KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF AGRIC AND NATURAL RESOURCES

FACULTY OF RENEWABLE NATURAL RESOURCES

DEPARTMENT OF WILDLIFE AND RANGE MANAGEMENT

ASSESSING THE FUNCTIONAL STATE OF THE OWABI WETLAND, USING THE PLANT SPECIES RANGE SHIFT APPROACH

ROCKSON ACOLATSE

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ASSESSING THE FUNCTIONAL STATE OF THE OWABI WETLAND, USING THE PLANT SPECIES RANGE SHIFT APPROACH, IN THE ASHANTI REGION (GHANA)

A THESIS SUBMITTED TO THE DEPARTMENT OF WILDLIFE AND RANGE MANAGEMENTIN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE BACHELOR OF SCIENCE DEGREE IN NATURAL RESOURCES MANAGEMENT

ROCKSON ACOLATSE

2020

DECLARATION

Candidate's Declaration

I hereby declare that this submission is my own work towards the Bachelor of Science Degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Candidate's signature: ....

Date: ....

Name: Rockson Acolatse

Supervisor's Signature: ....

Date: ....

Name: Collins Ayine Nsor (PhD)

ABSTRACT

The study investigated environmental factors that influenced species range shift in Owabi wetland, using the dominance ratio approach. It was conducted over a period of 4-months. The data collected was categorized into wetland and non-wetland plants using the prevalence index method. Log series, individual-based rarefaction and Hill's diversity ordering models were applied to quantify community structural assemblages, while the CCA ordination technique was used to determine the relationship between environmental variables and biological data set. In all 2185 individuals, belonging to 38 families and 68 species were recorded across five sites (Owabi, Esaase, Bokwankye, Atafua and Ohwim) in the Owabi Wildlife Sanctuary. A total of nine plant life forms were recorded and included: grasses (16%), herbs (37%), shrubs (10%), woody plants (22%), submerged (1%), sedges (6%), ferns (3%), creepers (1%), climbers (3%). Plant species were made up of 24% obligate wetland species (OBL), 26% of facultative species (FAC) and 41% of obligate upland species (UPL). The highest number of species per site was registered at Atafua site (n = 578, 5.67 ± 0.27 per plot), while the Owabi site recorded the least number of species (255, 5.10 ± 0.59 per plot). *Paspalum orbiculare, Pistia stratiotes, Polygonum lanigerum* and *Pteridium aquilinum* were the most abundant species recorded. Farming activities, NH_4+, DO, PO_4 and NO_3- were the major predictors that influenced species assemblages. Theses variables explained 72.01% of total variances in species abundance distribution, richness and diversity. The results of this study revealed the threats on this wetland and the need to protect it from further degradation.

Keywords: Environmental Factors. Rarefaction. Canonical Correspondence Analysis. Species Abundance Distribution.

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CHAPTER ONE
1.0 INTRODUCTION

1.1 Background

Range shift researches together with changes in climatic conditions in northern European countries have attracted a great deal of attention in recent decades, with experiments on numerous herbaceous cover and tree species dating back to the mid-1700s (Parmesan, 2006). Geographical shifts in the range of species associated with global climate change have been reported in a broad range of ecosystems and habitats across all continents and most oceans (Monzón et al., 2011). However, except for the impacts of climate change on the distribution of species, competition for the use of nutrients and the depletion of the hydrological environment linked with anthropogenic activities often plays important roles when it comes to moving species from their natural habitats (Van der et al., 2010). Further studies by Craft et al. (1995) have shown that plant species structure in a wetland will change as indigenous ecotone plant species are being substituted by species that require high nutrient loads for growth. The improvement in nutrients usually contributes to replacing unique or endangered species with species that are more tolerant of high nutrient levels (e.g., *Phragmites australis*) (Chambers et al., 1999). According to Crook et al., (2015), Human beings are increasingly altering interactions throughout a broad variety of geographical scales and habitat forms across ecosystems. About 50% of the world's wetlands have been lost to agriculture and industrial expansion over the last century (Shine and Klemm, 1999; Rolon and Maltchik, 2006).

Currently, Ghana's wetlands have been seriously damaged by anthropogenic practices such as cultivation, sand winning, refuse dumping in rivers and around water bodies, improper handling of industrial and domestic waste from surrounding communities and the Owabi wetland is no exception to these threats (Ameyaw, 2017). The rapid degradation of this special wetland ecosystem calls for the pressing need of ecological studies to give the scientific support needed for biodiversity conservation programs.

1.2 Problem Statement

Many wetlands of international significance around the world are under extreme human threat due to improper industrial and residential waste disposal, contributing to a shift in the distribution of biodiversity compared to shifts under the change in climatic conditions (Millennium ecosystem assessment, 2005). The loss of aquatic macrophytes, which play a very important role as primary producers in the wetland environment, has become the major challenge for most wetland habitats (Rejmánková, 2011). The distribution of plants has hardly been studied, except when ruderal organisms are established outside their natural range (Nsor et al., 2014).

A 50-year study of floristic composition at different Spatio-temporal scales in archeological sites in Rome has shown that more than 40 percent of plants have vanished due to environmental disruptions (Ceschin et al., 2010). Agricultural activities are the main contributors of nitrogen and phosphorus to aquatic ecosystems and their enrichment causes river, lake and dam eutrophication (Conley et al., 2009; Boadi et al., 2018). Plant species like *Phragmites australis* are noted to develop well in high nutrient loads, replacing the wetland's native species (Chambers et al., 1999). Elements such as nitrogen and phosphorus and their sources impacts the decision taken on the ecological status of aquatic systems as aquatic degradations in form of deoxygenation, odor and change in taste can result from excess of these nutrients in any freshwater aquatic system (Jarvie et al., 1998; Boadi et al., 2018).

The Owabi wetland (reservoir) is the second major source of drinking water for the Kumasi Metropolis and its surrounding communities (Boadi et al., 2018). About 20% of the water supplied to the metropolis is derive from the reservoir, serving mainly the northern part of Kumasi (Akoto et al., 2008). Over the years, The Owabi wetland's catchment area has experienced severe invasion. This has contributed to illegal activities along large wetland tributaries, including fishing, sand winning, and settlement encroachment. (Ameyaw, 2017). The reservoir's tributaries drains through some urban areas, as well as some farming communities (McGregor et al., 2000). Its major tributaries are Owabi, Sukobri, Atafua, Akyeampomene, Pumpunase, and Afu (Akoto and Abankwa, 2014). These rivers carry waste from human activities such as car repair works, washing bays and refuse dumps (Badu et al., 2013). Besides, Agrochemicals and fertilizers used by farmers within the catchment of the reservoir are also sources of pollution to the reservoir (Ntow, 2001; Boadi et al., 2018). Excess of these nutrients and pollution may cause explosion of algal blooms, deoxygenation, changes in taste and odour, the death of fish and other aquatic living organisms as well as the loss of biodiversity (Varol and Şen, 2012).

1.3 Justification

As one of the most bio-diverse ecosystems of the world, wetland ecotones make tremendous contributions through ecological and economic processes to the livelihood to rural communities around them (Perillo et al., 2018). These benefits include; water supply (for domestic, irrigation, and industrial use), climate regulation, flood attenuation, fish (food) supply, source of herbal plants, protection of the coast, recreational and tourism services as well as revenue generation (Millennium Ecosystems Services, 2005; Nsor et al., 2019). Today, the Owabi reservoir offers around 20 percent of Kumasi's drinking water. The local people also use the reservoir for fishing and irrigation of croplands. The Owabi wetland is surrounded by a wildlife sanctuary, the smallest wildlife protected area and the only in-land Ramsar site in Ghana (Nartey et al., 2019). There is an increase in the number of global reports on the rate of loss of wetlands and their resources despite all efforts through national and international conventions on the sustainable use of wetland resources (Tuluab, 2015). Human encroachment in the form of farming, sand winning and infrastructural development within the catchment area of the owabi reservoir may be negative affecting the quality of water, which intends endangers both plant and animal life in the area (Barnes, 2017). Most species in the wetland have high sensitivity to changes in the state of their habitat. In addition, it is important to have a group of plants that will serve as indicators to either present or future anthropogenic disturbances (Erwin, 2009). Due to the high levels of poverty, lack of law enforcement and the incompatibility of policies towards the management of wetlands in the communities where wetlands are located, there is a continuous loss of wetland at both regional and local scales even after the numerous international conventions and national policies (Nsor, 2012). While some scientists conclude that climate crisis is directly responsible for the local-to-regional and global shift in species distribution (Iverson, 1944), others agree that environmental disruptions are the key drivers of concern as compared with climate change (Ceschin et al., 2009).

With respect to the numerous functions of wetlands, the owabi wetland was selected for this study because it is currently the only inland Ramsar site in Ghana and currently under various forms of pressure in the form of eutrophication, chemical contamination and sedimentation (Nartey et al., 2019). As the only inland Ramsar site in Ghana, there is lack of scientific research to investigate the functional status of the wetland using the geographical range shift approach (Parmesan, 2006). Since wetland species have been observed for their sensitivity to variations in their living conditions, it is necessary to study them using the changes in the range in order to reverse, predict and mitigate the effects of range shift on their functional status. In addition, studies of range shift dynamics will help provide a list of the categories of plants that will serve as an indicator of the functional status of the owabi wetland.

1.4 Project Aim

The main goal of this study is to investigate environmental factors influencing plant community structure, distribution and diversity in Owabi wetland.

1.5 Project Objectives

1) Classify plants as obligate wetland species (OBL), facultative wetland species (FACW), facultative species (FAC), facultative upland species (FACU) and obligate upland species (UPL), using the prevalence index method developed by Cronk and Siobhan-Fennessy (2001).
2) Determine species abundance and distribution pattern.
3) Quantify species richness and diversity.
4) To determine which environmental factors are the principal drivers of species range shift as well as distribution pattern and diversity of species.

1.6 Hypothesis

It is hypothesized that;

(1) (a) Areas of low anthropogenic activities will have high species richness, low diversity and high species abundance.

(2) Areas of high environmental quality thresholds will have high plant range shifts.

(3) There will be no significant difference in the functions of the wetland between up-stream and down-stream.

CHAPTER TWO

2.0 Literature Review

2.1 Hydrophytes as an indicator of a functioning wetland

The vegetation of wetlands is distinctive, primarily because flooding and soil saturation create conditions that most plants cannot tolerate (Budu, 2015). These plants are called hydrophytes, and the plant communities are described as being dominated by hydrophytic vegetation (Tiner, 1993). Communities composed of these plant species have been used for decades to identify functional wetlands. Hydrophytes groupings are in five (5) status categories depending on their frequency of occurrence in wetlands under natural conditions (Tiner, 1999). These are:

1. Obligate Wetland Plants (OBL) {Plants that occur usually (estimated probability >99%) in wetlands under natural conditions, but which may also occur rarely (estimated probability <1%) in non-wetlands.)}
2. Facultative Wetland Plants (FACW) {Plants that occur usually (estimated probability >67% to 99%) in wetlands, but also occur (estimated probability 1% to 33% in non-wetlands)}.
3. Facultative Plants (FAC) {Plants with a similar likelihood (estimated probability 33% to 67%) of occurring in both wetlands and non-wetlands}.
4. Facultative Upland Plants (FACU) {Plants that occur sometimes (estimated probability 1% to <33%) in wetlands, but occur more often (estimated probability >67% to 99%) in non-wetlands}.
5. Obligate Upland Plants (UPL) {Plants that occur rarely (estimated probability <1%) in wetlands, but occur usually (estimated probability >99%) in wetlands under natural conditions}.

Several factors affect wetland plant structure and distribution and they include: altitude, disruption and soil resources. As main factors affecting plant community structure in wetlands (Zheng et al., 2019), soil properties such as soil moisture, salt content (Rath et al., 2015), soil organic matter (Zheng et al., 2019), Nitrate-N (Green et al., 2002), and microbial soil communities (Qin et al., 2017) had a greater impact on wetland plant community structure. Some studies have found the effect of hydrology (Timoney, 2008) although this association may not be evident as hydrology may also impact soil resources that are influenced by geographical location. Ultimately, research suggests that shifts in environmental variables may have significant effects on species distribution and structure, while multivariate processes may also operate and the influencing factors that affect wetland plant communities may be site-specific and rely on the individual plant community (Zheng et al., 2019).

Throughout the years, human actions and threats to wetlands have ended in the destruction of habitats and have impaired wetlands' importance and work (Tiner, 2003). The impacts on the wetland may be direct or indirect; direct impacts originate from events or disruptions that arise within the wetland. Several direct impacts involve habitat destruction, building, road and bridge development, water level adjustments and irrigation trends (Mensing et. al., 1998). Indirect effects arise from disturbance of locations outside the wetland such as uplands of wetlands. Indirect impacts include surface water and sediment flow, loss of recharge area or change in local drainage patterns (Tiner, 2003). Major human activities or disturbances affecting wetland vegetation or the wetland as a whole include Agriculture (Altinsacli & Griffiths, 2001), Mining, Urbanization (US EPA, 1995), Dredging and water diversion (Gopal, 2003), Grazing (Allen & Feddema, 1996).

2.2 Threats to Wetland vegetation in Ghana

Ghana's wetlands are an ecologically valuable resource that offers food, roosting and breeding places for thousands of migratory and resident birds, sea turtles, several fish species, plant genetic materials for study and a significant source of income for particularly poor communities from fishing, salt mining and other economic activities (Kwei & Ofori-Adu, 2005). Nevertheless, the very people served by the wetlands pose a major threat to them. These challenges include rapid urban destruction of wetlands, rapid slum development, mining, land and soil degradation, sanitation, and water contamination (Anku, 2006). Inland wetlands ecosystems in Ghana also have an unusual depletion of ecosystems by wood cutting activities, illicit and wasteful forestry practices, slash and burn agriculture and smuggling or bush-meat shooting (Wuver & Attuquayefio, 2006). Historically, surface mining has not been a national danger as compared to the present, as it has a major impact on the plant life and hydrology of freshwater wetlands by destroying habitat, deforestation, sedimentation, and depletion of water bodies (EPA-Ghana, 2008).

2.3 Threats to Urban Wetland Biodiversity

Urbanization is one of the supreme environmental changes and has a profound effect of wetlands around the world and in Ghana, Thus, urbanization contributes to significant wetland depletion and further wetland destruction (Budu, 2015). Wetland degradation is caused by changes in water quality, volume and flow rate; increased concentrations of contaminants and alterations in vegetation structure because of both the introduction of non-native species and distractions to our wetlands. In-land wetlands are under great threat; growing land demands and poor land management in Ghana's urban areas worsen this issue (Campion & Owusu-boateng, 2013). In 1988, Ghana joined the Ramsar Convention as a signatory. even so, after two decades later, wetlands are still known as' waste fields,'' flood zones' or' mosquito breeding grounds and, as such, excavated to promote water drainage, reused for other purposes or merely approved as dumping ground for all forms of refuse (Ministry of Lands and Forestry, 1999a; Campion, 2012). Recent advances in human development and socioeconomics tend to be the main threats to wetlands in Ghana, even with numerous attempts to protect or develop wetlands according to the Convention on Ramsar conservation. It is, therefore, necessary to consider the importance of natural wetland resources, including their economic contribution, while planning and executing infrastructure projects, in order to safely preserve and improve the wellbeing of many agricultural and urban communities' dependent on wetlands (Silvius et al., 2000; Campion, 2012).

2.4 Factors Influencing the Range Shift of Plants Species in Wetlands

In addition to the impacts of climate change triggering a shift in species distribution, rivalry for the use of resources and the depletion of hydrological environments related to human influence often plays a vital role in moving biodiversity beyond their natural ranges (Van der et al., 2010). A study by Craft et al., (1995), shows that historically, the composition of plant species in wetlands can change as native species decline and are substituted by species that benefit from high loads of nutrients to boost growth. Nutrient enhancement leads mostly to the substitution of endangered or rare species of plants with high-nutrient-tolerant plants (e.g., Phragmites australis) (Chambers et al., 1999).

Despite the various international Ramsar Agreement and National Policy Intervention Program to encourage the safe use and conservation of wetlands, wetlands have generally been destroyed or under serious threat (Turner et al., 2000). The cause of this limitation is partially due to the absence of policy system implementation or policy uncertainty against wetland management by different legal systems and the high levels of unemployment in rural areas (Turner et al., 2000). Nevertheless, it is most likely that increased human-led disruptions combined with climate change stresses on the biodiversity of wetlands could be responsible for the diminishing of indigenous species thus helping the colonization by adjacent dryland plants. Whereas, research by Hulme (2003) indicates that in understanding the distribution of plants, the combination of the effects of abiotic and biotic factors can overpower climatic factors. This claim was supported by the Millennium Ecosystem Service Report (2005), which indicated that anthropogenic impacts would lead to faster wetland habitat degradation and destruction than natural causes. Consequently, a better understanding of factors that contribute to the loss of wetland species can aid to mitigate wetland destruction. Most plant species of wetlands are noted for their responsiveness to adjustments in environmental conditions (Avisar & Fox, 2012). Therefore, it will be important to have a suit of plant species that can indicators of current environmental conditions (Rutherford et al., 1999). The unavailability of well-documented evidence on plant biodiversity would undoubtedly make it difficult to evaluate if current species have actually shifted their distribution to their current environments, decreased or remained unchanged in their natural ranges. To establish their specific functions in the change of species ranges, this research focused on anthropogenic disturbances. Although altitude has been noted to be associated strongly with plant species richness (Rolon & Maltchik, 2006), Veestgaard & Sand-Jensen (2000) argue that plant richness may be more associated with the invasion of an area than the total surface of the wetland. The lack of precision in the species-area relationship in sample plots in present studies indicates that several other human-induced or environmental factors might have compensated for the change in the distribution of plants. Therefore, the response to environmental changes by aquatic plant could be used at various spatio-temporal scales as an indicator of the functional state of the wetland. Some studies on wetland ecosystems have attributed the global depletion in plant diversity and change in species distribution to factors such as agricultural practices (Millennium Ecosystem Assessment, 2005; Kath et al., 2010), burning (Kutiel & Shaviv, 1993; Wuver et al., 2003), Grazing (Taddese et al., 2002) and soil conditions (wild et al., 2004). Verhoeven et al., (1993) stated that nutrient accumulation, such as phosphorus and nitrogen in several wetlands, resulted in total plant diversity reduction, shifts in species distribution, the invasive substitution of native species and the introduction of a diverse flora by a few common species in certain wetlands. A study conducted by Moore & Keddy (1989), reported that high species abundance is often correlated with low nitrogen status for undisturbed wetlands and that species-rich wetlands usually have reasonable production and healthy plants. From the contrasting result from these various authors, it can be concluded that there is a mediating effect from other soil nutrients on plants that a found in these wetlands.

2.5 The Effect of Encroachment on Wetland Ecosystem Services

Practices such as irrigation, sand winning and the expansion of infrastructure within the catchment of Owabi wetland pose a significant threat to the wetland's lifetime, economic and ecological roles (Ameyaw, 2017). Unlawful timber logging and fuelwood extraction within the surrounding forest, reduces the vegetation cover that serves as a buffer, intercept runoff speed and filter runoff. Even though deforestation takes place along the riverbanks, it is not evident (Ameyaw, 2017). Due to land usage along the banks of the river and the catchment area, the Owabi wetland is heavily silted from sediment deposition, which slowly decreases the volume of water in the wetland (Ameyaw, 2017).

According to Ameyaw et al. (2017) the expense of water purification for residential use is rising due to changes in land use in and around the Owabi wetland catchment areas. It costs around 36% more to the Ghana Water Company Limited to treat a specified quantity of water at the Owabi treatment plant in an urban area relative to the cost to treat the same quantity of water in the Barekese dam in a rural area. Waste from both homes and commercial areas are deposited into streams flowing to the Owabi wetland, which increases the cost of water treatment for public use. There is a need for collaboration among all stakeholders in conservation of wetlands and their resource to promote sharing of information and public education in the nearby communities of the Owabi wetland and its catchment area on the use of the wetland (Ameyaw, 2017).

CHAPTER THREE

3.0 Materials and Method

3.1 Study Area

The study was carried out in the Owabi wetland found within the Owabi Wildlife sanctuary, located between latitudes 6^0 47' 3.32"- 6^0 41' 52.31" N and longitudes 1^0 44' 0.81"- 1^0 37' 53.04" W in the Ashanti Region and bounded by Atwima, Kwabre districts, and the Kumasi metropolis. It is 19 km northwest of Kumasi, the second largest city of Ghana. The sanctuary is the only inland Ramsar site in Ghana. The study area has a semi- humid climate with an average rainfall of 1488 mm. There is a weak bimodal distribution of rain, a main wet season between March and June and a minor in September – October (Seidu, 2012). Forest ochrosol soils typical of high forest areas dominates the study area with moderate acidity of pH 6-7 and red or reddish brown color. The construction of the Owabi dam created the reservoir. The reservoir covers an area of about 13 km^2 (1300 ha) with an approximate water volume of 26,000,000-m^3; and the Owabi wildlife sanctuary surrounds the reservoir (Boadi et al., 2018). The depth of the reservoir is 7.4 m along its spillway and 11.5 m across the embankment (Boadi et al., 2018). Several rivers and streams drains into the Owabi reservoir and these include the Rivers Owabi, Sukobri, Akyeampomene, Pumpunase, and Atafua. These rivers drain through agricultural and populated urban and rural settlements around the reserve and these settlements include; Owabi, Esaase, Bokwankye, Atafua and Ohwim (Akoto et al., 2010; Badu et al., 2013). The Owabi wetland is surrounded by a secondary forest and a wildlife sanctuary.

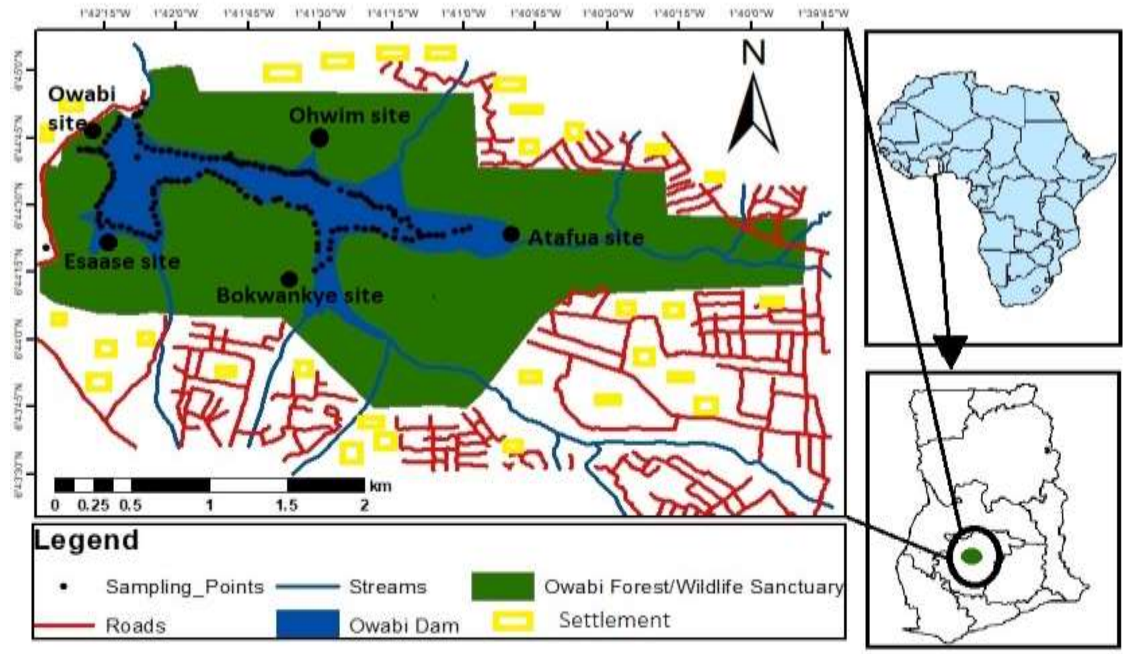

Figure 1. Map of Owabi Wildlife Sanctuary

3.2 Data Collection

3.2.1 Environmental Assessment

3.2.2 Water sampling and analysis of water quality

Using the multi-meter water probe and laboratory analysis, the physicochemical properties of the water were assessed per the outline standard methods used in the examination of water and wastewater (APHA 1998). The properties to be measured are: pH, turbidity, conductivity, total dissolved solids (TDS), nitrate-N (NO_3-N), phosphate (PO_4), Ammonia (NH_4-N), and dissolved oxygen (DO). Collection of the samples were done in all plots where plant species were sampled.

3.3 Biological data assessment

3.3.1 Sampling procedure of aquatic plants

Sampling of aquatic vegetation was done on plots randomly established through the bank of the wetland. A 5 x 5m size plots was used to sample trees and shrubs, a nested 2 x 2m plot for grasses and herbs. The sample plots were laid using a 15 m survey's tape and numbered. GPS coordinates of all plots were plots were recorded using GPS (GARMIN, GPSmap 60Cx). The plots were randomly laid along the environmental gradient on the sites being sampled, to record as many species types as possible. The following data were collected; plant height, ground or foliage cover, and stem girth. The Dormin-Krajina cover-abundance scale was be used to estimate ground cover (Muel-Donboise and Ellenberg, 1974). Species was measured in a 2 x 2 m plot, while species richness and stem girth were assessed in a 5 x 5 m plot. Plant species were identified up to the species level, with the aid of plant identification guide developed by Okezie and Agyakwa (1998).

3.4 Assessment of species range shift, using the hydrophyte community as an indicator.

The prevalence index method (Cronk and Siobhan-Fennessy, 2001) was used to find out whether plant species present are typical wetlands plants or from terrestrial systems and to sort out the weighted average of indicator status of species to be sampled and indicate as: Obligate wetland plants – (i.e. hydrophytes with >99% probability of occurring in wetlands); facultative wetland plants- (usually found in wetlands with an estimated probability of 67% - 99% occurrence, but occasionally found in uplands); facultative plants- (having 34% - 66% equal chance of occurring in wetlands); facultative upland plants- (usually occur outside wetlands, but occasionally found in wetlands), and obligate upland- (occur only in uplands) (Tiner, 1999).

In addition to the indicator status categories, a positive (+) sign was be used to indicate all facultative species categories with a frequency towards wetter ends (more frequently found in wetlands) and a negative (-) sign with a frequency towards drier ends (less frequently found in wetlands) (Tiner, 1999).

3.5 Statistical Analysis

Sample plots distribution were initially tested for normality using the Shapiro – Wilk test before subsequent analysis of their community assemblages. Species abundance as one of the measure of diversity, was quantified using the rank abundance model (Magurran, 2004). SADs help in testing models or hypothesis of how communities are structured and also highlight rare and common species in the community, for management purposes and also justify why some species are rare while others are common (Magurran and McGill, 2011). The generalized Fisher's logarithmic series was used to fit species abundance data, by ranking each species in a declining abundance order (Watterson, 1974). This Fisher's logarithmic series approach is a statistical inference procedure that is applied to measure species diversity (Watterson, 1974). This model gives a better fit for plant species data than log normal model (Kempton, 1975) and superior to classical distribution plots for fitting (Preston, 1948), as they do not lose information nor bias as a result of species grouping (Nekola et al. 2008, Ulrich et al. 2010). Log series model equation takes the form of:

$$\alpha\chi, \alpha\chi^2/2, \alpha\chi^3/3 ... \alpha\chi^n/n \text{ …………(Eq. 1) Fisher et al. (1943),}$$

Where $\alpha\chi$ is the number of species predicted to have one individual, $\alpha\chi^2$ to have two individuals. We estimated χ from the iterative solution of:

$$S/N = (1-\chi)/ \chi (-\ln(1-\chi) \text{ ………..(Eq. 2)}$$

where S = number of species, and N = number of individuals. The log series is applied to species in succession communities or approximates samples in complex communities. Fisher's Alpha (α) widely used as a diversity index to compare among communities differing in number of individuals (N), because theoretically species are independent of sample size. The log series distribution, always assumes most species to be represented by single individuals. The SAD model is mostly used to measure the impact of disturbance on community structure (Gray and Mirza, 1979).

Individual-based rarefaction techniques (Gotelli and Colwell 2001) was used to compare species richness among the five sites (*rarefaction curves*). Rarefaction curves are created by randomly re-sample the pool of N samples multiple times and then plotting the average number of species found in each sample (1, 2 ... N) (Gray and Mirza 1979). Rarefaction therefore generates the expected number of species in a small collection of n individuals (or n samples) drawn at random from the large pool of N samples. The rarefaction curve, f_n is defined as:

$$f_n = E[X_n] = K - \binom{N}{n}^{-1} \sum_{i=1}^{k} \binom{N - Ni}{n} \dots\dots (\text{Eq. } 3)$$

Where X_n = the number of groups still present in the subsample of "n" less than K whenever at least one group is missing from this subsample, $N = \text{total number of items}$, $K = \text{total number of groups}$, $Ni = \text{total number of items in group } i$ $(i = 1, \dots k)$ (Gray and Mirza 1979; Gotelli and Colwell, 2011). Rarefaction methods such as sample-based and individual-based – allow for the standardization and comparison of species datasets with varying amounts of sampling effort (Gray and Mirza, 1979) and have been applied to quantify plant richness (e.g. Nipperess et al. 2013). This is achieved by initially rarefying all datasets back to a common (typically the minimum) number of accumulation units of a sample plot or site (Gotelli and Colwell 2001).

Quantification of species across the five sites was done using Hill numbers (MacArthur,1965; Hill, 1973; Jost, 2006, 2007; Chao et al., 2014). Hill numbers are a mathematically unified family of diversity indices (differing among themselves only by an exponent q) that incorporate relative abundance and species richness and overcome many of these shortcomings (Chao et al., 2014). Hill (1973) showed that the converted Shannon and Gini–Simpson measures, along with species richness, are members of a continuum of diversity measures called Hill numbers, or effective number of species, defined for $q \neq 1$ as;

$$ {}^{q}D = \left(\sum_{i=1}^{S} p_i^q \right)^{1/(1-q)} \qquad \text{…………………… (Eq. 4)} $$

in which S is the number of species in the assemblage, and the i_{th} species has relative abundance p_i, $i = 1, 2, \ldots, S$. The parameter q determines the sensitivity of the measure to the relative frequencies. The measure ${}^{2}D$ can be interpreted as the number of “relatively abundant species” in the assemblage. The parameter q also determines how much the measure discounts rare species. When $q = 0$, the species abundances do not count at all, and species richness is obtained; $q = 1$, exponential of Shannon entropy is obtained; when $q = 2$, the inverse of the Simpson concentration and rare species are severely discounted. This measure weighs species in proportion to their frequency and can be interpreted as the number of “typical species” in the assemblage.

Diversity profile values (H-alpha) were calculated from the frequencies of each component species (proportional abundances pi = abundance of species i/ total abundance) and a scale parameter (α) ranging from zero to infinity as:

$$ (H_\alpha) = \left(log \sum_{i-1}^{s} pi^{\alpha}\right) \Big/ (1-\alpha) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq. 5)} $$ (Tóthmérész 1995).

Species were subjected to Kruskal-Wallis test to determine if overall species abundance significantly differed among the five sites. Dunn's posthoc test was then applied to determine which sites contributed significantly to explain the overall variations in species abundant data.

Canonical correspondence analysis (CCA) (terBraak 1986) was performed to determine the relationship between plant species distribution and environmental stressors using the Paleontological Statistical Tool Version 3 (PAST v3) (Hammer et al., 2001). CCA is a constrained ordination method, whose resulting product is the variability of the environmental data, as well as the variability of species data (Kent and Coker 1992). While spearman rank correlation test was performed to evaluate the significant relationship among environmental variables. Kruskal-Wallis test was used to evaluate for the mean differences among plant abundance, richness and diversity in the five sites, since initial test showed that plots were not normally distributed ($W = 0.249$, $P < 0.05$). Dunn's posthoc test was applied to determine which sites contributed significantly to the overall abundance distribution.

CHAPTER FOUR
4.0 RESULTS

4.1 Plant species composition as an indicator of species range shift using the Prevalence index method

Initial test for normality was performed and it showed that the data was not normally distributed ($p < 0.05$, Shapiro – Wilk test). A total of 2,185 individuals, belonging to 68 species and 32 families, were recorded across five sites (Owabi, Esaase, Bokwankye, Atafua and Ohwim). Nine plant life forms were identified and included: grasses (16%), herbs (37%), shrubs (9%), woody plants (24%), submerged (1%), sedges (6%), ferns (3%), creepers (1%), climbers (3%). A total of 16 obligate species (OBL) (e.g. *Ipomoea aquatic, Limnocharis flava, Ludwigia decurrens, Nymphaea lotus, Paspalum orbiculare, Pistia stratiotes, Typha latifolia*), were detected in 142 plots out of the 154 sampling plots, with an average of 0.1 species per plot and cumulative weighted average score of < 3 (Table 2). Obligate species (i.e. typical wetland plant) were generally less in abundance and constituted 24% of the total species recorded (Table 1). Obligate species were found to be widely distributed across all the five sites. Obligate upland species (UPL) (e.g. *Achyranthes aspera, Alchornea cordifolia, Aspilia Africana, Baphia nitida, Broussonetia papyrifera, Cassia siamea, Chromolaena odorata, Emilia sonchifolia*) were the most abundant species recorded and represented 41% of the total species sampled. Facultative wetland plant (FACW) (e.g. *Colocasia esculenta, Commelina diffusa, Cyperus esculentus, Cyperus iria, Diplazium sammatii, Eclipta alba, Ludwigia abyssinica, Ludwigia hyssopifolia*) contributed 29%, while facultative plant (FAC) and facultative upland plants constituted 26% and 29%, respectively, of the total species recorded (Table 1).

Apart from OBL species that are typical hydrophilic in nature, other species categories such as FACW, FAC, FACU and UPL have shown a significant shift towards wetter areas than drier areas (*t-test* = 5.63, $P < 0.001$), following their adaptation to water logged (wetter) areas (Figure 2). The average species per plot of these indicator statuses (FACW, FAC, FACU and UPL) ranged between 0.1 and 0.8, with a cumulative score of < 3.0. Woody plants (e.g. *Baphia nitida*, *Broussonetia papyrifera, Cassia siamea*, *Delonix regia, and Terminalia ivorensis*) were the most dominant in Owabi and Esaase sites.

4.2 Species Abundance Distribution (SAD) across the five sites

There was significant difference in species abundance across the five sites (*Hc* = 30.6, $p < 0.0003$). Dunn's post hoc test further showed significant difference between Owabi and Bokwankye ($p < 0.007$), Owabi and Atafua ($p < 0.0001$), Owabi, and Ohwim ($p < 0.0003$). Species abundance differed substantially between Esaase and Bokwankye ($p < 0.01$), Atafua ($p < 0.0003$) and Ohwim ($p < 0.0006$). The highest number of species per site was registered at Atafua site ($n = 578$, 5.67 ± SE 0.27) while the Owabi site recorded the least number of species (255, 5.10 ± SE 0.59) (Table 3). There was no significant difference in homogeneity of variance in species composition among the five sites was not significantly different (*p = 0.62, Levene's test*) (Table 4).

Although, species abundance distribution (SAD) fitted well in the log series model and depicted the general trend was not substantially different (Slope of SAD: $F_{\text{-test}} = 0.21$, p (regr): 0.93) (Table 4). However, from individual sites, there was a substantial difference in the spatial distribution of species along the slopes of the SAD curves {Esaase (slope [x] = 0.9854, $x^2P = 66.01$, $p = 0.0004$), Bokwankye (slope [x] = 0.9878, $x^2P = 42.64$, $p = 0.0005$), Atafua (slope [x] = 0.9963, $x^2P = 56.95$, $p = 0.0001$), Ohwim (slope [x] = 0.9958, $x^2P = 166.2$, $p = 0.0002$)}; with the exception of the owabi site, which displayed no difference in species distribution (slope [x] = 0.9538, x^2P = 5.777, p = 0.9998) (Table 4, Figure 3).

Comparing the SADs for the five sites helps in differentiating the environmental factors affecting the species abundance in the various sites. Therefore, the shape of the rank abundance curves typically showed the differences in the species spatial distribution and relative abundance from each of the sample plots. Thus, the Owabi site which registered less species abundance (n = 255, 5.10 ± 0.59) was more distributed spatially as indicated in its shallow rank abundance SAD curve as compared with the Atafua site with the highest species abundance (n = 578, 5.67 ± 0.27) which had a steeper rank abundance curve (Fig 3; Table 3).

Table 1. Plant species showing the application of Cronk and Siobhan-Fennessy (2001) and Tiner (1991) model to categorize species under different indicator species

Obligate wetland sp.	**Facultative wetland sp.**	**Facultative sp.**	**Facultative upland sp.**	**Obligate upland sp.**
Ceratophyllum demersum	*Acroceras zizanoides*+*	*Achyranthes aspera*+*	*Achyranthes aspera*+*	*Achyranthes aspera*+*
Colocasia esculenta	*Agerantum conizoides*+*	*Acroceras zizanoides*+*	*Agerantum conizoides*+*	*Albizia adianthifolia*+*
Cyperus alternifolius	*Axonopus compressus*+*	*Agerantum conizoides*+*	*Albizia adianthifolia*+*	*Alchornea cordifolia*+*
Eichhornia natans	*Bombax buonopozense*+*	*Alchornea cordifolia*+*	*Alchornea cordifolia*+*	*Aspilia africana*-*
Ipomoea aquatica	*Colocasia esculenta*+*	*Axonopus compressus*+*	*Asystasia gangetica*+*	*Asystasia gangetica*+*
Limnocharis flava	*Commelina diffusa*+*	*Bombax buonopozense*+*	*Baphia nitida*+*	*bambusa vulgaris*+*

Ludwigia decurrens	*Cyperus esculentus*-*	*Chromolaena odorata*+*	*Brachiaria deflexa*-*	*Baphia nitida*+*
Melothria dulcis	*Cyperus iria*+*	*Commelina benghalensis*+*	*Chromolaena odorata*+*	*Broussonetia papyrifera*+*
Nymphaea lotus	*Diplazium sammatii*+*	*Commelina diffusa*+*	*Commelina benghalensis*+*	*Cassia siamea*+*
Panicum polygonatum	*Eclipta alba*+*	*Cyperus esculentus*-*	*Hymenaea courbaril*+*	*Celtis mildbraedii*-*
Paspalum orbiculare	*Ludwigia abyssinica+*	*Cyperus iria*+*	*Imperata cylindrica*-*	*Chromolaena odorata*+*
Paspalum vaginatum	*Ludwigia hyssopifolia*+*	*Cyperus sphaceletus*+*	*Leucaena leucocephala*+*	*Combretum zenkeri*-*
Persicaria lanigera	*Luffa cylindrica*+*	*Ipomoea obscura*+*	*Ludwigia hyssopifolia*+*	*Commelina benghalensis*+*
Pistia stratiotes	*Marantochloa cordifolia*+*	*Psydrax subcordata*+*	*Mimosa pudica*+*	*Emilia sonchifolia*-*
Polygonum lanigerum	*Paspalum orbiculare+*	*Rauvolfia vomitoria*+*	*Pavonia peruviana*+*	*Ficus exasperata*-*
Typha latifolia	*Paspalum vaginatum*+*	*Sporobolus pyramidalis*+*	*Psydrax subcordata*+*	*Funtumia africana*+*
	Persicaria lanigera+*	*Stachytarpheta cayennensis*+*	*Pteridium aquilinum*+*	*Griffonia simplicifolia*+*
	Rauvolfia vomitoria+*	*Tridax procumbens*+*	*Rauvolfia vomitoria*+*	*Icacina trichantha*-*
	Sorghum arundinaceum+*		*Stachytarpheta cayennensis*+*	*Imperata cylindrica*-*
	Stachytarpheta cayennensis+*		*Tridax procumbens*+*	*Ipomoea involucrata*+*

				*Ipomoea obscura**+ *Delonix regia**- *Leucaena leucocephala**+ *Ludwigia hyssopifolia**+ *Milletia zechiana**- *Setaria barbata**+ *Terminalia ivorensis**- *Trichilia tessmanii**-
24%	**29%**	**26%**	**29%**	**41%**

The percentages at the bottom of the table describes the relative abundance of hydrophytic indicator categories (i.e. obligate wetland, facultative wetland, facultative, facultative upland and upland species) out of the total number recorded (N = 68 species). Species with asterisks '*' are dryland species. The positive sign '+' indicates the frequency of the species shifting towards wetter regions and the negative sign '-' refers to frequency of shifting towards drier areas.

Table 2. Summary of indicator species categories, representing their relative dominance on the 154 sample plots

Hydrophytic indicator status	No. of species	No. of plots dominated	Av. Species/plot	Rank
Obligate wetland species(OBL)	16	142	0.11	<3
Facultative wetland species(FACW)	20	137	0.15	<3
Facultative species(FAC)	18	37	0.49	<3
Facultative upland species(FACU)	20	75	0.27	<3
Obligate upland species(UPL)	28	33	0.85	<3

Ranks '< 3' are dominated by hydrophytes (Cronk and Fennessy, 2001).

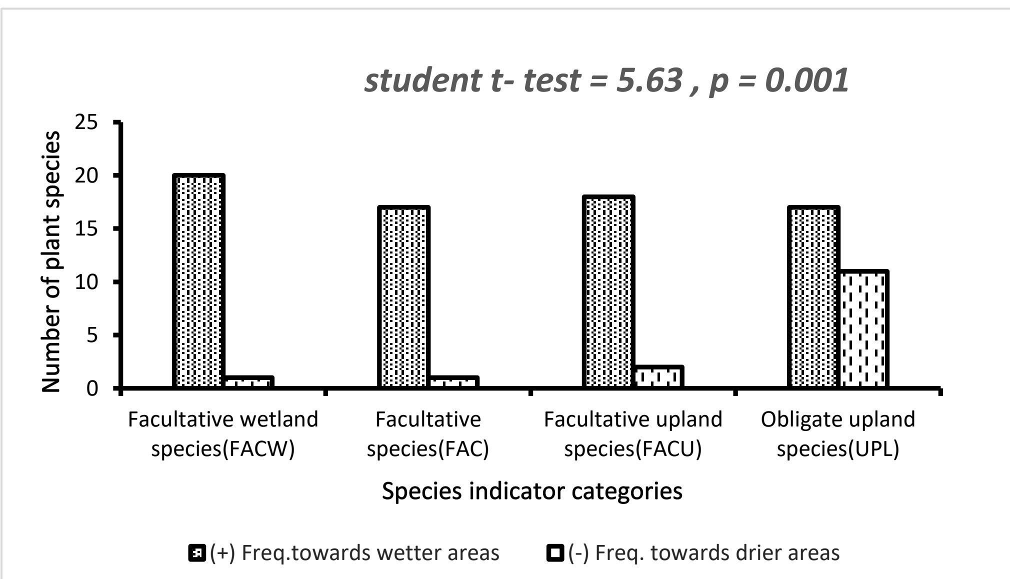

Fig. 2. Species indicator categories depicting the frequency of species shifting toward wetter and drier regions

Table 3.

Mean number of plants recorded on 154 sampling plots in the owabi wetland. *Number of species = 68*

Site	**No. of individuals**	**Mean ± SE**	**Variance (s^2)**
Owabi	255	5.10 ± 0.59	17.15
Esaase	543	4.85 ± 0.25	7.07
Bokwankye	368	4.53 ± 0.29	6.43
Atafua	578	5.67 ± 0.27	7.38
Ohwim	441	4.82 ± 0.22	4.28

Table 4*:* Results of the Log series model for the abundance rank distribution of five sites in Owabi Wildlife Sanctuary

Sites	**ά**	**χ**	**$\chi^2 p$**	**Prob.**
Owabi	12.36	0.9538	5.777	0.9998
Esaase	8.044	0.9854	66.01	0.0004
Bokwankye	4.537	0.9878	42.64	0.0005
Atafua	2.142	0.9963	56.95	0.0001
Ohwim	1.826	0.9958	166.2	0.0002

Slope of SAD: (*ANOVA,* $F_{\text{- test}}$ = 0.21, *p* (regr): 0.93)

Monte-Carlo test (*n* = 99999): (p= 0.95)

Levene's test for homogeneity of variance: (p = 0.62)

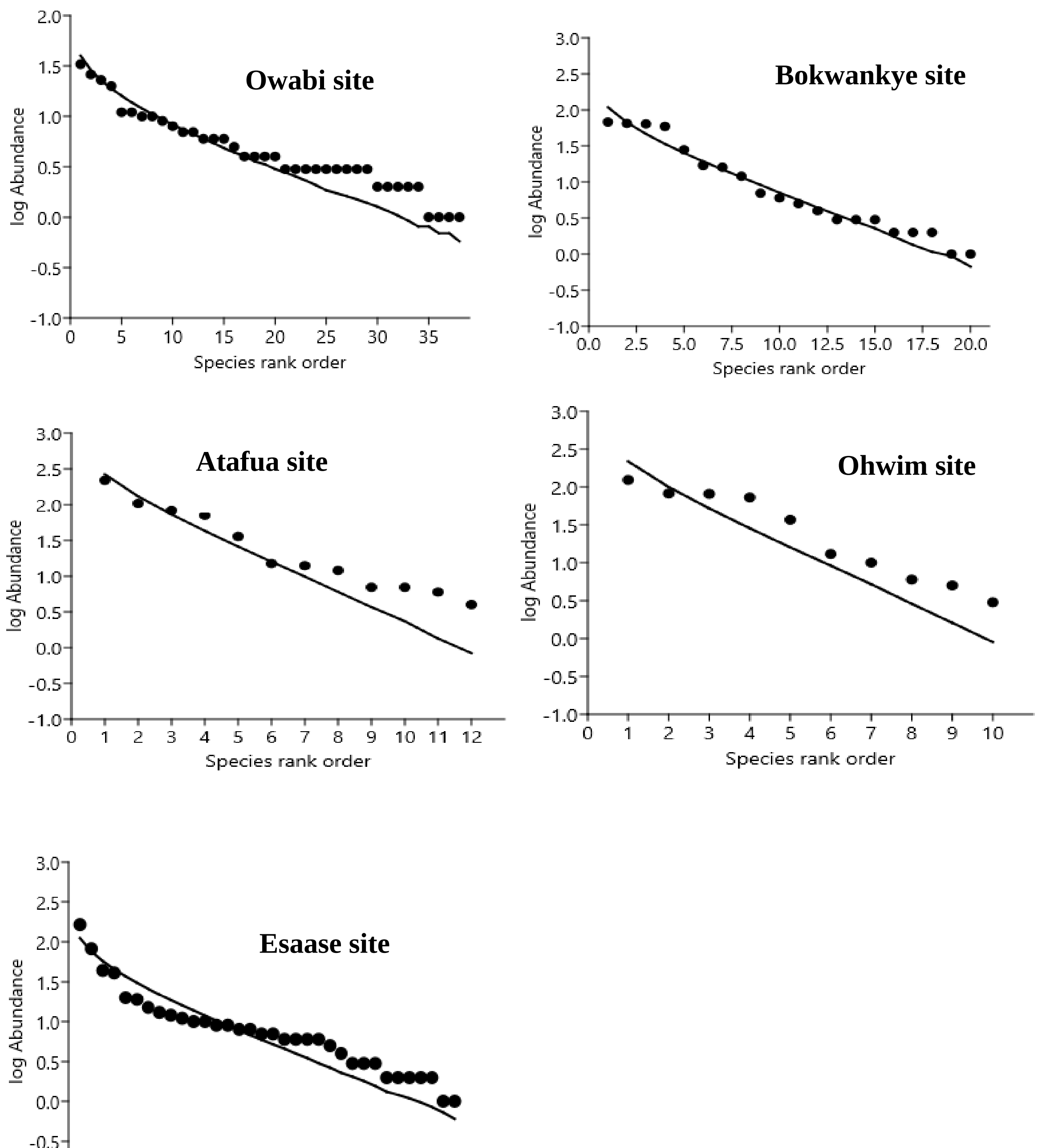

Figure 3: Log series model for species rank abundance distribution across the five sites in the owabi wetland. Abundance is based on cumulative cover values per species per sampling sites. Notice that SADs are ordered in decreasing magnitude and plotted along with their corresponding rank and in total, there was a significant difference across the five sites (*Hc* =30.6, $p < 0.0003$).

4.3 Plant species richness and diversity profiles between the five sites in the owabi wildlife sanctuary

Generally, species richness (individual-based rarefaction) showed a substantial variation among the five sites (Hc = 30.6, P < 0.0003, Kruskal-Wallis test) (Figure 4). Owabi site recorded the highest species richness (n = 38), followed by Esaase site (n = 34). The Atafua (n = 12) and Ohwim (n = 10) sites were the most species poor (Figure 4).

Overall, species diversity did not differ significantly across the five sites (Hc = 7.867, P = 0.09, Kruskal-Wallis test) (Figure 5). Difference in the profile of hill diversity numbers was associated with the spatially evenness distribution of species as indicated in SAD curves in Fig 3. The site with steeper slope appear to have low species diversity as against site with very gentle slope and least in species richness which was high in species diversity (fig 5). The five site have hill diversity numbers ranging between 1.90 and 2.59 (Fig 5: Table 5). From the hill diversity numbers, it can clearly be established that Ohwim site (with a gentle slope and ranked first) was evidently the most species diverse (D = 2.59) and the least species diverse site (D = 1.90) was the Esaase site (with the sharpest slope at the bottom of the curve) (Fig 5).

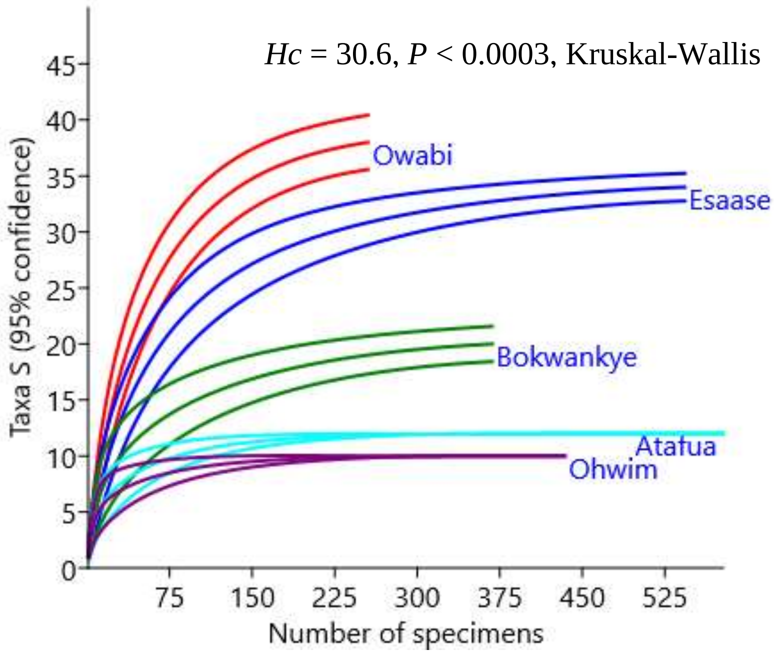

Figure 4. Standardized comparison of species richness for two individual based rarefaction curves. The data represent summary counts of plant species that were recorded across the five sites in the owabi wetland. The red, blue, green, turquois, and violet lines are the rarefaction curves, calculated from equation 3 of the rarefaction model (Gotelli and Colwell 2001).

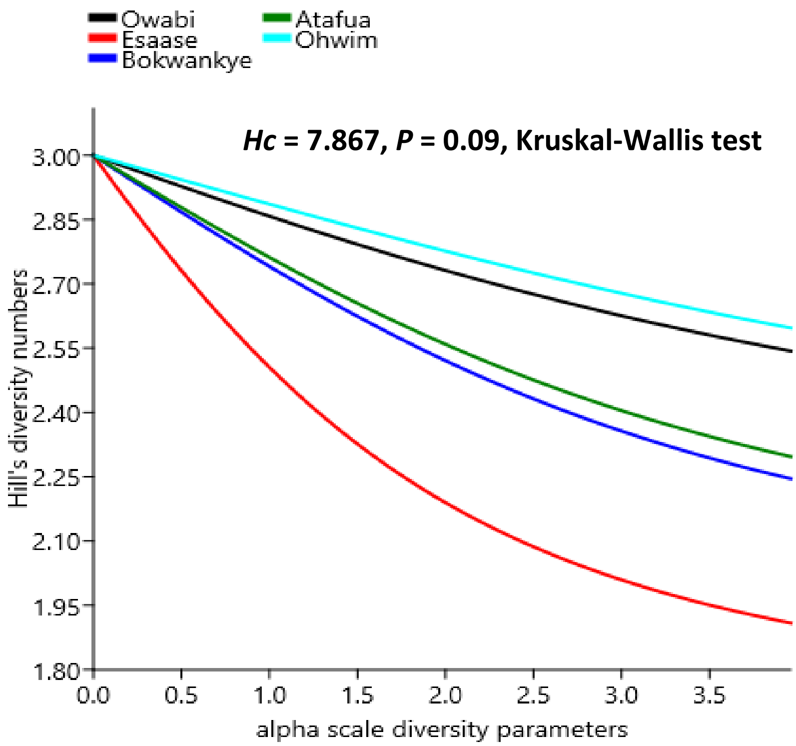

Figure 5: Hill diversity numbers that compares plant community evenness and richness in each of the sites in the owabi wetland. The shape of a site curves indicates their evenness profile. Thus, shallower shape reflects high diversity of a site, while steeper shape depicts less diversity. Notice that the Ohwim site in the turquoise blue is the shallowest curve (top most curve) and evenly distributed, while the Esaase site in the red and at the bottom of the profile curves is the steepest curve, with the least evenness distribution.

Table 5: Summary of Hill numbers (at α = 0, 1 and 2), Hill species diversity and Shannon Evenness, across the five sites in Owabi wildlife sanctuary

Alpha values	Owabi	Esaase	Bokwankye	Atafua	Ohwim
0(Number of sp.)	38	34	20	12	10
1(exp[Shannnon])	24.858	14.111	9.8426	6.2938	6.2511
2(Inv.[Gini_Simpson)	17.665	7.4685	7.4961	4.5942	5.2764
Shannon Evenness	0.8833	0.7506	0.7633	0.7403	0.796
Hill diversity numbers	2.5434	1.9088	2.2455	2.2971	2.5972

4.4 Environmental variables influencing community abundance distribution and diversity across the five sites

Over all observation of the CCA ordination diagram shows information on the community structural abundance, mediated by environmental changes across the five sites (Fig 6). It can be noticed from the ordination diagram that farming activities ($r = 0.25$, $p < 0.05$), ammonia (NH_4+) ($r = -0.24$, $p < 0.05$) on axis 1and dissolved oxygen (DO) ($r = 0.34$, $p < 0.05$), phosphate (PO_4) ($r = 0.51$, $p < 0.05$) and nitrate (NO_3-N) ($r = 0.38$, $p < 0.05$) on axis 2, were the major environmental factors that significantly influenced community composition and distribution patterns (Figure 6; Table 6).

Axes I (49.29%) and II (22.72%) jointly accounted for 72.01% of the variations in the weighted averages of the 68 species with reference to the 11 environmental factors across the five sites (Figure 6; Table 6). Following the recommendation of ter Braak (1986), axis III was not taken into account, since axes I and II accounted for more than 50% of variations in the community composition. Obligate wetland species (OBL) such as the *ipomoea aquatica*, *Paspalum orbiculare*, *Limnocharis flava, Colocasia esculenta* and facultative wetland species (FACW) like *Eclipta alba*, *Ludwigia hyssopifolia, Luffa cylindrica* in Bokwankye, Atafua and Ohwim sites had a negatively correlated with conductivity, ammonium and positively with farming activities on axis 1 (Fig 6).

Nitrate was found to have a significant correlation with TDS (r_p = -1, $p < 0.05$) and pH (r_p = -0.9, $p < 0.05$) (Table 7). Widespread farming activities at Ohwim site, correlated positively with TDS (r = 0.783), pH (r = 0.895), turbidity (r = 0.895) and negatively with nitrate (r = -0.783) and DO (r = -0.516) (Table 7). The owabi site, which had high levels of phosphate, dissolved oxygen, nitrate concentration, and bare ground may be due to the presence of in-situ human influences such as fishing activities and fish processing, walking trails and recreation activities such as picnic and bird viewing. Owabi wetland tends to receive volumes of solid and liquid in-flows from the numerous streams from the remaining four sites that drains into it. pH of the water was weak acidic to basic with an average from 6.4 – 7.8 and correlated well with phosphate (r_p = -0.9, $p < 0.05$), turbidity (r_p = 0.9, $p < 0.05$), nitrate (r_p = -0.9, $p < 0.05$) and ammonium (r_p = 0.7, $p < 0.05$). Although obligate wetland species dominated majority of sampling plots across the five sites (n = 142 plots) (Table 2), the highest percentage of species categorization recorded was the obligate upland species (41%) (Table 1). The CCA diagram did not show a bulk of species that grew in habitat with average conditions of the environmental variables assessed. Some common species (e.g. *Paspalum orbiculare*, *Pteridium aquilinum and Baphia nitida*) found across all site and near the centre of the CCA diagram indicates their ability to grow well in all environmental factors considered in the analysis.

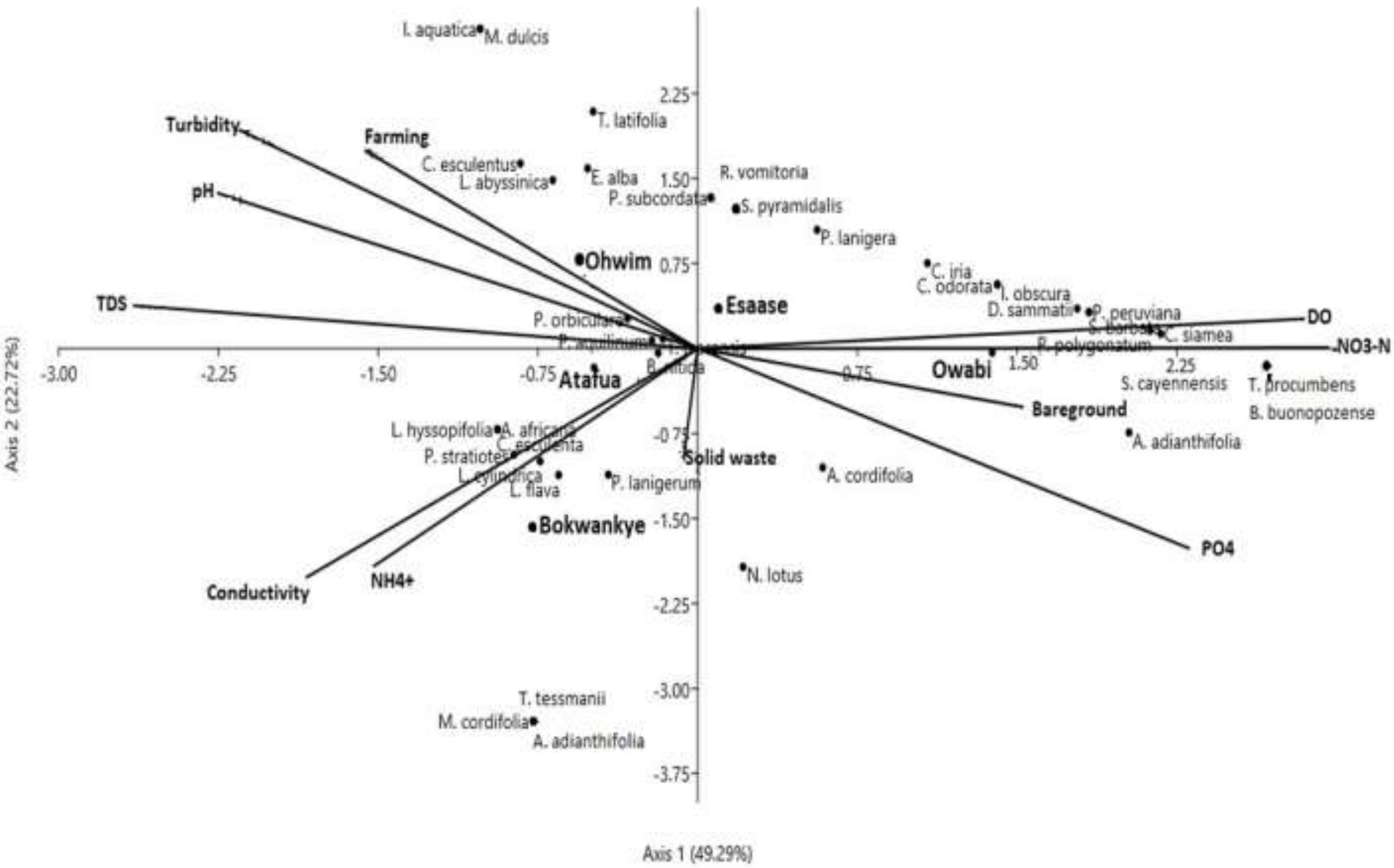

Figure 6. Canonical correspondence analysis (CCA) ordination diagram, showing the relationship between environmental variations and plant species across the five sites (Owabi, Esaase, Bokwankye, Atafua and Ohwim). The small dots represent the plant species recorded and thick lines reflects each of the environmental variables

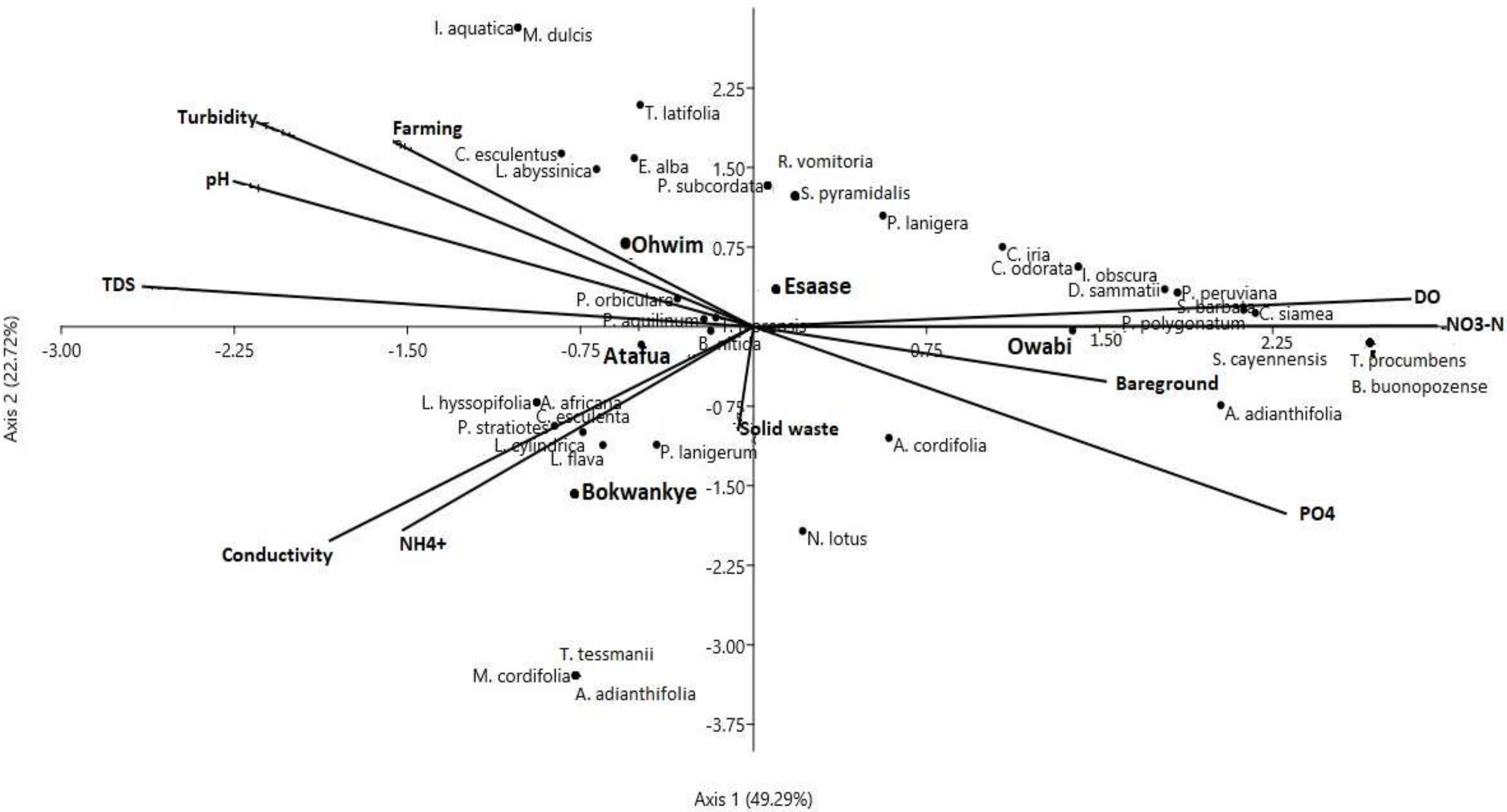

Figure 6. Canonical correspondence analysis (CCA) ordination diagram, showing the relationship between environmental variables and plant species across the five sites (Owabi, Esaase, Bokwankye, Atafua and Ohwim). The small round black dots represent the plant species recorded and thick lines represents each of the environmental variables.

Table 6: Summary of CCA axis length showing the levels of correlation between axes and environmental gradients, percentage variance of species and species–environment relationships. Asterisks (*) indicate environmental variables that were significant ($p<0.05$)

Variance and Eigenvalues	**Axis I**	**Axis II**
Canonical Eigenvalue	0.518	0.237
Morte- Carlo P	0.607	0.853
Cumulative % variance	49.29	22.72
% variance explained (72.01%)	49.29	72.01
Correlations		
Farming	0.25*	-0.19
Bareground	0.09	0.15
Solid waste	0.10	0.04
DO	0.16	0.34*
Conductivity	-0.09	0.01
TDS	0.07	-0.10
pH	0.10	0.01
Turbidity	0.08	0.06
NH4+	-0.24*	-0.18
PO4	-0.02	0.51*
NO3-N	0.21	0.38*

Table 7: Summary of Spearman rank (r_s) correlation matrix between the environmental factors in Owabi wildlife sanctuary. Significance of *R*-values: $*p < 0.05$

	Farming	**Bareground**	**Solid waste**	**DO**	**Conductivity**	**TDS**	**pH**	**Turbidity**	**NH4+**	**PO4**	**NO3-N**
Farming		0	0.395	-0.516	0.112	0.783	0.895	0.895	0.335	-0.895	-0.783
Bareground			0.408	0.592	0	0	-0.289	-0.289	-0.579	0.289	0
Solid waste				-0.363	0	0.354	0.354	0	0.354	0	-0.354
DO					-0.410	-0.667	-0.821	-0.564	-0.975*	0.564	0.667
Conductivity						0.7	0.4	0.3	0.5	-0.3	-0.7
TDS							0.9*	0.8	0.6	-0.8	-1*
pH								0.9*	0.7	-0.9*	-0.9*
Turbidity									0.4	-1*	-0.8
NH4+										-0.4	-0.6
PO4											0.8
NO3-N											

CHAPTER FIVE

5.0 DISCUSSION

Several studies on wetland ecosystems have shown that modifications in the community assemblages of wetland vegetation were mainly attributed to phosphate from agriculture activities (Millenium Ecosystem Assessment, 2005), fire (Wuver et al., 2003), soil characteristics (Kirkman et al., 2000), hydrological factors like duration and depth of flooding (Patten 1998) and sewage and industrial waste (Lambert and Davy, 2010) occurring in and around the wetland at a particular point in time. In this research, farming activities, ammonia (NH_4+), dissolved oxygen (DO), phosphate (PO_4), nitrate (NO_3-N) were the major environmental factors that have significant influence on the plant community composition, diversity and distribution patterns as indicated on the CCA diagram. Relative to some of the earlier studies, the differences in findings may be due to the different environmental variables dominating the different biogeographical sites. According to Hulme (2003), the interactions between the disturbances and biotic factors in a system may possibly prevail over climatic variability in explaining species distribution. From the assessment of the relationship that existed between plants and their environments, it was noticed that the first two axes of the CCA ordination accounted for 72.01% of the explained variance in species richness, diversity and distribution, while the remaining 27.99% not accounted for in the explainable variance, could be as a result of the presence of other natural drivers of change such as climate change. Through the findings of this study, the functional status of the owabi wetland could be compromised through the alteration of its hydrological processes, introduction alien invasive species and plant gene pool destruction. Occurrence of these alien species (e.g. *Chromolaena odorata, Alchornea cordifolia and Baphia nitida*), have equally been reported in disturbed aquatic systems in some humid parts of Ghana (Anning and Yeboah-Gyan, 2007).

According to Fennessy et al. (1998), ecological variables can be a means of classifying suite of species and communities that are significant indicators of crucial variations in their ecosystem. Estimating the relative abundance of hydrophytes is a way of assessing the functional status of a wetland, which implies that the low abundance as compared with the other indicator categories (i.e. FACW, FAC, FACU and UPL) in this research was evidenced of the high human-led actions on the wetland functions. For example, the widespread distribution of solid waste across all five sites may have influenced diversity in all sites, despite the high abundance at the Owabi, Esaase and Bokwankye sites. The non-uniform distribution of species, which may cause a rise in competition for resources in a niche space. Nsor et al. (2019) confirmed these findings. According to Mathooko and Kariuki (2000), human and wildlife activities are main cause of an array of disturbances in the wetland vegetation zone and some of the evidence from a combination of the disturbances include loss of wetland vegetation, introduction of alien invasive species and increased or decreased plant diversity. Phosphate and nitrate concentration in the water may be due to fish processing along the edge of the wetland and dumping of the residue into the water. High levels aquatic nutrients in general can be attributed to the different streams that drains into the Owabi wetland and some of which flow through urban, industrial and farming areas. The rapid growth of *Cyperus* species may be attributed to the combined influence of phosphorus and potassium as these nutrients are the driving force in *Cyperus papyrus*- dominated vegetation community (Vellend et al., 2000).

From field discussions with fisher folks, although not scientifically established, but through local observation, they have seen a drastic reduction in the depth and volume of water because of the high inflow of solid and liquid waste, which was not the case some seven years ago. This may have resulted in the growth and development of *Paspalum orbiculare* all-round the periphery of the wetland, due the increase in the nutrient loads in the water.

Farming practices around the highland sections of Ohwim and its neighboring villages, could in the near future affect species diversity since some species may not be able to withstand the pressure from this form of disturbance. Secondly, consistent farming may also allow the establishment of invasive alien species and making these new species more competitive over the native species (Nsor et al., 2019). Ssegawa et al. (2004), found out crop farming in Ugandan wetlands is a vital cause of species composition and structural distribution whereas these practices are the leading cause of loss of wetland plants that are crucial to wetland ecosystem services in the Ethiopian wetlands (Mulatu et al., 2004).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

In total, plant diversity was moderately high. Due to the high levels of anthropogenic activities, although species richness was high there was unevenness in species distribution. Farming activities, NH_4+, DO, PO_4 and NO_3- were the major predictors of species range shift, spatial distribution and species diversity. Relatively, obligate upland species (UPL), facultative upland species (FACU) and facultative species (FAC) were more than the obligate species suggesting the impact of human interference on the ongoing range shift of native species out of their natural ranges and their replacement with upland species. Although some heterogeneous vegetation has been created because of the ecological disturbances in the Owabi wetland, the total negative effect if this heterogeneous community seems to overshadow its positive aspects. This phenomenon arises from the majority of species recorded in this study being typical upland species that have adapted morphologically and physiologically to grow well in the wetland conditions. The ubiquitous species recorded in this study can also serve as indicator species in monitoring their resilience to anthropogenic activities. Meanwhile, having a suite of hydrophytes as indicators to measure the functional status of the owabi wetland will be worthwhile.

Recommendation

1. Further detailed studies should be conducted to determine how anthropogenic activities are affecting keystone hydrophytes in the Owabi wetland, considering both dry and wet seasons.
2. There should be solidarity among stakeholders and more resources (education, finances and law enforcement) should be committed to the proper management and conservation of

this delicate but important inland Ramsar site and wetland to protect it from further destructions.

3. There should be a study on the economic value of the Owabi wildlife sanctuary to help in its conservative measures.

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APPENDIX A

FIELD PICTURES

UPSTREAMS

DOWNSTREAMS

APPENDIX B
SAMPLE DATA SHEET

PLOT NUMBER	SPECIES	PLANT HEIGHT (CM)	% FOLIAGE COVER	NUMBER OF INDIVIDUALS	NUMBER OF SPECIES	QUADRATS SIZE	WAYPOINT	NAME/ ID	FAMILY

Appendix C

Number of individuals sampled across the five sites in the owabi wildlife sanctuary

Family and species	Owabi site	Esaase site	Bokwankye site	Ohwim Site	Atafua site
Acanthaceae					
Asystasia gangetica	3	0	0	0	0
Alismataceae					
Limnocharis flava	0	2	2	4	0
Amaranthaceae					
Achyranthes aspera	2	0	0	0	0
Apocynaceae					
Funtumia africana	0	0	2	0	0
Rauvolfia vomitoria	0	2	0	0	0
Araceae					
Colocasia esculenta	0	0	0	14	0
Pistia stratiotes	0	6	59	83	37
Asteraceae					
Agerantum conizoides	1	0	0	0	0
Aspilia africana	0	0	0	15	0
Chromolaena odorata	5	10	0	0	0
Eclipta alba	0	19	0	7	13
Emilia sonchifolia	2	0	0	0	0

Tridax procumbens	3	0	0	0	0
Athyraceae					
Diplazium sammatii	10	11	0	0	0
Bombacaceae					
Bombax buonopozense	3	0	0	0	0
Ceratophyllaceae					
Ceratophyllum demersum	0	2	0	0	0
Combretaceae					
Combretum zenkeri	0	12	0	0	0
Terminalia ivorensis	0	4	1	0	0
Commelinaceae					
Commelina benghalensis	11	0	0	0	0
Commelina diffusa	6	0	0	0	0
Convolvulaceae					
Ipomoea aquatica	0	0	0	0	6
Ipomoea involucrata	3	0	0	0	0
Ipomoea obscura	4	8	0	0	0
Cucurbitaceae					
Luffa cylindrica	0	3	3	12	0
Melothria dulcis	0	0	0	0	3
Cyperaceae					
Cyperus alternifolius	0	9	0	0	0
Cyperus esculentus	2	2	12	6	73

Cyperus iria	3	10	0	0	0
Cyperus sphaceletus	0	7	0	0	0
Dennstaedtiaceae					
Pteridium aquilinum	26	82	64	71	81
Euphorbiaceae					
Alchornea cordifolia	9	15	16	0	0
Fabaceae					
Albizia adianthifolia	3	0	1	0	0
Baphia nitida	0	7	2	0	0
Cassia siamea	10	5	0	0	0
Delonix regia	0	1	0	0	0
Griffonia simplicifolia	0	0	4	0	0
Hymenaea courbaril	0	1	0	0	0
Leucaena leucocephala	1	0	0	0	0
Milletia zechiana	0	2	0	0	0
Icacinaceae					
Icacina trichantha	7	0	0	0	0
Malvaceae					
Pavonia peruviana	6	6	0	0	0
Marantaceae					
Marantochloa cordifolia	0	0	6	0	0
Meliaceae					

Trichilia tessmanii	0	0	3	0	0
Mimosaceae					
Mimosa pudica	1	0	0	0	0
Moraceae					
Broussonetia papyrifera	3	0	0	0	0
Ficus exasperata	0	0	5	0	0
Nymphaeaceae					
Nymphaea lotus	8	8	28	0	0
Onagraceae					
Ludwigia abyssinica	2	41	7	36	82
Ludwigia decurrens	0	0	17	0	0
Ludwigia hyssopifolia	0	0	0	7	0
Poaceae					
Acroceras zizanoides	3	0	0	0	0
Axonopus compressus	6	0	0	0	0
Bambusa vulgaris	0	0	3	0	0
Brachiaria deflexa	4	0	0	0	0
Panicum polygonatum	23	13	0	0	0
Paspalum orbiculare	33	164	65	219	131
Paspalum vaginatum	7	0	0	0	0
Setaria barbata	20	20	0	0	0
Sorghum arundinaceum	3	0	0	0	0

Sporobolus pyramidalis	4	0	0	0	0
Polygonaceae					
Persicaria lanigera	1	9	0	0	0
Polygonum lanigerum	11	44	68	104	10
Pontederiaceae					
Eichhornia natans	0	3	0	0	0
Rubiaceae					
Psydrax subcordata	0	3	0	0	0
Typhaceae					
Typha latifolia	0	6	0	0	5
Ulmaceae					
Celtis mildbraedii	0	6	0	0	0
Verbenaceae					
Stachytarpheta cayennensis	2	0	0	0	0