

# THREATS AND POTENTIALS OF INVASIVE MACROPHYTE SPECIES TO INLAND FRESHWATERS IN RELATION TO CHANGING CLIMATE IN NORTHERN NIGERIA

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## ABSTRACT

There are over 12 million hectares of inland freshwater bodies in Nigeria. This includes mainly river systems and streams, natural and man-made lakes, naturally occurring and excavated seasonal ponds etc. Field studies over a period of two decades in northern Nigeria identified species of invasive aquatic macrophytes that pose major concerns to the ecosystem. In addition to other species considered of minor significance, the major species of concern were the water hyacinth (*Eichhornia crassipes*), Water lettuce, (*Pistia stratiotes*), Niger grass (*Echinochloa stagnina*), and the Cattail (*Typha* sp). These and other species considered of less nuisance were found to occur in natural and man-made lakes and other water bodies that are mainly used as sources of domestic drinking water, for fishing, recreation and significantly, for irrigation. Farm run-off such as fertilizers, increase nutrient loading of the water and this results in the explosive growth of aquatic vegetation. Changing climatic patterns have been predicted to among other impacts, alter precipitation patterns world- wide. In the arid and semi-arid regions, this will result in the decrease in duration and intensity of rainfall. Increasing intensity of soil tillage for irrigated agriculture will therefore lead to declines in available water volume in such water bodies, due to both an increase in water demand and a decreased volume. This threatens the maintenance of the aquatic ecosystems. Presently, in order to safeguard ecosystem health emphasis on management of aquatic vegetation is placed on their removal and destruction. However, there are potentials for beneficial utilization of aquatic plant resources, at subsistence and perhaps industrial levels. These potentials have largely neither been evaluated nor explored. This paper reports data collected from field observations and surveys involving indigenous human populations on the potentials of identified species of aquatic vegetation, as well as possibilities for the beneficial exploitation and management of these aquatic resources in northern Nigeria.

**Keywords:** Invasive Macrophytes, freshwaters, climate change, Nigeria.

## INTRODUCTION

The term "aquatic macrophyte" in its strictest sense refers to those species of hydrophytic plants that spend part or all of their life cycle either partially or completely in contact with the aquatic environment. It generally excludes filamentous algae and basically grassland species that grow as a natural biotic component in most shallow depth, still, slow flowing and running water bodies. Freshwater macrophytes are generally classified into four categories as: Free-floating (with roots if present hanging in water or plants that float on the surface of water bodies, and whose

roots are suspended in water); Submerged (usually rooted in the substrate with vegetative parts permanently submerged); Emergent (rooted in shallow water with the vegetative parts emerging above the water surface) and Marginal (macrophytes that can survive on land or water).

## Distribution of Freshwaters in Nigeria

There are over 12 million hectares of inland freshwater bodies in Nigeria. This includes

mainly river systems and streams, natural and man-made lakes, naturally occurring and excavated seasonal ponds etc. (Ita *et al.*, 1985; Ita, 1994). As far back as the 1980s there were 347 reservoirs and lakes, 839 floodplains and rivers, 5000 fish ponds (Satia, 1990), 89 cattle drinking ports, and many earth wells and boreholes. Several abandoned mine pits particularly in Plateau, Anambra, and Enugu States, having areas varying from 0.2–0.7 hectares hold considerable volumes of water all year round. Also excavation ponds of abandoned sand and stone quarries associated with road construction sites are common along major highways. Man made lakes and reservoirs are abundant in the northern parts of the country most affected by drought, such as Kano, Jigawa and Katsina States. Water in these reservoirs come from both surface and underground sources (Ayoade, 1981) with rainfall as the primary contributor. Rainfall varies from 10 months in the coastal areas to about 2–3 months in the Sahelian part of the country. The rainfall range therefore varies from 3000mm on the coast to 250mm at the farthest north. A general hydrological map (Fig 1) of the country shows details of the distribution of freshwaters in major rivers and lakes.

### **Aquatic macrophytes in Northern Nigerian Freshwaters**

In the largely agrarian communities of northern Nigeria, inland freshwaters are commonly utilized for irrigated agriculture. Changing climates alter precipitation patterns world-wide. In the arid and semi-arid regions, this will result in the decrease in duration and intensity of rainfall. Increasing intensity of soil tillage for irrigated agriculture will therefore lead to declines in available water volume in such water bodies, due to both an increase in water demand and a decreased volume. Farm run-off such as fertilizers, increase nutrient loading of the water and this results in the explosive growth of aquatic vegetation. Invasive aquatic plants in new geographic ranges, multiply rapidly through both vegetative and sexual reproduction; favoured by the absence of their natural enemies and eutrophic nutrient-rich

conditions. Consequently, large biomass is produced, most times covering the entire surface of water bodies (Bako and Oniye, 2004; Bako and Balarabe, 2005; Bako *et al.*, 2005; Bako, *et al.*, 2007; Ajuonu *et al.*, 2010). The plants threaten the survival of lakeside and riparian communities, kill other aquatic life by blocking out light, harbour the carriers of such diseases as malaria and bilharzia, impede transport, threaten biodiversity by displacing native species, stifle commercial activities such as fishing and irrigation and have even led to the abandonment of settlements along rivers and lagoons, which became inaccessible (Ajuonu *et al.*, 2010; Olubode *et al.*, 2011).

In response to the renewed awareness of the threats that unregulated growth of aquatic vegetation presents to the well being of ecosystems world wide, efforts are now intensified towards having updated and reliable assessments of the situation, as well as emphasizing the beneficial roles that these aquatic resources could play in the well being of human populations. This paper therefore reports data collected from field observations and surveys involving indigenous human populations on the potentials of identified species of aquatic vegetation, as well as possibilities for the beneficial exploitation and management of these aquatic plants in northern Nigeria.

### **METHODOLOGY**

The study area covered four states of northern Nigeria including, Kaduna, Kano, Adamawa and Taraba states. The data presented was obtained from observations during field trips spanning a period of two decades of the increasing occurrence and increasing preponderance. Sampling techniques employed included the line transect and quadrat methods. Depending on the surface area and other morphometric parameters of the water bodies concerned, appropriate methods were employed. The aquatic macrophytes encountered were identified, and where necessary, samples were collected, processed and preserved in the herbarium of the Department of Biological Sciences, Ahmadu Bello University, Zaria. Field

identifications were confirmed by reference to relevant manuals such as Obot and Ayeni (1987), Akobundu and Agyakwa, (1998). Descriptive data is mainly presented in the form of photographs.

## RESULTS AND DISCUSSION

On the whole, ten (10) species of aquatic macrophytes belonging to nine (9) families were encountered on field trips (table 1). The poaceae was represented by two genera, while the other eight families were represented by one genus in each case. The grasses by virtue of their mechanism of photosynthesis (the C4/Hatch and Slack pathway) are generally more tolerant to the high light intensity and temperatures that characterize the savannas of northern Nigeria. In a warming climate, it is possible that the ecological amplitude of such genera will be extended beyond limits that are presently recognized. This obviously implies that the diversity and abundance of plant species with the capacity to cope under such conditions will increase.

Aquatic macrophytes were found to grow mainly as floating or emergent forms, and their range of coverage of the water bodies varied widely, depending on the trophic

conditions of the water body. Four of the ten species (40.00%) were floating forms. The remaining six (60.00%) were either emergent, with their shoots held well above the surface of water, but rooted at the bottom, or had their leaves/shoots resting/floating on the surface of the water. Preponderance of emergent forms indicate that the water bodies are rapidly getting sedimented/silted up. The effective volumes of such basins are in danger of being depleted due to both evapotranspiration from plant leaf surfaces, and reduction in mean depth due to deposition of silt (siltation) resulting from erosion of loosened agricultural soil and other anthropogenic activities (Adesina *et al.*, 2010). On the other hand, a strong appearance of notorious floating species like the water hyacinth and water lettuce is worthy of note. These species (particularly the water hyacinth) are known to constitute nuisance to major aquatic ecosystems across Africa (Mustapha, 2008), with widely reported cases occurring in east Africa (Albright *et al.*, 2004). So far efforts at controlling their invasions have met only slow and limited success (Adebayo and Uyi, 2010; Ajuonu *et al.*, 2010).

**TABLE 1. COMMON AQUATIC WEEDS OF NORTHERN NIGERIAN FRESHWATERS**

Common names	Family	Botanical names	Local names (Hausa)	Growth form
Water hyacinth	Pontederiaceae	<i>Eichhornia crassipes</i>	Dafe ruwa	Floating
Water Lettuce	Araceae	<i>Pistia stratiotes</i>	Kainuwa	Floating
Water Ferns	Salviniaceae	<i>Salvinia molesta</i> , <i>S. nymphetulla</i>	Yayan kainuwa	Floating
Duckweed	Lemnaceae	<i>Lemna paucicostata</i>		Floating
Knotweed/Knotgrass	Polygonaceae	<i>Polygonum</i> spp.	Kafula	Emergent
African wild/red rice/Long-stamen rice	Poaceae	<i>Oryza longistaminata</i> (syn: <i>O. barthii</i> )	Shinka-shinka	Emergent
Cattail	Typhaceae	<i>Typha australis</i>	Kashalla/Shalla	Emergent
Niger grass	Poaceae	<i>Echinochloa stagnina</i>	Buruku	Emergent
Swamp Morning glory	Convolvulaceae	<i>Ipomoea aquatica</i>	Awarwaro	Floating leaved/Emergent
Water chestnut	Trapaceae	<i>Trapa natans</i>	Gurjiyar ruwa	Floating leaved/Emergent
Water lily	Nymphaeaceae	996): <i>Standard N. micrantha</i>	Bado Bado/Kwala	Floating leaved/Emergent

The most notorious of these species in the northern Nigerian states covered by this survey are the Water hyacinth, Cattail, Niger grass, Water lily and Water lettuce, with lower levels of infestation by the knotweed and the African wild rice.

**The floating Water Hyacinth (*Eichhornia crassipes* (Mart.) Solms-Laub.) (Figs 2 a-d)**  
A glabrous aquatic herb with submersed stem and roots suspended in water. Reproduces

from seeds and from stolons. Floating leaves broadly-ovate to orbicular about 1.5-2.5cm long and wide, usually with long slender petioles about 30cm-1m long, entire at the margins, heart-shaped at the base, smooth on both surfaces and have many closely ascending nerves on the undersurface. Inflorescence is a loose terminal spike with showy light blue to violet flowers. Flowers bear a yellow marking on the upper portion of the petal. This plant of South American

origin has become a major floating water weed in Africa. In West Africa, it infests rivers and lagoon systems linking adjacent countries, and interferes with water use, fishing and transport, sometimes cutting off entire villages (Mitchell *et al.*, 1990).

#### **The Water Lettuce (*Pistia stratiotes* Linn.)(Figs. 3a-b)**

A free-floating aquatic herb, with thick succulent leaves, profuse underwater stolons and long, white, unbranched fibrous roots that may sometimes attach to the bottom of shallow waters. It reproduces mainly vegetatively by buds and stolons. It rarely produces seeds. The rosettes of gray-green leaves are spirally arranged around a short central axis and occurring singly or connected to others by short stolons. The leaves are oblong or spatulate in shape, 6-12cm long and 5cm wide, spongy, strongly inflated and softly hairy on both surfaces, the lower surface has conspicuous veins radiating from the base of the leaves. The flowers are inconspicuous and are in spathes in the leaf axils at the centre of the rosette. The female flowers are separate, but are in the same inflorescence. It is believed to be of African or South American origin, but is now widespread in West African still waters, ponds, and slow flowing streams and rivers. Capable of forming vast mats that disrupt submersed plant and animal communities and interfere with water movement and navigation

#### **The cattail (*Typha australis* K. Schum. and Thonn.)(Figs 4a-b)**

*Typha australis* is an emergent species, which is mainly rooted or anchored in the substratum to produce emergent vegetative shoots. It is predominant in the vegetative community of many swamps and marshes and often forms a fringe of vegetation along lakeshores or other water bodies especially slow running water. *Typha* spp like other swamp plants are generally very fibrous. Where the plant population is massive it impedes water transportation, farming and fishing activities as well as delivery of irrigation water along the canals with substantial consequences on the income

generating activities of the local communities. The plant can colonise the canal preventing supply of water through the canal after sometime. It can also reduce solar radiation at the water surface, lower wind speeds. *Typha* encourages evapo-transpiration in tropical swamps area.

#### **The Niger grass (*Echinochloa stagnina* Beauv)(Fig 5)**

A large perennial grass occasionally behaving as an annual with straggling precumbent stems up to about 1m long under non-flooded conditions and elongating up to 7-9m (very rarely up to 11m) in flooded areas. The spongy stem, 3-5cm in diameter, roots sparsely at the nodes. Under flooded conditions the stem trails on the surface of the water, but the leaves and inflorescence are held in an upright position above the water. The length of the internodes is variable ; up to 18cm. Leaves are ligulate. The leaf ligule is represented by a fringe of pale coloured bristles about 5mm long at the widest point and hairless although roughly silicaceous to the touch and with tiny prickles along the margins. The leaf blade is dark green with a whitish mid-rib. The sheaths, as long as the internodes, may be brown or green in colour. Plants flower whenever the root zone is flooded. The inflorescence is paniculate, the peduncle being up to 25cm in length. Panicle branches are crowded, alternate, the basal ones being up to about 6cm long. The sessile spikelets are acute-acuminate up to about 5cm in length, the upper lemma ending in a stiff bristle 5-20mm long. Spikelets are secund to the branches of the panicle and are not persistent but fall off when mature to leave a bare panicle with fractiflex branches. Usually found in swampy areas and along the margins of streams and lakes. Sometimes it forms floating mats on water surfaces.

#### **The Water Lily (*Nymphaea lotus* Linn.)(Fig 6a-b)**

A perennial herb with submerged rhizomes and large leaves that float on water. It reproduces from seeds and vegetatively from rhizomes. The stem is rhizomatous, always submerged in water and roots freely. The leaf

is large, circular-shaped, up to 30cm in diameter with a slender petiole that is up to 30cm long and arises from the submerged rhizome. The petiole is centrally attached to the undersurface of the leaf. The leaves are sharply toothed at the margins, heartshaped at the base, strongly nerved and hairy on the undersurface. The flowers are solitary, showy, large (about 20cm in diameter), have many white petals and equally as many yellow stamens. These flowers are borne on long slender flower stalks. The fruit is an ovoid, many-seeded berry that ripens under water. Commonly found on still waters, ponds, dams, lakes and edges of streams.

The knotweed (*Polygonum lanigerum* R. Br. var. *africanum* Meisn.) (Figs 7a-b)

A stout rather erect, many branched perennial herb up to 2m high that reproduces from seeds. Stems are swollen at the nodes, robust and ribbed, rather prominently sheathed (with ochrea) and are covered with white soft woolly hairs. The leaves are alternate, lanceolate to broadly lanceolate, about 10-30cm long and 2.5cm across. They are often dotted with oil glands. The base of each leaf bears a tubular sheath (ochrea) which has weak short hairs at the tip. The inflorescence is an expanded raceme over 2cm long with pinkish-white flowers about 5mm long. The fruit is a black indehiscent nut that is shiny, pointed at the tip and about 3mm across. Widely distributed in Africa and New Zealand. Found in wet areas, depressions, edges of swamps. Weed of watercourses, roadsides, wet areas and disturbed areas.

**The African Wild rice (*Oryza longistaminata* A. Chev. & Roehr) (Fig 8a-b)**

An erect, rather lax and robust perennial grass 2-3m high. It reproduces from seeds and vegetatively from rhizomes. The stem consists of underground rhizomes and above ground culms. The culms are soft and root at the lower nodes. The leaves have long, linear blades, 25-30cm long and 1-2cm across. They are smooth at the lower surface, but rough on the upper surface and at the margin. The leaf tapers from the middle to a fine point at the

apex and to a narrow, falsely-petioled base. The ligule is large, prominent and acutely pointed and the sheath is smooth. The inflorescence is a panicle about 25cm long with ascending branches, each about 5cm long or more bearing flat, deciduous spikelets each about 4.5-6mm long with long, pale pinkish-brown awns about 2cm long or more. There are 25 species of *Oryza* from tropical regions of the world of which 3 species are indigenous to southern Africa. *Oryza longistaminata* occurs throughout tropical Africa including Nigeria. Found in swampy areas, at the edges of lakes or ponds, streams or river sides, in irrigation canals, in and at the edges of rice fields. Grows in water up to 4 m deep, but usually 1 m or less, in open savanna or openings in rain or gallery forests. Grows in full sunlight. It is ecologically important in swamps and floodplains

### Control efforts

In Nigeria, as well as other west African countries, the most determined efforts at control of aquatic vegetation have been directed at the water hyacinth, water lettuce and the cattail. The approach has been largely manual/ mechanical (Uka *et al.*, 2007; Ajuonu *et al.*, 2010).

Although chemical control of water hyacinth has been investigated (Bako and Umar, 2004 a and b; Uka *et al.*, 2007), the method is not in favour due to the negative effects on the environment and risks to human health. Biological control using the water hyacinth weevil, *Neochetina eichhorniae* (Warner) is considered a long term management option (Moran, 2006) and is favoured by the Nigerian Government. A similar approach has been directed at the water lettuce, while cutting is the most common method applied to the cattail (Birmin-Yauri *et al.*, 2005)

### Utilization options

#### Food for fish and other aquatic vertebrates

It has been reported that aquatic plants play an important role in the life cycle of fish. Several species of herbivorous fish, other invertebrates and vertebrates feed on aquatic macrophytes (Mbagwu and Adeniji, 1988; Shell, 1993; Ezeri *et al.*, 2003), and under

controlled conditions, supplemental feeding with macrophytes like the duckweed have been shown to improve the specific growth rate of fish like the Nile Tilapia (*Oreochromis niloticus*) (Chowdhury *et al.*, 2008). Other fish species feed on periphytic algae growing on the surfaces of aquatic plants (Ayeni *et al.*, 1999).

### **Breeding grounds for aquatic life**

Aquatic vegetation also provides breeding substrate for a large number of insects and other invertebrates, which serve as fish food. Under non-explosive, non-invasional conditions, fishery managers consider floating aquatic plants as beneficial except where they interfere with methods of harvesting fish. Imevbore and Bakare (1974) had reported that fish fry used aquatic vegetation for shelter purpose as well as their spawning grounds. In Kainji Reservoir aquatic vegetation has been identified as a valuable spawning and breeding ground for a large variety of economically important fish species.

### **Aquatic plants as bio-fertilizers**

Aquatic plants accumulate large quantities of nitrogen and phosphorus, in their tissues. They will therefore improve soil if applied as soil additives. The concept of biofertilizers, the growing of a minor crop that provides nutrients to a major crop, though relatively new to aquatic science, is already becoming popular. *Azolla* sp., a free-floating fern that fixes nitrogen in a symbiotic relationship with the Cyanobacterium *Anabaena azollae*, is widely used as a bio-fertilizer for rice crops. Rice-fish polyculture, with *Azolla* sp. as a bio-fertilizer, has become popular in Asian flooded rice field. Maltby, (1988) reported that *Azolla* sp has been used to a larger extent to fuel rice production in waterlogged areas in China. Dried water hyacinth has been successfully used as a supplementary material that enhances the cultivation of mushrooms like *Volvaria* sp (Ratchance 1972), and the oyster mushroom (*Pleurotus sajor-caju*) (Nageswaran *et al.*, 2003).

### **Source of energy**

The value of aquatic plants as energy source centers mainly on its use as fuel for fish smoking and for domestic energy. For example, it has been reported that the stems of *Aschynomene crassicaulis*, *Echinochloa* spp. and *Cyperus papyrus* among others are used as fuel especially for cooking and fish smoking (Kio and Ola-Adams 1987). In NIFFR, Eyo, (2000) highlighted the use of water hyacinth in the production of biogas, and proposed the construction of dome type biogas digester to utilize water hyacinth for biogas production that will provide energy for the local community and the slurry that will be ready source of fertilizer for the farmland.

### **Industrial uses of macrophytes**

Aquatic plants offer a wide range of materials that could serve the needs of innovative industry. The materials could be used for construction, matting, bedding and pulp/paper. Obot, (1984) reported that the mature silky inflorescences of the spike of *Typha australis* are used in stuffing pillows and mattresses and the fragrant dry tuber of *Cyperus articulatus* is also sold in Northern Nigeria as perfume. He asserted that perfume is also produced from underground stems of *Cyperus articulatus*, while the leaves are burnt over the fire as a mosquito repellent, and that the aerial stems are used in the weaving of colourful mats commonly sold in northern part of Nigeria. *Vossia cuspidata*, *Cyperus papyrus* and *Eichhornia crassipes* have also been identified to possess economic potentials for pulp, paper and fibre. The potential for aquatic plants in water treatment has also been investigated. Several species of aquatic plants, including the water hyacinth are very sensitive to pollutants and could be used as biomonitoring and phytoremediation agents for heavy metals and organic pollutants (Liao and Chang, 2004; Bako and Daudu, 2007; Dar *et al.*, 2011; Uka and Chukwuka, 2011; Ndimele and Jimoh, 2011).

### **Source of human/ or animal food**

Because of the nutritional potentials of aquatic plants (Bako, *et al.*, 2002) they offer possibilities for use as food items. For

example, the seeds of burugu (*Echinochloa stagnina*) are collected for food in Monai on the western shore of Lake Kainji. The seed of *Echinochloa stagnina* is also an important food item for fishermen in the Inner Delta of the Niger River and prized sugary syrup is obtained from the stalks of the grass. Kio and Ola-Adams (1987) reported that the rhizome, floral receptacle and fruits of *Nymphaea lotus* (water lily) are either eaten raw or cooked for food and *Ludwigia stolonifera* is used as an ingredient of soup in the, Yelwa area of Kebbi State (Obot and Ayeni, 1987). Imevbore, (1971) and Obot, (1984) in a survey of aquatic environments; identified 14 out of 52 macrophyte species that were found utilizable for livestock production. Some aquatic plants can be processed as animal feeds. Even water hyacinth can be used in limited quantities in a mixture with other feeds by cattle, sheep, goats and other ruminants. Aquatic macrophytes used as fodder include *Vossia cuspidata*, *Leersia hexandra*, *Bracharia mutica*, *Echinochloa pyramidalis*, *Sorghum arundinaceum*, *Paspalum virginatum* and *Echinochloa stagnina* (Obot and Mbagwu, 1988; Obot *et al.*, 1991)

### Medicinal value

A variety of aquatic plants are also used in curative therapy in traditional communities. A good number of these ethno-botanic materials have been reported to yield compounds, which could be of use as modern drugs and pharmaceuticals Okojie (1998). Kio and Ola-Adams (1987) reported that *Polygonum senegalense* is pounded with native hydrated sodium carbonate and rubbed on the limbs for rheumatic and other swellings. This concoction is also applied to syphilitic sores. *Althenanthera nodiflora*, on the other hand, is used for simple stomach disorders and *Pistia stratiotes* is used for ulcerative conditions of the mouth and tongue. Obot and Ayeni (1987) also report that *Pistia stratiotes* is used as part of a concoction for the treatment of 'flu. The emergent nitrogen-fixing legume *Neptunia oleracea* is used in the treatment of yellow fever and Guinea worm infection. Many of these aquatic medicinal plants yield

exceptionally promising compounds for use in modern drugs and pharmaceutical industries. *Polygonum senegalense* and *Nymphaea lotus* stems and roots are traditionally used in eruptive fevers and for urethral discharges. The stems and roots are also regarded as emollient and diuretic while the decoction of the flower is narcotic and sedative. In some parts of the country *Heliotropium indicum* is used for treatment of fever in children and also as a vermifuge and eye-lotion. In Ghana, it is commonly mixed with clay to arrest abortion. The juice of *Elodea conyzoides* can be squeezed into the eyes for headache; the root when mixed with red pepper treats constipation, and the leaves are given in food to prevent abortion. *Cyperus articulatus* is used to treat cough and when mixed with grains of paradise (*Aframomum melegueta*) would cure headache if applied to the forehead. Dried and pulverized *Cyperus articulatus* is useful as fumigant and can be mixed with scented resins for the clothing, and airfreshener in rooms. Kio and Ola-Adams (1990) also confirmed that, in Cameroon, mangrove bark is used for leprosy and ring worm (craw-craw), when pulverised and rubbed into the scarified skin and it is also boiled for use as a lotion.

### Source of recreation, tourisms, aesthetics and other uses

Some aquatic plant species of great potentials in horticulture and recreation have been identified. Of greater potential are some members of the Family Orchidaceae such as *Eulophia caricifolia*, *Eulophia horsfallii* and *Eulophia angolensis*, smaller aquatic plants such as *Najas* sp. may also be used in the aquarium as ornamentals and as agents of aeration (Okojie, 1998).

The presence of aquatic plants has favoured the possibilities of most Nigerian water bodies being developed into recreation centres that will include sport, hunting, fishing, bird watching, nature photography etc. For example, it has been reported that the annual income from visitors to Kenya's Amboseli National Park was estimated as US \$1.3 million in 1979, where the associated aquatic systems are one of its principal attractions

(MENR, 1981). US Dept. of the interior and Dept. of Commerce (1982) have shown that in 1980, 5.3 million Americans spent US \$638 million on hunting macrophyte-dependent water fowl and migratory birds in the USA.

## CONCLUSION

This paper has highlighted the significant ecological roles of the major species of aquatic macrophytes found in northern Nigeria. It is obvious that their occurrence and distribution will increase as the factors which favour their growth persist. This is more so as changing climatic patterns and consequent limitations in availability of rainfall, will necessitate increased emphasis on irrigated agriculture. In recognition of their obvious potentials, particularly in relation to the frequently encountered massive growth tendencies, efforts should now be directed at harnessing them as a renewable natural resource for the benefit of humankind.

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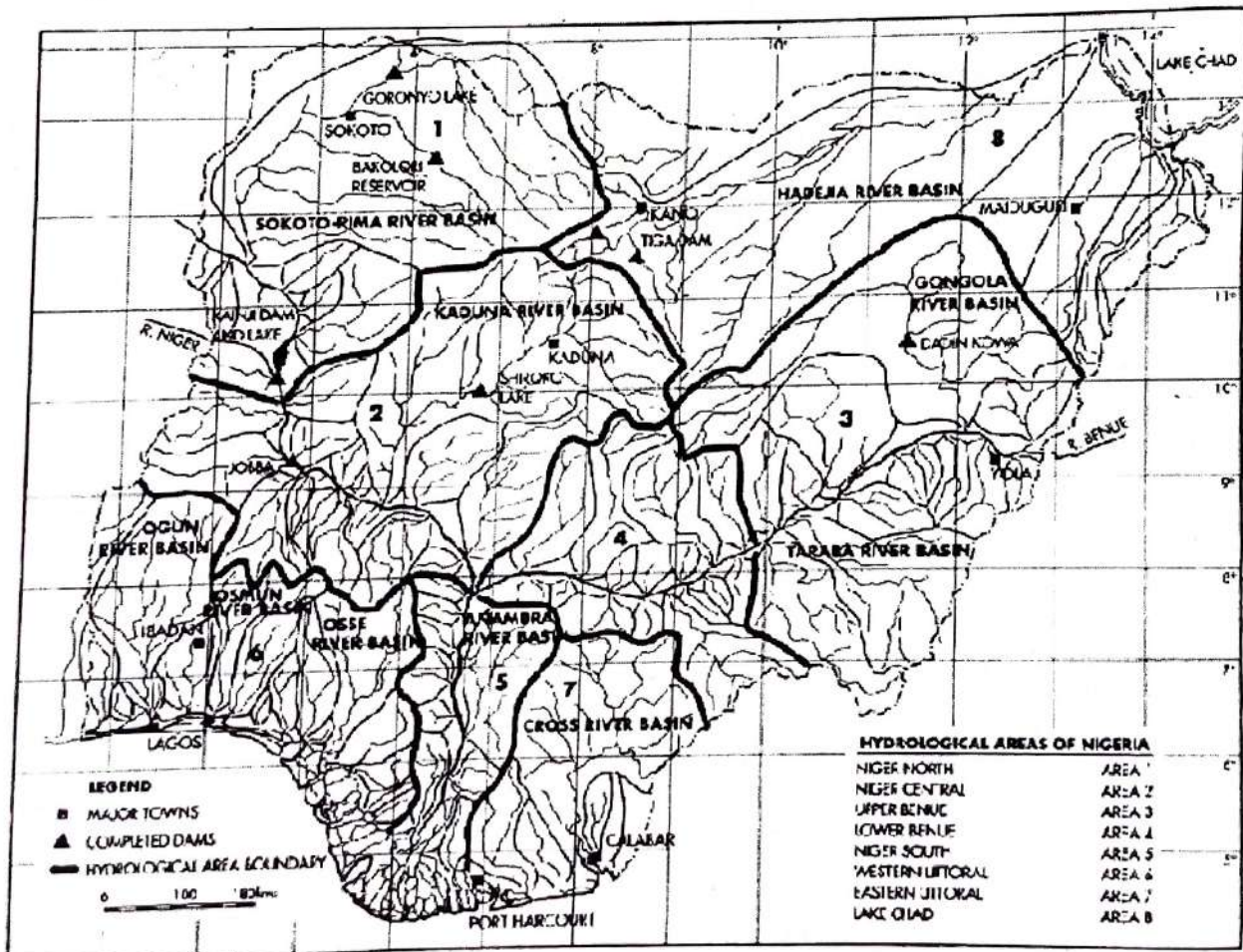


Figure 1. Hydrological map of Nigeria.



Fig 2a. Invasion of the water hyacinth in River Benue at Yola, Adamawa state - Lois S.P.Bako



Fig 2b. Inflorescence of the water hyacinth - Lois S.P.Bako



Fig 2c. Early invasion of the water hyacinth in River Benue at Ibi Taraba state - S.P.Bako



Fig 2d. Water way blocked by water hyacinth. - F. Beed



Fig 3a. The water lettuce - Lois S.P.Bako



Fig 3b. Invasion of the Water lettuce in a lake - F. Beed



Fig 4a. Invasion of the Cattail in an irrigation Pond in Kano state - S.P.Bako



Fig 4b. Inflorescence of the Cattail - S.P.Bako