in 1984, where it bred colonially in *Acacia robusta* trees on the banks of the Hluhluwe River (Bowker & Downs, 2012). After 33 breeding events, the site was abandoned and a new one was established at Nsumo pan where a further 23 breeding records were recorded. Along with the newest breeding site at Nyamithi Pan in the Ndumo Game Reserve, these sites are the only places in South Africa where the Pink-backed Pelicans breed regularly (Bowker & Downs, 2012). The Nyamithi Pan also hosted seven mixed colony breeding species during one breeding season (Bowker & Downs, 2012).

2.5. Riparian bird assemblages

Riparian bird assemblages vary substantially within riparian vegetation, as well as from the adjacent environment. Taking the variation in the characteristics of the river environment, and the context and contrast provided by the surrounding areas into account, it cannot be stated that there is a specifically cohesive characteristic riparian bird assemblage for any riparian area (Woinarski *et al*., 2000). Despite the small total extent of riparian areas, they are extremely important to birds (Woinarski *et al*., 2000). It seems that birds associate more with riparian landscapes in lower rainfall areas than higher rainfall areas, and therefore birds that generally occur in higher rainfall areas would typically be found in riparian strips in a low rainfall area (Woinarski *et al*., 2000).

Many elements influence riparian bird diversity, such as variation in water levels, change in flood regimes, vegetation, and consequently the assembly of bird species is also wide and varied. Birds from almost every ecological group, feeding guild, nesting guild, and habitat preference can be found. Some species are bound to riparian areas as a result of the high habitat heterogeneity, others are not. The distinctiveness of riparian areas does not result from a few resource types, but rather a large difference in resources between riparian and non-riparian areas (Woinarski *et al*., 2000).

As habitats are never static but change, expand, or shrink in response to a number of influences, riparian bird assemblages are also never static. When comparing bird species richness and diversity with non-riparian areas, or even areas adjacent to riparian areas, riparian areas were significantly richer, supporting more species than non-riparian areas and significantly more birds. The overall composition of bird assemblages differed significantly between riparian and adjacent non-riparian habitats (Palmer & Bennett, 2006).

A number of factors may influence the importance that riparian habitats have for wildlife. Some factors were mentioned earlier, while others are easy access to water, great habitat heterogeneity, and relatively accessible food and nesting sites (Palmer & Bennett, 2006). Some studies have even linked greater species richness and diversity directly to greater vegetation heterogeneity (Palmer & Bennett, 2006; Woinarski *et al*., 2000).

According to Palmer and Bennett (2006), it would be easy to assume that smaller areas, such as riparian areas, would be less abundant in species and individuals than larger areas with more space. Secondly, as birds are especially mobile, they can move relatively freely between riparian and non-riparian sites, thus creating a more homogenous species composition than what is actually present. Thirdly, in more tropical climates, the gradient of vegetation change away from riparian sites would also create a change in species and less of an impact on the structure of bird assemblages.

It would seem however, that even with the smaller areas riparian habitats cover, when compared to non-riparian areas, there is a clear difference in richness and composition of bird communities between the two types and that riparian areas strongly influence bird species distribution (Palmer & Bennett, 2006). Palmer and Bennet (2006) found that species that occurred in the riparian area under study was a mixture of species with otherwise widespread distributions and habitat requirements, but also more abundant in riparian areas than non-riparian areas. Species affinities can differ however, across large spatial scales as some species that are found to be more abundant in riparian zones may be more abundant in non-riparian zones in different locations elsewhere. This may be a scale-specific reaction or even a response to other factors that influence the composition of vegetation as well as bird species over a larger scale (Palmer & Bennett, 2006).

Many studies have linked greater bird species richness and diversity directly to greater vegetation heterogeneity (Cody, 1981; Palmer & Bennett, 2006). MacArthur (1964) has even gone so far as to say that the number of breeding bird species is greatest where the three layers of vegetation have equal amounts of foliage. However, knowledge of the number of plant species or their volume does not improve our prediction of the number of bird species or their diversity even if prediction of their abundance can be derived from measurements of patches of vegetation present (MacArthur, 1964). Assuming that bird species choose their habitats exclusively according to the vegetation density profile, predicting species and their numbers may be more possible than in more complicated environments, where the birds seem to use more than just the vegetation profile in selecting suitable habitats. It can be assumed that the vegetation layers within a habitat account for the number of species – more layers would mean more species – but variation between habitats is caused by more variables than the layers alone (MacArthur, 1964; Palmer & Bennett, 2006).

There are a few things to keep in mind when predicting species diversity based on foliage height and diversity. Some bird species, especially parrots and crossbills (MacArthur, 1964), do not necessarily make use of specific foliage profiles in selecting appropriate habitats, but rather look for areas with abundant fruit supply. Different foliage types would also vary in usefulness to different bird species, especially in terms of perching and foraging. Ferns, for example, may be less useful to breeding birds than a layer of better plant structure and the predicted bird species might differ from the observed number. As foliage structure and cover change with seasonal changes, bird diversity might change accordingly, and different bird species could select the same spot during different times of the year as the foliage changes according to their needs, including fruit-bearing plants (MacArthur, 1964).

Different ecosystems have different plant species, different vegetation structure dynamics, and thus different bird species compositions. Maputaland has 21 different ecosystems, some of which stretch across the Ndumo Game Reserve. The following are a few ecosystems of which parts run through Ndumo Game Reserve, with their representative plant and bird species (Moll, 1980).

Table 2: Ecosystems in Ndumo Game Reserve, with plant species, bird species, and Roberts numbers for birds as found in Hockey *et al*. (2005).

Ecosystem	**Representative plants**	**Representative birds**	**R.no**
Acacia luderitzii / Acacia grandiflora Thickets	*Acacia grandicornuta*	Natal Spurfowl	183
	Acacia luderitzii	Crested Guineafowl	193
	Pappea capensis	White-throated Robin-Chat	582
	Gardenia cornuta	Pale Flycatcher	662
	Euphorbia grandicornis (shrub)	Southern Boubou	709
		Three-streaked Tchagra	714
		Grey-headed Bush-Shrike	723
		Blue Waxbill	839
Riverine Forest and Thicket	*Ficus capreifolia*	Green Pigeon	323
	Ficus sycamorus	Purple-crested Turaco	337
	Syzygium guineense	Pel's Fishing-Owl	370
	Rauvolfia caffra	White-eared Barbet	433
		Scaly-throated Honeyguide	441
		Arrow-marked Babbler	533
		Terrestrial Bulbul	546
		White-browed Robin-Chat	580
		Yellow-breasted Apalis	625
		Blue-mantled Crested Flycatcher	680
Floodplain Grasslands	*Echinochloa pyramidalis*	Cattle Egret	61
	Hemarthria altissimma	Squacco Heron	62
		Little Bittern	71
		Saddle-billed Stork	75

		Sacred Ibis	81
		Spur-winged Goose	88
		African Marsh-Harrier	167
		Wattled Lapwing	247
		Pratincole	281
		Orange-breasted Waxbill	838
Lakes, Pans and River (mud substrate)	*Nymphaea capensis*	White Pelican	42
	Ceratophyllum demersum	Goliath Heron	56
	Pogamogeton crispus	Little Egret	59
	Phragmites mauritianus	Black Heron	64
	Trapa natans var. *bispinosa*	Night Heron	69
		Hamerkop	72
		African Openbill	74
		Yelllow-billed Stork	76
		Spoonbill	85

2.6. Factors affecting bird diversity and communities in riparian ecosystems

Both Woinarski *et al*. (2000) and Palmer and Bennett (2006) showed that riparian areas had significantly greater species richness, abundance and diversity than non-riparian areas. Riparian sites were floristically distinct from non-riparian sites and had a composite vegetation structure (Palmer & Bennett, 2006). Riparian areas also harboured more migrants, indicating that riparian areas are especially important for breeding birds (Woinarski *et al*., 2005; Gentry *et al*., 2006; Palmer & Bennett, 2006).

As mentioned before, there are different factors affecting the choice of habitat for birds. Specialists are very constricted in their choice of habitats, while generalists are more prone to adapt to multiple types of habitats. Dispersal constraints, environmental constraints, and internal dynamics are some of the factors affecting species composition (Begon *et al*., 2006). Cody (1981) suggests that vegetation structure, competitors, and productivity act as constraints on habitat acceptability to birds.

Species also do not occur everywhere that conditions and recourses are appropriate for them (Begon *et al*., 2006) as physiological ecology and behavioural patterns affect habitat selection too. Behaviour patterns sometimes keep species from occupying habitats that would otherwise be very well suited. Hockey *et al*. (2005) uses the example of two species of pipits - tree pipit (*Anthus trivialis*) and the meadow pipit (*Anthus pratensis*) – where both are ground nesters, but one needs trees for end-of-aerial song, and consequently inhabit areas with more trees than the other species of pipit that mostly stays on the ground.

Few detailed studies have been done on exactly how the environment influences both habitat complexity and habitat heterogeneity (Doherty *et al*., 2000), and how these attributes determine, in turn, the distribution and abundance of species. Some of the factors that affect riparian bird species composition and distribution are as follows and will be discussed below; time, space, riparian habitats, riparian vegetation structure, disturbance and patchiness, habitat fragmentation, food and feeding, nesting sites, water, competition, predation, presence of other species, and migration. Many, if not all of these factors are interrelated and are all responsible for the differences in bird species composition and distribution in riparian habitats in some way.

2.6.1. Time

Time is a factor that influences, directly or indirectly, the diversity of bird species in riparian habitats (Doherty *et al*., 2000) as many factors that influence bird diversity and communities change over time. Time affects bird species composition and distribution in many ways (Doherty *et al*., 2000; Smucker *et al*., 2005; Hawkins *et al*., 2005).

Vegetation composition and structure changes as seasons change, creating different kinds of habitats. As vegetation changes, so does food availability, which in turn changes foraging habits of birds (Maclean, 1990). If food is available in abundance, and vegetation structure is desirable, the habitat might be suitable for breeding too.

Seasonal changes also affect areas with high or low rainfall, as bird abundance would be greater during high rainfall seasons than dry seasons (Woinarski *et al*., 2000). Chan *et al*. (2008) recorded greater numbers of birds per visit during the dry season, which might reflect birds from adjacent landscapes using the riparian habitats as refuge during dry seasons, as well as migrants making use of riparian areas specifically during migration time. Fires are a threat during dry seasons. After a fire has burned through a habitat (Smucker *et al*., 2005), succession and recovery bring patterns of change in vegetation structure, in seed availability, and therefore in bird abundance.

2.6.2. Space

Conditions and resources that are favourable for reproduction and survival are of cardinal importance for the selection of habitat. Normally, these are patchily distributed in space and time (Begon *et al*., (2006). Spatial scale is of great importance to bird species composition. Hydrological and geomorphic processes can also alter riparian ecosystems (Gregory *et al*., 1991) by controlling landscape structures, fluvial landforms, riparian vegetation and much more. Geomorphic processes modify riparian zones with time (months, years, decades, and centuries) and on spatial scales ranging from small shifts of a few square meters to basin-wide flooding (Gregory *et al*., 1991). This has an impact of species composition and the surrounding community.

2.6.3. Riparian habitats

The more diverse a habitat, the higher organism diversity would be in that habitat (Rosenzweig, 1995). Changes in habitat and the environment bring about change in plant diversity and ultimately species diversity in general. The changing environment constantly places new and more stress on organisms, causing them to adapt. Doherty *et al*. (2000) suggests that the environment influences both habitat complexity and habitat heterogeneity, and these, in turn, influence the distribution and abundance of species. Habitat complexity refers to the level or strength of interaction between a species and their environment. Habitat heterogeneity refers to spatial or temporal change across a landscape. Habitat heterogeneity can also be called habitat diversity (Doherty *et al*., 2000).

When birds select their habitat, they are essentially choosing a place in which to not only live in, but also reproduce and thrive. This would be a response to key aspects of the environment (Hockey *et al*., 2005). If a species is present, reproduces, and lives in an area, it would mean that all its needs are essentially met and that it can successfully compete with other species (Hockey *et al*., 2005). Environmental heterogeneity, productivity, and resource diversity have major effects on functional diversity and species richness (Naiman *et al*., 1993). More diverse habitats create niches for more species, and therefore habitat heterogeneity leads to greater species diversity.

Abiotic (non-living, physical, and chemical) factors also play a role in habitat selection. The most limiting factors are temperature and moisture, but physical factors (light, soil, structure, fire, etc.) and chemical factors (oxygen, soil nutrients, salts, pH, etc.) also play an important role in limiting habitat selection and ultimately presence or absence of bird species (Hockey *et al*., 2005).

2.6.4. Riparian vegetation structure

Vegetation has a direct influence on bird species diversity, even more so than topography or climate (Seoane *et al*., 2004). Nesting and foraging needs are often directly linked to vegetation structure, which makes it a parameter of potential prediction for avian diversity. Bird species diversity in South Africa in different habitats is strongly dependent on habitat structure and rainfall - the driest areas with least structure vegetation have the fewest species (Hockey *et al*., 2005). Where vegetation structure and foliage cover changes with seasonal changes, species diversity also changes (MacArthur, 1964).

Prominent vegetation classes in riparian areas are trees, shrubs, grasses, reeds, forbs/herbs and sedges (Edwards, 1983). Reeds and sedges are normally found on the shores of waterbodies, while trees, shrubs, grasses, and forbs occur on land, bringing together two ecosystems and creating a more diverse and complex vegetation structure than in non-riparian areas. These diverse vegetation structures increases heterogeneity and complexity, and creates different niche opportunities for a greater variety of bird species.

Changes in habitat and the environment bring about change in plant diversity and ultimately species diversity in general (Doherty *et al*., 2000). Geomorphic and hydrological processes influence vegetation structure either directly, or by changing the landform (Gregory *et al*., 1991; Naiman *et al*., 1993; Wakeley *et al*., 2007).

Streamside vegetation along a riparian corridor exerts some control over the stream environment (Naiman *et al*., 1993). A great variety in plant species richness occurs in space and time along stream margins, which has important influences on the in-stream biota and processes. These in-stream biota and processes influence the feeding and nesting site availability for birds. Riparian vegetation regulates light and temperature, provides food to aquatic as well as terrestrial biota (which may, in turn, be food for birds), regulates the flow of water and nutrients from uplands to the stream, and serves to maintain biodiversity by providing diverse habitat and ecological services. Large wood pieces and debris influences sediment deposits, morphology of the river and in-stream habitat (Naiman *et al*., 1993). As the riparian corridor is constantly flooded and disturbed by flood debris, it creates a complex environment of potential bird habitats.

Riparian vegetation has therefore a notable influence on birds, affecting shelter and food to perching sites and nesting sites. This complex influence that vegetation has on habitat creation serves as the basis for habitat selection in birds.

2.6.5. Disturbance and patchiness in riparian corridors

Land use practises and urban development threaten the ecological integrity of many streams and their associated riparian wetlands. Human activities directly modify existing riparian wetlands by agricultural practices, flood control programs, and waterway commerce (Mensing *et al*., 1998; Lankford *et al*., 2010), and indirectly by adjacent and regional land use, which is considerably more permeant. Anthropogenic disturbances generally affect the integrity of aquatic ecosystems negatively. Adjacent land use practises may imperil the integrity, continuity, and persistence of the riparian corridor as a diverse array of habitat types and associated biota (Mensing *et al.,* 1998).

Dramatic changes in global climate are resulting from deforestation, the burning of fossil fuels and other human influences (Begon *et al*., 2006). Climate change affects vegetation, which affect habitats and eventually species distribution. Habitat loss, fragmentation, and loss of connectivity between habitat patches because of forestry practices resulted in the drastic decline of squirrel populations (Begon *et al*., 2006). These patches were important for migration between them for male squirrels.

Because of continued habitat destruction and loss, the list of endangered species is growing alarmingly (Mensing, 1998; Begon *et al*., 2006).

An active natural disturbance regime, such as fires, floods, landslides, debris torrents, and channel migration, which operate over a wide range of spatial and temporal scales, maintains ecological diverse riparian corridors, as change is a constant (Naiman & Decamps, 1993). These natural disturbances, if spaced over time and space, produce significant heterogeneity and temporal variability in species richness and diversity. Some disturbances happen in synchronised fashion or phases, where extensive areas are damaged at once. Examples of such disturbances are fires and deforestation where a large tract of a climax community is destroyed at once. Succession of the whole area then proceeds in more or less synchronised fashion as time passes. The early colonisation phase sees an increase in diversity and then a decrease through competitive exclusion as the climax is approached (Begon *et al*., 2006). Smaller disturbances, if un-phased or unsynchronised, produce a patchwork of habitats that do not increase to a climax community together, as they will be at different stages of succession. A mosaic of climax communities has a much richer species composition than a large, undisturbed area dominated by a few climax species (Begon *et al*., 2006).

However, where some studies found that the effects of fragmentation on abundance were positive, others found that the response to fragmentation was weak. Westphal *et al*. (2003) found little to no commonality between the predictions of models and the rather ambiguous results of empirical studies (Westphal *et al*., 2003). The intermediate disturbance hypothesis states that the highest diversity is maintained at intermediate levels of disturbance (Begon *et al*., 2006). Diversity increases with time as more species invade a patch before the next disturbance occurs. Persistent species rich communities can result when many unstable patches (out of phase with each other) integrate to form a larger landscape patch.

Movement between habitat patches is very important in patch dynamics (Begon *et al*., 2006). Most often, this process is the dispersal of young individuals, but may very well include adult individuals from one patch to another (this is not the same as migration from one country to another during seasonal changes). Not all species are flexible enough to adapt and consequently may suffer population declines. Higher densities of consumers left behind in smaller patches may result in higher competition levels, lower food intake, and eventually higher winter mortality and lower overall population size, even as an indirect result of reduced breeding habitat (Dolman & Sutherland, 1994).

When no new movement into a patch occurs, that patch is, by definition, a closed system, and any extinction caused by disturbance would be final. If a patch in an open system undergoes disturbance, the possibility of reinvasion by species from other patches would save it from extinction (Begon *et al*., 2006). In this case, disturbance would act as a reset mechanism and patches being disturbed would be recolonised by individuals of various species.

Riparian ecosystems provide habitat, shelter, food, and nesting sites to many species, act as the transition and filter between land and water, and function as corridors for migrating organisms. They are also good indicators of environmental change as they are particularly sensitive to change and variation, especially in the hydrological cycle (Nilsson & Berggren, 2000). River regulation constitutes an important factor in habitat degradation or change. Riparian zones have high species richness that need to be sustained, but as they are highly susceptible to change, many riparian habitats degrade quite fast. Nilsson and Berggren (2000) used the Macquarie River in Australia as an example. Degradation of the wetland has been noticeable since river regulations have affected the amount of water down stream and water bird numbers have especially dwindled since the amount of water has decreased.

Even if controlled floods are continued in a regulated river, the extent of the change in the amount of water and nutrients, and the change that it has on the environment over time is not yet fully understood (Nilsson & Berggren, 2000). Merely the changes in timing of floods could result in environmental change. Delaying, reducing or eliminating floods and their effects could negatively affect reproduction and feeding patterns of animals such as fish that have evolved with this seasonality, and a change in flood timing could affect their reproduction and growth. Grazing could impact floodplains if floods are not regular and grass remain unflooded, not allowing for enough time to rest between grazing seasons (Nilsson & Berggren, 2000). Where flooding has stopped, the species composition of riparian forests changes to that of unflooded, upland forest areas (Nilsson & Berggren, 2000).

2.6.6. Food and feeding

Habitat degradation to the extent of habitats deteriorating beyond repair or recovery will result in specialist species disappearing from these spaces. Generalists, who are more tolerant to habitat changes, will move in and may change and further degrade the ecological integrity (Sudlow, 2004).

Different bird species prefer different food types and use different foraging methods and behaviour to find it. In order to reproduce successfully, a bird must seek out the best habitat with the best kind of vegetation for its survival. It has to be able to find, capture, and handle prey successfully, and even then, competitors can affect the success of survival by competing for similar food using similar foraging techniques (Cody, 1981). Different species, however, mostly have different food needs and different ways of acquiring food. A wide variety of vegetation structure, foliage, fruits, and even perching sites is required to harbour a wide variety of species. This, coupled with the differences in dependence on aquatic preys, can lead to great heterogeneity of birds in riparian zones (Murakami & Nakano, 2001). Species can also share a habitat but feed in different sites within habitats (Cody, 1981). Some species, like thrushes, kingfishers and flycatchers, find food visually. They need perches to spot prey from and dense vegetation might hinder the process. Other species prefer dense foliage from which to glean insects. There is quite a difference in the vegetation needs of species in order to forage successfully (Hockey *et al*., 2005).

More food is normally available at riparian than non-riparian sites (Murakami & Nakano, 2001). Insectivores are attracted by the large amount of aquatic and terrestrial insects living in riparian areas. Some species, like the Great Tit (*Parus major*) remain near streams, tracking groups of aquatic insects during the period of peak emergence, consuming large amounts of these adult insects during this time. Chan *et al*. (2008) found twice the amount of birds in riparian zones during the wet season when adult aquatic insects were present in large numbers, than further inland. The higher the insect numbers, the more birds were attracted to the riparian zone.

When food is scarce, each species faces foraging obstacles according to species-specific requirements. Species might aggregate not because of the abundance of food, but rather the lack of terrestrial resources elsewhere (Murakami & Nakano, 2001). This stresses the importance of aquatic resources in riparian zones for birds (Murakami & Nakano, 2001).

Foliage is generally abundantly available in riparian habitats. Foliage-eating species can cause significant amounts of defoliation to the tree species they prefer (Clout & Hay, 1989). Foliage is mainly eaten when fruit is least available, and birds occur primarily along rivers and valleys where most abundant foliage occurs. Some birds (like the New Zealand Pigeon, *Hemiphaga novaeseelandiae*) feed exclusively from one or two trees for several days, leading to quite intense browsing pressure. Noticeable defoliation is caused within a few weeks of ongoing browsing pressure (Clout & Hay, 1989).

The Wattlebird's (*Callaeas* sp; New Zealand) primary food item is the Sixpenny Scale Insect (*Ctenochiton viridis*) which adheres to the underside of leaves of various tree species. These birds remove the leaves and systematically pick the insects off the leaves, resulting in a profound litter of discarded leaves after the feeding bout and significant defoliation of the trees it was gleaned from (Clout & Hay, 1989).

To a greater or lesser extent, seed dispersal along streams is dependent on birds. Frugivorous bird movements play a central role in seed dispersal and plant ecology, with important implications for ecological succession and habitat restoration. Fruit-eating species add to the environment by chewing seeds along with fruit, cracking them and helping with seed dispersal (Clout & Hay, 1989). Bird-mediated seed dispersal plays a notable role in the survival of trees. Birds are important dispersers of seeds especially upstream and between different streams (Hampe, 2004). Species such as the African Green-Pigeon (*Treron calvus)*, Red-faced Mousebird (*Urocolius indicus)* and White-eared Barbet (*Stactolaema leucotis*) are frugivores which may disperse smaller seeds (Hockey *et al*., 2005). Species such as Kea (*Nestor notabilis*), Kakapo (*Strigops habroptilus*), Red-crowned Parakeet (*Cyanoramphus novaezelandiae*), and Yellow-crowned Parakeet (*Cyanoramphus auriceps*) are seed predators, cracking large seeds with their strong beaks. About 70% of New Zealand's woody plants have fleshy fruit suited specifically for bird dispersal (Clout & Hay, 1989).

Riparian habitats further provide a large variety of other food types for bird species, such as plant seeds, vegetable material, and arthropods, and habitat for species that are bird prey, such as frogs, fish, worms, reptiles, larvae, insects, molluscs, and crustaceans.

2.6.7. Nesting sites

Birds have a fixed morphology that determines breeding preferences and breeding behaviour. Behaviour might be flexible, but there are limits to this flexibility, and thus the choice of where to breed has to meet all the requirements in order for birds to breed successfully and flourish (Cody, 1981).

Habitat structure is very important in nesting site selection. Different birds respond to different structural attributes, like the Catbird (*Dumetella carolinensis*) which responds to the size and shape of leaves, and Bobolinks (*Dolichonyx oryzivorus*) which prefer areas with little to no litter on the ground (Cody, 1981). Some species require non-vegetation structural features; e.g. swallows and swifts prefer man-made structures or vertical rock faces to attach nests to (Hockey *et al*., 2005). Yet other species require different vegetation structures and qualities for foraging or cover (Cody, 1981); e.g. Passenger Pigeons (*Ectopistes migratorius*) which nested only among beech trees where the nearby fruit crop of forest trees was high. Less evidence is available for insectivores, but similar results to those of the pigeons were found for frugivores, piscivores, and seed-eating birds.

Generalist species are less selective in terms of habitat and nest requirements, and nest-site availability is less of a limiting factor for them. However, generalisation in nest placement may not be advantageous in all cases, as specialization reduces exposures to mortality factors. A greater variation of vegetation structure might also include a greater variation in nest predators (Best & Stauffer, 1980). Significantly lower nest success was achieved by species selecting general nesting sites than those using specialised nesting sites (Best & Stauffer, 1980).

Several other factors also aid in nest failure, such as predation, intemperate weather, vegetation structure failure (a branch breaks and the nest falls), or inexperienced, first time breeders. Best and Stauffer (1980) found the following causes for nest failure in their study: predation by birds, snakes, small mammals and large mammals (bigger species were less predated than smaller species), as well as cowbird parasitism, and natural disasters. Open cup nests were the victims of predation more than any other type of nests, and nests below 5 m or higher from the ground were significantly more successful than nests built lower than that (Gentry *et al*., 2006). Nests in more protected locations suffer less from nesting failure as they are better protected from weather conditions and predation (Best & Stauffer, 1980).

Apart from birds requiring specific vegetation, some birds parasitize other species. Parasitic breeders such as cuckoos lay their eggs in a different bird species' nest and the host species then raises the parasitic young. The Western Kingbirds use nests abandoned by other birds, or hollows in trees, and do not need to build nests (Bergin, 1997; Hockey *et al*., 2005).

Some birds breed in colonies, such as the Pink-Backed Pelican and Yellow-billed Stork – on the ground (at sites safe from land predators) or in trees, reeds, bushes or even on cliff faces (Hockey *et al*., 2005; Bowker & Downs, 2012). Most of these species are associated with riparian or wetland habitats.

According to Knopf *et al*. (1988), 82% of all bird species that breed in northern Colorado do so in riparian vegetation and 61% of all bird species in southwestern states are completely dependent upon riparian habitats. Pearson and Manuwal (2001) found that despite differences in vegetation features between riparian zones and upland habitats, bird species richness and composition did not differ significantly, but total abundance was higher in riparian zones. This abundance was correlated with the amount of berry-producing shrubs, as well as the amount of deciduous trees and their canopy cover.

2.6.8. Water

Fauna and flora are dependent on water as it is both a resource and a condition (Begon *et al*., 2006). Different species need different amounts, and as water is a limiting factor in habitat selection, the value of food increases in the presence of water (Kotler *et al*., 1998; Hockey *et al*., 2005). All birds suffer from water loss during foraging; if water were available in excess at a specific site, that site would be favoured by birds over other sites. Different foods vary in water content (Kotler *et al*., 1998); granivores drink more water than waders do, as they need water to balance the dry content of their food (Kotler *et al*., 1998). Waders receive water with their food, such as tadpoles, fish and aquatic insects, and insectivores receive water from their prey and do not need to drink so much (Naiman *et al*., 1993).

Non-riparian birds may still visit riparian strips irrespective of vegetation structure. These birds might include granivorous finches, pigeons and cockatoos, which visit riparian zones specifically to drink water (Kotler, *et al*., 1998). In dryer landscapes, species may adapt their food to exclude types of food that result in water loss. Results from a study done by Kotler *et al*. (1998) show that dry foods and water are complementary resources for Australian ravens in the Simpson Desert. Water levels may vary with seasonal fluctuations due to variation in rainfall, which will affect species composition (Woinarski *et al*., 2000). However, even with these fluctuations in water levels, water might not be the biggest factor in affecting species composition. Other factors may influence the presence of species even more than water, such as foraging potential, nesting sites, predators and competition (Woinarski *et al*., 2000).

2.6.9. Competition

Bird species do not only respond to vegetation but also to competition. Competition is the interaction between individuals where they require and share the same resources in the same habitat (Begon *et al*., 2006). A site might be suitable for a specific species but might already be inhabited by an individual of the same species or another species with the same habitat requirements (Cody, 1981). Intraspecific competition is the competing of individuals within a population that can influence the number of individuals of that species. Interspecific competition is the competing of individuals of two or more species. This can influence the total number of species present in a habitat (Begon *et al*., 2006). Even though a range of vegetation types might be suitable, bird species will only occupy that site which it can co-inhabit with a complementary species (Cody, 1981). In this way, competition could be responsible for species distribution patterns over a range of habitats, such as was found by Wyma (2012).

Many species require similar resources and would co-occur wherever those resources exist. If competition did not limit the number of individuals in a habitat, more abundant numbers of birds would lead to higher densities, which, according to Begon *et al*. (2006) can also be termed crowding. However, like species compete for like resources (Hockey *et al*., 2005). Food availability and suitable nesting sites are significantly reduced in the presence of competition species (Cody, 1981). Generally, foreign species adapt relatively well (sometimes because of the absence of natural predators) and some generalist species could affect the presence of native species (Hockey *et al*., 2005).

Competition is influenced by heterogeneous, inconstant, or unpredictable environments and is therefore particularly strong in riparian habitats (Begon *et al*., 2006). Competition can influence the number of species and individuals occurring in riparian habitats as it affects fecundity, growth, and survivorship of some of the species (Begon *et al*., 2006). Migrating species also add to competition when they arrive and compete for resources and nesting sites during breeding season.

Specialists are more likely to compete for resources than generalists as a wider range of conditions have to be met in order to survive and breed successfully, especially as they are restricted in selection of suitable conditions. Territoriality is a contest and therefore foraging grounds, nesting sites, perching sites, and/or roosting sites are competed for more aggressively between specialists than generalists (Begon *et al*., 2006). When one of two competing species were removed during an experimental study (Begon *et al*., 2006), the other species fledged between 78 – 129 % more young per nest and feeding rate also increased.

When species are able to adapt, like generalists, they are able to use the habitat in slightly different ways and so foster coexistence between species (Begon *et al*., 2006). When closely related species seem to coexist in the same habitat, there might be the slightest difference in behaviour. Both species might forage for insects, but the size of insect prey may differ, the seed hardness might differ for granivores and, despite similarities, they might be able to share a habitat. Niche differentiation can therefore foster the coexistence of like species, when species living in exactly the same niche make use of different resources (Begon *et al*., 2006).

2.6.10. Predation

As with competition, predation also affects abundance. Predators attack prey while they are still alive, and while some bird species are frugivores and herbivores, others are predators. Predators can affect individuals or communities through lethal effects or non-lethal effects. Lethal effects include consumption of prey. Non-lethal effects affects the behaviour of prey. Predator avoidance is a trait-mediated effect because of predators in the vicinity (Cresswell, 2008). Riparian zones are especially rich in diversity and would be profitable habitat for predators to search for prey. The more diverse the prey is, the more diverse the predators will be. If prey numbers fluctuate or decline, predator numbers will also fluctuate or decline (Begon *et al*., 2006). Ultimately, that has an effect on total bird diversity and community structure.

Nest predation occurs frequently and especially in densely populated habitats. Certain bird species, cats, snakes, iguanas, otters, mongoose, mice, and squirrels can be nest predators (Hockey *et al*., 2005). Birds such as Burchell's Coucal (*Centropus burchellii)*, Brown-hooded Kingfisher (*Halcyon albiventris)*, Red-backed Shrike (*Lanius collurio)*, and Common Fiscal (*Lanius collaris*) often prey on bird-nest contents. A study done by Miller and Hobbs (2000) shows those nests close to recreational trails were attacked by birds more often than nests further away, whereas mammals appeared to avoid nests close to recreational trails. However, nest predation increased with distance from trails. Nest predation can have a significant impact on bird diversity in a habitat, shown by Miller and Hobbs (2000), who found that 226 out of 240 nests that were studied were predated.

Anthropogenic disturbances can also include the consumption or predation of bird species. The rural communities around Ndumo Game Reserve catch fish and hunt wildlife to eat (Meer & Schnurr, 2013) and heavier birds, such as Helmeted

Guineafowl, are hunted for meat (Pers. Comm. Game rangers in the Ndumu Game Reserve).

2.6.11. Presence of other species

Many species occur somewhere because of other species already inhabiting that area. Raptors and predators occur where the prey is abundant and brood parasites occur where the nesting requirements of the host species is optimal (Hockey *et al*., 2005). Predator avoidance would cause some species to leave because of the predators present, and certain species would suffer lower fecundity as a result of brood parasitism and fail to raise young of their own, lowering their success in the area and limiting their survival in that habitat.

If densities become too high, density-dependent emigration dispersal could result. Species could migrate to further habitats of similar composition with fewer individuals to avoid overcrowding. The highest rates of dispersal will be away from the most crowded patches (Begon *et al*., 2006).

2.6.12. Migration

Migration is the regular, recurrent, seasonal movement of populations from one geographic location to another and back again (Lincoln *et al*., 1998). It may be learned behaviour or genetically determined (Dolman & Sutherland, 1994), and could be either a round trip or a one-way movement (Lincoln *et al*., 1998; Hockey *et al*., 2005). There are permanent non-migratory (resident) populations, partial migrants, and fully migratory species. Some species have migrating individuals while others of the same species are residents (Lincoln *et al*., 1998). Some individuals might expand their range due to intraspecific competition into an area with greater resources during breeding season, but variable resources during non-breeding season. They then return to their previous habitat during non-breeding seasons, and forage and rest until the next breeding season.

Temporal and spatial variance in climate and resource availability influence the temporal and spatial differences in animal composition in important ways. (Hockey *et al*., 2005; Papes *et al*., 2012). Heterogeneous, inconsistent, or unpredictable environments influence competition, which influences the number of species and individuals occurring in riparian habitats. This in turn affects breeding success, growth, and survivorship (Begon *et al*., 2006). Migration occurs when densities become too high and overcrowding occurs (Begon *et al*., 2006). Migratory species also add to competition when they arrive and compete for resources and nesting sites.

Migratory species are subject to rigorous selection pressure as their journeys may be exhaustive, predators in the interim sites may feed on them, habitats between the two end destinations might not be suitable for foraging or resting, and interspecific competition may be intense at the sites they migrate to. This may result in decreased adult survivorship. Non-migratory species are also subject to harsh conditions, as the seasonal changes and loss in vegetation during dry months could affect them (Hockey *et al*., 2005).

Migration should therefor offer a balance between the costs and benefits of such a venture (Lincoln *et al*., 1998). The advantages for migratory species are that they have an adequate food supply and favourable climatic conditions throughout the year. They move to an area that meets the specific requirements for breeding and has adequate food for their young. Some species migrate to a habitat specifically for the foraging advantages for its young, while other species migrate to a specific habitat for its vegetation structure and good nesting sites (Lincoln *et al*., 1998).

2.7. Community

All of the above factors influence community composition. A community is an aggregation of species populations that occupy a habitat in space and time. Abiotic environmental factors and interactions between species, as well as dispersal constraints, environmental constraints, and internal dynamics can influence these assemblies of species and populations to form communities (Begon *et al*., 2006). There is, however, more to communities than just the sum of its constituent species (Wiens, 1989a; Begon *et al*., 2006). Successful establishment of breeding populations and loss of species through local extinction plays a significant role in determining the composition of a community (Wiens, 1989a).

A simple way to distinguish a community is to list the species present and calculate the species richness. Community richness is determined by combining diversity and species richness (Begon *et al*., 2006). Communities can change with time and space, and scale affects the composition. On a large spatial scale, community composition would look different than at a small scale, and the boundaries are difficult to determine as communities are not often whole entities with sharp boundaries (Begon *et al*., 2006). A species that occurs at a specific place under specific circumstances is likely to occur somewhere else under different circumstances (Begon *et al*., 2006).

If conditions, resources and/or the influence of enemies fluctuate, so will community composition. Animals can be passive followers of change and succession in plants, and it is wise to look at both space and time when studying community composition patterns (Begon *et al*., 2006).

2.8. Specialists and generalists

Bird species can be either specialists or generalists. This can reflect in feeding habits, nesting prerequisites and general habitat selection.

Diets are an important distinction between specialists and generalists. Specialists are limited in their flexibility to adapt to change. Often, they only consume specific types of food, specific species, or even only parts of their food. Many bird species only eat seeds, but could then choose from a wide variety of plant species to choose the seeds from, while other specialists may even feed on only one species of plant seeds (Begon *et al*., 2006). Generalists may often eat anything (within limits) and have a wide variety from which they can choose, though they may have preferences if alternatives are available.

More often than not, generalists live longer than specialists do. Long-lived species are likely to be generalists, as they cannot rely on a specific food source to be available throughout their lifespan. Short-lived species are usually specialists and can afford to settle on/for a specific food source. Whenever the food source is scarce, the bird would spend more time foraging further to find it, or be constrained to a specific habitat patch where the distribution of that food source is limited. This is one of the costs of specialisation (Begon *et al*., 2006).

Riparian habitats with their heterogeneous communities are often safe havens for specialists as they contain a wide variety of food resources, nesting sites and general habitat traits that specialists require.

2.9. Synthesis

Riparian communities are unique, diverse, and influenced by many factors. Birds choose their habitat as a result and combination of all of these factors. Because of such differences in environmental factors, different species might be associated with different habitats. Bird species richness and abundance would therefore differ among diverse habitats and over time, and create intricate community structures. This is the subject of my thesis.

Chapter 3: Methods

3.1. Study Area

3.1.1. Location

The study area was located in the Phongolo floodplain (Figure 3.1). (There are a few ways to spell Pongolo. Therefore, for the duration of this study I will use Phongolo, except where indicating Pongolapoort Dam.) The Phongolo Floodplain within the Makhatini Flats, occupies the north-western corner of KwaZulu-Natal, South Africa, in-between the Pongolapoort Dam and the Ndumo Game Reserve, with the floodplain between 18 – 170 m above sea level (Kyle & Marneweck, 1996). It is this area which is flooded by the Phongolo River during summer, when the river floods about 13 000 ha of the floodplain (Rogers, 1980). The Pongolapoort Dam was constructed for irrigating planned farms in the area (Heeg & Breen, 1982). An artificial flooding regime has been put in place to provide the floodplain with the water it needs. Even after the river subsides in autumn, water remains in pans in the flooded area, covering an area of about 2 600 ha. Many of the minor pans dry out during winter, while others retain water even in the driest of years. Figure 3.1 illustrates the position of the Phongolo floodplain in relation to KwaZulu-Natal.

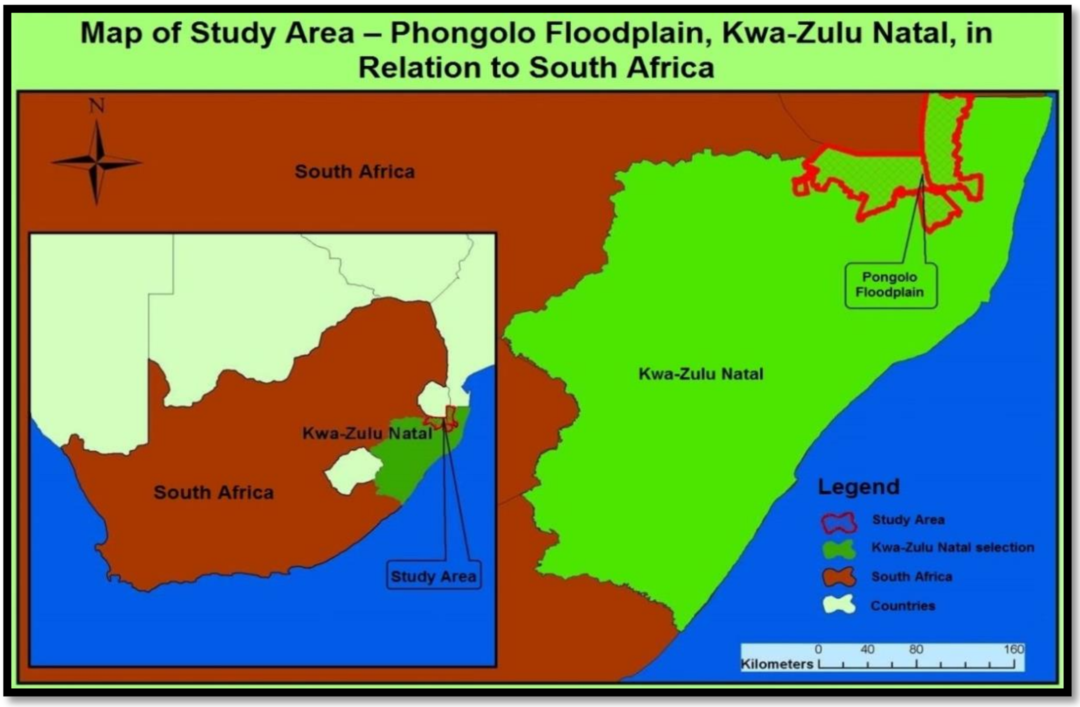

Figure 3.1: Phongolo Floodplain in relation to South Africa.

Figure 3.2 is a more detailed map of the study area, with the Pongolapoort Dam, broad vegetation descriptions and main water uses. It also contains names of adjacent rivers and types of land use. Note the Ndumo Game Reserve at the top right of the figure.

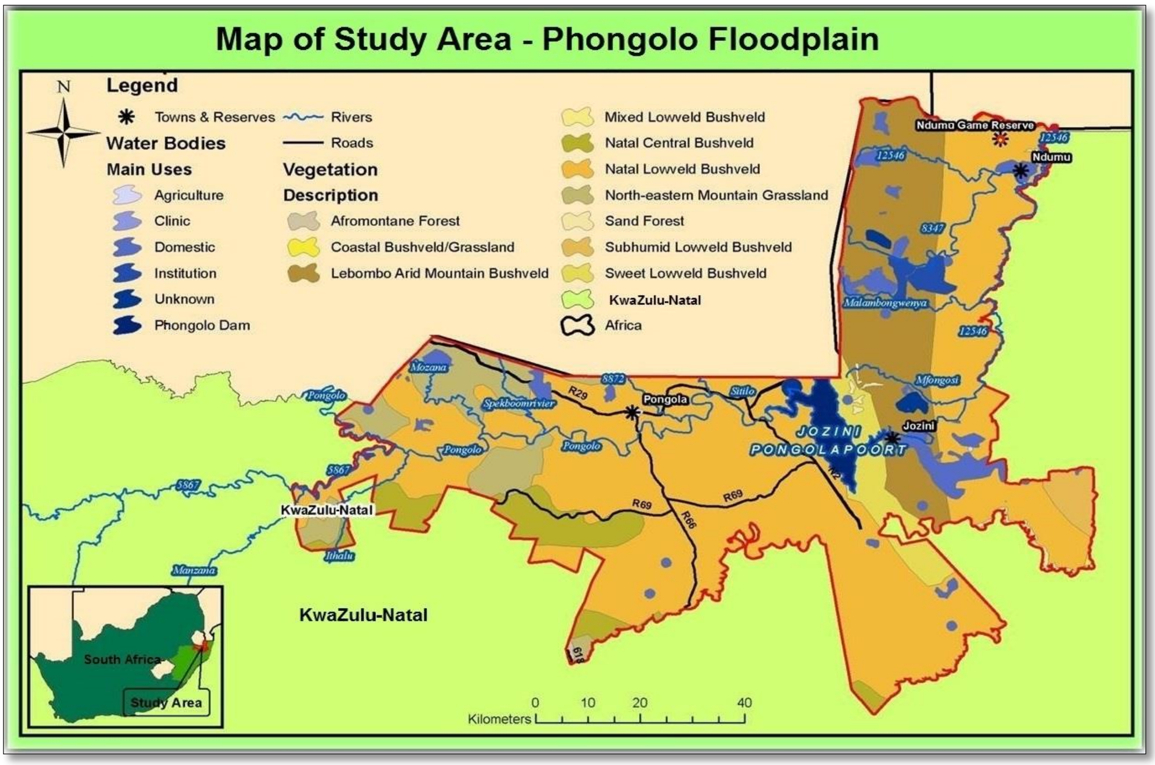

Figure 3.2: Phongolo Floodplain, with Ndumo Game Reserve.

3.1.1.1. The Ndumo Game Reserve

The Ndumo Game Reserve is situated in the northern-most parts of KwaZulu-Natal, South Africa, on the border with Mozambique. It is part of the Phongolo Floodplain in Maputaland, a large, flat, low-level coastal plain. The soils in western Maputaland are fertile, especially those along the west bank of the Phongolo River, as it is derived from Cretaceous sediments, alluvium and river terraces. Average annual rainfall, which is 638 mm in Ndumo (Maud, 1980), is the most important factor affecting the ecology in Maputaland, apart from soils.

The Ndumo Game Reserve (26°54'32.48"S, 32°18'48.85"E) is 10 117 ha in extent and known for its bird species richness – between 340 and 430 species recorded (Cooper, 1980; Jayway, 2015). It is rich in vegetation and a few plant species only occur here (Moll, 1980). Figure 3.3 is a representation of many of the major vegetation types that occur in Maputuland. The Ndumo Game Reserve is located in the Savanna Biome. The Ndumo Game Reserve contains Floodplain, Red Sand Bushveld, Thicket, and Lebombo Forest vegetation types, and there are even more detailed vegetation types within the floodplain vegetation, of which two major ones are the Lowveld Riverine Forest and Makatini Clay Thicket (Mucina & Rutherford, 2006). Utilisation of the seasonally flooded communities by birds is extensive and the riverine forest provides a good habitat for many bird species (Rogers, 1980).

No other area of South Africa possesses such a rich variety of tropical bird species for its size as does Maputaland. The bird species in Maputaland represent 56% of South Africa's total species richness, with Ndumo Game Reserve alone harbouring almost as many birds species as the entire Kruger National Park (477-500 bird species in 1 948 528 ha) (Cooper *et al.*, 1980; Patton *et al.*, 2008). This is quite remarkable if one considers the size difference of the two reserves, and it is undoubtedly due to the great variety of different ecosystems represented in this relatively small area, which also represents the southern end, or telescoping-down, of the great Mozambique Plain (Cooper, 1980), that forms the southern portion of a long coastal plain that is bounded in the north in Somalia.

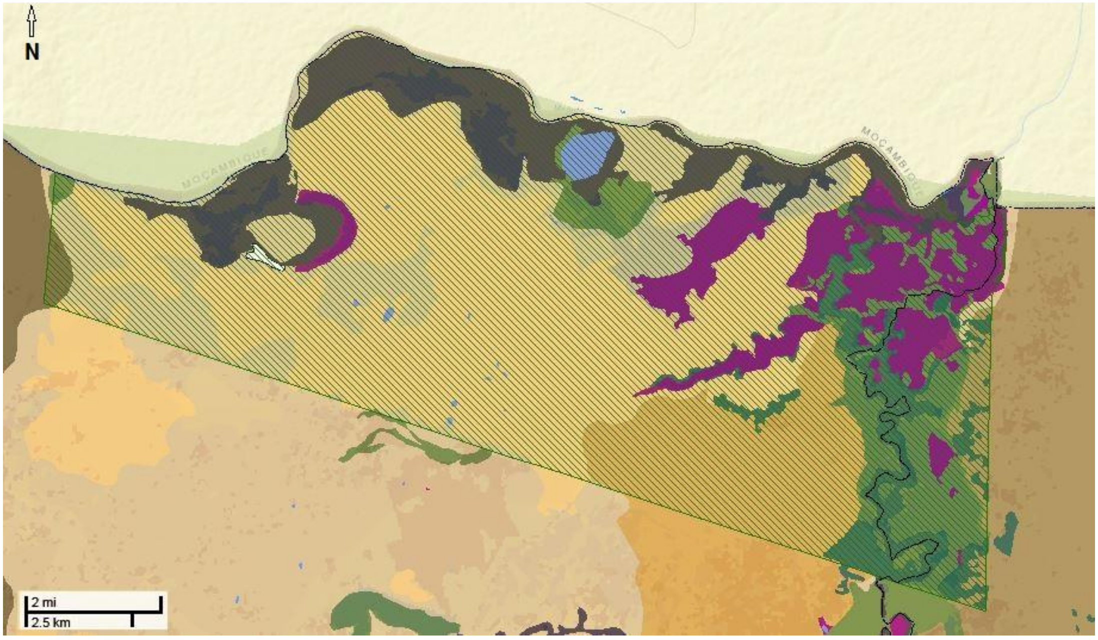

Figure 3.3: Representation of vegetation types in Ndumo Game Reserve.

3.1.2. Site selection

Reconnaissance throughout the Ndumo Game Reserve was undertaken in November 2012 and the vegetation and habitat types were noted in order to select suitable sites. One pan site and four riparian sites were chosen based on accessibility, safety, and observability for biodiversity surveys, and their GPS locations noted (Figure 3.4). Within each of the five sites, four sub-plots were chosen for point counts. Photographs were taken of the northern, eastern, southern and western aspect of each of the four sub-plots at each of the five sites. Impacts (perceived anthropogenic changes such as cut-down trees, etc.), if present, were noted and a general site description recorded.

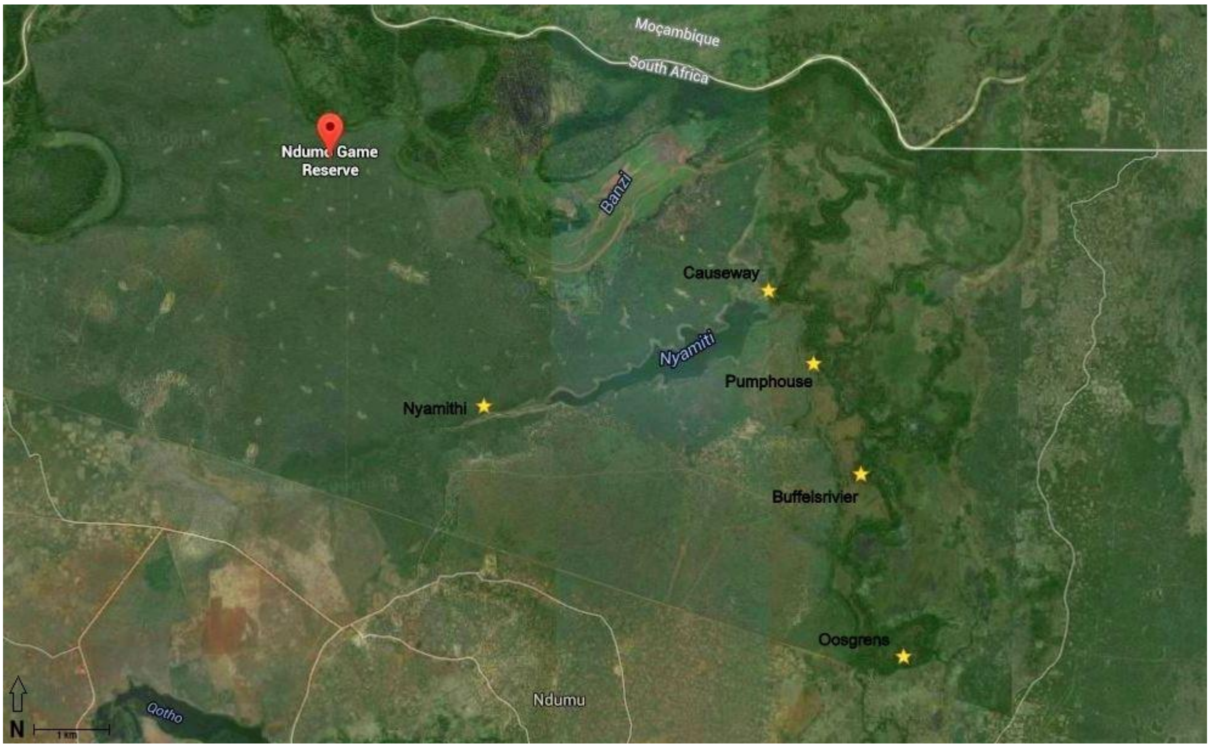

Figure 3.4: Ndumo Game Reserve with sites Oosgrens, Pumphouse, Buffelsrivier, Causeway and Nyamithi.

Sites with general vegetation description:

- Oosgrens: Thick riverine forest, many wild fig trees;
- Pumphouse: Thick riverine forest, many wild fig trees;
- Buffelsrivier: Thin strip of riverine bush, grassveld, reeds;
- Causeway: Thin strip of riverine bush, grass, reeds, and some medium trees;
- Nyamithi: Mostly grassy, with bushveld on perimeter.

3.2. Bird surveys

Five, week-long surveys were done between April 2013 and February 2014 to identify bird species and count individuals to obtain abundance and diversity. Point counts was the chosen method for monitoring as the vegetation was most suitable for this method and it is an efficient means to survey birds. It is easier to locate points randomly or systematically than it is to lay out transect routes, as routes require better access that may bias the habitats sampled (Bibby *et al*., 1992. Point counts are time-efficient – many sites can be covered in a day, allowing the collection of data from more points. There are no fixed rules for point counts, but using standardised methods might be undesirable since different sites, depending on circumstances, might be better studied by different designs (Bibby *et al*., 1992).

Five sites with four sub-plots in each site were selected. The sub-plots were located 100-150 m from each other within each site in order to reduce pseudo-replication as far as possible. I positioned survey points in such a way that each was homogenous with respect to density of large trees and canopy closure within that site. The dense vegetation was assumed to limit bird movements between plots during the observations and the potential for double counting was deemed negligible. Sites were reached by vehicle, parking at least 200 m from the first sub-plot and surveying was done on foot. After arriving at a sub-plot, a settling period of two minutes was allowed. At each sub-plot, birds were identified by sight and sound for 10 minutes per sub-plot within a radius of 50 m, and recorded using a field notebook. The date, time, site, plot number, bird species, and number of individuals were noted. This was then entered into Excel datasheets for data analysis. Surveys were done in the early mornings and late afternoons (sunrise and sunset) to coincide with peak bird activity. No surveys were done during exceptional windy or rainy conditions as bird activity, observability and sound detection was compromised. Nocturnal surveys were not undertaken and therefore species active at night (e.g. owls and nightjars) were poorly sampled. Birds only flying over the selected site were not counted; however, if a bird was actively foraging in the air (for example, swallows) it was counted.

Each site was surveyed five times during each field trip (five trips) and thus each site was surveyed 25 times over five trips. Since each site had four sub-plots, 100 sub-plot surveys (25 x 4) were conducted in total. Care was taken to rotate plots in different time slots per day to reduce the bias of time of day as far as possible.

The following materials were used for counting birds:

- GPS
- Compass
- Binoculars
- Laser range finder
- Digital camera
- Data sheets
- Tape recorder
- Bird identification guides
- Recordings of bird calls.

The two observers have ample previous experience with bird identifications and surveys. Notes were made of birds that were difficult to identify, and calls were recorded if it could not be identified. Bird guides and the supervisor were consulted for further confirmation. Species were named according to the 7th edition of the Roberts Birds of Southern Africa (Hockey *et al*., 2005).

As distance increases from the observer, smaller birds become less detectable faster than larger birds (Bibby *et al*., 1992). Observation conditions might not have remained 100% the same throughout the entire survey, as some vegetation changes might have occurred over time, considering the different seasons the surveys were conducted in. Some of the smaller bird species might also have been missed or under-counted in some spots with seasonal vegetation. However, taking the relatively short survey length (50 m), as well as intensity and reproducibility of sampling into consideration, the samples were considered representative enough for the main purpose of the study, namely bird composition and changes over time. A complete species list was not attempted nor expected.

Bird species were assigned to broad foraging and nesting categories and biomass was calculated for each species, based on the information and classification given by Hockey *et al.* (2005).

3.3. Environmental factors

3.3.1. Vegetation

Vegetation was classified using a broad-scale classification system (Edwards, 1983) to quantify vegetation structure. Reeds were added to the four vegetation classes (trees, shrubs, reeds and herbs) that Edwards (1983) used.

Height and cover percentages were estimated for each of these categories, in each sub-plot for each site. Every sub-plot was given a score to represent the degree of cover for each specific vegetational category, e.g. semi-open (for trees) would be assigned a score of four, being 11 – 25% covered with trees. The different height and cover classes are given in Tables 3.1, 3.2, and 3.3.

Table 3.1: Primary and subsidiary cover classes of vegetation and their consequent categorical scale, used for the broad-scale classification of vegetation structure as used by Edwards (1983). Vegetation in each sub-plot was scored by these standards and used in multivariate statistics with bird data.

	Cover classes	**Categorical score**
Continuous	100 - 76%	7
Sub-continuous	75 - 51%	6
Moderately closed	50 - 26%	5
Semi-open	25 - 11%	4
Open	10 - 1%	3
Sparse	1 - 0.1%	2
Scattered	< 0.1%	1

Table 3.2: Height classes of trees and their consequent categorical scale, used for the broad-scale classification of vegetation structure as used by Edwards (1983). Trees in each sub-plot were scored by these standards and used in multivariate statistics with bird data.

	Trees	Categorical score
High	> 20m	7
Tall	10 - 20m	6
Short	5 - 10m	5
Low	2 - 5m	4

Table 3.3: Height classes of shrubs, grasses, reeds, and forbs and their consequent categorical scale, used for the broad-scale classification of vegetation structure as used by Edwards (1983). These vegetation types were scored in each sub-plot by these standards and used in multivariate statistics with bird data.

	Shrubs	Grasses	Reeds	Forbs	Categorical score
High	2 - 5m	> 2m	> 2m	> 2m	4
Tall	1 - 2m	1 - 2m	1 - 2m	1 - 2m	3
Short	0.5 - 1m	0.5 - 1m	0.5 - 1m	0.5 - 1m	2
Low	< 0.5m	< 0.5m	< 0.5m	< 0.5m	1

Variables (height and cover) were scored for all these units (trees, shrubs, grass, reeds and forbs), and then analysed together. Data was relativized in order to portray each vegetation type as a proportion of the maximum unit (McCune & Grace 2002). PcOrd (Version 6.7 – MjM Software; McCune & Mefford 1999) was used to process data, and elements (vegetation scores) for each sub-plot were adjusted by row or column as necessary. Relativization of categorical values occurred across each column, after which multivariate statistics were applied.

3.4. Data analysis

3.4.1. Basic data analyses

Shannon diversity indices were calculated using PcOrd (Version 6.7; (www.pcord.com). Linear regression was done using Prism (Version 5; www.graphpad.com).

3.4.2. NMS (Non-metric multidimensional scaling)

Multivariate statistics used were non-metric multidimensional scaling (NMS), principal component analyses (PCA), and indicator species analysis using PcOrd (Version 6.7). NMS was chosen as the best model as it avoids the assumption of linear relationships among variables by using ranked distances to linearize the relationships between measured distances in ordination space. NMS deals much better with zero (equivalent to records of absence in the matrices) compared with other ordination methods. The NMS approach attempts to find the configuration of samples in ordination space such that the distances of samples (sites in this case) correspond best to the dissimilarities of their species composition. The distance measure used was Sørensen.

PcOrd can calculate more than two axes, but only the two dimensions that cumulatively explain the most variation were selected for representation. Final stress plotted against the number of dimensions can determine which dimension has the lowest final stress from a real run, to give the best results (McCune & Mefford, 1999). If any additional dimensions reduced the final stress by 5 or more on a scale of 0-100, they might be practicable. PcOrd then selects the most appropriate dimensionality (McCune & Mefford 1999). The two dimensions with the highest percentage explanatory power were chosen for representation of the NMS graphs (Chapter 4).

Interpreting stress for NMS was done using the indications given in McCune and Grace (2002). A final stress of less than 5 was considered an excellent representation with no prospect of misrepresentation; a stress between five and 10 was considered a good ordination with little risk of drawing false inferences; between 10 and 20 provides a usable picture with a potential to mislead at the higher end of the scale, and; greater than 20 provides a plot that is dangerous to interpret.

Bi-plot ordinations show sample units as well as environmental variables in one graph. Successional vectors can be added where samples were done over a period of time and successional data is available (McCune & Grace 2002). Bi-plot ordinations used in this study show the sites along with the vegetation factors, illustrating temporal changes in bird species composition.

The changes in bird diversity in five different months/surveys were illustrated in NMS successional vector plots for the five sites. The vectors connect the bird composition of each site with its corresponding survey. The length and the direction of each vector indicate the direction and magnitude of diversity changes with the changes in time. Convex hulls were drawn to connect the outermost sample units of the same group for some of the ordinations to indicate possible overlaps in bird species composition

Point counts and environmental factors, as well as feeding guilds, nesting guilds and biomass were ordinated using NMS and presented in bi-plots. The vectors represent the environmental factors, and are labelled accordingly (cover or height variables). The vectors in the NMS bi-plot associated with each site indicate the dominant environmental factors associated with that site.

In some instances, principal component analyses (PCAs) were done, as the data were not amenable to NMS ordination – only a one-dimensional solution could be derived, due to at least one large outlier. Species with less than five occurrences were excluded from some ordination calculations where indicated, as they contribute little to overall interpretation (McCune and Grace, 2002). PcOrd was also used to construct a species-area curve in order to determine whether enough point counts were done. This gave enough information to identify focal species/indicator species. At a broad scale, focal (indicator) species can indicate overall landscape quality (Padoa-Schioppa *et al*., 2005). At a local scale, focal (indicator) species abundances can be related to structural characteristics of landscape elements, thus, providing valuable indications of the most effective locations for restoration projects (Padoa-Schioppa *et al*., 2005), or in this case, comparing sites. Dufrêne and Legendre’s (1997) procedures were followed, combining the concentration of species richness with the faithfulness of a species occurring in a specific site. The indicator values (IVs) are then tested using the Monte Carlo randomization technique.

Chapter 4: Results

4.1. Sites

Surveys were done during 9 - 19 April 2013, 30 July – 3 August 2013, 10 – 14 September 2013, 17 – 21 November 2013, and 2 – 10 February 2014. Another survey in April 2014 was logistically not possible.

The locations of the sites are indicated in Figure. 4.1; all sites fall within a 3 km radius. Vegetation within the sites was mostly quite dense, with riverine forest and riverine bush the most abundant vegetation type and habitat. The Nyamithi-site had bushveld vegetation and many thorn trees. Pumphouse and Oosgrens were very similar in composition, with riverine forest and wild fig trees the dominant vegetation type. Both Causeway and Buffelsrivier had dense thickets next to the river, with open patches and trees every few meters.

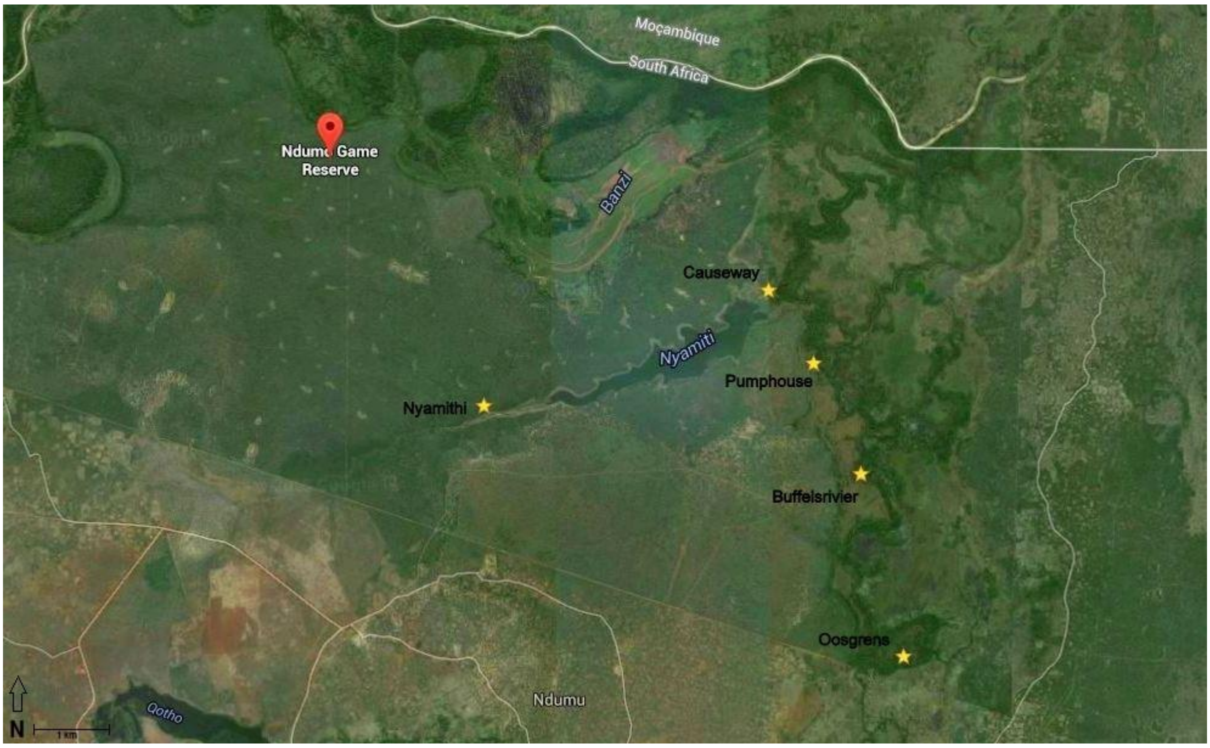

Figure 4.1: Ndumo Game Reserve with survey-sites Oosgrens, Pumphouse, Buffelsrivier, Causeway and Nyamithi.

4.1.1. Oosgrens

Oosgrens (26º55’47.04”S, 32º19’30.33”E): The river ran on the south-eastern side of this site (Figure 4.2), with informal settlements across the river. This site has many tall trees, mainly wild fig trees. Young saplings and bushy vegetation dominated, with vines and creeping vegetation creating a thick riverine bush. The many tall trees were close together, resulting in quite a high, closed leaf canopy. Grass was sparse, very few forbs present and no reeds. Anthropogenic disturbances that were observed: on the eastern banks of the river, trees were cut down and burned, grass patches were uprooted, and houses built. Across the river, on the eastern and southern sides, cattle grazed the land with crops right up to the edge of the river. Figures 4.3 – 4.6 display each of the four cardinal directions in each sub-plot within Oosgrens.

Figure 4.2: Oosgrens, one of the five sites used for surveying in Ndumo Game Reserve

Figure 4.3: Each of the four cardinal directions in Plot 1 (Oosgrens)

Figure 4.4: Each of the four cardinal directions in Plot 2 (Oosgrens)

Figure 4.5: Each of the four cardinal directions in Plot 3 (Oosgrens)

Figure 4.6: Each of the four cardinal directions in Plot 4 (Oosgrens)

4.1.2. Pumphouse

Pumphouse (26º54’18.88”S, 32º19’28.84”E): The site was on the western shore of the river (Figure 4.7). The vegetation of this site was similar to that of Oosgrens, with tall wild fig trees being the most prominent and numerous feature. The leaf canopy was closed with very few gaps for sunshine. Fewer shrubs covered the ground than at Oosgrens, with little to no grass present and no reeds. Hardly any anthropogenic impacts were noticeable from the sub-plots. However, although not visible from the sampling plots, there was disturbance on the eastern banks beyond the riverine forest belt where trees were cleared for land. The small pumphouse on the site seems to have been in disuse, so was not considered an anthropogenic impact other than the presence of the structure itself. Weekly guided bird walks were conducted at this site. Figures 4.8 – 4.11 display each of the four cardinal directions in each sub-plot within Pumphouse.

Figure 4.7: Pumphouse, one of the five sites used for surveying in Ndumo Game Reserve

Figure 4.8: Each of the four cardinal directions in Plot 1 (Pumphouse)

Figure 4.9: Each of the four cardinal directions in Plot 2 (Pumphouse)

Figure 4.10: Each of the four cardinal directions in Plot 3 (Pumphouse)

Figure 4.11: Each of the four cardinal directions in Plot 4 (Pumphouse)

4.1.3. Buffelsrivier

Buffelsrivier (26º53’10.43”S, 32º18’59.46”E): This site had the river passing by the sub-plots to the south-east (Figure 4.12). There were fewer trees than in the previous sites, mostly open grass veld and reed beds. A few tall trees were present, with a patch of very thick, dense, but short river bush. Grass was short and reeds were abundant, with steep riverbanks and some shrubbery on the bank. No anthropogenic disturbances could be discerned. Figures 4.13 – 4.16 display each of the four cardinal directions in each sub-plot within Buffelsrivier.

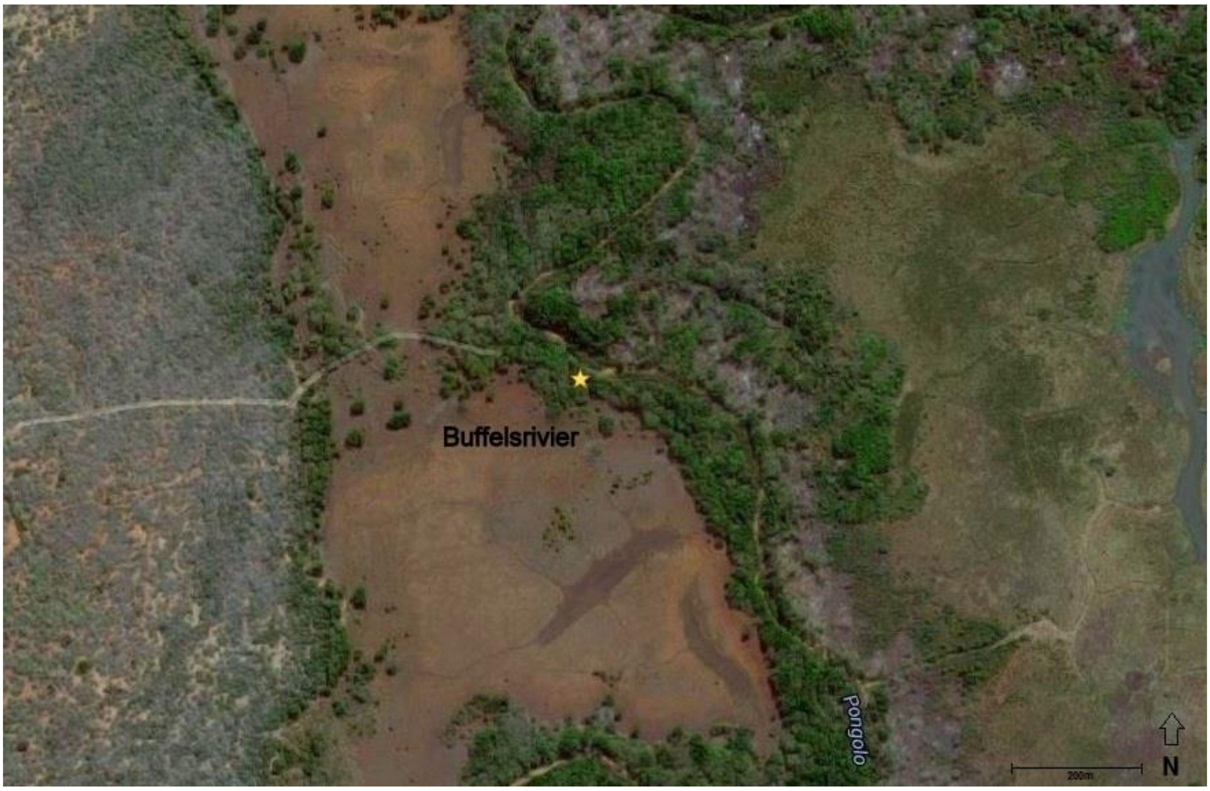

Figure 4.12: Buffelsrivier, one of the five sites used for surveying in Ndumo Game Reserve

Figure 4.13: Each of the four cardinal directions in Plot 1 (Buffelsrivier)

Figure 4.14: Each of the four cardinal directions in Plot 2 (Buffelsrivier)

Figure 4.15: Each of the four cardinal directions in Plot 3 (Buffelsrivier)

Figure 4.16: Each of the four cardinal directions in Plot 4 (Buffelsrivier)

4.1.4. Causeway

Causeway (26º52’58.45”S, 32º18’44.46”E): The river was located on the northern side of this site, with Nyamithi Pan downstream and a few other small pans close by (Figure 4.17). Tall trees and thick riverine bush grew right on the river banks, with short grass inland. Two patches of reeds are present. Raffia palms were abundant. Anthropogenic disturbances that were observed was a disused low-water concrete bridge at one sub-plot, a bird hide located close by (± 100 m), and a dirt road passing through the site. Figures 4.18 – 4.21 illustrate each of the four cardinal directions in each sub-plot within Causeway.

Figure 4.17: Causeway, one of the five sites used for surveying in Ndumo Game Reserve

Figure 4.18: Each of the four cardinal directions in Plot 1 (Causeway)

Figure 4.19: Each of the four cardinal directions in Plot 2 (Causeway)

Figure 4.20: Each of the four cardinal directions in Plot 3 (Causeway)

Figure 4.21: Each of the four cardinal directions in Plot 4 (Causeway)

4.1.5. Nyamithi

Nyamithi (26º53’53.97”S, 32°16’10.32”E): This site was situated on a river running into Nyamithi pan to the east (Figure 4.22). Large open spaces with grass and some tall fever trees dominated this area. Thick bushveld with medium sized trees and dense shrubbery is located about 30 m from the river, with the most prominent vegetation type being grass (ranging from short to about 50 cm tall). Wide mud flats are characteristic, with typical riverine bush almost completely absent except for a few scattered shrubs. Anthropogenic disturbances were a gravel road (gravel was added to stabilise the road) along the edge of the bushveld and occasional game drives on the other side of the pan but not within the site. Figures 4.23 – 4.26 illustrate each of the four cardinal directions in each sub-plot within Nyamithi.

Figure 4.22: Nyamithi, one of the five sites used for surveying in Ndumo Game Reserve

Figure 4.23: Each of the four cardinal directions in Plot 1 (Nyamithi)

Figure 4.24: Each of the four cardinal directions in Plot 2 (Nyamithi)

Figure 4.25: Each of the four cardinal directions in Plot 3 (Nyamithi)

Figure 4.26: Each of the four cardinal directions in Plot 4 (Nyamithi)

4.2. Vegetation survey

Table 4.1 shows the scores assigned to each site concerning vegetation height and cover classes. Vegetation height and cover remained the same during the entire survey period, with no fires or effects from grazing. Forbs were few and far between, with trees and grass covering most of the sites. Shrubs were also abundant and reeds only present at two sites.

Table 4.1: Vegetation height and cover class scores for each site recorded during November 2012.

Site	**Height**					**Cover**				
	Tree (HTree)	Shrub (HShrub)	Grass (HGrass)	Reeds (HReeds)	Forb (HForbs)	Tree (CTree)	Shrub (CShrub)	Grass (CGrass)	Reeds (CReeds)	Forb (CForbs)
Oosgrens	5	3	1	0	1	6	6	4	0	2
Pumphouse	7	4	1	0	1	6	5	3	0	1
Buffelsrivier	7	4	1	1	1	3	4	7	1	2
Causeway	6	4	1	2	1	4	5	7	2	2
Nyamithi	5	4	2	0	1	3	4	7	0	1

Pumphouse and Buffelsrivier had the highest trees. Causeway had the second highest trees, and Oosgrens and Nyamithi the shortest. Pumphouse and Oosgrens had the greatest percentage tree cover and Buffelsrivier and Nyamithi the least.

The shrubs at Oosgrens were smaller and lower than those at any of the other sites, but the shrub cover was the greatest. Nyamithi had the tallest grass, and just as much grass as Buffelsrivier and Causeway, both of which were scored as/at 7. Pumphouse had the least grass.

Only Buffelsrivier and Causeway had reeds; Causeway had the biggest and tallest reed-beds of the two. Forbs did not grow very high/tall at any of the sites, but Oosgrens, Buffelsrivier and Causeway had the greatest forb-coverage.

4.3. Species list

4.3.1. Species and records

The aggregated number of birds counted over the five surveys were 7756, comprising an aggregate of 165 species. Table 4.3 is a summary of the species and aggregated counts recorded during the survey.

Table 4.3: Species recorded and aggregated counts during each of the surveys, as well as species recoded and aggregated counts at each of the sites.

Surveys			**Sites**		
	Species	**Number**		**Species**	**Number**
April	119	2272	**Oosgrens**	68	1477
July	90	1693	**Pumphouse**	61	1067
September	94	1152	**Buffelsrivier**	83	1355
November	96	1133	**Causeway**	91	1663
February	111	1506	**Nyamithi**	100	2194

Table 4.4 is a list of birds recorded during the entire study.

Table 4.4: List of all bird species recorded during the survey, with Roberts number, family name, species name, common name, abbreviation used, and aggregated counts. All names were according to Hockey *et al*. (2005).

R.No.	**Family**	**Scientific Name**	**Common Name**	**Abbreviation**	**Total**
490	Eurylaimidae	*Smithornis capensis*	African Broadbill	AfrBroad	8
60	Anhingidae	*Anhinga rufa*	African Darter	AfrDart	5
690	Muscicapidae	*Muscicapa adusta*	African Dusky Flycatcher	AfDuFlyC	1
229	Heliornithidae	*Podica senegalensis*	African Finfoot	AfrFinf	4
148	Accipitridae	*Haliaeetus vocifer*	African Fish-Eagle	AfrFishE	33
160	Accipitridae	*Accipiter tachiro*	African Goshawk	AfrGosH	2
361	Columbidae	*Treron calvus*	African Green-Pigeon	AfrGPig	46
169	Accipitridae	*Polyboroides typus*	African Harrier-Hawk	Gymnogen	1
451	Upupidae	*Upupa africana*	African Hoopoe	AfrHpoe	11
421	Apodidae	*Cypsiurus parvus*	African Palm Swift	AfrPalmS	1
710	Monarchidae	*Trepsiphone viridis*	African Paradise-Flycatcher	AfrPFlyC	55
711	Motacillidae	*Motacilla aguimp*	African Pied Wagtail	AfrPWagt	10
716	Motacillidae	*Anthus cinnamomeus*	African Pipit	AfrPipit	6
432	Alcedinidae	*Ispidina picta*	African Pygmy-Kingfisher	AfPygKFi	1
91	Threskiornithidae	*Threskiornis aethiopicus*	African Sacred Ibis	AfSacrIb	13
95	Threskiornithidae	*Platalea alba*	African Spoonbill	Spoonb	29
394	Strigidae	*Strix woodfordii*	African Wood-Owl	AfrWdOwl	1
797	Zosteropidae	*Zosterops senegalensis*	African Yellow White-eye	AfrYWEye	275
560	Sylviidae	*Turdoides jardineii*	Arrow-marked Babbler	ArMrkBab	7
691	Muscicapidae	*Muscicapa caerulescens*	Ashy Flycatcher	AshyFlyC	40

R.No.	Family	Scientific Name	Common Name	Abbreviation	Total
518	Hirundinidae	*Hirundo rustica*	Barn Swallow	BarnSwal	199
617	Muscicapidae	*Cercotrichas quadrivirgata*	Bearded Scrub-Robin	BeardScR	1
487	Picidae	*Dendropicos namaquus*	Bearded Woodpecker	BeardWdP	3
213	Rallidae	*Amaurornis flavirostris*	Black Crake	BlckCrke	1
538	Campephagidae	*Campephaga flava*	Black Cuckooshrike	BlkCuShr	1
126	Accipitridae	*Milvus migrans*	Black Kite*	YeBilKite	5
536	Hirundinidae	*Psalidoprocne holomelaena*	Black Saw-wing	BlkSawW	36
158	Accipitridae	*Accipiter melanoleucus*	Black Sparrowhawk	SparHawk	2
740	Malaconotidae	*Dryoscopus cubla*	Black-backed Puffback	BBPfBck	67
768	Sturnidae	*Lamprotornis corruscus*	Black-bellied Starling	BlkBelSt	84
63	Ardeidae	*Ardea melanocephala*	Black-headed Heron	BlkHdHer	6
545	Oriolidae	*Oriolus larvatus*	Black-headed Oriole	BlkHOrio	11
258	Charadriidae	*Vanellus armatus*	Blacksmith Lapwing	BlkSmLpW	2
295	Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt	BlkWngSt	4
844	Estrildidae	*Uraeginthus angolensis*	Blue Waxbill	BlueWaxB	16
440	Meropidae	*Merops persicus*	Blue-cheeked Bee-eater	BluChBEa	145
708	Monarchidae	*Trochocercus cyanomelas*	Blue-mantled Crested-Flycatcher	BMCrFlyC	60
450	Coraciidae	*Eurystomus glaucurus*	Broad-billed Roller	BroadBRol	5
743	Malaconotidae	*Tchagra australis*	Brown-crowned Tchagra	BrCrChag	2
435	Dacelonidae	*Halcyon albiventris*	Brown-hooded Kingfisher	BrHdKFi	82
391	Centropodidae	*Centropus burchellii*	Burchell's Coucal	BurchCou	37
764	Sturnidae	*Lamprotornis nitens*	Cape Glossy Starling	CGloStar	80
354	Columbidae	*Streptopelia capicola*	Cape Turtle-Dove	CapeTDve	4
796	Zosteropidae	*Zosterops virens*	Cape White-eye	CaWhtEye	4
486	Picidae	*Dendropicos fuscescens*	Cardinal Woodpecker	CardWPk	12
71	Ardeidae	*Bulbulcus ibis*	Cattle Egret	CatlEgrt	158
701	Malaconotidae	*Batis molitor*	Chinspot Batis	ChinsBat	36
692	Muscicapidae	*Ficedula albicollis*	Collared Flycatcher***	CollFlyC	1
793	Nectariniidae	*Hedydipna collaris*	Collared Sunbird	CollSunB	50
270	Scolopacidae	*Tringa nebularia*	Common Greenshank	ComGreenS	6
264	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	ComSanP	10
454	Rhinopomastidae	*Rhinopomastus cyanomelas*	Common Scimitarbill	ComScimB	6
189	Phasianidae	*Dendroperdix sephaena*	Crested Francolin	CrestFr	78
204	Numididae	*Guttera edouardi*	Crested Guineafowl	CrestGui	82
460	Bucerotidae	*Tockus alboterminatus*	Crowned Hornbill	CrowndHB	49
808	Ploceidae	*Ploceus bicolor*	Dark-backed Weaver	DrkBWeav	110
568	Pycnonotidae	*Pycnonotus tricolor*	Dark-capped Bulbul	DCBulbul	728
637	Sylviidae	*Chloropeta natalensis*	Dark-capped Yellow Warbler	DrkCYelW	1
386	Cuculidae	*Chrysococcyx caprius*	Diderick Cuckoo	DiedeCuc	3
575	Pycnonotidae	*Nicator gularis*	Eastern Nicator	EastNict	47
102	Anatidae	*Alopochen aegyptiaca*	Egyptian Goose	EgyptGse	152

R.No.	Family	Scientific Name	Common Name	Abbreviation	Total
358	Columbidae	*Turtur chalcospilos*	Emerald-spotted Wood-Dove	EmSptDve	186
543	Oriolidae	*Oriolus oriolus*	Eurasian Golden Oriole	EurGoldO	1
438	Meropidae	*Merops apiaster*	European Bee-eater	EuroBEat	9
405	Caprimulgidae	*Caprimulgus pectoralis*	Fiery-necked Nightjar	FieryNNj	1
541	Dicruridae	*Dicrurus adsimilis*	Fork-tailed Drongo	FTDrong	77
429	Cerylidae	*Megaceryle maximus*	Giant Kingfisher	GiantKFi	30
93	Threskiornithidae	*Plegadis falcinellus*	Glossy Ibis	GlosIbis	2
816	Ploceidae	*Ploceus xanthops*	Golden Weaver	GoldWeav	1
884	Fringillidae	*Emberiza flaviventris*	Golden-breasted Bunting	GldBrBunt	6
483	Picidae	*Campethera abingoni*	Golden-tailed Woodpecker	GTailWPk	73
64	Ardeidae	*Ardea goliath*	Goliath Heron	GolHeron	2
747	Malaconotidae	*Telophorus viridis*	Gorgeous Bush-Shrike	GorBuShri	29
66	Ardeidae	*Egretta alba*	Great Egret	GrtEgret	19
835	Estrildidae	*Mandingoa nitidula*	Green Twinspot	GrnTwinS	1
452	Phoeniculidae	*Phoeniculus purpureus*	Green Wood-Hoopoe	GrnWdHpo	84
657	Cisticolidae	*Camaroptera brachyura*	Green-backed Camaroptera	GrBkCama	180
74	Ardeidae	*Butorides striata*	Green-backed Heron	GrBkHron	33
62	Ardeidae	*Ardea cinerea*	Grey Heron	GreyHern	24
558	Paridae	*Anthoscopus caroli*	Grey Penduline-Tit	GreyPTit	7
789	Nectariniidae	*Cyanomitra veroxii*	Grey Sunbird	GreySunB	118
693	Muscicapidae	*Myioparus plumbeus*	Grey Tit-Flycatcher	GTitFlyC	18
751	Malaconotidae	*Malaconotus blanchoti*	Grey-headed Bush-Shrike	GreyHBSh	3
94	Threskiornithidae	*Bostrychia hagedash*	Hadeda Ibis	Hadeda	346
81	Scopidae	*Scopus umbretta*	Hamerkop	Hamerkop	18
203	Numididae	*Numida meleagris*	Helmeted Guineafowl	HelmGuin	88
385	Cuculidae	*Chrysococcyx klaas*	Klaas's Cuckoo	KlaasCuc	1
355	Columbidae	*Streptopelia senegalensis*	Laughing Dove	LaughDve	1
815	Ploceidae	*Ploceus intermedius*	Lesser Masked-Weaver	LeMskdWv	8
527	Hirundinidae	*Hiruno abyssinica*	Lesser Striped Swallow	LeStrSwa	213
444	Meropidae	*Merops pusillus*	Little Bee-eater	LittBEat	15
67	Ardeidae	*Egretta garzetta*	Little Egret	LittEgrt	39
638	Sylviidae	*Bradypterus baboecala*	Little Rush-Warbler	LittRshW	13
417	Apodidae	*Apus affinis*	Little Swift	LitSwift	50
651	Sylviidae	*Sylvietta rufescens*	Long-billed Crombec	LngBCrom	1
431	Alcedinidae	*Alcedo cristata*	Malachite Kingfisher	MalchKFi	9
89	Ciconiidae	*Leptoptilos crumeniferus*	Marabou Stork	MrabStrk	1
427	Trogonidae	*Apaloderma narina*	Narina Trogon	NariTrog	5
196	Phasianidae	*Pternistis natalensis*	Natal Spurfowl	NatalSpF	9
546	Cisticolidae	*Cisticola fulvicapilla*	Neddicky	Neddicky	1
790	Nectariniidae	*Cyanomitra olivacea*	Olive Sunbird	OlivSunB	1
748	Malaconotidae	*Telophorus sulfureopectus*	Orange-breasted Bush-Shrike	OrBrBShr	14
696	Muscicapidae	*Bradornis pallidus*	Pale Flycatcher	PaleFlyC	4

R.No.	Family	Scientific Name	Common Name	Abbreviation	Total
403	Strigidae	*Scotopelia peli*	Pel's Fishing-Owl	PelsOwl	2
428	Cerylidae	*Ceryle rudis*	Pied Kingfisher	PiedKFi	57
50	Pelecanidae	*Pelecanus rufescens*	Pink-backed Pelican	PinkBPel	26
65	Ardeidae	*Ardea purpurea*	Purple Heron	PurplHer	3
780	Nectariniidae	*Cinnyris bifasciatus*	Purple-banded Sunbird	PurBSunB	54
371	Musophagidae	*Gallirex porphyreolophus*	Purple-crested Turaco	PurpCTur	86
672	Cisticolidae	*Cisticola chiniana*	Rattling Cisticola	RattCist	16
842	Estrildidae	*Lagonosticta senegala*	Red-billed Firefinch	RBiFireF	7
821	Ploceidae	*Quelea quelea*	Red-billed Quelea	RedBQuel	41
600	Muscicapidae	*Cossypha natalensis*	Red-capped Robin-Chat	RCaRobCh	162
377	Cuculidae	*Cuculus solitarius*	Red-chested Cuckoo	RedCCuck	9
352	Columbidae	*Streptopelia semitorquata*	Red-eyed Dove	RedEyeDv	201
674	Cisticolidae	*Cisticola erythrops*	Red-faced Cisticola	RFaceCis	1
246	Coliidae	*Urocolius indicus*	Red-faced Mousebird	RdFMousB	36
469	Lybiidae	*Pogoniulus pusillus*	Red-fronted Tinkerbird	RFroTink	35
58	Phalacrocoracidae	*Phalacrocorax africanus*	Reed Cormorant	ReedCorm	6
754	Malaconotidae	*Prionops retzii*	Retz's Helmet-Shrike	RetzHShr	4
649	Cisticolidae	*Apalis ruddi*	Rudd's Apalis	RuddsApa	8
88	Ciconiidae	*Ephippiorhynchus senegalensis*	Saddle-billed Stork	SadlBSto	1
475	Indicatoridae	*Indicator variegatus*	Scaly-throated Honeyguide	ScThrHGd	2
791	Nectariniidae	*Chalcomitra senegalensis*	Scarlet-chested Sunbird	ScChSunB	16
572	Pycnonotidae	*Andropadus importunus*	Sombre Greenbul	SombrGrB	191
694	Muscicapidae	*Melaenornis pammelaina*	Southern Black Flycatcher	SBlaFlyC	11
554	Paridae	*Parus niger*	Southern Black Tit	SuthBTit	51
736	Malaconotidae	*Laniarius ferrugineus*	Southern Boubou	SuthBoBo	26
804	Passeridae	*Passer diffuses*	Southern Grey-headed Sparrow	SGrHSpar	1
810	Ploceidae	*Ploceus ocularis*	Spectacled Weaver	SpectWev	3
116	Anatidae	*Plectropterus gambensis*	Spur-winged Goose	SpurWGse	97
72	Ardeidae	*Ardeola ralloides*	Squacco Heron	SquacHer	7
542	Dicruridae	*Dicrurus ludwigii*	Square-tailed Drongo	SqTailDr	231
437	Dacelonidae	*Halcyon chelicuti*	Striped Kingfisher	StripKFi	3
	Nectariniidae		Sunbird (General)	SunB	138
359	Columbidae	*Turtur tympanistria*	Tambourine Dove	TambDove	24
683	Cisticolidae	*Prinia subflava*	Tawny-flanked Prinia	TwnyFPri	76
569	Pycnonotidae	*Phyllastrephus terrestris*	Terrestrial Brownbul	TerrBrBu	119
807	Ploceidae	*Amblyospiza albifrons*	Thick-billed Weaver	ThkBWeav	4
249	Charadriidae	*Charadrius tricollaris*	Three-banded Plover	ThrBPlov	56
455	Bucerotidae	*Bycanistes bucinator*	Trumpeter Hornbill	TrumpHBi	168
786	Nectariniidae	*Cinnyris venestus*	Variable Sunbird**	VarSunB	1
402	Strigidae	*Bubo lacteus*	Verreaux's Eagle-Owl	GEaglOwl	18
811	Ploceidae	*Ploceus cucullatus*	Village Weaver	VillWver	7
761	Sturnidae	*Cinnyricinclus leucogaster*	Violet-backed Starling	ViolBSta	12

R.No.	Family	Scientific Name	Common Name	Abbreviation	Total
298	Burhinidae	*Burhinus vermiculatus*	Water Thick-knee	WterThkK	14
787	Nectariniidae	*Cinnyris talatala*	White-bellied Sunbird	WhBeSunB	15
55	Phalacrocoracidae	*Phalacrocorax lucidus*	White-breasted Cormorant	WhBrCorm	5
599	Muscicapidae	*Cossypha heuglini*	White-browed Robin-Chat	HeugRbCh	27
613	Muscicapidae	*Cercotrichas leucophrys*	White-browed Scrub-Robin	WhBrScRb	11
753	Malaconotidae	*Prionops plumatus*	White-crested Helmet-Shrike	WhtCrHeS	67
466	Lybiidae	*Stactolaema leucotis*	White-eared Barbet	WhEarBar	228
99	Dendrocygnidae	*Dendrocygna viduata*	White-faced Duck	WhtFDuck	250
602	Muscicapidae	*Cossypha humeralis*	White-throated Robin-Chat	WhThrRCh	1
522	Hirundinidae	*Hirundo smithii*	Wire-tailed Swallow	WireTSw	94
266	Scolopacidae	*Tringa glareola*	Wood Sandpiper	WoodSand	13
433	Dacelonidae	*Halcyon senegalensis*	Woodland Kingfisher	WoodKF	17
86	Ciconiidae	*Ciconia episcopus*	Woolly-necked Stork	WoollyNS	4
574	Pycnonotidae	*Chlorocichla flaviventris*	Yellow-bellied Greenbul	YelBelGB	21
771	Sturnidae	*Buphagus africanus*	Yellow-billed Oxpecker	YeBilOxp	6
90	Ciconiidae	*Mycteria ibis*	Yellow-billed Stork	YelBStrk	74
648	Cisticolidae	*Apalis flavida*	Yellow-breasted Apalis	YelBrApa	115
869	Fringillidae	*Crithagra mozambicus*	Yellow-fronted Canary	YelFrCan	25
471	Lybiidae	*Pogoniulus bilineatus*	Yellow-rumped Tinkerbird	YRumTink	75
805	Passeridae	*Petronia superciliaris*	Yellow-throated Petronia	YeThPetr	1

*Black Kite and Yellow-billed Kite were considered as one species for the purpose of this study.

**Variable Sunbird was possibly misidentified. Collared Sunbird more likely.

***Collared Flycatcher was a possible new record for Ndumu Game Reserve.

4.3.2. Biomass, feeding guilds and nesting guilds

Table 4.5 is a list of all the bird species recorded during the entire study, with mean individual length and mass (mean of male and female reported masses; Hockey *et al*. 2005), as well as total species biomass (total recorded multiplied with mean mass). It also shows the allocation to feeding and nesting guild for each species, based on information from Hockey *et al*. (2005). The species were classified into nesting and feeding guilds according to their main diets as adults and their preferred nesting sites. (Sunbirds that could not be identified to species level were grouped together as Sunbird General, and a mean was calculated based on all species that were observed. Nesting and feeding guilds were taken as the most frequently assigned for all sunbirds.)

Table 4.5: Species recorded during survey, with common name, totals of each species recorded, mean length of each species, mean mass of individuals of each species, biomass per species summed over all five surveys, total biomass per species, and the feeding and nesting guilds species were assigned to.

Common Name	**Total Birds**	**Length (cm)**	**Individual Biomass (g)**	**Summed biomass (g)**	**Feeding guild**	**Nesting guild**
African Broadbill	8	14	26.5	212	Insectivore	Tree
African Darter	5	90	1400	7000	Piscivore	Tree/Reed
African Dusky Flycatcher	1	13	11	11	Insectivore	Cavity
African Finfoot	4	55	500	2000	Insectivore	Shrub/tree
African Fish-Eagle	33	54.5	2500	82500	Carnivore	Tree
African Goshawk	2	41.5	580	1160	Carnivore	Tree
African Green-Pigeon	46	29	240	11040	Frugivore	Tree
African Harrier-Hawk	1	63	800	800	Carnivore	Tree
African Hoopoe	11	26	57	627	Insectivore	Ground/Cavity
African Palm Swift	1	15	14	14	Insectivore	Structure
African Paradise-Flycatcher	55	37	15.5	852.5	Insectivore	Tree
African Pied Wagtail	10	20	27	270	Insectivore	Ground/Grass
African Pipit	6	16.5	24.5	147	Insectivore	Grass
African Pygmy-Kingfisher	1	12.5	14.5	14.5	Insectivore	Burrow
African Sacred Ibis	13	77	1250	16250	Carnivore	Tree/Reed
African Spoonbill	29	82.5	1600	46400	Piscivore	Tree/Reed
African Wood-Owl	1	33	292.5	292.5	Carnivore	Cavity
African Yellow White-eye	275	11.5	10	2750	Insectivore	Tree
Arrow-marked Babbler	7	24	72	504	Insectivore	Tree
Ashy Flycatcher	40	14.5	16.5	660	Insectivore	Cavity
Barn Swallow	199	20	18	3582	Insectivore	Extralimital
Bearded Scrub-Robin	1	17	26	26	Insectivore	Cavity
Bearded Woodpecker	3	24	82.5	247.5	Insectivore	Cavity
Black Crake	1	21	90	90	Omnivore	Grass/Reed
Black Cuckooshrike	1	20.5	32	32	Insectivore	Tree
Black Kite*	5	55	781.5	3907,5	Carnivore	Tree
Black Saw-wing	36	17	11	396	Insectivore	Burrow
Black Sparrowhawk	2	52	720	1440	Carnivore	Tree
Black-backed Puffback	67	17.5	26	1742	Insectivore	Tree
Black-bellied Starling	84	18	50	4200	Frugivore	Cavity
Black-headed Heron	6	92	1108	6645	Carnivore	Tree/Reed
Black-headed Oriole	11	25	65	715	Insectivore	Tree
Blacksmith Lapwing	2	29.5	165	330	Insectivore	Ground
Black-winged Stilt	4	37.5	165	660	Carnivore	Ground
Blue Waxbill	16	12.5	10	160	Granivore	Tree/Shrub
Blue-cheeked Bee-eater	145	25	45	6525	Insectivore	Extralimital
Blue-mantled Crested-Flycatcher	60	15	10	600	Insectivore	Tree/Shrub
Broad-billed Roller	5	29.5	105	525	Insectivore	Cavity

Common Name	Total Birds	Length (cm)	Individual Biomass (g)	Summed biomass (g)	Feeding guild	Nesting guild
Brown-crowned Tchagra	2	17.5	32.5	65	Insectivore	Tree/Shrub
Brown-hooded Kingfisher	82	23	60	4920	Carnivore	Burrow
Burchell's Coucal	37	41	180	6660	Carnivore	Ground/Tree
Cape Glossy Starling	80	25	90	7200	Omnivore	Cavity
Cape Turtle-Dove	4	27	150	600	Granivore	Tree
Cape White-eye	4	11.5	13.5	54	Insectivore/Frugivore	Tree/Shrub
Cardinal Woodpecker	12	15	30	360	Insectivore	Cavity
Cattle Egret	158	54	365	57670	Carnivore	Tree
Chinspot Batis	36	12.5	12.2	439.2	Insectivore	Tree
Collared Flycatcher***	1	13	15	15	Insectivore	Extralimital
Collared Sunbird	50	10.5	8	400	Insectivore/Nectar-feeding	Shrub
Common Greenshank	6	31.5	170	1020	Piscivore/Insectivore	Extralimital
Common Sandpiper	10	31.5	47.5	475	Piscivore	Extralimital
Common Scimitarbill	6	26	32.5	195	Insectivore	Cavity
Crested Francolin	78	32.5	350	27300	Herbivore/Insectivore	Ground
Crested Guineafowl	82	50	1350	110700	Omnivore	Ground
Crowned Hornbill	49	52.5	225	11025	Frugivore/Insectivore	Cavity
Dark-backed Weaver	110	15	35	3850	Insectivore	Tree
Dark-capped Bulbul	728	21	37.5	27300	Frugivore/Insectivore	Tree
Dark-capped Yellow Warbler	1	14.5	12	12	Insectivore	Shrub
Diderick Cuckoo	3	19	35	105	Insectivore	Parasitic
Eastern Nicator	47	21	46.2	2171.4	Insectivore	Shrub
Egyptian Goose	152	67.5	2110	320720	Omnivore	Ground
Emerald-spotted Wood-Dove	186	19.5	65	12090	Granivore	Tree/Shrub
Eurasian Golden Oriole	1	23	64	64	Frugivore/Insectivore	Extralimital
European Bee-eater	9	27	52	468	Insectivore	Tunnel/ Burrow
Fiery-necked Nightjar	1	24	52	52	Insectivore	Ground
Fork-tailed Drongo	77	25	45	3465	Carnivore	Tree
Giant Kingfisher	30	44	362.5	10875	Piscivore	Burrow
Glossy Ibis	2	57.5	625	1250	Carnivore	Reed
Golden Weaver	1	17	40.5	40.5	Insectivore	Reed/Grass
Golden-breasted Bunting	6	15.5	20	120	Insectivore/Granivore	Tree/Shrub
Golden-tailed Woodpecker	73	21	70	5110	Insectivore	Cavity
Goliath Heron	2	142.5	4330	8660	Carnivore	Tree/Reed
Gorgeous Bush-Shrike	29	19	37	1073	Insectivore	Shrub
Great Egret	19	95	1100	20900	Carnivore	Tree/Reed
Green Twinspot	1	11	10	10	Granivore	Tree
Green Wood-Hoopoe	84	33	76.5	6426	Insectivore	Cavity
Green-backed Camaroptera	180	12.5	11	1980	Insectivore	Grass/Shrub
Green-backed Heron	33	41	215	7095	Carnivore	Tree
Grey Heron	24	94	1545	37080	Carnivore	Tree/Reed

Common Name	Total Birds	Length (cm)	Individual Biomass (g)	Summed biomass (g)	Feeding guild	Nesting guild
Grey Penduline-Tit	7	8.5	6.5	45.5	Insectivore	Tree
Grey Sunbird	118	14.5	12	1416	Nectar-feeding	Tree
Grey Tit-Flycatcher	18	14	21	378	Insectivore	Cavity
Grey-headed Bush-Shrike	3	26	77	231	Carnivore	Tree
Hadeda Ibis	346	76	1250	432500	Insectivore	Tree
Hamerkop	18	56	505	9090	Carnivore	Tree
Helmeted Guineafowl	88	55.5	1440	126720	Granivore/Insectivore	Ground
Klaas's Cuckoo	1	18	26	26	Insectivore	Parasitic
Laughing Dove	1	25	100	100	Granivore	Tree
Lesser Masked-Weaver	8	14.5	20	160	Insectivore	Tree
Lesser Striped Swallow	213	17	17	3621	Insectivore	Structure
Little Bee-eater	15	16	15	225	Insectivore	Burrow
Little Egret	39	64	520	20280	Carnivore	Tree
Little Rush-Warbler	13	17	14	182	Insectivore	Reed/Shrub
Little Swift	50	13	25	1250	Insectivore	Structure
Long-billed Crombec	1	11	12	12	Insectivore	Tree/Shrub
Malachite Kingfisher	9	14	17	153	Carnivore	Burrow
Marabou Stork	1	1500	6500	6500	Carnivore	Tree
Narina Trogon	5	31.5	67	335	Insectivore	Cavity
Natal Spurfowl	9	34	445	4005	Granivore/Frugivore	Ground
Neddicky	1	10.5	9	9	Insectivore	Shrub/Grass
Olive Sunbird	1	14.5	11.5	11.5	Insectivore/Nectar-feeding	Tree
Orange-breasted Bush-Shrike	14	19	27	378	Insectivore	Tree
Pale Flycatcher	4	16	22	88	Insectivore	Tree
Pel's Fishing-Owl	2	63	2140	4280	Piscivore	Cavity
Pied Kingfisher	57	25	85	4845	Carnivore	Cavity
Pink-backed Pelican	26	127.5	5450	141700	Piscivore	Tree
Purple Heron	3	84.5	872.5	2617.5	Carnivore	Reed
Purple-banded Sunbird	54	11	7.5	405	Insectivore/Nectar-feeding	Tree
Purple-crested Turaco	86	41.5	300	25800	Frugivore	Tree
Rattling Cisticola	16	15	15	240	Insectivore	Shrub/Grass
Red-billed FireFinch	7	9.5	8.5	59.5	Granivore	Tree/Shrub
Red-billed Quelea	41	12	20	820	Granivore	Tree
Red-capped Robin-Chat	162	18	32	5184	Insectivore/Frugivore	Cavity
Red-chested Cuckoo	9	29	75	675	Insectivore	Parasitic
Red-eyed Dove	201	34.5	250	50250	Granivore	Tree
Red-faced Cisticola	1	14	15	15	Insectivore	Tree/Shrub
Red-faced Mousebird	36	32	55	1980	Frugivore	Tree
Red-fronted Tinkerbird	35	12	17	595	Frugivore	Cavity
Reed Cormorant	6	55	555	3330	Carnivore	Tree/Reed
Retz's Helmet-Shrike	4	21.5	44	176	Insectivore	Tree

Common Name	Total Birds	Length (cm)	Individual Biomass (g)	Summed biomass (g)	Feeding guild	Nesting guild
Rudd's Apalis	8	13	10	80	Insectivore	Shrub/Tree
Saddle-billed Stork	1	150	7000	7000	Piscivore	Tree
Scaly-throated Honeyguide	2	19	48	96	Insectivore	Parasitic
Scarlet-chested Sunbird	16	14	13.5	216	Insectivore/Nectar-feeding	Tree
Sombre Greenbul	191	21	31	5921	Frugivore/Insectivore	Tree
Southern Black Flycatcher	11	20	30	330	Insectivore	Cavity
Southern Black Tit	51	15.5	21	1071	Insectivore/Frugivore	Tree
Southern Boubou	26	22	60	1560	Omnivore	Tree
Southern Grey-headed Sparrow	1	15.5	24	24	Granivore	Cavity
Spectacled Weaver	3	15.5	30	90	Insectivore	Tree
Spur-winged Goose	97	98	4300	417100	Herbivore	Grass/Reed
Squacco Heron	7	43	300	2100	Carnivore	Reed/Shrub
Square-tailed Drongo	231	19	30	6930	Insectivore	Tree
Striped Kingfisher	3	18	37.5	112.5	Insectivore	Cavity
Sunbird (General)	138	12	10	1380	Nectar-feeding	Tree
Tambourine Dove	24	22	72	1728	Granivore	Tree
Tawny-flanked Prinia	76	12.5	9.5	722	Insectivore	Shrub/Grass
Terrestrial Brownbul	119	21	31.5	3748.5	Insectivore	Shrub
Thick-billed Weaver	4	18	47	0	Frugivore/Granivore	Reed
Three-banded Plover	56	18	34	1904	Carnivore	Ground
Trumpeter Hornbill	168	57.5	642.5	107940	Frugivore	Cavity
Variable Sunbird**	1	10	7	7	Nectar-feeding	Shrub/Sapling
Verreaux's Eagle-Owl	18	61.5	2000	36000	Carnivore	Tree
Village Weaver	7	16	34.5	241.5	Insectivore	Tree
Violet-backed Starling	12	18	45	540	Insectivore	Cavity
Water Thick-knee	14	39.5	355	4970	Omnivore	Ground
White-bellied Sunbird	15	11	7	105	Insect/Nectar-feeding	Tree/Shrub
White-breasted Cormorant	5	90	2000	10000	Carnivore	Tree
White-browed Robin-Chat	27	19.5	35	945	Insectivore	Tree
White-browed Scrub-Robin	11	15	20	220	Insectivore	Grass
White-crested Helmet-Shrike	67	19	34	2278	Insectivore	Tree
White-eared Barbet	228	18	54	12312	Frugivore	Cavity
White-faced Duck	250	47	700	175000	Omnivore	Ground/Grass
White-throated Robin-Chat	1	16	22.5	22.5	Insectivore	Ground
Wire-tailed Swallow	94	14	13	1222	Insectivore	Structure
Wood Sandpiper	13	20	60	780	Omnivore	Extralimital
Woodland Kingfisher	17	23	62.5	1062.5	Insectivore	Cavity
Woolly-necked Stork	4	83.5	1800	7200	Carnivore	Tree
Yellow-bellied Greenbul	21	21.5	40	840	Frugivore/Insectivore	Shrub
Yellow-billed Oxpecker	6	20	60	360	Insectivore	Cavity
Yellow-billed Stork	74	97	2000	148000	Carnivore	Tree

Common Name	Total Birds	Length (cm)	Individual Biomass (g)	Summed biomass (g)	Feeding guild	Nesting guild
Yellow-breasted Apalis	115	12.5	8	920	Insectivore	Tree/Shrub
Yellow-fronted Canary	25	12	12	300	Insectivore/Granivore	Tree/Shrub
Yellow-rumped Tinkerbird	75	12	14.5	1087.5	Frugivore	Cavity
Yellow-throated Petronia	1	15.5	24	24	Insectivore/Granivore	Cavity

*Black Kite and Yellow-billed Kite were considered as one species for the purpose of this study.

**Variable Sunbird was possibly misidentified. Collared Sunbird more likely.

***Collared Flycatcher was a possible new record for Ndumu Game Reserve.

4.4. Multivariate analyses

Multivariate analyses (relative multiple relationships between species and sites) were done using MjM Software PC-ORD version 6.07 (www.pcord.com) as explained in section 3.4 in Chapter 3.

4.4.1. Shannon diversity index

In Table 4.6, Shannon indices were calculated for birds and vegetation structure. Pumphouse had the smallest diversity and Causeway the largest. The values did not, however, differ very much.

Table 4.6: Mean Shannon diversity index (H) for birds and vegetation classification for the five sites.

Site	Bird diversity	Structural diversity
Oosgrens	3.622	1.996
Pumphouse	3.588	1.980
Buffelsrivier	3.954	2.164
Causeway	4.035	2.237
Nyamithi	3.975	2.044

Association between bird (using data from all five surveys per site) and structural diversities were done using linear regression (Figure 4.27). Nyamithi was excluded in Figure 4.34B as this site differed from the other sites (Section 3.1.2). In both cases, regression was significantly different from zero; when Nyamithi was excluded, significance improved from p = 0.0481 to p = 0.0126. The r^2 values also improved from $r^2 = 0.1594$ to $r^2 = 0.2991$.

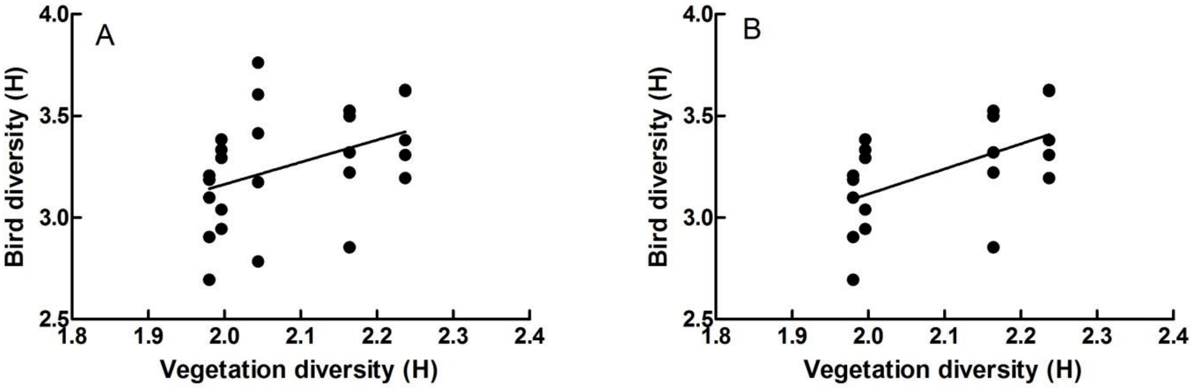

Figure 4.27: Regression between bird and vegetation structural diversities. A: All 5 sites. p = 0.0481; $r^2 = 0.1594$. B: Four sites, without Nyamithi. p = 0.0126; r^2: 0.2991.

4.4.2. Bird indicator species

Table 4.7 lists the results of the bird indicator species analysis. The greater the IV value, the more frequently that species was recorded at a specific site. Significance was chosen at $p < 0.05$.

Table 4.7 shows that Nyamithi had the most indicator species (7), followed closely by Causeway (5). Buffelsrivier and Pumphouse did not have any significant indicators. African Pipit, Little Rush-Warbler and Scuacco Heron had the highest IVs (80.0), followed by Verreaux's Eagle-Owl (75.6).

Table 4.7: Indicator species (birds) for three of the five sites. Buffelsrivier and Pumphouse did not have any significant indicator species and were therefore not included. Species were arranged according to highest indicator value for all species with p-value below 0.05.

Species	Site	Indicator Value (IV)	p-value (p*)
Verreaux's Eagle-Owl	Oosgrens	75.6	0.0022
Black-headed Oriole	Oosgrens	58.2	0.0186
Little Rush-Warbler	Causeway	80.0	0.0024
Scuacco Heron	Causeway	80.0	0.0018
Grey Heron	Causeway	54.2	0.0098
Village Weaver	Causeway	51.4	0.0378

Species	Site	Indicator Value (IV)	p-value (p*)
Hamerkop	Causeway	50.0	0.0072
African Pipit	Nyamithi	80.0	0.0030
Orange-breasted Bush-Shrike	Nyamithi	62.9	0.0084
Blue Waxbill	Nyamithi	60.0	0.0232
Wood Sandpiper	Nyamithi	60.0	0.0236
Grey Tit-Flycatcher	Nyamithi	53.3	0.0498
Rudd's Apalis	Nyamithi	52.5	0.0410
Common Sandpiper	Nyamithi	48.0	0.0276

4.4.3. Species-area curve

The species-area curve (Figure 4.28) indicates the relationship between species richness and the number of sub-plots used, evaluating the adequacy of a sample size in a community data set (McCune & Mefford, 1999). Figure 4.28 shows a very gradual curve, with 165 species observed in 20 subplots. The first-order jackknife estimate lies at 195.7 species expected to occur. Thirty-two species (20%) had only one occurrence, and 23 species had two occurrences (33% combined).

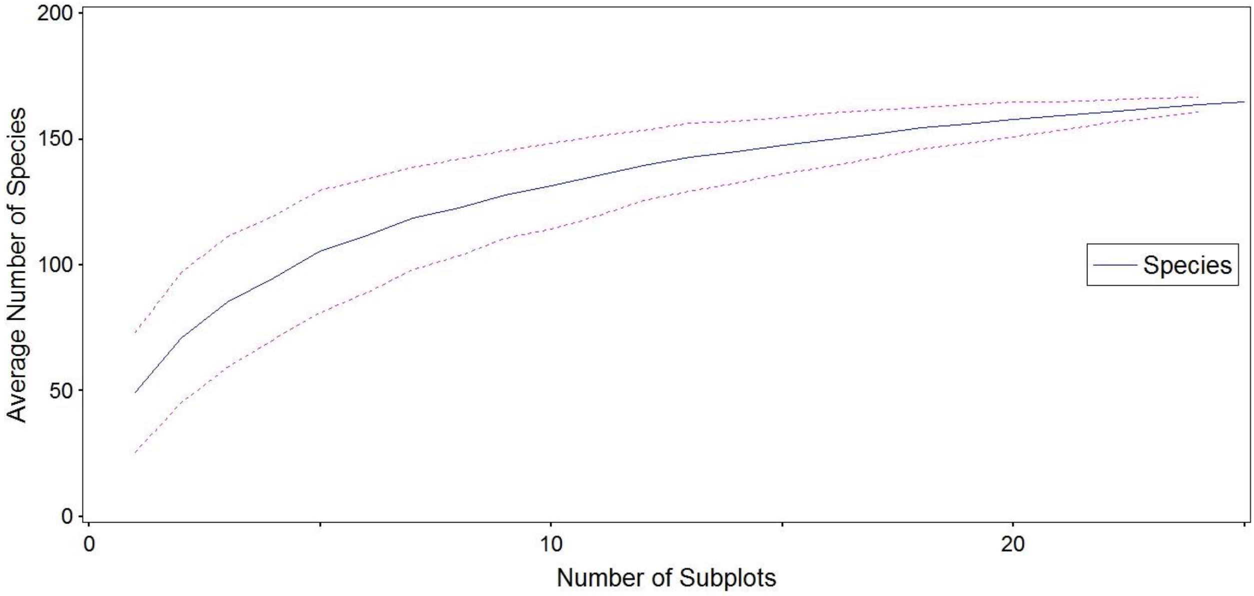

Figure 4.28: Species area curve of bird species observed at the five sites (20 subplots) in the Ndumo Game Reserve. The dotted lines are the confidence bands, indicating +/- two standard deviations from the line (McCune & Mefford, 1999). Sørensen was used as distance measure.

4.4.4. Bird species composition

Figure 4.29 is an NMS ordination of bird species and sites, irrespective of survey period, to describe the relative bird species composition relative to each site. Species with a total of five or less individuals over all five surveys were not included, as rare species contribute little to the overall interpretation and add clutter to the graph (McCune & Grace, 2002). Biplot vectors of vegetation structure were added to aid interpretation.

Buffelsrivier ordinated close to the origin of the ordination (Figure 4.29). Species ordinated close to Buffelsrivier occurred at all sites (such as Fork-tailed Drongo, Ashy Flycatcher, Black-backed Puffback, Green-backed Camaroptera, Yellow-breasted Apalis and Purple-banded Sunbird). Causeway's bird composition ordinated towards the top of the figure, Oosgrens to the far right on axis 1, and Nyamithi to the far left. Pumphouse ordinated to the bottom right of the graph and Buffelsrivier ordinated close to the origin.

The Little Rush-Warbler, Squacco Heron and Little Swift were strongly associated with Causeway. The Verreaux's Eagle Owl only associated with Oosgrens (the only site where it was recorded). The Blue-cheeked Bee-eater, Scarlet-chested Sunbird and Spur-winged Goose ordinated towards Pumphouse. Several species clustered around Nyamithi: Wood Sandpiper, Southern Boubou, Red-billed Firefinch, Grey Penduline Tit, Common Greenshank, African Pipit, Yellow-billed Oxpecker, Red-billed Quelea, Cape Glossy Starling and Blue Waxbill.

Most of the species ordinated along Axis 1 (Figure 4.29), which described 82% of the ordination. HGrass, CGrass and HShrubs, along with HTrees, CTrees and CShrubs were the environmental descriptors that dominated the variation in the horizontal dimension. HReeds, Creeds and CForbs influenced the variation on the vertical dimension.

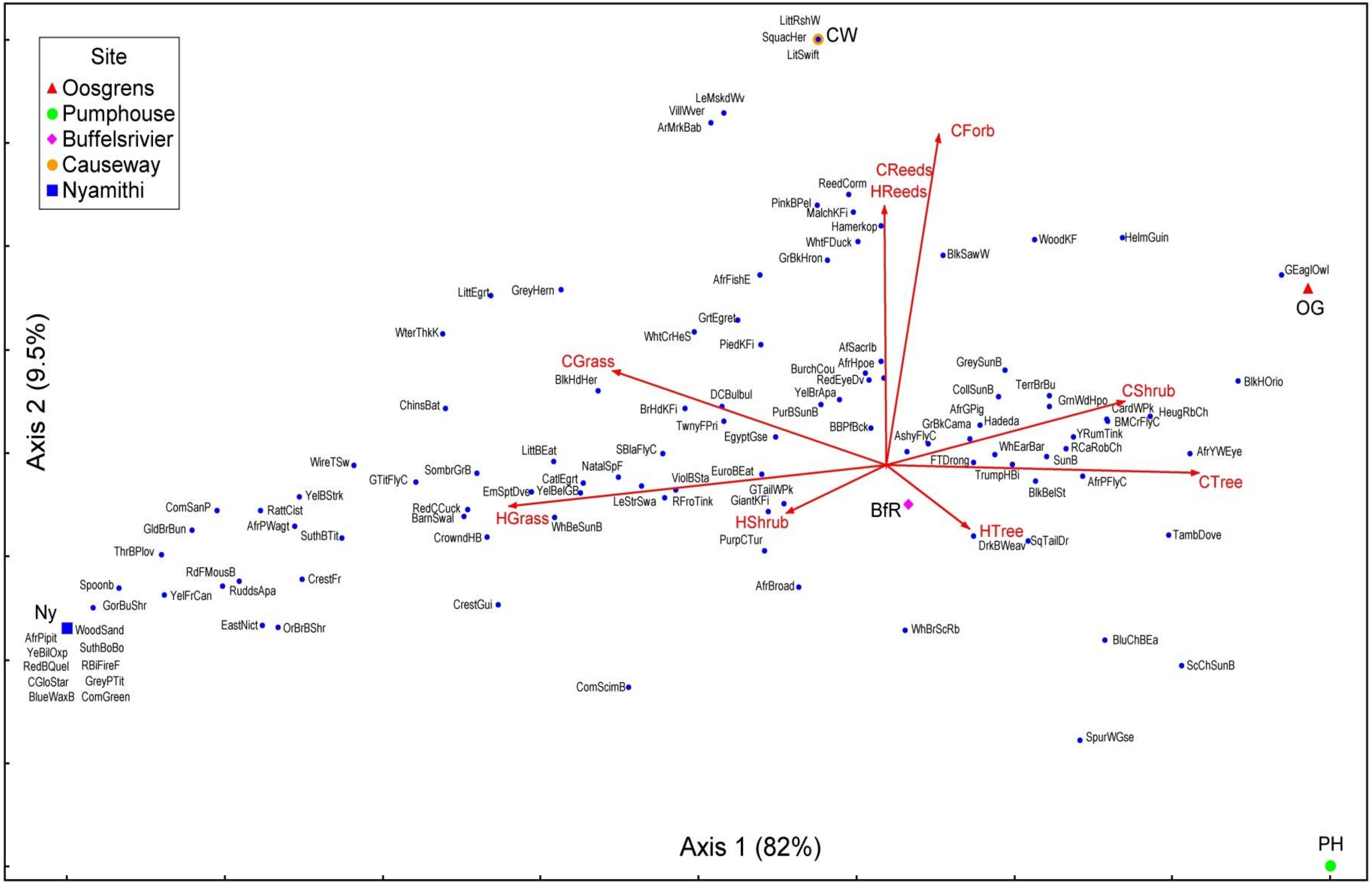

Figure 4.29: NMS ordination of the relationship between species and sites, using Sørensen as distance measure.
The data was relativized in columns (per species), with parameters allowing for up to six axes, with 500 iterations set as maximum. Random starting configurations were used with 250 runs of real data and 250 runs of randomised data. Stress was 0.00000, with instability at 0.0104 after 20 iterations. Axis 1 explains 82% of the variation, and Axis 2 explains 9.5%, for a cumulative explanation of 91.5%. For explanation of abbreviations see Tables 4.1 and 4.4.

Figure 4.30 is an NMS ordination with convex hulls per site according to surveys. Species with five or less individuals recorded in total over all five surveys were not included as rare species contribute little to the overall interpretation (McCune & Grace, 2002). Oosgrens had the smallest convex hull. Causeway and Buffelsrivier overlapped, but Causeway does not overlap with Oosgrens. Pumphouse and Nyamithi ordinated either side of the three sites in the centre.

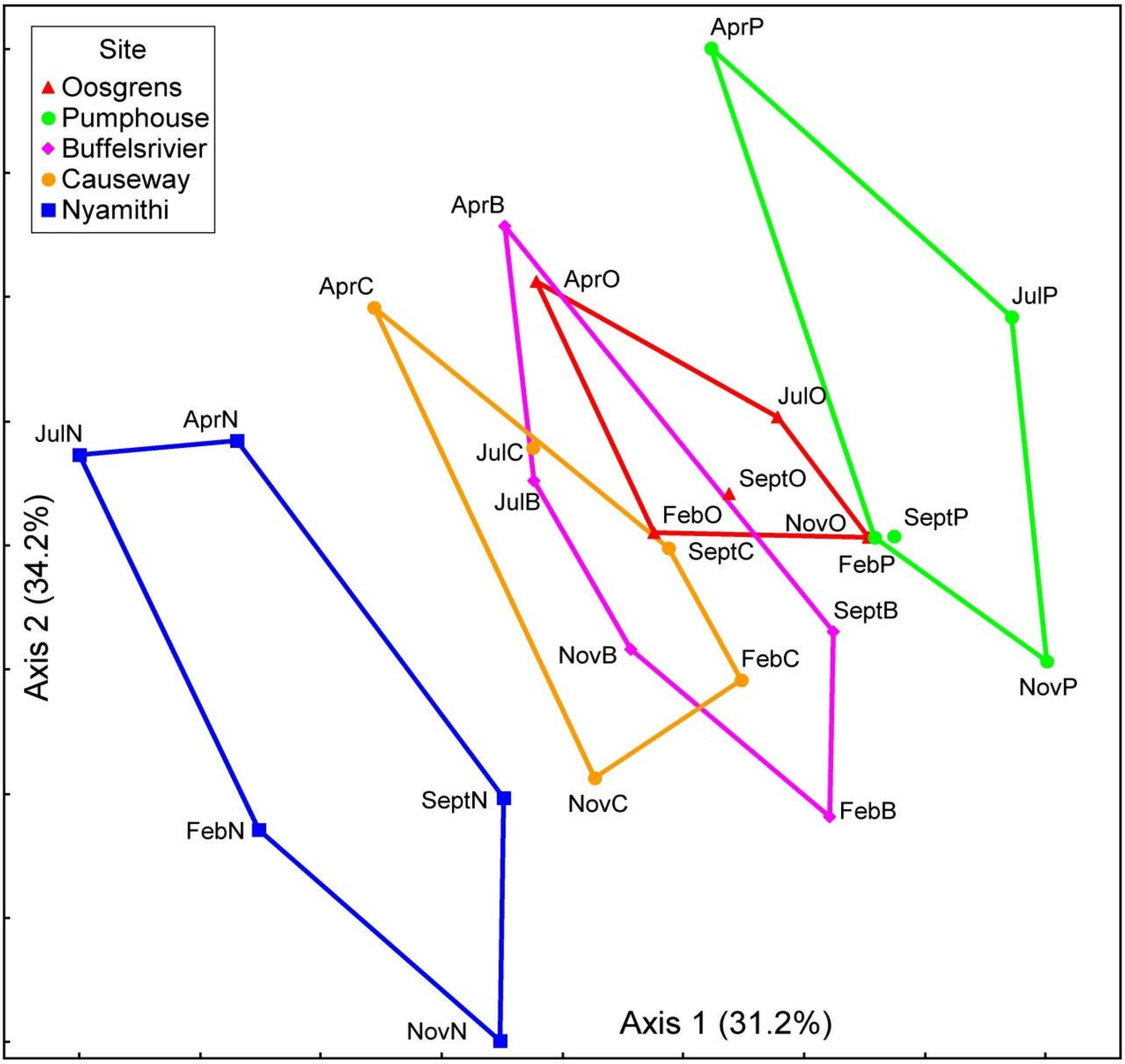

Figure 4.30: Convex hulls of the ordinations of each survey per site according to bird composition.

Non-relativized and untransformed data were used, with Sørensen as distance measure. Five dimensions were allowed. Random starting configurations were used with 250 runs of real data and 250 runs of randomised data. The number of real runs of data was set at 50. Final stress was 12.6 with a final instability of 0.00000 reached after 48 iterations. Axis 1 explains 31.2% of the variation, axis 2, 34.2%, and axis 3, 17.1%, for a cumulative explanation of 82.5% (65.4% without the 3rd axis).

Each month is abbreviated and the first letter of the site added as suffix. For further explanation of abbreviations see Table 4.1.

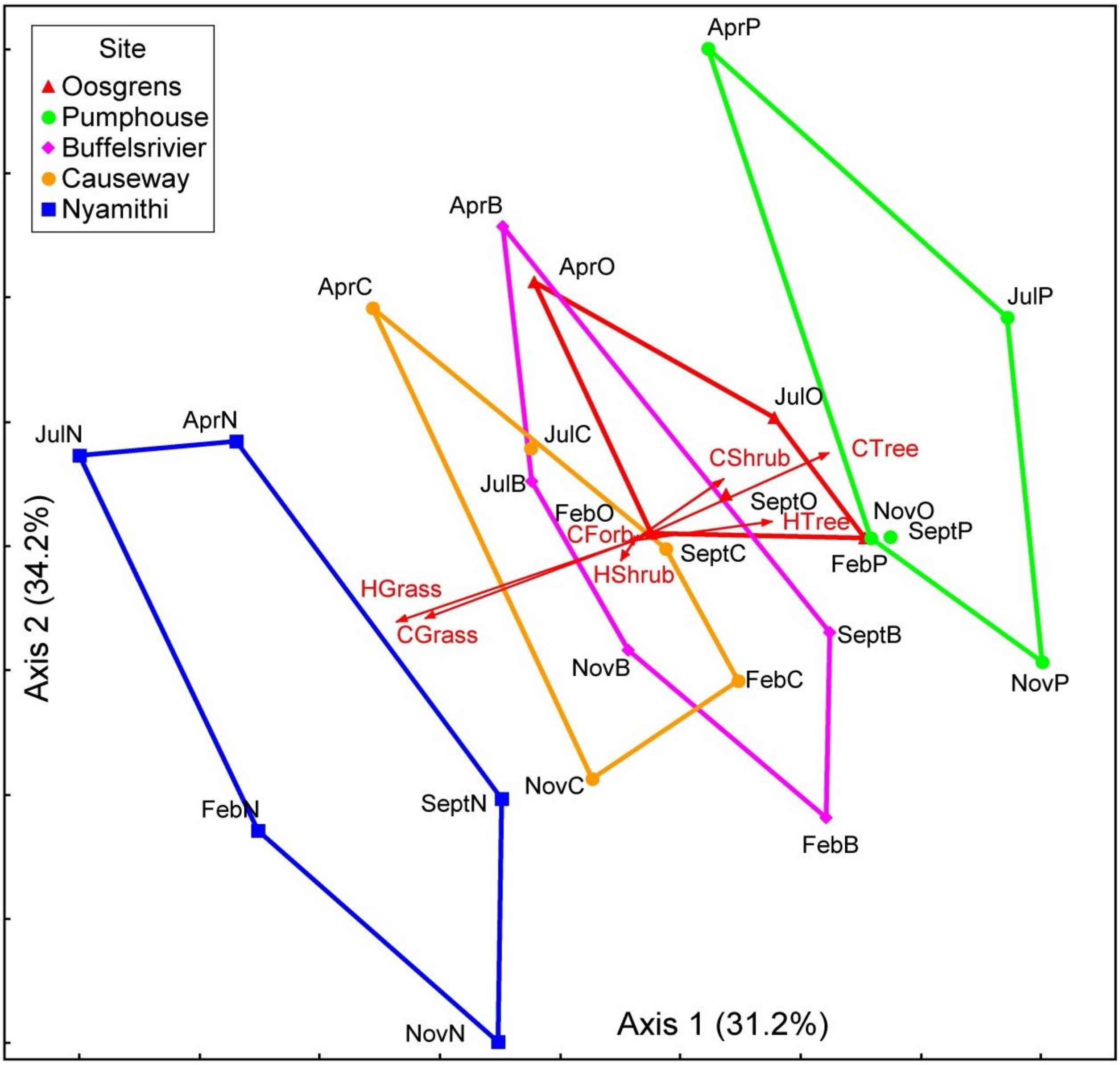

Figure 4.31: Convex hulls of the ordinations of each survey per site according to bird composition, with vegetation factors.

Non-relativized and untransformed data were used, with Sørensen as distance measure. Five dimensions were allowed. Random starting configurations were used with 250 runs of real data and 250 runs of randomised data. The number of real runs of data was set at 50. Final stress was 12.6 with a final instability of 0.00000 reached after 48 iterations. Axis 1 explains 31.2% of the variation, Axis 2, 34.2% and axis 3, 17.1%, for a cumulative explanation of 82.5% (65.4% without the 3rd axis). Vegetation factors were added. Each month is abbreviated and the first letter of the site added as suffix. For further explanation of abbreviations see Table 4.1.

Figure 4.31 is the same as Figure 4.30, but with the vegetation factors added as a biplot. Species with five or less individuals recorded in total over all five surveys were not included as rare species contribute little to the overall interpretation (McCune &

Grace, 2002). CTree and HTree ordinated opposite HGrass and CGrass (seemingly co-variate) on the horizontal axis. CForb and HShrub contributed very little descriptive or explanatory power to the ordination.

4.4.5. Successional changes in bird composition

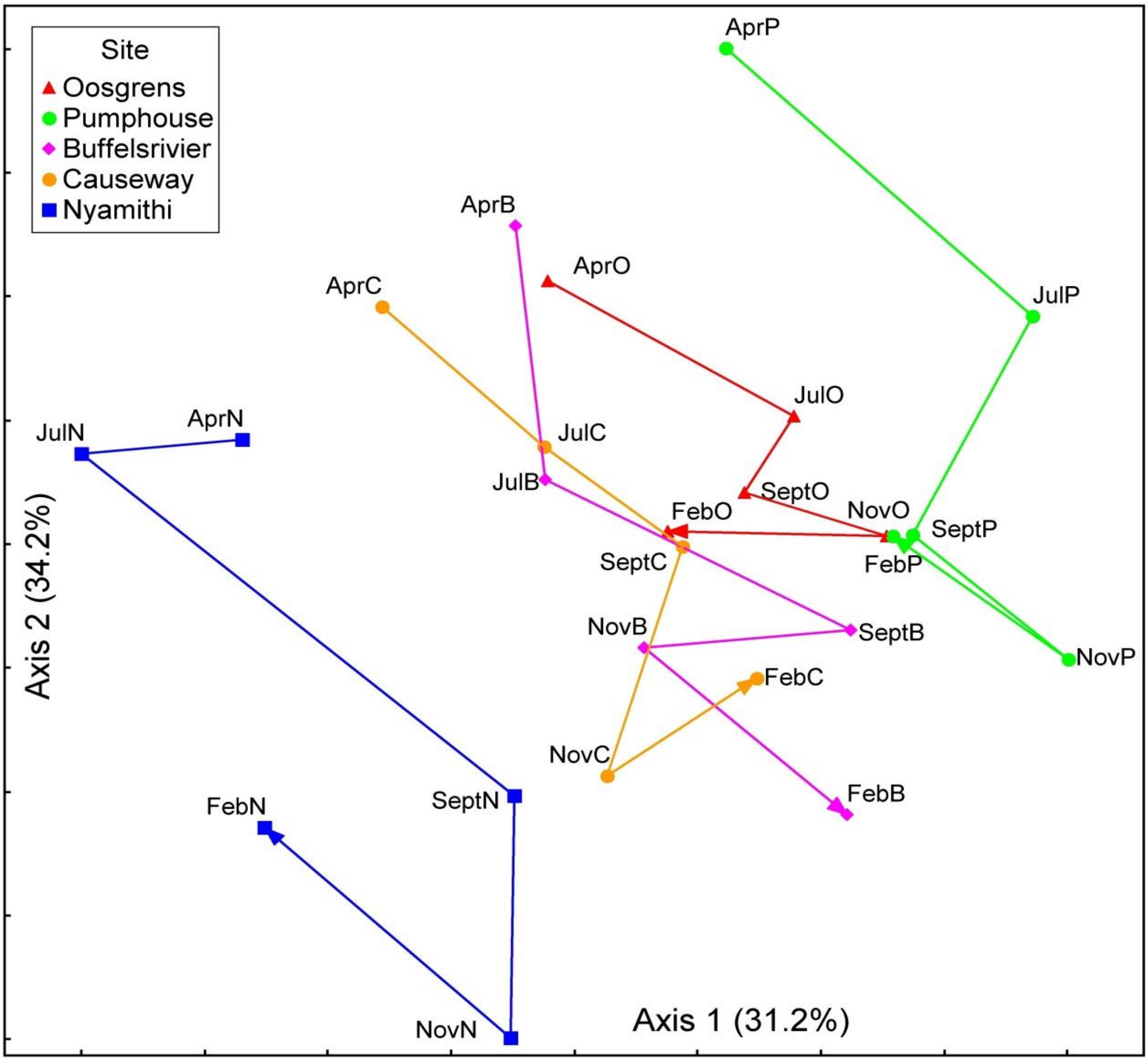

Figure 4.32: Successional vectors show change in bird composition at the sites over time. Each month has been abbreviated and the first letter of the site added as a suffix.

Non-relativized and untransformed data were used, with Sørensen as distance measure. Five dimensions were allowed. Random starting configurations were used with 250 runs of real data and 250 runs of randomised data. The number of real runs of data was set at 50. Final stress was 12.6 with a final instability of 0.00000 reached after 48 iterations. Axis 1 explains 31.2% of the variation, Axis 2, 34.2% and axis 3, 17.1%, for a cumulative explanation of 82.5% (65.4% without the 3rd axis). Each month is abbreviated and the first letter of the site added as suffix. For further explanation of abbreviations see Table 4.1.

Figure 4.32 is an ordination of the changes in species composition over time. Species with five or less individuals recorded over all five surveys were not included, as rare species contribute little to the overall interpretation (McCune & Grace, 2002).

The successional vectors of the five sites in Figure 4.32 show how bird composition changed with time relative to each other. The length of the successional vectors indicates the relative magnitude of change of bird composition, although changes in the third dimension (explaining 17.1% of the variation in the ordination) should be kept in mind. Nyamithi showed clear differences of changes in bird composition compared with the other four sites, mainly by being clearly separated from the other four. The relative bird composition at all sites, except Nyamithi, moved down and left between October and July, while Nyamithi's moved perpendicular to this direction towards the left. Thereafter, the changes showed more or less the same pattern at all sites.

Pumphouse's bird composition started at the top of axis 2 in April, moving slightly down and right on axis 1 in July. It moved down and to the right again in November and returned to almost the same coordinates in February. Oosgrens showed a similar temporal pattern to Pumphouse, with the exception of February, shifting leftwards on Axis 1. Buffelsrivier started at the top and moved down and slightly to the right in July, but then moved far right in September, left in November, and down and right in February.

Causeway's bird composition went down and right from April through to September, down and slightly left in November, and then up and right in February. Nyamithi started to the left of the ordination, about halfway up on axis 2, and moved further left in July. It then moved down and right in November, and up and left in February.

In Figure 4.33, species coordinates were added to the same plot as in Figure 4.32. Specific bird species occurred at specific sites during specific times of the year, such as the Cape Glossy Starling and Yellow Billed Oxpecker at Nyamithi during July. Little Swift was found at Causeway during November, with no species occurring exclusively at Pumphouse during the entire survey. Most species ordinated near Buffelsrivier and Causeway during July, with the Black-backed Puffback, Green-backed Heron, Red-eyed Dove, Hamerkop, Little Rush Warbler, and Brown-hooded Kingfisher ordinating closest to those sites.

Nyamithi's trajectory did not overlap with any of the other sites. Pumphouse did not overlap anywhere except for the February survey overlapping slightly with Oosgrens in November. Overlapping of the sites' trajectories indicate a similarity in bird composition, although the third dimension should be kept in mind.

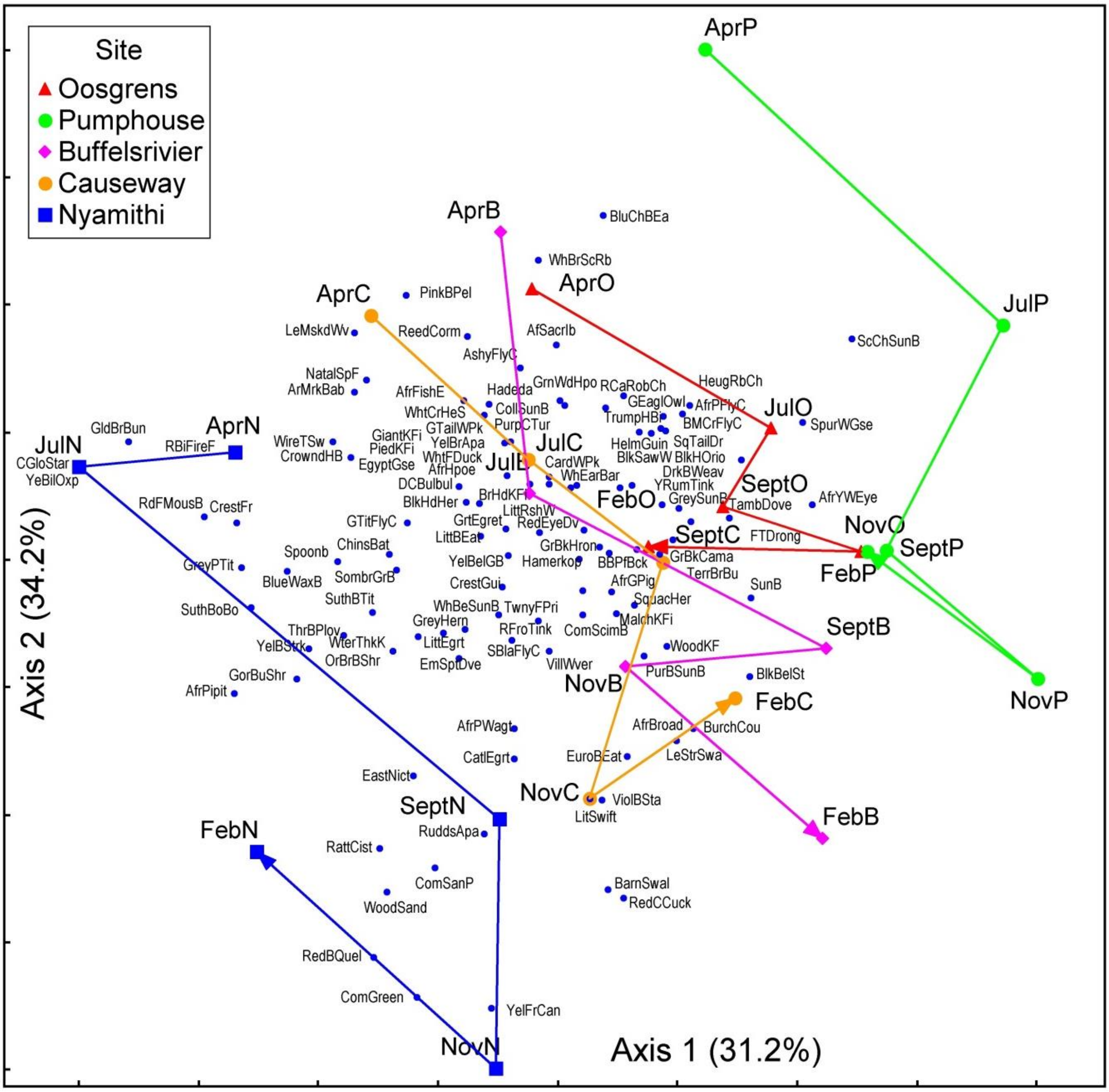

Figure 4.33: Successional vectors show change in bird composition at sites over time, with species plotted.

Non-relativized and untransformed data were used, with Sørensen as distance measure. Five dimensions were allowed. Random starting configurations were used with 250 runs of real data and 250 runs of randomised data. The number of real runs of data was set at 50. Final stress was 12.6 with a final instability of 0.00000 reached after 48 iterations. Axis 1 explains 31.2% of the variation, Axis 2, 34.2% and axis 3, 17.1%, for a cumulative explanation of 82.5% (65.4% without the 3rd axis). Each month is abbreviated and the first letter of the site added as suffix. For further explanation of abbreviations see Table 4.1.

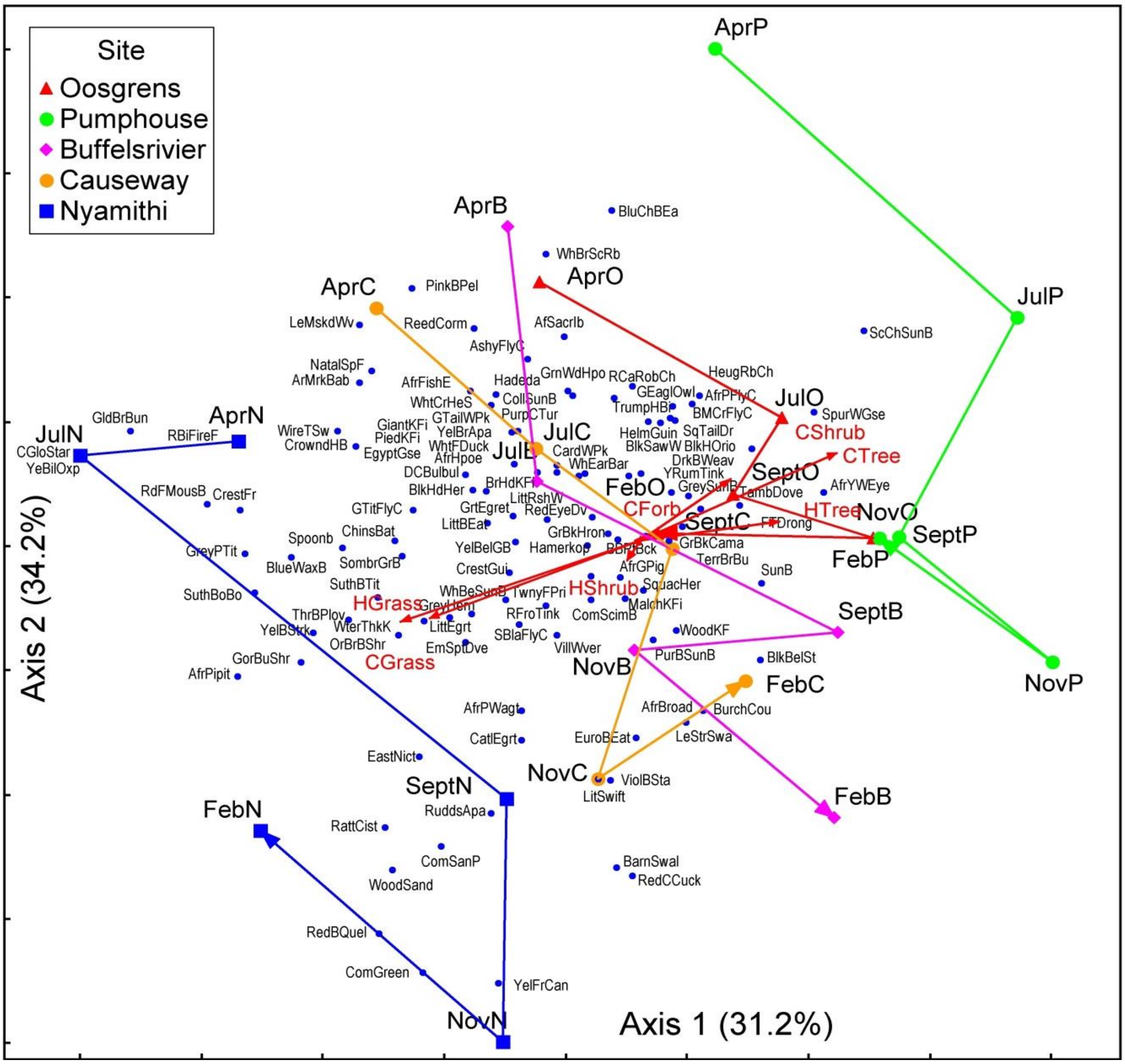

Figure 4.34: Successional vectors show change in bird composition at sites over time, with species, and vegetation factors.

Non-relativized and untransformed data were used, with Sørensen as distance measure. Five dimensions were allowed. Random starting configurations were used with 250 runs of real data and 250 runs of randomised data. The number of real runs of data was set at 50. Final stress was 12.6 with a final instability of 0.00000 reached after 48 iterations. Axis 1 explains 31.2% of the variation, Axis 2, 34.2% and axis 3, 17.1%, for a cumulative explanation of 82.5% (65.4% without the 3rd axis). Each month is abbreviated and the first letter of the site added as suffix. For further explanation of abbreviations see Table 4.1.

As already seen in Figure 4.32 and Figure 4.33, strong vector lines representing HGrass and CGrass ordinated to the left of the origin in Figure 4.34, with a relatively short vector line for HShrubs, also to the left. The vector line for CTree ordinated strongly in the upward right direction, away from the origin, with the HTree and CShrubs in the same direction but with relatively shorter vectors. The vector line for the CForbs is short, indicating little influence by forb cover on species composition over time. Reeds did not feature as a vegetation factor in any of the ordinations, indicating its lack of explanation to the overall picture.

Species associated with the grassier areas (to the left on the X-axis) were Water Thick-knee, Orange-breasted Bush Shrike, Three-banded Plover, Yellow-billed Stork, Little Egret, Southern Black Tit, Emerald-spotted Dove and Grey Heron. Species associated with taller, denser trees (to the right on the X-axis) were Fork-tailed Drongo, African Yellow White-eye, Tambourine Dove, Spur-winged Goose, Grey Sunbird, Yellow-rumped Tinkerbird, Dark-backed Weaver and Black-headed Oriole. Species that ordinated closer to the origin were Black-backed Puffback, African Green Pigeon, Hamerkop, Squacco Heron, Terrestrial Brownbul and Green-backed Camaroptera. Species not specifically associated with or influenced by any of the vectors ordinated more to the top and bottom of the Y-Axis. These species include (top of the ordination): Blue-cheeked Bee-eater, White-browed Scrub-Robin, Pink-backed Pelican, African Sacred Ibis, Reed Cormorant, Lesser-masked Weaver and Ashy Flycatcher, as well as (bottom of the ordination): Yellow-fronted Canary, Barn Swallow, Red-chested Cuckoo, Little Swift and Violet-backed Starling.

4.4.6. Feeding Guilds

Figure 4.35 represents the distribution of the bird feeding guilds identified during the study: carnivorous, omnivorous, piscivorous, herbivorous, granivorous, insectivorous, frugivorous, and nectarivores.

Nectivores and insectivores ordinated opposite omnivores, piscivores, carnivores, and granivores. Herbivores and frugivores ordinated perpendicular to that grouping, and opposite each other.

Frugivores ordinated closest to Oosgrens, directly opposite HShrub, associating with

CForbs more than any other vector. Herbivores ordinated opposite CForb, associating with HShrub and HTree. Nectivores and insectivores ordinated close to HTree and CTree, but were not associated strongly with any site. Granivores ordinated directly opposite HTree and did not associate specifically with any site. Carnivores did not associate with any specific site, but correlated with HGrass, CGrass, CReeds and HReeds. Piscivores ordinated opposite CShrub and associated with Causeway more than any other site. Omnivores also ordinated directly opposite CShrub, associating strongly with Causeway.

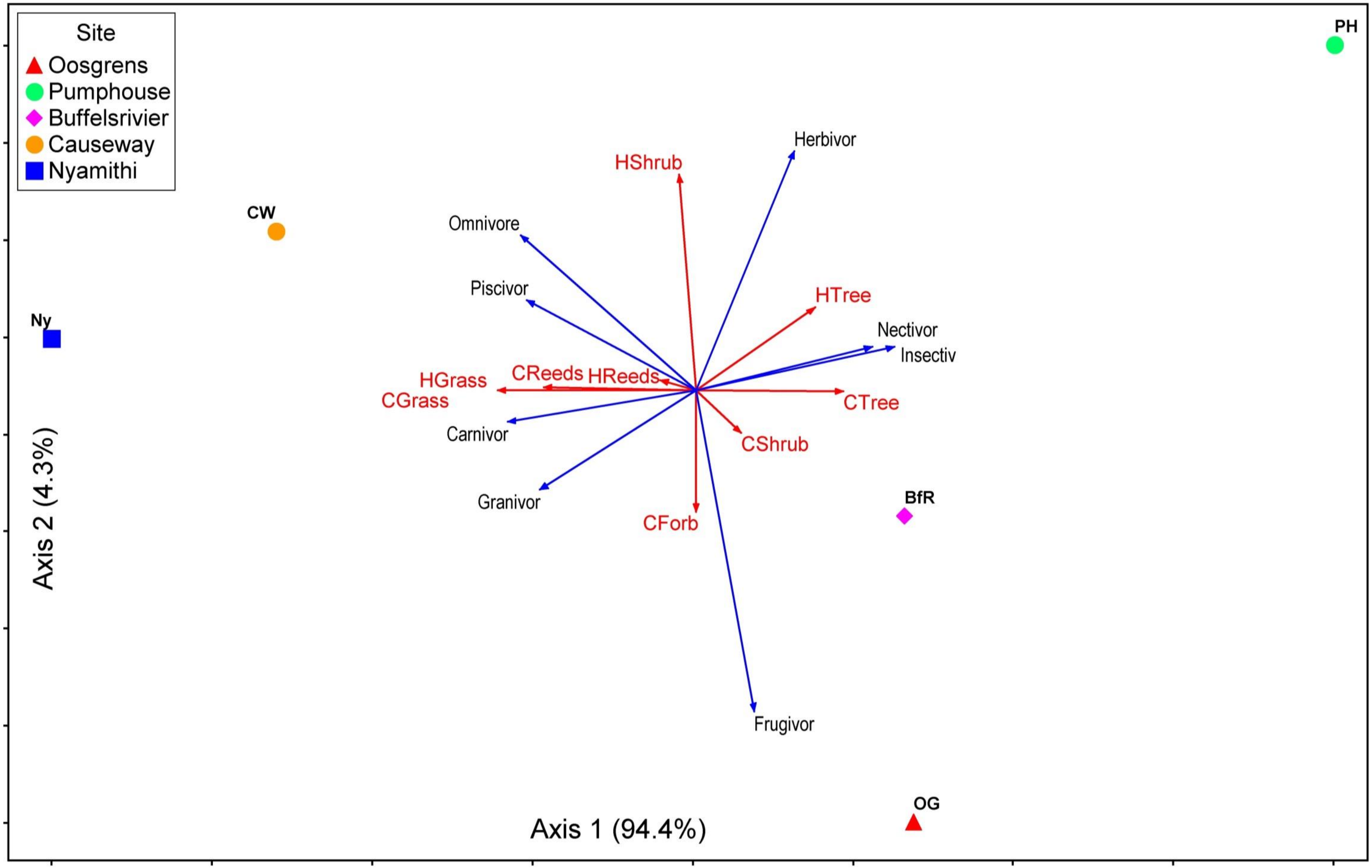

Figure 4:35: PCA ordination of feeding guilds for 165 species at different sites, with species and vegetation biplot data. Data is relativized and generalised according to sites. Cross product matrix is a correlation. Axis 1 explains 94.4% of the ordination and axis 2 explains 4.3%. For explanation of abbreviations see Tables 4.1 and 4.5.

4.4.7. Nesting guilds

Figure 4.36 is an NMS ordination of the nesting guilds of the birds identified in this study. The nesting guilds present were as follows: ground, shrub, tree, burrow, parasitic, structure, grass, and extralimital.

Ground, burrow, parasitic, and structure nesters ordinated opposite cavity nesters. Grass, reed, and extralimital nesters ordinated opposite shrub and tree nesters. All four groups (these two groupings) ordinated perpendicular to each other.

Reed and grass nesters (as well as extralimital nesters) associated strongly with HTree and somewhat with HShrub. Cavity nesters associated strongly with CTree. Shrub and tree nesters ordinated opposite HSrub and HTree, Reed nesters ordinate perpendicular to HReeds and CReeds, Burrow and ground nesters associate with HGrass and gravitate towards Nyamithi, where HGrass and CGrass were factors. HReeds and CReeds were factors at Causeway, and birds nesting in structures ordinated close to this site, as well as parasitic nesters.

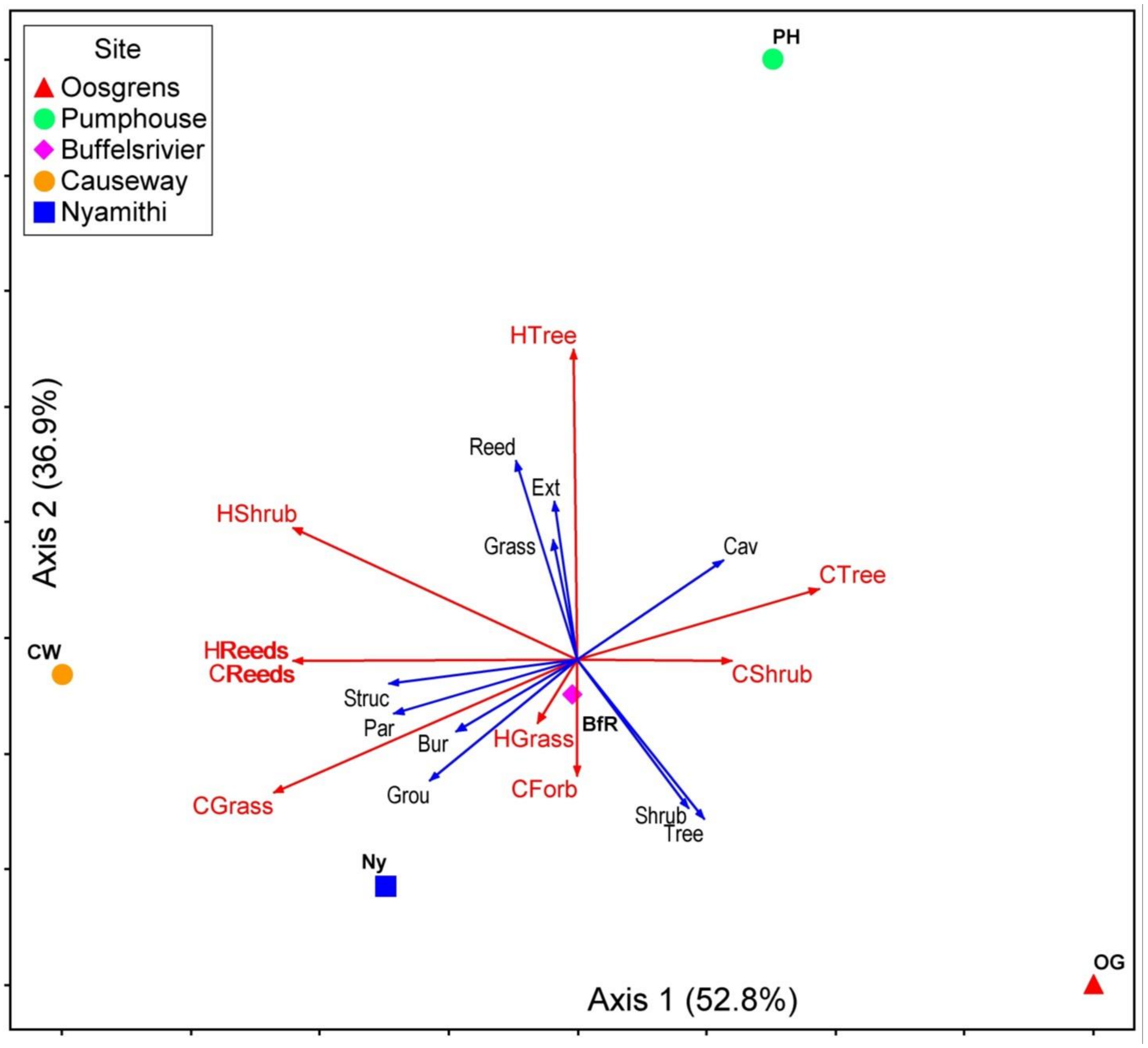

Figure 4:36: PCA ordination of nesting guilds for 165 species at different sites, with species and vegetation biplot data.

Data was relativized according to sites. Cross product matrix is a correlation. Axis 1 explains 52.8% of the ordination and axis 2 explains 36.9%. Grou = ground; Bur = burrow; Par = parasitic; Struc = structural; Grass = grass; Reed = reed; Ext = extralimital; Cav = cavity; Shrub = shrub; Tree = tree. For further explanation of abbreviations see Tables 4.1 and 4.5.

4.4.8. Biomass

Table 4.8: Total bird biomass calculated per month and site

Biomass per month (kg)		**Biomass per site (kg)**	
Oosgrens	428	April	1093.24
Pumphouse	510	July	688.36
Buffelsrivier	460	September	306.82
Causeway	682	November	171.73
Nyamithi	642	February	460.55

Table 4.8 shows the total biomass of all the species recorded at all the sites during the survey. All the individuals were tallied together for each month and each site. April was the month with the highest biomass, with a total biomass of 1093.2 kg (Figure 4.37). November was the month with the lowest biomass, with 171.7 kg. The site with the highest total biomass was Causeway with 682.3 kg, and Oosgrens was the lowest with 427.7 kg (Figure 4.38).

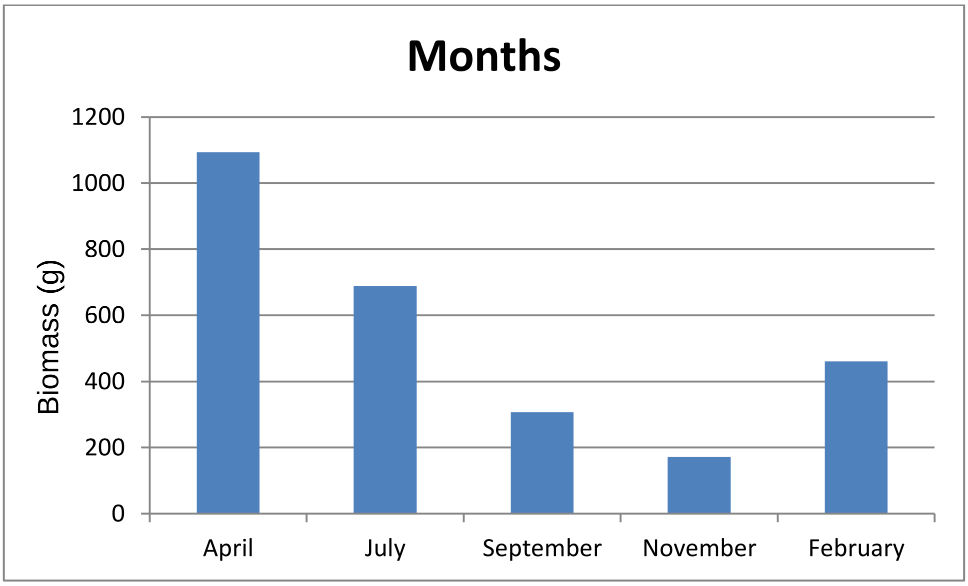

Figure 4.37: Total bird biomass per month, aggregated for all the surveys.

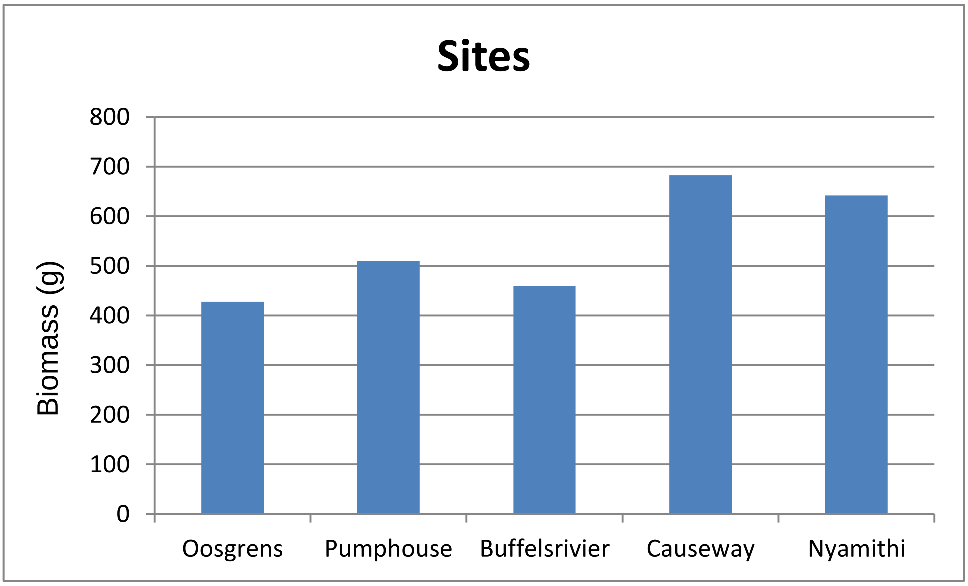

Figure 4.38: Total biomass per site, aggregated for all the sites combined.

To investigate possible effects of anthropogenic impact on birds, the mass data was divided into two categories: birds with a mass of less than 1 kilogram per individual (144 species), and birds with a mass of more than 1 kilogram per individual (21 species). The prediction was that larger birds would be more affected by human disturbances than smaller birds. The division at 1 kg was arbitrary.

Figure 4.37 depicts the change in biomass over the five surveys. April (end of summer) had the highest biomass, slowly becoming less until November (beginning of spring) which had the lowest biomass. February increased again.

Difference in biomass between sites is depicted in Figure 4.38. Causeway had the highest biomass, Nyamithi less, and Pumphouse was intermediate. Buffelsrivier had the second lowest biomass and Oosgrens had the lowest bird biomass of all the sites.

Figure 4.39 is a PCA ordination with successional vectors of the biomass of species weighing less than 1 kg, predicting they would be less affected by disturbance than larger birds. Each month is linked to the next with successional vectors showing bird biomass trajectories (changes in bird biomass over time). Each time period had different vector lengths, indicating greater or lesser changes in bird biomass. July to September at Nyamithi showed the greatest relative change (longest vectors) in bird biomass. Relatively smaller changes occurred in July to September time at both Oosgrens and Pumphouse. The ordination changed mainly in relation to axis 2, which explained 43.8% of the variation.

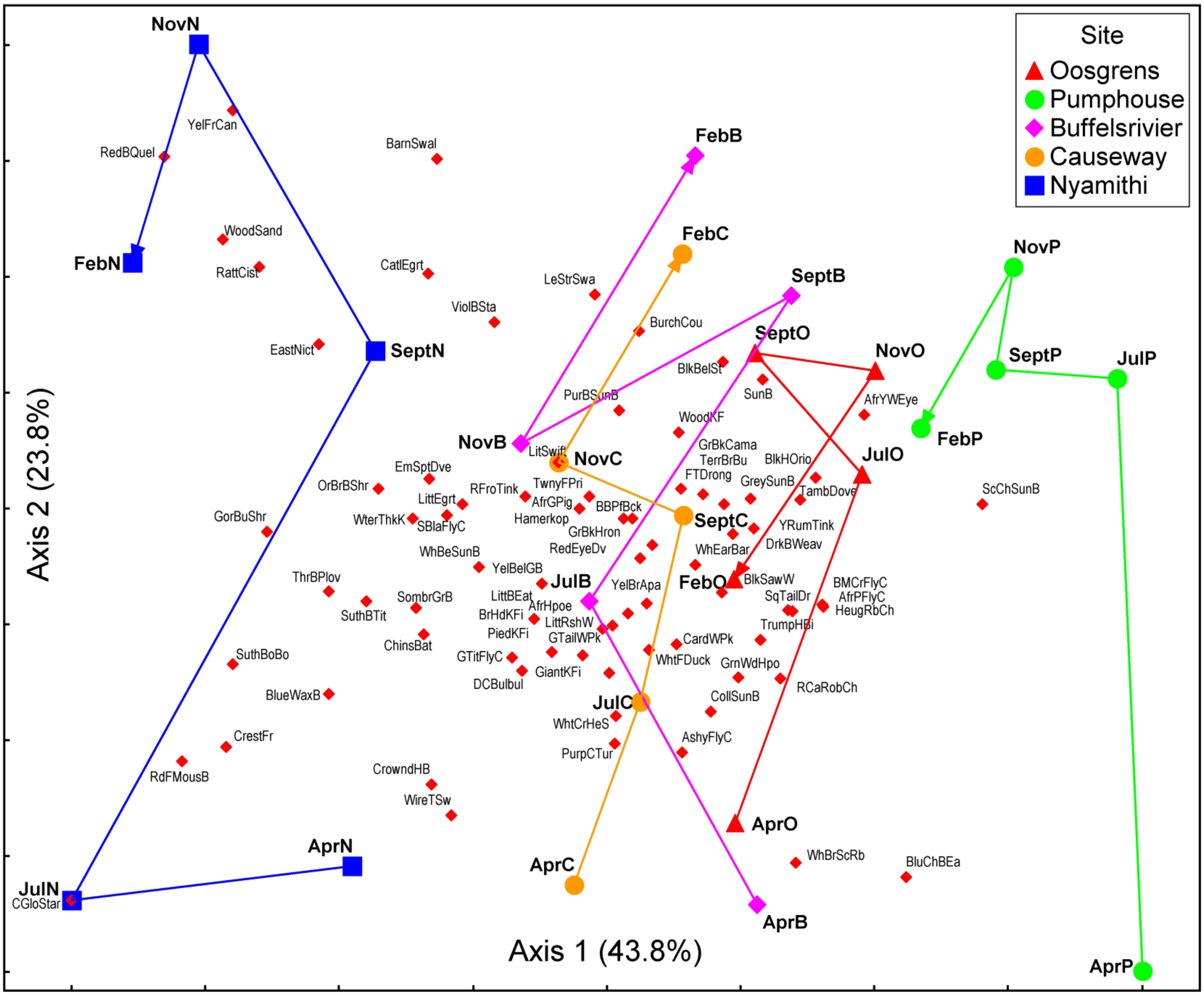

Figure 4:39: Successional vectors show change in total bird biomass (for species weighing less than 1 kg), at sites over time, with species, and vegetation biplot added.

Non-relativized and untransformed data were used, with Sørensen as distance measure. Five dimensions were allowed. Random starting configurations were used with 250 runs of real data and 250 runs of randomised data. The number of real runs of data was set at 50. Final stress was 11.88 with a final instability of 0.00000 reached after 45 iterations. Axis 1 explains 43.8% of the variation, Axis 2, 23.8% and axis 3, 17.2%, for a cumulative explanation of 84.4% (67.7% without the 3rd axis). Each month is abbreviated and the first letter of the site added as suffix. For further explanation of abbreviations see Tables 4.1 and 4.5.

Figure 4.40 is a PCA ordination with successional vectors of the biomass of birds recorded with an individual mass greater than 1 kg. Each month is linked to the next with successional vectors showing bird biomass trajectories (change in bird biomass over time). Each time period had different vector lengths, indicating greater or lesser changes in bird biomass. Oosgrens during November stands out, as does Buffelsrivier during November, Pumphouse during November, and Causeway during November. Very little changes occurred between July and September at Oosgrens.

Most species ordinated around Nyamithi. If species with less than 5 individuals were omitted from the ordination, the pattern did not change. The ordination changes mainly in relation to axis 1, but many vectors also change in relation to axis 2, with a few outliers causing the pattern on axis 1.

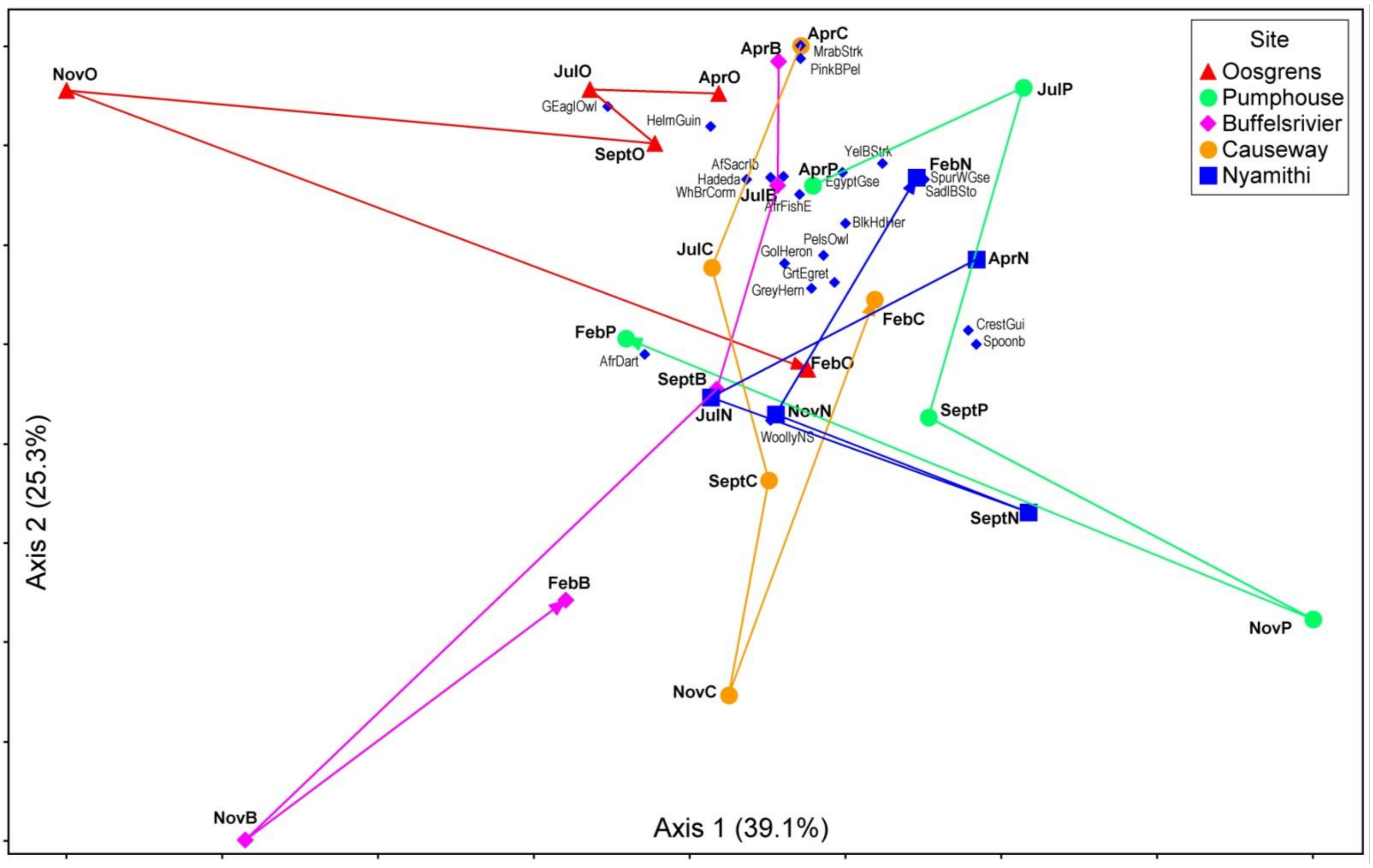

Figure 4:40: Figure 4.33: Successional vectors show change in bird biomass (individuals over 1 kg each), at sites over time, with species and vegetation biplot added.

Non-relativized and untransformed data were used, with Sørensen as distance measure. Five dimensions were allowed. Random starting configurations were used with 250 runs of real data and 250 runs of randomised data. The number of real runs of data was set at 50. Final stress was 18.98758 with a final instability of 0.00000 reached after 50 iterations. Axis 1 explains 39.1% of the variation, Axis 2, 25.3% and axis 3, 14.2%, for a cumulative explanation of 78.6% (64.4% without the 3rd axis). Each month is abbreviated and the first letter of the site added as suffix. For further explanation of abbreviations see Tables 4.1 and 4.5.

Chapter 5: Discussion and conclusion

For the purposes of this study, I assumed that the vegetation structure did not change over the seasons. There were no burns, changes in grass height, no noticeable differences in foliage density (although there changes in flowers, fruits, and changes in colour over the wet and dry season – but no structural changes), or any other changes in vegetation structure during the duration of the study. Water levels did change but these were not measured. Presumably, this might have affected birds at Nyamithi more than at other sites. I also did not measure food availability such as insects and seeds. My study concentrated on bird community associations with vegetation structure and changes of season as the main explanatory factors.

5.1. Sites and vegetation

Riparian areas are important habitats for birds (Woinarski *et al*., 2000). The woody fringe of trees (up to 35 m high) along the Phongolo river consists of species such as Sycamore Fig (*Ficus sycamorus*), Quinine Tree (*Rauvolfia caffra*) and Water Pear (*Syzygium guineense*), and shorter woody plants such as River Sandpaper Fig (*Ficus capreifolia*) (Cooper, 1980). This was confirmed in this study, with most sites having these species as the dominant vegetation type. The pans (including Nyamithi) have a slightly different vegetation composition, with Fever Tree (*Acacia xanthophloea*) communities surrounding them and a dense sward of stoloniferous grasses beneath them, such as *Cynodon*, *Sporobolus* and *Digitaria*. This mat of grass extends from the high flood level to the low flood level (Cooper, 1980).

Well-developed communities of *Ficus sycomorus* and *Rauvolfia caffra* grow in the Ndumo Game Reserve and are seasonally flooded. These composed the riverine habitats that were chosen for this study. These tree communities cover 246 ha within the reserve. Outside the reserve, these stands have been extensively thinned out and burnt for crops. This was also evident in the destruction of vegetation at Oosgrens (Figure 4.2) where the habitat transformation to the east and south is very evident. Only 160 ha were still recognisable as sizeable communities outside the reserve (Cooper 1980), but this has likely diminished in the meantime.

Big reed stands (*Phragmites*) cover large areas of Ndumo Game Reserve. Two reed species form distinct communities; Reed Grass/Lowveld Reed (*P. mauritianus*) grows on river banks, inlet channels and pan margins where water levels fluctuate; Common Reed (*P. australis*), on the other hand, prefers flat swampy areas (Cooper, 1980). Causeway and Buffelsrivier were the only two sites with reeds.

Each site and subplot that were surveyed had unique characteristics that set them apart from each other, especially in terms of vegetation composition and structure. They also shared many common features because of the close proximity of the sites. Many elements make up the complex patchwork of a riparian ecosystem, including vegetation (Woinarski *et al*., 2000). Many of these elements are interrelated and work together to influence bird diversity. Vegetation is influenced by various factors, including climate, topographic variations, and disturbances such as floods. This in turn influences the bird species distributions (Wiens 1989b; Naiman *et al*. 1993; Seoane *et al*. 2004; Wakeley *et al*. 2007; see also Section 2.6). The changes of vegetation on a spatial scale therefore affect the processes that influence bird community patterns.

5.1.1 Oosgrens

I recorded an aggregate of 68 bird species and 1477 combined bird counts (total of all individuals counted over the five surveys) at Oosgrens – a riverine site (Table 4.3 and Figure 4.2). This site had the second lowest aggregate species richness and the second lowest number of aggregated counts. Oosgrens had the greatest tree coverage, but tree height was classified as category 5 (short – 5-10m) (Table 4.1). Shrub cover was also greatest out of all the sites, but shortest of all (1-2m). Figure 4.29 clearly shows that CTree strongly associates with Oosgrens, as well as CShrub. This site ordinated perpendicular to CReeds, HReeds and CForbs, indicating that these factors had no influence on the bird species present at that site (there were no reeds; the ground was covered in 11-25% grass and 0.1-1% forbs). However, Oosgrens ordinated opposite HShrub, indicating that although the shrub cover was extensive, the shortest shrubs occurred here. Oosgrens was situated on the north-western aspect of the river and vegetation seemed to be intact within the site, despite the disturbances on the other side of the river. Disturbances on the other side of the river (still in the reserve) included a small, illegal informal settlement, cut-down trees, music and dogs that could frequently be heard, and smoke trails that rose from cooking fires. Figure 4.2 clearly illustrates the difference between riverine forest (very thick riverine strip) and agricultural sites. Figures 4.3 – 4.6 illustrate the vegetation at the site, showing intact vegetation on the side of the river that was not disturbed, and Figures 5.1 and 5.2 illustrate the disturbance opposite the river from Oosgrens.

Figure 5.1: Disturbances opposite the river from Oosgrens.

Figure 5.2: Disturbances opposite the river from Oosgrens. A field of maize (yellow) is visible.

Even though a level of disturbance was found at Oosgrens, the site still had more species than Pumphouse, and more individual counts than Pumphouse and

Buffelsrivier. This could point to the fact that species at this site have adapted to disturbances as floods frequently cover the area. The thick band of riverine forest on the western side of the river could also act as a buffer, where all the birds that lived on the other side of the river have now moved. Species diversity can be higher in habitats that experience an intermediate amount of disturbance than those without disturbance, or habitats exposed to severely degrading disturbances (Connell, 1987). It is likely that the intermediate-disturbance hypothesis explains the intermediate land-use modification and resultant species richness at Oosgrens.

5.1.2. Pumphouse

I recorded an aggregate of 61 species and 1067 combined counts at Pumphouse (Table 4.3). This is the lowest species richness and combined counts for any of the sites. This was also a riverine site with a thin strip of riverine bush along the western side of the river where the site was located (Figure 4.7). Pumphouse had the tallest trees (along with Buffelsrivier) and greatest tree coverage (along with Oosgrens) (Table 4.1). This can be seen on the ordination where Pumphouse is associated with HTree (Figure 4.29). Pumphouse ordinated opposite CGrass and perpendicular to HShrub, HGrass, and CShrub. It had the least grass cover of all the sites, no reeds, and very little forbs. Shrubs did not grow very high either. The understorey vegetation was sparse, with very few layers in the vegetation. MacArthur *et al*. (1962) found that the layers within the vegetation account for species richness. Fewer layers would mean fewer species. It can therefore be assumed that as Pumphouse had fewer vegetation layers than the other sites, this explains the low species diversity and abundance.

5.1.3. Buffelsrivier

Eighty three bird species and 1355 combined counts were recorded at Buffelsrivier (Table 4.3). This site had the third highest species richness, but second lowest combined counts. It was also a riverine site. Buffelsrivier had the tallest trees (along with Pumphouse) and tall shrubs, but little shrub cover (Table 4.1). Figure 4.29 shows that Buffelsrivier is associated with HTree and HShrub. It ordinated perpendicular to HGrass, CGrass, CTree and CShrub, which confirms visual estimations at the site. However, this was one of the only two sites with reed beds and some of the better forb cover occurred there, but it ordinated opposite HReeds, CReeds, and CForb. This could be ascribed to the fact that Causeway had bigger and taller reed stands than Buffelsrivier and therefore ordinated stronger with these two vectors than Buffelsrivier did. The difference in bird species composition describes the ordination space between Buffelsrivier and Causeway (Figure 4.29).

5.1.4. Causeway

An aggregate of 91 species and 1663 combined counts were recorded at Causeway (Table 4.3). This site was a transition between pan and river vegetation, with the second most aggregated species and combined counts. Two of the subplots within Causeway were dominated by bushy vegetation and the other two were dominated by grass and mudflats. Tree cover and height, shrub cover and height, and forb cover and height were all medium compared to the other sites (Table 4.1). Causeway ordinated right at the top of Figure 4.29. Only Causeway and Buffelsrivier had reeds. Ndumo Game Reserve’s extensive reed stands is one of the known breeding sites of the African Openbill (*Anastomus lamelligerus*) (Heeg & Breen, 1982). Oosgrens had much bigger and taller reed stands than Buffelsrivier, thus Oosgrens association strongly with HReeds and CReeds. Grass was abundant at some of the subplots within this site, but trees were not as tall as elsewhere. Causeway ordinated opposite HTree and HShrub, confirming the fact that vegetation was of medium height. Causeway ordinated perpendicular to HGrass and CTree, indicating that the absence of these two factors did influence bird composition as species that would select for HGrass and CTree would be less likely found here.

5.1.5. Nyamithi

Nyamithi was the most abundant and species rich site, with an aggregate of 100 species and 2194 combined counts (Table 4.3). This site was dominated by pan vegetation, with some riverine vegetation. Nyamithi had some of the shortest trees and the least tree cover (Table 4.1), ordinating opposite CTree in Figure 4.29. The shrubs that were present were tallish, hence the HShrub vector associated with Nyamithi, although the relative short length of this vector indicates a weakerg influence. Grass was abundant but forbs were few, evident in HGrass and CGrass associating with this site. CReeds, HReeds, and CForb ordinated perpendicular to this site, showing that birds associating with these factors were less likely to be found here. The rich species diversity and the relatively large aggregated bird count could be ascribed to the fact that the heterogeneity of this site had more niche opportunities, as both pan-related and riverine bush species are to be found here. Vegetation at the edge of lakes and pans may show greater specialization than communities bordering flowing water, thus resulting in a richer bird diversity (Richardson & Moore, 2010). Foraging opportunities might also be more, with a variety of substrates to choose from, most notably the presence of mud banks and grass swards that the other sites lacked. The presence of patches (canopy, bushes, herbaceous layers, and other cover types) may influence the habitat of birds and their resultant presence (MacArthur & MacArthur, 1961).

The influence of the mud banks were not measured in the present study, but non-vegetation ‘layers’ should be considered as environmental variables in studies such as these.

5.2. Species

I recorded an aggregate of 7756 birds of 165 species at the five sites along the floodplain in Ndumo Game Reserve, recorded over five surveys covering 10 months, in five sites consisting of four subplots each. Although not directly comparable, other studies on riparian birds found (aggregated totals in each):

- 767 birds of 48 species during 36 visits of two week intervals (Chan *et al*., 2008);
- 660 birds of 54 species during 75 surveys over six years (Choi *et al*., 2014);
- 4646 birds of 62 breeding bird species over three years (Pearson & Manuwal, 2001);
- 34 bird species during 117 surveys (Whitaker & Montevecchi, 1997); and,
- 4011 birds of 57 bird species over four years (Wakeley *et al*., 2007).

This indicates the abundance and richness of birds in the very small space that is Ndumo Game Reserve, and its importance to its protection. It serves as a haven for not only riparian species, but also probably for more terrestrial bird species from the surrounding, unprotected areas.

Most species were present during late summer, early autumn, with an aggregate of 119 species counted in April (late summer). The least amount of species was found during mid-winter (July) – only 90 species. This correlates with a study done on the pans in Ndumo Game Reserve, where more species were found during the summer than in winter, probably due to the influx of migratory species (Whittington *et al*., 2013). Even though the highest number of detections were also made during April (2272 combined counts), the fewest detections were recorded during November (1133 combined counts), aggregating to 7756 combined detections during the entire survey.

Some of the species recorded during the present survey were migratory, such as the African Paradise Flycatcher, African Pygmy-Kingfisher, Barn Swallow, Black Kite, Broad-billed Roller, Blue-cheeked Bee-eater, Collared Flycatcher, Common Greenshank, Common Sandpiper, Diderick Cuckoo, Eurasian Golden Oriole, European Bee-eater, Klaas's Cuckoo, Red-chested Cuckoo, Violet-backed Starling, Woodland Kingfisher and Wood Sandpiper. Lesser Striped Swallow, Black Saw-wing and Yellow-billed Stork can also to a certain extent considered migrants.

Different species were recorded during different seasons (Table 4.3). Most species were recorded during April (119 species), followed by February (111 species), November (96 species), September (94 species), and July (90 species). Most detections were recorded during April too (2272 combined counts), followed by July (1693 combined counts), February (1506 combined counts), September (1152 combined counts) and November (1133 combined counts). This may be because April is still late summer and most migrants might not have left yet. It could also be because the summer rains attributed to the vegetation being lush and green, maintaining suitable riverine habitats for migrant species. Another reason could be that the breeding season has just passed and fledglings contributed to the individuals being counted, as no distinction was made between adult and juvenile birds during the surveys.

When looking at which sites had the most species and combined counts (Table 4.3), Nyamithi far out-weighed the rest, with an aggregate of 100 species and 2194 detections. Next were/was Causeway (91 species, 1663 detections), Buffelsrivier (83 species, 1355 detections), Oosgrens (68 species, 1477 detections), and Pumphouse (61 species, 1067 detections).

Species with highest aggregated counts were mostly those that occur in flocks or family groups, like Barn Swallow (199), Cattle Egret (158), Terrestrial Brownbul (119), White-eared Barbet (228), Trumpeter Hornbill (168), Lesser Striped Swallow (213), and White-faced Duck (250). However, some species that do not usually occur in flocks, mostly singly or in pairs (Hockey *et al*., 2005), were also recorded in abundance, probably because these species are well adapted to these habitat types. That may well be the reason they were present all over in relatively large numbers. Some of these species were:

- African Paradise-Flycatcher (55 – only one detection at Nyamithi, as they prefer well-wooded areas);
- Black-backed Puffback (67 – least detections at Pumphouse);
- African Yellow White-eye (275 – no detections at Nyamithi);
- Dark-backed Weaver (110);
- Dark-capped Bulbul (sometimes small family parties; least detections at Pumphouse) (728);
- Emerald-spotted Wood-Dove (186);
- Fork-tailed Drongo (77);
- Golden-tailed Woodpecker (73 – most detections at Nyamithi);
- Green-backed Camaroptera (180 – most detections at Oosgrens);
- Grey Sunbird (118 – least detections at Nyamithi);
- Hadeda Ibis (found in small groups) (346 – most detections at Oosgrens);
- Purple-crested Turaco (86);
- Red-capped Robin-Chat (162 – least detections at Nyamithi);
- Red-eyed Dove (201);
- Sombre Greenbul (191 – one detection at Pumphouse, 106 detections at Nyamithi);
- Sunbird (General) (138); and,
- Yellow-breasted Apalis (sometimes small family groups) (115 – least detections at Pumphouse).

Twenty five species were only detected once. Of those species, eight were present in April, five in July, four in September, one in November, and eight in February.

5.3. Shannon diversity index

Riparian habitats have greater species richness, diversity, and abundance, and is more complex than non-riparian areas (Naiman *et al*., 1993; Woinarski *et al*., 2000; Palmer & Bennett, 2006). The Shannon Diversity index is used to classify sites as most or least diverse in terms of species richness. During this study, an aggregate of 7756 detections of 165 bird species were obtained, signifying the richness and diversity in a three kilometre radius. These sites are important conservation sites as they maintain such high diversity.

The Shannon diversity index (Table 4.6) calculated the highest H' bird diversity for Causeway and the lowest to Pumphouse. This is consistent with the results that were found during the surveys (Table 4.3). Pumphouse could possibly be the least diverse in terms of vegetation structural diversity as the habitat types within Pumphouse were also the least diverse (Table 4.6). Causeway had the highest bird and structural diversity. This is also shown in the regression (Figure 4.27).

5.4. Indicator bird species

The use of indicator species to monitor or assess environmental conditions is firmly established in ecology, environmental toxicology, pollution control, agriculture, forestry, and wildlife and range management (Noss, 1990). Indicators are measurable surrogates for environmental points such as biodiversity that are assumed to be of value to the public. Nilsson and Bergren (2000) argue that indicators species might be of great value when studying the effects of hydrological alterations on floodplains, as they serve as surrogates for overall species diversity in that group. Different groups of species are distributed differently along rivers and the distribution might change with alterations to hydrological cycles such as controlled floods. If species in a group change in synchrony because of flood regulation, the relationship between the species might suggest that indicator groups will suffice as representatives of overall species composition (Nilsson & Berggren, 2000).

Table 4.7 depicts the indicator species for Oosgrens, Causeway, and Nyamithi. Buffelsrivier and Pumphouse did not have significant indicator species. Verreaux's Eagle-Owl was the strongest indicator species for Oosgrens; 17 detections of this species were noted at Oosgrens and one at Causeway. These owls occur in sites with tall trees and abundant roosting sites; they are absent from shrub and desert lacking large trees (Hockey *et al*., 2005). Black-headed Oriole was a strong indicator for Oosgrens, detected eight times, in comparison to being detected once at Pumphouse and twice at Buffelsrivier.

Little Rush-Warbler was a very strong indicator for Causeway and only detected at this one site (13 detections), along with Squacco Heron (seven detections). The shallow water and muddy riverbanks with thick, low hanging branches are excellent habitat types for these species (Hockey *et al*., 2005).

African Pipit was the strongest indicator for Nyamithi, the only site it was detected at (six detections). Other indicators for Nyamithi were Orange-breasted Bush-Shrike (11 detections there, less elsewhere), Blue Waxbill (16 detections only at Nyamithi) and Wood Sandpiper (13 detections at Nyamithi only).

No significant indicator species ($p < 0.05$) were observed for either Pumphouse or Buffelsrivier. The reason is not immediately clear, but may be related to both having high trees in common with other sites (Table 4.1 and Figure 4.29); therefore, also sharing species with each other.

5.5. Species area curve

Species-area curves were used to evaluate whether enough sample points were used to produce valid data sets (McCune & Grace, 2002). Adequate sample sizes produce reliable findings; however, even if sample size was not big enough, deductions can still be made with a certain level of confidence.

The curve in Figure 4.28 flattens out very gradually, suggesting that sample size was sufficient to reflect species diversity. The estimated first-order jackknife was 195.7 species, but only 165 species were detected at the 20 subplots. The very gradual curve could be because of 48 (29 %) species with less than 5 detections, and 34

(21%) species with less than 3 occurrences. Those species might be seen as rare and not adequately represented in the data set. Increasing the sample points would mean that rare species would be included in more sites, but not necessarily in greater in numbers and the curve would still not flatten out. With 165 species recorded in Ndumu Game Reserve, this is a likely scenario, and I believe the dataset used here adequately serves the purpose of this investigation.

5.6. Vegetation diversity and species diversity

Because vegetation structure creates various niches for birds, it is thought to be an important factor influencing the distributions and abundances of bird species. Vegetation structure affects individual species as well as community composition through its influence on diversity and abundance (MacArthur & MacArthur, 1961; Rotenberry & Wiens, 1980). This is confirmed by Figure 4.27.

Pumphouse had the lowest structural diversity and therefore the lowest bird diversity, as this influence habitat selection by birds that might need diverse structural aspects in order to flourish. Causeway might have had less bird species than Nyamithi, but the diversity was greater because of greater vegetation structure diversity at Causeway. As vegetation types increase, habitats become more heterogeneous and complex, leading to increased niche diversity (Posa & Sodhi, 2006; Wakeley *et al*., 2007), and therefore bird because of more options to choose from. The hydrological gradient affects vegetation, which in turn affects bird distributions (Wakeley *et al*., 2007). Seoane *et al*. (2004) suggested that vegetation structure and variables could therefore be used as a potential source of predictors, as they considered it to be more directly linked to reproductive necessities of species than topography and climate.

When association between bird species and vegetation structure was measured, the linear regression line was significantly different from zero ($p = 0.0481$ and $r^2 = 0.1594$; Figure 4.27). This shows that bird species distribution was indeed correlated with vegetation structure, as was also found by Murakami and Nakano (2001), Palmer and Bennett (2006), and Woinarski *et al*. (2000). When Nyamithi was removed from the dataset (because of the large differences in habitat structure), the relationship became even stronger ($p = 0.0126$ and $r^2 = 0.2991$) for the riverine forest habitats.

Interpreting what can be gleaned from Figure 4.29, it becomes clear that birds are active habitat selectors, taking many factors into account when selecting the perfect habitat to forage, rest, nest and hide away, including aspects of vegetation structure. Again, it should be reiterated that additional structural 'layers' could be added in future studies, such as mud banks that are devoid of vegetation of note, but still attract birds due to food and other resources.

Since the X-axis describes 82% of the ordination (Figure 4.29), the left-to-right distribution of species and factors is most important. Species that ordinated close to Nyamithi, e.g. African Pipit, Yellow-billed Oxpecker, Blue Waxbill, Wood Sandpiper and Common Greenshank did so independently of reeds and forbs, selecting the habitat for its grass, woodland edges and pan-related attributes. Three Banded Plover and African Pipit preferred still standing water rather than flowing, and were seen on the muddy river banks, next to the open grass plain. Species such as the Little Rush-Warbler, Reed Cormorant, and Green-backed Heron ordinated directly in line with HReeds and CReeds, associating very strongly with marshy habitats, reed beds, and vegetated freshwater margins. This site was selected independently of the cover of trees or height of grass at the site. Species that ordinated close to HTree, like Dark-backed Weaver and Square-tailed Drongo, did so independently of CShrub or HShrub, and vice versa, preferring forest type habitats with closed canopies over shrub land. Purple-crested Turaco was closely associated with HShrub, as it prefers dense vegetation and thickets.

African Yellow White-eye was closely associated with CTree where they forage in tree canopies, gleaning insects off leaves, eating aphids and caterpillars (Hockey *et al*., 2005). This species was found mostly at Oosgrens and Pumphouse, which was reflected on the ordination (Figure 4.29). Tambourine Dove ordinated directly opposite grass cover. They forage on bare or sparsely vegetated ground, feeding on seeds and small fruits, and occur where tall trees and little grass grow, like Pumphouse, where the highest numbers of this species were recorded.

Habitat selection of Reed Cormorant is directly influenced by the height and cover of reeds. Reed Cormorants feed in water < 2 m and therefore Causeway had good habitat for these birds. Shallow marginal pools for foraging, and deeper water for diving are present at Causeway, with reed beds as well as trees to rest in. Causeway was the site with the most Reed Cormorants recorded.

White-browed Scrub-Robin ordinated directly opposite HReeds and CReeds, indicating that their habitat preference leans towards areas with little to no reeds, but tall trees and shrubs present. White-browed Scrub-Robin scurries around shrub thickets, foraging for termites and ants. This species was found everywhere in small numbers but was absent from Nyamithi.

Verreaux's Eagle-Owl and Black-headed Oriole were strongly associated with Oosgrens, indicating their preference for this kind of vegetation structure. No specific species were associated with Buffelsrivier, suggesting that the vegetation structure as well as bird species composition of this site was quite general. Only three species of birds were recorded at Buffelsrivier only: African Dusky Flycatcher, Dark-capped Yellow Warbler, and Klaas's Cuckoo. These species were present in such low numbers relative to the other sites, that the calculations did not give Buffelsrivier a unique species composition or even any indicator species.

Some species require two or more types of vegetation or habitat types (e.g. to feed and nest), and would therefore not be associated with any specific site, but rather a combination of sites (MacArthur *et al*., 1962). Species might not use the foliage profile alone in choosing their habitat; and if they do, they might use more than one variable in selecting the preferred habitat, therefore associating with more than one site. Generalists may be good examples of bird species making use of this tactic; making use of various habitats in the landscape matrix instead of being restricted to only one (Devictor *et al*., 2008).

5.7. Site specific differences in bird species composition

5.7.1. Site-specific bird compositions

Figure 4.30 depicts the bird community compositions of the five sites and vegetation structure as vectors. Vegetation is influenced by various factors, including climate, topographic variations, and disturbances such as floods or fires (Wiens 1989b; Naiman *et al*., 1993; Seoane *et al*., 2004; Wakeley *et al*., 2007; see also Section 2.6). The resultant differences in habitats affect the selection by birds for the different sites. The spatial differences of vegetation structure therefore affect the processes that bring about not only abundance and diversity of birds, but also community patterns. Both Nyamithi and Pumphouse are unique in terms of species composition (their convex hulls do not overlap with any other), as each site had more in common with itself than with any other site. The convex hulls of Oosgrens, Buffelsrivier, and Causeway overlapped slightly, indicating a similarity in some of the species present at these sites, probably due to niche overlaps.

Bird composition differed between the sites; when vegetation biplot information was added to the ordination (Figure 4.31), it shed more light on the reason for the differences. HGrass and CGrass seemed to be responsible for the specific community composition at Nyamithi (Figure 4.31), indicated by the long vector lines. These factors therefore strongly influenced bird composition at this site, indicating the species that occurred there did so because of the cover and height of grass and lack of trees. CForb and HShrub contributed little to the community patterns of the sites, as indicated by the short vector length of these factors. CTree and HTree, as well as CShrub seemed to affect bird species composition at Oosgrens, and Pumphouse to a lesser extent. Little understory vegetation was present at these two sites, causing them to ordinate to one side of the ordination, opposite HGrass and CGrass. Trees, shrubs, and reeds seemed to enhance the diversity of communities, and where these three occurred in one site, relatively high bird diversity can be expected. Reeds ordinated in the third dimension (explaining 17.1%) and its effects were therefore not visible in Fig. 4.31.

Oosgrens, Causeway, and Buffelsrivier shared species and their species composition was therefore similar. Nyamithi had a very distinct species composition, as did Pumphouse, as their convex hulls did not overlap with any other sites. The uniqueness of Nyamithi can be ascribed to the multiple edges evident at the site. There is a forest-edge (gallery), the land-water edge, as well as a grassland-bushveld edge where pan vegetation meets thickets to create a complex mosaic of habitats.

According to Begon, *et al*. (2013), conditions and resources that favour reproduction and survival dictate the aggregation of organisms and their composition, abundance and richness. These conditions and resources are sometimes patchily distributed in both time and space and it is favourable for individuals to disperse to these patches when (and where) they occur, and in addition, creating new niches for other species, and/or affecting the niches for species already present. At Ndumo Game Reserve, within a very small space (3 km radius), there exists a large heterogeneity of habitat forms, each with a characteristic bird species composition and abundance pattern. Differences in habitat structure and vegetation, again, seem to explain the uniqueness of species and abundance patterns observed.

5.7.2. Seasonal changes

Bird species diversity can vary temporally (at a site over a period) and spatially (between different sites) in any environment (Sudlow, 2004). Temporal variation in bird species diversity refers to the changes in the bird composition over time, at each site, and these changes can be brought about by the arrival and departure of migratory species, the abundance of food or the lack thereof, nesting requirements, and weather conditions, amongst others. Temporal and spatial variation in seasons and resource availability influences the temporal and spatial variation in animal composition in important ways (Hockey *et al*., 2005; Papes *et al*., 2012).

The temporal aspects of variation in bird composition has been largely ignored (Rotenberry & Wiens, 1980). As discussed in section 2.6.1., and according to Rotenberry and Wiens (1980), if vegetation structure changes, it would result in the change in distribution and abundance of birds as well. As water is a limiting factor, it would be anticipated that changes in the water levels, such as during floods, should bring about large changes in vegetational composition or growth and thus affect habitat structure. Many studies have documented the changes in bird abundances without regard to the factors affecting these variations (Rotenberry & Wiens, 1980). In the present study, as indicated before, I only measured vegetation structure that did not change during the study, and time; food availability, and changes in flowers, fruit, and leaf colour was not measured. However, the latter is likely associated with seasonal changes, and therefore seasons act as a robust proxy for these changes.

The vector lengths in Figure 4.32 indicate the relative magnitude of change of bird composition according to the time of year; Nyamithi showed clear difference of changes in bird composition compared with the other four sites. This site is separate from the other four and composition changed in a different way than the rest. As both axes have the similar explanatory weight, it is clear that species had greater shifts on the y-axis than the x-axis. The x-axis probably reflect differences in vegetation structure, as discussed before, and seasonal changes is reflected in the Y dimension, but this will again be discussed with Figure 4.34.

It can be seen by the non-overlap of the bird community trajectories of Nyamithi and Pumphouse (Figure 4.31) that these two sites had differences in changes in bird community trajectories than the other sites. As already mentioned, the lengths of the successional vectors indicate the relative scale of bird community changes. For instance, greater change in communities occurred at Pumphouse from April to July, than September to November.

Causeway and Buffelsrivier overlapped at certain times and might share certain species during certain times of the year. This could be due to some of the traits they share in terms of vegetation structure. Seasonal fluctuations in vegetation structure might influence the levels of available resources, which, in turn, might affect species interactions and changes within communities.

Although these trajectories are divergent, where the sites ordinated toward each other, the similarities in bird composition are greater between the sites. Some of the changes could also be brought about by seasonal shifts affecting general factors that influence habitat selection. The large change/shift from April to July at Pumphouse might indicate the emigration of migratory species at the end of breeding season (119 species were present in April but only 90 in July). The change during that time is much smaller at Nyamithi than at any of the other sites, but the magnitude of change from July to September at Nyamithi indicates that the bird composition at the pan site, and the changes in the bird composition at that site, differed from the riverine forest sites. Nyamithi, Causeway, and Buffelsrivier all changed in more or less the same direction between those months, indicating that there may be a similarity in change in species composition. Overall, there were more species in September (94) than in July (90) at all sites. The long vector of change at Nyamithi might indicate the last of the summer migrants leaving the pan later than the forest migrants leave the forest sites.

Some changes in community composition can therefore be ascribed to factors other than vegetation composition and the changes therein. Food variability over time affects habitat selection of birds, resulting in changes in bird species composition as birds adapt their foraging strategies. Birds can move between habitats in response to fluctuating resource availability, and this is especially true for habitat generalists. Birds also make decisions to select an appropriate habitat according to their specific behaviour, which leads to distinct bird distribution patterns and community compositions. Migrating species that breed extralimitall would also have an effect on the composition and patterns of bird communities over time (Rotenberry & Wiens, 1980), as they are present only during a certain time of year.

Pans are an especially important winter feeding ground for White-faced Duck where they feed on the turions of *Potamogeton crispus* (Heeg & Breen, 1982). Many species track resources during shifts in seasons and conduct local movements in search of better feeding grounds. (Hockey *et al*., 2005; Scott, 2012). The Thick-billed Weaver, for example, was spotted at Buffelsrivier and Causeway, the only sites with reeds (it was removed from the ordination as less than 5 individuals were detected). These birds breed in reeds during summer and move to forests and woodlands in winter for foraging (Hockey *et al.,* 2005). The African Fish-Eagle was more abundant during summer than winter because of the increased water flow after the floods.

Disturbance affects composition by creating change in habitats. If disturbance results in enhanced rates of primary production (intermediate disturbance hypothesis), an influx of bird species would change community composition to include more bird species. Disturbances such as floods could also change community composition, as well as species diversity and abundance. Negative change, such as deforestation, would drive species away from a site. Even when species richness and species diversity (which are numbers only) do not change significantly, species composition can undergo major changes. Some factors affect density directly while some merely vary with density (Begon *et al*., 2006), thus altering species composition in the process.

Figure 4.33 and 4.34 show species ordinating at sites that provide the habitat they associate with, as well as how the changes were affected by vegetation vectors. Most species ordinated in the middle of the graph, indicating the overlap of composition between Buffelsrivier, Causeway and Oosgrens that share ordination space. Some species, such as the Cape Glossy Starling and Yellow-billed Oxpecker, were only present at Nyamithi, only in July, and therefore associated very strongly with that site at that time of year. It seems there is no unique species composition at Pumphouse throughout the year, with very few species associating strongly with that site.

Open habitat, with abundant grass, ordinated to the left of the graph, with Nyamithi and its associated species far removed and not overlapping with any of the other sites. It would seem that this site had a unique species composition with seasonal changes relatively independent of the other sites.

Rotenberry and Wiens (1980) found that not all temporal changes in bird species composition are because of changes in vegetation structure. They found only a few random correlations with variations in habitat structure (shrub-steppe) and there was little evidence that changes in the shrub floristics affected species assemblages. However, the magnitude of change was very little and probably insufficient to account for the changes in bird species composition, and thus it cannot be said that changes in vegetation does not induce changes in bird species composition. It could be said that food availability induces change in species composition because of fluctuating resource availability. This causes birds to move between habitats in search of prey – riparian-obligate species would exhibit less change in foraging habitat as they are bound to a specific habitat associated with riparian vegetation.

Lower water levels during dry seasons could negatively affect riparian-obligate species and force them to search for habitats with more stable water supply, such as a pan or nearby flowing river. Prey generalists can move between foraging habitats and therefore they would be less affected by changes in space and time. This could give them the competitive advantage to avoid exclusion by specialists all year long (Rotenberry & Wiens, 1980).

5.8. Feeding guilds

A number of habitat prerequisites must be fulfilled in order for birds to inhabit areas and thrive in them. Different habitats contain different (and a variety of) conditions and resources which provide the niches required by bird species (Begon *et al*., 2006). All birds rely on water, adequate foraging space, and resting sites, as well as available nesting sites and material. Birds are also to a greater or lesser extent dependent on certain species or families of plants for feeding purposes, whether directly or indirectly. Most birds favour certain foods when they are available but eat a variety of food during the rest of the year, as many species can adapt their eating habits and change their preferences with the change in seasons.

Community dynamics are very often driven by the changes (seasonal or yearly) in vegetation structure and the subsequent food availability (Wiens, 1989a). Feeding guilds can be used to classify and describe the different food needs and foraging habits of different bird species. A wide variety of vegetation structure, foliage, fruit and even perching sites is required for a wide variety of species (Wiens, 1989b), thus making the process of predicting community composition a little easier. As resource availability changes during certain times of the year, food availability becomes a key element in seasonal community changes, and certain feeding guilds are favoured more than others (Scott, 2012). A vast array of food types are found in indigenous vegetation, including insects. Birds from every feeding guild can benefit from natural plant communities which provides the foraging needs of many bird species (Sudlow, 2004)

Figure 4.35 portrays the distribution of feeding guilds across the five sites that were surveyed. It is possible that all the guilds were present at all the sites, at all times, but those guilds associated with specific vegetation cover at specific sites are ordinated on the graph as such.

Piscivores, such as the African Spoonbill, were closely associated with Causeway and Nyamithi as both sites had shallow water for fishing. Twenty-seven detections of African Spoonbill were documented at Nyamithi and only two at Causeway, but as the cover of shrub at Nyamithi was minimal, piscivores ordinated opposite CShrub, indicating its lack of association with that vector. Common Sandpiper and Saddle-billed Stork both occurred only at these sites, possibly due to the foraging opportunities, the food resources that the substrates supplied, and the uniqueness of vegetation at these sites. The Cape Glossy Starling was only documented at Nyamithi - 80 individuals at once - and this once-off sighting in a site with very little shrubs is why omnivores ordinated directly opposite CShrub on Figure 4.35.

Omnivores, such as Egyptian Goose, Water Thick-knee and White-faced Duck, were abundant at Causeway. Brown-hooded Kingfisher, African Fish-Eagle, Burchell’s Coucal and Goliath Heron are carnivores that were present at this site. Causeway had the highest habitat heterogeneity and therefore likely the most diverse prey. Insectivores were also abundant at this site.

Frugivorous species such as the Purple-crested Turaco, African Green-Pigeon, Red-faced Mousebird and White-eared Barbet favour tall trees with fruit in the canopy. African Green-Pigeons seldom venture onto the ground. As seen in Figure 4.34, frugivores ordinated towards Oosgrens where tall wild fig trees and a closed leaf canopy was the dominant vegetation. Oosgrens also did not have much grass, but many little wild figs was scattered on the ground. Tambourine Dove is a frugivore/granivore that forages on bare or sparsely vegetated ground and this species was present at Oosgrens.

The Emerald-spotted Wood Dove, Red-eyed Dove, Red-billed Quelea and Red-billed Fire Finch are granivores and prefer to forage on the ground, under trees and on grass. They eat dry seeds, including grass seeds (Hockey *et al*., 2005) which are available in abundance at Nyamithi. Insectivores are abundant in grass and mud flats, which were also present at Nyamithi. Insectivores such as the Brown-crowned

Tchagra (forages on the ground and beneath bushes and tall grass), Common Scimitarbill (forages in trees and on the ground), Eastern Nicator (forages in tree canopy, low vegetation and on the ground) and Gorgeous Bush Shrike (forages in dense, tangled vegetation, or on the ground beneath) were present at Nyamithi as the vegetation was suitable for their foraging needs. Insectivores and nectivores ordinated perpendicular to HShrub and CShrub, as well as CForb, CReeds and HReeds. These species are strongly associated with HTree and CTree. Most species (75) were insectivores, and eight species were true insectivores as well as fitting into one other feeding guild, thus bringing the total to 83. Thirty two species were carnivores, eight frugivores (plus ten that could be classified as something else, making a total of 18). All other guilds had less than 8 species per feeding guild.

Herbivores, like Crested Francolin and Spur-winged Goose, and nectar-feeders, like Grey Sunbird and Purple-banded Sunbird, associated with HShrub and HTree but was not associated with a specific site. This guild ordinated directly opposite CForb, and perpendicular to CShrub, Creeds, and HReeds.

The difference in bird assemblages may be because of the difference in vegetation types (different plant species) at different sites. Some plant species might harbour more and different invertebrates than others, which in turn influences food availability and might influence bird species distribution (Murakami & Nakano, 2001; Oisin *et al*., 2010). Some species shift their diet with the changes in season to adapt to new resource availability (Scott, 2012), becoming generalist feeders in a food limited season.

5.9. Nesting guilds

Vegetation (or its absence) influences a bird's decision-making process when choosing a habitat. Shelter, food, resting sites, and nesting sites are all either supplied or affected by vegetation. Limitations on these resources (food requirements, vegetation or nesting sites) are often associated with limited bird species richness/abundance. Most species have niche requirements, especially when breeding, but often wander and when migrating, may travel through many different habitats (Newman, 1988). However, specialized nesting species are sometimes even restricted to nest placement in a single substrate type and would not nest in an environment where the vegetation is not suitable for their specific needs.

Figure 4.35 ordinates nesting guilds in association with vegetation factors. Tree and shrub nesters are negatively associated with HShrubs, but negatively with HTree. Oosgrens, where trees and shrubs were not the highest but cover is greatest of all sites, was associated with tree nesters like the Black Sparrowhawk, African Goshawk, Fork-tailed Drongo, Verreaux’s Eagle-Owl, African Yellow White-eye and Hadeda Ibis, as well as shrub nesters like Terrestrial Brownbul, African Finfoot and Green-Backed Camaroptera.

Structural nesters (Swifts and Swallows) are associated with Causeway, which in turn is associated with CGrass, Creeds, and HReeds. Their nests are built with all kinds of material and glued together by saliva (African Palm Swift and Little Swift) or mud (Lesser Striped Swallow and Wire-tailed Swallow). Interestingly, grass nesters, such as White-browed Scrub-Robin, Spur-winged Goose and Black Crake (grass nesters), and reed nesters, such as African Sacred Ibis, Black-headed Heron, Grey Heron, African Darter, Thick-billed Weaver and Golden Weaver (reed), converged and were associated with HTrees, but not necessarily with any specific site. Extralimital breeders (Eurasian Golden Oriole, Barn Swallow, Blue-cheeked Bee-eater, Collared Flycatcher, Wood Sandpiper, Common Sandpiper and Common Greenshank) were also more closely associated with height of trees than any other vector.

Cavity nesters like Yellow-rumped Tinkerbird, Southern Grey-headed Sparrow, African Dusky Flycatcher, Ashy Flycatcher and Southern Black Flycatcher are very strongly associated with Buffelsrivier. Burrow nesters like Brown-hooded Kingfisher, Malachite Kingfisher, Black Saw-wing, Little Bee-eater and Giant Kingfisher, and parasitic nesters like Diderick Cuckoo, Klaas’s Cuckoo, Red-chested Cuckoo and Scaly-throated Honeyguide, do not associate with any site or vector.

Ground nesters, like Three-banded Plover, Crested Francolin, Egyptian Goose, Black-winged Stilt, Natal Spurfowl and strongly associated with Nyamithi where grass was plentiful and open spaces for nests on ground were abundant. HShrubs was perpendicular to ground nesters and thus had no influence on them.

Vegetation influencing breeding is nothing new. Robinson *et al*. (1995) found that reproductive success of forest nesting bird species was positively correlated with percentage of forest cover, percentage of forest interior, and average patch size in a landscape. Because the latter two variables were strongly correlated with percentage of forest cover, these all represent positive effects of habitat amount on reproductive success.

Some of the associations between nesting guilds and vegetation factors does not make sense. Keeping in mind that the survey was done over 10 months, it is possible that the apparent random ordination of especially tree and shrub nesters, but also reed nesters, are a result of surveys done out of breeding season for those specific species. These distributions might be because of foraging behaviour (during or out of breeding season), predator avoidance, or any of the other factors that influence bird species distribution. In order to present correctly nesting guilds, surveys must be done during the correct breeding season for each species within each guild, and subsequently ordinated to symbolise the true factors affecting habitat selection for nesting opportunities. In the present case, associating breeding guilds with vegetation structure was not successful due to the lack of applicability of the study design. It would be more accurate to survey the locations of the nests rather than the birds.

5.10. Biomass

Biomass density can be defined as the mass of organisms per surface unit (Begon *et al*., 2006). Since the survey radius was 50 m in all cases, the bird biomass comparisons per site is valid. Causeway had the highest aggregated biomass with Nyamithi not far behind (Table 4.8 and Figure 4.38). Pumphouse had higher bird biomass than either Buffelsrivier or Oosgrens. It is not clear why Pumphouse had such a high biomass as it was the least species rich and also had the lowest aggregated number of bird detections, but it could be because of the number of Hadeda Ibises (60 detections), Spur-winged Geese (64) and Trumpeter Hornbills (54) that are all heavy birds. Nyamithi had the second highest biomass, which might be ascribed to the fact that this was the site with the greatest species richness and the greatest number of combined counts. It might be a large number of small birds resulting in the high biomass. Causeway, which had the highest biomass, but second highest species richness and combined counts, was host to large birds such as African Fish-Eagle (16), Egyptian Goose (43), Green-backed Heron (20), Grey Heron (13), Hadeda Ibis (61), Helmeted Guineafowl (26), Little Egret (22), Pink-backed Pelican (17), Trumpeter Hornbill (47), White-faced Duck (134) and Yellow-billed Stork (15).

April had the highest biomass, July the second highest, and February the third highest (Table 4.8 and Figure 4.37). November had the lowest biomass, coinciding with the month with the lowest number of birds, likely due to the absence of migrants

Figure 4.39 shows the changes in biomass of birds with a mass of less than one kilogram per individual. All the sites except Nyamithi had more or less the same pattern, each with a long, upwards vector of change from April to July. After that, Pumphouse and Oosgrens changed in a similar way, and Buffelsrivier and Causeway had a similar pattern too. Nyamithi, on the other hand, had a completely difference pattern of change. The first vector was relatively short and moved to the left of the ordination. Cape Glossy Starlings ordinated on JulN, occurring only at that site only for that survey. The vector length between July and September is much longer than other vector and in an upwards direction.

A possible explanation for the difference in patterns of change is that forest birds might migrate before water birds or birds associating with shrubland and bushveld vegetation, resulting in a change of species composition and biomass. Grassland species, bushveld species, and pan-associated species all occur at Nyamithi. These smaller birds might be good indicators of the effects anthropogenic disturbances have on riparian areas, and seem to be resilient to the disturbances that were present at the time of the study, keeping in mind that a broad riparian strip was still intact on the western side of the river at Oosgrens.

Figure 4.40 shows the changes in bird biomass composition of birds with a mass of more than one kilogram per individual. Very few, if any, of the birds in this ordination were riparian-related birds. Crested Guineafowl might be the only bird that is a riparian obligate. Predictably, several forest specialists in our study, especially large-bodied frugivores such as Livingstone’s Turaco and the Trumpeter Hornbill (see also Owens and Bennett 2000), were sensitive to forest fragmentation. (Wilson *et al*., 2007). The use of larger birds seems not have been successful as indicator of disturbance at Oosgrens, as there is no clear pattern that distinguish it from the other sites, and there was little congruity of species between the sites.

There are three possible ways of interpreting the results of these analyses.

- There was no effect of the disturbance on the eastern side of Oosgrens on the bird composition of birds smaller than one kilogram, and probably also on birds heavier than one kilogram.
- The approach I followed was not applicable.
- Ordinations might not be applicable to investigate the effect of disturbances.

However, the lack of any clear differences observed between Oosgrens and the other two comparable riparian sites (Causeway and Buffelsrivier) as seen from Figures 4.30, 4.32, 4.39, and (possibly) 4.40 shows very little support (against expectation) for an impact of the disturbance on the bird community of the Oosgrens site. Oosgrens is backed to the west and north by a large expanse of protected forest (Figure 4.2). This area might be a reservoir of birds towards the east. In addition, intermediate disturbance might explain the lack of measurable impact. However, based on the evidence presented, there was no discernible impact.

5.11. Conclusion

Ndumo Game Reserve is undoubtedly rich in bird diversity. An aggregate of 7756 birds of 165 species were recorded at the five sites along the floodplain in Ndumo Game Reserve, all within a 3 km radius, during a ten-month long study. Diverse and complex vegetation structures with provided diverse habitats for a wide variery of bird species.

Sites that were structurally more diverse had greater species richness. Vegetation influenced the habitat selection of birds by provding shelter, resting sites, food and nesting sites. Forest species associated with tall trees and a closed canopy, while waterbirds associated with the pan-site and grassier areas.

Each site could support birds in three different ways: 1) Vertically. Species that forage on the ground, in the middle layers of forests and in tree canopies can all inhabit a specific area but utilise it in such a way that competision is minimised. 2) Horisontally. There were different vegetation patches at Nyamithi, specifically pan-vegetation with open water, and forest edges. Different species utilise these patches and create a diverse species composition. 3) Temporally. Seasons affect vegetation, food, water levels and a variety of other factors that, in turn, affect species composition. When migrating species leave, other species inhabit the areas, specifically riparian areas, to utilise the food resources that might be more abundant than in adjacent areas (MacArthur, 1964).

Anthropogenic disturbances may alter riparian habitat to such an extent that certain species no longer exist. In this study, the birds seemed resilient enough to not be affected by the disturbances and keep a relative general species composition.

The objectives of this study and the major findings were:

- Characterise riparian habitat by vegetation structure:
- The five sites chosen differed in vegetation structure. This was described successfully and remained stable over the course of the study. However, I identified the need for other descriptors to be added in future studies, such as mud banks and water flow, as these may also have effects on bird composition.
- Identify temporal and spatial changes in bird diversity:
- Bird composition at the five sites changed over ten months. Three sites showed very similar changes, while two sites showed changes on a similar scale and direction, but with different bird communities.
- Compare the environmental and avian metrics:

- Bird species composition and feeding guilds by and large could be associated with vegetation factors, such as trees, shrubs and forbs.
- Derive insights into the bird ecology of the study area:
- The many bird species could by and large be associated through their known biology with the environments they were found in.
- Investigate is the human disturbance at one site is affecting bird composition.

It does not seem that the human disturbance at one site affected the bird composition of the site, especially because the composition at that site did not differ with two other, very similar sites. Intermediate disturbance might be in effect.

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