RESEARCH PAPER

A comparative identification and species characteristics of aquatic macrophytes for dry and rainy seasons of the floodplains of river Benue at Makurdi

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Abstract

An survey experiment was conducted during the dry (March- April) and the rainy seasons (June-August) of 2013 in the floodplains of River Benue in the streams, ponds, main drainage channels and marshy areas within Makurdi metropolis to determine the prominent aquatic macrophytes infesting these areas, their distribution and species characteristics in nine (9) locations. Macrophyte survey was carried out based on a combination of transects (WISER, 2011). In each transect all species and ecological groups (emergent and floating-leaved plants) were recorded. A total of 31 aquatic macrophytes were identified. Of all the macrophyte species identified, those belonging to the families *Cyperaceae Onagraceae, Poaceae* and *Pontederiaceae* respectively were the dominant group found and most distributed in the sample locations, however, Water hyacinth (*Eicchornia crassipes),* was observed to be the single most distributed macrophyte specie. The dry season recorded significantly higher (p<0.05) number of macrophytes in all the locations compared to the rainy season. River Benue recorded significantly higher (p<0.05) number of macrophyte species both in the dry and rainy seasons. At Makurdi Industrial Layout, even though *Eicchornia crassipes* recorded a comparatively less MA (4), the FO (100%) and DI (100%) was observed to be the same as in Adubu and New Bridge Abattoir while the RF was 57.1%. The Simpson's divertsity index (SDI) results indicated the following order: River Benue 0.92% > Berbesa 0.86% > Tyumugh 0.84% > University Agriculture Annex, Katsina-ala street 0.81% > Adubu 0.79% > Benue Bottling Company (BBL) 0.77%.

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Introduction

Freshwater bodies (such as River Benue) constitute a vital component of a wide variety of living environments as integral water resource base in many human societies of tropical Africa. They have been regarded as key strategic resources essential for sustaining human livelihood, promoting economic development and maintaining the environment (UNWDR, 2005).

Rivers have always been the most important freshwater resources (Vyas *et al.,* 2012). Rivers and streams play an important role in human development and are important natural potential sources of irrigation water (Ladu *et al.,* 2012). The Fresh wetlands in Nigeria are Niger delta, Niger River, Benue River, Cross river and Imo River, Ogun-Osun River, and Lake Chad.

The Benue River is the longest tributary of river Niger, about 1,083 km in length. It rises from northern Cameroon as the Bénoué at about 1,340 m and in its first 240 km, descends more than 600m over many falls and rapids, the rest of its course being largely uninterrupted (Enclopeadia Britanica 2012).. A considerable volume of imports (particularly petroleum) is transported by river, and cotton and peanuts (groundnuts) are exported in the same way from the Chad region between Yola and Makurdi. The Benue River is joined by the Gongola, and it then flows east and south for about 480 km.

River Benue contains rich Fadama areas. The Fadama area (flooplains) provides good fertile land for commercial vegetable, cereal (maize, rice,) and cassava production and livestock grazing respectively. Local fishing activities are also carried out daily. The flood plains of River Benue is one of the richest areas in the State for its land, recreation and water resources, with the key commercial activities being grazing, agriculture,and fishing. This has provided gainful employment for inhabitant settlers along its fringes, yet, its habitat and biodiversity are recognized to be under serious threat by aquatic weed infestation, like in many others at global level (Revenga and Kura 2003; Leveque *et al.* 2005; Dudgeon *et al.* 2006)

Aquatic weed infestation of water bodies is a worldwide problem (Adesina *et al.,* 2011). Aloo *et al.,* (2013) reported that aquatic weeds are higher plants that grow in water or in wet soils. They usually occur along the shores of water bodies like dams, lakes and along rivers and river mouths. Aquatic plants develop explosively large population only when the environrnment is altered either physically or through the introduction of pollutants (Okayi and Abe 2001).

The aquatic macrophytes are important components of freshwater ecosystems because they enhance the physical structure of habitats and biological complexity, which increases biodiversity within littoral zones (Estevez, 1998; Wetzel 2001; Agostinho *et al.* 2007, Pelicice *et al.* 2008). They are an important part of the aquatic food web of water bodies as they play an important role in aquatic systems worldwide because they provide food and habitat to fish, wildlife and aquatic organisms (Gross, 2003). Lembi (2003) summarized problems associated with excessive aquatic plant density as follows: Impairment or prevention of recreational activities such as swimming, fishing, and boating, excessive densities and biomass can also result in stunted fish growth and overpopulation of small-bodied fishes because the production of too much vegetative cover prevents effective predation of small fish by larger fish. Excessive aquatic plant growths decrease localized dissolved oxygen levels, which can cause fish kills. Oxygen levels are affected by the Diel cycle of photosynthesis (oxygen levels are high during the day) and respiration (night-time oxygen levels are depleted)

Other problems associated with excessive plant growth include provision of stagnant habitat ideal for mosquito breeding; certain algae can impart foul tastes and odors to the water, and can produce substances toxic to fish and wildlife. Plants impede

water flow in ditches, canals, and culverts and cause water to back up, deposition of dead organic matter can cause the gradual filling in of water bodies, nutrients, particularly organic carbon and phosphorus, released from senescent plants into the water can result in algal blooms, excessive growth can lower property values and decrease aesthetic appeal, and invasion of nonnative plants (i.e., invasive species) can cause shifts in community structure and function that may negatively impact native animal and plant species.

Since 1984, aquatic weeds, especially Water hyacinth (*Eicchornia crassipes)* and Cattail (*Typha* spp.) have increasingly invaded and spread in Nigeria's major rivers, streams and lakes (Ofoeze and Akinyemiju, 2002, Avav *et. al,* 2010). *Typha* infestation is a major problem of water resource management in the wetlands of the Chad Basin, Hadejia-Jama'are and the Sokoto-Rima river basins in the northern states of Nigeria (Bdliya *et. al,* 2006). Water hyacinth was first observed on River Benue at Makurdi in 1988 (Avav, Personal Communication).

In Nigeria, aquatic weed infestation in inland waters is increasing geometrically (Uka *et. al*, 2007). The spread is augmented by anthropogenic activities like the use of fertilizers and organic manures in farming and dumping of wastes in water bodies and channels. Aquatic weeds respond to the high level of nutrient in urban, industrial and municipal wastewater (Barret and Farno, 1982). Therefore, this study was carried out to identify the prominent aquatic macrophytes and their density, distribution and to determine the anthropogenic activities that augment the spread of aquatic weeds in the flood plains of the River Benue.

Materials and methods
A survey was conducted during the dry season (March- April) and the rainy season (June – August) of 2013 in the floodplains of River Benue in the streams, ponds, main drainage channels and marshy areas within Makurdi metropolis (River Benue with an area of 4249585. 935m² and 433 sampling points);

Adubu (area of 164,636. 405m² and 17 sampling points); Berbesa (area of 26, 115.382m² and 11 sampling points); Tyumugh (area of 7,294. 422m² and 3 sampling points); Agongul (area of 23,759.601m² and 8 sampling points); New Makurdi Bridge Abattoir (area of 155,811.547m² and 16 sampling points); Katsinal-ala Street Makurdi (area of 132,735.657m² and 12 sampling points); Benue Bottling Company (BBL) (area of 45,515. 212m² and 15 sampling points) and Makurdi Industrial Layout(11,183.010m² and 4 sampling points), to determine the prominent aquatic macrophytes infesting these areas and their distribution.

Macrophyte survey was carried out based on a combination of transects (WISER, 2011). The method consisted of establishing transects (sectors) perpendicular to the shoreline, with a length covering the complete depth range of the macrophyte occurrence in the streams, ponds, main drainage channels and marshy areas, to estimate the quantitative and maximum colonization depth of each species identified within the transects. In each transect all species and ecological groups (emergent and floating-leaved plants) were recorded. Transects were marked out using tall pegs, measuring tape and a handheld GARMIN product Global Positioning System (GPS), (Model GPS MAP 76 CSx), (Hugh, 2002). Water depth was determined using a calibrated deep stick. The GPS unit was used to provide coordinates for the grid (all the locations) which consisted of 544 sites (Fig. 1), all laid out at equal spacing of either 50 meters or 100 meters apart, between all points to ensure thorough coverage and to locate sampling sites while in the field. The shape of the water bodies and the size of the littoral zone were the two factors used to determine the number of sites/points and their spacing (Swenson *et al.,* 2008).

In River Benue and BBL Macrophytes were investigated in two depth zones (0-1 m, 1-2 m), using a canoe to move from one point to another (Toivonen and Huttunen 1995, Heegaard *et al.* 2001). Movement by the canoe was achieved by slowly

paddling through areas that supported aquatic macrophytes, recording all macrophytes present based on visual observations (Capers *et al.,* 2009), while for Adubu, Berbesa, Tyumugh, Agongul, New Makurdi Bridge Abattoir, University of Agriculture Annex Katsinal-ala Street, and Makurdi Industrial Layout, the depth zone investigated was restricted to only one (0.4-1m) mainly due to the shallow and stagnant water conditions of these areas which depths could not sustain a canoe, and involved physically moving from one point to another. This was achieved by moving perpendicular from the shoreline to just beyond the maximum depth of aquatic plant growth throughout to measure plant densities and population composition (species identification) in quadrats placed in regular intervals along the line. These quadrats were 1 square meter (Primer, 2005). Macrophyte abundance was estimated based on the WISER, (2011) and five-point Kohler Scale (1978), (from 1 – Rare species to 5 – Dominant species).

The weeds which could not be identified on site were collected by hand and samples placed in a 250µm mesh net and all sediments removed from the sample by washing in the water at the point where the samples were collected (Mormul, *et al.,* 2010), specimens were covered with wet paper sheets and placed in a sealed plastic bag, kept cold in a cooler box and transported to the Crop and Environmental Protection Laboratory of Federal University of Agriculture, Makurdi, for identification, (Lynch, 2009; Mormul, *et al.,* 2010). The modified method of macrophyte collection by Wood (1975) was used. The method involved collection of plant species with their flowers, seeds and roots by hand collection around the lakes.

Macrophytes were identified and classified according to their life forms (Crow and Hellquist 2006), because each life form colonizes and uses water and sediment resources quite differently and different life forms occupy distinct positions in the water column (free floating, and emergent), have different access to light and nutrients, sediment and/or water column

(Mormul, *et al.,* 2010). An identification of the macrophytes was carried out using *A Handbook of West African Weeds* by Akobundu and Agyakwa (1987), Western Weeds: *A Guide to the weeds of Western Australia by* Hussey *et al.,* (2007), MCIAP, (2007), National Pest Plant Accord (2008), *A Field Guide to Common Aquatic Plants of Pennsylvania* (2009) and *Biology and Control of Aquatic Weeds: Best Management Practices* by Gettys *et. al.,* (2009).

Equipment used for the Survey

Boat, suitable for local conditions, with appropriate safety equipment from National Inland Waterways Authority (NIWA), Makurdi office, ropes and anchors,global Positioning System (GPS), rakes with extendable rod for sampling submerged weeds, floating rope and/or measuring tape, sticks for transect marking, calibrated dip stick for measuring depth of plant growth, 250µm mesh net, cooler box

Data collected

Parameters observed were;

Surface area (m^2) of the water bodies, altitude of the Benue River (m), start- point depth (m) using a calibrated dip stick, end-point depth (m) using a calibrated dip stick. Other parameters include:

Floristic Inventory: Based on a list of species present, observations and/or sampling from the shore or a boat (Palmer *et al.* 1992, Toivonen and Huttunen 1995, Heegaard *et al.* 2001). The taxonomic composition was taken on;

Distribution and Vegetation (mapped at the peak of the vegetation season (June-August) using the Global Positioning System for mapping purposes (Jäger *et al.* 2004, Ciecierska, 2008).

Macrophyte Abundance **(MA)** measured using a descriptive scale (Rare, Occasional, Frequent, Abundant, Dominant, using the Kohler scale of 1 to 5, where 1= Rare and 5= Dominant, (WISER, 2011 and Kohler, 1978).

Frequency of occurrence: The frequency of occurrence (**FO**) value is a measure of the percent of the points sampled that had vegetation. This parameter measured the proportion of points where each species was present and was calculated as (s/N)*100, where **s** is the number of points where the species is present and **N** is the total number of points surveyed (LARE-TIER II, 2010).

Relative frequency: **(RF)** Relative frequency allows us to see what the frequency of macrophyte specie is, compared to the other plants, without taking into account the number of sites. It is calculated by dividing the number of times a plant is sampled to the total of all plants sampled (Williamson and Kelsey, 2009). The relative frequency of all plants will add to 100%.

Dominance index: **(DI)** This measure combined frequency of occurrence and relative abundance into a dominance value that characterized how dominant any species was within the macrophyte community. This was calculated as:

((Σra-z)/(N*rmax))*100, where r was the abundance score for a species at each point, summed from points numbered from a to z, rmax was the theoretical maximum abundance score of 5, and N was the total number of points surveyed (LARE-TIER II, 2010; Williamson and Kelsey, 2009)..

Simpson's diversity index **(SDI)**: quantifies biodiversity. It measures the probability that two individuals randomly selected from a sample belong to the same species or some other species (diversity of the plant community), Where D = Simpson's Diversity, n= the total number of organisms of a particular species, N=the total number of organisms of all species. This value can range from 0 to 1.0. The greater the value, the more diverse the plant is (Williamson and Kelsey, 2009; CEN 2003).

It is expressed as D= $\frac{1-\Sigma n(n-1)}{N\ (N-1)}$

Aquatic vegetation analysis was confined to the assessment of species abundance, frequency of occurrence, relative abundance, dominance index and Simpson's Diversity Index.

Data Analysis

GenStat statistical tool (Discovery Edition 4), was used to carry out a One-way analysis of variance (ANOVA) as indicated by Wood (1975) to test for significant differences in macrophyte number in the dry and rainy seasons and between or among the locations surveyed (Idowu and Gadzama, 2011).

Results and discussion

Identification of Aquatic Macrophytes

A total of 31 aquatic macrophtytes representing 19 families were identified in the floodplains of River Benue during the two prominent seasons (Rainy and Dry) of 2013. (Tables 1 and 2; Fig. 1). No submerged macrophytes were present in all the sample locations. The absence of submerged macrophytes in Adubu, Tyumugh, Berbesa, New Bridge Abattoir, University of Agriculture Annex, Katsina-ala Street and Industrial Layout must have been because of the dense mats of *Eicchornia crassipes* which inhibited or prevented light penetration into the water (Uka *et al.,* 2009; Gross, 2003), and the turbid nature of water in these waters (UNEP, 2008) while their absence in River Benue and BBL may be attributed to the sandy soil nature which are also very poor in organic matter content such that rooting, support and nutrient supply to submerged macrophytes may not have been possible or too limited to ensure the emergence or growth of submerged macrophytes.

Compared to the rainy season (Table 2), River Benue recorded significantly higher (p<0.05) number (18) of macrophyte species in the dry season than in the other 8 locations surveyed. This was followed by Berbesa and Tyumugh (9 each), Agongul (6), Adubu (5) and New Bridge Abattoir (6) respectively (Fig. 2). Peterson and Lee, (2005) observed that aquatic weed problems typically occur in clear, shallow water that is high in nutrients. The comparatively higher

number of macropyhtes species in River Benue may be as a result of the river's fertility status or larger/longer size and that of its catchment and the drainage patterns and type of activities along the catchment. This collaborates the findings of Wandell, (2007) who reported that a lake's (or water body's) fertility and therefore its amount of aquatic plant is greatly influenced by its watershed characteristics and size, topography, soil fertility, drainage patterns and land use. These watershed characteristics determine the quantity of nutrients such as nitrogen and phosphorus that will be washed into the water body from land to stimulate plant growth. Generally, the larger the watershed, the greater the inflow of nutrients.

Figure 1. Map of Makurdi Showing Study Area
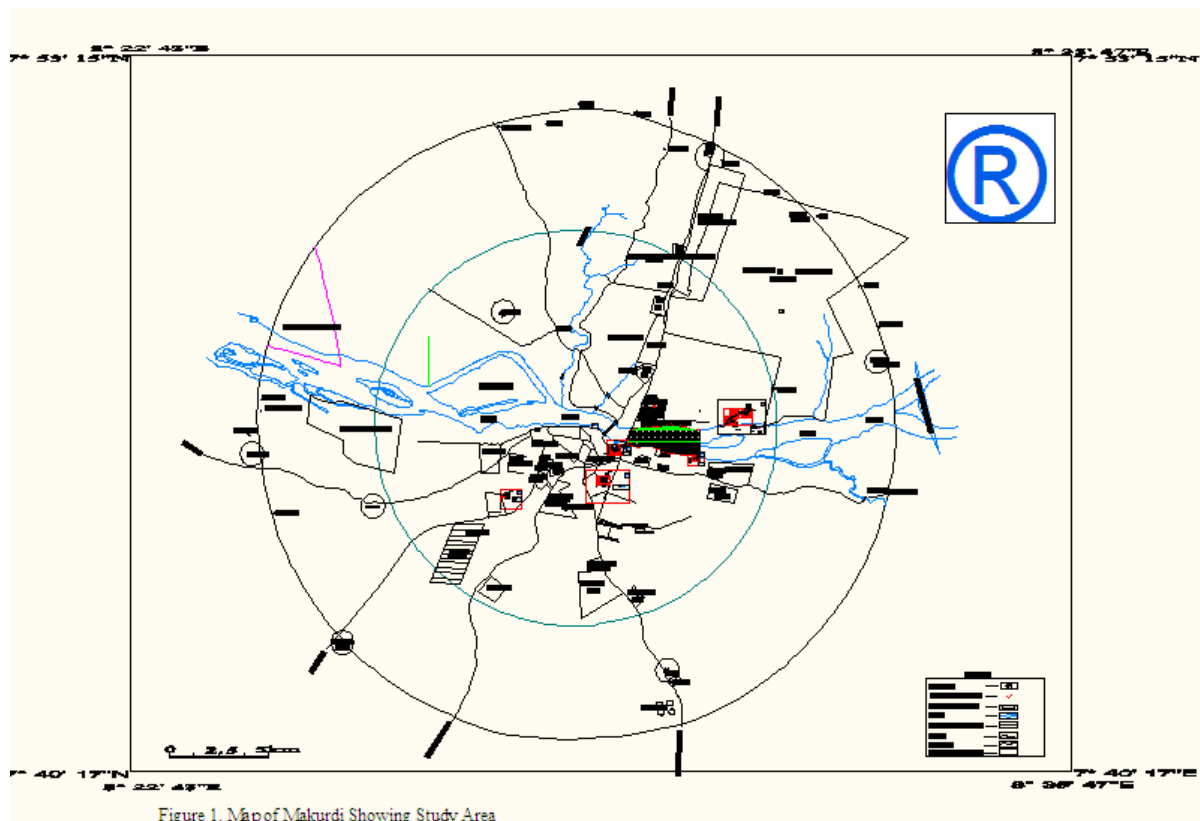
Common Anthropogenic Activities

This research observation found that more than at any of the locations surveyed a lot of dry season commercial farming activities (vegetables such as pumpkin, spinach, okra and garden eggs and sugar cane respectively) were carried out along the catchment or watershed of River Benue, often, with robust applications of both organic and inorganic doses of fertilizers some of which might have eroded into the river, some of these fertilizers because of regular irrigation activities. This assumption is predicated on observations that of some the water used to irrigate these crops flowed back into the river together with the unused fertilizer pellets. Besides, probably because of the river's clearer water, a lot of washing of domestic items were observed along the river shores and is capable of increasing River Benue's fertility status.

Nutrient Sources

These nutrient-rich sources are likely to have increased the fertility status of River Benue which was obviously responsible for the larger number of observed macrophyte species in the dry season. Further to this, a report by Peterson and Lee, (2005) indicated that if floodplains (such as observed in Berbesa, Tyumugh, Agongul, University of Agriculture annex, Katsina-ala Street, BBL Adubu, New Bridge Abattoir and Industrial Layout) become disconnected from the main rivers because of reduced

inflows, aquatic productivity and diversity may decline (Poff *et al.,* 2002). This over time could lead to drying up of such disconnected flooplains. However,in the rainy season, the distribution and densities of *Eicchornia crassipes, Azolla pinnata* and *Salvinia nympellula* at River Benue, Makurdi Industrial Layout (*Eicchornia crassipes, Persicaria decipens*) and University of Agriculture Annex, Katsina- ala street (*Nymphae lotus, Pista stratiotes*) were observed to increase together with the number of sites where these macrophytes were present. This may be attributed to the effects of increased soil erosion, flooding, transportation of nutrient-rich sources from both industrial and domestic sources into these areas thereby providing rich nutrients that can boost plant growth and the supply of the propagules of these plants from other sources (Obot and Mbagwu, 1988).

Distribution of Macrophytes

Apart from industrial layout where only two macrophytes were found, all the other sample locations had no fewer than 4 macrophyte species growing during the dry season. This indicates that where growing conditions are favorable (inflows of nutrients into a water ecosystem), several aquatic macrophytes are likely to grow simultaneously. Earlier, Gorham, (2008) reported that in most situations, several species of aquatic plants are present in a water body outbreaks (or presence of several macrophytes) of aquatic plants shows changes in the physical, chemical and biological conditions brought about by the uncontrolled flow of nutrients from urban, agricultural and industrial centers and in silt eroded from watersheds (Gutiérrez *et al.* 1994; Mandal, 2007). Martins *et al.,* (2008) studied 18 reservoirs and found a total of 39 species in all of them. Thomaz *et al.* (2005) recorded 37 species in the Rosana Reservoir (Paranapanema River). Both reported that this number of species (39 and 37) indicated rich assemblage of aquatic macrophytes, suggesting that the floodplains of River Benue also have a rich assemblage or presence of macrophytes.
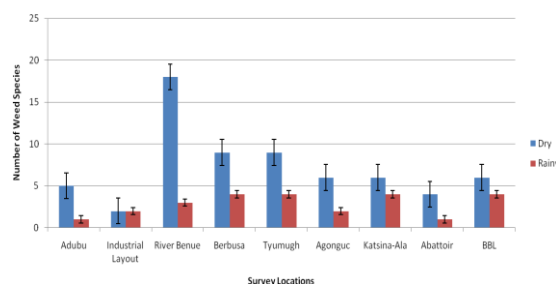

Fig. 2. Showing the Number of Aquatic Macrophytes in the Dry and Rainy seasons among the Surveyed Locations.

Differences in the number of macrophytes present in each location could have been due to several non-independent factors, such as differences in area, physico-chemistry characteristics of the water bodies sampled and even taxonomic resolution of the macrophytes.

Of all the macrophyte species identified, those belonging to the families *Cyperaceae* (7) and *Onagraceae* (3) *Poaceae* (2) and *Pontederiaceae* (2) respectively were the dominant group found and most distributed in the sample locations. This agrees with the reports of Pott *et al.* (1992), Bini *et al.* (1999) and Kita and Souza, (2003) that Poaceae and Cyperaceae, which are among the best-represented families, are also the most important families in other freshwater ecosystems, while less prominent specie include *Mariscus longibrateatus, Ipomea aquatic* and *Poliginium lanigerum* (Adesina *et al.,* 2011).

Water hyacinth (*Eicchornia crassipes),* was observed to be the single most distributed (found in 7 locations out of 9 with the highest FO of 66.7, RF=10.0, DI=60) macrophyte specie of all (31) of the identified macrophyte species (Table 3). This may be attributed to its prolific multiplication and growth habit and its ability to quickly colonize areas where it is found. Reports by Gutiérrez *et al.* (1996) have indicated that Water hyacinth is successful owing to its life cycle and survival strategies that have given it a competitive edge over other species, it produces large quantities of long leafed seeds that can survive up to 30 years and weed populations can double every 5-15 days (Denny,

1991; Masifwa *et al.* 2001). UNEP, (2012) reported that Water hyacinth (*Eicchornia crassipes),* is efficient in utilizing aquatic nutrients and solar energy for profuse biomass production.

Table 2. showing floristic inventory of aquatic macrophyte in the benue floodplain at makurdi for the rainy season of 2013.

S/N	SCIENTIFIC NAME	COMMON NAME	LIFE FORM	FAMILY	DS (m²)	MA	SLS	FO	RF	DI
A			RIVER BENUE (433 Sample Sites)							
1	*Eicchornia crassipes*	Water hyacinth	Floating	Pontederiaceae	56	5	424	97.9	67.2	97.9
2	*Azolla pinnata*	Water velvet	Floating	Azollaceae	51	5	109	25.2	17.3	25.2
3	*Salvina Nymphellula* Desv.	Nil	Floating	Salvianiaceae	14	2	98	22.6	15.5	9.1
B			ADUBU (17 Sample Sites)							
1	*Eicchornia Crassipes*	Water hyacinth	Floating	Pontederiaceae	74	5	17	100	100	100
C			INDUSTRIAL LAYOUT (4 Sample Sites)							
1	*Eicchornia crassipes*	Water hyacinth	Floating	Pontederiaceae	74	5	4	100	57.1	100
2	*Persicaria decipens*	Slender knotweed	Emergent	Polygonaceae	59	4	3	75	42.9	60
D			BERBUSA (11 Sample Sites)							
1	*Eicchornia crassipes*	Water hyacinth	Floating	Pontederiaceae	71	3	8	72.7	34.8	43.6
2	*Ludwgia decurrens*	Water primrose	Emergent	Onagraceae	43	3	5	45.5	21.7	27.3
3	*Pistia stratiotes*	Water lettuce	Floating	Araceae	80	3	4	36.4	17.4	21.8
4	*Azolla pinnata* R.Br. var. *africana* Desv.	Water velvet	Floating	Azollaceae	60	4	6	54.5	26.1	43.6
E			TYUMUGH (3 Sample Sites)							
1	*Pteridium esculentum*	Nil	Emergent	Dannstaedficea-e	18	3	2	37.5	33.3	66.7
2	*Azolla pinnata*	Water velvet	Floating	Azollaceae	48	3	2	37.5	33.3	66.7
3	*Nymphae lotus*	Water lily	Floating	Nymphaeceae	69	4	2	66.7	33.3	88.9
F.			AGONGUL (8 Sample Sites)							
1	*Pteridium esculentum*	Nil	Emergent	Dannstaedficeae	46	4	5	62.5	55.6	50.0
2	*Heliotropium indicum* Linn.	Cock's comb	Emergent	Boranginaceae	27	3	4	50.0	44.4	30.0
G.	UNIVERSITY OF AGRICULTURE ANNEX, KATSINA-ALA STREET (12 Sample Sites)									
1	*Eicchornia crassipes*	Water hyacinth	Floating	Pontederiaceae	79	5	11	91.7	29.7	18.3
2	*Nymphae lotus* Linn.	Water lily	Floating	Nymphaeceae	66	4	10	83.3	27.0	66.7
3	*Pistia stratiotes*	Water lettuce	Floating	Araceae	78	4	9	75.0	24.3	60.0
4	*Salvinia nymphellula*	Salvinia	Floating	Salviniaceae	42	3	7	58.3	18.9	35.0
H.			ABATTOIR (16 Sample Sites)							
1	*Eicchornia crassipes*	Water hyacinth	Floating	Pontederiaceae	78	5	16	100	100	100
I			BENUE BREWERY LIMITED (15 Sample Sites)							
1	*Polygomium lanigerum*	Knotweed	Emergent	Polygonaceae	51	4	11	73.3	34.4	58.7
2	*Nymphae lotus*	Water lily	Emergent	Nymphaeceae	36	3	9	60.0	28.1	36.0
6	*Persicaria decipens*	Slender knotweed	Emergent	Polygonaceae	54	4	12	80.0	37	64.0

MA Scale from1 – 5: where 1=Rare, 2=Occasional, 3=Frequent, 4=Abundant and 5=Dominant

DS = Density, MA = Macrophyte Abundance , SLS = Sample Location Site, FO = Frequency of Occurrence , RF = Relative Frequency, DI = Density Index

Seasonal and Species Characteristics
Contrary to the findings of Idowu and Ngamarju, (2011) who reported high species composition of aquatic macrophytes at Lake Alau (Nigeria) in the rainy season which they attributed to increased water level and flooding regime which could have favored the increase in aquatic vegetation and other biological communities, the findings of this research showed

that except at Berbesa and BBL where no differences (p<0.05) were observed in the number of macrophytes species, generally fewer and mainly floating macrophytes species were observed to exist in all the sampled locations of the rainy season compared to the dry season (Table 2), in all the floodplains of Makurdi surveyed. This may be attributed to the generally increased water volume and depth in all the sample locations mainly arising from increased rainfall (during the rainy season) which led to the submergence of most macrophyte species that grew as emergent aquatic plants in the dry season. Whereas, the increased number of macrophytes in the rainy season at Lake Alau was attributed to increased water level and flooding regime, the reduced number in the floodplains of River Benue may be attributed to relatively higher water levels, amounts and flooding regimes. This assumption is predicated on the fact that Lake Alau is located in the Arid zone of Nigeria (with far lesser rainfall amount and flooding regime: July-August) than River Benue and its flooplains which are located in the Southern Guinea Savanna of Nigeria with comparatively longer rainfall (April-October) and flooding regimes and amounts respectively. Moreso,that the rainy season in the area under study in the floodplains of makurdi (June-August) had experienced up to 5 months of rainfall as compared to Lake Alau with only 2 months of rainfall. Besides, increased water velocity in natural and free-flowing water bodies such as found in the sample areas, is a common occurrence during rainy seasons and might have washed off or moved both the sediment soils and emergent macrophytes thus dislodging the macrophytes or carrying them off and away to new locations. Biggs, (1996) reported that increased current velocity can physically affect the ability of macrophytes to colonize or survive in a certain area. (Chambers *et al.,* (1991) and French, (1995) also reported that organic particles, due to their low density, tend to erode easily. Therefore, coarse substrates, which are characteristic of strong flow areas, generally lack organic matter and are nutrient-poor to supply nutrients to rooted plants. And

because rooted macrophytes obtain most of their needed phosphorus and nitrogen (2 essential nutrients for most macrophytes) from the sediments, current velocity, through its effect on sediment particle size and organic content also have the potential to constrain macrophyte growth (Barko and Smart, 1981, 1986; Anderson and Kalff, 1986). In addition, it may be difficult for macrophytes to root firmly into coarse sediments.

During the dry season at River Benue, *Eicchornia crassipes, Azolla pinnata, Cyperus difformis, Cyperus erecta, Kyllinga pumila, Pycreus lanceolatus* and *Cyperus haspan* showed the highest macrophtye abundance (MA) of 4 (Abundant) while *Polygonium lanigerum, Rorripa nasturtium-aquaticum, Salvinia nymphellula, Anredera cordifolia* and *Myriophyllum aquaticum* showed the lowest abundance of 1 (Rare). This seems to indicate the equal competitiveness of the macrophyte populations found in this location, probably as a result of the equal ability of their roots to absorb and efficiently utilize the nutrients present in the water or their inability to out-compete each other. Compared to the other 17 macrophyte species observed in River Benue in the dry season, *Eicchornia crassipes* had the highest frequency of occurrence (FO) (92.6%) relative frequency (RF) (11.3%) and dominance index (DI) (74.1%) (Table 1). This was followed by *Pycreus lanceolatus* (FO=82%, RF=10.0%, DI=65.6%), *Azolla pinnata* (FO=81%, RF=9.9%, DI=64.8%) and *Cyperus difformis* (FO=74.4%, RF=9.0%, DI=59.5%). *Anredera cordifolia* had the lowest FO, RF and DI of 4.8%, 0.6% and 1.5% respectively. *Eicchornia crassipes* is generally known to out-compete other aquatic plant species. Its comparatively higher frequency of occurrence compared to the other species may therefore, have been as a result of its characteristic prolificacy.

At Berbesa, *Ludwigia hyssopifolia* and *Myriophyllum aquaticum* showed the highest MA of 4 and FO, RF and DI of 72.7%, 16% and 58.2% each during the dry season. *Eicchornia crassipes,*

Sacciolepis africana and *Luwigia decurrens* followed with MA of 3 each, RF of 54.5%, 45.5% each and DI of 32.7% and 27.3% each respectively while the least MA, RF and DI were recorded on *Heliotropium indicum, Pistia stratiotes* and *Cardiospermum heliocacabum* with MA of 2, FO of 36.4%, RF of 8% and DI of 14.5% each (Table 1). The higher MA values for *Ludwigia hyssopifolia* and *Myriophyllum aquaticum* showed that these 2 macrophyte species had higher population explosion than *Eicchornia crassipes, Sacciolepis africana* and *Luwigia decurrens.*

At Tyumugh, *Kyllinga pumila, Ludwigia hyssopifolia* and *Myriophyllum aquaticum* recorded the highest MA of 4 each and FO, RF and DI of 66.7%, 16.7% and 53.3% respectively compared to the rest of the macrophyte species found at this location.

At Agongul, *Pteridium esculentum, Mariscus longibracteatus, Heliotropium indicum* and *Spheynoea zeylonica* recorded the highest MA (4) each. compared to the other macrophyte species, *Pteridium esculentum* recorded FO (62.5%), RF (22.7%) and DI (50%) followed by *Mariscus longibracteatus, Heliotropium indicum* and *Spheynoea zeylonica* with the FO of 50% each, RF of 18.2% each and DI of 30% each. *Cardiospermum heliocacabum* recorded the lowest MA (1), FO (25%), RF (9.1%) and DI (5%).

At University of Agriculture Annex, Katsina-ala Street, *Eicchornia crassipes* showed the highest MA (5), FO (91.7%), RF (20.8%) and DI (91.7%), followed by *Nymphae lotus, Pontederia cordata* and *Pistia stratiotes* with MA of 4, FO of 75%, RF of 17% and DI of 60% respectively. *Salvinia nymphellula recorded* the least MA (3), FO (58.3%), RF (13.2%) and DI (35%).

At BBL, the highest MA (4) was recorded on *Persicaria decipens, Polygonium lanigerum, Sphenoclea zeylonica* and *Heliotropium indicum.* Also, *Persicaria decipens* and *Heliotropium indicum*

had the highest FO (80%), RF (18.8%) and DI (64%) this was followed by *Polygonium lanigerum* and *Sphenoclea zeylonica* with FO, RF and DI of 73.3%, 17.2% and 58.7% respectively.

At Adubu and New Bridge Abattoir *Eicchornia crassipes* was observed to have maximum MA (5), FO (100%), RF (26.6%) and DI (100%) respectively. At Makurdi Industrial Layout, even though *Eicchornia crassipes* recorded a comparatively lesser MA (4), the FO (100%) and DI (100%) was observed to be the same as in Adubu and New Bridge Abattoir while the RF was 57.1%. This is followed by River Benue (FO=92.6 %, DI= 74.1%), University of Agriculture Annex, Katsina-ala Street (FO=91.7% and DI= 91.7%. The least was recorded at Berbesa (FO=54.5%, DI= 32.4%).

The high FO and DI values indicate that there was a proliferation of *Eicchornia crassipes* in these water ecosystems. This shows a major symptom of river pollution (rich nutrient status) which could be ascribed to the highly altered nature of the littoral zones of these locations and their nutrient-rich status which have brought about the explosive growth of *Eicchornia crassipes.* At Adubu for example, a lot of farming activities (rice and maize) and soil excavation for block making have been taking place along its shores. At New Bridge Abattoir, a minimum of 180 ruminant animals (goat ant cattle) are slaughtered daily, processed and their wastes dumped at the shores and into the water body harboring *Eicchornia crassipes,* while several piles of refuse dumps litter the fringes of Makurdi Industrial Layout. All of these activities have potential of nutrient richness which can improve the nutrient status of these water bodies. The growth of *Eicchornia crassipes* is reported to be stimulated by the inflow of nutrient rich water from urban and agricultural runoff, deforestation, products of industrial waste and insufficient wastewater treatment (Villamagna and Murphy 2010, Ndimele *et al.* 2011).

The proliferation of the *Eicchornia crassipes*, a weed that thrives under conditions of contaminated or nutrient rich water (Moyo, 1997; Mandal, 2007) showed the extent to which water in these locations was contaminated (nutrient rich). Mapira and Mungwini, (2005) had also reported that Rivers which passed through some urban centres of Zimbabwe were heavily polluted by wastewater resulting in eutrophication, a condition to promoting growth and proliferation of Water hyacinth. The passage and existence of these water bodies within Makurdi metropolis and their proximity to or the direct discharge of wastes into them (Adubu, New Bridge Abattoir and Industrial Layout especially) obviously increased nutrient status which could therefore, have been responsible for the abundance of *Eicchornia crassipes* in these locations. In addition, these locations are small and shallow (about 1m deep) compared to the other locations. Wandell, (2007) had reported that small shallow lakes have an abundance of macrophyte plants.

All situations of high Macrophyte Abundance (4-5), (as observed at River Benue, Berbesa, Tyumugh, University of Agriculture Annex, Katsina-ala Street, Adubu, New Bridge Abattoir, BBL and Industrial layout) indicate macrophyte population explosion mainly due to ecosystem alteration. These locations are generally characterized by robust anthropogenic activities (farming, soil excavation for extraction of sand and making of burnt bricks, refuse dumps, industrial effluents etc.) which have greatly altered their original statuses and conditions. According to Okayi and Abe (2001), aquatic plants develop explosively large population only when the environment is altered either physically or through the introduction of pollutants (nutrients) which according to Thomaz and Ribero da Cunha, (2011) colonize many different types of aquatic ecosystems, such as lakes, reservoirs, wetlands, streams, rivers, marine environments and even rapids and falls. The distribution, permanency and quality of water available for their occupation govern their distribution and ecology Jones *et al.,* (2010).

Conversely, decreasing Macrophyte Abundance indicate reducing population explosion due also, to decreasing nutrients.

A consistent trend that was observed to be common to *Cyperus difformis* Linn., *Cyperus erecta* [schumach.] Mattf & Kuk., *Kyllinga pumila* Michx., *Cyperus haspan,* and *Kyllinya erecta* [schumach.] Var. *erecta* all present only in the dry season was that it never grew near nor was it present in shaded areas provided by shoreline trees. Also, these plants never existed within or near fetch zones. This trend was presumed to be due to their intolerance to shading and disturbance. Reports by Aloo *et al.,* (2013) indicated that concentrations of phosphorus increase substantially within deep waters while nitrogen levels increased closer to the shores. The assumption is that these plant species are either limited by phosphorous or that their critical nutrient need is phosphorous so they tend to grow more in the inner and relatively deeper areas where phosphorous is more likely to be present and in warm tropical temperature which fosters plant growth (Aloo *et al..,* 2013).

The presence of macrophytes species such as *Azolla* among others, which are regarded as native, was considered less noxious and of relatively less threat especially since they were also, not found in large quantities. Gorham, (2008) reported that native free floating plants include *Azolla* species and *Lemna* species. The presence of water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiote*) was regarded as a threat in these water bodies since they are generally known to be noxious by nature. This collaborates the findings of Gorham, (2008) that the free floating plants that are declared as noxious weeds include the introduced *Salvinia* spp., water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*). Water hyacinth has been identified by the International Union for Conservation of Nature (IUCN) as one of the 100 most aggressive invasive species (Téllez *et al.* 2008) and recognized as one of the top 10 worst weeds in the world (Shanab *et al.* 2010, Gichuki *et al.* 2012, Patel, 2012).

Besides, the contentions by Aloo *et al.,* (2013); UNEP, (2013); Villagna and Murphy, (2010) and Ndimele, *et al.,* (2011) that *Eichhornia crassipes* is a shoreline plant was obtainable only at River Benue and BBL which are free flowing waters and this was only during the dry season. In the rainy season however and mainly between August to October when rainfall was heavier and more regular, *Eichhornia crassipes* was observed to be distributed throughout the breadth of River Benue. This may be a consequence of increased water velocity, flooding, water volume or level and plant parts detachment due to the impact of rain drops which could have enhanced the movement, transportation, floating and number of *Eichhornia crassipes* from the floodplains and other catchment areas densely populated with this plant into River Benue and increased supply of Water hyacinth propagules and hence, increased reproductive output (UNEP, 2013). In the floodplains where water movement was restricted or stagnant (Adubu, Berbesa, New Bridge Abattoir, Universtity of Agriculture Annex, Katsina-ala street and Industrial Layout), *Eichhornia crassipes* was observed to be densely populated and heavily distributed throughout their length and breadth. This was presumed to be a result of nutrient depositions from both point and non-point sources around these areas and the recycling of nutrients from dead macrophyte species within these water bodies which could have induced or triggered their sustained growth so long as water was available.

Table 3. Showing macrophytes and their overall percentage frequencies and dominance index for the dry and rainy season of 2013.

S/N	SCIENTIFIC NAMES	COMMON NAMES	FREQUENCY OF OCCURRENCE (%)	RELATIVE FREQUENCY (%)	DOMINANCE INDEX (%)
1	*Eicchornia crassipes* (Mart.) Solms-Laub	Water hyacinth	66.7	10.0	60.0
2	*Azolla pinnata* R. Br. Var. *africana* (Desv.)	Water velvet	33.3	5.0	22.2
3	*Cyperus diffomis* Linn.	Nil	22.2	3.3	17.8
4	*Cyperus erecta* [schumach.] Mattfa Kuk.	Nil	11.1	1.7	6.7
5	*Kyllinga pumila* Michx.	Nil	44.4	6.7	33.3
6	*Pteridium esculentum*	Bracken	33.3	5.0	20.0
7	*Polygonium lanigerum* R.Br. Var. *africanum* Meisn.	Lady's thumb	22.2	3.3	13.3
8	*Rorripa nasturtium-aquaticum*	Watercress	11.1	1.7	2.2
9	*Ludwigia abyssinica* A.Rich.	Water primrose	11.1	1.7	4.4
10	*Scleria naumanniana*	Nil	11.1	1.7	6.7
11	*Eleocharis calva*	Nil	11.1	1.7	4.4
12	*Limnocharis flava*	Yellow burhead	11.1	1.7	6.7
13	*Pycreus lanceolatus*	Nil	22.2	3.3	17.8
14	*Cyperus haspan*	Nil	11.1	1.7	8.9
15.	*Ludwigia decurrens* Walt.	Water primrose	33.3	5.0	20.0
16	*Anredera cordifolia*	Madeira vine	11.1	1.7	2.2
17	*Myriophyllum aquaticum*	Parrot feather milfoil	22.2	3.3	13.3
18	*Liptochloa caerulescens*	Nil	11.1	1.7	6.7
19	*Sacciolepes Africana*	Nil	11.1	1.7	6.7
20	*Ludwigia hyssopifolia*	Water primrose	22.2	3.3	17.8
21	*Heliotropium indicum*	Cock's comb	22.2	5.0	13.3
22	*Pistia stratiotes*	Water lettuce	22.2	3.3	13.3
23	*Cardiospermum heliocacabum*	Balloon vine	33.3	5.0	6.7
24	*Nymphaea lotus*	Water lily	33.3	5.0	20.0

S/N	SCIENTIFIC NAMES	COMMON NAMES	FREQUENCY OF OCCURRENCE (%)	RELATIVE FREQUENCY (%)	DOMINANCE INDEX (%)
25	*Persicaria decipens*	Slender knotweed	44.4	6.7	22.2
26	*Mariscus longibracteatus* Cherm.	Nil	11.1	1.7	6.7
27	*Sphenoclea zeylonica*	NIL	22.2	3.3	15.6
28	*Melochia corchorifolia*	Nil	22.2	3.3	13.3
29	*Pontederia cordata*	Pickerelweed	11.1	1.7	8.9
30	*Kyllinga erecta*	nil	11.1	1.7	6.7
31	*Ipomea aquatica* Forsk.	Water spinach	11.1	1.7	6.7

The simpson diversity index (SDI) results presented in Table 4 showed that during the dry season, River Benue had the highest SDI of 0.92 followed by Berbesa (0.85), Tyumugh (0.84), University of Agriculture Annex, Katsina-ala Street (0.81), Adubu and BBL (0.79) each, Agongul (0.77) and Industrial Layout (0.49). In the Rainy season, Berbesa and University of Agriculture Annex, Katsina-ala Street had the highest SDI of 0.74 each followed by BBL (0.66), River Benue and Tyumugh with 0.60 each, Industrial Layout (0.50), Agongul (0.47) and Adubu (0.0) respectively. The comparatively higher SDI in River Benue, Berbesa, Tyumugh and University of Agriculture Annex, Katsina-ala Street during the Dry season indicated higher macrophyte species diversity (number) and so showed the probability of the individual macrophyte species at these locations varying or belonging to some other species compared to those in the other locations surveyed. This according to Williamson and Kelsey, (2009), shows that River Benue (especially), has a richer or healthier (less polluted) water ecosystem compared to the others. The comparatively higher SDI at Berbesa and University of Agriculture Annex, Katsina-ala Street (0.74) during the rainy season is attributed to the additional presence of emergent macropytes which the increased water volume and level during the rainy season could not submerge and complimented by the presence and density of floating macrophytes as against River Benue where all emergent plants were submerged or (and) moved by increased water depth, level, volume and velocity.

Table 4. Showing Simpson's Diversity Index (SDI) for the Sampled Locations in the Dry and Rainy Seasons.

S/n	LOCATION(S)	NUMBER of OBSERVED MACROPHYTES		SDI (%)	
		Dry Season	Rainy season	Dry Season	Rainy season
1	River Benue	18	03	0.92	0.60
2	Berbusa	9	04	0.85	0.74
3	Tyumugh	9	O3	0.84	0.60
4	University of Agriculture Annex, Katsina-ala Street	6	04	0.81	0.74
5	Adubu	5	01	0.79	0.0
6	BBL	6	03	0.79	0.66
8	Agongul	6	01	0.77	0.47
9	Industrial Layout	2	02	0.49	0.50

Conclusion

A total of 31 aquatic macrophtytes representing 19 families were identified in the floodplains of River Benue during the two prominent seasons (Rainy and Dry) of 2013. No submerged macrophytes were present in all the nine (9) sampled locations. Water hyacinth (*Eicchornia crassipes),* was observed to be the single most distributed (found in 7 locations out of 9 with the highest FO of 66.7, RF=10.0, DI=60) macrophyte specie of all (31) of the identified macrophyte species. The large number of macrophyte species in the dry season might be as a result of farming activities which are carried out along the catchment of the river Benue coupled by robust

application of both organic and inorganic doses of fertilizers are eroded into the the River floodplain.

The results of this study have indicated a threatening and dangerous trend in the rate at which invasive aquatic macrophytes are colonizing River Benue and its prominent and water rich water bodies. The water bodies are of high economic importance to the riparian populace and other stakeholders and dependents for their economic activities. It is therefore very crucial to monitor and manage the influx and emergence of both the native and exotic aquatic macrophyte species in River Benue and its floodplains as most water bodies and countries which had experienced uncontrolled infestations of Water Hyacinth (*Eichhornia crassipes*) especially and other aquatic plants bore heavy financial losses to their economies hence the need to nip the threats of these aquatic weed infestations.

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