Potential menace posed by invasive grass and water quality deterioration on macroinvertebrates structural distribution in a dam in North-Western Nigeria

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ABSTRACT
Water bodies in the world have been studied for varied reasons based on their biota composition, diversity, and influence of environmental variables. A study was carried out to ascertain the probable menace posed by Typha grass and some selected environmental variables on the composition and diversity of benthic macroinvertebrates of Kalgwai Dam, Jigawa State, Nigeria. Three (3) distinct sites were selected for the study. Water and macroinvertebrates samples were collected once in a month on each sampling expedition for a period of four (4) months between January and April, 2018, using standard techniques. Among the sampled months, physico-chemical variables were significantly different ($p < .05$), while no significant difference existed for all the physico-chemical variables ($p > .05$) except for electrical conductivity, salinity, total dissolved solids, and BOD$_5$. A total of 260 benthic macroinvertebrate specimens comprising of 20 taxa belonging to 9 orders and 20 families were recorded during the study period. Site 2 harbors more macroinvertebrates than other sites and Gastropoda was the most occurring taxa in the study area with Site 2 having the highest abundance among the taxa sampled during the study period. Significant difference ($p < .05$) was noticed in abundance (number of individuals) among the sites. Species number (taxa) and abundance (number of individuals) were significantly high at Site 2. Shannon diversity of macroinvertebrates taxa was lowest in Site 1 (0.98 ± 0.28). Analysis of variance (ANOVA) performed showed no significant differences in the indices calculated ($p > .05$) except for Evenness. Canonical correspondence analysis (CCA) showed a weak relationship between macroinvertebrates composition/abundance and the selected physico-chemical variables. Species such as Corbucilidae, Chironomus sp., Potadoma sp., Unio sp. portray the characteristics of potential bioindicators due to their association to prevailing environmental condition of the sampled sites. Cluster analysis (Bray-Curtis) similarity showed no marked pattern of clustering in the dam. The study revealed that incessant anthropogenic activities and high density of Typha grass in Kalgwai Dam have a deteriorating effect on the structural composition, abundance and diversity of macroinvertebrates in the dam.

INTRODUCTION

Water bodies in the world have been studied for varied reasons ranging from species composition, diversity, and the influence of anthropogenic activities on their distribution and abundance. The devastating effect of anthropogenic activities on the water quality, sustainability, and functionality of the aquatic ecosystems is alarming (Arimoro, Odume, Uahunoma, & Edegbene, 2015; Edegbene, Arimoro, Odoh, & Ogidiaka, 2015; Yazdian, Jafarzadeh, & Zahraie, 2014; Yung-Chu et al. 2016), most especially in the third world countries (Nigeria inclusive) where laws guiding water bodies and their catchments are weakly enforced (Arimoro, 2009; Edegbene et al., 2015). Unenforced or weakly enforced laws guiding Nigeria freshwater systems have caused serious threat to the functionality and sustainability of organisms that inhabits the systems. Several organisms such as plankton, macroinvertebrates, fishes and birds have been used to assess ecosystems health globally, the organisms (Edegbene, 2018; Yazdian et al., 2014; Yung-Chu et al., 2016). Presently, the biota mostly used is benthic macroinvertebrates (Barman & Gupta, 2015; Edegbene & Arimoro, 2012; Patang, Soegianto, & Hariyanto, 2018; Shimba & Jonah, 2016). Macroinvertebrates are mostly explored biota for assessing riverine health due to their sessile nature, easy to sample, and wide diversity based on their position in the aquatic ecosystem food chain (Edegbene, Arimoro, & Odume, 2019, 2020).

Macroinvertebrates composition and diversity have been reported to be in downward progression occasioned by varied degree of pollution bedeviling water courses most especially in the Sub Sahara Africa (Arimoro et al., 2015; Edegbene & Omovoh, 2014). Downward progression of macroinvertebrates structural and functional composition in Nigeria freshwater systems are occasioned by varied anthropogenic activities, which include open defecation, use of chemical for...

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fishing, and point source pollution from nearby farmlands (Arimoro et al., 2015).

Furthermore, aside the varied anthropogenic activities mentioned above, in northern part of Nigeria, there have been reported cases of the menace posed by invasive plant species (Typha species) in some rivers and wetlands affecting the functionality and sustainability (Edegbene, 2018). This has led to a great threat to the biodiversity of water bodies which include wetlands, dams, rivers, streams and other associated freshwater ecosystems in this part of Nigeria. Typha grass is an invasive plant found in most freshwater ecosystems in Jigawa and Yobe States of Nigeria. Once the Typha grass is established on the water course it forms dense monotypic colonial stands with the potential to spread through rhizomatous growth up to 4 m in diameter per year (Boers & Zedler, 2008). Presently, the Typha grasses obstruct water ways, hinder fishing activities and pose serious risk to the surrounding communities along the water course. This is the case in the study area, Kalgwai Dam as most parts of the dam have been invaded by the Typha grasses.

Kalgwai Dam, where this study was carried out, is a special intervention project by the Federal Government of Nigeria to the people of Jigawa State. The dam was built solely for irrigation activities for farmers in Auyo, Kafin Hausa, Hadejia and Kaugama Local Government Areas of Jigawa State of Nigeria. The purpose in which the dam was built is gradually becoming defeated; as some reaches of the dam, now serve as refuse dump site, illegal fishing, nomadic farming, washing of clothes, and other households belongings, using detergents and other debilitating activities, which is increasing pollution influx into the dam.

Hence, this present study was carried out to ascertain the relationship between macroinvertebrates faunistic structural distribution and anthropogenic impacts that may be deteriorating the water quality of Kalgwai Dam. Elsewhere several studies have been conducted to ascertain the influence of anthropogenic activities on aquatic fauna composition and diversity in urban rivers and streams (Barman & Gupta, 2015; Patang et al., 2018; Shimba & Jonah, 2016), whereas in developing countries such as Nigeria, social-economic development is prioritized over environmental concerns (Arimoro et al., 2015). Lately, there have been increasing studies on the use of macroinvertebrates as bioindicators of water quality in Nigeria (Arimoro et al., 2015; Edegbene & Arimoro, 2012; Iyagbaye & Iyagbaye, 2017), but much have not been reported on the composition, diversity, and abundance of benthic macroinvertebrates in Nigeria dams. The present study therefore contributes to the baseline information on which environmental as well as water resource managers can base their planning when approving development around the studied dam – enabling sustainable management of the Kalgwai dam. Hence, this study was conducted to ascertain the probable menace posed by Typha grass and some selected physico-chemical variables on the composition and diversity of benthic macroinvertebrates of Kalgwai Dam, Jigawa State, Nigeria.

**Materials and methods**

**Study area**

Kalgwai Dam is located about 50 m away from Kalgwai village in Auyo Local Government Area of Jigawa State, Nigeria (Figure 1). It is located on the interception of latitude 12°35ʹN – 10°7ʹE and longitude 12.230°N –
10.022°E of the equator. The Kalgwai Dam is a storage pond constructed across the Hadejia River for storage. The water is released from the upstream Challawa and Tiga Dams, in Kano, Kano State, Nigeria. Water from the dam is diverted through water control structures into the irrigation canals of the project area for use by farmers and other domestic purposes.

The area is characterized by a tropical climate with mean annual temperature of about 37.0°C with two distinct seasons: wet and dry season. The wet season is between May and September and dry season between October and April (Edegbene, 2018). Harmattan weather condition also characterized the climatic condition of this area, which is usually in the dry season months of November to February. During the season of harmattan the temperature of the area can be as low as 10.0°C most especially between December and January (Edegbene, 2018). The study was carried out in four (4) months, between January and April, 2018.

**Sites selection**

Three (3) distinct sites were selected based on community and anthropogenic activities. They are: Site 1: Gajegumi, Site 2: Galadimawa, and Site 3: Yanruwa (Figure 1). Generally, the riparian zone of the dam has been invaded by *Typha* spp. (Typha grass).

**Site 1 (Gajegumi):** The infestation of Typha grass around the bank of this station is dense and the other activities here include bathing, washing of clothes, farming and fishing. The substratrum of Site 1 is covered by clay and loamy soil.

**Site 2 (Galadimawa):** This site is located about 1 km away from the Site 1. It is characterized by less dense Typha grass infestation. The site substratrum consists of clay and sand and other activities carried out here include bathing, farming, and other human activities.

**Site 3 (Yanruwa):** This is located about a kilometer away from Site 2. The water here is characterized by high concrete dykes. The substratrum here is covered by clay and sand. The activities here are majorly fishing and bathing. No farmland around the bank in this site. The state of Typha grass infestation is minimal as sparse distribution of Typha grass was noted in this site.

**Water quality analysis**

Sampling of physico-chemical variables were carried out in each sampling site once in a month for a period of four months between January and April, 2018. The physicochemical variables sampled include water temperature, water depth, transparency, electrical conductivity (EC), salinity, total dissolved solids (TDS), turbidity, pH, dissolved oxygen (DO), five day biochemical oxygen demand (BOD₅), phosphate, and nitrate. On every sampling expedition, subsurface was measured using mercury in glass thermometer. Water depth and transparency were measured using a calibrated rod and secchi disc, respectively. EC, salinity, and TDS were measured using conductivity meter DDSJ-308A, while turbidity and pH were measured using portable turbidity meter model WGZ-B and pH meter (HANNA HI 9828 multiprobe meter manufactured by HANNA instruments), respectively. DO, BOD₅, phosphate, and nitrate were analyzed according to American Public Health Association [APHA] (1998) methods.

**Macroinvertebrates sampling and processing**

Macroinvertebrates samples were collected once in a month for a period of four months between January and April, 2018. Samples of macroinvertebrates were collected by a 3-minutes modified kick method with a 4.4 square-feet (1.36 m²) square shaped-frame net (700 µm mesh) along an approximate 25 m long wadeable stretch of the river as modified from Lazorchak, Klemm, & Peck (1998). Seven different kicking were done at each sampling site, which covered different substrates and flow regime zones. Samples collected from different substrates and flow regimes were pooled together as one composite sample.

Samples collected were sorted before preservation. Live sorting was done on the field, immediately after collection. Samples collected after sorting were preserved in 70% methanol and transported to the laboratory for identification and enumeration.

Sorted macroinvertebrates were identified to the lowest taxonomic level, mostly to family according to Merrit et al. (1996), De Moor, Day, & De Moor (2003), and Javier, David, and Rafael (2011). Confirmation of some of the macroinvertebrate taxa were done at Unilever Centre for Environmental Water Quality, Rhodes University, Makhanda (Grahamstown), South Africa.

**Statistical analyses**

Descriptive statistics that include range, mean, and standard deviation for each environmental variable were calculated per site. Diversity indices (Shannon diversity index, Evenness, Dominance, Simpson dominance and Margalef’s index) were calculated using PAST statistical package (Hammer, Harper, & Ryan, 2001). Then, physico-chemical variables were compared between sites using two-way analysis of variance (ANOVA). Significant differences between sites indicated by ANOVA ($p < .05$) were followed by Kruskal Wallis Test. Canonical correspondence analysis (CCA) was used to evaluate associations between benthic macroinvertebrates composition, distribution, and environmental variables using PAST statistical
package (Hammer et al., 2001). Prior to the final CCA, variables exhibiting high multi-collinearity (Pearson correlation $r > 0.80$, $p < 0.05$) were removed. Rare taxa, occurring less than 1% of sampling event at each sampling site, were not included in the CCA. Physico-chemical variables used for the CCA analysis were also log($x + 1$) transformed to prevent the undue influences of extreme values on the final CCA ordination. Species–environment correlation coefficients provided a measure of the explanation of community patterns by individual water quality variables. A Monte Carlo permutation test with 999 permutations (Jcik, 1986) was used to assess the significance of the first three canonical axes. Cluster analysis based on Bray–Curtis similarity index was used to ascertain whether the macroinvertebrates assemblage distribution was influenced mostly either by differences in sampling sites or months. Cluster analysis was performed on log($x + 1$) transformed macroinvertebrate abundance data. Cluster analyses were performed using PAST statistical package (Hammer et al., 2001).

Results

Physico-chemical variables

The mean and standard error of the environmental variables are summarized in Table 1. Water temperature, EC, DO, BOD$_5$, nitrate, and phosphate were significantly different among the sampled months ($p < 0.05$), while no significant difference existed for all the environmental variables ($p > 0.05$) among the sites sampled except for EC, salinity, TDS, and BOD$_5$. Sites means of all the physico-chemical variables showed no significant difference as revealed by Kruskal Wallis test. The analyzed variables were within the maximum permissible limit given by Nigeria Federal Environmental Protection Agency (FEPA) and Standard Organization of Nigeria (SON) except for TDS, with a proportionately high TDS mean values.

Benthic macroinvertebrates composition, distribution, and abundance

A total of 260 benthic macroinvertebrate specimens, 20 taxa belonging to 9 orders, and 20 families were sampled during the entire study period (Table 2). The absolute composition of the macroinvertebrates individuals during the study period revealed that Site 2 harbors more biota than the other sites (Table 2). Gastropoda, among the orders collected, was the most occurring macroinvertebrate. Ephemeroptera, Trichoptera, were sparsely distributed as they occurred in very minimal number during the study period. They were only represented in Site 2. Overall, there was no significant difference ($p < 0.05$) in abundance (number of individuals) among the sampled site (Table 3).

Table 1. Physico-chemical variables measured at the study sites of Kalgwai Dam, North-Western Nigeria during the study period (January to April 2018).

| Variables                  | Site 1                  | Site 2                  | Site 3                  | F-value | p-value | F-value | p-value |
|----------------------------|-------------------------|-------------------------|-------------------------|---------|---------|---------|---------|
| Water temperature ($^\circ$C) | 22.88 ± 3.92            | 23.3 ± 4.42             | 20.75 ± 2.5             | 13.14   | 0.0048  | 2.74    | 0.14    |
| Water depth (m)            | 0.31 ± 0.056            | 0.28 ± 0.068            | 0.42 ± 0.138            | 0.72    | 0.58    | 0.73    | 0.52    |
| Transparency (cm)          | 20.75 ± 4.73            | 23.01 ± 5.24            | 16.56 ± 3.92            | 2.06    | 0.21    | 2.67    | 0.15    |
| Electrical conductivity    | 150.05 ± 21.87          | 123.43 ± 13.80          | 120.55 ± 9.67           | 5.06    | 0.044   | 9.80    | 0.013   |
| Turbidity (NTU)            | 76.25 ± 83.97           | 151.3 ± 19.84           | 151.43 ± 18.1           | 1.23    | 0.38    | 3.12    | 0.11    |
| Salinity (%)               | 0.01 ± 0.001            | 0.01 ± 0.0              | 0.01 ± 0.0              | 3.79    | 0.070   | 17.99   | 0.003   |
| Total dissolved solids     | 90.48 ± 11.48           | 77.3 ± 9.61             | 73.68 ± 5.78            | 3.99    | 0.070   | 6.09    | 0.036   |
| pH                         | 10.53                   | 11.05                   | 10.7                   | 1.38    | 0.38    | 3.12    | 0.11    |
| Dissolved oxygen (mg l$^{-1}$) | 3.15 ± 1.24             | 5.30 ± 1.21             | 4.71 ± 2.36             | 5.69    | 0.034   | 4.45    | 0.005   |
| Biochemical oxygen demand | 1.95 ± 0.97             | 1.58 ± 0.84             | 0.94 ± 0.24             | 3.82    | 0.015   | 6.30    | 0.013   |
| Nitrate (mg l$^{-1}$)      | 0.30 ± 0.09             | 0.28 ± 0.07             | 0.27 ± 0.051            | 13.43   | 0.005   | 0.65    | 0.26    |
| Phosphate (mg l$^{-1}$)    | 1.46 ± 0.19             | 1.59 ± 0.26             | 1.46 ± 0.25             | 15.85   | 0.0029  | 2.49    | 0.16    |

Values are means±standard deviation; range in parenthesis. Different superscript letters in a row show significant differences ($p < 0.05$) indicated by Kruskal Wallis Tests.

$*$Nigerian Water Quality Standard for Inland Surface Water (FEPA [Federal Environmental Protection Agency], 1991).

$**$Nigerian Standard for Drinking Water Quality (SON [Standards Organization of Nigeria], 2007).
Table 2. Macroinvertebrates composition and abundance in Kalgwai Dam, North-Western Nigeria during the study period (January to April 2018).

| Order | Family | Taxa | Taxa Code | Site 1 | Site 2 | Site 3 |
|-------|--------|------|-----------|-------|-------|-------|
| Bivalvia | Unionidae | Uni sp. | Uni | 14 | 15 | 7 |
| | Corbiculidae | Cob | Cob | 2 | 15 | 4 |
| Gastropoda | Viviparidae | Vlv | 1 | 2 | 0 |
| | Thiarae | Potadoma sp. | Pot | 25 | 97 | 15 |
| | Viviparidae | Vlv | 2 | 0 | 1 |
| | Hydrobiidae | Hd | 1 | 7 | 0 |
| | Valvatidae | Val | 1 | 2 | 1 |
| | Planorbidiae | Pla | 0 | 0 | 1 |
| | Physidae | Phy | 1 | 2 | 0 |
| Planaria | Hirudinidae | Hirudo sp. | Hir | 0 | 2 | 0 |
| Coleoptera | Notidae | Not | 2 | 0 | 0 |
| | Gyrinae | Gyrinus sp. | Gyn | 0 | 1 | 0 |
| | Hydrobiidae | Hal | 0 | 1 | 0 |
| Dytiscidae | Diptera | Chironomidae | Chironomus sp. | Chi | 1 | 9 | 0 |
| | Ephemeroptera | Potamanthidae | Poa | 0 | 1 | 0 |
| | Odonata | Gomphiidae | Gom | 0 | 1 | 1 |
| | Cordulegastidae | Cor | 1 | 1 | 0 |
| | Trichoptera | Phryganidae | Phr | 0 | 1 | 0 |
| Decapoda | Atyidae | Caridina sp. | Car | 1 | 4 | 8 |
| Absolute Composition | | | | 52 | 169 | 39 |

Different superscript letters in a row show significant differences (p < 0.05) indicated by Kruskal–Wallis test.

** = ANOVA calculated showed no significant difference among sampling sites.
** = ANOVA calculated showed significant difference among sampling sites.

Diversity indices of macroinvertebrates

Summaries of species numbers, abundance, dominance, Simpson dominance, Shannon Weiner diversity, evenness, Margalef’s indices of macroinvertebrates in Kalgwai Dam, North-Western Nigeria during the study period (January to April 2018). Value ± standard deviation.

Table 3. Mean number of species (taxa), abundance, dominance, Simpson dominance, Shannon Weiner diversity, evenness, Margalef’s indices of macroinvertebrates in Kalgwai Dam, North-Western Nigeria during the study period (January to April 2018). Value ± standard deviation.

| Indices | Site 1 | Site 2 | Site 3 |
|---------|-------|-------|-------|
| Taxa (Species No.)* | 4.5 ± 2.08* | 6.25 ± 2.87* | 4.25 ± 2.22* |
| Abundance (No. of individuals)* | 13 ± 8.60* | 41.5 ± 35.1* | 10.0 ± 7.35* |
| Dominance (D)* | 0.50 ± 0.10* | 0.47 ± 0.20* | 0.39 ± 0.20* |
| Simpson dominance (D)* | 0.50 ± 0.10* | 0.53 ± 0.20* | 0.61 ± 0.20* |
| Shannon Weiner index (H)* | 0.98 ± 0.20* | 1.12 ± 0.48* | 1.16 ± 0.50* |
| Evenness (E)** | 0.68 ± 0.22* | 0.57 ± 0.14* | 0.84 ± 0.10* |
| Margalef index (taxa richness) (d)* | 1.43 ± 0.53* | 1.44 ± 0.75* | 1.43 ± 0.59* |

Relationship between macroinvertebrates and selected physico-chemical variables

The CCA showed a weak relationship between the macroinvertebrate composition/abundance and the selected physico-chemical variables. Axes 1 and 3 accounted for 75.42% of variation in the data set. Monte Carlo permutation test calculated showed that Axes 1, 2, and 3 were not significantly different (p > 0.05). The Eigen values for Axes 1, 2, and 3 are 0.36, 0.19, and 0.106, respectively (Table 4). Axis 1 was associated with Valvatidae, Corbiculidae, Thiarae (Potadoma sp.), Chironomidae (Chironomus sp.), Caridina sp. and Viviparidae, and this was slightly explained by nitrate, water temperature, and DO. In the same Axis 1, turbidity had a strong link with Chironomus sp. and Corbiculidae (Figure 2 and Table 4). Most of the species collected in the sampled sites are positioned on the left except for Unionidae (Unio sp.), Noteridae which were positioned on the right of the CCA ordination plot (Figure 2). Valvatidae

Table 4. Weighted intraset correlations of physico-chemical variables with the first three axes of canonical correspondence analysis (CCA) in Kalgwai Dam, North-Western Nigeria during the study period (January to April 2018).

| Variables | Axis 1 | Axis 2 | Axis 3 |
|-----------|-------|-------|-------|
| Eigen value | 0.36 | 0.19 | 0.106 |
| % Variation of species data explained | 48.35 | 25.17 | 14.26 |
| Monte Carlo test-p-value | 0.245 | 0.18 | 0.35 |
| Water temperature (°C) | −0.514 | −0.0058 | 0.277 |
| Water depth (cm) | 0.32 | 0.063 | 0.55 |
| Transparency (cm) | 0.195 | −0.048 | −0.199 |
| Electrical conductivity (µS cm−1) | 0.578 | 0.0018 | −0.291 |
| Turbidity (NTU) | −0.1187 | −0.228 | 0.530 |
| Total dissolved solid (mg l−1) | 0.548 | −0.053 | 0.244 |
| pH | 0.123 | −0.144 | −0.244 |
| Dissolved oxygen (mg l−1) | −0.339 | −0.091 | 0.362 |
| Biochemical oxygen demand (mg l−1) | 0.216 | 0.109 | −0.446 |
| Nitrate (mg l−1) | −0.484 | 0.313 | −0.375 |
| Phosphate (mg l−1) | 0.287 | 0.143 | 0.237 |

All canonical axes were not significantly different (p > 0.05) for the three axes.
was associated to water temperature, while transparency decrease slightly influenced the distribution and abundance of *Unio* sp. Nitrate, water temperature, and DO were negatively correlated to BOD₅, phosphate, water depth, EC, and TDS.

On the whole, based on the CCA plot, species such as Corbucilidae, *Chironomus* sp. and Thiaridae (*Potadoma* sp.), Unionidae (*Unio* sp.) portray the characteristics of potential indicator taxa due to their association to prevailing environmental condition of

Figure 2. Triplot of the first and second CCA axes of macroinvertebrate taxa, environmental variables and the sampling sites of Kalgwai Dam, North-Western Nigeria during the study period (January to April 2018). Macroinvertebrate abbreviation: Uni (*Unio* sp.), Cob (Corbucilidae), Viv (Viviparidae), Val (Valvatidae), Not (Noteridae), Pot (*Potadoma* sp.), Chi (*Chironomus* sp.), Cor (Cordulegastidae), and Car (*Candina* sp.) (Ja January, Fe February, Ma March, Ap April and numbers 1, 2, and 3 represent the sampling sites). 18 attached to months represent the year sampling was done, 2018.

Figure 3. Dendrogram derived from the cluster analysis (Bray–Curtis similarity index) of log (x + 1) transformed macroinvertebrate abundance data in the Kalgwai Dam, North-Western Nigeria during the study period (January 2018 to April 2018). Ja January, Fe February, Ma March and Ap April. 18 attached to months represent the year sampling was done, 2018. Numbers 1, 2, and 3 attached to the months represent the sampling sites.
the sampled sites. These taxa were strongly associated with increased turbidity and decreased transparency. Nutrients (nitrate and phosphate) had no link with any biological constituents of the dam. Viviparidae and Noteridae was like an outlier, as they were positioned at the extreme of Axes 1 and 2, respectively. Corbuciliidae can also be suggested as a potential indicator of fairly clean water as it was slightly associated with increased DO concentration of the sampled sites. The CCA ordination plot showed no singular pattern of association between the months/sites and the biological entities of the dam. Cluster analysis (Bray–Curtis) performed based on log \((x + 1)\) macroinvertebrate transformed abundance data revealed that macroinvertebrates showed no marked pattern of clustering in the dam. Sites 2 and 3 in February showed the highest similarity of about 0.94, while the least similarity cluster was the cluster between February and March in site 1 (Figure 3).

**Discussion**

**Physico-chemical variables**

Physico-chemical variables in an aquatic ecosystem may be influenced by varied degree of anthropogenic activities and other natural factors such as unwanted vegetation which may obstruct water flow, thus disrupting the community structure and function of the ecosystem. To sustain aquatic resources, it is significant to ascertain factors that negatively impact on the aquatic biota so that sustainability and management measures can be taken to assess the health of the aquatic ecosystem (Arimoro et al., 2015). The Kalgwai Dam is an important source of water for irrigation and other domestic activities for the communities around the riparian zone of the dam. Exceptional high values of TDS (66.2–108.3 mg l\(^{-1}\)), turbidity (2.5–176.5 NTU), and EC (108.5–178.7 \(\mu S cm^{-1}\)) are pointer to the fact that the water body has been subjected to perturbation occasioned by human influences. Earlier studies have hinged exacerbated water quality on mechanized agricultural activities along river continuum (Shimba & Jonah, 2016), some of these activities were prominent in the studied dam. Sedimentation, waste accumulation, and runoff are also another factors that influence the quality of water negatively (Shimba & Jonah, 2016). In the present, *Typha* sp., an invasive grass, posed threat to water quality of the studied dam, as farmers try to cut down the grass, so that their fishing and other farming activities may not be hindered by the invasive grass they may as well be obstructing the structural composition of the inherent biota in the dam.

Furthermore, when the grasses are been cut down, proper disposition is not been done by the farmers, as they allow the grasses to decay and form organic matters that aggravates the deteriorating state of physical and chemical characteristics of the dam, thereby affecting the structural and functional diversity of macroinvertebrates community in Kalgwai Dam. This can be seen in the slightly increased nutrient concentration and similar study by Mase, Muchiri, and Raburu (2009) have reported increased nutrient to have debilitating effect on aquatic biota community structure. The increased mean DO (5.30 ± 1.21) in Site 2 and relatively low BOD\(_5\) mean value (0.94 ± 0.24) in Site 3 are indication of less impact probably due to less dense *Typha* sp. vegetation in Site 2 and the absence of farmlands in Site 3. Low DO mean value and the highest mean BOD\(_5\) value (1.95 ± 0.97) were noted in Site 1, this portends the relatively perturbed reach of the dam in Site 1. The site is disturbed by varied human activities such as washing/bathing with detergents and even farming activities.

Generally, freshwater ecosystems in Nigeria are degrading seriously because of incessant discharges of organic and inorganic materials from activities within and around the ecosystem catchments (Arimoro et al., 2015; Edegbene et al., 2015). Improper regulatory mechanism, and lack of pollution abatement techniques by the water users, agricultural run-off from nearby communities around the water catchments also posed serious health risk to Nigerian freshwater ecosystems (Andem, Okorafor, Eyo, & Ekpo, 2014; Olomukoro & Dirisu, 2014; Kaaya, Day, & Dallas, 2015).

**Benthic macroinvertebrates composition, distribution, and abundance**

Species composition, distribution, and abundance modification can change the community structure of an aquatic biota (Sharma & Rawat, 2009). Macroinvertebrates composition may differ significantly among freshwater bodies across various reaches of an ecosystem and different ecosystems in the same region (Shimba & Jonah, 2016). These differences are caused by the level of awareness among riparian communities bordering these water bodies, as pollution are less minimal in areas were the inhabitants are enlightened about the negative impact of their activities on the aquatic ecosystems health. Awareness measures should be organised by the dam managers to enlighten the local dwellers, this will help to curtail the dwindling macroinvertebrate taxa composition, abundance, and diversity in the study area.

A total of 260 macroinvertebrates individuals belonging to 20 taxa, 9 orders, and 20 families were recorded during the study period. These values were low compared to species composition and abundance of macroinvertebrates reported from some selected water bodies in other parts of Nigeria (Arimoro et al., 2015; Edegbene &
Omovoh, 2014). Relative abundance was also low in the sampled months, this may be attributed to deteriorating physico-chemical characteristics and obstruction of the distribution of the organisms by the invasive grass (Typha sp.). This further buttress the fact that Typha sp. may be a potential menace to macroinvertebrates abundance and composition in Kalgwai Dam as Site 2 was not totally invaded by Typha grasses.

Of the macroinvertebrates groups recorded in this study area, Gastropoda were the most preponderance in all the sampling sites, with the highest abundance in Site 2. Potadoma sp. was the most abundant species among the Gastropoda taxa. Studies in a river in southern Nigeria reported a similar trend of Potadoma sp. of the Gastropoda group (Edegbene & Arimoro, 2014; Edegbene & Omovoh, 2014). This they ascribed to the increased alkalinity of the water body studied. It can be seen from the mean pH value of this present study area that the water is alkaline in nature with Site 2 having the highest mean pH value of 11.05. This may further lends credence to the preponderance of Potadoma sp. in Site 2.

Ephemeroptera and Trichoptera (ET), which are pollution sensitive species, were only recorded in Site 2. Abundance of ET has been reported to portray a fairly clean and/or clean water body (Edegbene & Arimoro, 2012; Edegbene et al., 2015). Contrarily reports in a river in Tanzania have reported Simuliidae (Diptera) to be a pristine water dweller (Shimba & Jonah, 2016). Also, Edegbene et al. (2015) suggested Chironomus sp. (Diptera) as potential pollution sensitive species, as their absence were noted in a heavily perturbed river in north central Nigeria. This report in a river in Tanzania is similar to the present study as a fairly high abundance of Diptera was recorded in Site 2, thus further affirming the abundance of Chironomus sp. in Site 2 to be unrelated to pollution state of the site owing to the fact that established sensitive taxa of the Ephemeroptera and Trichoptera were only recorded in Site 2.

Odonata have been reported to generally prefer floating aquatic vegetations, which creates suitable habitat for their reproduction (Arimoro et al., 2015; Edegbene & Arimoro, 2012; Edegbene et al., 2015). Contrarily, in this present study area, odonates were sparsely distributed as against the ubiquitous abundance reported for rivers in Southern Nigeria with dense vegetation cover (Arimoro et al., 2015; Edegbene & Arimoro, 2012).

**Diversity of macroinvertebrates**

Diversity indices are statistical parameters that are used to plan and evaluate the variety of data group consisting of different types of components (Barman & Gupta, 2015). Mean Shannon diversity (H) was 0.98 ± 0.28 (Site 1), while Sites 2 and 3 had 1.12 ± 0.48 and 1.16 ± 0.50 mean Shannon diversity, respectively. Study in streams in India and New Zealand reported a lower Shannon diversity of 0.77, which was said to be high and ascribed to environmental stability (Barman & Gupta, 2015; Iwasaki, 1999). This assertion confirms that environmental factors of this present study area do not negatively affect the diversity of macroinvertebrates. Margalef index showed no significant difference among the sites sampled and the values were less than 3. According to Lenat, Smock, and Penrose (1980), Margalef water quality index value greater than 3 indicates clean condition; value less than 1 indicates some pollution and intermediate value indicate moderate pollution. From the present study, Margalef index (taxa richness) were greater than 1, which goes to say that they are in the intermediate category as portended by Lenat et al. (1980). Hence, the dam is moderately polluted.

**Relationship between macroinvertebrates and selected physico-chemical variables**

The CCA ordination showed that macroinvertebrates species were weakly associated with the selected physico-chemical variables measured in Kalgwai Dam. Nitrate, water temperature, and DO explained the composition and abundance of Valvatidae, Corbulidae, Potadoma sp., Chironomus sp., Caridina sp., and Viviparidae. Some studies have implicated the preponderance of Potadoma sp. and Chironomus sp. in moderately polluted water bodies (Andem et al., 2014; Arimoro et al., 2015; Edegbene & Arimoro, 2012; Edegbene et al., 2015). Increased turbidity correlated favorably to the composition and abundance of Corbulidae, Chironomus sp., Potadoma sp., and Unio sp. Therefore, Corbulidae, Chironomus sp., Potadoma sp., and Unio sp. have been suggested in this present study as potential indicator taxa for monitoring polluted waters infested by invasive grasses and other anthropogenic activities. Earlier studies have attributed the abundance of Unio sp., Potadoma sp., and Chironomus sp. to relatively perturbed water body (Edegbene & Arimoro, 2012; Edegbene & Omovoh, 2014). The present study revealed that the selected physico-chemical variables and the invasion of Typha grass have contributed to the dwindling composition and abundance of macroinvertebrates in Kalgwai Dam.

**Conclusion**

This study provides information on the present status of Kalgwai Dam and the potential menace posed by the invasive grass (Typha sp.) on the structural distribution of macroinvertebrates. Freshwater bodies in Nigeria have been reported in many quarters as fast deteriorating as a result of unenforced environmental laws, thus leading to the disruption of the functional and structural composition, abundance and diversity of aquatic biota in the systems. In Kalgwai Dam, the incessant anthropogenic...
activities which include fishing, farming, open defecation, and the potential risk posed by invasive grass (*Typha* sp.) are of serious concern to the management and sustainability of the Dam and its inherent aquatic resources. Increased nutrients, BOD₅, and reduced DO were recorded in some of the sampled sites portraying the deteriorating state of the studied dam. Furthermore, macroinvertebrates such as the Ephemeroptera and Trichoptera were negatively affected by increased nutrient concentration and other pollution indicator physicochemical variables. On the other hand, *Typha* sp. were discovered to be a potential risk to the functional and structural diversity of macroinvertebrates in Kalgwai Dam most especially in Sites 1 and 2 with relatively high density of *Typha* grass. Overall, the study serves as a baseline investigation of the benthic macroinvertebrates fauna of Kalgwai Dam. Some selected macroinvertebrates taxa which include Corbuciliidae, *Chironomus* sp., *Potamona* sp., and *Unio* sp. have been suggested as potential biological indicator for monitoring water quality in North-Western Nigeria.

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