sciendo
DOI: 10.2478/eces-2022-0013 ECOL CHEM ENG S. 2022;29(2):169-181

Charles Obinwanne OKOYE[1,2*], Daniel ECHUDE[1], Chike Obinna CHIEJINA[1]
Felix Atawal ANDONG[1], Kingsley Chukwuebuka OKOYE[1], Samuel Ejike UGWUJA[1]
Chigozie Damian EZEONYEJIAKU[3] and Joseph EYO[1*]

PHYSICOCHEMICAL CHANGES AND ABUNDANCE OF FRESHWATER SNAILS IN ANAMBRA RIVER (NIGERIA) DURING THE RAINY SEASON

Abstract: Rapid diversification is a way of responding to environmental change for freshwater organisms. This work examined the physicochemical changes and abundance of freshwater snails in Anambra River (Nigeria) during the rainy season. Field studies were conducted fortnightly from June to August 2019 at three stations of the river namely: Otuocha (station I), Otunsugbe (station II), and Ukwubili (station III) about 8.35 kilometers apart from each other. A scoop net of 2 cm mesh size and handpicking was used to sample freshwater snails randomly and water samples were taken to the laboratory for physicochemical analysis. A total of 896 freshwater snails belonging to 6 species (*Afropomus balanoidea*, *Pomacea maculata*, *Lymnea stagnalis*, *Lanistes ovum*, *Pila wernei*, and *Saulea vitrea*) were collected. *Pomacea maculata* was the most dominant species with a relative abundance of 45.87 %, while *Saulea vitrea* was the least dominant species with a relative abundance of 2.34 %. There was a significant negative correlation between dissolved oxygen and *Pomacea maculate* ($r = -0.877$, $p = 0.002$) and a positive correlation between dissolved oxygen and *Stagnalis lymnea* ($r = 0.840$, $p = 0.005$). The diversity of species was highest at Otuocha (1.171) followed by Ukwubili (1.133) and Otunsugbe (0.856) with average mean temperatures of (23.1 ±0.1) °C, (27.30 ±0.00) °C, and (26.80 ±0.03) °C respectively. The distribution of freshwater snails was influenced by the physicochemical variability of Anambra River during the rainy season. Therefore, further studies for a longer time and different seasons to examine the impact of physicochemical changes on the snail distribution are encouraged.

Keywords: freshwater snail, biodiversity, physicochemical changes, rainy season, Anambra River, Nigeria

Introduction

Freshwater snails are highly diverse and their ecological adaptations range from morphological characteristics to specific physiological and metabolic reactions coupled with their variability and ecological relevance [1]. The ecology of snails is affected by various environmental factors, including physical factors such as temperature, water current, turbidity, transparency and distribution of suspended solids and chemical factors such as ion concentration and water dissolution, and biological factors such as food availability, competition, and predator-prey interactions [2]. Snail distribution was found to be limited in most habitats due to climatic factors such as rain and drought. For this reason,

[1] Department of Zoology and Environmental Biology, University of Nigeria, Nsukka, 410001 Nigeria, ORCID: COO 0000-0002-6205-4886
[2] Biofuels Institute, School of Environment and Safety Engineering, Jiangsu University, Zhenjiang, 212013 China
[3] Bioconservation Unit, Department of Zoology, Nnamdi Azikiwe University, Awka, 5025 Nigeria
[*] Corresponding authors: charles.okoye@unn.edu.ng; joseph.eyo@unn.edu.ng

species may not colonise some habitats while they may be abundant in some other similar habitats [3]. Therefore, it is very important to examine environmental factors influencing the distribution of snails in the freshwater ecosystem [4]. With 12 percent of the population deemed vulnerable in West Africa [5], freshwater snails are among the most endangered groups of aquatic organisms. This makes it pertinent to look at the impacts of climate on the snail population. Over the past 80 years, there has been a dramatic decline in the abundance and variety of snails, especially species that inhabit streams and rivers. Studies show that approximately 60 species of freshwater snails are thought to be extinct and the disappearance of freshwater snails started in the early twentieth century [6].

The rapid decline in the diversity of freshwater snails is due to a variety of human destruction of their natural habitats. Destruction of wetlands and other improvements to channels, siltation, and industrial and agricultural emissions have all destroyed the river ecosystems on which most species depend. As a result, habitat diversity has declined dramatically. This decline has been particularly pronounced in Africa, where these animals are most diverse [7]. The continued loss and depletion of freshwater snails is a testament to the fact that, despite significant changes in the quality of water over the past 25 years, more work remains to be done to prevent species extinction. Freshwater snail studies in East Nigeria are approximately ten years old [8]. Based on this evidence, few studies have investigated the effects of environmental changes on populations of freshwater snails. However, one of the objectives of freshwater ecology is to understand how communities of freshwater species are structured in space and time and how physicochemical changes of the river affect their distribution [9]. The value of freshwater snails in the aquatic food web lies in their ecological role and in maintaining the quality of water as many species are excellent indicators of water quality [7]. The study evaluated the physicochemical changes and abundance of freshwater snails in Otuocha, Otu Nsugbe and Ukwubili sections of Anambra River *during the rainy season.*

Materials and methods

Study area

Anambra river is River Niger’s largest tributary below Lokoja and is often considered to be a component of the lower lowlands of Niger. The river flows into the Niger river for 210 kilometers and has its source from Ankpa hills where it flows through a narrow trough in a southern direction that gradually spreads as it runs down [10]. The river has a large basin of 14,010 km^2 which is located between latitude 6°10’ and 7°20’, longitude 6°35’ and 7°40’, east of the river Niger (Fig. 1). Anambra falls under the *savanna* vegetation type with two climatic seasons: rainy season (April-October) and dry season (November-March). The rainy season is characterised by heavy peak from (June-August) accompanied by thunderstorms, heavy flooding, soil leaching, extensive drainage, ground infiltration, and percolation [11]. The area’s annual rainfall is more than 2000 mm. The seasonal variations throughout the year and the relative annual rainfall account for the fluctuating water level as well as the river-dependent human [12]. The temperature ranges between 22 °C and 26 °C during the rainy season with high relative humidity. Agriculture and fishing are the main occupations of the inhabitants, and these major economic practices are oriented towards the two seasons of the year [13, 14].

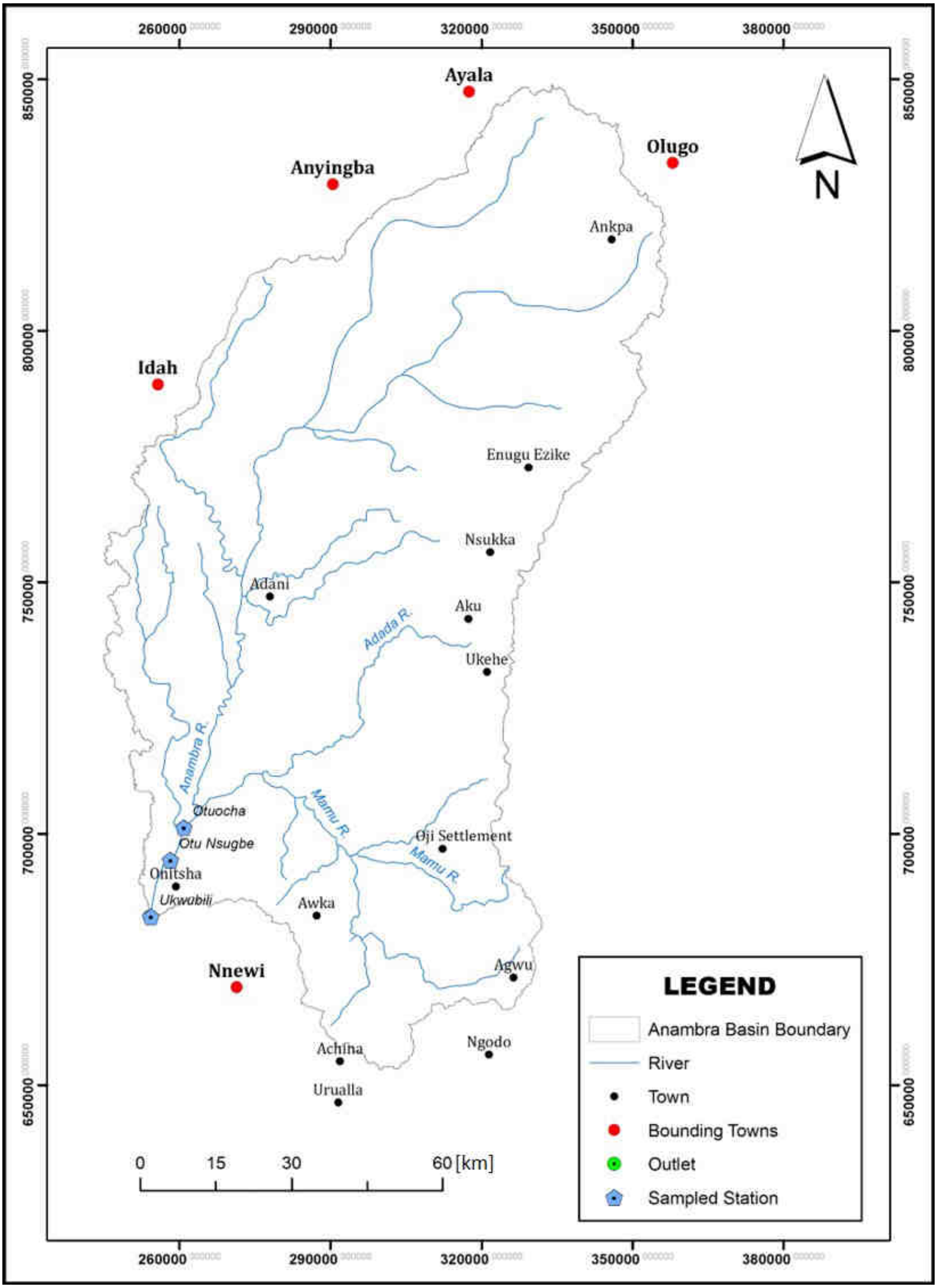

Fig. 1. Map of Anambra River showing the study stations

Study design

A reconnaissance survey was carried out on the river using a global positioning system (GPS). Three stations; I = Otuocha (latitude 6°20’41.35” N and longitude 6°50’40.37” E), II = Otu Nsugbe (latitude 6°16’49.51” N and longitude 6°48’52.30” E) and III = Ukwubili (latitude 6°27’35.24” N and longitude 6°54’30.45” E) separated by a distance of approximately 8.35 km each were selected for sampling and collection of data based on the extent of human activities. Besides, the top, middle, and bottom of each cross-section of the lotic water column were sampled. Snail sampling and water collection were done fortnightly for three months during the rainy season. Water samples were collected at the shores using acid-washed plastic containers dipped 6 cm - 10 cm below the surface film of the water body and then stored at 4 °C until further laboratory analyses [15].

The pH and dissolved oxygen (DO) were measured in the field using conventional techniques. In a nutshell, the pH probe (Hanna Field pH meter, Model PHS 25) was put (2 m) into the river, allowed to stabilise, and then recorded. The DO of the river was determined using Winkler’s technique and protocols. The biochemical oxygen demand (BOD) was determined using iodometric technique while other physicochemical properties, including turbidity, alkalinity, electrical conductivity (*EC*), total suspended solids (TSS), total dissolved solids (TDS), phosphate, and nitrate were analysed in the laboratory following analytical methods recommended by APHA (American Public Health Association) [15].

Snails were sampled at the three stations with a long-handled scoop net of 2 cm mesh size and handpicking at the river banks and in the hyporheic zone since the depth varies within sampling stations for lotic ecosystems [8, 16]. Specimens were collected in pre-labelled plastic containers containing humid or rotting leaves, covered with perforated lids, and transported to the Department of Zoology and Environmental Biology, Nsukka University. Snails were identified using relevant identification keys by Thompson [17] and Brown [18]. The samples were grouped based on their shells’ size, colour, shape, number of whorls, number of tentacles, and position of the eyes as described by Verma [19] and Brown and Wright [20]. Control samples were obtained from the zoological museum of the Department of Zoology and Environmental Biology, University of Nigeria Nsukka. Further authentication was done with the help of Freshwater Mollusk Conservation Society (FMCS), USA.

Statistical analysis

Data were analysed using Statistical Product and Service Solutions (SPSS) version 20.0 (IBM Corporation, Armonk, USA). Analysis of variance (ANOVA) was used to test the level of significance, $P < 0.05$. The relationship between physicochemical parameters and snail species was evaluated using Pearson’s correlation coefficient. Estimation of species abundance, S [%] and diversity using Shannon-Weiner diversity index, H, which accounts for both abundance, evenness and richness of the species present within the three stations were calculated using the formulas [13, 21]:

$$S = \frac{I_{si}}{\sum N_{si}} \cdot 100 \quad (1)$$

$$H = -\sum P_i \ln P_i \quad (2)$$

where I_{si} is the number of individual species, N_{si} is the total number of species, and P_i is the relative abundance of each species.

Results

Snail assemblage structure

A total of 896 gastropod snails belonging to 6 species (*Afropomus balanoidea*, *Lanistes ovum*, *Pila wernei*, *Pomacea maculate* and *Saulea vitrea*, *Lymnea stagnalis*) were recorded during the study (Fig. 2). *Pila wernei* was the most abundant species (58.80 %) at Otuocha. *Pila wernei* and *Pomacea maculata* recorded the highest and equal percentage composition of 48 (47.52 %) at Otunsugbe. *Pomacea maculata* recorded the highest relative abundance of 66.80 % at Ukwubili. All species were encountered in Ukwubili station. *Saulea vitrea* was not collected at Otuocha and Otunsugbe respectively, and *Afropomus balanoidea* and *Lanistes ovum* were not recorded at Otunsugbe.

The Shannon-Wiener diversity index, *H*, was highest at Otuocha (1.1710) followed by Ukwubili (1.1330) and Otunsugbe (0.8559) (Fig. 3).

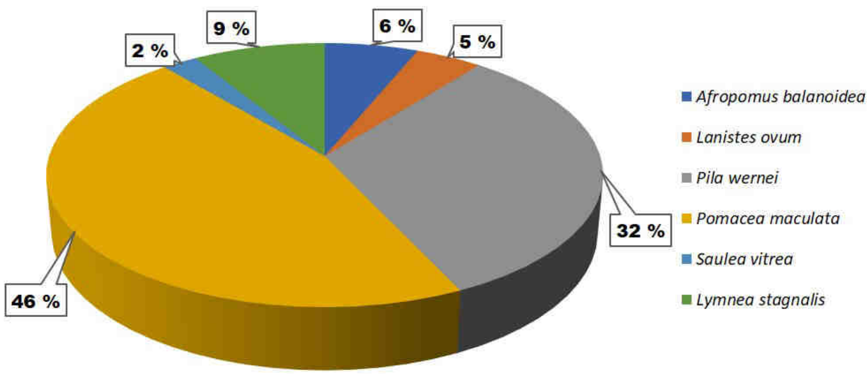

Fig. 2. Relative abundance of snails in Anambra River

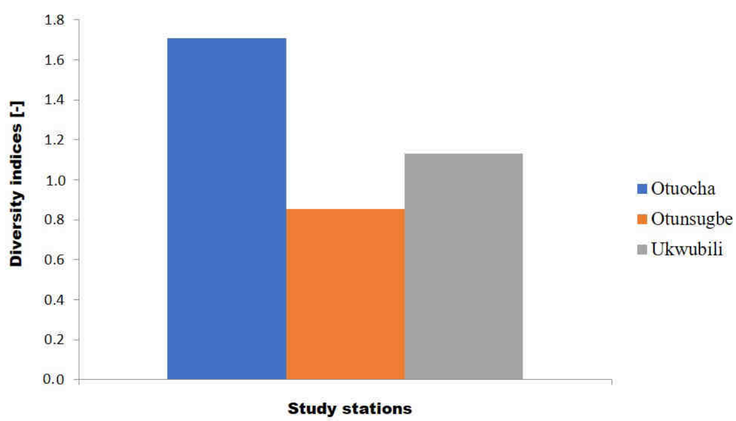

Fig. 3. Diversity of snails in Anambra River

Monthly variations in physicochemical parameters

There was no monthly significant ($P > 0.05$) variation in the mean of temperature, pH, turbidity, hardness, BOD, TSS, and nitrate at Otuocha. Electrical conductivity, *EC*, and dissolved oxygen, DO, were recorded higher in June and July respectively, while and TDS were observed higher in August, with significant ($P < 0.05$) differences respectively. Temperature, turbidity, hardness, BOD, TSS, and nitrate did not show any significant ($P > 0.05$) variation at Otunsugbe. The mean pH was highest ($P < 0.05$) in July, while *EC*, DO were highest in August ($P < 0.05$). Temperature, turbidity, hardness, BOD, phosphate, and TSS respectively showed significant ($P < 0.05$) differences between the months, while other parameters differed but not significantly ($P > 0.05$) in Ukwubili (Table 1).

Table 1

Monthly variations of physicochemical parameters of the three stations

Locations	**Months**	**Temp. [°C]**	**pH [-]**	**Turb. [NTU]**	**Hardness [mg/L]**	***EC* [μS/cm]**
Otuocha	June	23.50 ±0.29[a]	8.30 ±0.06[a]	30.10 ±0.05[a]	7.50 ±0.28[a]	9.00 ±0.00[b]
	July	26.0 ±1.1[a]	8.20 ±0.17[a]	30.0 ±1.4[a]	8.00 ±0.00[a]	8.75 ±0.14[b]
	August	26.0 ±1.1[a]	8.00 ±0.17[a]	30.05 ±0.02[a]	7.25 ±0.72[a]	8.25 ± 0.14[a]
Otunsugbe	June	27.50 ±0.29[a]	7.85 ±0.03[a]	42.5 ±1.1[a]	8.05 ±0.03[a]	9.30 ±0.17[a]
	July	28.00 ±0.00[a]	8.40 ±0.12[b]	45.0 ±1.4[a]	8.75 ±0.14[a]	9.60 ±0.06[a]
	August	26.50 ±0.86[a]	8.30 ±0.12[b]	46.25 ±0.14[a]	8.10 ±0.05[a]	10.7 ±1.0[b]
Ukwubili	June	28.50 ±0.28[b]	8.18 ±0.34[a]	31.00 ±0.28[b]	6.25 ±0.14[a]	8.25 ±0.14[a]
	July	28.00 ±0.00[b]	8.05 ±0.38[a]	30.75 ±0.14[ab]	6.00 ±0.00[a]	8.75 ±0.14[a]
	August	27.00 ±0.00[a]	7.80 ±0.00[a]	30.25 ±0.14[a]	6.75 ±0.14[b]	8.50 ±0.13[a]
FMWR		< 35	6.5-8.5	-	-	-

Locations	**DO [mg/L]**	**BOD [mg/L]**	**Phosphate [mg/L]**	**TDS [mg/L]**	**TSS [mg/L]**	**Nitrate [mg/L]**
Otuocha	5.10 ±0.06[a]	7.0 ±2.6[a]	16.25 ±0.14[b]	0.03 ±0.00[ab]	4.00 ±0.00[a]	4.11 ±0.03[a]
	6.25 ±0.14[b]	8.5 ±4.3[a]	14.25 ±0.43[a]	0.02 ±0.00[a]	4.50 ±0.28[a]	4.25 ±0.14[a]
	5.83 ±0.17[b]	6.5 ±1.4[a]	17.2 ±0.7[b]	0.04 ±0.00[b]	4.60 ±0.06[a]	5.10 ±0.64[a]
Otunsugbe	4.7 ±1.3[a]	8.2 ±7.6[a]	19.25 ±0.72[b]	0.26 ±0.14[b]	10.25 ±0.14[a]	4.50 ±0.00[a]
	5.5 ±1.9[b]	5.2 ±1.6[a]	19.50 ±0.00[a]	0.16 ±0.08[a]	11.25 ±0.43[a]	5.0 ±1.1[a]
	5.25 ±0.43[b]	6.50 ±0.28[a]	22.25 ±0.43[b]	0.23 ±0.04[ab]	12.25 ±0.14[a]	3.25 ±0.43[a]
Ukwubili	5.75 ±0.75[a]	4.50 ±0.28[a]	11.00 ±0.58[a]	0.51 ±0.28[a]	6.25 ±0.14[c]	3.25 ±0.14[a]
	5.7 ±1.3[a]	4.50 ±0.28[ab]	15.75 ±0.72[b]	1.00 ±0.00[a]	5.25 ±0.43[b]	3.80 ±0.17[a]
	5.5 ±1.4[a]	4.0 ±2.3[b]	11.75 ±0.43[a]	1.00 ±0.28[a]	4.25 ±0.14[a]	4.15 ±0.66[a]
FMWR	7.5	8.3	<13.5	-	-	50

Values with the different superscript within a column are significantly different; Temp. - Temperature, Turb. - Turbidity, *EC* - Electrical conductivity, DO - Dissolved oxygen, BOD - Biological oxygen demand, TDS - Total dissolved solids, TSS - Total suspended solids, FMWR - Federal Ministry of Water Resources

Relationship between physicochemical parameters and snail species

At Otuocha, there was significant negative and positive correlation between the dissolved oxygen and *Pomacea maculata* ($r = -0.877$, $p = 0.002$) and *Lymnea stagnalis* ($r = 0.840$, $p = 0.005$) respectively. Biological oxygen demand showed a significant positive correlation with *Pomacea maculata* ($r = 0.757$, $p = 0.018$) and positive correlation with *Pila wernei* ($r = 0.850$, $p = 0.004$). Phosphate had a positive and negative correlation with *Lymnea stagnalis* ($r = -0.833$, $p = 0.005$) and *Lanistes ovum* ($r = -0.856$, $p = 0.003$) respectively (Table 2).

Table 2
Correlation matrix showing the relationship between the physicochemical parameters and snail species collected at Otuocha, Anambra River

Parameter	Temp. [°C]	pH [-]	Turb. [NTU]	Hardness [mg/L]	*EC* [μS/cm]	DO [mg/L]	BOD [mg/L]	Phosphate [mg/L]
Temp.	1							
pH	–0.850**	1						
Turb.	0.489	–0.578	1					
Hardness	0.536	–0.311	–0.040	1				
EC	–0.438	0.458	–0.329	0.472	1			
DO	0.801**	–0.518	0.198	0.378	–0.387	1		
BOD	–0.391	0.496	–0.128	0.272	0.580	–0.627	1	
Phosphate	–0.471	0.147	–0.220	–0.75*	–0.428	–0.583	–0043	1
TDS	0.192	–0.532	–0.200	0.139	–0.139	–0.125	–0.198	0.438
TSS	0.200	–0.013	–0.684*	0.121	–0.287	0.473	–0.425	0.083
Nitrate	0.733*	–0.874**	0.154	0.428	–0.355	0.385	–0.349	0.021
Ab	0.242	0.189	–0.185	0.412	0.217	0.678*	–0.200	–0.782*
Pm	–0.456	0.204	0.016	–0.078	0.322	–0.877**	0.757*	0.459
Ls	0.620	–0.157	0.116	0.567	–0.027	0.840**	–0.180	–0.833**
Lo	0.528	–0.175	0.420	0.373	0.000	0.750*	–0.250	–0.856**
Pw	–0.205	0.149	0.247	0.373	0.649	–0.569	0.850**	–0.209
Sv	C	C	C	C	C	C	C	C

Parameter	TDS [mg/L]	TSS [mg/L]	Nitrate [mg/L]	Ab	Pm	Ls	Lo	Pw	Sv
Temp.									
pH									
Turb.									
Hardness									
EC									
DO									
BOD									
Phosphate									
TDS	1								
TSS	0.304	1							
Nitrate	0.807**	0.326	1						
Ab	–0.585	0.365	–0.267	1					
Pm	0.284	–0.541	–0.060	–0.778*	1				
Ls	–0.484	0.302	–0.036	0.884**	–0.731*	1			
Lo	–0.653	–0.059	–0.141	0.814**	–0.705*	0.895**	1		
Pw	–0.086	–0.740*	–0.166	–0.298	0.766*	–0.222	–0.123	1	
Sv	C	C	C	C	C	C	C	C	C

**Correlation is highly significant at $p < 0.01$ (2-tailed). *Correlation is significant at $p < 0.05$ (2-tailed). C = Cannot be computed because at least one of the variables is constant. Ab - *Afropomus balanoidea*, Pm - *Pomacea maculata*, Ls - *Lymnea stagnalis*, Lo - *Lanistes ovum*, Pw - *Pila wernei* and Sv - *Saulea vitrea*. For abbreviations see Tables 1 and 2

At Otunsugbe, the pH recorded a significant negative correlation with *Pila wernei* (r = –0.749, p = 0.0) (Table 3). Hardness showed a positive correlation with *Pomacea maculata* (r = 0.796, p = 0.010), and negative correlations with *Lymnea stagnalis* (r = 0.986, p = 0.0001) and *Pila wernei* (r = –0.832, p = 0.005) respectively.

Table 3

Correlation matrix showing the relationship between the physicochemical parameters and snail species collected at Otunsugbe, Anambra River

Parameter	Temp. [°C]	pH [-]	Turb. [NTU]	Hardness [mg/L]	*EC* [μS/cm]	DO [mg/L]	BOD [mg/L]	Phosphate [mg/L]
Temp.	1							
pH	–0.239	1						
Turb.	–0.088	0.373	1					
Hardness	0.507	0.620	–0.046	1				
EC	–0.938**	0.546	0.247	–0.227	1			
DO	–0.384	–0.047	0.403	–0.235	0.349	1		
BOD	–0.489	0.110	0.658	–0.367	0.460	0.821**	1	
Phosphate	–0.263	0.275	0.693*	–0.305	0.294	0.000	0.560	1
TDS	–0.079	0.093	–0.035	–0.189	0.105	–0.767*	–0.514	0.276
TSS	–0.442	0.525	0.898**	–0.107	0.578	0.531	0.830**	0.745*
Nitrate	0.172	–0.199	0.168	–0.071	–0.124	0.510	0.031	–0.559
Ab	C	C	C	C	C	C	C	C
Pm	0.350	0.481	0.238	0.796*	–0.114	0.387	0.142	–0.292
Ls	0.460	0.637	–0.049	0.986**	–0.168	–0.245	–0.423	–0.367
Lo	C	C	C	C	C	C	C	C
Pw	–0.345	–0.749*	–0.447	–0.832**	0.001	0.050	0.106	0.018
Sv	C	C	C	C	C	C	C	C

Parameter	TDS [mg/L]	TSS [mg/L]	Nitrate [mg/L]	Ab	Pm	Ls	Lo	Pw	Sv
Temp.									
pH									
Turb.									
Hardness									
EC									
DO									
BOD									
Phosphate									
TDS	1								
TSS	–0.136	1							
Nitrate	–0.356	–0.037	1						
Ab	C	C	C	C					
Pm	–0.660	0.203	0.436	C	1				
Ls	–0.113	–0.124	0.164	C	0.773*	1			
Lo	C	C	C	C	C	C	C		
Pw	0.038	–0.311	–0.282	C	–0.765*	–0.863**	C	1	
Sv	C	C	C	C	C	C	C	C	C

**Correlation is highly significant at $p < 0.01$ (2-tailed). *Correlation is significant at $p < 0.05$ (2-tailed). For abbreviations see Tables 1 and 2

At Ukwubili, *Pila wernei* showed a positive significant correlation with temperature ($r = 0.8124$, $p = 0.008$) and turbidity ($r = 0.886$, $p = 0.001$). *Afropomus balanoidea* and *Pila wernei* showed positive correlations with total soluble solids ($r = 0.682$, $p = 0.043$) and ($r = 0.689$, $p = 0.040$) (Table 4).

Table 4
Correlation matrix showing the relationship between the physicochemical parameters and snail species collected at Ukwubili, Anambra River

Parameter	Temp. [°C]	pH [-]	Turb. [NTU]	Hardness [mg/L]	*EC* [µS/cm]	DO [mg/L]	BOD [mg/L]	Phosphate [mg/L]
Temp.	1							
pH	0.384	1						
Turb.	0.883**	0.156	1					
Hardness	–0.530	–0.188	–0.231	1				
EC	–0.295	–0.347	–0.046	–0.056	1			
DO	–0.491	0.166	–0.637	0.387	–0.605	1		
BOD	–0.788	–0.255	–0.486	0.703*	0.515	0.253	1	
Phosphate	–0.037	–0.202	–0.058	–0.656	0.551	–0.293	–0.011	1
TDS	–0.203	–0.065	0.161	0.481	0.483	–0.052	0.738*	0.120
TSS	0.875**	0.068	0.867**	–0.434	–0.087	–0.738*	–0.743*	–0.068
Nitrate	–0.422	–0.015	–0.561	0.058	–0.467	0.856**	0.114	0.171
Ab	0.556	–0.005	0.581	0.070	–0.280	–0.369	–0.442	–0.545
Pm	–0.240	–0.438	–0.039	0.008	0.438	–0.023	0.422	0.565
Ls	0.625	–0.123	0.588	0.000	–0.471	–0.160	–0.504	–0.482
Lo	–0.166	0.045	–0.029	0.348	0.243	–0.154	0.304	–0.279
Pw	0.812**	0.333	0.886**	–0.034	–0.406	–0.248	–0.470	–0.291
Sv	–0.408	–0.050	–0.320	0.192	0.385	0.164	0.583	0.212

Parameter	TDS [mg/L]	TSS [mg/L]	Nitrate [mg/L]	Ab	Pm	Ls	Lo	Pw	Sv
Temp.									
pH									
Turb.									
Hardness									
EC									
DO									
BOD									
Phosphate									
TDS	1								
TSS	–0.299	1							
Nitrate	–0.074	–0.648	1						
Ab	–0.240	0.682*	–0.547	1					
Pm	0.574	–0.293	0.242	–0.205	1				
Ls	–0.203	0.598	–0.293	0.778*	–0.116	1			
Lo	0.183	–0.034	–0.360	0.393	–0.099	–0.111	1		
Pw	0.136	0.689*	–0.252	0.614	–0.065	0.620	–0.027	1	
Sv	0.500	–0.526	0.120	–0.393	0.203	–0.408	0.512	–0.393	1

**Correlation is highly significant at $p < 0.01$ (2-tailed). *Correlation is significant at $p < 0.05$ (2-tailed). For abbreviations see Tables 1 and 2

Discussion

The result showed a total of 896 gastropod snails belonging to 6 species. Similarly, Duwa [22] recorded 14 species of freshwater snails in three parts of Jakara Dam, Kano State, Nigeria. Priawandiputra et al. [23] noted that precipitation during the rainy season influenced the population abundance and composition of 14 freshwater gastropod species recorded in the Gede system. Olorunniyi and Olofintoye [24] reported the coexistence of freshwater snail species namely *P. moerchi*, and *Lanites libycus*, and *B. globosus*, in six streams and a total of 4 snail species namely *P. moerchi*, *Lanites libycus*, *B. globosus*, and

Bellamyia unicolar from their study of the occurrence and distribution of freshwater snails in three communities of Ekiti State, Nigeria. The relationship between physicochemical parameters and snail species gathered at Anambra River shows both positive and negative correlations with significant differences. This is similar to the study at Atavu River, suggesting that anthropogenic activities in the river might have a negative impact leading to habitat change of freshwater snails [25]. Water physicochemical factors could reduce or otherwise increase the prevalence, abundance, and distribution of snails [26]. The importance of physicochemical parameters indicates a moderate positive relationship between gastropods and temperature, pH, dissolved oxygen, and total alkalinity [27]. In line with our results, Olatayo [28] evaluated pollution levels by human activities on water physicochemical parameters in Ilaje, Nigeria, and the condition of the aquatic ecosystem where the average temperature was 29.75 °C with a mean pH of 6.7, suggesting that there was no significant difference between all the physicochemical parameters and the results obtained in this study were within the acceptable limits (temperature < 35 °C and pH = 8.5) by the Federal Ministry of Water Resources [29]. Agi and Okwuosa [30] recorded a high degree of tolerance and adaptation of freshwater snails within a reasonable range of physicochemical fluctuations.

The water temperature in the present study favoured the distribution of snails. El-Zeiny et al. [26] noted that snails recorded high abundance because of their tolerance to a relatively high-temperature. The pH is an important parameter that affects snail distribution and high pH is associated with high levels of calcium, and these habitats are usually associated with draining streams of calcareous catchments [31]. Chang [32] reported that increased pH tends to be related to increased use of alkaline detergents in residential areas and wastewater alkaline materials in industrial areas. A pH higher than 7 but lower than 8.5 was reported by Abowei [33] to be ideal for biological productivity, while pH lower than 4 was detrimental to water life. Both the water temperature and pH were within the recommended limits of < 35 °C and 6.5-8.5 respectively by the Federal Ministry of Water Resources. These results indicate a sufficient buffering property of the river that is adequate for aquatic life, suggesting safe agricultural and domestic uses [29].

During the study, the DO and BOD had a significantly positive correlation with the snails and are within the recommended limits of 7.5 mg/L and 8.3 mg/L respectively by the Federal Ministry of Water Resources. Aquatic species can change their behaviour by increasing the supply of oxygen or by decreasing demand for oxygen. Snails extend siphons or palps, decrease burial depth or even float in higher DO waters above the water layer and also minimise their demand for oxygen by decreasing food and movement [34, 35]. Water contamination with feces has been reported to increase the level of BOD because it mainly contains organic matter, which reduces the availability of oxygen and thus decreases the number of organisms [36]. Igbinosa et al. [4] found that lower river BOD rates increased the distribution and abundance of snails with higher BOD values, resulting in a marked decrease in snail composition. Phosphate and nitrate levels have a significant negative correlation with the distribution of snails in all the stations. There is no or limited of dissolved or suspended matter during the rains, which appears to absorb the sun’s rays and thus limit photosynthesis and oxygen release. Similar to recent studies in river ecosystem, turbidity and TSS showed positive and a negative correlation with snail abundance in different stations but with higher values at Otunsugbe (42; 46) NTU compared to other stations, indicating that snails were less likely to occur and less abundant at sites with high turbidity [37]. Besides, El-Kady et al. [38] noted that turbidity was the most effective ecological factor in irrigation channels acting on snail abundance. Phosphate and nitrate from fertilisers from agricultural lands lead to eutrophication of freshwater ecosystems [29].

In the case of species abundance, most of the snails in the different study stations showed marked occurrence, which is common in all species. Besides, the peak abundance of snails was recorded for *P. maculata*; followed by *P. wernei*, *L. stagnalis*, *A. balanoidea*, *L. ovum*, and *S. vitrea*. This trend agrees with the reports of several researchers that have demonstrated the usefulness of physicochemical parameters in the increase or decrease of snail population [39-41]. In addition, the *H* index was substantially highest at Otuocha (1.1710), followed by Ukwubili (1.1330) and Otunsugbe (0.8559). Similar values (0.324; 0.822) were reported by Salawu and Odaibo [42] in four water bodies in Yewa North, Ogun State, Nigeria. However, Okeke [13] stated that the diversity index ranges from 1.5 to 3.5 to rarely more than 4 for an ideal ecosystem.

Conclusion

This study revealed the abundance of snail species in habitats disturbed by anthropogenic activities by demonstrating high tolerance to physicochemical changes in the river. Moreover, snail diversity in the different stations showed high adaptability despite significant changes in water quality. Nevertheless, these findings suggest integrating snail control strategies to protect the diversity of snails by reducing the impact of anthropogenic activities on the physicochemical parameters of the Anambra River. Moreover, recognizing detailed individual species' environmental needs will provide critical information to decode physicochemical changes in the river.

Acknowledgments

The authors wish to thank the Freshwater Mollusk Conservation Society, USA, for their guidance in identifying these species. We would also like to thank Prof. Fabian Okafor and Dr. Chika Ikele for their professional advice and assistance throughout the course of this research.

References

[1] Okafor FC, Nyang I. Freshwater snails of Niger-Cem Nkalagu, Eastern Nigeria: observations on some demographic aspects of the Schistosome transmitting Bulinids. Anim Res Int. 2004;1:120-4. DOI: 10.4314/ari.v1i2.40754.

[2] Owojori OJ, Asaolu SO, Ofoezie IE. Ecology of freshwater snails in Opa reservoir and research farm ponds at Obafemi Awolowo University Ile-Ife, Nigeria. J App Sci. 2006;6:3004-15. DOI: 10.3923/jas.2006.3004.3015.

[3] Adekiya TA, Aruleba RT, Oyinloye BE, Okosun KO, Kappo AP. The effect of climate change and the snail-schistosome cycle in transmission and bio-control of schistosomiasis in Sub-Saharan Africa. Int J Environ Res Public Health. 2019;17(1):181. DOI: 10.3390/ijerph17010181.

[4] Igbinosa BI, Izegaegbe JI, Okafor FC, Uhunwangho DA. Ecological survey of freshwater ecosystems of Ovia, Edo State Nigeria for gastropod molluscs. J Sust Dev. 2015;8:257-69. DOI: 10.4314/ARI.V12I2.

[5] IUCN. Red List Categories and Criteria. IUCN: Gland; 2001. ISBN: 9782831706337; 2831706335. Available from: https://portals.iucn.org/library/node/7977.

[6] Strayer DL. Understanding how nutrient cycles and freshwater mussels (Unionoida) affect one another. Hydrobiology. 2014;735:277-92. DOI: 10.1007/s10750-013-1461-5.

[7] Johnson PD, Bogan AE, Brown KM, Burkhead NM, Cordeiro JR, Garner JT, et al. Conservation status of freshwater gastropods of Canada and the United States. Fisher. 2013;38:247-82. DOI: 10.1080/03632415.2013.785396.

[8] Okoye CO, Okeke ES, Okoye KC, Echude D, Andong FA, Chukwudozie KI, et al. Occurrence and fate of pharmaceuticals, personal care products (PPCPs) and pesticides in African water systems: A need for timely intervention. Heliyon. 2022;18:8(3):e09143. DOI: 10.1016/j.heliyon.2022.e09143.
[9] Iheanacho SC, Nworu SA, Ogueji EO, Nnatuanya I, Mbah CE, Anosike F, et al. Comparative assessment of proximate content and organoleptic quality of African catfish (Clarias gariepinus) processed by smoking and solar drying methods. Afr J Agric Res. 2017;12(38):2824-9. DOI: 10.5897/ajar2017.12599.
[10] Odo, GE, Inyang NM, Ezenwaji HMG, Nwani CD. Macroinvertebrate fauna of a Nigerian freshwater ecosystem. An Res Int. 2007;4:611-6. DOI: 10.4314/ari.v4i1.40802.
[11] Ezeonyejiaku C, Okoye C, Ezenwelu C. Ecological assessment for trace metal pollution in a freshwater ecosystem. Int J Ecotoxicol Ecobiol. 2019;4:73-80. DOI: 10.11648/j.ijee.20190 403.11.
[12] Ezeonyejiaku CD, Obiakor MO, Okoye CO. Noncarcinogenic risk assessment of ten heavy metals in nine freshwater species sourced from market-ready landing sites. SN App Sci. 2020;2(10). DOI: 10.1007/s42452-020-03576-3.
[13] Okeke JJ, Okoye CO, Ayadiuno RU, Nwosu MC, Ibemenuga KN, Arazu VN. Evaluation of the ichthyofaunal diversity of some sections of Omambala, Ezu and Ahommiri Rivers in Anambra State, Nigeria. Int J Forest Animal Fisheries Res. 2012;2(1):18-27. DOI: 10.22161/ijfaf.2.1.3.
[14] Okoye CO. Comparative limnological studies of Unizik and Amansea streams in Awka South L.G.A, Anambra State, Nigeria. Scient Rev. 2016;2:53-6. Available from: https://www.arpgweb.com/?ic=journal&journal=10&info=aims.
[15] APHA. Standard methods for the examination of water and wastewater. 21st Ed. Baltimore US: Port City Press; 2005. Available from: http://srjcstaff.santarosa.edu/~oraola/Assets/APHA_SM_20.pdf.
[16] Takougang I, Barbazan P, Tchounwou PB, Noumi E. The value of the freshwater snail dip scoop sampling method in macroinvertebrates bioassessment of sugar mill wastewater pollution in Mbandjock, Cameroon. Int J Environ Res Public Health. 2008;5(1):68-75. DOI: 10.3390/ijerph5020068.
[17] Thompson FG. An identification manual for the freshwater snails of Florida. Gainesville Florida: Florida Museum of Natural History; 2004. Available from: https://www.floridamuseum.ufl.edu/iz/resources/florida-snails/.
[18] Brown D. Freshwater Snails of Africa and Their Medical Importance. London: CRC Press; 1994. DOI: 10.1201/9781482295184.
[19] Verma, P.S. Invertebrate Zoology. Multicolour Edition (revised). New Delhi India: S. Chand Publishing; 2001. pp. 161. Available from: https://books.google.com/books?id=osGsEa1TfjcC.
[20] Brown DS, Wright CA. Molluscs of Saudi Arabia. Fr Moll F Saudi Arabia. 1980;2:341-58. DOI: 10.5897/AJB12.1631.
[21] Bezuidenhout J, Nekhoroshkov P, Zinicovscaia I, Yushin N, Frontasyeva M. Accumulation features of micro and macroelements in indigenous and alien molluscs in Saldanha Bay, South Africa. Ecol Chem Eng S. 2020;27:495-508. DOI: 10.2478/eces-2020-0030.
[22] Duwa RS. Survey of freshwater snails on three parts of Jakara Dam, Kano State, Nigeria. Int J Zoo Res. 2017;13:20-5. DOI: 10.3923/ijzr.2017.20.25.
[23] Priawandiputra W, Nasution DJ, Prawasti TS. Comparison of freshwater mollusc assemblages between dry and rainy seasons in situ Gede System, Bogor, Indonesia. Earth Environ Sci. 2017;58:1-9. DOI: 10.1088/1755-1315/58/1/012007.
[24] Olorunniyi OF, Olofintoye LK. Occurrence and distribution of freshwater snails in three communities in Ekiti State. J Bio Innov. 2017;6:847-52. Available from: https://www.jbino.com /docs/Issue06_01_2017.pdf.
[25] Ikpeze OO, Eze GC, Ngenegbo UC, Obikwelu ME, Nri M-J, Ubaka AU. Some physico-chemical parameters of atavu river that influence gastropod density at Amagunze Nigeria. South Asian J Parasitol. 2020;4(4):64-79. Available from: https://journalsajp.com/index.php/SAJP/article/view/30131.
[26] El-Zeiny ME, Ghoneim AM, Abu Samak OA, Khidr AA. Abundance and annual distribution of freshwater snails and some trematode Cercariae at Damietta Governorate, Egypt. Helminthologia. 2021;30:58(3):233-47. DOI: 10.2478/helm-2021-0026.
[27] Smitha S, Mustak MS. Gastropod diversity with physico-chemical characteristics of water and soil in selected areas of Dakshina Kannada district of Karnataka, India. Int J Fau Bio Stud. 2017;4:15-21. Available from: http://www.faunajournal.com.
[28] Olatayo AA. Assessment of physico-chemical parameters of waters in Ilaje Local Government Area of Ondo State, Nigeria. Int J Fisher Aqua Stud. 2014;1:84-92. Available from: http://www.fisheriesjournal.com/vol1issue5/pdf/106.1.pdf.
[29] Andong FA, Ezenwaji NE, Melefa TD, Hinmikaiye FF, Nnadi OV, Olasoji O. Assessment of the physical and chemical properties of Lake Oguta (Nigeria) in relation to the water quality standard established by the Nigerian Federal Ministry of Water Resources. Adv Oceanogr Limnol. 2019;10:8522. DOI: 10.4081/aiol.2019.8522.

[30] Agi PI, Okwuosa VN. Aspects of water quality of freshwater systems harboring snail vectors Schistosome parasites in Jos, Nigeria. J Aqua Sci. 2001;16:13-7. DOI: 10.4314/JAS.V16I1.19994.
[31] Thorp JH, Covich AP. Ecology and Classification of North American Freshwater Invertebrates. 2nd Edition, San Diego: Academic Press; 2001. DOI: 10.1016/B978-012690647-9/50011-9.
[32] Chang H. Spatial analysis of water quality trends in the Han River Basin, South Korea. Water Res. 2008;42:3285-304. DOI: 10.1016/j.watres.2008.04.006.
[33] Abowei JFN. Salinity, dissolved oxygen, pH, and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. Adv J Food Sci Technol. 2010;2(1):36-40. Available from: https://maxwellsci.com/print/ajfst/v2-36-40.pdf.
[34] Long WC, Bryce J, Brylawski BJ, Seitz RD. Behavioral effects of low dissolved oxygen on the bivalve Macoma balthica. J Exp Mar Bio Ecol. 2008;359:34-9. DOI: 10.1016/j.jembe.2008.02.013.
[35] Sagasti A, Schaffner LC, Duffy JE. Effects of periodic hypoxia on mortality, feeding and predation in an estuarine epifaunal community. J Exp Mar Bio Ecol. 2001;258:257-83. DOI: 10.1016/s0022-0981(01)00220-9.
[36] Obiakor M, Okonkwo J, Ezeonyejiaku C, Okonkwo C. Bioaccumulation of heavy metals in fish sourced from environmentally stressed axis of River Niger: threat to ecosystem and public health. Resour Environ. 2014;4(6):247-59. DOI: 10.5923/j. re.20140 406.01.
[37] Olkeba BK, Boets P, Mereta ST, et al. Environmental and biotic factors affecting freshwater snail intermediate hosts in the Ethiopian Rift Valley region. Parasit Vectors. 2020;13(1):292. DOI: 10.1186/s13071-020-04163-6.
[38] El-Kady GA, Shoukry A, Reda LA, El-Badri YS. Survey and population of dynamics of freshwater snails in newly settled areas of the Sinai Peninsula. Egypt J Bio. 2000;2:42-8. Available from: https://www.ajol.info/index.php/ejb/article/view/29903.
[39] Oloyede OO, Otarigho B, Morenikeji O. Diversity, distribution and abundance of freshwater snails in Eleyele dam, Ibadan, south-west Nigeria. Zoo Ecol. 2016;27(1):35-43. DOI: 10.1080/21658005.2016.1245934.
[40] Czerniawska-Kusza I. Assessing benthic macroinvertebrates in relations to environmental variables and revitalisation works. Ecol Chem Eng S. 2022;29(1):99-110. DOI: 10.2478/eces-2022-0009.
[41] Brysiewicz, A, Czerniejewski P, Bonisławska M, Dąbrowski J. The effect of maintenance works to physical and chemical conditions of small rivers in agricultural areas. Ecol Chem Eng S. 2022;29(1):39-49. DOI: 10.2478/eces-2022-0005.
[42] Salawu OT, Odaibo AB. The bionomics and diversity of freshwater snails species in Yewa North, Ogun State, Southwestern Nigeria. Helminthologia. 2014;51:337-44. DOI: 10.2478/s11687-014-0250-7.