INFLUENCE OF HYDROLOGICAL FLUCTUATIONS ON VEGETATION AND AVIFAUNA SPECIES COMPOSITION, ABUNDANCE AND DIVERSITY IN THE BAHI SWAMP WETLANDS CENTRAL TANZANIA

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ABSTRACT

This study was conducted in Bahi wetlands to assess the influence of hydrological fluctuations on the vegetation and avifauna species composition, abundance and diversity. A total of 80 rectangular vegetation plots measuring 2m x 5m were established along transect lines radiating from the core wetland, along eight cardinal directions each transect having a length of 1200m and accommodating 10 sampling points. Avifauna species were inventoried in 3 points along each transect making a total of 24 sampling points for birds. One-way ANOVA was performed to test for significant differences in the avifauna species diversity along the hydrological gradient. A total of 40 avifauna species and 56 plant species belonging to 18 and 7 families respectively were recorded. There were significant differences ($p<0.05$) in avifauna and plant species composition, abundance and diversity between distances from the centre of the wetland. Avifauna species abundance and diversity decreased with increasing distance from centre of the wetland. Likewise, the abundance of plant species decreased with increasing distance from the centre of the wetland. The flora and avifauna species composition, abundance and diversity in the Bahi wetlands are influenced by hydrological fluctuations, whereby the composition, abundance and diversity are higher closer to the wetland than away from the edge of the wetland. The vegetation of wetland is dominated by *Leersia hexandra* and other members of the Graminae family. Bahi wetland is a refuge for migratory avifauna species. It was observed that both distant and African migrants visit the wetland for wintering. The most abundant species were Greater Flamingoes and Red Knobbed Coot. Awareness and education on the biodiversity values of the wetland is needed to influence conservation and sustainable utilization of the wetland resources.

INTRODUCTION

According to RAMSAR Convention Secretariat (2006) "Wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static of flowing, fresh, brackish or salty including areas of marine water the depth of which at low tide does not exceed six metres". Ramsar Convention classifies different kinds of wetlands to provide simple identification of main wetland habitats correspond to each Ramsar site, the types of wetlands identified by Ramsar Convention are Coastal wetlands, Inland wetlands and human-made wetlands (Bernacksek 1992). In this classification Bahi wetland falls in the category of inland wetlands. However, The Ramsar Convention demands each member states to put in place its own mode of classification pertinent to country's environment. Wetlands in Tanzania have been classified explicitly under six important categories, namely highland headwater wetlands, fresh water estuarine wetlands, internal drainage wetlands, rivers and inland floodplains wetlands, man-made wetlands and marine and coastal wetlands (URT 2003).

In this classification system, Bahi wetland belongs to the internal drainage wetlands category. The wetlands in this category have internal drainage system, their annual rainfall do not exceed 600 mm with high evaporation and hence high concentration of caustic soda forming soda lakes (URT 2003). The vegetation of such wetlands is dominated by sedges and grasses. Tanzania has numerous wetlands offering extensive functions to humans, wildlife and plants. Wetlands provide diversity of ecosystem services and cultural services such as firewood, clean air, water, hydro electric power, food and aesthetic value. Tanzania has four wetlands recognized internationally as Ramsar sites, which are Kilombero Valley Floodplains, Malagarasi-Muyovozi, Lake Natron Basin and Rufiji-Mafia-Kilwa Marine Ramsar sites (URT 2003). Such wetlands have high endemism and biodiversity. Despite the fact that they are remarkable internationally (Baker 2001), there is no specific policy and law to protect their utilization in Tanzania. Bahi wetland is one of the wetlands which are not included in the Ramsar Convention and is a common property resource which can be used by anybody and sometimes subjected to unsustainable use.

Wetland ecosystems are influenced by surface and subsurface hydrological regimes (Mol and Ouboter 2003). Hydrological fluctuations of wetland ecosystems may have significant impacts on composition and abundance of biodiversity. Climatic changes and daily human caused-disturbances could be the key influencing factors for hydrological fluctuation such as increased sediment loads from soil erosion due to large scale deforestation, unsustainable agricultural farming practices, overstocking nearby wetland ecosystem and flooding (Huhta and Nikula 2003). Dramatic hydrological fluctuation in wetlands does not only affect wetland vegetation but also other wetland biodiversity including avifauna, fish, reptiles and invertebrates, which are part of the wetland (Keddy 2000; Meryem 2005). Environmental variables such as chemical parameters and nutrients dynamics depend on particular hydrologic regimes (Pacini and Harper 2001). Changes in hydrologic regimes will tend to change the composition and abundance of different biodiversity. Boyd (1977) showed that environmental variables affect species composition, abundance and stability of indigenous population of aquatic community.

Given the extent of pressures on the hydrology of wetlands and the need to provide relevant information for wetland management, research is necessary to develop integrated approaches for assessment of the influence of hydrological fluctuations on vegetation and avifauna species composition, abundance and diversity to support conservation objectives.

In Tanzania, particularly in Bahi wetland, there is no study that has been conducted to determine the influence of hydrological fluctuations on vegetation and avifauna species composition, abundance and diversity. This study therefore assessed the influence of hydrological gradient on vegetation and avifauna species abundance, composition and diversity in Bahi wetland.

MATERIAL AND METHODS

Site Description

Bahi wetland is located in central Tanzania, It is situated between latitudes 5º 51' and to 6º 16' South and longitudes, 34º 59' and 35º 19' East (Figure 1). The elevation of land in which this swamp is located ranges from 796 – 804 m above sea level. The wetland is found in Bahi district (Dodoma region) and Manyoni district (Singida region). The total area of the wetland is 1250 km². Bahi is a seasonally inundated semi-permanent endorheic wetland. Vegetation of Bahi swamp is a monodominant grass community, dominated by salt-tolerant grass species mainly *Sporobolus spicatus*, *Leersia hexandra*, *Cynodon dactylon*, sedges and reeds. The wetland was formed by deposition of eroded parent rock materials of Irangi Hills in Kondoa District, which are uplifted from Maasai plain. The hills have many tectonic blocks formed by earth quakes which caused uplift, faulting and tilting of Irangi hills. Morphotectonics cause drainage of the area and deposition of river sediments. Due to appearance of faults and scraps, large two seasonal rivers, namely Chikuyu and Bahi rivers penetrated the faults scraps and follow antecedent stream courses and when small streams blocked were blocked by the hills the wetland was formed (Eriksson 1999).

Bahi wetland is situated in a Tropical East African semi-arid area with a long dry season of eight months. Annual rainfall average is 500 mm per annum. The rainfall occurs from late November till late March or early April. The coolest months are June to August; mean temperature is 21.7ºC. The highest or hottest months are October, November and December, with mean temperature of 25.3ºC.

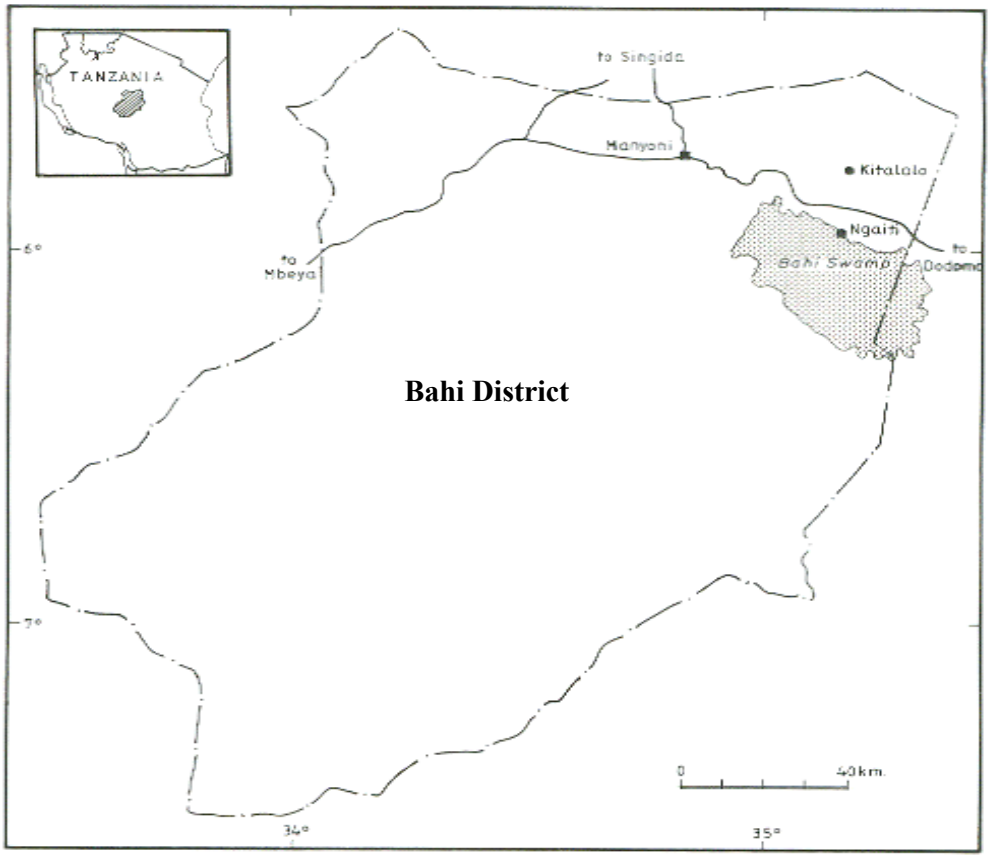

Figure 1: A map showing the location of Bahi Wetlands in Bahi District, Tanzania

DATA COLLECTION

Research Design

Rectangular plots of 2m x 5m were established along the transect lines radiating from the edge of the core wetland. Transects were established along eight (8) cardinal directions namely, North, North-East, West, North-West, East, South-East, South and South-West depending on accessibility of the wetland. The distance between plots was 115 m, the transect length was 1200 m to accommodate 10 plots each and making a total of 80 plots and 24 points for birds counting.

Sampling Technique for Vegetation

Herbaceous plants were identified and their % cover estimated in 2m x 5m quadrants. Species abundance was recorded as the %age cover of individual species in the plot (Bonham, 1989) using the following scales: abundant 100-76%, common 75-51%, moderate 50- 26%, and rare 25-1% cover. In each plot, altitude and distance parameters were collected. The information collected on vegetation were analysed for species composition, richness abundance and diversity.

Sampling Technique for Avifauna

Point Count Technique was used to provide the composition and estimates of the relative abundance of each avifauna species. Sampling points were established along transect lines with a minimum distance between points of 360 m. A total of 24 points were established (3 in each transect line) and birds were counted up to a fixed distance of 50 m in a concentric circle around one central position. At each sampling point, three minutes were spent to allow birds settle down before counting begins and ten minutes were spent for counting the birds (Swarth 2003). At each sampling point, all birds observed were identified and recorded. Signs of presence including nesting and vocalization were also used to determine the existence of birds. Local people's knowledge on the observed birds in different points was also used. The information collected on avifauna were analysed for composition, species richness, abundance and diversity.

For both plant and avifauna species richness was computed as the total number of species encountered. Abundance was computed as the observed frequency for birds and % cover for plants, diversity was computed using Shannon – Wiener Index of diversity (*H'*). All these parameters were computed for each sampling unit to establish changes in the parameters along the hydrologic gradient from the wetland towards the terrestrial ecosystem. One-way ANOVA was performed to test for the significant differences in the avifauna species diversity along the hydrological gradient.

RESULTS AND DISCUSSION

Avifauna Species Composition and Richness

A total of 40 resident and migrant avifauna species were identified. They belong to 18 families including Anatidae, Ardeidae, Pelecanidae, Ciconiidae, Alcedinidae, Jacanidae, Accipitridae, Charadriidae, Scopidae, Gruidae, Phoenicopteridae, Laridae, Podicipedidae, Recurvirostridae, Threskiornithidae, Phalacrocoracidae, Rallidae and Rostratulidae. Greater Flamingo (*Phoenicopterus ruber*) and Marabou Stock (*Leptoptilos crumeniferus*) were the most sighted bird species (Table 3, Figures 2 & 3, Appendix 1 & 2).

Table 3: Birds species composition and relative frequency at Bahi wetland

Family	Common Name	Scientific Name	Relative frequency (%)
Accipitridae	Black Kite	*Milvus migrans*	5.13
	African Fish Eagle	*Haliaeetus vocifer*	3.85
	Black Shouldered Kite	*Elanus caeruleus*	1.28
Alcedinidae	African Pygmy Kingfisher	*Ispidina picta*	1.28
Anatidae	Knob Billed Duck	*Sarkidiornis melanotos*	1.28
	Mallard	*Anas platyrhynchos*	1.28
	Egyptian Goose	*Alopochen aegyptiacus*	3.85
	Red Billed Teal	*Anas erythrorhyncha*	1.28
	Southern Pochard	*Netta erythrophthalma*	2.56
	African Black Duck	*Anas sparsa*	2.56
	Cape Teal	*Anas capensis*	2.56
	Spur Winged Goose	*Ptectropterus gambensis*	1.28
Ardeidae	Black Headed Heron	*Ardea melanocephala*	2.56
	Black Egret	*Egretta ardesiaca*	2.56
	Striated Heron	*Butorides striatus*	1.28
	Purple Heron	*Ardea purpurea*	1.28
	Dwarf Bittern	*Lxobrychus sturmii*	1.28
Charadriidae	Spotted Sandpiper	*Actitis macularia*	3.85
	Caspian Plover	*Charadrius asiaticus*	1.28
	Common Ringed Plover	*Charadrius hiaticula*	2.56
Ciconidae	Marabou Stock	*Leptoptilos crumeniferus*	6.41
	White Stock	*Ciconia ciconia*	1.28
	African Open-billed Stock	*Anastamus lamelligerus*	1.28
	Yellow Billed Stock	*Mycterius ibis*	1.28
Gruidae	Common Crane	*Grus grus*	3.85
	Grey Crowned Crane	*Balearica regulorum*	1.28
Jacanidae	African Jacana	*Actophilornis africanus*	2.56
Laridae	Grey Headed Gull	*Larus cirrocephalus*	3.85
Pelecanidae	Pink Backed Pelican	*Pelecanus rufescens*	1.28
	Great White Pelican	*Pelecanus onocrotalus*	2.56
Phalacrocoracidae	Long Tailed Cormorant	*Phalacrocorax africanus*	1.28
	Greater Flamingo	*Phoenicopterus ruber*	6.41
Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	1.28
Rallidae	Red Knobbed Coot	*Fulica cristata*	1.28
Recurvirostridae	Black Winged Stilt	*Himantopus himantopus*	5.13
Rostratulidae	Greater Painted Snipe	*Rostratula benghalensis*	1.28
Scopidae	Hamerkop	*Scopus umbretta*	5.13
Threskiornithidae	Hadada Ibis	*Brostrychia hahedash*	2.56
	African Spoonbill	*Platalea alba*	2.56
	Sacred Ibis	*Threskiornis aethiopicus*	2.56

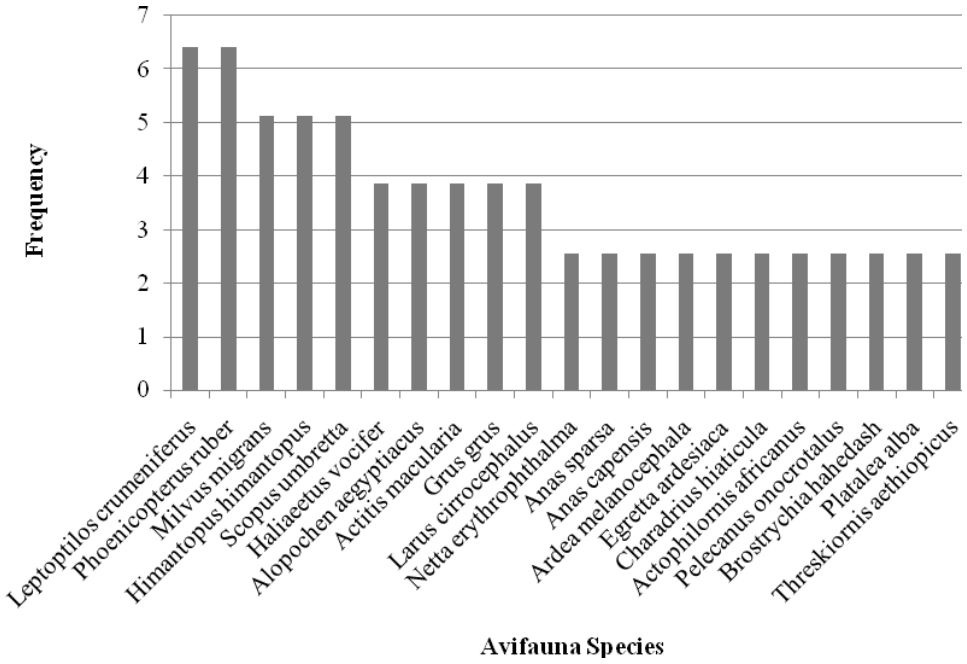

Figure 2: Frequency of observation of the most abundant avifauna species in Bahi wetlands

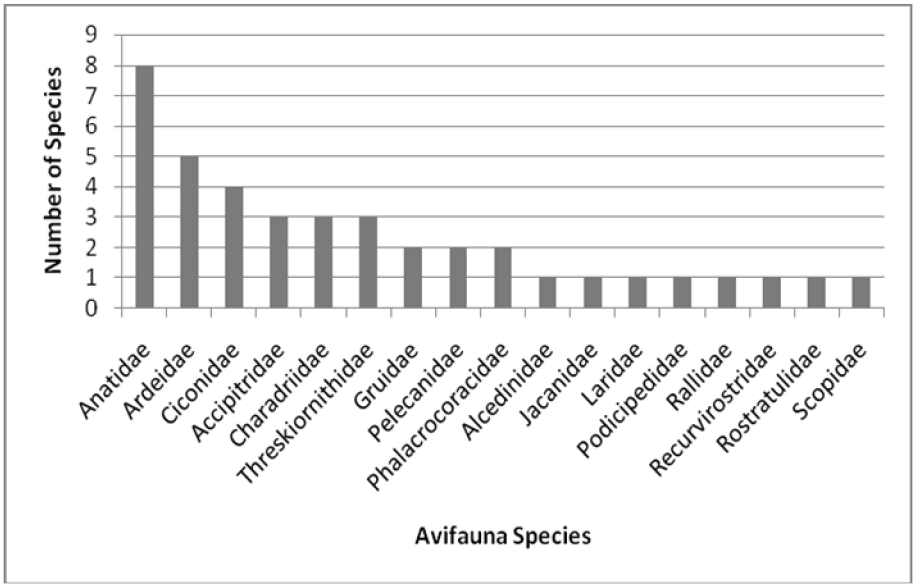

Figure 3: Avifauna family and species composition of species in Bahi wetlands

Changes in Avifauna Species along a hydrologic gradient

There was a notable decrease in the average numbers of both resident and migrant avifauna

species from the centre of the wetland. The highest abundance of 21 species was recorded at the centre of wetland, where there was permanent inundation, and the lowest abundance of 10 species was recorded at 1000 m away from the centre of the wetland, where inundation was considered temporary (Fig. 5).

Changes in avifauna species diversity along a hydrological gradient

Avifauna species diversity varied greatly in permanently and temporarily inundated areas, whereby the diversity was higher (*H'* = 0.28) at the centre of wetland, where inundation is

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A total of 1920 avifauna individuals and 40 species were recorded at the wetland, where 22 and 18 species were native and migrant avifauna species respectively. Migrant avifauna species included both African and long distant migrant species.

permanent, and low (*H'* = 0.16) at 1000 m distance from the centre of wetland, where inundation is temporary (see Fig. 4). There was a significant different ($p<0.05$) in the avifauna species diversity along the hydrological gradient

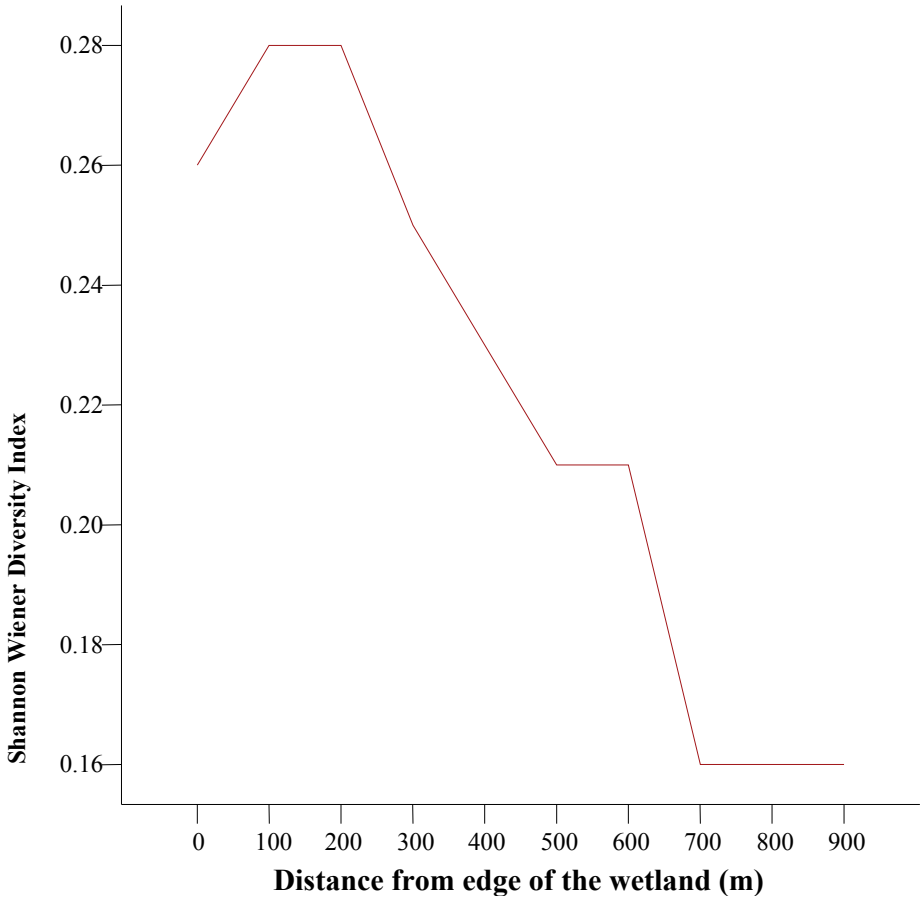

Figure 4: Change in avifauna species diversity from the wetland

Variation of avifauna species abundance from the wetland

The highest number of both migrant and resident birds' species and abundance were recorded within 500 m from the centre of wetland, and the lowest abundance was recorded within 700 m away from the core wetland, where inundation was considered temporary. One Way ANOVA showed a significant difference in avifauna species abundance between distances from the centre of wetland ($p<0.05$) (Figure 5).

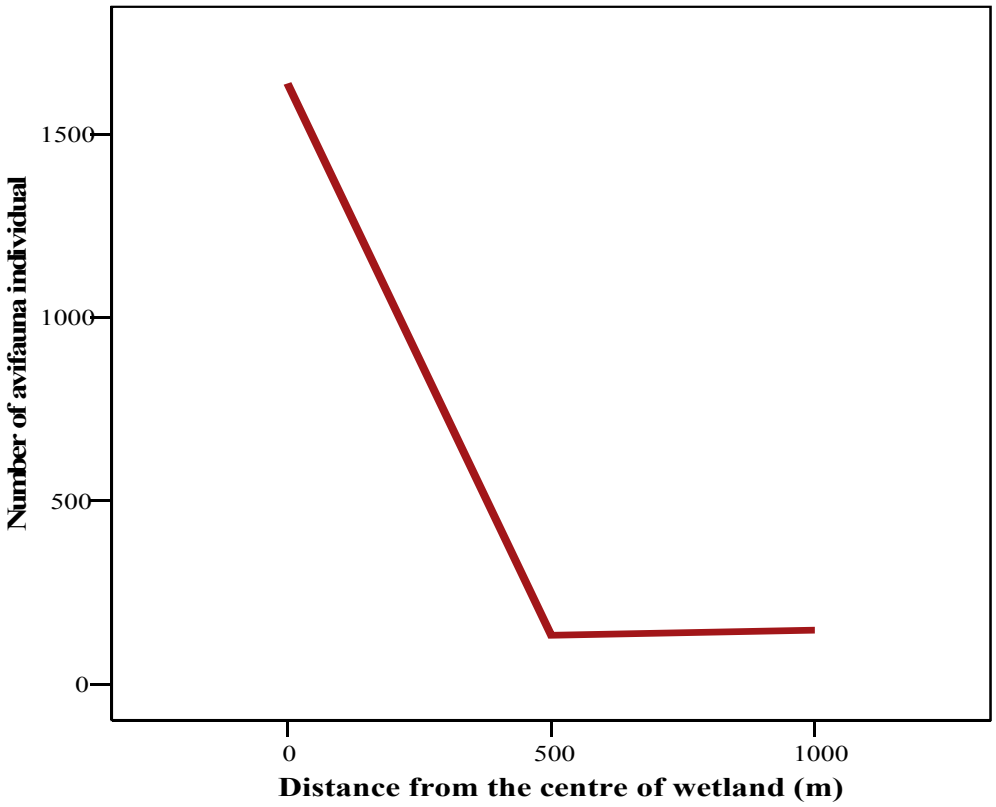

Figure 5: Change in avifauna abundance from centre of the wetland

Plant Species Composition and Abundance

A total of 56 plant species belonging to 7 families were identified at Bahi wetland. Cyperaceae was the most dominant plant family with 47 species followed by family Graminae which had only 4 species Family Tamaricaceae, Cecropiaceae, Ceratophyllaceae, Nymphaeceae and Lemnaceae had only one plant species each (Table 2).

Table 4: Checklist of plant species at Bahi wetland

Plant fFamily	Scientific Name	Sub species
Cecropiceae	*Cecropia insignis*	
Ceratophyllaceae	*Ceratophyllum dermesum*	
Cyperaceae	*Ascolepsis eurocauloide*	
	Ascolepsis protea	*anthemiflora*

	Bulbostylis burchellii	
	Bulbostylis densa	
	Bulbostylis hispidula	*hispidula*
	Bulbostylis pilosa	
	Carex chlorosaccus	
	Cyperus alopecuroides	
	Cyperus assimilis	
	Cyperus colymbetes	
	Cyperus cyperoides	*flavus*
	Cyperus cyperoides	
	Cyperus deciduus	
	Cyperus denudatus	
	Cyperus dichroostachyus	
	Cyperus dubius	*dubius*
	Cyperus gracillimus	
	Cyperus hirtellus	
	Cyperus margaritoceus	
	Cyperus niveus	
	Cyperus obsoletenervosl	
	cyperus pseudo-vestitus	
	Cyperus ruduncus	
	Cyperus rigidifolius	
	Cyperus rotundus	*merkeri*
	Cyperus rotundus	*rotundus*
	Cyperus rotundus	*tuberosus*
	Eleocharis songeensis	
	Fimbristylis bisumbellata	
	Fimbristylis ferruginea	*sieberiana*
	Fuirena angolensis	
	Fuirrena pubescens	
	Fuirena stricta	*chlorocarpa*
	Fuirena welwitschii	
	Kyllinga cartilaginea	
	Kyllinga melanosperma	
	Kyllinga peruviana	
	Pycreus aethiops	
	Pycreus longistolon	
	Pycreus peleophilus	
	Pycreus zonatissimus	
	Rhyncospora brownii	
	Rhyncospora candida	
	Scleria pergracilis	
	cyperus exaltatus	
	cyperus exaltatus	
	Cyperus colymbetus	
	Cyperus articulatus	
	Cynodon dactylon	
	Sporobolus spicatus	
Graminae	*Scirpus mauritiancey*	
	Leersia hexandra	
Lemnaceae	*Pistia stratiotes*	
Nymphaeaceae	*Nymphaea burtii*	
Tamaricaceae	*Tamarix nilotica*	

Plant species composition along the hydrological gradients

Plant species in seasonally inundated areas varied largely from those in permanent inundated areas. Bahi wetland includes water patches that possess different stability to wet-dry phase or hydrological fluctuations. Species richness was higher closer to the edge of the wetland with more frequent inundation than in areas away from the wetland where inundation was less frequent (Figure 6). The variation in species richness could be influenced by inundation and salinity. The salinity and inundation conditions could be harsh to some plant species while favourable to others. Salinity and moisture contents were higher in permanently inundated than in seasonally

inundated areas. Keddy (2000) explained that the hydrology and salinity were among the major factors that controlled wetland plants composition.

However, there was a variation in the degree of resilience and tolerance of plant species against extreme salinity and inundations. For example, some plant species were found in both temporary and permanently inundated areas such as *Sporobolus spicatus, Leersia hexandra,* and these two grass species dominated the entire wetland. Others were found only in permanently inundated areas such as *Cecropia insignis*, *Nymphaeae burtii* and *Ceratophyllum dermesum* and various species of sedges belonging to the family Cyperaceae (Table 2).

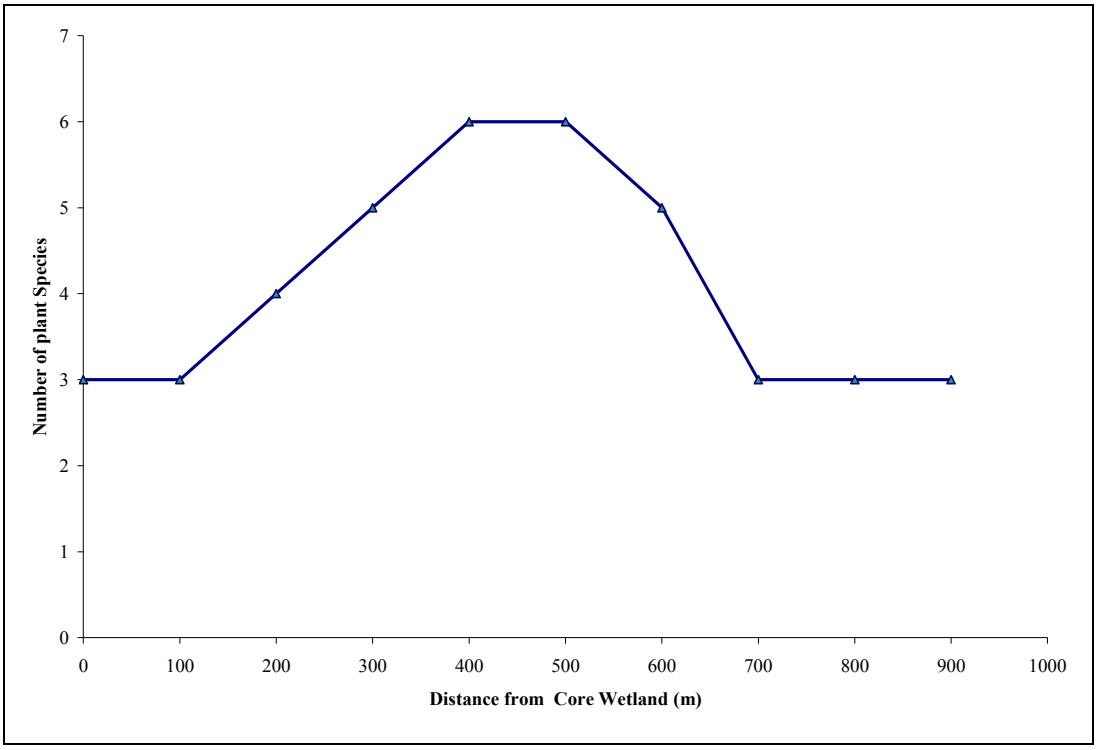

Figure 6: Change in plant species richness from the edge of the wetland

Plant species abundance along a hydrological gradient

There was a remarkable variation in vegetation cover (abundance) in seasonally and permanently inundated areas among vegetation families depending on the type of plant species. One-Way ANOVA showed significant difference ($p<0.05$) between vegetation cover (abundance) and distance from centre of wetland. It was observed that *Sporobolus spicatus* cover/abundance increased from the core wetland towards temporary inundated areas (Figure 7) as it is a facultative wetland species. According to Tiner (2006), facultative wetland species usually occurs in wetlands but occasionally found in non wetland area.

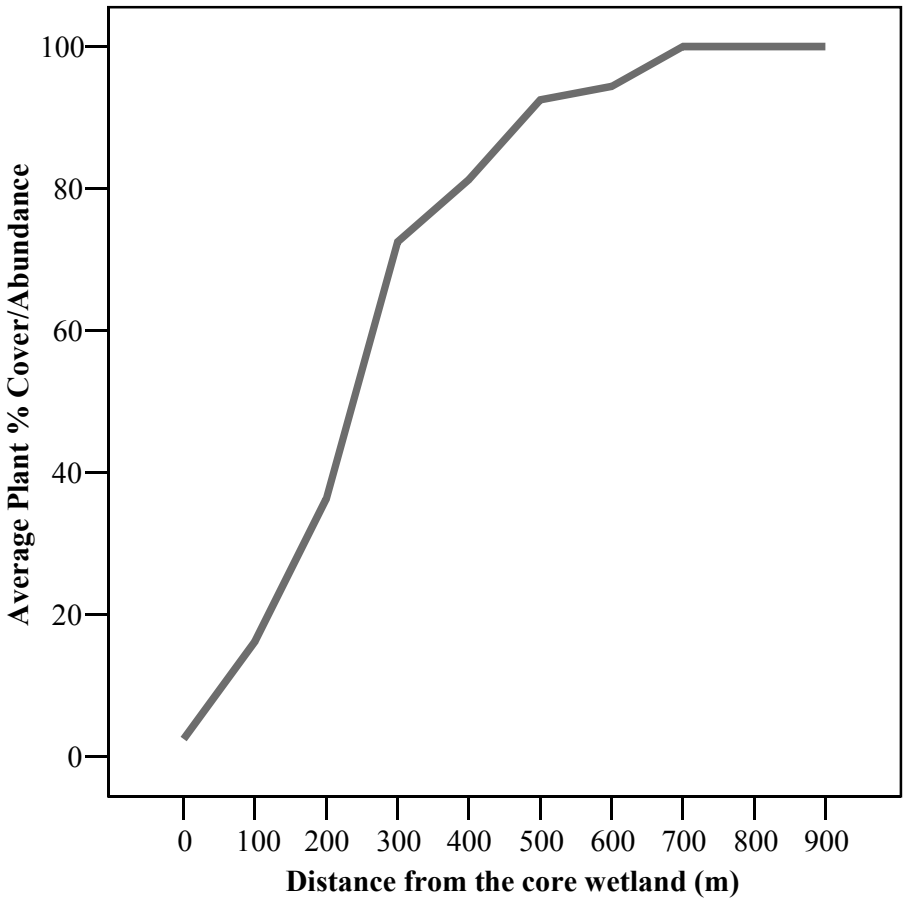

Figure 7: Change in abundance of *Sporobolus spicatus* from centre of the wetland

The cover of different species of the Cyperaceae family increased from centre of the wetland and attained its peak about 300 m, from the centre of the wetland. Thereafter, the abundance decreased sharply away from the centre of the wetland. Plant species in the family Cyperaceae were only found in permanently inundated areas (Figure 8) and considered to be obligate wetland species. They only occur in wetland in natural conditions under estimated probability of 99% (Tiner, 2006)

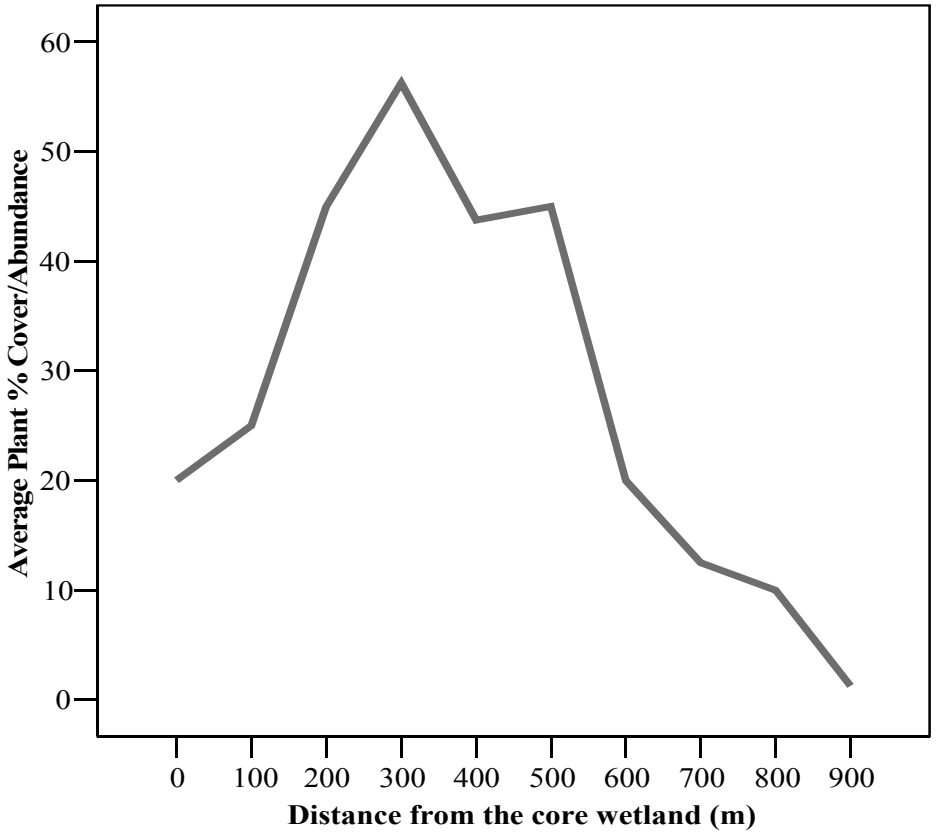

Figure 8: Changes on the cover of different plant species along a hydrologic gradient in the Bahi wetlands Central Tanzania

It was observed that the abundance of *Tamarix nilotica* generally increased from 0 m to 600 m and declined sharply with increasing distance from the core wetland to constant abundance at about 700 m. *T. nilotic*a is considered to be a facultative perennial wetland species and occurs only in temporary inundated areas. Its cover fluctuated due to water patches that varied irregularly with distance from the centre of the wetland.

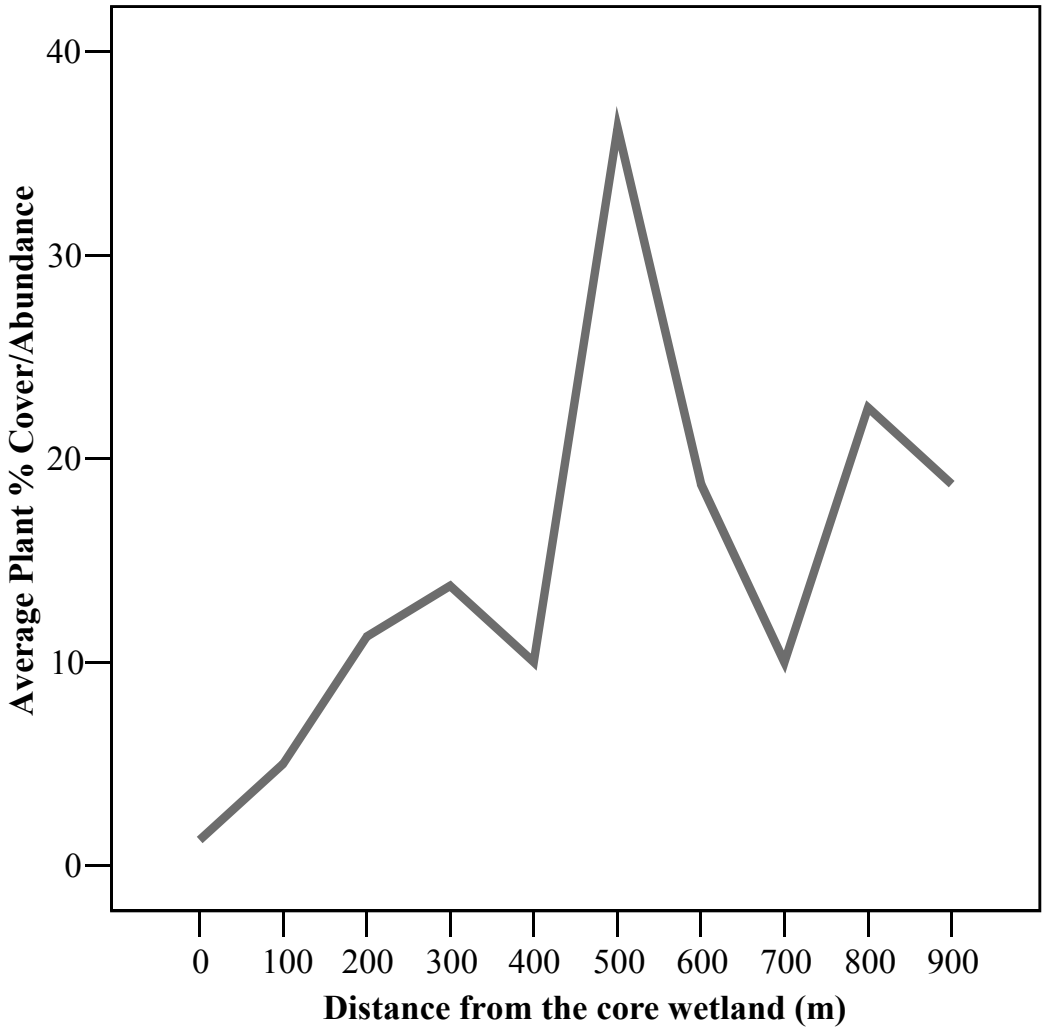

Figure 9: Change in abundance of *Tamaris nilotica* from centre of the wetland

It was observed that the %age vegetation covers for *Cecropia insignis, Nymphaea burtii and Pistia stratiotes* declined sharply from 0 m to 300 m away from the core wetland. These species are considered obligate wetland plants or strict wetland plants and thus cannot tolerate drier conditions away from the wetland. Wetland plants are those species that occur almost under natural condition in wetlands (Tiner 2006). They are only found in permanently inundated areas and rarely found in dry conditions.

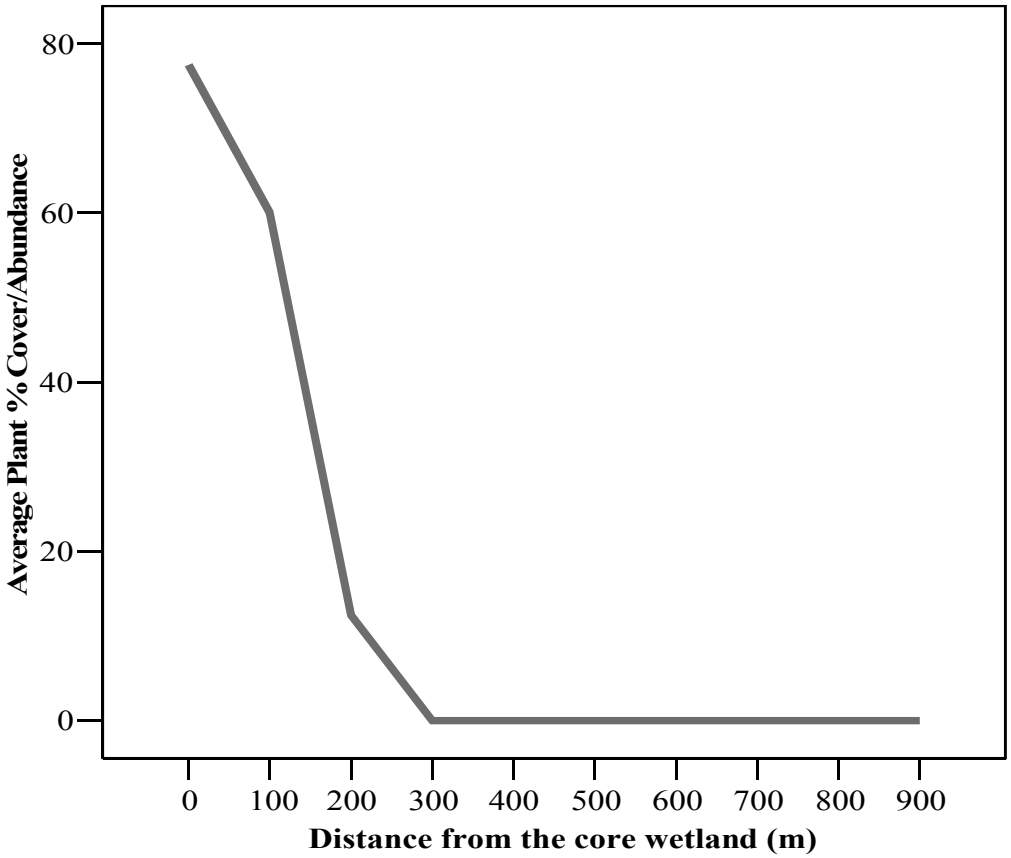

Figure 10: Change in abundance of *Cecropia insignis* from centre of the wetland

The two plant species (*Scirpus mauritiancey* and *Ceratophyllum dermesum*) appeared to be more persistent compared to others by decreasing gently from 0 to 800 m and from the core wetland. They are facultative wetland plants appearing in wetlands but occasionally found in non-wetland area, where soil moisture content is low. They can persist in dry conditions. The plants were more abundant in permanently inundated than in temporary inundated areas.

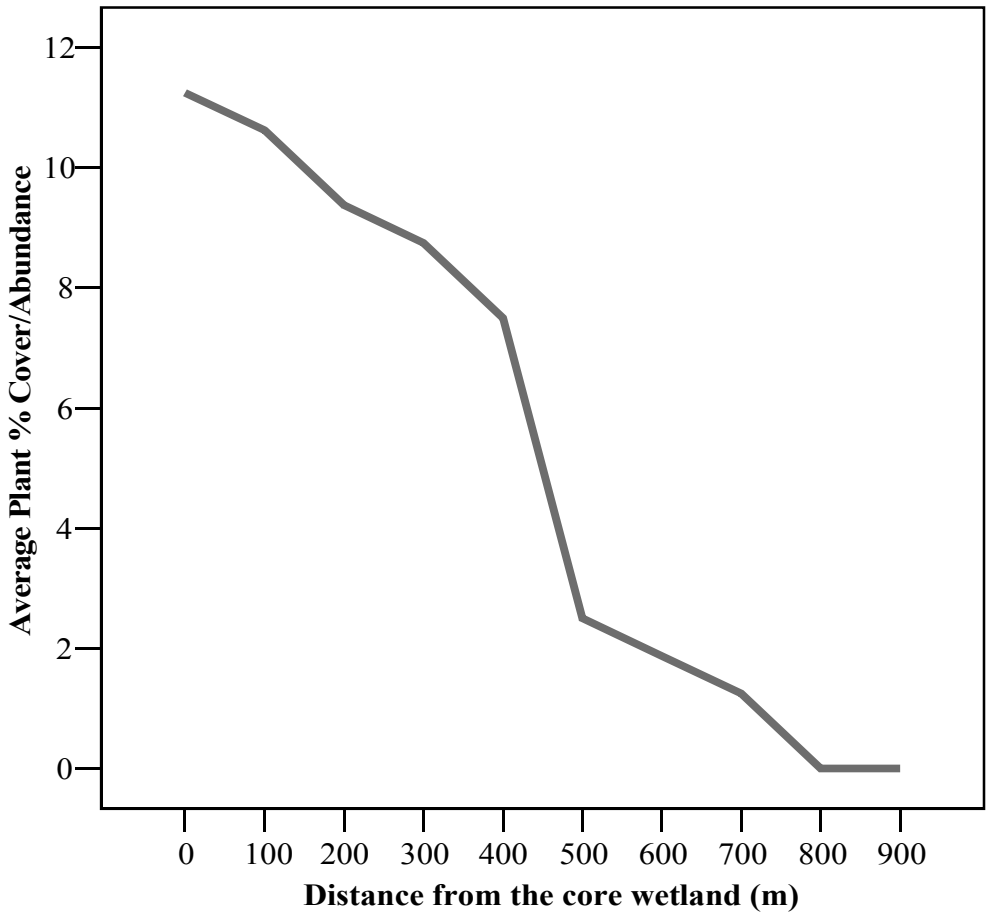

Figure 11: Change in abundance of *Ceratophyllum dermesum* from centre of wetland

Cynodon dactylon %age cover decreased constantly from sampling distance 0 m to 700 m from the core wetland. *C. dactylon* is a facultative plant, and it equally occurs in wetlands and non-wetlands areas, its estimated probability of occurrence ranges between 34 – 66% (Tiner 2006).

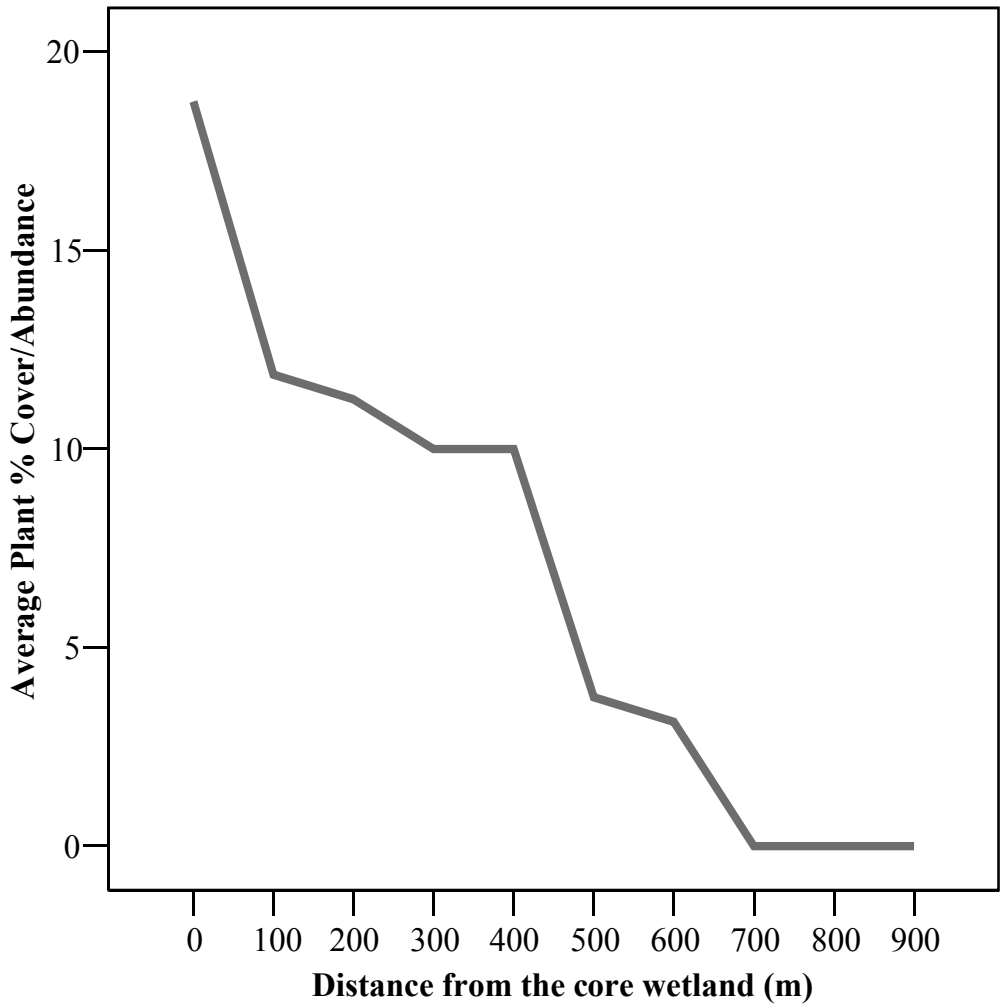

Figure 12: Change in abundance of *Cynodon dactylon* from the centre of the wetland

DISCUSSION

Water and zooplanktons are the main causes of high avifauna species abundance and diversity in permanently inundated areas of Bahi wetland. According to Ali (2005), detection of many avifauna species and individuals close to core wetland may be influenced by moisture content. Permanently inundated areas have high water contents, which enrich the wetland with plants, invertebrates and vertebrates, which are important resources for the survival of waterfowls in the wetland. It was observed that some avifauna species obtain their food in the wetland soil while some find it in the water column, some feed on vertebrates and invertebrates that are found in emerged and submerged vegetation.

The relationship between wetlands and waterfowls is shaped by many factors including the availability, depth and quality of water, availability of shelter and presence or absence of predators (Weller 1975). Other determining physical or biological factors include water temperature, presence or absence of vegetation, type of vegetation, water chemistry, type of soil and geographic or topographic areas. Deeper wetlands with growth of aquatic plants attract more water birds, where they could dabble to acquire their food (Ali 2005).

According to Ali (2005), avifauna use of resources in wetland varies largely from species to species, at Bahi wetland 75% species were waterfowls (strictly water birds) while 25% species were terrestrial birds. Marabou Stocks (*Leptoptilos crumeniferus*)

and Greater Flamingoes (*Phoenicopterus ruber*) were the most dominant avifauna species counted in this study. The two species were considered to be migrants because they use the wetland as a refuge. The wetland offers migrant birds adequate shelter, food and water thoughout the year.

The permanently inundated areas have higher avifauna diversity than seasonally inundated areas. The variation of diversity is more pronounced in migrant species, it is higher in permanently inundated than in seasonally inundated areas. The observed high avifauna diversity in permanently inundated areas was perhaps due to the scarcity of food resources and nesting sites in the temporarily inundated areas. The lack of such resources in temporarily inundated areas is influenced by various factors such as plant species diversity and lack of desirable vegetation structure (Ali 2005).

Human induced disturbance in temporarily inundated areas was another contributing factor to the low diversity of avifauna species. Grazing, fishing and cultivation were observed to be the core development activities at the wetland but overgrazing had more negative impacts on vegetation. Mahinya (2000) reported that that human activities especially grazing and cultivation had negative impacts on vegetation and avifauna species richness and diversity. Overgrazing minimizes vegetation cover and then reduces zooplanktons, which are food for avifauna.

Bahi wetland is of great significance for migrating birds. About 40% of the recorded bird species were migrant avifauna species, of which 69% were African migrants and 31% were distant migrants from Asia and America. However, Ali (2005) ascertained that some of migratory birds breed in Europe, Northern Asia and America in summer when the days are long and food is abundant, they use short temperate summer to rise up their young. When wetlands become frozen due to onset winter, then food and water become scarce, following snow cover. Large numbers of avifauna species that breed in these areas in summer migrate to southern latitudes for purpose of seeking relevant shelters and food (Ali 2005).

Most of the migratory species are globally threatened and they are strictly water birds, which need international attention to be conserved. Migratory species highlight the importance of conserving unambiguously Bahi wetland not only as a trans-boundary habitat and refuge for distant and African migratory birds but also as a breeding site for resident avifauna species.

Plant species composition at Bahi wetland is monodominant, dominated by the family Graminae, though family Cyperaceae consisted of 47 species compared to 4 species of Graminae. Most of members in family Graminae are facultative wetland species that can also survive in seasonally inundated areas. *Sporobolus spicatus*, *Cynodon dactylon* and *Leersia hexandra* were the most dominant grass species in the wetland. Plant species in the family Cyperaceae are obligate wetland species, occurring permanently in inundated areas for their survival (Tiner 2006).

The variation in vegetation species abundance and composition in permanently and seasonally inundated areas was caused by many factors. Colwell and Lees (2000) stated that distribution of species abundance trends along gradient was governed by a series of biological, climatic, chemical and historic factors. Fernandez (2001) clarified explicitly that the floristic species composition and richness in semi arid area is strongly determined by soil water. The species covers of obligate wetland plant species such as *Cynodon dactylon* and *Cecropia insignis* were influenced by soil water but species covers of facultative wetland species such as *Tamarix nilotica* was influenced by other factors than soil water.

Plant species richness peaked in permanently inundated areas, which ranged between 100 m to 700 m from centre of the wetland. Similar findings were reported by Edwards and Armbruster (1989) where species richness peaking at intermediate elevation along a steppe tundra gradient in Alaska. Wang (2003) also reported similar results along elevation gradient in northern slopes of Qilianshan Mountains in China. Vettas and Gerytnes (2002) concluded that about half of published studies showed a mid-elevation peak in plant richness.

Rahbek (1997) identified three main landscape elevation patterns: monotonic decline in species abundance from low to high elevation, a hump-shaped pattern with a maximum at mid-elevations, or essentially constant abundance from the lowlands to mid-elevations followed by a strong decline further up. In case of Bahi wetland *Sporobolus spicatus, Leersia hexandra* and *Nymphaea burtii* assumed monotonic decline pattern, *Tamarix nilotica* and Species in family Cyperaceae assumed hump shaped pattern but *Cecropia insignis* and *Cynodon dactylon* assumed a constant pattern of abundance.

According to Becker (2007), the hump shaped pattern has several potential reasons such as moderate moisture and temperature that permit the existence of such species, which otherwise have either high, mid or low centre of elevation. Ricklets (2004) explained that the elevation at which plant abundance trend peaks up varies with taxonomic group as determined by its ecophysiology, reproductive requirements and evolutionary history.

However, Yossef (2009) concluded that in arid and semi-arid areas, at least flooding and run off waters create a gradient of improved soil fertility from the dry to wet sites. Therefore, hydrological fluctuation caused gradient of productivity and thereby a patches of vegetation directly through its availability in the soil and indirectly by creating soil fertility gradient.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Vegetation species composition and abundance at Bahi wetland are influenced by hydrological fluctuations, whereby the composition and abundance of vegetation were higher in permanently inundated than in temporary inundated areas. Salt tolerant and facultative wetland species such as *Sporobolus spicatus, Leersia hexandra* and *Cynodon dactylon* and obligate wetland plants such as *Cecropia insignis* and species from the family Cyperaceae were more abundant closer to the wetland than facultative species such as *Tamarix nilotica*. The wetland vegetation is monodominant, dominated by family Graminae and few species such as *Leersia hexandra, Sporobolus spicatus and Cynodon dactylon.*

Bahi wetland offers food, cover and spectacular habitat for avifauna. Migrants and residents avifauna species abundance and diversity were influenced by hydrological fluctuations. Both migrant and resident avifauna species responded differently to permanent and temporary inundations. Waterfowls become more abundant in permanently inundated than in temporary inundated areas, which was vice versa to terrestrial avifauna species such as Hamerkop.

Bahi wetland can be considered to be a refuge for migrant species. Both distant and African migrants visit the wetland for wintering. The most abundant migrant were the Greater Flamingoes (the resident migrant) and Red Knobbed Coot, the distant migrant from America. The wetland provides the migrants and residents avifauna with food in forms of invertebrates, seeds and fish.

RECOMMENDATIONS

Bahi wetland is important for communities living adjacent to the wetland and it is a transboundary avifauna habitat. Rural people largely depend on it for agricultural and household satisfactions. Migrant birds use it as refuge during extreme temperature. The area is vulnerable to several factors, which need serious monitoring. The following are measures suggested for sustainable management of Bahi wetland:

(i) Preparation and implementation of a Integrated General Management Plan to conserve the wetland

(ii) Afforestation as an important habitat improvement and conservation measure is important to avoid siltation of the wetland.

(iii) Adjacent communities need to be sensitized on the importance of conserving the wetlands for its socio-ecological importance.

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Appendices

Appendix 1: Avifauna species composition, richness and frequency

Family	Common Name	Scientific Name	Frequency	Remarks
Anatidae	Knob Billed Duck	*Sarkidiornis melanotos*	1	Resident
	Mallard	*Anas platyrhynchos*	1	African Migrant
	Egyptian Goose	*Alopochen aegyptiacus*	3	Resident
	Red Billed Teal	*Anas erythrorhyncha*	1	Resident
	Southern Pochard	*Netta erythrophthalma*	2	African Migrant
	African Black Duck	*Anas sparsa*	2	African Migrant
	Cape Teal	*Anas capensis*	2	African Migrant
	Spur Winged Goose	*Ptectropterus gambensis*	1	Resident
Ardeidae	Black Headed Heron	*Ardea melanocephala*	2	Resident
	Black Egret	*Egretta ardesiaca*	2	Resident
	Striated Heron	*Butorides striatus*	1	Resident
	Purple Heron	*Ardea purpurea*	1	Resident
	Dwarf Bittern	*Lxobrychus sturmii*	1	African Migrant
Pelecanidae	Pink Backed Pelican	*Pelecanus rufescens*	1	Resident
	Great White Pelican	*Pelecanus onocrotalus*	2	Resident
Ciconiidae	Marabou Stock	*Leptoptilos crumeniferus*	5	African Migrant
	White Stock	*Ciconia ciconia*	1	African Migrant
	African Open-billed Stock	*Anastamus lamelligerus*	1	Resident
	Yellow Billed Stock	*Mycterius ibis*	1	Resident
Alcedinidae	African Pygmy Kingfisher	*Ispidina picta*	1	Resident
Jacanidae	African Jacana	*Actophilornis africanus*	2	Resident
Accipitridae	Black Kite	*Milvus migrans*	4	Resident
	African Fish Eagle	*Haliaeetus vocifer*	3	African Migrant
	Black Shouldered Kite	*Elanus caeruleus*	1	Resident
Charadriidae	Spotted Sandpiper	*Actitis macularia*	3	Asian Migrant
	Caspian Plover	*Charadrius asiaticus*	1	Asian Migrant
	Common Ringed Plover	*Charadrius hiaticula*	2	Distant Migrant
Scopidae	Hamerkop	*Scopus umbretta*	4	Resident
Gruidae	Common Crane	*Grus grus*	3	African Migrant
	Grey Crowned Crane	*Balearica regulorum*	1	Resident
Phoenicopteridae	Greater Flamingo	*Phoenicopterus ruber*	5	African Migrant
Laridae	Grey Headed Gull	*Larus cirrocephalus*	3	Distant Migrant
Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	1	Resident
Recurvirostridae	Black Winged Stilt	*Himantopus himantopus*	4	Resident
Threskiornithidae	Hadada Ibis	*Brostrychia hahedash*	2	African Migrant
	African Spoonbill	*Platalea alba*	2	Resident
	Sacred Ibis	*Threskiornis aethiopicus*	2	African Migrant
Phalacrocoracidae	Long Tailed Cormorant	*Phalacrocorax africanus*	1	Resident
Rallidae	Red Knobbed Coot	*Fulica cristata*	1	Distant Migrant
Rostratulidae	Greater Painted Snipe	*Rostratula benghalensis*	1	Distant Migrant

Appendix 2: Diversity of different Avifauna Species

Common Name	Scientific Name	Abundance	Diversity Index
Mallard	*Anas platyrhynchos*	3	0.00923
Pink Backed Pelican	*Pelecanus rufescens*	1	0.00359
Egyptian Goose	*Alopochen aegyptiacus*	163	0.9219
Red Billed Teal	*Anas erythrorhyncha*	7	0.0188
Marabou Stock	*Leptoptilos crumeniferus*	51	0.0892
African Pygmy Kingfisher	*Ispidina picta*	10	0.0251
African Jacana	*Actophilornis africanus*	4	0.0118
Black Headed Heron	*Ardea melanocephala*	2	0.0118
Hamerkop	*Scopus umbretta*	8	0.0209
Spotted Sandpiper	*Actitis macularia*	4	0.1177
Common Crane	*Grus grus*	2	0.2512
Greater Flamingo	*Phoenicopterus ruber*	927	0.3622
Black Winged Stilt	*Himantopus himantopus*	4	0.0118
Black Kite	*Milvus migrans*	17	0.0385
African Fish Eagle	*Haliaeetus vocifer*	4	0.0118
Hadada Ibis	*Bostrychia hahedash*	13	0.0311
Southern Pochard	*Netta erythrophthalma*	22	0.0917
Black Egret	*Egretta ardesiaca*	2	0.0065
Striated Heron	*Butorides striatus*	2	0.0065
Purple Heron	*Ardea purpurea*	35	0.0674
White Stock	*Ciconia ciconia*	1	0.0005
Knob Billed Duck	*Sarkidiornis melanotos*	92	0.1355
African Spoonbill	*Platalea alba*	53	0.0917
Yellow Billed Stock	*Mycteria ibis*	11	0.0271
Grey Headed Gull	*Larus cirrocephalus*	58	0.0272
Little Grebe	*Tachybaptus ruficollis*	20	0.0438
Great White Pelican	*Pelecanus onocrotalus*	4	0.0118
African Black Duck	*Anas sparsa*	4	0.0118
Cape Teal	*Anas capensis*	57	0.0967
African Open Billed-stock	*A lamelligerus*	9	0.0231
Sacred Ibis	*Theskiornis aethiopicus*	64	0.1051
Spur Winged Goose	*Ptectropterus gambensis*	123	0.1644
Caspian Plover	*Charadrius asiaticus*	3	0.0092
Common Ringed Plover	*Charadrius hiaticula*	4	0.0118
Long Tailed Cormorant	*Phalacrocorax africanus*	23	0.0488
Dwarf Bittern	*Lxobrychus sturmii*	5	0.0142
Black Shouldered Kite	*Elanus caeruleus*	1	0.0036
Red Knobbed Coot	*Fulica cristata*	51	0.0892
Grey Crowned Crane	*Balearica regulorum*	53	0.0917
Greater Painted Snipe	*Rostratula benghalensis*	2	0.0065
Grand Total		1920	3.1149