OPEN ACCESS
International Journal of Aquatic Science
ISSN: 2008-8019
Vol. 10, No. 1, 11-18, 2019

Habitat studies of freshwater mussel (*Etheria elliptica*) in some water bodies in Ondo State Nigeria

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Received: January-12-2018 **Accepted:** April-19-2018 **Published:** January-01-2019

Abstract: The report of the decline in the population of *Etheria elliptica* necessitate the habitat study of the mussel in river Ogbese and Owena reservoir, Ondo state, Nigeria in order to know the status of the organism within the ecosystem. Thirty (30) specimens each from the water bodies were sampled between May to August 2012. The meristic variables and the condition factor of mussels showed that the samples from Owena reservoir (K = 16.33) were heavier than River Ogbese (K = 8.34). The water quality parameter buttress a better mussel in Owena reservoir, this is as a result of controlled human activities experienced by the reservoir. Nevertheless, the water quality parameters obtained from both water bodies were within the requirements of the mussel. Positive allometric growth pattern was observed in *Etheria elliptica* from both water bodies (Ogbese b = 3.02; Owena b = 3.01). The flow rate of both water bodies differ slightly, with river Ogbese having the highest flow rate. The study revealed that *Etheria elliptica* in both study areas were in good and healthy conditions despite the various human activities on the water bodies.

Keywords: Condition factor, Human disturbance, Owena Reservoir, River Ogbese, *Etheria elliptica*

Introduction

Etheria elliptica has a widespread distribution throughout Africa and Madagascar with no major threats to its global population (Van Damme, 2011). The freshwater oyster *Etheria elliptica* has inner gills with marsupial and relatively small eggs of about 0.05 mm in diameter. Beyond the egg stage, nothing else is known about the early morphogenic development (Bogan and Roe, 2008). The scant literature available on the family is limited to the geographical distribution, shell cementation and taxonomy of the group based on shell characteristics and habitats (Pilsbry and Bequaert, 1927; Yonge, 1962). However, there are 206 recognized genera of freshwater bivalves, most families represented by only one to five genera. The highest diversity is found in the Sphaeriidae and Unioniformes families. The Unionoida are made up of six families; Etheriidae, Hyriidae, Iridinidae, Margaritiferidae, Mycetopodidae and Unionidae, having 180 genera and 800 species (Bogan, 2008). The bivalve of the order Unionoida is found in freshwater water bodies, with a preference for fast flowing rivers, lakes and waterfalls attaching itself to hard substrate such as rocky shores. They are distributed in all continents except Antarctica; they are widely distributed throughout the African continent including Northern Madagascar (Graf and Cumming, 2007).

In Northern Madagascar, *E. elliptica* is now likely to be extinct since it has not been recorded live since the early 20th century (Van Damme, 2011). Habitat degradation is often recognized as one of the major causes for mussels' decreased biodiversity (Allan and Flecker, 1993). This significant loss of benthic biomass may result in large scale alteration of freshwater ecosystem processes and functions (Strayer, 1993). Several anthropogenic activities degrade mussel habitat and are responsible for accelerating the decline of mussel populations over the past century (Watters, 1999). These activities include logging, agricultural, construction activities. In addition, freshwater mussels are preyed upon by a range of terrestrial and aquatic organisms (Öktener, 2004; Vaughn, 2010). They serve as the intermediate hosts for several parasitic species, and some species are themselves parasitic as larvae (Dillon, 2000). Globally, freshwater bivalves are threatened, primarily through habitat deterioration, and in some cases through direct exploitation (Lydeard *et al.,* 2004). Despite their key ecological role and threatened status, mussel faunas in many regions are poorly studied and there are few baseline data against which to measure ongoing population. In Nigeria, freshwater bivalve communities have received little attention, though a study on the morphormetric features of some mussels were carried out by Blay (1989) while

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Oyewole *et al.* (2013) worked on the length-weight relationship of freshwater mussel (*E. elliptica*) from river Ogbese. Also, Akele *et al.* (2015 a,b) researched on the population dynamics and the traditional exploitation of edible freshwater mussel; *E. elliptica* in Pendjari River (Benin-Western African).

However, until now, no study was carried out on habitat study of *E. elliptica* in River Ogbese and Owena reservoir. Both water bodies have some levels of human activities such as construction of bridge, dredging, waste disposal and construction of dam on the reservoir which resulted in habitat alteration; a threat to the aquatic organisms. Also, both water bodies (River Ogbese and Owena Reservoir) were chosen for this research because of the availability of the organism (*E. elliptica*), hence this study will bring out the performance of the organisms in two water bodies having different substrate, hydrological factors and local hydraulics thereby revealing the preference of the species for both water bodies. However, there are no specific threats concerning the fresh water systems of Africa documented for this species as recorded in the International Union for Conservation of Nature (IUCN) Red list of threatened species (Van Damme, 2011). As a result, this research focused on the habitat studies of *E. elliptica* in two water bodies; River Ogbese and Owena reservoir. River Ogbese supports many uncontrolled human activities leading to its extensive contamination while the activities in the Reservoir are regulated by the State Government.

The study aims at assessing the physico-chemical parameters of the water body and sediment of the water bodies as it affect shell dimension and condition factor of the mussel in the said environments.

Materials and Methods

Study areas

River Ogbese (5˚26'E and 6˚43'N; Fig. 1a) runs through Ogbese town; which is about five kilometres from Akure, in Akure North Local Government Area, Ondo state, Nigeria. River Ogbese is one of the major perennial fast flowing rivers with rocky shore in South Western Nigeria; it took its source from Awo Ekiti in Ekiti State. It flows for approximately 22km from its source to meet River Ose which is 265 km long and discharges into the Atlantic Ocean through an intricate series of creeks and lagoons. Over the decade, some human activities such as construction of bridge, dredging, and waste discharge through run-off from agricultural practices around the banks have caused some habitat modification/alteration which bring a change in the ecosystem of the water body (Olawusi-Peters *et al.,* 2014).

Owena reservoir (4˚47'E and 7˚15'N) is in the suburb of Owena town in Ifedore Local Government Area, Ondo-State, Nigeria (Fig. 1b). The first reservoir was constructed in 1966 by the state government as water supply scheme for Akure and its environs but the water supply became insufficient due to the rapidly increasing population. Consequently, the state government came up with the design of the second Owena reservoir; 14km upstream of the first Owena river water supply scheme. In 1976, the project was taken over by the Federal Government of Nigeria through the Benin-Owena River Basin Authority, wherewith it was reviewed in its design in addition to the supply of portable, fisheries exploitation, irrigation of agricultural lands and hydro-electric power generation. The reservoir is about 300m long and 9m in its deepest part, and it impounds about 36.25 million cm^3 gross capacity of freshwater and the catchments area controlled by the reservoir is $790km^2$ (Fapohunda and Godstates, 2007).

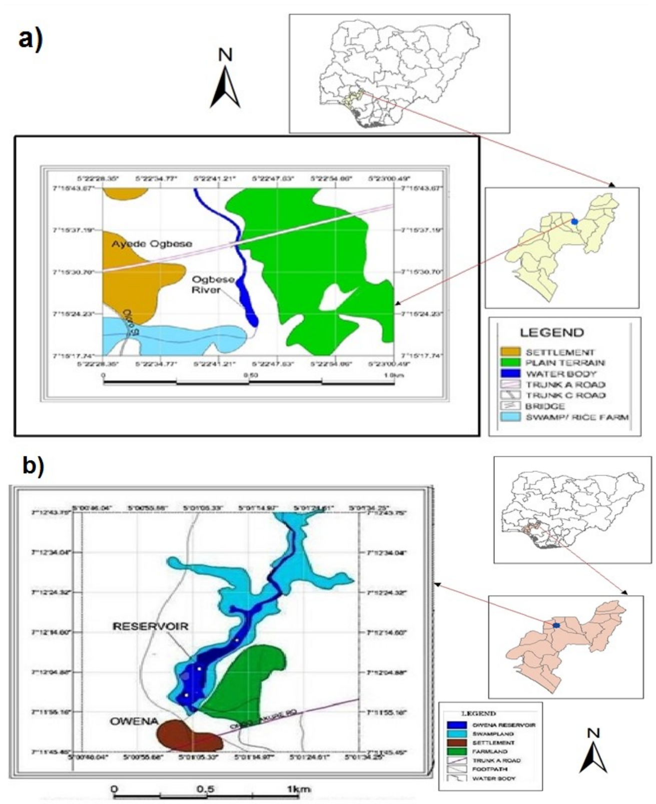

Fig. 1: a) The map of River Ogbese. b) The map of Owena Reservoir.

Sample collection

Samples (mussels, water and sediments) were collected from both River Ogbese and Owena Reservoir from May to August, 2012. During the studied periods, water and sediment samples were collected in triplicate around the mussels' beds. The water parameters were tested in-situ using Hanna CE HI 08129. Also, the sediments were collected using vaveen grab, which was lowered into the bottom of the water bodies using rope attached to it atop of a canoe.

Mussel collection

Thirty (30) specimens of *E. elliptica* were collected by the fishermen in River Ogbese and Owena Reservoir due to availability. The mussels were placed in plastic bags together with the river water and transported to the laboratory. The maximum length, width and height were measured to the nearest 0.01cm using a caliper while the weight was measured to the nearest gramme (0.01g) using mettler Toledo sensitive electronic weighing balance (Model PB 8001). The length-weight relationship was determined using the formula:

$W = aL^b$ (Pauly, 1983)

$\text{Log } W = \log a + b \text{ Log } L$,

$K = 100W/L^3$ (Ricker, 1975)

Water samples analysis

The physico-chemical parameters such as pH, conductivity, Total Dissolved Solids (TDS) and temperature of both water bodies were determined *in-situ* using Hanna CE HI 08129. The Dissolved Oxygen (DO) and Biochemical Oxygen Demand were determined using the methods of APHA (1998).

Sediment pH

Ten grams of sieved sediments were measured into cleaned beakers using sensitive electronic weighing balance and 20 ml of distilled water was added. The mixture was stirred and allowed to settle for 30 minutes after which a standardized pH meter electrode was immersed. The readings observed from the meter were recorded (USEPA, 2004).

Sediment phosphorous

Ten grams sieved samples were measured into cleaned beakers using sensitive electronic weighing balance and 35 ml of Bray-P solution was added and stirred for a minute. The mixture was filtered using filter paper. 4ml of complete Murphy and Rily solution was added to 5ml of filtered samples and 16 ml of distilled water was added. Samples were put inside the blank of spectrophotometer and zeroed. The readings were taken and read directly in mg/l at 660 mm from spectrophotometer (Bray and Kurtz, 1945).

Sediment calcium

Ten grams of sieved samples were measured into a clean beakers using sensitive electronic weighing balance. 100 ml ammonium acetate was added and vigorously shaken after which it was allowed to settle for 30 minutes and was filtered using filter paper. 5 ml of KOH, 5 drops of NH_4Cl, 5 drops of 2% KCN, a pinch of Alizarin black SN was added to 10ml of the filtered solution. The mixture was titrated till the solution turns light purple from deep blue color (APHA, 1998).

Sediment magnesium

Ten grams of sieved samples were measured into a clean beakers using sensitive electronic weighing balance. 100 ml of ammonium acetate was added then shook vigorously and allowed to settle for 30 minutes then filtered using filter paper. 5ml of ammonia, 5 drops of 2% KCN, 5 drops of hydroxylamine chloride (NH_4Cl), and three drops of Erichromy Black T were added to 10ml of the filtered solution. The solution was titrated till it turned pink from light blue (APHA, 1998).

Sediment organic matter

A gram of mechanically stirred samples was measured.10ml of 0.5 Potassium dichromate ($K_2Cr_2O_7$) were pipette into it, 20ml concentrated H_2SO_4 was added for 30 minutes. 100ml distilled water; 3 drops of Ferroine was added. Solution was titrated against Ferrous Sulphate till it changes color from orange to dark green then finally to moron red. Blank titration was made in the same manner and blank readings were taken (Byers *et al.,* 1978).

Sediment texture

Fifty gram of oven-dried samples was weighed into 250 ml beaker and 100 ml of Calgon were added. It was soaked for 30 minutes after which it was transferred to mechanical stirrer and stirred. 100 ml of 5% Calgon was added to each sample. The soil suspension was transferred quantitatively to sedimentation cylinder and made up to one liter. After 40 seconds, hydrometer in suspension and temperature were read. After two hours, hydrometer in the suspension and temperature were taken. The stem of the hydrometer reads directly in grams of soil per liter of suspension. To correct the hydrometer reading for temperature, 0.36g per liter was added for every 1^0C above 20˚C and 0.36 g was subtracted for every 1˚C below 20˚C (Sheldrick and Wang, 1993).

Flow rates

Two stakes were placed in the river and the distance between them were measured using meter rule to the nearest 0.01 m. An orange was put to the first stake, it's allowed to flow through to the second stake via the water. This was done thrice, after which the average river flow rates were recorded.

$$\text{Flow rate (m/s)} = \frac{\text{Distance travelled by float (m)}}{\text{Time to cover distance (s)}}$$

River velocity is estimated by multiplying time by 0.8 before the application of the above formula. This compensates for the drag caused by the river bed (Michaud and Wierenga, 2005).

$$\text{Flow rate (m/s)} = \frac{\text{Distance travelled by float (m)}}{\text{Time to cover distance x 0.8(s)}}$$

Statistical analysis

The result obtained was subjected to descriptive statistics such as mean, standard deviation and bar chart. The levels of significant differences were tested using student T-test. The length–weight relationship was analysed using regression analysis. Statistical Package for Social Sciences (SPSS) version 20.0 was used for the analysis.

Result

The shell dimension and Condition Factor of Mussels

Mussels collected from both Owena Reservoir and River Ogbese exhibit variation in shell size (length, width and height) and body weight as shown in Figure 2. Specimens from Owena Reservoir had mean maximum length, width, height and body weight of 8.80±1.38 cm, 6.51±1.24 cm, 0.22±0.68 cm, 111.70 ±65.64 g respectively while River Ogbese had means of 8.42±1.59 cm, 3.78±2.42 cm, 0.53±0.63 cm and 38.19±38.19 g respectively. Shell dimensions of mussels from Owena reservoir were significantly different (P<0.05) from the values obtained in River Ogbese as shown in Table 1. The coefficient of determination of the shell maximum length and body weight of samples from River Ogbese (b = 3.02) was greater than the b values of specimens obtained from Owena Reservoir (b = 3.01). The relationship between the body weight and the shell maximum length of *E. elliptica* in each water bodies showed positive allometric growth as shown in Figure 2. The condition factor of the mussel shows that samples from Rivers Ogbese and Owena Reservoir had 8.34 and 16.33 respectively.

Tab. 1: Mean (SD) of shell dimension and Condition Factor of Mussels in Owena Reservoir and River Ogbese.

Parameter	Owena R.	R. Ogbese	T stat	T crit	*P*
Length (cm)	8.80[b] (0.38)	8.42[a] (0.59)	46.54	2.78	0.00
Width (cm)	6.51[b] (0.24)	3.78[a] (0.42)	334.36	2.78	0.00
Height (cm)	0.22[a] (0.68)	0.53[b] (0.63)	-37.97	2.78	0.00
Weight (g)	111.7[b] (0.64)	38.19[a] (0.19)	1266.91	2.78	0.00

Means in column with similar superscript are not significantly different (P>0.05).

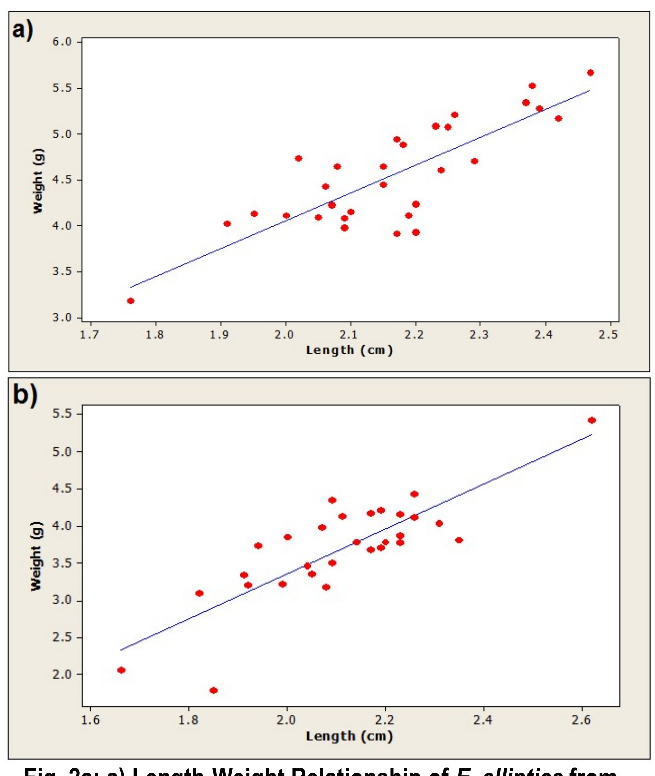

Fig. 2a: a) Length-Weight Relationship of *E. elliptica* from Owena Reservoir. b) Length-Weight Relationship of *E. elliptica* from River Ogbese.

The physico-chemical parameters

The physicochemical parameters of water from Owena Reservoir and River Ogbese are shown in Table 2. Also, some of the physicochemical parameters such as pH, TDS, conductivity were significantly different (P>0.05) from each other. However, highest values of TDS (102.00±0.21), conductivity (183.00±0.28) and BOD (0.80±0.08) were recorded in Owena Reservoir. In addition, the correlation matrix of the shell dimension, condition factor and the physic-chemical parameters of both water bodies are shown in Table 3. In Owena Reservoir, both length and width of *E. elliptica* are negatively correlated with height, DO, temp and BOD, whereas in River Ogbese, the length and width have a negative correlation with weight, pH, DO and temperature.

Tab. 2: Mean (SD) physicochemical parameters of water from Owena Reservoir and River Ogbese.

Water Parameters	Owena R.	R. Ogbese
pH	7.69^b (0.51)	7.12^a (0.40)
TDS (ppm)	102.00^b (0.21)	72.00^a (0.21)
DO (ppm)	3.10^a (0.07)	3.20^a (0.11)
Conductivity (µ)	183.00^b (0.28)	145.00^a (23.60)
Temperature (˚C)	24.10^a (0.14)	24.30^a (0.16)
BOD (ppm)	0.80^a (0.08)	0.70^a (0.07)

Means in column with similar superscript are not significantly different (P>0.05).

Tab. 3: The correlation matrix of the shell dimension, condition factor and the physico-chemical parameters of Owena Reservoir and River Ogbese.

River Ogbese										
parameters	**Length (cm)**	**Width (cm)**	**Height (cm)**	**Weight (g)**	**Condition Factor**	**pH**	**TDS**	**DO**	**Conductivity (µ)**	**Temp. (˚C)**
Length (cm)	1.00									
Width (cm)	1.00	1.00								
Height (cm)	-0.98	-0.98	1.00							
Weight (g)	0.98	0.99	-0.94	1.00						
Condition Factor	1.00	1.00	-0.98	0.99	1.00					
pH	0.99	1.00	-0.96	1.00	1.00	1.00				
TDS (ppm)	0.99	0.99	-0.90	0.96	0.99	0.98	1.00			
DO (ppm)	-0.99	-0.98	1.00	-0.94	-0.98	-0.96	-1.00	1.00		
Conductivity (µ)	0.54	0.55	-0.39	0.69	0.57	0.63	0.45	-0.40	1.00	
Temp. (˚C)	-0.99	-0.99	1.00	-0.95	-0.99	-0.97	-1.00	1.00	-0.43	1.00
BOD (ppm)	-0.64	-0.63	0.76	-0.49	-0.62	-0.55	-0.72	-0.75	0.30	0.73
River Ogbese										
parameters	**Length (cm)**	**Width (cm)**	**Height (cm)**	**Weight (g)**	**Condition Factor**	**pH**	**TDS**	**DO**	**Conductivity (µ)**	**Temp. (˚C)**
Length (cm)	1.00									
Width (cm)	0.94	1.00								
Height (cm)	0.63	0.85	1.00							
Weight (g)	-0.45	-0.12	0.41	1.00						
Condition factor	-0.64	-0.34	0.19	0.97	1.00					
pH	-0.67	-0.38	0.15	0.96	1.00	1.00				
TDS (ppm)	0.39	0.05	-0.48	-1.00	-0.95	-0.94	1.00			
DO (ppm)	-0.66	-0.36	0.17	0.97	1.00	1.00	-0.95	1.00		
Conductivity (µ)	0.36	0.02	-0.50	-0.99	-0.94	-0.93	1.00	-0.94	1.00	
Temp. (^oC)	-0.50	-0.18	0.36	1.00	0.98	0.98	-0.99	0.98	-0.99	1.00
BOD (ppm)	0.46	0.13	-0.40	-1.00	-0.98	-0.97	1.00	-0.97	0.99	-1.00

The sediment composition and flow rate

The Sediment composition analysis revealed that samples from Owena Reservoir are significantly different (P<0.05) from that of River Ogbese as shown in Table 4. Owena Reservoir had pH, P, Ca, Mg and organic matter of 6.66, 3.34, 4.40, 1.2 and 0.66 respectively while samples from River Ogbese showed pH, P, Ca, Mg and organic matter of 5.96, 78.79, 3.60, 1.90 and 0.17 respectively as shown in Table 5. A negative relationship exist between the sediment pH and some shell dimensions such as length (r = -0.72), width (r = -0.73) and weight (r = -0.84) whereas in River Ogbese, pH was negatively correlated with height (r = -0.20) and weight (r = -0.98). The sediment texture for Owena Reservoir had sand, clay and silt of 70%, 22% and 8% respectively while River Ogbese had sand, clay and silt of 74%, 18% and 8% respectively. The Owena Reservoir flows at the rate of 0.22 m/s and River Ogbese at 0.26 m/s.

Tab. 4: Mean (SD) sediment composition of Owena Reservoir and River Ogbese.

Parameter	Owena R.	R. Ogbese	T stat	T crit	*P*
pH	6.66[b] (0.02)	5.96[a] (0.02)	85.73	2.78	0.00
Phosphorus	3.34[a] (0.01)	78.79[b] (0.55)	-9240.7	2.78	0.00
Calcium	4.40[b] (0.03)	3.60[a] (0.02)	97.98	2.78	0.00
Magnesium	1.20[a] (0.01)	1.90[b] (0.01)	-10.34	2.78	0.00
Organic matter	0.66[b] (0.01)	0.17[a] (0.01)	60.01	2.78	0.00

Means in column with similar superscript are not significantly different (P>0.05).

Discussion

Previous work on habitat studies of the species *E. elliptica* are scanty, therefore, outcomes on the habitat studies of the species were compared with data of other freshwater mussels belonging to the order unionoida with reference to Akele *et al.* (2015a) in the absence of literature on growth parameters of *E. elliptica* compared with published studies on freshwater clam *Galatea paradoxa* and marine oyster in genus crassostrea. Also, Oyewole *et al.* (2013) in their study on length-weight relationship of freshwater mussel (*E. elliptica*) compared their result with studies on fish due to the same reason. The maximum length of mussel found in both water bodies could be many factors such as availability of food, environmental condition (human activities, flow rate, sediment type), among other factors. Akele *et al*. (2015a) obtained a similar values (length: 1.7 to 13.8 cm) in Pendjari River, Benin, West-Africa. This agrees with the observation of Zuiganov *et al.* (1994) who stated that freshwater pearl mussels, *Margaritifera margaritifera* develop very slowly and can live for more than 100 years, reaching 12 to 15cms in length. This proves that the null hypothesis stating that there were no significant effect of the physicochemical parameters on the shell dimension should be rejected. The life span and maximum size reached are variables among populations that depend on environmental conditions. The study further revealed that the freshwater mussel found in River Ogbese and Owena Reservoir exhibit positive allometric growth (b = 3.02 and 3.01 respectively). This is an indication that the volume of the body enclosed by its shell is not proportional to its height. Oyewole *et al*. (2013) obtained allometric growth pattern in *E. elliptica* collected from River Ogbese, Nigeria. This agrees with the pattern of growth obtained in this study, although, mussels are known to have a constant shape regardless of size. The results reveal no significant differences (P>0.05) in the mussel shell length–weight ratio between the water bodies. Lajtner *et al.* (2004) examined shell morphometrics in three sites of different sediments types, depth and physical and chemical conditions. Their analysis showed that the shells differed significantly among all three sites. Mussel shell growth and shape are influenced by biotic (endogenous /physiological) and abiotic (exogenous/environmental) factors (Satit *et al.* 2008). In this study, the sediment composition has effect on the shell dimension and conditions factor of the mussels, hence the need to accept the second alternative hypothesis. Alunno-Bruscia *et al*. (2001) identified food availability and population density as important determinants of shell morphometry and shell length–body mass ratio in Mytilus edulis. The condition factor showed that mussels from both water bodies were healthy even though the K value obtained in River Ogbese (K = 8.34) was less than Owena Reservoir (K = 16.33). According to Fresh *et al.* (2005), physical habitat alteration that affect temperature, current flow, food availability and related factors are thought to have a major impact on the growth and health of fish. Owena being a reservoir has less alteration as a result of activities. This could have resulted in a heavier mussel than in River Ogbese; a river that experience uncontrolled human activities. A variety of environmental factors are known to influence shell morphology and the relative body proportions of many bivalve species (Gaspar *et al*., 2002). Such include the type and quality of phytoplankton as a food of the mussels (Kovitvadhi *et al.,* 2006; Alunno-Bruscia *et al.,* 2001), water quality, depth, currents and turbulence, type of sediment (Blay, 1989), type of bottom (Claxton *et al.,* 1998) and wave exposure (Akester and Martel, 2000). Shell shape varies also among the families reflecting partially their phylogenetic history and the habitat in which they are living. Byssally attached mussels are often much thinner shelled than those species living buried in cobble and gravel substrates. Many of the species of the Unioniformes families have heavy shells with a variety of surface sculpture that aid in stability in the substrate (Bogan, 2008).

The higher values of pH and calcium obtained in Owena Reservoir could explain the reason why mussels from the reservoir are bigger and healthier than the river. The result showed that the waters are alkaline, rich in calcium and well oxygenated agrees with Lajtner *et al.* (2004) who studied the shell morphology of zebra mussel in three water bodies. Claudi and Mackie (1994) reported that the most important environmental factors for the survival and growth of zebra mussels were temperature, calcium levels and pH. Furthermore, the result revealed a significant effect of some physicochemical parameters on the shell dimension and condition factor in both water bodies. This agrees with the first alternative hypothesis of the study. The percentage of clay (22%) composition of Owena Reservoir is higher than that of River Ogbese (18%). Barry *et al.* (2004) however, stated that dense mussel beds typically had low percent of sand, fines and high percent gravel and cobble. This disagrees with the result from this study, Strayer and Ralley (1993) observed that physical variables traditionally thought to regulate distribution (e.g., sediment grain size, current speed) have almost no explanatory basis whereas sediment stability during floods appears satisfactorily in explaining the presence of local patchiness of unionoid communities. Mussels are filter feeder and inadequate food, low interstitial dissolved oxygen, and crayfish predation may limit populations.

Conclusion

Although the IUCN red list of threatened species did not list that *E. elliptica* among the species of mussels that are endangered however, it was observed during the study that it took several efforts before getting the required sample size. Hence data generated could effective facilitate more effective conservation measure which will promote the growth and abundance of *E. elliptica* in both studied areas. The present study will provide baseline data for future work on some ecological studies of mussel in the country. Comprehensive studies focusing on ecology-ical and habitat requirement of native and non-native mussel species are needed to better understand the conservative measure requirement.

References

- ✓ Akele G.D., Agadjihouede H., Mensah G.A. and Laleye P.A. (2015a) Population dynamics of freshwater oyster *Etheria elliptica* (Bivalvia: Etheriidae) in the Pendjari River (Benin-Western Africa). Knowledge and Management of Aquatic Ecosystem, 06: 416-423.
- ✓ Akele G.D., Ahouansou M.S., Chikou A., Mensah G.A. and Laleye P.A. (2015b) Traditional Exploitation of edible freshwater oyster *Etheria elliptica* (Lamarck, 1807) in the Pendjari River (Benin- West Africa); Assessment of income, human pressure and options for management. International Journal of Biology Chemical Science, 9: 246-258.
- ✓ Akester R.J. and Martel A.L. (2000) Shell shape, dysodont tooth morphology, and hinge-ligament thickness in the bay mussel *Mytilus trossulus* correlate with wave exposure. Canadian Journal of Zoology, 78: 240-253.
- ✓ Allan J.D. and Flecker A.S. (1993) Biodiversity conservation in running waters: Identifying the Major factors that threaten destruction of riverine species and ecosystems. BioScience, 43:32-43.
- ✓ Alunno-Bruscia M., Bourget E. and Frechette M. (2001) Shell allometry and length–mass–density relationship for *Mytilus edulis* in an experimental food-regulated situation. Marine Ecology Program Series, 219:177-188.
- ✓ APHA (American Public Health Association). (1998) Standard methods for the Examination of Water and Wastewater. New York: American Public Health, Association 292.
- ✓ Barry P.B., Riva-Murray K. and George E.S.(2004) Effects of environmental and spatial features on mussel populations and communities in a North American River. Walkerana, 14: 1-32.
- ✓ Blay J. (1989) Morphometric length–weight relationships and length distributions of five populations of the freshwater bivalve *Aspatharia sinuate* (Unionacea, Mutelidae) in Nigeria. Malacologia, 30: 365-372.
- ✓ Bogan A.E. (2008) Global diversity of freshwater mussels (Mollusca, Bivalvia) in freshwater. Hydrobiologia, 595:139-147.
- ✓ Bogan A.E. and Roe K.J. (2008) Freshwater bivalve (Unioniformes) diversity, systematics and evolution: status and future directions. Journal of the North American Benthological Society, 27: 349-369.
- ✓ Bray R.H. and Kurtz L.T. (1945) Determination of total organic and available forms of phosphorus in soil. Soil Science, 59: 39-45.
- ✓ Byers S., Mills E. and Stewart P. (1978): Comparison of

methods of determing organic carbon in marine sediment, with suggesting for a standard method. Hydrobiologia, 58: 43-47.

- Claudi R. and Mackie G.L. 1994. Practical manual for zebra mussel monitoring and control. London: Lewis Publishers.
- Claxton W.T., Wilson A.B., Mackie G.L. and Boulding E.G. (1998) A genetic and morphological comparison of shallow and deep-water populations of the introduced dreissenid bivalve *Dreissena bugensis*. Canadian Journal of Zoology, 76: 1269-1276.
- Dillon R.T. (2000) The Ecology of Freshwater Mussels. United Kingdom: Cambridge University Press 12.
- Fapohunda O.O. and Godstates R. (2007): Biometry and composition of fish species in Owena Reservoir, Ondo state, Nigeria. Journal of Central European Agriculture, 8: 99-104.
- Fresh K.L., Casillas E., Johnson L.L. and Bottom D.L. (2005) Role of the estuary in the recovery of Colombia River Basin. Evaluation of the effects of selected factors on salmonid population viability. NOAA Technical Report 105.
- Gaspar M.B., Santos M.N., Vasconcelos P. and Monteiro C.C. (2002) Shell morphometric relationships of the most common bivalve species (Mollusca: Bivalvia) of the Algarve coast (southern Portugal). Hydrobiologia, 477: 73-80.
- Graf D. and Cummings K. (2007) Review of the systematic and global diversity of freshwater mussel species (Bivalves: Unionoida). Journal of Molluscan Studies, 73: 291-314.
- Kovitvadhi S, Kovitvadhi U, Sawangwong P, Thongpan A and Machado J. (2006) Optimization of diet and culture environment for larvae and juvenile freshwater pearl mussels, *Hyriopsis* (Limnoscapha) *myersiana* (Lea, 1856). Invertebrate Reproductive Development, 49:61-70.
- Lajtner J., Marus¡ic´ Z., Klobuc¡ar G.I.V., Maguire I. and Erben R. (2004) Comparative shell morphology of the zebra mussel, Dreissena polymorpha in the Drava River (Croatia). Biologia, 59: 595-600.
- Lydeard C., Cowie R.H., Ponder W.F., Bogan A.E., Bouchet P., Clark S.A., Cummings K.W., Frest T.J., Gargominy O. and Herbert D.G. (2004) The global decline of non marine mussels. BioScience, 54: 321-330.
- Michaud J.P. and Wierenga M. (2005) Estimating discharge and stream flows; a guide for sand and gravel operators. Washington State Department of Ecology 05-10-070:1-37
- Öktener A. (2004) A preliminary research on Mollusca species of some freshwaters of Sinop and Bafra. G. U. Journal of Science, 17: 21-30.
- Olawusi-Peters O.O., Ayo-Olalusi C.I. and Adeyemi T.V. (2014) Bioaccumulation of some trace element (Zn, Fe, Pb and Cu) in the gills and tissue of *Clarias gariepinus* and *Oreochromis niloticus* in River Ogbese, Ondo state, Nigeria. Journal of Environmental chemistry and Ecotoxicology, 6: 13-19.
- Oyewole O.O., Aboderin O.O., Aluko O.J. and Adeyemo J.O. (2013) Length-Weight relationship of freshwater mussel (*Etheria elliptica*) from River Ogbese, Nigeria. Nigerian Journal of Fisheries, 10: 627-631.
- Pauly D. (1983) Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper 234.
- Pilsbry H.A. and Bequaert J. (1927) The aquatic mollusks of the Belgium Congo; with a geographical and ecological account of Congo malacology. Article II. Bulletin of the American Museum of Natural History 53: 69-601.
- Ricker W.E. (1975) Computation and interpretation of biological statistics of fish population. Bulletin of Fisheries Research Board of Canada, 191:1-382.
- Satit K., Uthaiwan K., Pichan S., Premjai T. and Jorge M. (2008) Morphometric relationship of weight and size of cultured freshwater pearl mussel, Hyriopsis (Limnoscapha) myersiana under laboratory conditions and earthen pond phases. Aquaculture International, 6:21-34.
- Sheldrick B.H. and Wang C. (1993) Particles size distribution, Soil sampling and Methods of Analysis. Canadian Society of Soil Science, 499-511.
- Strayer D.L. and Ralley J. (1993) Micro habitat use by an assemblage of stream-dwelling unionaceans (Bivalvia) including two rare species off Alasmidonta. Journal of the North American Benthological Society, 12**:** 247-258.
- USEPA (2004) Method 9045D soil and waste pH in test method for evaluating solid waste. SW846, Revision 4.
- Van Damme D. (2011) *Etheria elliptica*. The IUCN Red List of Threatened Species. www.iucnredlist.org
- Vaughn C.C. (2010) Biodiversity losses and ecosystem function in freshwaters: emerging conclusions and research directions. BioScience, 60: 25-35.
- Watters W. I. (1999): Notes on the Natural host of Freshwater Mussels. Bulletin of the United States Bureau of Fisheries 32: 101-116.
- Williams J., Young M.R., Hastie L.C., Gaywood M. and Boon P.J. (1993) The status of the Freshwater pearl mussel *Margaritifera margaritifera* in Scotland. Aquatic Conservation: Marine and Freshwater Ecosystems, 10: 197-208.
- Yonge C.M. (1962) On the Primitive Significance of the byssus in the Bivalvia and its effects in Evolution. Journal of the Marine Biology, 42: 113-125.
- Zuiganov V., Zotin A., Nezlin L. and Tretiakov V. (1994) The freshwater pearl mussels and their relationships with salmonid fish. VNIRO: Russian Federal Institute of Fisheries and Oceanography, 104.