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Ecology and control of *Typha* species in Hadejia-Nguru Wetlands, Nigeria

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Abstract. *Abdullahi YBY, Balarabe ML, Khan AU, Adamu AK. 2019. Ecology and control of* Typha *species in Hadejia-Nguru Wetlands, Nigeria. Bonorowo Wetlands 9: 71-91. Typha* proliferation causes several ecological problems, including transforming aquatic environments into terrestrial ones, interfering with various methods of catching fish, blockading river channels, and impeding navigation. The Hadejia Nguru wetland in Nigeria has an area of about 58,100 hectares, of which Typha species infested 35,000 hectares. The wetlands were divided into three sections, i.e., Upper, Middle, and Lower. In these segments, *Typha* species, water, soil, and sediment samples were collected, and the impact of *Typha* species on fish catch and distribution was assessed by splitting each segment into two sections: *Typha* uninfested and *Typha* infested. Each segment was separated into four sections for the biological control, each containing 2000 individuals of *Typha* interplant with 50kg, 25kg, 10kg, and no *Phragmites karka*, respectively. Each segment was manually separated into six sections as cutting *Typha* 15 cm, 10 cm, 5 cm below and 15 cm, 10 cm, 5 cm above the water. Each segment was divided into four sections for physical control, i.e., single black tarpaulin, double, triple, and no black tarpaulin. *Typha latifolia* and *Typha angustifolia* made up 64-70% and 30% of *Typha* species of the wetlands, respectivelyPhysico-chemical physics-chemical characteristics of water and sediment exposed substantial fluctuations, with PO4-P, NO3-N, and Mg concentrations ranging from 3.5-13.5 mg/L, 3-13 mg/L, and 1-10 mg/L, respectively. phosphate-phosphorus concentrations in the sediment ranged from 6.5 to 16 mg/kg, nitrate-nitrogen concentrations from 6 to 14 mg/kg, and organic matter concentrations from 4 to 12 mg/kg. The results also showed that high PO4-P, NO3-N, and Mg concentrations in water promote *Typha* development and proliferation. Sediment phosphate-phosphorus, nitrate-nitrogen, and organic matter concentrations showed a similar trend. The concentrations of water PO_4-P, NO3-N, Mg, and sediment PO_4-P, NO3-N, and Organic matter throughout the three segments revealed that the upper channel had a higher concentration than the middle, and the middle course had a higher concentration than the lower course. The distribution of *T. latifolia* and *T. angustifolia* followed the same pattern. The influence on fish catches and distribution revealed that open water had the maximum quantity and weight of fish taken, ranging from 83,167 to 173,026 kg and 14,402 to 59,355 kg, respectively, compared to *Typha* infested areas. Biological, manual, and physical strategies were used to control the spread of *Typha*. Biological control with *P. karka* reduced *Typha* species proliferation by 25%, with manual cutting at 15 cm below water level accounting for 95% of overall control. *Typha* proliferation was reduced by 54% when a black tarpaulin provided shade. Cutting at 15cm below the water's surface provided the finest control. Farmers should be educated on proper farming practices, particularly those that include manure rather than inorganic fertilizer. The optimum time to control *Typha* is when their density is low during the wet season.

Keywords: Control, ecology, Hadejia-Nguru Wetlands, *Typha*

INTRODUCTION

According to Mitsch and Gosselink (1986), Wetlands are places that transition between terrestrial and aquatic ecosystems and have a water table at or near the surface or are covered in shallow water (Prasad et al. 2002). Wetlands are gaining in popularity due to their numerous benefits to the environment. This includes a wide range of direct and indirect uses (Acharya 1998), such as (i) water retention during dry periods, keeping the water Table high and relatively stable; (ii) flood mitigation, and (iii) trapping of suspended solids and attached nutrients, resulting in streams flowing into lakes via wetland areas transporting fewer suspended solids and nutrients to the lakes than streams flowing directly into the lakes (Prasad et al. 2002). Wetland water quality is often impacted when wetland systems are removed due to urbanization or other circumstances (Barbier 2002).

Wetlands are also significant for wildlife because they provide resting and stopping locations for migrating and resident species, as well as refuges (Lameed 2011). Like any other natural environment, Wetlands play a vital role in maintaining species diversity. Different values include the use of wetlands for home and agro-industrial water supply (Ibrahim and Chiroma 1998), harvesting wetland bio-resources including fish and plants, and the role of wetlands in groundwater recharge and discharge (Ibrahim and Chiroma 1998). (Yahaya et al. 2010). The Hadejia-Nguru Wetlands, which cover 58,100 hectares and are designated as a Ramsar Site, are of international importance on the Ramsar wetlands. Wetlands are vital for water birds as a breeding area and a water source. The projected waterbird population ranges from 200,000 to 325,000, with about 377 bird species seen in the wetlands, including the near-threatened pallid harrier and great snipe species (Sanusi and Daura 2007). Drought struck the northeast of Nigeria in the early 1960s and 1970s, and to alleviate the situation, a water project was expanded upstream. As a result, the Tiga Dam was built, and aquatic weeds, particularly *Typha* species, became a nuisance, harming the social and economic well-being of the people who rely on the wetlands. Blockage of river channels is one of the issues connected with *Typha* weeds, but it also provides breeding and nesting habitat for Quelea birds (Sanusi and Daura 2007). The Hadejia Nguru Wetlands (HNWs) are located in north-eastern Nigeria's Sahel zone. The area is a floodplain marsh with permanent water bodies and sections flooded seasonally. Approximately 40% of the wetlands remain wet throughout the year, resulting in *Typha* mats (currently over 200 hectares, compared to 550 ha in 1999). (Sanusi and Daura 2007).

The frequency of *Typha* species was first discovered in the Lake Chad Basin. It was classified as one of the basin's seven top regional environmental issues by Transboundary Diagnostic Analysis (TDA) (Sanusi and Daura 2007). Variability in the hydrological regime and fresh water availability, water pollution, decreased biological resource viability, ecosystem loss, alteration, and sedimentation in rivers and water bodies are among the others. However, the Komadougou-Yobe subbasin (KYB), Chari Logone subsystem, and the lake itself are the most affected. *Typha* species and Quelea birds are two major invasive species in the KYB sub-system. Water hyacinth dominates the Chari-Logone system, while *Typha* species have taken over the lake. *Typha* is a water-loving plant that can multiply and become difficult to control in favorable conditions (i.e., shallow, persistently flooded regions), making it invasive. It out-competes practically all other plants in such conditions.

The invasion of *Typha* species has posed one of the most severe challenges to the economy and ecology of the Hadejia-Nguru Wetlands and other portions of the Hadejia-Jamaare-Komadugu-Yobe Basin (HJKYB) in general in recent years. *Typha* has recently taken over river channels, lakes, and fadamas in the wetlands and several hectares of farmland and prospective grazing pastures. Over 35,000 hectares of potential farming and grazing fields have been taken over by the *Typha* species in the Marma Channel and Nguru Lake (a portion of Hadejia-Nguru Wetlands), for example, where *Typha* invasion is especially severe. On the other hand, it has contributed to the desiccation of the Burum Gana Channel, which has hampered around 60% of dry season irrigation crops. Furthermore, *Typha* serves as a haven for vast flocks of Quelea birds (another invasive bird species in the basin), which are a nuisance to cereal crops (Sanusi and Daura 2007).

The most significant environmental impact of weed infestation is channel blockade and channel diversion in some instances. This has resulted in cases of simultaneous channel desiccation and inundation in HNWs, with the net result of lost livelihoods, poverty, and resource use disputes (Lameed 2011).

The goal of the study was to look into the diversity and influence of *Typha* species in the Hadejia-Nguru Wetlands, as well as to provide management advice for long-term ecology, with the following specific objectives: (i) To identify the *Typha* species that live in the Hadejia-Nguru Wetlands and their relative abundance monthly over two years. (ii) To determine the monthly physicochemical characteristics linked with *Typha* species proliferation for two years. (iii) To assess the soil, nutritional condition, and qualities that support *Typha* species growth every month for two years. (iv) To assess the impact of *Typha* species on fish catches and distribution during two years. (v) To determine the most effective management strategy for the Hadejia Nguru wetlands community.

MATERIALS AND METHODS

The study site and background to the research location

The Hadejia-Nguru Wetlands (HNW) is located in north-eastern Nigeria and covers around 58,400 ha. They are located between the latitudes of 12°40’N and 13°60’N and the longitudes of 10°20’E and 11°00’E. (Figure 1). Hadejia-Nguru Wetlands (HNW) is bordered by a flood plain consisting of a network of channels and pools that produce a whole pattern of constantly and seasonally flooded land and dry land (Hollis et al., 2003).

Field methods

Sampling stations

The wetlands were separated into three divisions based on preliminary study findings: a topography of the wetland system, human settlement, and fishing activity (Figure 1). The sampling stations were:

Upper course. Between N12 49’16.1’ and E l0 24’ 21.5’, Punjamu is near the entrance to the marsh where water drains from the Marma canal. It is located at 343 meters above sea level and has a high concentration of aquatic macrophytes, particularly *Typha* species, due to higher water, soil, and sediment nutrients.

Middle course. Badun is situated near the Dabar Magini town, between N12 50’ 27.9’ and El0 24’ 08.1’, at an altitude of 334m. There is a lot of fishing and farming going on there. In addition, the residents of this community work in the potash exploration and refinement industry.

Lower course. This location, between coordinates N12 49’ 40.7’ and El0 24’ 21.1’ with a height of 341m above sea level, has minimal human activity and few *Typha* species.

Identification of *Typha* species in Hadejia-Nguru Wetlands

Plants were sampled in the study region, and *Typha* species were identified using the Aquatic Plant Information System (APIS 1996) (Table 1).

Percentage occurrence of *Typha* species

Line transects were used to establish the percentage occurrence of each *Typha* species. The Typha species were counted every five meters from the shoreline to the open water. According to Titus, the percentages of occurrence of each species of *Typha* were calculated using the formula below (2003). The population density is defined as the number of people per unit area divided by the total land area. The proportionate representation of a species in a given ecosystem is called abundance.

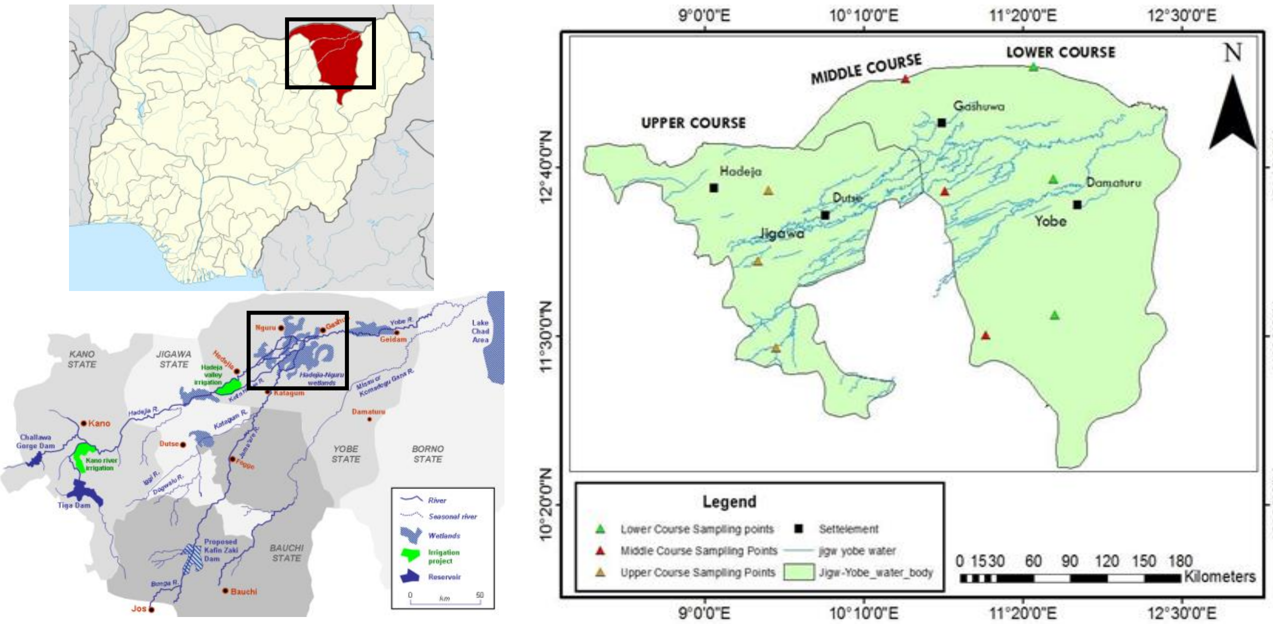

Figure 1. Map of Yobe State, Nigeria showing Hadejia-Nguru Wetlands (*left*) and area of the sampling points and site locations (*right*)

Table 1. Morphological features for identifying *Typha* species (APIS 1996)

Parameter	***T. latifolia***	***T. angustifolia***	***T. xgluca***	***T.dominigensis***
Appearance	Coarse stout	Slender	Either	Slender
Leaves x-section	Flat 8-15	Convex on back 5	Convex on back 6-12	Convex on back 6-12
Width of leaves in mm sheaths	Tapering	Auriculate	Auriculate	Tapering
Length between female and male	Non	5-12cm	0-4cm	0.7-4.5cm
Pith color at the base	White	White	Yellow buff	White
Female flower bract	None	Darkbrown blunt	Non rarely like ang and dom	Light brown ovate and apiculate

$$\text{Percentage of species (\%)} = \frac{\text{The area covered by each species}}{\text{Whole Total area of the habitat}}\ x\ 100$$

Determination of *Typha* species density

The following approach was used to determine the density of *Typha* species, as stated by Smith (2009): Each sampling location was divided into 50mx50m areas infested with *Typha* species. For two years, the number of each species in a 2500m^2 area was recorded and correlated with each physicochemical parameter of water, sediment, and soil nutrients.

Collection of water samples

A Van Dorn Water Sampler was used to take water samples in the wetlands, and it was dropped into the water with a graduated rope at a higher water level. Temperature, transparency, electrical conductivity, and pH were measured at the sample stations. Before being transported to the NIFFR hydrobiology laboratory for analysis, the water was transferred into clean sample bottles.

Determination of physical characteristics of water

Determination of temperature

A mercury thermometer calibrated to the nearest 1oC was used to determine the air and water temperature. Holding the thermometer above the water for 5 minutes until it stabilized was used to take air temperatures. Before recording the temperature, the thermometer was lowered into the water inclined at 10cm for 5 minutes to allow for equilibrium.

Determination of Transparency

The APHA-recommended Secchi disc was used to measure transparency in the field (2005). To estimate the openness, a Secchi-disc with a diameter of 25cm was lowered into the water with a measuring tape until it vanished from view, and the measurement was recorded as P1. The Secchi-disc was then removed, and the depth of reappearance was measured and recorded as P2, with the transparency computed using the formula below: Transparency = P_1+P_2/2.

Electrical conductivity (EC)

The electrical conductivity of soil samples was measured using a HANNA digital Electrical Conductivity (EC) meter with a soil-water ratio of 1-2 (w/v) (HI98129 model). 0.1M KCI was used to calibrate the electrical conductivity meter. In 100ml plastic containers, ten grams (10g) of 2mm sieved air-dried soil samples were weighed, and 20ml of distilled de-ionized water was added. After that, the mixes were agitated for 30 minutes. The soil suspensions were then left undisturbed for 30 minutes. After that, the EC meter's electrode was put into the settled suspension. The EC of soil samples was determined. Micro-ohms/cm (s/cm) was used to test electrical conductivity.

Determination of chemical characteristics of water

Determination of pH

Each sampling station's surface water was collected in plastic bottles, and the pH was calculated at 25°C using a 3015 model's pH meter. The electrode was dipped into the water sample, and a reading was taken and recorded. The pH meter was standardized with a buffer solution at pH 4.0, 7.0, and 9.0.

Dissolved Oxygen (DO)

The modified Winkler's method was used to determine the amount of dissolved oxygen (APHA, 2005) 250ml of water was collected from the designated sampling sites. Amber sampling bottles and filled up to the full. On the spot, 2 mL of standard Manganous sulfate solution and 2 mL of alkaline-iodide solution were added, and the contents were agitated for 10 seconds. To avoid air being trapped in the sample, 2ml concentrated Sulphuric acid (H2SO4) was added, and the stopper was replaced immediately. The bottle was shaken for a few seconds more to dissolve the precipitation. The samples were subsequently transported in an icebox to the NIFFR hydrobiology laboratory.

With sodium thiosulphate 0.2000N, the produced solution was titrated until the sample changed color from yellow to colorless. The number of digits from the counter window was read, and the value was multiplied by 0.1 to get the dissolved concentration in mg/L (APHA, 2005). A D.O. meter, model HI9142, was also used to measure DO.

Biological oxygen demand (BOD)

The water sample was incubated in 250ml BOD bottles at 20ºC for five days after the initial dissolved oxygen (DO) was calculated using the modified Winkler's method described above. On the fifth day, DO was determined on the incubated water sample once more, and BOD_5 (mg/L or mgL-1) was calculated as DO_1-DO_5 (mg/L). Where DO_1= Dissolved oxygen concentration before incubation. DO_5= Dissolved oxygen concentration after 5 days incubation (APHA, 2005) crosschecking using DO meter HI9142 for comparison.

Water phosphorus

Total phosphorus in water was measured using the APHA method (2005). To transform all chemical properties of phosphorus into phosphates, the sulphuric acid-nitric acid digesting process was applied. 50 mL of water and 1 mL of concentrated solution were pipetted into a microkjedhl flask. H_2SO_4 and 5 mL concentrated solution HNO_3 were added to the mix. The combination was digested to a clear solution volume of 1 mL. The solution was chilled before adding 20 mL of distilled water. After neutralizing NaOH, the solution was prepared up to 100 mL with distilled water. 50 mL of the treated sample and 8.0 mL of the mixed reagent were pipetted into a volumetric flask. After complete mixing, the solution was allowed to sit for 10 to 30 minutes to produce the blue color. The sample's absorbance was measured at 880 nm on a 634 UV-visible spectrophotometer with a reagent blank as the reference solution. Extrapolation from a calibration curve utilizing standard phosphate-phosphorus concentrations was used to estimate total phosphorus content.

Water nitrate-nitrogen

Mackereth (1978) and APHA (2005) described the phenol sulphonic acid technique, which was used in this study, as Fifty (50ml) of the sample was measured into a Kjeldahl flask, 0.3g of magnesium oxide was added, 0.4g was also added, the flask was attached to the distillation machine, and the sample distills were collected. The distillate had a greenish hue to it. The distillate was then titrated with standard acid, and a green to pink color was seen; the titer value was recorded from the burette for nitrate-nitrogen calculation, as shown below:

$$N = \frac{Titre\ value\ x\ 100}{Mills\ of\ aliquot\ (50ml)}$$

The result was recorded as the concentration of nitrate in mg/L

Water magnesium and calcium

Twenty's (20 mL), 5 mL buffer solution, 3 drops, potassium cyanide, potassium ferrocyanide, hydroxylamine, hydrochloride, triethanolamine, and eriocromy black-T indicative were added for each of the following reagents. The solution turned purple, and EDTA 0.01M was added to titrate it.

The endpoint turned a permanent blue color, and the titer value was recorded, along with the Magnesium ion concentration, which was calculated using the formula:

$$Mg + Ca = \frac{Titre\ value\ x\ 0.01}{Mills\ of\ aliquot} x1000$$

The results were equivalent to Ca + Mg. As a result, the amount of calcium was subtracted from this value to get the Magnesium value.

Sediment determination

Sediment pH

In a beaker, 10 g of dried sediment were weighed and mixed with 10 mL of distilled water. After 30 minutes of stirring with a glass rod, the liquid was left undisturbed for another 30 minutes. The pH level was measured and recorded (Udo and Ogunwale 1986).

Electric Conductivity (EC)

The EC was calculated by immersing the electrode of the conductivity meter in the sample and recording the EC in s/cm. Ten (10g) of dried silt was weighed and put into a beaker with 50 mL of distilled water (Udo and Ogunwale 1986).

Sediment nitrate-nitrogen

Two (2g) desiccated sediment was weighed and placed in a Kjeldahl flask with 20 mL concentrated Sulphuric acid. Digestion was carried out in the fume cupboard's digestion chamber for one hour.

After allowing the contents to cool, distilled water was added to dilute the digested sample to a volume of 50 mL. Distillation was performed by placing 10 mL of the digested material in a macro Kjeldahl flask and adding 30 mL of distilled water. Then 20 mL of 40% NaOH was added, and the flask was coupled to the distillation machine. Under the condenser, a boric acid indicator was inserted. Then, against 0.01 molar H_2S0_4, titrated. The mixture turned from green to pink, and the titer value was recorded so that the amount of nitrogen in the sample could be calculated using the formula:

N = titre value x 0.01 molar x 0.014 x 50 x 1000/weight of sediment x mills of aliquot. The concentration was calculated as nitrate-nitrogen in g/kg.

Sediment Calcium Ion Exchange Capacity (CEC)

Five (5) grams of silt were weighed and transferred to a conical flask containing 20 mL of ammonium acetate solution, saturated overnight. The filtrate was collected in a conical flask after the mixture was filtered with a funnel and filter paper. A 30 mL solution of ammonium acetate was also added to wash the sediment residue from the flask, which was then filtered with paper and funnel. Na, K, Ca, and Mg was measured in the filtrate solution. A flame photometer was used to determine Na and K. The Atomic Absorption Spectrophotometer (AAA) determined Ca and Mg.

Sediment phosphate-phosphorus

Two (2) grams of silt were weighed and put into a conical flask, along with 7 mL of phosphorus extraction solution, and mechanically agitated for 30 minutes. The filtrate was collected after the mixture was filtered. As a result, 2 mL of the filtrate was added to a 50 mL volumetric flask, followed by 2 mL of ammonium molybdate, 30-40 mL of distilled water, 1 mL of fresh diluted stannous chloride, and distilled water. The spectrophotometer was used to measure the color intensity at 660 wavelengths; the reading was obtained and used to determine the phosphorus concentration as follows:

$$P = \frac{Reading\ x\ conversion\ factor\ (0.61) x\ dilution\ factor\ (25)}{Atomic\ weight\ of\ phosphorus}$$

The value was recorded as phosphorus in g/kg

Sediment total organic matter content (TOC)

Researchers employed Agbeti and Smol's (1995) approach to calculate TOC. In a 250 mL conical flask, 1g of finely ground silt sample was added. After that, 10 mL 17N $K_2\ Cr_2\ O_7$ and concentrated H_2SO_4 were added, and the mixture was allowed to cool for 30 minutes. Whatman filter paper N01 was used to filter the suspension. 1-5 drops of ferroin indicator were added, then titrated with 0.4N $(NH_4)_2\ SO_4.6H_20$ until the endpoint changed from dark green to red. The following formula was used to determine the TOC:

$$Total\ organic\ matter\ content\ (TOC)\ (g) \frac{meg\ of\ Cr_2O_2\ meqfe - NH_4\ SO_4 x4}{Wt. of\ sample}$$

Sediment particles size distribution and textural classification

The hydrometer method was used to determine the particle size (Bouyoucos 1951). A 250 mL plastic beaker was filled with fifty grams (50g) of a 2mm sieved soil sample. Fifty milliliters (50 mL) of 6% H2O2 was added, covered with glass, and set on a water bath to oxidize the organic materials (indicated by the presence of effervescence). The beaker was taken out and set aside to cool. The contents were placed in a dispersion cup with 400 mL of distilled water. A 100 mL Calgon solution was added, and the mixture was churned for 10 minutes with a glass rod. The suspension was poured into a setting cylinder, filled to the 1-liter mark. The mouth of the cylinder was then sealed with a rubber stopper, and the cylinder was vigorously shaken for 1 minute. The cylinder was then placed on a table, and after four minutes, the first reading was taken. The suspension's temperature was also measured and recorded. The suspension was left alone for a while. Two hours after the first shaking ended, the hydrometer was reinserted into the suspension, and the reading was taken for the second time.

The sand, silt, and clay compositions were calculated, and the texture of the soil sample using the textural triangle. The following formula was used to calculate the sand, silt, and clay composition (percentage):

% Silt= d-g/ax100
% Clay= g/ax100
% Sand= 100-(%Silt+%Clay)

Where;
d: corrected hydrometer reading at 4 mins
g: corrected hydrometer reading at 2 hours observation
a: weight of the soil sample (g)

Verma and Agarwal (2007) reported that the soil texture triangle was used to classify the soil samples based on the samples' relative percentage composition of clay, silt, and sand.

Soil chemical determination

Soil phosphate-phosphorus

Five (5) grams of dry soil was weighed and placed into a tube with a stopper, and $35cm^3$ of extraction solution was added (with a pipette). After 1 minute of shaking, the suspension was filtered into a dry bottle. Back through the filter with the solution.

Ten (10) cm^3 of the filtrate was transferred to a dry $100cm^3$ beaker with a 25cm3 ammonium molybdate reagent. A $5cm^3$ stannous chloride dilutes solution was added and stirred. The absorption was measured at 890 nm on a spectronic 20 after 10 minutes of color development.

Soil nitrate-nitrogen

The chemical composition of the soil was determined according to Gee and Bauder's guidelines (1986). In a 500 mL Kjeldahl flask, one (1) gram of 100 mesh dirt was weighed. For around 30 minutes, four drops of water were left to stand. 5g Kjeldahl catalyst combination and concentrated sulphuric acid were added. Digestion was carried out in the digestion chamber under the fume cupboard for one hour.

After cooling the contents, distilled water was added to dilute the digested sample to 50 mL. Distillation was carried out by adding 30 mL of distilled water to 10 mL of digested sample in a macro Kjeldahl flask. After that, 20 mL of 40% NaOH was added, and the associated flask was placed on the distillation machine. Under the condenser, a boric acid indicator was inserted. The sample was then heated to distillate, which was then titrated against 0.01 molar H2S04, the mixture-colored pink, and the titer value was recorded to calculate the quantity of nitrogen in the sample using the formula below:

N = titre value x 0.01 molar x 0.014 x 50 x 1000/Weight of sediment x mills of aliquot.

The concentration was calculated as nitrate-nitrogen in g/kg.

Soil organic carbon and organic matter determination

The method of Walkley and Black (1934), which IITA used, was used to determine organic carbon (OC) (1979). One (1) gram of dirt was weighed into 250 mL conical plasmin triplicates. Each flask received 10 mL of 0.02moldm^{-3} potassium dichromate, gently swirled to disseminate the soil, followed by 20 mL concentrated H_2SO_4. The flask was gently stirred to thoroughly and reagents completely. The mixture was then allowed to sit for 30 minutes on a glass plate before being diluted with 200 mL distilled water and 1 mL ferroin indicator, then mixed and titrated with 0.25moldm^{-3} ferrous ammonium sulfate. A blank titration was performed simultaneously but without the soil sample to determine organic carbon (OC) and organic matter (OM). The formula below was used:

% OC= (Blank titre-Actual title) X 0.3xf/weight of air-dried soil sample

Where: f = correction factor =1.33M = concentration ferrous ammonium sulphate% OM in soil=%) OC X 1.729

Soil calcium, magnesium

Five (5) gram of soil was weighed and put to a conical flask containing 20 mL of ammonium acetate solution, which was saturated overnight. The filtrate was collected in a conical flask after the mixture was filtered with a funnel and filter paper. A 30 mL ammonium acetate solution was also added to wash the sediment residue in the flask, filtered with paper and a funnel. Na, K, Ca, and Mg concentrations were determined using the filtrate solution. Impact of *Typha* species on fish catch and distribution in Hadejia-Nguru wetland

The Hadejia Nguru wetland was divided into three sampling sites, with each sampling site was split into A and B for collecting data. A is an uninfested area, whereas B is a *Typha-infested* area. For two years, experimental gillnet mesh sizes of 1; 1.5; 2; 2.5; 3; 3.5; 4; 5; 7; were set in the evening and checked early in the morning. Weighing and spring balances of various sizes measured the caught fish. Olaonsebikan and Raji (2004) identified fish species by hand. Dissolved oxygen (DO), biological oxygen demand (BOD), and the number of caught fish species were all recorded at the three sampling sites. Management Methods

Biological control of *Typha* species with varying weights of *Phragmites karka* (As noticed by Birnin-Yauri, 2009 in the field). *Typha* species infested plots were labeled A, B, C, and D. Two thousand (2000) *Typha* species per 2500m^2 were randomly selected for the experiment in each sample station; (i) A: *P. karka* was interplanted with 50kg of *P. karka*. (ii) B: *P. karka* was interplanted with 25kg. (iii) C: 10kg of *P. karka* were interplanted with. (iv) D: Control studies used *Typha* species devoid of *P. karka*. For two years, the mortality rates of *Typha latifolia* and *Typha angustifolia* were recorded monthly.

Manual control

Manual control was carried out by the instructions of Nelson and Dietz (2006). A 2500m^2 plot infected with *Typha* species was repeated three times, with two thousand stands of *Typha* species plants chosen at random in each sampling site A, B, C, and D. (i) A: shoots of *Typha* plants which were cut 5cm below the water's surface and immersed for two years. (ii) B. submerged shoots that have been cut 10cm below the surface of the water. (iii) C. shoots, cut 15cm below the water, and submerged. (iv) D: shoots which were cut 5cm, 10cm, and 15cm above the water as control experiments. For two years, the number of dead plants and regrowth were counted at three sites within the sampling site.

Physical control using shading

Linde et al. (1976) described how physical control was carried out. Three times a 50m by 50m plot infected with *Typha* species was duplicated (A, B, C, and D). For the experiment, each was counted and included two thousand *Typha* species. A 50mx50m plot infected with *Typha* species containing two thousand *Typha* species was covered with 100mx100m of black tarpaulin, marked A, B, C, and D in each sampling site. (i) A represents a single black tarpaulin; (ii) B represents a doubled black tarpaulin; (iii) C represents a tripled black tarpaulin; (iv) D is a control experiment with no black tarpaulin. The mortality rate of *Typha* species was measured in three locations inside the sampling station for two years.

Statistical analysis

Analysis of Variance (ANOVA) was performed on the data acquired using the Statistical Package for Social

Sciences (SPSS). Data were subjected to the Principal Components Analysis for physical and chemical parameters, soil nutrients, and sediment nutrients. The significance of the difference between *T. latifolia* and *T. angustifolia* was determined using analysis of variance (ANOVA). The fish's numbers and weights were captured in two distinct places: the Typha-free area (site A) and the *Typha*-infested area (site B). In terms of the influence of different *P. karka* weights, (i) A. *P. karka* (50kg) was tested. (ii) B. 25kg of *P. karka,* (iii) C. 10kg of *P. karka,* (iv) D. Free from *P. karka* as control. In terms of re-growth rate, there is a significant difference among (i) A. 5cm below the water level, (ii) B. 10cm below the water level, (iii) C. 15cm below the water level, and (iv) D. 5cm, 10cm, 15cm above the water level as control. To separate the means of the data collected, Duncan's Multiple Range Test was employed. The correlations between the physicochemical parameters of sediment, soil nutrients, and *Typha* species were determined using Pearson's product-moment correlation coefficient. The T-test was employed to see a significant difference between the two years assessed environmental and biotic variables. The significance level was chosen at ($P<0.05$).

RESULTS AND DISCUSSION

Typha species resident in Hadejia-Nguru wetland

Typha latifolia and *T. angustifolia* were the species of *Typha* identified in Hadejia-Nguru wetland over two years, with 65-70% and 30-35% occurrence, respectively, as shown in Figures 2 and 3. According to the findings, T. latifolia had a higher population than T. angustifolia. The inflorescence is an easy way to distinguish the two *Typha* species. In the inflorescence of *T. angustifolia*, the male and female reproductive components are separated. The male and female reproductive components in the inflorescence of *T. latifolia* are not separated. *T. latifolia* has narrow leaves, but *T. angustifolia* has broad leaves. The quantity of *T. latifolia* and *T. angustifolia* differed significantly (Table 2). In the interaction between *T. latifolia* and *T. angustifolia*, there was a substantial variation between Month and Sample, Month and Location, and Sample and Location. There is no significant difference between location and Season and Month x Sample ($P<0.05$).

Typha species density

The density of two *Typha* species was *T. latifolia*, followed by *T. angustifolia*. *T. latifolia* and *T. angustifolia* density ranged from 40 to 100, and 20 to 60 stands per $9m^2$, respectively (Figure 2).

Principal components analysis

Six variables were discovered to be responsible for the expansion of *T. latifolia* and *T. angustifolia* in the Hadejia-Nguru Wetlands, according to the results of principal component analysis. Water phosphate-phosphorus, Nitrate-Nitrate, Magnesium, Sediment phosphate-phosphorus, Nitrate-Nitrate, and organic matter were among them (Table 3).

Relationship between some physical and physicochemical parameters and *Typha* species density

Principal component analysis revealed that physical characteristics such as air temperature transparency and electrical conductivity (EC) have no relation to Typha species' growth in the Hadejia Nguru wetland. The air temperature ranges from 21 to 35 degrees Celsius, 0.4 to 1.9 meters, and 166 to 375 (s/l), respectively. Dissolved oxygen (DO) and biological oxygen demand (BOD) were measured and varied from 7.0 to 8.8, 0.9 to 8.84 mg/L, and 4.11 to 15.00 mg/L, respectively (Tables 4 and 5).

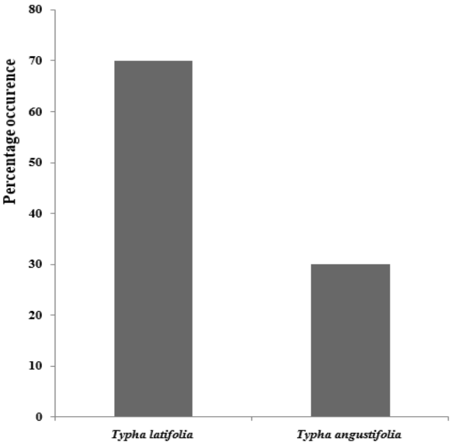

Figure 2. The percentage occurrence of *Typha latifolia* and *T. angustifolia* resident in Hadejia Nguru Wetland during dry season 2010 and 2011.

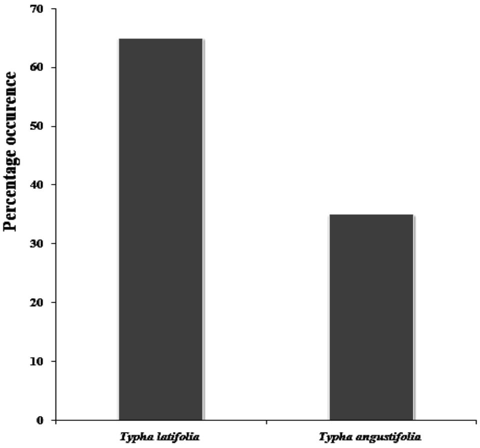

Figure 3. The percentage occurrence of *Typha latifolia* and *T. angustifolia* existing in Hadejia Nguru Wetland during wet season 2010 and 2011

Table 2. Analysis of variance between *Typha latifolia* and *T. angustifolia* density in the study area for two years (2010 and 2011)

Source of variation	DF	*Typha latifolia*	*Typha angustifolia*
TL (Treatment)	116	0.001*	0.003*
Month	11	0.004*	0.004*
Sample	2	0.002*	0.003*
Location	2	0.021*	0.025*
Season	1	0.008*	0.042*
Month sample	12	0.001*	0.372
Month location	22	0.0278*	0.001*
Sample location	4	0.0421*	0.042*
Location season	2	0.043*	0.367
Month sample location	44	0.021*	0.234
Sample location season	6	0.021*	0.041*
Error	206		

Note: * Significant; at ($P<0.05$).

Table 3. Principal component analysis of chemical characteristics of sediment and water from Hadejia-Nguru wetlands 2010 and 2011

Variables	Extraction	Main factors extracted
Phosphorus water	0.999065	Water Phosphorus
Nitrogen Water	0.999065	Water Nitrate
Magnesium	0.998774	Water Magnesium
Sediment phosphate-phosphorus	0.998233	Sediment phosphate-phosphorus
Sediment nitrate nitrogen	0.997911	Sediment nitrate nitrogen
Sediment organic	0.996365	Sediment organic matter

Table 4. The average physicochemical parameters extracted out by Principal Component Analysis in Hadejia Nguru wetland in 2010

Month water Temp. °C	Air temp. (°C)	pH	Transp. (m)	DO_2 mg/L	BOD mg/L	Conduct. (µs/l)
Jan. 10 16	21	7.8	1.8	9.24	10.05	328
Feb. 10 18	24	7.8	0.7	4.83	14.41	297
Mar. 10 17	24	7.7	0.9	3.15	9.53	285
Apr. 10 20	27	8.1	1.9	2.24	8.65	289
May 10 25	35	7.5	1.8	8.84	12.71	261
Jun. 10 21	33	7.6	1.7	1.55	11.46	302
Jul. 10 20	30	6.9	1.0	1.92	10.88	268
Aug. 10 15	21	7.0	0.4	0.91	7.53	260
Sept. 10 16	22	7.3	0.9	5.82	14.91	266
Oct. 10 22	26	7.8	1.4	2.64	8.72	268
Nov. 10 21	25	8.0	1.5	3.11	7.99	370
Dec. 10 18	24	7.4	1.7	3.15	4.11	375

Table 5. The average physicochemical parameters extracted out by Principal Component Analysis in Hadejia Nguru wetland in the year 2011

Month water temp. (°C)	Air temp. (°C)	pH	Transp. (M)	DO_2 mg/L	BOD mg/L	Conduct. (µs/l)
Jan. 11 15	21	7.8	1.8	9.24	8.05	308
Feb. 11 20	25	7.9	0.7	4.83	14.25	297
Mar. 11 19	22	7.7	0.9	3.15	9.52	185
Apr. 11 22	28	8.1	1.9	2.24	14.23	280
May. 11 25	35	7.5	1.8	8.82	15.00	266
Jun. 11 23	32	7.5	1.7	1.55	1.46	302
Jul. 11 20	30	6.5	1.0	1.92	9.89	268
Aug. 11 15	22	7.0	0.4	0.91	10.54	260
Sept. 11 14	22	7.3	0.9	5.82	9.92	166
Oct. 11 17	27	7.8	1.5	2.64	8.73	265
Nov. 11 21	25	8.0	1.6	3.11	9.89	276
Dec. 11 19	24	7.5	1.7	3.15	12.12	275

In terms of transparency, temperature, electrical conductivity, and pH, most aquatic plants can thrive in various conditions: biological oxygen demand (BOD) and dissolved oxygen (DO) (BOD). Similar trends were seen in soil texture and nutrient concentrations related to soil mineral leaching into the sediment. The elements that govern *Typha* species proliferation must be studied directly from the root and those that control photosynthetic activities.

Relationship between water phosphate-phosphorus and *Typha* species density

phosphate-phosphorus is necessary for organism growth and can be the nutrient that restricts water's primary production. Figure 4 shows the results of the phosphate-phosphorus concentration in the Hadejia-Nguru Wetlands. phosphate-phosphorus concentrations ranged from 3.5mg/L to 13.5mg/L. *T. latifolia* densities ranged from 60 to 100 stands per $9m^2$, and *T. angustifolia* densities ranged from 40 to 65 stands per $9m^2$. During the extreme dry season (April-May), high values of water phosphate-phosphorus were recorded, while lower values were observed during the rainy season (July-August). With phosphate-phosphorus concentration, the populations of *T. latifolia* and *T. angustifolia* follow the same pattern. Months, sample size, location, and season exhibited substantial differences in the results. Month and Sample, Month and Location, Sample and Location, location and Season, and month x sample x location interactions with *T. latifolia* density were also significant. However, no correlation was found between the season and the density of *T. angustifolia*. *T. latifolia, T. angustifolia* densities, and phosphate-phosphorus concentration were found to have a significant correlation ($P<0.05$) (Tables 6, 7, 8, and 12)

Relationship between water nitrate-nitrogen concentration and *Typha* species density

nitrate-nitrogen constitutes the second most abundant element in nutrition and is present in various organic forms like carbon. Nitrogen is one of the key nutrients in the aquatic environment for the growth of *Typha* species. The results of nitrate-nitrogen water levels in the wetlands of Hadejia-Nguru and the density of *T. latifolia-T. angustif*olia are shown in Figure 5. nitrate-nitrogen concentrations in water vary between 3mg/L and 13mg/L. *T. latifolia* was 60 to 100 stands per nine square meters and 40 to 65 stands per nine square meters, respectively. During the extreme dry season (April-May), the high value (NO_3-N) of water was obtained, while lower values were obtained during the wet season (July-August). Regarding nitrate-nitrogen concentrations, *T. latifolia* and *T. angustifolia* have the same pattern. The results revealed a significant difference (P<0.05) between months, sampling stations, locations, and seasons. Similarly, the interaction between month and sample, month and location, sample and location, location and season, month x sample x location, and season years and seasons with *T. latifolia* density was significant. *T. latifolia* and *T. angustifolia* density exhibited a significant correlation (P<0.05) between nitrate-nitrogen concentrations and *T. latifolia* and *T. angustifolia* densities (Tables 6, 7, 8, and 12).

Table 6. Analysis of variance of *Typha latifolia* concerning physicochemical parameters for two years (2010 and 2011)

Source of variation	**DF**	**Water PO_4-P (mg/L)**	**Water NO_3-N (mg/L)**	**Water Mg (mg/L)**
TL (Treatment)	116	0.024*	0.035*	0.036*
Month	11	0.036*	0.031*	0.042*
Sample	22	0.034*	0.330	0.012*
Location	2	0.032*	0.004*	0.008*
Season	1	0.020*	0.003*	0.011*
Month* sample	22	0.003*	0.032*	0.048*
Month* location	22	0.021*	0.002*	0.034*
Sample* location	4	0.002*	0.033*	0.026*
Location* season	2	0.040*	0.002*	0.002*
Month *sample *location	44	0.002*	0.002*	0.760
Sample location season	6	0.003*	0.043*	0.243
Error	207			

Note: *Significant; at (P<0.05), TL= *Typha latifolia*

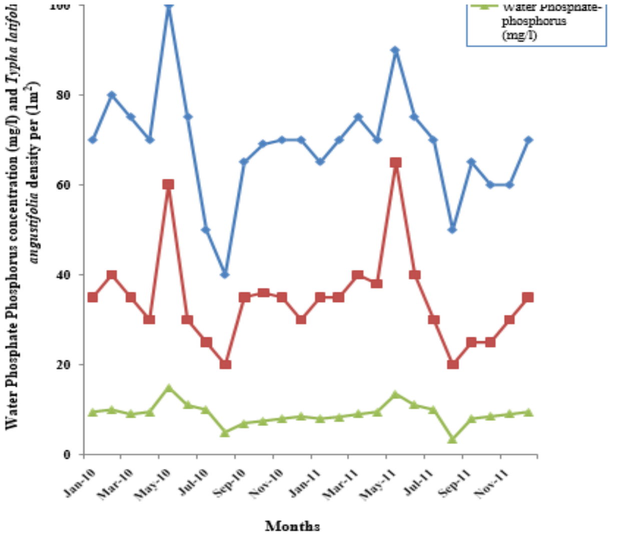

Figure 4. Monthly variation between water phosphate-phosphorus concentration and *Typha* species density in Hadejia-Nguru wetland in 2010 and 2011.

Table 7. Analysis of variance of *Typha angustifolia* concerning physicochemical parameters concentration for two years (2010 and 2011)

Source of variation	**DF**	**Water PO_4-P (mg/L)**	**Water NO_3-N (mg/L)**	**Water Mg (mg/L)**
TA (Treatment)	116	0.434	0.020*	0.031*
Month	11	0.436	0.011*	0.002*
Sample	22	0.012*	0.312	0.001*
Location	2	0.021*	0.004*	0.004*
Season	1	0.351	0.003*	0.002*
Month* sample	22	0.028*	0.214	0.037*
Month* location	22	0.002*	0.003*	0.003*
Sample* location	4	0.027*	0.003*	0.0185
Location* season	2	0.030*	0.003*	0.013*
Month*sample*location	44	1.33	0.004*	0.019*
Sample location season	6	0.004*	0.013*	0.001*
Error	207			

Note: *significant at (P<0.05), TA= *Typha angustifolia*

Table 8. Mean values seasonal variation of surface water chemical concentrations and *Typha* species density concerning season and year in Hadejia-Nguru Wetlands

Season/ years	***T. latifolia* dens. / 1m²**	***T. angustifolia* dens. / 1m².**	**Water PO_4-P (mg/L)**	**Water NO_3-N (mg/L)**	**Water Mg (mg/L)**
Seasons					
Wet	65.53^{b}	35.06^{b}	3.00^{b}	2.00^{b}	3.62^{b}
Dry	80.53^{a}	40.49^{a}	7.00^{a}	4.00^{a}	5.20^{a}
Years					
2010	75.91^{b}	50.59^{b}	9.13^{b}	5.92^{b}	4.56^{b}
2011	88.29^{a}	57.82^{a}	11.94^{a}	6.01^{a}	6.35^{a}

Note: Means with the same letters across columns are not significantly different (P<0.05)

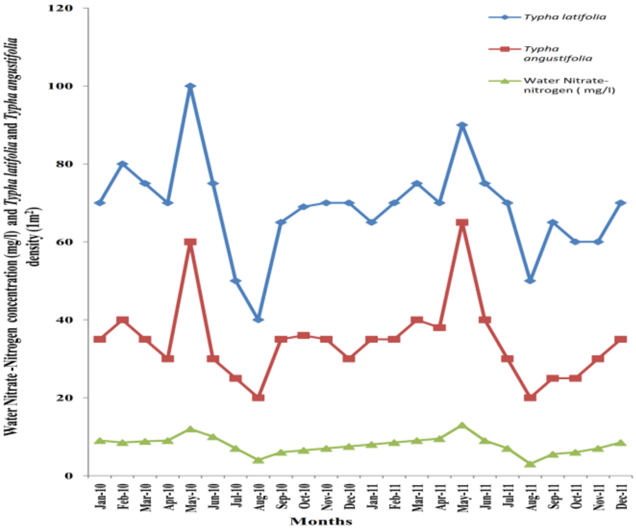

Figure 5. Monthly variation between water nitrate-nitrogen concentration and *Typha* species density in Hadejia-Nguru wetland in 2010 and 2011.

Relationship between water Magnesium concentration and *Typha* species density

Figure 6 shows the results for water Mg concentration in Hadejia-Nguru Wetlands water. The concentration ranges from 1 to 10 milligrams per liter. *T. latifolia* density was 60 to 100 stands per 9m^{2,} and *T. angustifolia* density was 40 to 65 stands per 9m^2, respectively. Water magnesium (Mg^{4-}) levels were highest during the extreme dry season (April-May) and lowest during the wet season (July-August). However, the density of *T. latifolia* and *T. angustifolia* fluctuated similarly. The results revealed a significant difference ($P < 0.05$) between months, sampling stations, location, and season. Again, the interaction between month and sample, month and location, sample and location, location and season, month x sample x location, and season years and seasons with *T. latifolia* density was significant. Except for month x sample x location, no significant correlation was found between magnesium concentration and *T. latifolia* density. It also revealed a significant correlation ($P<0.05$) between *T. latifolia* and the density of *T. angustifolia* and magnesium content, as well as a non-significant difference between Sample, Month, sample location (Tables 6, 7, 8, and 12).

Relationship between sediment phosphate-phosphorus concentration and *Typha* species density

Figure 7 shows the results of the soil sediment phosphate-phosphorus concentration of Hadejia-Nguru Wetlands. Phosphate-phosphorus concentrations in the silt ranged from 6.5 to 16 mg/kg. *T. latifolia* and *T. angustifolia* densities ranged from 60 to 100 stands for *T. latifolia* and 40 to 65 stands for *T. angustifolia*, respectively. During the dry season (April-May), higher sediment phosphate-phosphorus (PO_4-P) concentrations were measured, while during the peak of the rainy season, lower concentrations were recorded (July-August). *T. latifolia* and *T. angustifolia* have similar fluctuation patterns. The results also revealed that the sediment phosphate-phosphorus concentration was significant at ($P<0.05$) in all treatments, including months, sampling stations, location, and season. Similarly, there was a significant interaction between month and sample, month and location, sample and location, location and season, month x sample x location, and season years and seasons with *T. latifolia* and *T. angustifolia* density. It also revealed a significant correlation between the densities of *T. latifolia* and *T. angustifolia* and sediment phosphate-phosphorus concentration (Tables 9, 10, 11, and 12).

Relationship between sediment nitrate-nitrogen concentration and *Typha* species density

The content of nitrate-nitrogen in the sediment ranged from 6 to 14 mg/kg (Figure 8). *T. latifolia* and *T. angustifolia* densities were from 60 to 100 stands per 9m^3 and 40 to 65 stands per 9m^3, respectively. Sediment nitrate-nitrogen concentrations were greater during the extreme dry season (April-May) and lowered in the wet season (July-August). The populations of T. latifolia and T. angustifolia followed a similar trend, increasing concentrations as density rose. They examined data that revealed the sediment nitrate-nitrogen concentrations for all treatment months, sampling stations, locations, and seasons. Similarly, the interaction between month and sample, month and location, sample and location, location and season, month x sample x location, and season years and seasons with *T. latifolia* and *T. angustifolia* density was significant. It also revealed a significant correlation between the densities of *T. latifolia* and *T. angustifolia* and sediment nitrate-nitrogen concentrations (Tables 9, 10, 11, and 12).

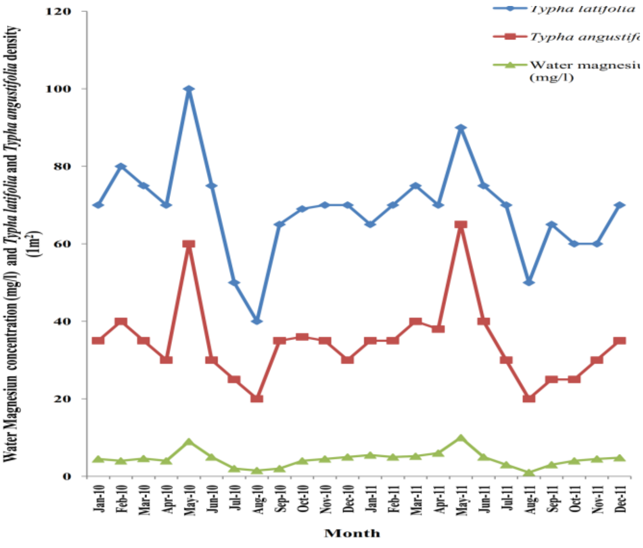

Figure 6. Monthly variation between water magnesium concentration and *Typha* species density in Hadejia-Nguru wetland in 2010 and 2011

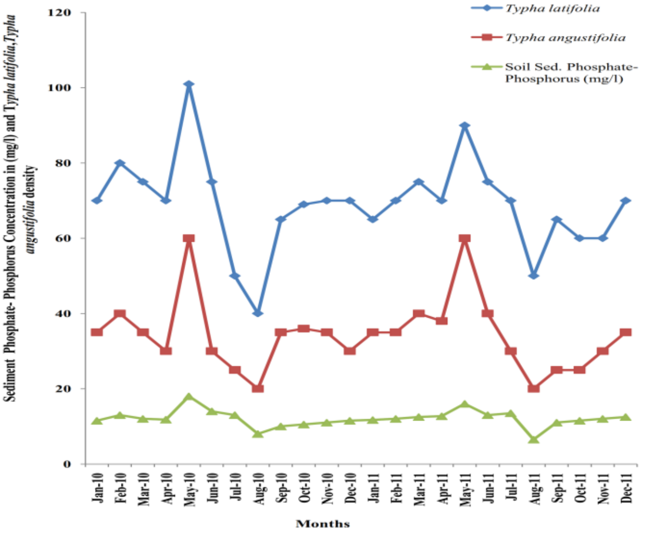

Figure 7. Monthly variation between sediment phosphate-phosphorus concentration and *Typha* species density in Hadejia-Nguru wetland in 2010 and 2011.

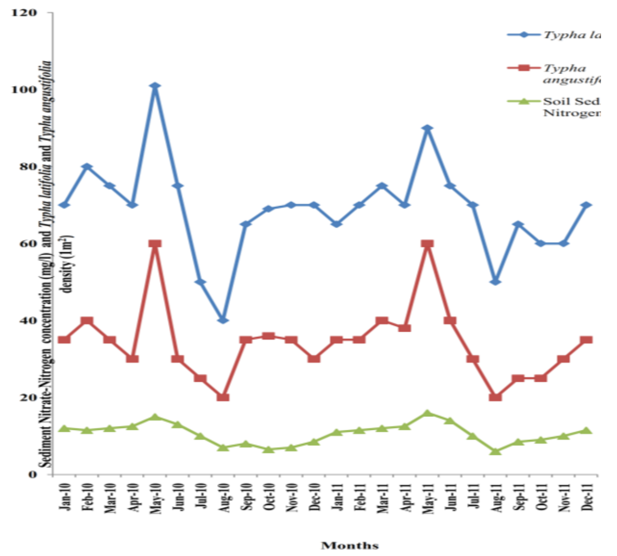

Figure 8. Monthly variation between sediment nitrate-nitrogen concentration and *Typha* species density in Hadejia-Nguru wetland in 2010 and 2011.

Relationship between sediment organic matter concentration and *Typha* species density

Organic matter content is the second most abundant nutrient element, and it comes in a variety of organic forms, similar to carbon. It is one of the most critical nutrients for rhizomes in *Typha* species. The organic matter concentration in the Hadejia-Nguru wetland is depicted in Figure 9. The concentration of organic materials ranged from 4 to 12 mg/kg. The density of *T. latifolia* and *T. angustifolia*, respectively, ranges from 40 to 100 and 20 to 65 stands per 9m^2. As the wet season progressed, the amount of organic matter in the soil reduced. The maximum organic matter concentration was found during the peak of the dry season (April-May). The density of *T. latifolia* and *T. angustifolia* fluctuated in the same way. The results revealed that the concentration of sediment organic matter was considerable for all treatments, sample stations, locations, and seasons. Similarly, the interaction between month and sample, month and location, sample and location, location and season, month x sample x location, and season years and seasons with *T. latifolia* and *T. angustifolia* density was significant. Similarly, the interaction between month and sample, month and location, sample and location, location and season, month x sample x location, and season years and seasons with *T. latifolia* and *T. angustifolia* density was significant, except during therapy and for a few months. There was also a significant correlation (P<0.05) between the densities of *T. latifolia* and *T. angustifolia* and the sediment organic matter concentration (Tables 9, 10, 11, and 12).

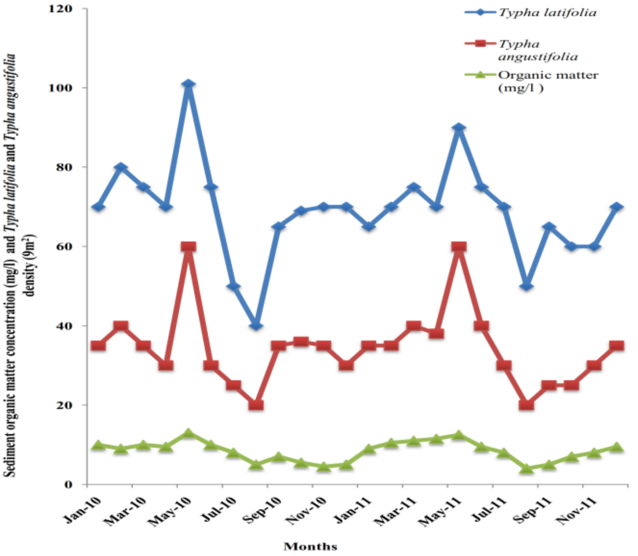

Figure 9. Monthly variation between sediment organic matter concentration and *Typha* species density in Hadejia-Nguru wetland in 2010 and 2011.

Table 9. Analysis of variance concerning Sediment Nutrients concentration (mg/kg) for two years (2010 and 2011)

Source of variation	DF	Sediment PO$_4$-P (g/kg)	Sediment NO$_3$-N (g/kg)	Sediment OM (g/kg)
TL (Treatment)	116	0.034*	0.025 *	0.236
Month	11	0.436	0.0131*	0.000*
Sample	22	0.012*	0.0251*	0.011*
Location	2	0.021*	0.040*	0.388
Season	1	0.031*	0.028*	0.000*
Month* sample	22	0.027*	0.003*	0.238
Month* location	22	0.015*	0.032*	0.000*
Sample* location	4	0.027*	0.028*	0.226
Location* season	2	0.030*	0.028*	0.000*
Month *sample*location	44	0.033*	0.023*	0.025*
Sample location season	6	0.024*		
Error	207			

Note: *significant at (P<0.05), TA= *Typha latifolia*

Table 10. Analysis of variance of *Typha angustifolia* concerning sediment nutrients concentration for two years (2010 and 2011)

Source of variation	DF	Sediment PO$_4$-P (mg/L)	Sediment NO$_3$-N (g/kg)	Sediment OM (g/kg)
TL (Treatment)	116	0.334	0.031*	0.003*
Month	11	0.036*	0.023*	0.000*
Sample	22	0.001**	0.050*	0.001*
Location	2	0.003*	0.040*	0.041*
Season	1	0.031*	0.019*	0.000*
Month* sample	22	0.035*	0.001*	0.038*
Month* location	22	0.023*	0.042*	0.001*
Sample* location	4	0.027*	0.031*	0.046*
Location* season	2	0. 002*	0.032*	0.000*
Month *sample*location	44	0.023*	0.003*	0.001*
Sample location season	6	0.034*	0.015*	0.034*
Error	207			

Note: *Significant, TA= *Typha angustifolia*

Variation in water PO_4-P, NO_3-N, and Mg in different sampling stations

Chemical concentrations differ from sampling station to sampling station (Figure 10). The upper course had the highest concentration, followed by the middle and lower courses. Phosphorus, Nitrate, and Magnesium concentrations in water varied from 13 to 20 mg/L in the upper course, 12 to 16 mg/L in the middle course, and 5.5 to 12 mg/L in the lower course. From upper to lower courses, the density of *T. latifolia* and *T. angustifolia* followed the same trend in decreasing order. *T. latifolia* and *T. angustifolia* density ranges are 60 to 95 stands per $9m^2$ and 30 to 55 stands per $9m^2$, respectively. With *T. latifolia* and *T. angustifolia* densities, there was a substantial variation in water PO_4-P, NO_3-N, and Mg concentrations. The density of these aquatic plants grew as the chemical concentration increased (Table 13 and 14). From upper to lower courses, the density of *T. latifolia* and *T. angustifolia* followed the same pattern in decreasing order. *T. latifolia* and *T. angustifolia* density ranges are 60 to 95 stands per $9m^2$ and 30 to 55 stands per $9m^2$, respectively. With *T. latifolia* and *T. angustifolia* densities, there was a substantial variation in water PO_4-P, NO_3-N, and Mg concentrations. The density of these aquatic plants grew as the chemical concentration increased (Table 13 and 14).

Variation in sediment PO_4-P, NO_3-N, and organic matter in different samplings stations

Chemical concentrations differ from sample station to sampling station (Figure 11). The upper course had the highest concentrations, followed by the middle and lower courses. Sediment phosphate-phosphorus, nitrate-nitrogen, and organic matter concentrations in the upper, middle, and lower course varied from 23 to 35 mg/kg, 16 to 22 mg/kg, and 13 to 20 mg/kg, respectively. The density of *T. latifolia* and *T. angustifolia* decreased in the same sequence from upper to lower course. *T. latifolia*, *Typha*, and *T. angustifolia* density ranged from 60 to 100 stands, 30 to 55 stands, and 30 to 55 stands per $9m^2$, respectively. Water PO_4-P, NO_3-N, and organic matter concentrations differed significantly ($P<0.05$) with *T. latifolia* and *T. angustifolia* densities of aquatic plants increased as chemical concentrations increased (Tables 13 and 14).

Impact of *Typha* species on fish catch and distribution in Hadejia-Nguru wetland (2010 and 2011)

Tables 15 and 16 show that the average water, air temperature, dissolved oxygen (DO), Biological oxygen demand (BOD), number, and weight of fish caught monthly for two years in A (un-infested area) ranged from 795 to 1.948, 83,167.9 to 173,026.8kg and B (*Typha* infested area) 150 to 600, 14,402 to 59,355 in Hadejia-Nguru Wetlands. In 2011, the number of fish species and their weight declined. In A (open water area), twenty-three different families and sixty-two fish species were caught in 2010, while twenty-two families and fifty-six species were seen in 2011. As a result of the increase in *Typha* species infestation, one family and eight species were lost in 2011. The results were statistically analyzed for both 2010 and 2011, revealing a substantial difference between the months. There was a significant difference of (DO) and (BOD) significant infested areas. The air temperature did not differ significantly between (January, February, and March) (May and June), (August and September) (November and December). The number and weight of fish taken in two locations in both years showed a similar pattern (Tables 15 and 16). There was a significant difference in the weights and number of fish taken in A (*Typha* uninfested area) and B (*Typha* infested area) between seasons and years (Table 17).

Table 11. Mean values (g/kg) for some sediment PO_4-P, NO_3-N, and Organic matter between seasons and years in Hadejia-Nguru wetland

Season/ years	*T. latifolia* dens. / $1m^2$	*T. angustifolia* dens. / $1m^2$.	Sediment PO_4-P (g/kg)	Sediment NO_3-N (g/kg)	Sediment OM (%)
Seasons					
Wet	70.53^b	30.06^b	4.10^b	2.50^b	5.62^b
Dry	95.53^a	45.49^b	7.50^b	4.50^a	8.80^a
Years					
2010	80.01^b	60.09^b	13.23^b	8.52^b	7.56^b
2011	90.09^a	65.02^a	15.94^a	10.02^a	8.05^a

Note: Means with the same letters across columns are not significantly different at ($P<0.05$)

Table 12. Correlation between *Typha latifolia*, *T. angustifolia,* and physicochemical parameters and soil nutrients

Variables	TL	TA	Water (PO_4P) mg/L	Water (NO_3N) mg/L	Water (Mg^4) mg/L	Sediment (PO_4P) g/kg	Sediment (NO_3N) g/kg	Sediment Org. matter g/kg
TL	1.000							
TA	0.0031	1.000						
Water (PO_4P)	0.032*	0.002*	1.000					
Water (NO_3N)	0.0234*	0.0203*	0.010*	1.000				
Water (Mg^4)	0.0245*	0.0140*	0.0412*	0.0101*	1.000			
Sed. (PO_4P)	0.0341*	0.0234*	0.0341*	0.0162*	0.0301*	1.000		
Sed. (NO_3N)	0.0001*	0.0210*	0.0323*	0.0231*	0.0134*	0.0231*	1.000	
Sed. Organic matter	0.0020*	0.3102*	0.023**	0.102**	0.0010**	0.2312**	0.2103**	1.000

Note: *Significant at $P<0.05$; **Significant at $P<0.01$, TL: *Typha latifolia,* TA: *Typha angustifolia,* Sed. : Sediment

Management methods

Figure 11 shows biological management in the Hadejia-Nguru Wetlands using different *P. karka* weights. There were few changes in the first five months. However, as the weight of *P. karka* increased, the density of *Typha* species reduced. As demonstrated in Figure 12, the control experiment, free of *P. karka*, continued to grow each month. The best controls were obtained between June and August and can be linked to low physicochemical parameters and sediment nutrients. The experiment also revealed that the more *P. karka* weight, the more effective the control. The data analysis revealed that all treatments, years, and seasons had significant differences. However, there was no significant difference between the control experiment (Tables 18 and 19).

Manual control of Typha latifolia *and* T. angustifolia *using cutting*

The manual control results showed that in February, April, and June, the *Typha* species cut at 5cm, 10cm, and 15cm below the water showed no more re-growth (Figure 13). It was also discovered that the lower the incision below the water, the better the control of *Typha* species was. At the same time, the density of *Typha* species cut at 5cm, 10cm, and 15cm above the water (which served as a control experiment) continued to rise. These also demonstrated a consistent rate of re-growth. There were significant differences at ($P<0.05$) between all cutting levels, years, and seasons, according to the results (Tables 20 and 21). Above the water, however, there was no significant difference in cutting levels.

Physical control of Typha latifolia and T. angustifolia using shading

Figure 14 shows the results of the impact of shade on *Typha* species. The results showed that when triple black tarpaulin was utilized, *Typha* species only lasted four months, while doubled tarpaulin lasted eight months, and single tarpaulin lasted thirteen months. The shade's efficiency was determined by the shading effect of the black tarpaulin cover. After two months, the control experiment with the single, double, and triple black tarpaulin and control increased. The findings also demonstrated that the same black tarpaulin used to control *Typha* species could manage other aquatic macrophytes. The data analysis showed significant differences between single, double, triple, year, and seasons (Tables 22 and 23). Different techniques of controlling *T. latifolia* and *T. angustifolia* have their mean values compared. *Typha* mortality was highest when cutting below the water, followed by shading with black tarpaulin and a biological approach utilizing P. karka (Table 24).

Discussion

Typha species resident in Hadejia-Nguru Wetland

Using an aquatic plant information system, two species of *Typha* were found during the two years of research. *T. latifolia* and *T. angustifolia* were the species in question, with infection levels of 65% to 70% and 30% to 35%, respectively. This contradicts Wetzel's study (2003) that *T. angustifolia* is not abundant in West African wetlands. Their densities ranged from 60 to 100 stands per $9m^2$ and 40 to 60 stands per $9m^2$, respectively. *T. latifolia* has a larger density than *T. angustifolia* due to seasonal changes caused by flooding (flood fluctuation). This supports Smith's (2004) results that *T. latifolia* can endure a wider variety of tropical environments than *T. angustifolia. T. angustifolia*, on the other hand, tended to grow slightly in density during higher floods. This could be related to the fact that it could withstand higher flood levels. Environmental variables may play a significant difference between *T. latifolia* and *T. angustifolia*. Wilcox (2006) made a similar observation at New Delhi Lake, where phosphate-phosphorus levels rose due to irrigation efforts, increasing the prevalence of *T. latifolia* and eradicating practically all other aquatic macrophytes.

Table 13. Mean values of chemical parameters of surface water in sampling sites and *Typha latifolia, T. angustifolia* density in Hadejia-Nguru Wetlands

Sample	***Typha latifolia* density per $9m^2$**	***Typha angustifolia* density per $9m^2$**	**Water $(PO\text{-}P)_4$ (mg/L)**	**Water $(NO\text{-}N)_3$ (mg/L)**	**Water2+ Mg (mg/L)**
Upper course	74.620^a	27.953^a	1.494^a	0.702^a	0.598^a
Middle course	73.722^b	25.521^b	1.362^b	0.601^b	0.384^b
Lower course	71.435^c	23.721^c	0.800^c	0.502^c	0.280^c

Table 14. Mean values of sediment nutrients in sampling sites and *Typha latifolia, T. angustifolia* density in Hadejia-Nguru Wetlands

Samples	***Typha latifolia* density per $9m^2$**	***Typha angustifolia* density per $9m^2$**	**Sediment $(PO\text{-}P)^4$ (g/kg)**	**Sediment $(NO\text{-}N)^3$ (g/kg)**	**Sediment organic matter (%)**
Upper course	74.620^a	27.953^a	3.494^a	2.002^a	2.008^a
Middle course	73.722^b	25.521^b	b2.262^b	1.201^b	1.840^b
Lower course	71.435^c	23.721^c	c1.100^c	0.702^c	0.600^c

Table 15. The average (DO), (BOD) Air temperature, Number, and weight of fish caught in two locations, A (Un-infested) and B (*Typha* species infested area) in Hadejia-Nguru wetland 2010.

Month	Family name	Species	Area A number	Weight (kg)	DO (A) mg/L	BOD (A) Mg/L	Area B number	Weight kg	DO (B) 9mg/L	BOD (B) mg/L
Jan 2010	Dasytidae, Protopteridae, Polypteridae	*Dasyatis garouaensis, Protopterus annectens, Polypterus ansorgi, Polypterus bichirbihir, Polypterus* (e) *endicheri, Polypterus(s) senegalus, Erpetoiochthys calabaricus*	842	86,187	5.9	15	162	17,400	4.4	14..5
Feb 2010	Clupeidae	*Odaxothris samento, Pellonula vorax*	1,227	127, 200	6.8	15.5	225	39,460	4.5	14.1
	Osteoglosidae,	*Heterotis niloticus,*								
	Pantodontidae	*Pantodon buchholzi*								
	Mormyridae	*Mormyrus rume, Mormyrus tapiru,s Hippopotamyrus psittacu,s Mormyrops anguilloides, Campylomyrustaman dua*								
Mar 2010	Gymnarchidae	*Marcuseninus syprinoides, Marcuseninus senegalensis, Gytmnorchus niloticus*	1,051	134,809	7.5	15.1	250	30,047	5.0	14.0
	Cromeridae, Hepsetidae	*Cromeia nilotica, Hepsetusodoe*								
	Characidae	*Hydrocynus brevis, Hydrocynus vittatus, Hydrocynus forskalii, Alestes dentex, Brycinus leuciscus, Micralestes elongates*								
Apr 2010	Distichodontidae	*Phago loricatus*	111	170,142	6.8	15.8	200	37,057	4.2	13.5
May 2010	Citharinidae	*Distichodusengyce phajus, Citharidiumansorgii, Citharinus latus, Citharinus citharinus*	1,150	154,929	6.2	15.3	310	40,015	4.0	14.2
Jun 2010	Cyprinidae, Icthyboridae	*Chelaethiops bibie, Labeo coubie, Labeo senegalensis, Barbus bynni occidentalis*	1,948	140,147	6.8	15.4	400	34,500	4.0	14.2
Jul 2010	Bagridae	*Bagrus docmak, Bagrus filamentosus, Bagrus bajad, Clarotes laticeps, Chrysichthys aluluensis, Chrysichthys auratus, Chrysichthys nigrodigitatus, Auchenoglanis biscutatus*	1,334	133,026	7.0	16.0	361	23,633	4.1	14.6
Aug 2010	Schilbeidae	*Parailia pellucid, Schilbe intermedius, Schilbe mystus*	1,025	127,315	9.0	15.8	467	25,236	4.2	14.8
Sep 2010	Clariidae	*Gymnalla bestypus, Heterobranchus isopterus, Clarias gariepinus, Clarias anguillaris, Clarias jaensis, Clarias macromystax*	1,063	119,773	8.4	15.0	474	35,910	4.7	14.6
	Malapteruridae	*Malapterurus electricus, Malapterurus minjiriya*								
Oct 2010	Channidae	*Parachanna africana, Parachanna obscura*	1,070	114,473	7.4	15,9	329	48,137	46	14,7
	Mochokidae	*Chiloglanis benuensis, Synodontis resupinatus, Synodontis budgetti, Synodontis clarias , Synodontis omias, Synodontis robbianus, Synodontis nigrita, Synodontis schitt*								
Nov 2010	Channidae	*Parachanna african Parachanna obscura*	1,047	115,656	8.2	16,1	402	53,338	4,8	14,3
	Centropodae	*Lates niloticus, Chromidatilapia guntheri, Tilapia dageti, Tilapia zilli, Tilapia guineensis*								
Dec 2010	Channidae	*Parachanna african Parachanna obscura*	1,000	115,656	8.2	16,1	402	53,338	4,3	14,3
	Centropomidae	*Lates niloticus, Chromidotilapia guntheri, Tilapia dageti, Tilapia zilli, Tilapia guineensis*								

Table 16. The average (DO), (BOD) Air temperature, Number and weight of fish caught in two locations, A (Un-infested) and B (*Typha* species infested area) in Hadejia-Nguru wetland 2011

Month	Family name	Species	Area A number	Weight (kg)	DO (A) mg/L	BOD (A) Mg/L	Area B number	Weight kg	DO (B) 9mg/L	BOD (B) mg/L
Jan 2011	Protopteridae	*Protopterus annectens*	800	83,167	6.0	15,4	127	14,402	4,2	14,5
	Polypteridae	*Polypterus ansorgii, Polypterus bichir, Polypterus endltcheri, Erpetoiochthys calabaricus*								
Feb 2011	Clupeidae, Osteoglossidae, Pantodontidae,	*Odoxothris samento, Heterotis niloticus, Pantodon buchholzi*	1,100	117,199	5.9	16,1	600	31,465	5,0	14,2
	Mormyridae	*Mormyrus rume, Mormyrus tapirus, Hippopotamyrus psittacus, Campylomyrus tamandua, Marcuseninus syprinoides*								
Mar 2011	Gymnarchidae, Cromeridae, Hepsetidae, Characidae	*Gytmnorchus niloticus, Cromeia nilotica, Hepsetidae odoe, Hydrocynus brevis, Hydrocynus vittatus, Hydrocynus forskalii, Alestes dentex, Brycinus leuciscus, Micralestes elongates*	1,022	121,799	6.7	15,3	250	30,047	4,6	14,4
Apr 2011	Distichodontidae	*Phagolo ricatus Distichodusengy cephajus*	111	170,142	6.9	15,5	150	32,067	4,7	14,4
May 2011	Citharinidae	*Citharidium ansorgii, Citharinus latus, Citharinus citharinus Chelaethiops bibie, Labeo coubie*	1,150	134,929	7.2	15,3	300	40,000	4,3	14.9
Jun 2011	Cyprinidae	*Chelaethiops bibie, Barbus occidentalis*	1,338	121,472	8.7	15,6	403	25,510	4,3	14,6
Jul 2011	Bagridae	*Bagrus docmak, Bagrus filamentosus, Bagrus bajad, Chrysichthys aluluensis Auchenoglanis biscutatus*	1,334	173,026.8	8.4	15.4	355	43,643	4.1	14.8
Aug 2011	Schilbeidae	*Paraphilia pellucida, Schilbe intermedius, Schilbe mystus*	795	11,305	7.8	15.6	450	42,365	4.0	14.6
Sep 2011	Clariidae	*Gymnalla bestypus, Heterobranchus isopterus, Clarias gariepinus, Clarias anguillaris, Clarias macromystax, Malapterurus electricus*	953	109,763	6.9	15.4	479	57,714	4.2	14.8
Oct 2011	Malapteruridae	*Malapterurus minjiriya*	1,030	142,463	5.0	15.4	370	38,147	4.6	14.5
	Mochokidae	*Chiloglanis benuensis, Synodontis resupinatus, Synodontis budgetti*								
Nov 2011	Channidae	*Parachanna africana Parachanna obscura*	1,000	111,646	6.8	15.5	450	41,348	5.0	14.2
	Centropmidae	*Lates niloticus, Chromidotilapia gunther, Tilapia dageti, Tilapia zillii*								
Dec 2011	Anabantidae	*Clenopoma nebulosum, Ctenopoma murei, Ctenopoma paetherici*	1,043	102,346	7.5	15.4	430	48,233	4.9	15.0

Table 17. Mean values per (1m^2) of fish caught in *Typha* species free and *Typha* infested area between the seasons and years in Hadejia-Nguru Wetlands

Source of variation	**Mean values**
(A) *Typha* unifested area	85.998^{a}
(B) *Typha* infested area	60.880^{b}
Seasons	
Dry (A) *Typha* unifested area	90.324^{a}
Dry (B) *Typha* infested areas	40.562^{b}
Wet (A)*Typha* Unifested area	50.231^{a}
Years	
2010 (A)*Typha* unifested area	85.761^{a}
2010 (B) *Typha* infested areas	55.264^{b}
2011 (A) *Typha* unifested area	70.452^{a}
2011 (B) *Typha* infested areas	42.642^{b}

Note: Means with the same letters across column are not significantly different at (P<0.05)

Table 18. Mean values of difference *Phragmites karka* and mortality rate per (1m^2) of *Typha latifolia* and *T. angustifolia* interplanted with different *P. karka* weight Hadejia Nguru Wetlands

Treatments	**Mean value of mortality rate of *Typha latifolia, T. angustifolia***
50kg of *Phragmites karka*	55.342^{a}
25kg of *P. karka*	33.653^{b}
10kg of *P. karka*	25.672^{c}
Free from *P. karka*	10.324^{d}

Note: Means with the same letters across columns are not significantly different at P<0.05

Table 19. Mean values of different *Phragmites karka* and mortality rate per (1m^2) of *Typha latifolia* and *Typha angustifolia* interplanted with different *Phragmites karka* weight concerning years and seasons in Hadejia Nguru Wetland.

Source of variation	**50kg of *P.karka***	**25kg of *P.karka***	**10kg of *P.karka***	**Free from *P.karka***
Year				
2010	90.232^{b}	53.127^{b}	20.653^{b}	345.230^{a}
2011	120.620^{a}	75.230^{a}	32.234^{a}	345.231^{a}
Seasons				
Dry	50.342^{b}	42.103^{b}	25.120^{b}	246.781^{a}
Wet	75.531^{a}	55.107^{a}	35.708^{a}	246.781^{a}

Note: Means with the same letters across columns are not significantly different at P<0.05

The initial *Typha* species community arose due to multiple succession routes or colonization from nearby water and other physical characteristics that allowed for water or wind dissemination or direct transportation by waterfowls. Due to seasonal and periodic changes, changes in the environment may also impact *Typha* species (Chiroma et al., 2005). The distribution, composition, and quantity of *T. latifolia* and *T. angustifolia* in the Hadejia Nguru wetlands could be linked to various events, including the construction of the Tiga dam upstream, which changed the environmental circumstances.

Table 20. Mean values of different cutting levels of *Typha latifolia* and *T. angustifolia* and re-growth rate per (1m^2) in Hadejia Nguru Wetlands

Treatments	**Mean value re-growth rate of *Typha latifolia, T. angustifolia (*1m^2)**
15 cm above the water	95.342^{a}
10cm above the water	80.321^{b}
5cm above the water	72.461^{c}
5cm below the water	55.672^{d}
10cm below the water	33.653^{e}
15 cm below the water	15.342^{f}

Note: Means with the same letters across columns are not significantly different at P<0.05

Table 22. Mean values of difference black tarpaulin number and mortality rate per (1m^2) of *Typha latifolia* and *T. angustifolia* covered with black tarpaulin Hadejia Nguru Wetlands

Treatments	**Mean value re-growth rate of *Typha latifolia, T. angustifolia (*1m^2)**
Triples black tarpaulin	80.342^{a}
Double black tarpaulin	40.653^{b}
Single black tarpaulin	21.672^{c}
Without black tarpaulin	8.324^{d}

Note: Means with the same letters across columns are not significantly different at P<0.05

Table 23. Mean values of different numbers black tarpaulin and *Typha latifolia-T. angustifolia* mortality rate per (1m2) concerning years and seasons in Hadejia-Nguru wetland

Source of variation	**Without black tarpaulin**	**Single black Tarpaulin**	**Double black tarpaulin**	**Triples black tarpaulin**
Year				
2010	70.451^{a}	63.000^{a}	60.345^{a}	45.306^{a}
2011	70.443^{a}	52.125^{b}	50.798^{b}	35.202^{b}
Seasons				
Dry	69.532^{a}	58.324^{a}	35.307^{a}	35.812^{a}
Wet	68.435^{a}	45.453^{b}	25.209^{b}	20/254^{b}

Note: Means with the same letters across columns are not significantly different at P<0.05

Table 24. Comparison of mean values of different peak levels of mortality rate per (1m^2) of *Typha latifolia* and *T. angustifolia* with different methods of controlling in Hadejia-Nguru wetland

Methods	**Mean value of mortality rate of *Typha latifolia, T. angustifolia***
Manual control (Cutting below the water levels)	95.653^{a}
Mechanical control (Shading using black tarpaulin)	54.753^{b}
Biological control (*Phragmites karka*)	25.765^{c}

Note: Means with the same letters across columns are not significantly different at (P<0.05)

Table 21. Mean values of different cutting levels of *Typha latifolia* and *T. angustifolia* re-growth rate per (1m^2) concerning years and seasons in Hadejia-Nguru Wetlands

Source of variation	15 cm above the water	10 cm above the water	5cm above the water	15 cm below the water	10cm below the water	5cm below t water
Year						
2010	98.673^a	65.342^a	50.875^a	20.365^a	35.642^a	45.678^a
2011	98.672^a	65.456^a	50.798^a	10.123^b	30.750^b	40.320^b
Seasons						
Dry	98.654^a	65.342^a	50.860^a	15.646^a	33.123^a	35.105^a
Wet	98.653^a	65.453^a	50.873^a	6.532^b	25.432^b	30.000^b

Note: Means with the same letters across columns are not significantly different at ($P<0.05$)

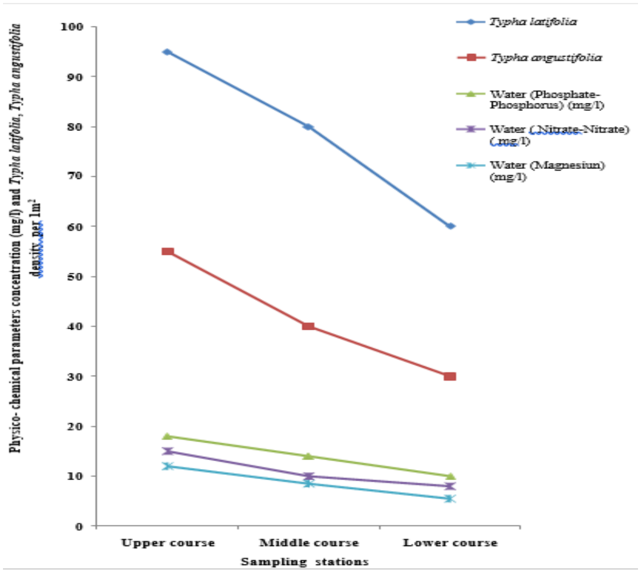

Figure 10. Variation between surface water PO_4-P, NO_3-N, and Mg concentrations in different sampling stations and *Typha* species density in Hadejia-Nguru wetland

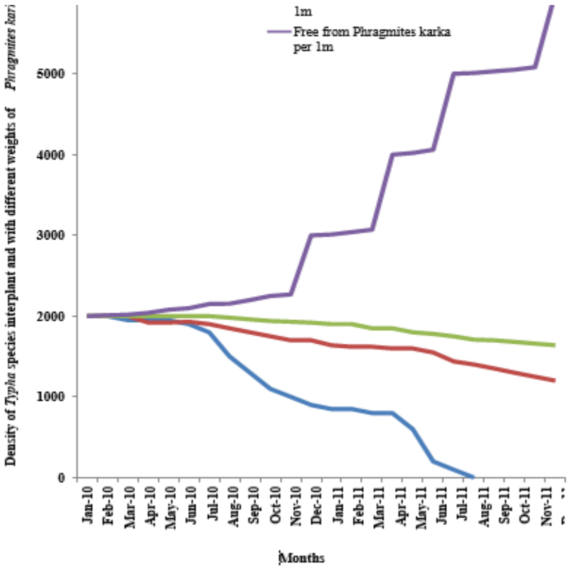

Figure 12. Monthly variation between different *Phagramites karka* weight and *Typha latifolia* and *T. angustifolia* cut at different levels in Hadejia-Nguru, wetland (2010 and 2011)

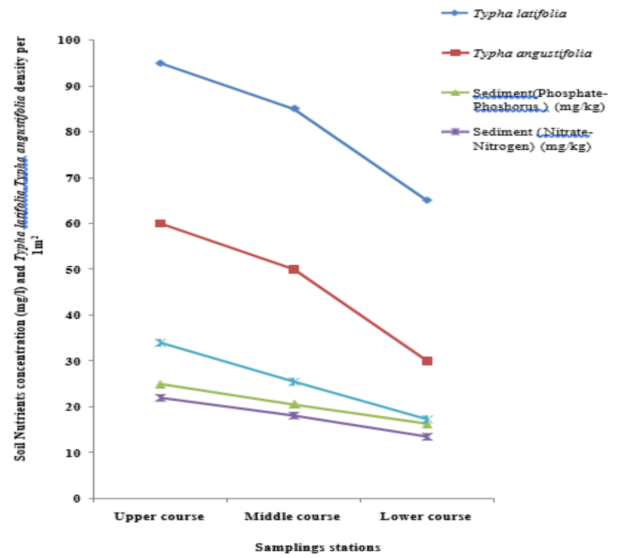

Figure 11. Variation between sediment PO_4-P, NO_3-N, and sediment organic matter in different sampling stations and *Typha species* density in Hadejia-Nguru Wetlands

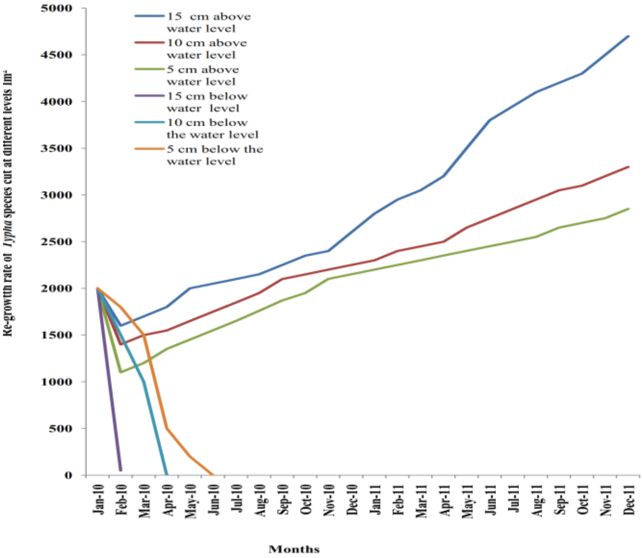

Figure 13. Monthly variation between different regrowth rates of *Typha latifolia* and *T. angustifolia* density in Hadejia-Nguru wetland in the years 2010 and 2011

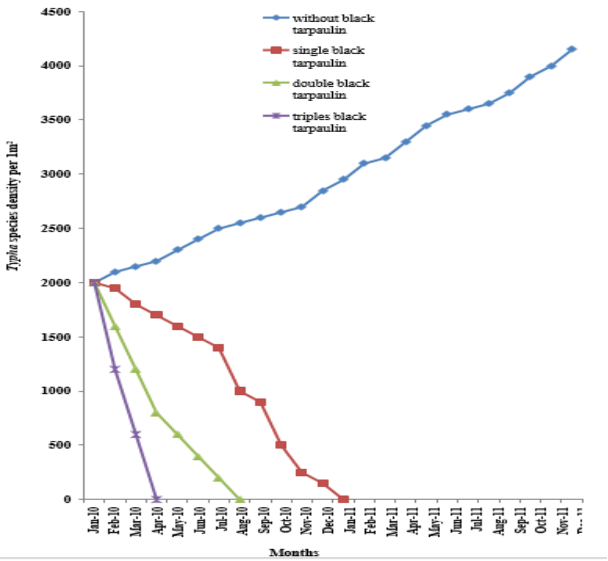

Figure 14. Monthly variation between different numbers of black tarpaulin number and *Typha latifolia-T. angustifolia* density in Hadejia-Nguru wetland in the year 2010 and 2011

According to Wetzel (2003), environmental conditions change favor aquatic macrophytes infestation. The complicated link connects ecosystem components to the succession pattern via biotic and abiotic factors. The cycling of materials from non-living abiotic sources through producers, consumers, and decomposers is one of these interconnected elements. Smith (2009) discovered a strong correlation between the nitrogen cycle and the *Typha* species structure on the one hand. He found that increasing water and sediment nutrients boosted the density of *Typha* species. Climate, rainfall patterns, water usage, and human activities all impact water chemistry and *Typha* species. The major water chemistry and *T. latifolia, T. angustifolia* differences in densities in Hadejia Nguru wetland could have been accounted for by the extent of human activities based on locations, catchment characteristics, and water volume fluctuations, which vary from time to time as a result of seasonal variations. Smith (2009) found that water chemistry impacted the density of *T. latifolia* and *Typha diminigensis*. The water levels in the Hadejia Nguru wetland fluctuated throughout the seasons, with the highest volume during the rainy season. When the water level drops to around one-third of its greatest capacity during the dry season, it shows the most variance. As the dry season progressed, the entire littoral area, covered during the wet season, became exposed. Increased anthropogenic activities, such as increased water demand through intense irrigation around the surrounding wetlands, block making, washing, and cattle population concentration, could be linked to the overall alteration in water chemistry. As the draw-down continued, the vegetation of the exposed littoral area also increased—the rate of livestock droppings and urine increased due to grazing activity. As the wet season begins, all of these exposed locations become inundated, resulting in a build-up of organic debris. These variances could be attributable to differences in individual characteristics of the Hadejia Nguru wetlands in response to seasonal variations in water physicochemical properties, influencing the densities of *Typha latifolia* and *T. angustifolia.*

The morphology of the Hadejia Nguru wetland basin has a significant impact on physical, chemical, and biological parameters that may all be used to estimate the value of wetlands (Singh et al., 2006). *Typha* species react in varied ways to changes in their drainage basins throughout time due to biological factors and the usage of wetland categorization. Stone (2001) found that the ecological connections between *Typha* species had changed significantly. Gradual drying and shrinking of the Hadejia Nguru wetland surface area resulted in enhanced proliferation of *T. latifolia* and *T. angustifolia*. Individual adaption patterns, survival, life history patterns, and generation lines may have contributed to the development of *T. latifolia* and *T. angustifolia* in the Hadejia Nguru wetland. The extent and nature of the Sudan savannah's irregular and harsh environmental conditions, particularly climatic variations caused by wind, may impact the wetland environment (Smith 2004).

In the Hadejia Nguru wetlands, the distribution of *T. latifolia* and *T. angustifolia* was higher in the upper, middle, and lower courses. This may be due to the fact that human activities in the Hadejia Nguru wetland are concentrated in the upper and middle portions, with virtually very few activities in the lower course. The quantity of water nutrients and sediment nutrients altered the character and distribution of *Typha* species. The differences in the high density of *Typha* species demonstrate this. Changes in organic matter accumulation and ecosystem stability may also influence the makeup of *Typha* species, as seen by the higher population density of species in the upper and middle courses. The extent and size of the catchment regions, soil qualities, topography, and vegetation cover could all be connected to the wetland's primary physicochemical parameters. The intensity and rate of human activities could have considerably affected the Hadejia Nguru wetland due to its bigger catchment size and population. Irrigation, fishing, and farming along coastal borders and in catchment areas may have contributed to the increasing prevalence of *Typha* species in the Hadejia Nguru wetland.

Surface water, PO_4-P, NO_3-N, and Mg concentrations

In the Hadejia Nguru wetlands, high transparency and conductivity turbidity did not affect the density of *T. latifolia* and *T. angustifolia*. This could be due to the non-response of *Typha* species to specific physicochemical factors. Singh et al. (2006) made a similar observation. *Typha* species density was unaffected by transparency or turbidity, which could be linked to the ability of *Typha* species to tolerate different climatic conditions and environmental changes. This extremely fast-growing plant is sometimes considered an invasive native in aquatic ecosystems (Murkin and Ward 1980). Higher or lower pH did not affect the density of *T. latifolia* and *T. angustifolia* in Hadejia Nguru wetlands, which could be due to the ability of *Typha* species rhizomes to minimize higher pH concentration. This is consistent with the findings of Singh et al. (2006) that *Typha* species can tolerate a wide range of pH because the rhizome has the potential to reduce higher pH to a lower one. However, this contradicts the findings of Balarabe (2001), who found that decreased pH resulted in a reduced density of aquatic macrophytes. Plants that use dissolved oxygen (DO) do not need oxygen and even give it out during photosynthetic activities. Because plants produce oxygen into the atmosphere, areas with dense *Typha* species have plenty of oxygen. Comparing areas with high *Typha domingesis* is growth to areas lacking *T. domingesis* is growth, Smith (2009) found that areas with high *T. domingesis* growth had greater oxygen. The density of *T. latifolia* and *T. angustifolia* is influenced by Biological Oxygen Demand (BOD). BOD was required for microorganisms to decompose organic materials. This is consistent with the findings of Smith (2009) that low BOD had a minor impact on *T. latifolia* density due to the sluggish decomposition of organic waste. Based on watershed parameters, the level of human activities influences the water chemistry of the Hadejia-Nguru wetland. Water volume changes accounted for significant limnological discrepancies between T. latifolia and T. angustifolia densities, varying from time to time due to seasonal variation. According to Torres-Orozeo et al. (1996), environmental factors may have influenced variance in lakes in New Delhi, India. The water level of Hadejia-Nguru Wetlands changed throughout both seasons, with the wet season having the highest volume. When the water level declined significantly during the dry season, the wetland showed more variety (NIFFR 2002).

The substantial influence of nitrate-nitrogen (NO3-N), phosphate-phosphorus (PO4-P), and organic matter concentrations could have been attributed to human activities such as livestock grazing, watering, and irrigation within the extended catchment and coastal areas of Hadejia-Nguru wetland. This could be associated with greater fecal matter deposition along the wetland's periphery. Nitrate-nitrogen (NO3-N) content may be predicted to grow dramatically under the impact of edaphic variables, notably during flood seasons and organic pollution (Stone 2001). Metabolic processes in the water body determine the amount of nitrate in solution at any specific time through deposition and decomposition (Smith 2004). Continuous mixing and resuspension of sediment particles may have influenced *T. latifolia* and *T. angustifolia* densities by increasing nutrient cycling and release in water. The influence of transparency and electrical conductivity on the growth of *T. domigesis* and *T. latifolia* was studied under higher and lower transparency and electrical conductivity, according to Habibah et al. (2012). There was no evidence of a link between *Typha dominingsis* and *T. latifolia*. This is consistent with the findings of this research.

Phosphorus concentrations were generally higher in the upper stream. This could be linked to the agricultural activities that take place in the area, which include both irrigation and rain-fed crops. The concentration of phosphate-phosphorus at all sites followed a similar pattern, with Phosphorus levels rising as the dry season progressed. The concentration was maximum near the end of the dry season (April-May). During this time, *T. latifolia* and *T. angustifolia* had the largest numbers. This could be because both species require phosphorus at all phases of growth. This verifies Smith's (2004) results that phosphate-phosphorus is essential for rhizome phloem and xylem production, as well as flowering.

Nitrate-nitrogen is the second most abundant nutritional element, and it appears in a variety of organic forms, similar to carbon. Nitrogen is a crucial ingredient for the growth of *Typha* species in the aquatic environment. The amount of nitrate-nitrogen at all sampling sites followed a similar pattern during the study period, with concentrations increasing as the dry season proceeded. The maximum concentration was found right after the rainy season (April-May). The top course yielded the highest concentration. This could be linked to run-off water and agricultural activity, which could explain why there are more *T. latifolia* and *T. angustifolia* plants at this location. The findings revealed a substantial variation in nitrate-nitrogen concentration between *T. latifolia* and *T. angustifolia*. Magnesium levels were found to strongly correlate with the abundance of *T. latifolia* and *T. angustifolia*. During the extreme dry season (April-May), high values of water magnesium (Mg2+) were measured, with lower values obtained during the wet season (July-August). *T. latifolia* and *T. angustifolia* have the same fluctuating pattern. The increase and decrease in water volume due to seasonal change could explain these variances in water chemical fluctuations (wet and dry season). Hillman (2012) observed that repeated filling and slow drying frequently culminate in total dehydration, resulting in vast variations in aquatic habitats' physical and chemical characteristics. The results revealed a significant difference in water Magnesium concentration and *T. latifolia*, *T. angustifolia*, except within month and sample site, at ($P<0.05$). Sediment PO4-P, NO_3-N, organic matter concentration and *T. latifolia, T. angustifolia* density

During the extreme dry season (April-May), high dry season means phosphate-phosphorus (PO4-P) levels were recorded, while lower values were observed between July and August. The results also revealed a substantial variation in the concentration of Sediment phosphate-phosphorus and *T. latifolia* and *T. angustifolia*. This could be due to the increased concentration of surface run-offs, which carried in plant materials and debris, which degraded and delivered nutrients to the soil throughout the dry season. Similarly, Green (2013) found that sediment phosphate-phosphorus, which is highly soluble in water and does not attach to the soil, has a strong migratory potential through the soil when water volumes decrease, resulting in high concentrations.

Nitrate-nitrogen in Sediment is the second most prevalent nutritional element, and as carbon, it can be found in various organic forms in soil nitrate. In the aquatic environment, nitrogen is a key nutrient for the growth of *Typha* species. During the severe high dry season (April-May), the mean value of nitrate-nitrogen (NO_3-N) was obtained. The lowest results were acquired within July to August. Both *Typha* species have the same fluctuating pattern. These results could be related to the species' reaction to increased nitrate-nitrogen levels. This verified the effect of Birnin-Yauri et al.'s (2004) study that a rise in nitrate-nitrogen increased *Typha australis* density. Organic matter concentration is the second most abundant nutrient element, and it comes in a variety of organic forms, similar to carbon. During the study period, the maximum concentration of sediment organic matter content was found in Hadejia-Nguru Wetlands during the extreme dry season (April-May). The lowest concentration was seen during the peak of the rainy season (July-August). Both *T. latifolia* and *T. angustifolia* grew in a similar pattern of organic matter. The results revealed a substantial difference in the concentrations of Sediment Organic Matter. These could be linked to all run-off detritus ending up in sediment. Green (2013) found that both soil and water organic matter concentrations were highly soluble in water, did not attach to the soil, had a high migratory potential across the soil, and formed high concentrations in sediment when water volume decreased, as previously reported. The upper course had the highest concentration of *T. latifolia* and *T. angustifolia*, followed by the middle and lower courses. The exposed littoral zone was flooded during the dry season, accompanied by emergent macrophytes that attracted animal grazing. As the draw-down progressed, it frequently accumulated droppings around the edges of the surrounding vegetation, with the severity increasing—organic matter accumulated due to the subsequent effects. Similar observations were made by Balarabe (2001) in Dumbi and Kwangila ponds, with increased *Typha* species at the pond's littoral borders, especially during the dry season. The increased organic carbon in the Kwangila above Dumbi was linked to intensive agricultural activity and fecal waste deposition. During the research period, all of these conditions could have contributed to the higher density of *T. latifolia* and *T. angustifolia* in the upper and middle courses. The water level variation was minor at the bottom course. Human activities were limited in type and scope with little or no cropland within the lower course and no vegetation except a few T. latifolia near the western littoral borders.

Impact of Typha *species on fish catch and distribution in Hadejia-Nguru Wetlands*

Fish in uninfested areas were more numerous and heavier than those caught in *Typha*-infested areas. This could be due to fish species migrating from *Typha*-infested to uninfested areas. Low dissolved oxygen (DO), high biological oxygen demand (BOD), high temperature, and transparency in a *Typha* species-infested area could all contribute to migration. This is consistent with Smith's findings from Delhi Lake, India, where *Typha australis* infestation resulted in the extinction or emigration of four families and twenty-two species of fish. Fish distribution may be influenced by changes in water level and temperature. Scheffer et al. (2003) found that reducing water volume raises fish harvest in Sudan Lake, which was corroborated by higher density found during the dry season. Similarly, favorable conditions in some regions of the wetlands may explain seasonal or yearly variations in composition and abundance. Daddy (2003) also found low catches in macrophytes-infested sections of the Tatabu flood plain of Niger state.

Management of Typha latifolia *and* T. angustifolia

Biological control with *P. karka* at various weights, manual control with cutting at various water levels, and physical control with shading at various tarpaulin numbers were all utilized to control Typha species throughout the two-year study period. Biological control

Biological control was used in the sampling site by utilizing varying weights of *P. karka*. After five months, the first observation was made. The number of tillers, leaves, and inflorescence decreased in each treatment, while nothing was observed in the control experiment. This is consistent with Smith (2004), who stated that the first effect of any control on the plant was observed in the leaves. It was also discovered that the more *P. karka* weight, the more successful the control. These effects could be related to the allopathic component found in the root of *P. karka*. Although the biological control is slow and gradual, it sometimes requires several years to manifest, its permanent effect is certain. Total biological control is the "only cost-efficient, permanent and environmentally friendly method." Greathead and Root (2010) confirmed that it takes several years for biological control agent monitoring to document their impact. However, significant successes have been reported using *Neochetina bruchi* in Argentina, Australia, India, and the USA (Harley 2000). In several countries, including the Sudanese systems of the Nile River, water hyacinth was controlled through biological control. In Nigeria, biological control with *Eichhornia bruchi* and *Neochetina bruchi* was utilized in the Kainji Dam, which reduced water hyacinth proliferation by 30% (Daddy 2006). The fascinating part about these discoveries is that *P. karka* could be used as animal fodder.

Manual control. Cutting at various levels for manual control: Cuttings were made at two levels below and above the water level. The results revealed that cuttings below the water level progressively died after 3-5 months, whereas *Typha* species cut above the water level gradually grew back. The lower the cutting depth below the water, the more effective it is, and the deeper the cutting depth, the higher the re-growth rate. This could be because lower cutting below water levels eradicates *Typha* species' rhizome. *Typha australis* stands are reduced when shoots of *Typha* species are clipped below the water surface in one growing season before flower formation (Weller 1975; Birnin-Yauri et al. 2004).

Physical control. Various quantities of the black tarpaulin were used. The results showed that the black tarp there were, the more successful the control was, and the fewer there were, the less effective the result was. This is due to *Typha* species being deprived of their ability to photosynthesize. It is also possible that the heat generated by the black tarpaulin is to blame. The best results were achieved in July to August, when *Typha* species' food supplies were thought to be the lowest. This is consistent with the findings of Nelson and Dietz (2006), who found that when actively growing *Typha* species tips were totally covered for at least sixty days, they were killed. However, it was discovered that tremendous success was attained when the food supplies of *Typha* species were thought to be at their lowest, i.e., during the peak of the wet season, when nutrient dilution was at its highest.

To conclude, *T. latifolia* and *T. angustifolia* were discovered in the Hadejia-Nguru Wetlands, accounting for 65-70% and 30-35% of the total occurrence, respectively. The expansion of *Typha* species in the Hadejia Nguru wetlands was caused by water PO_4-p, NO_3-N, Magnesium, and sediment PO_4-p, NO_3-N, organic matter. The density, distribution, and consequently fish catches in Hadejia Nguru wetlands were reduced by *Typha latifolia* and *T. angustifolia*, as *Typha* uninfested area is more abundant by fish caught than the infested area in terms of the weight and number of fish caught. The optimum management approach for controlling *Typha* species in Hadejia Nguru wetlands, according to the study, is to cut the *Typha* below the water surface at a depth of 15cm.

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