# A review of the effects of dams on the hydrology, water quality and invertebrate fauna of some Nigerian freshwaters

**Akindele, E. O.**[1] and **Indabawa, I. I.**[2]
[1]Department of Zoology, Obafemi Awolowo University, Ile Ife, Nigeria
[2]Department of Biological Sciences, Bayero University, Kano, Nigeria
*Corresponding author: eoakindele@yahoo.com

## Abstract

In this paper, the effects of dams on the hydrology, water quality and invertebrate fauna of some Nigerian inland waters were reviewed. The freshwaters considered include Awba Reservoir (Oyo State), Shiroro Lake (Kaduna State), Moro Lake (Kwara State), Aiba Reservoir (Osun State), Ikpoba Reservoir (Edo State), Onah Lake (Delta State), Tiga Lake (Kano State), Alau Lake (Borno State), Kainji Lake (Niger State) and Pan Lake (Plateau State). Dams negatively impacted the hydrology of the downstream waters by obstructing the flow of water from the reservoirs and quantitatively reducing the discharge (volume) of the receiving waters. The physico-chemical water quality of the surface freshwaters was enhanced as water flowed towards the dams and sediments were trapped in the reservoirs. In terms of biodiversity of invertebrates, dams positively enhanced the community structure of zooplankton but adversely affected that of the benthic macro-invertebrates at the deepest point of the reservoirs/lakes. On a general note, the dams can be considered as conservation apparatus for water quality and freshwater invertebrates in spite of their short comings. Their continued significance along a river course should however be periodically evaluated through environmental audits, and when necessary, decommissioned in the overall interest of conserving freshwater biodiversity in their respective ecological systems.

**Keywords:** biodiversity, conservation, dams, hydrology, invertebrates, water qualities.

Accepted: 23 July, 2015.

## Introduction

*Status of world freshwaters*

Freshwaters have been described as one of the world's most severely impacted environments which have received many of the direct impacts of human activities (McAllister *et al*, 2001). Freshwaters are under immense pressure in parts of sub-Saharan Africa due to land use changes, and their great benefits in achieving food security and meeting the needs of rural livelihoods (Millenium Ecosystem Assessment, 2005; Schuyt, 2005). Despite the benefits and services that they provide for humans, freshwaters all over the world are threatened (Schuyt, 2005). Understanding the adverse impact of human activities on aquatic ecosystems has resulted in growing worldwide calls for the sustainable management of this fragile resource (Kangalawe and Liwenga, 2005), because the effects of human disturbances have been particularly serious in freshwater ecosystems (Goudie, 2000; Cowx, 2002; Crivelli, 2002). The global human population has been predicted to reach 10 billion by 2050, in a direct proportion to human demands for freshwater resources and with attendant negative effects on freshwater environments (Boon and Pringle, 2009). This has justifiably led to a surge in the global campaign for freshwater conservation. For instance, Boon and Pringle (2009) reported that the number of websites containing freshwater conservation-related terms recorded the highest percentage increase between 2005 and 2007, as against all other conservation-related terms (e.g. nature conservation, habitat conservation, and species conservation).

*Economic importance and ecological consequences of dams*

Dams, built to change natural flow regimes, are one of the most significant human interventions in the hydrological cycle (McCartney *et al*, 2001). They are some of the largest engineered structures on earth. Dams supply almost a fifth of the world's electricity and they significantly reduce the risk of floods and droughts. While the construction of large dams in the industrialized world is almost at a standstill largely because suitable sites have already been exploited, it continues apace in developing countries (Smithsonian Earth, 2007). The damming of rivers has traditionally been one of the main ways to ensure adequate water resources for irrigation, hydropower generation and domestic use. About 60 per cent of the world's largest 227 rivers have been strongly or moderately fragmented by dams, diversions or canals, with effects on freshwater ecosystems (WCD, 2000). An important factor of fluvial habitat degradation is the physical transformation of water courses by means of hydraulic works (Almeida *et al*, 2013). The construction of dikes, weirs and dams obstruct dispersal and migration routes and alter natural flow regimes (Nilsson *et al*, 2005), disturbing refuges and trophic resources for the fauna and homogenizing the abiotic environment (Cortes *et al*, 1998; Growns and Growns, 2001; Wang *et al*, 2011).

The construction of a dam results in post-impoundment phenomena that are specific to reservoirs and do not occur in natural lakes. However, once a reservoir has formed and has reached stability, its subsequent dynamic behaviour is often very much the same as that of a natural lake. Older reservoirs can thus be considered as lakes and the challenges presented in managing them are often the same (Dinar *et al*, 1995). Dams have impacts on both upstream and downstream ecosystems. Many of these changes are immediate and obvious, while some are gradual, subtle and more difficult to predict, e.g. changes in the thermal regime, water quality and land-water interactions result in changes in primary production which in turn has long term implications for fish and other fauna higher up in the food chain. Dams may also cause changes in ecosystems at great distances from the dam (McCartney *et al*, 2001). These changes can affect the biota for long distances down the river (McAllister *et al*, 2001).

## The major dams of Nigeria

In Nigeria, the major dams are concentrated in the drought-prone and semi-arid northern part of the country in a bid to ensure adequate supply of water in the prolonged dry season, and also to check flood occasioned by torrential rainfall in the zone. Such dams include Kainji Dam (River Niger), Tiga Dam (Rivers Kano and Duku), Jebba Dam (River Niger), Kafin Zaki Dam (River Jama'are), Dadin Kowa Dam (River Gongola) and Shiroro Dam (River Kaduna) (Figure 1), all of which can be classified as large dams based on the International Committee on Large Dams (ICOLD) criteria for classifying dams (McCartney *et al*, 2001). Aside these large dams, river flows in Nigeria are punctuated by numerous small dams with a fair representation in every state (Ita *et al*, 1985). Although electricity is the chief reason for building mega-dams (as in the case of Kainji, Jebba and Shiroro Dams in Nigeria), they also smooth out seasonal variations in water flow, preventing potentially dangerous floods (Smithsonian Earth, 2007). In this paper, the ecological effects of dams on the hydrology, physico-chemical water quality and invertebrate fauna of Nigerian freshwaters are reviewed in the overall interest of conserving freshwater resources.

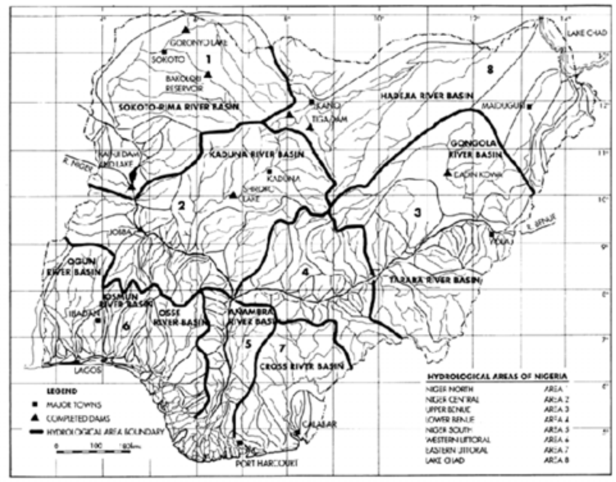


**Figure 1.** Hydrological map of Nigeria showing the large dams and their locations in their respective river basins.

*Source:* Ita, 1994.

## Hydrological effects

Although the hydrological regimes of rivers of inter-tropical Africa are directly influenced by rainfall (Nami, 2002), dams have been reported to alter their natural flow regimes (Nilsson *et al*, 2005). Despite the relative abundance of water at times in the Lake Chad Basin area (north-eastern Nigeria), the flow of rivers has been constantly diminishing (Nami, 2002) partly due to decreasing rainfall in the hydrologically active upstream basins but also as a consequence of increased flow alterations and abstraction for human consumption (World Bank, 2002). Hadejia Jama'are River Basin is one of the headwaters of Lake Chad but the river flow is punctuated along its course by several dams such as Tiga Dam, Kafin-Zaki Dam, Challawa Dam and Bagauda Dam (Akindele, 2012). The impacts of these dams on Lake Chad were particularly underscored by Shettima (2009) who reported that the river flow at Gashua in Yobe State, downstream of Tiga Dam fell by about 100 million cubic meters per year on completion of the dam. As a result of this significant reduction in the water flow of the Kano and the Hadejia Rivers downstream of Tiga Dam, various ecological and socio-economic problems (e.g. desert encroachment, poverty, migration, and conflicts between arable farmers and herdsmen) do arise along the water course. The worst effect is that there is a great reduction in the flow of River Yobe into the Lake Chad (Ojeifo, 2009). In the hydrological study of Aiba Stream in Iwo (Osun State), Akindele (2013) also reported that an upstream reservoir failed to release water downstream in the dry season which consequently reduced the stream's ability to buffer environmental stress occasioned by drought. Therefore, any alteration in the flow of streams and their hydrological regime would definitely have significant ecological effects on such systems, since the physico-chemical and biological water quality of inland waters are closely linked with their hydrology (Akindele and Adeniyi, 2013a).

## Effects on physico-chemical water quality

Conventionally, rivers have been regarded as the one-way transfer of matter downstream and when such a transfer is blocked, it affects the physico-chemical and biotic nature of the system (McAllister *et al*, 2001). Water storage in reservoirs induces physical, chemical and biological changes in the stored water all of which affect water quality. The chemical composition of water within a reservoir can be significantly different from that of the inflows (McCartney *et al*, 2001). Downstream, the water discharged from reservoirs can be of different compositions and show a different seasonal pattern to that of the natural river (McCartney *et al*, 2001). The salinization of water below dams in arid climates (arising from increased evaporation) is problematic and has proved to be a problem on floodplain wetlands in the absence of periodic flushing and dilution by flood water. If sufficiently high and prolonged, elevated salinity will affect aquatic organisms (Hart *et al*, 1991).

Some previous studies on impounded rivers in Nigeria have indicated a significant difference between upstream and downstream sections of reservoirs (Table 1). Physical parameters such as turbidity, total solids (TS), total suspended solids (TSS), apparent colour, and true colour tend to decrease from the inflow rivers towards the dam site (Atobatele and Ugwumba, 2008; Akindele *et al*, 2013), while water transparency tends to increase (Kolo, 1996; Olele and Ekelemu, 2008; Akindele *et al*, 2013). Most Nigerian rivers are turbid especially in the rainy season and are usually less productive than reservoirs and lakes on account of the variations in the afore-mentioned physical parameters, which play a major role in determining the euphotic zone and photosynthetic ability of such systems (Akindele and Olutona, 2014).

Variations in the chemical parameters of dammed rivers have also been reported by some workers for Nigerian freshwaters. Biological oxygen demand (BOD), conductivity, dissolved oxygen (DO) and phosphate

**Table 1.** Mean (±S.D.) values of some physico-chemical water parameters of some Nigerian reservoirs.

| Water body | Physico-chemical water parameter | Inflow | Dam site | Reference |
|---|---|---|---|---|
| Shiroro Lake | Transparency (m) | 0.34 | 0.41 | Kolo, 1996 |
| (Kaduna State) | Conductivity (µS/cm) | 79.3±18.5 | 71.4±11.4 | |
| | pH | 6.8±0.5 | 6.9±0.7 | |
| | Dissolved oxygen (mg/L) | 11.1±4.4 | 10.2±2.6 | |
| | Nitrate (mg/L) | 0.47±0.3 | 0.50±0.3 | |
| | Phospahte (mg/L) | 0.76±0.5 | 0.64±0.4 | |
| Moro Lake | Transparency (m) | 0.41±0.08 | 0.24±0.05 | Mustapha and Omotosho, |
| (Kwara State) | Conductivity (µS/cm) | 76.5±6.7 | 68.5 ±5.9 | 2005 |
| | pH | 7.25±0.15 | 7.06±0.15 | |
| | Total hardness (mg$CaCO_3$/L) | 38.2±3.4 | 29.5±3.0 | |
| | Dissolved oxygen (mg/L) | 5.3±1.1 | 4.0±0.7 | |
| Aiba Reservoir | Turbidity (NTU) | 43.06 ± 6.72 | 39.93 ± 6.78 | Atobatele and Ugwumba, |
| (Osun State) | Conductivity (µS/cm) | 70.34 ± 7.16 | 64.85 ± 7.08 | 2008 |
| | pH | 8.00±0.21 | 7.99±0.19 | |
| | Dissolved oxygen (mg/L) | 7.10±0.30 | 7.13±0.35 | |
| | Total alkalinity (mg$CaCO_3$/L) | 67.70 ± 1.48 | 62.64 ± 1.34 | |
| | Total hardness (mg$CaCO_3$/L) | 46.02 ± 1.44 | 45.16 ± 1.79 | |
| Onah Lake | Transparency (m) | 0.32 ± 0.04 | 0.38±0.03 | Olele and Ekelemu, 2008 |
| (Delta State) | Conductivity | 51.2±6.08 | 45.3±4.48 | |
| | pH | 6.54±1.2 | 5.95±0.3 | |
| | Dissolved oxygen (mg/L) | 5.0±0.73 | 4.6±1.30 | |
| Awba Reservoir (Oyo State) | pH | 6.75±0.35 | 6.81±0.26 | Popoola *et al*, 2011 |
| | Total alkalinity (mg$CaCO_3$/L) | 88.5±9.97 | 81.75±9.97 | |
| | Dissolved oxygen | 3.10±0.35 | 1.21±0.92 | |
| | Phospahte (mg/L) | 0.05±0.03 | 0.03±0.01 | |
| Tiga Lake | Transparency (m) | 0.20±0.03 | 0.58 ± 0.05 | Akindele *et al*, 2013 |
| (Kano State) | Turbidity | 80.2 ± 12.7 | 18.6 ± 4.5 | |
| | Apparent colour (Pt.Co) | 974.8 ± 138.9 | 372.6 ± 77.6 | |
| | Conductivity (µS/cm) | 150.5 ± 22.8 | 73.0 ± 1.7 | |
| | Total alkalinity (mg$CaCO_3$/L) | 56 ± 9 | 26 ± 2 | |
| | Total hardness (mg$CaCO_3$/L) | 33.4 ± 3.3 | 21.4 ± 1.3 | |
| | Dissolved oxygen (mg/L) | 6.0 ± 0.2 | 7.9 ± 0.1 | |
| | Nitrate (mg/L) | 1.06 ± 0.13 | 0.38 ± 0.05 | |
| | Phosphate (mg/L) | 0.20 ± 0.01 | 0.18 ± 0.01 | |
| Alau Lake | Transparency (m) | 0.50±0.32 | 0.53±0.49 | Usman *et al*, 2014 |
| (Borno State) | pH | 8.07±0.15 | 7.99±0.15 | |
| | Dissolved oxygen (mg/L) | 6.94±0.34 | 6.53±0.28 | |
| | Phosphate (mg/L) | 0.19±0.03 | 0.26±0.04 | |

decreased from the inflows towards the dam site of Shiroro Lake (Kolo, 1996). The variation was attributed to less allochthonous input and organic matter decomposition at the dam-site which would have used up much dissolved oxygen. This trend was also similar to the accounts of Mustapha and Omotosho (2005) on Moro Lake, and Olele and Ekelemu (2008) on Onah Lake in which they reported decline in conductivity and dissolved oxygen towards the dam site of the lakes. In an ecological study of Awba Reservoir (University of Ibadan), Popoola and Otalekor (2011) observed that pH was lowest at the inflow section and increased towards the dam site while the reverse was the case for dissolved oxygen concentration. Most of the investigated chemical parameters of Lake Tiga (Kano State) showed a decrease towards the dam site (Akindele *et al*, 2013), particularly conductivity, total alkalinity, total conductivity, total hardness, $NO_3^-$, $PO_4^{3-}$ and major ions ($Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, $Cl^-$, $SO_4^{2-}$ and $HCO_3^-$), while pH and dissolved oxygen showed an increase. In Lake Alau (Maiduguri, Borno State), water transparency was lowest at the inflow section and highest at the dam site. The general pattern in the physico-chemical nature of these waters suggests that the reservoirs (e.g. Shiroro Lake, Aiba Reservoir and Lake Tiga) underwent self-purification process as concentrations of suspended sediments decreased and phosphate concentrations increased towards the dam site.

Another effect of dams on Nigerian freshwaters is homogenization of surface waters, as has been observed in Lake Tiga (Akindele *et al*, 2013) where there was little or no variation in the physico-chemical parameters of the lake's lacustrine section up to 10-15 km upstream of the dam. This trend would particularly be noticeable in reservoirs of great length where the effect of transition from lotic to lentic status is usually nullified by longitudinal distance coupled with a longer water retention time.

Vertically, impounded rivers in Nigeria have shown thermal and chemical stratifications at their limnetic and profundal zones. Holomixis was observed in Lake Tiga between December and January as a result of a near uniform temperature between the epilminnetic and the hypolimnetic zones, which was followed by a period of thermal stratification between February and June (Akindele and Adeniyi, 2014). This observation was similar to the holomictic and thermal stratification patterns of Kainji Lake which experiences overturn in December and thermal stratification between February and May (Henderson, 1973). An account of thermal stratification had also earlier been given on Bakolori Reservoir (Adeniji, 1980) and Tiga Reservoir (Adeniji and Ita, 1977). Biological consequences of stratification include the progressive exclusion of obligate aerobes such as fish and invertebrates, as dissolved oxygen levels fall to zero in the hypolimnetic waters (Walker *et al*, 1984).

## Effects on invertebrate fauna

### *Effects on zooplankton fauna*

Within natural lotic systems, plankton production is negligible and often only derived from lakes, low velocity waters and from benthic algal communities. Upon dam closure, the lentic system establishes itself rapidly as the reservoir fills. Thereafter, a microbial population explosion occurs, releasing nutrients from the newly submerged organic matter. This stimulates a rapid development of the phytoplankton which harnesses solar energy, and by extension the zooplankton. The introduction of water into a river system downstream of a reservoir, particularly as a result of impoundment in headwater areas can markedly alter the plankton component of river systems (McCartney *et al*, 2001).

The general pattern of zooplankton distribution in Nigerian freshwaters is such that they are favoured by lentic environments (reservoirs and lakes) and relatively less distributed in running waters especially at high discharge. Opa Reservoir's headwaters (Rivers Opa, Esinmirin and Obudu) in the south-western part of the country were reported to be comparatively lower than the downstream Opa Reservoir in terms of zooplankton species richness (Akinbuwa and Adeniyi, 1991; Akindele and Adeniyi, 2013a). The same trend was observed in Lake Tiga where a total of 28 zooplankton species was recorded at the inflow as against a total of 40 species at the dam site. The species richness of crustacean zooplankton was also reported to show an increase towards the dam site, while rotifers species richness/ population at the dam site (deepest point) decreased from the surface down to the bottom (Akindele and Adeniyi, 2013b). Idowu *et al* (2011) in their study of Lake Alau. Several factors can be attributed to the higher species richness/abundance of zooplankton usually recorded at the lacustrine section of Nigerian reservoirs when compared to their inflows. First, the headwaters of most tropical reservoirs usually record lower transparency and higher concentrations of suspended solids, which have consequently resulted in their low biological productivity (Carr and Neary, 2006). Reservoirs trap suspended particles, reducing turbidity downstream at the dam site (McAllister *et al*, 2001). Increased turbidity above natural levels can interfere with photosynthesis and attenuate algal development. Reduced turbidity at a dam site consequently enhances plankton development, and may even affect plankton their downstream of a reservoir (Arthington and Welcomme, 1995; McCartney *et al*, 2001).

The second factor is that running waters are largely inhospitable environments for the development of plankton, particularly the micro-crustaceans (Hynes, 1970; Winner, 1975). The residence time for planktonic animals in lotic environments is quite low and only organisms with rapid growth and high renewal rate can proliferate in them due to their flowing nature (Pourriot *et al*, 1997). Except when flows are interrupted naturally as a result of drought, or as a result of environmental manipulation by man (e.g. impoundment), zooplankton composition in Nigerian running waters is usually dominated by Rotifera fauna and with very few representations of crustacean fauna. Longitudinal transfer time which is often too short to allow intense clonal development of crustaceans has been attributed to their rarity in running waters (de Ruyter van Steveninck *et al*, 1990, 1992; Marneffe *et al*, 1996, Viroux, 1997).

*Effects on benthic macro-invertebrates*

Dams do not only alter river hydrology but also the faunal characteristics of downstream stations, particularly the benthic macro-invetebrates (McAllister *et al*, 2001; Ogbeibu and Oribhabor, 2002). The general pattern of benthic macro-invertebrates distribution in Nigerian reservoirs is that of decline in biodiversity towards the dam site.

In a comparative study of Aiba Reservoir with its inflows (Aiba and Onikan Streams) and outflow (Aiba Stream), a wide disparity was recorded between the reservoir and these adjacent streams in terms of macro-invertebrate taxonomic composition. The following taxa which were unaccounted for in the previous study of the reservoir were recorded in the streams: Odonatans (Families Coenagrionidae, Corduliidae, Gomphidae, Macromiidae, Lestidae and Libellulidae), Dipterans (Families Stratyomidae and Syrphidae), Coleopteran (Family Elmidae), Heteroptera (Families Gerridae and Pleidae), Planarian Platyhelminth (family Dugesiidae) and Molluscs (Families Ampullaridae, Planorbidae, Viviparidae and Unionidae) (Akindele and Liadi, 2014; Akindele and Olutona, 2015). Most of these animals are insects which only need to spend their larval stage in the aquatic environment and later move to the terrestrial environment soon after emerging as adults. A similar observation to the Aiba freshwater systems had earlier been made by Ogbeibu and Oribhabor (2002) while studying the ecological impact of river impoundment on a fourth order stream in southern Nigeria. The upstream station recorded 36 taxa of benthic macroinvertebrates while the reservoir and the downstream stations recorded 16 and 19 respectively. Ephemeroptera, an insect order which has generally been adjudged as a good indicator of water quality was considerably high in terms of taxa richness and abundance at the upstream station but significantly reduced within the reservoir and the downstream stations. Furthermore, occurrences of Orders Hemiptera, Lepidoptera and Odonata were only recorded at the upstream station.

In Awba Reservoir, species richness, abundance and diversity of benthic macroinvertebrates were highest at the reservoir's inflow and lowest at the dam site (Adeogun and Fafioye, 2011; Popoola *et al*., 2011). Atobatele and Ugwumba (2010) also reported that there were no benthic macroinvertebrates recorded at the deep sites near the dam of Aiba Reservoir, while the highest densities were recorded at the upper reaches of the reservoir. The absence of the organisms at the dam site of the reservoir was attributed to factors such as lack of inadequate food, unsuitability of the substrate and anoxic water conditions in the benthic zone. Apart from 'depth' factor, the benthic zone of most reservoirs/lakes is oxygen-poor and relatively acidic as a result of decomposition of organic matter by microbes which makes the zone most unfavourable for their development. Organisms' extinctions are a significant problem in freshwater invertebrates (McAllister *et al*, 2001), some of which could be caused locally by environmental manipulation by man through impoundment. The 1996 IUCN Red List of threatened animals for instance indicated that a total of 199 species of bivalves and 493 species of gastropods are on the Red List, out of which 12 species of bivalves and 14 species of gastropods have gone extinct. On a global scale, an average of 70% of mollusc species were lost in 66 cases around the world and an extinction rate of up to 50% or even 90% reached in rich faunas (McAllister *et al*, 2001). This underscores the need to double up efforts aimed at conserving freshwater invertebrates, some of which could have gone into extinction (locally/globally) before ever realizing their economic importance.

## Are dams still relevant to the conservation of freshwater resources in Nigeria?

The tropics are home for much of the richest freshwater biodiversity. Freshwaters comprise only 0.8% of the surface area of the world and they have fewer species than other systems, but contain more species per unit area than terrestrial and marine environments (Table 2) (McAllister *et al*, 2001). Although dams seem not to favour diversity and distribution of benthic macro-invertebrates in the lacustrine/limnetic section of a reservoir, their positive impacts in ensuring adequate water quantity and quality, as well as the overall animal biodiversity cannot be over-emphasized. In Nigeria for instance, water quality of dammed rivers typically increases towards the dam area, and so is biodiversity of zooplankton. Although, the effects of dams on icthyofauna were not covered in this review, it is worthy of note to state that profundal areas of reservoirs may provide refuge for fishes unlike the inflow streams/rivers which are relatively shallow and usually characterized by indiscriminate fishing activities.

**Table 2.** Species richness of the world's major environments.

| Environment | Area of world surface (%) | Number of living species (%) | Richness: % species/% area |
|---|---|---|---|
| Freshwater | 0.8 | 2.4 | 3.0 |
| Terrestrial | 28.4 | 77.5 | 2.7 |
| Marine | 70.8 | 14.7 | 0.2 |
| Alternate shifts in the above-mentioned environments | N/A | 5.3 | N/A |

NA: Not applicable.
*Source:* McAllister *et al*, 2001.

Furthermore, anthropogenic impacts on reservoirs are not usually as strong as on their headwaters (rivers/ streams), most likely because the former are usually much deeper than the latter, and because dams are in most cases close to the administrative offices of river basin development authorities or state water corporations. Such anthropogenic activities in the upstream areas include dumping of wastes, bathing, washing, water abstraction for irrigation, and channelization of water for aquaculture among others. All of these have the potential to expose invertebrates and fishes in particular to undue stress.

Although, loss of some species (e.g. fish) due to river impoundments has been reported in Nigeria (Lewis, 1974; Welcomme and Henderson, 1976), reservoirs however still remain a refuge for a number of amphibians, reptiles, birds and mammals. Pan Lake, an artificial lake located in Plateau State (north-central Nigeria) was reportedly a sanctuary for manatee, red river hog, crocodile and hippopotamus and a variety of fish species (Ebin, 1983). Kainji Lake, the largest dammed river in the country was reported to have 75 species of aquatic birds, four species of Chelonia (turtles), two species of crocodiles (*Crocodylus niloticus* and *C. cataphractus*), with an abundance of Nile monitors and Bosc's monitor lizards (Ita, 1994). Others include over 12 species of amphibians including two species of toads, 62 species of mammals which include those associated with aquatic systems such as the hippopotamus, manatee and clawless otter (Ita, 1994). It is noteworthy to state that the rate of decline in the conservation status of freshwater amphibians is greater than that of terrestrial species, and lotic freshwaters have more threatened amphibian species than lentic ones. The largest river basin in Nigeria (Niger Basin) has been identified as one of the global biodiversity hotspots for amphibians i.e. one of those recording the highest number of threatened freshwater amphibian species (Millennium Ecosystem Assessment, 2005). The implication of this is that proliferation of dams along the Niger Basin and other inland basins could further endanger amphibians and other animals in the nation's freshwater systems.

Conservation of freshwater ecosystems has been justifiably described as the key to freshwater species conservation (McAllister *et al*, 2001). In view of this, it is important to conserve the respective freshwater environments of most of these endangered wildlife species given the fact they are freshwater-dependent and they play their own ecological role in the ecosystem. In Nigeria, the creation of dams and establishment of River Basin Development Authorities to manage the nation's large reservoirs has proved to be effective in the conservation of freshwater environments. Although reservoirs may have caused local species decline of some freshwater animals in Nigeria, their overall benefits however seem to outweigh their demerits.

## Conclusion

In conservation sense, reservoirs and lakes are to freshwater biodiversity what national parks and forest reserves are to terrestrial biodiversity. Impounded rivers have contributed to the conservation of freshwaters in Nigeria both quantitatively and qualitatively. However, environmental audits need to be carried out periodically on the nation's reservoirs so as to assess their water quality and biodiversity status, and to determine if there is still a need to maintain some of the dams or decommission them. The proliferation of dams along a river course should be discouraged as this may threaten species that are naturally adapted to shallow/running waters. Impounded rivers (including the smaller ones that are scattered all over the country) need to be conserved not only for adequate water supply and river regulation flow, but also for their biological integrity.

### References

Adeniji, H. A. 1980. Preliminary study of the fisheries limnology of Bakolori Lake, Nigeria. *Kainji Lake Research Institute 1985 Annual Report*, pp. 44-50.

Adeniji, H. A. and Ita, E. O. 1977. Preliminary investigations into the limnology and fisheries of Tiga Lake, Kano State, Nigeria. Report presented to Kainji Lake Research Institute, 19pp.

Adeogun, O. A. and Fafioye, O. O. 2011. Impact of effluents on water quality and benthic Macro-invertebrate fauna of Awba Stream and Reservoir. *J. Appl. Sci. Environ. Manage. 15 (5):* 105-113.

Akinbuwa, O. and Adeniyi, I. F. 1991. The rotifera fauna of Opa Reservoir, Ile-Ife, Nigeria. *J. Afri. Zool. 105(5):* 383-391.

Akindele, E. O. 2012. An ecological study of the water quality and zooplankton fauna of Tiga Lake, Kano, Nigeria. Ph.D. Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria. 319pp.

Akindele, E. O. 2013. Downstream assessment of the zooplankton fauna and hydrology of Aiba Stream, Iwo, Nigeria. In: S. O. Olajuyigbe, O. M. Coker and F. Olaleru (eds), *Sustaining the remaining tropical biodiversity.* Nigerian Tropical Biology Association (NTBA)/ Developing Research among African Scientists (DRECA), 47-53.

Akindele, E. O. and Adeniyi, I. F. 2013a. A study of the physico-chemical water quality, hydrology and zooplankton fauna of Opa Reservoir catchment area, Ile Ife, Nigeria. *African Journal of Environmental Science and Technology 7(5):* 192-203.

Akindele, E. O. and Adeniyi, I. F. 2013b. Zooplankton composition and community structure in Lake Tiga, Kano, Nigeria. *African Journal of Aquatic Science 38(3):* 279-286.

Akindele, E. O., Adeniyi, I. F. and Indabawa, I. I. 2013. Spatio-temporal assessment and water quality characteristics of Lake Tiga, Kano, Nigeria. *Research Journal of Environmental and Earth Sciences 5(2):* 67-77.

Akindele, E. O. and Adeniyi, I. F. 2014. Holomixis and stratification patterns of a Northern Nigeria Lake. *Journal of Aquatic Sciences 29(1):* 23-29.

Akindele, E.O. and Liadi, A. A. 2014. Diversity and response of benthic macro-invertebrates to natural and induced environmental stresses in Aiba Stream, Iwo, south-west Nigeria. West *African Journal of Applied Ecology 22(4):* 101-111.

Akindele, E.O. and Olutona, G. O. 2014. Water physico-chemistry and zooplankton fauna of Aiba Reservoir's headwater streams. *Journal of Ecosystem, Volume 2014, Article ID 105405,* 11 pages. http://dx.doi.org/10.1155/2014/105405.

Akindele, E. O. and Olutona, G. O. 2015. Environmental variables and benthic macro-invertebrate assemblage in the headwater streams of an Afro-tropical reservoir. *Water and Environment Journal,* doi:10.1111/wej.12117.

Almeida, D., Merino-Aguirre, R. and Angeler, D. G. 2013. Benthic invertebrate communities in regulated Mediterranean streams and less-impacted tributaries. *Limnologica 43:* 34-42.

Arthington, A. H. and Welcomme, R. 1995. The conditions of large river systems of the world. In: N. B. Armantrout (Ed.), *Condition of the World's Aquatic Habitats. Proceedings of the World's Fisheries Congress, Theme 1.* Science Publishers Inc., Lebanon, USA, 44-75.

Atobatele O. E. and Ugwumba, O. A. 2008. Seasonal variation in the physico-chemistry of a small tropical reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). *African Journal of Biotechnology 7(12):* 1962-1971.

Atobatele O. E. and Ugwumba, O. A. 2010. Distribution, abundance and diversity of macro-zoobenthos in Aiba Reservoir, Iwo, Nigeria. *African Journal of Aquatic Science 35(3):* 291-297.

Boon, P. J. and Pringle, C. M. 2009. Introduction. In: P. J. Boon and C. M. Pringle (eds.), *Assessing the Conservation Value of Fresh Waters: An International Perspective*. Cambridge University Press, United Kingdom, 1-5.

Carr, G. M. and Neary, J. P. 2006. *Water quality for ecosystem and human health*. United Nations Environment Programme Global Environment Monitoring System (GEMS)/Water Programme, 132pp.

Cortes, R. M. V., Ferreira, M. T., Oliveira, S. V. and Godinho, F. 1998. Contrasting impacts of small dams on the macroinvertebrates of two Iberian mountain rivers. *Hydrobiologia 389:* 51-61.

Cowx, I. G. 2002. Analysis of threats to freshwater fish conservation: Past and present challenges. In: M. J. Collares-Pereira, I. G. Cowx and M. M. Coelho (eds.), *Conservation of Freshwater Fishes: Options for the future.* Fishing News Books, Oxford, 201-220.

Crivelli, A. J. 2002. The role of protected areas in freshwater fish conservation. In: M. J. Collares-Pereira, I. G. Cowx and M. M. Coelho (eds.), *Conservation of freshwater fishes: Options for the future.* Fishing News Books, Oxford, 373-388.

de Ruyter van Steveninck, E.D., Admiraal, W. and van Zanten, B. 1990. Changes in plankton communities in regulated reaches of the Lower River Rhine. *Regulated Rivers 5:* 67-75.

de Ruyter van Steveninck, E.D., Admiraal, W., Breebart, L., Tubbing, G.M.J. and van Zanten, B. 1992. Plankton in the River Rhine – structural and functional changes observed during downstream transport. *Journal of Plankton Research 14(10):* 1351-1368.

Dinar, A., Seidl, P., Olem, H., Jorden, V., Duda, A. and Johnson, R. 1995. *Restoring and Protecting the World's Lakes and Reservoirs. World Bank technical Paper No. 289.* The World Bank, Washington D.C., 85pp.

Ebin, C.O. 1983. An appraisal of the biotic and material resources of some game reserves and wildlife management in Nigeria. *Nigerian Conservation Foundation*, Lagos, 30pp.

Goudie, A. 2000. *The Human impact on the natural environment, 5th ed.* The MIT Press, Cambridge, 511pp.

Growns, I. O. and Growns, J. E. 2001. Ecological effects of flow regulation on macro-invertebrates and periphytic diatom assemblages in the Hawkesbury-Nepean River. *Australia. Regul. Rivers 17:* 275-293.

Hart, B. T., Bailey, P., Edwards, R., Hortle, K., James, K. I., Mchamon, A., Meredith, C. and Swaling, K. 1991. A review of the salt sensitivity of the Australian freshwater biota. *Hydrobiologia 210:* 105-144.

Henderson, F. 1973. A limnological description of Kainji Lake (1969-1971). A report prepared for the Kainji Lake Project. Food and Agriculture Organization of the United Nations, 47pp.

Hynes, H. B. N. 1970. *The ecology of running waters.* University of Liverpool Press, Liverpool, 555pp.

Ita, E. O. 1994. *Aquatic plants and wetland wildlife resources of Nigeria*. CIFA/FAO occasional paper, 52pp.

Ita, E.O., Sado, E.K., Balogun, J.K., Pandogari, A. and Ibitoye, B. 1985. A preliminary checklist of inland water bodies in Nigeria with special reference to lakes and reservoirs. *Kainji Lake Research Institute Technical Report Series No. 14,* 51pp.

Kangalawe, R. Y. M. and Liwenga, E. T. 2005. Livelihoods in the wetlands of Kilombero Valley in Tanzania: Opportunities and challenges to integrated water resource management. *Phys. Chem. Earth 30:* 968-975.

Kolo, A. I. 1996. The assessment of physic-chemical parameters of Shiroro Lake and its major tributaries. *Proceedings of 1996 FISON Conference*, pp. 260-268.

Lewis, D.S.C. 1974. The effects of the formation of Lake Kainji upon the indigenous fish population. *Hydrobiol. 45:* 281-301.

Marneffe, Y., Descy, J. P. and Thome, J. P. 1996. The zooplankton of the lower River Meuse, Belgium: Seasonal changes and impact of industrial and municipal discharges. *Hydrobiologia 319:* 1-13.

McAllister, D. E., Craig, J. F., Davidson, N., Delany, S. and Seddon, M. 2001. *Biodiversity impacts of large dams. Background Paper Nr 1.* Prepared for IUCN/UNEP/WCD, 68pp.

McCartney, M. P., Sullivan, C. and Acreman, M. C. 2001. Ecosystem Impacts of Large Dams: Background Paper Nr 2. Prepared for IUCN/UNEP/WCD, 82pp.

Millenium Ecosystem Assessment. 2005. *Ecosystems and human well-being: Wetlands and water synthesis.* World Resources Institute, Washington, DC, 80pp.

Mustapha, M. K. and Omotosho, J. S. 2005. An assessment of the physico-chemical properties of Moro Lake, Kwara State, Nigeria. *African Journal of Applied Zoology and Environmental Biology 7:* 73-77.

Nami, B. 2002. *Environmental degradation of the Lake Chad Basin: Implications for food security.* Joseph Henry Press, Washington DC, pp. 125-38.

Nilsson, C., Reidy, C. A., Dynesius, M. and Revenga, C. 2005. Fragmentation and flow regulation of the world's large river systems. *Science 308:* 405-408.

Ogbeibu, A. E., Oribhabor, B. J. 2002. Ecological impact of river impoundment using benthic macro-invertebrates as indicators. *Water Research 36 (2002):* 2427-2436.

Ojeifo, S. 2009. A Senator's Worries Over Kafin-Zaki Dam. *ThisDay,* 3 August 2009. http://allafrica.com/stories/200908040019.html.

Olele, N. F. and Ekelemu, J. K. 2008. Physico-chemical and periphyton/phytoplankton study of Onah Lake, Asaba, Nigeria. *African Journal of General Agriculture 4(3):* 183-193.

Popoola, K. O. K. and Otalekor, A. 2011. Analysis of aquatic insects' communities of Awba Reservoir and its physico-cheical properties. *Research Journal of Environmental and Earth Sciences 3(4):* 422-428.

Pourriot, R., Rougier, C. and Miquelis, A. 1997. Origin and development of river zooplankton: Example of the marine. *Hydrobiologia 345:* 143-148.

Schuyt, K. D. 2005. Economic consequences of wetland degradation for local populations in *Africa. Ecol. Econom. 53:* 177-190.

Shettima, K. A. 2009. *Dam politics in Northern Nigeria: The case of the Kafin Zaki Dam.* York University, Canada.

Smithsonian Earth. 2007. DK Publishing, New York, 519 pp. http://pi.library.yorku.ca/ojs/index.php/refuge/article/view File/21922/20591.

Usman, A., Solomon, S. G. and Okayi, R. G. 2014. Some physico-chemical parameters and macro-element of Lake Alau, north-east Nigeria. *Nigerian Journal of Fisheries and Aquaculture 2(1):* 24-36.

Viroux, L. 1997. Zooplankton development in two large lowland rivers, the Moselle (France) and the Meuse (Belgium), in 1993. *Journal of Plankton Research 19(11):* 1743-1762.

Walker, T.D., Waterhouse, J. and Tyler, P. A. 1984. Thermal stratification and the distribution of dissolved oxygen in Billabongs of the Alligator Rivers Region, Northern Territory (Final Report), *Open File Record (OFR)* *28.

Wang, L., Infante, D., Lyons, J., Stewart, J. and Cooper, A. 2011. Effects of dams in river networks on fish assemblages in non-impoundment sections of rivers in Michigan and Wisconsin, USA. *River Res. Appl. 27:* 473-487.

Welcomme, R. L. and Henderson, A. F. 1976. Aspects of the management of inland water for fisheries. FAO. *Fish. Tech. Paper,* 161pp.

WCD. 2000. *Dams and Development: A New Framework for Decision-Making. The Report of the World Commission on Dams*. London, Earthscan http://www.damsreport.org/wcd_overview.htm [Geo-2-122].

Winner, J. M. 1975. Zooplankton. In: B. A. Whitton (ed.), *River Ecology.* Oxford University Press, Oxford, 155-169.

World Bank. 2002. *GEF Project on the Reversal of Land and Water Degradation Trends in the Lake Chad Basin. Project Brief.* World Bank: Washington DC, 13pp.

---

**Citation:** Akindele, E. O. and Indabawa, I. I.
A review of the effects of dams on the hydrology, water quality and invertebrate fauna of some Nigerian freshwaters.
*The Zoologist, 13:* 28-35 December 2015, ISSN 1596 972X.
Zoological Society of Nigeria.