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PHYSICOCHEMICAL CHARACTERISTICS OF SNAIL BREEDING HABITATS IN NDOKWA WEST LGA, DELTA STATE

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ABSTRACT

Snails are considered vectors of schistosomiasis due to their contribution in facilitating the expression of this disease of public health concern in Nigeria. The physicochemical characteristics of the water of the snail breeding site were assessed in order to inform the design of control interventions in Ndokwa West communities. Water and snails were sampled from Umoni, Ase, and Adofi rivers as well as from Atama and Atuode streams, within six months (May and October 2017) using standard protocols. Results showed that temperature was within tolerable level for snail survival (between 18.3°C and 26.8°C), rivers and streams were more of shallow depth (0.43 and 1.65m) and slightly turbid (1.73 and 8.33NTU), conductivity was low (20.9 and 49.9µs/cm), hydrogen ion concentration was between moderate and slightly alkaline (7.3 and 8.4), dissolved oxygen (4.7 and 8.1) was high. Nitrate and Phosphate were between 0.6 and 8.4, and 0.3 and 0.9, respectively. The differences between air and water temperature, depth, turbidity, conductivity, and nitrate were significantly different ($P<0.05$) compared to others. The physicochemical qualities of these water bodies were at optimum for snail abundance and distribution, and the plant species supported snail abundance and distribution. In conclusion, concerted efforts should be geared towards the manipulation of the physicochemical parameters of snail breeding sites to reduce the infectivity rate of schistosomiasis in the area.

Keywords: Delta State, Ndokwa West LGA, Physicochemical parameters, Snail abundance

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1. INTRODUCTION

Freshwater snails (Mollusca: Gastropoda) live in a variety of freshwater habitats including lakes, rivers, roadside ditches, and ponds within homes. There are about 5,000 kinds of snails that live in various settings around the world. The aquatic snails that vector schistosomes typically live in shallow water close to the edges of lakes, ponds, marshes, streams, and irrigation canals. Snails can be discovered on various kinds of debris or on rocks, stones, or concrete that have been covered with algae. Snails eat aquatic plants and dirt that contain a lot of decomposing organic material. Snails could be beneficial to the environment in that they are vulnerable species that exhibit physical and biological changes when exposed to inorganic and natural toxins, thereby acting as a warning sign for environmental pollution (Gnatyshyna 2020). *Limacina helicina*, a sea snail species, acts as a warning sign for ocean acidification (Newton 2018). *Cepaea hortensis*, is a snail species that acts as a bio-indicator of pesticide pollution, especially DDT. They increase the purity of water in their habitat and may equally promote the growth of submerged plants by releasing chemicals that aid in the coagulation of suspended particles. Freshwater snails make up the largest component of invertebrate biodiversity (Mo et al. 2017). The preponderance of plants in a defined aquatic habitat due to organic matter, like feces and urine as it is close to human habitations, could encourage snail abundance. Snail diversity and abundance have drastically decreased over the past 80 years, especially for species that live in streams and rivers. Freshwater snails are one of the most threatened groups of aquatic organisms. According to studies, about 60 species of freshwater snails are believed to be extinct, and the decline of these animals began in the early 20th century. According to Strayer (2014), freshwater snails are one of the most threatened groups of aquatic organisms. The river ecosystems on which most species depend have been devastated as a result of siltation, industrial and agricultural pollutants, the destruction of wetlands, and other modifications to

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channels, and other factors. Under natural circumstances, snails are exposed to a variety of varying and frequently interacting environmental factors that have an impact on the populations of snails as a whole. It is therefore important to consider how the climate has affected the snail population. However, one goal of freshwater ecology is to comprehend the spatial and temporal organization of freshwater species communities as well as how physicochemical changes in rivers affect the distribution of these species. The dispersal of snails is hinged on the biotic and abiotic elements present in the environment. Biotic components of the environment are defined by the flora, food supply, human influence, and predators whereas the geology of the region, sunshine, turbidity, chemical analysis, and climate (temperature and rainfall) of the area relate to abiotic elements (Ayanda 2009). Therefore, it is important to comprehend how seasonal variations, which primarily alter the dominant abiotic and biotic elements of their habitats, would affect the abundance of intermediate snail hosts. Temperature, pH, turbidity, dissolved oxygen, calcium, magnesium, and phosphate are among the physicochemical characteristics of the water body that are thought to be the most significant components in the aquatic environment, particularly for freshwater snails (Abbasi et al. 2011). Temperature fluctuations can have an impact on the feed intake and growth of the Nucella canaliculata intertidal community (Stickle et al. 2017). Exposure to heavy metals impairs growth, and energy status, affects fecundity rate, lowers embryonic survival, and prolongs hatching time. The digestive and albumen glands of snails are known to be impacted by heavy metals (Kruatrachue 2011; Engwa 2019).

Snails can graze on epiphytic communities which can have a direct effect and an indirect impact on the development of macrophytes. Some studies have noted that snail activity can increase nutrient release to the water and sediment re-suspension, aggravating the eutrophication issue (Zhang et al. 2017). snails such as *Radix swinhoei*, *Lymnaea nurricula*, and *Lymnaea stagnalis* consume living submerged plants (Mo et al. 2017; Kuroda and Abe 2020). However, grazing by snail species *Parafossarulus striatulus* and *Bellamya aeruginosa* benefits macrophyte growth. Land snails are significant pests of a wide variety of fruit orchards, ornamental plants, vegetables and field crops worldwide, feeding on the young parts of plants, causing feeding damage to plant seedlings, irregular holes in leaves, roots, tubers and fruits, and decreasing yield or the quality of plants, all attributed to the prevalence of snails (Marwa 2010). The clover land snail, *Monacha cantiana* (Montagu), and the garden brown snail, *Eobania vermiculata* (Muller), are two of Egypt's most common and serious pests, causing significant damage to a variety of agricultural crops across the country. They were observed with a comparatively high population density on the major economic crops' Egyptian clover (*Trifolium alexandrinum*), cabbage (Brassica oleracea), lettuce (Lactuca sativa), and guava, (Psidium guajava) in Dakahlia governorate (Bayoumi et al. 2023).

Freshwater snails are significant intermediate candidates for a variety of helminthic infections that affect both humans and animals causing medical and veterinary concerns (Abaje et al. 2012; Abdulhamid et al. 2018). Among snail-borne diseases, schistosomiasis causes a major public health concern. Schistosomiasis that over 770 million people are at risk of Schistosomiasis (Adenowo et al. 2015). The World Health Organization's Schistosomiasis Plan, which has the vision of a "World Free of Schistosomiasis" and aims to eradicate illness as a public health issue by 2025, is the foundation for the global drive to eradicate schistosomiasis. (WHO, 2010; 2020) The majority of human schistosomiasis cases currently are caused by snails from the genera Biomphalaria, Bulinus, and Oncomelania (Agi and Okafor 2005; Hailegebriel et al. 2020). *Schistosoma haematobium* and *S. mansoni* are caused by Nigerian snails belonging to the genera Biomphalaria and Bulinus (Abubakar et al. 2019). In addition to schistosomiasis, freshwater snails also spread foodborne flukes that harm both humans' and animals' livers, lungs, and intestines. These illnesses include, among others, paragonimiasis, clonorchisis, and fascioliasis. These diseases are brought about by three different species: Fasciola sp., *Clonorchis sinensis*, and *Paragonimus westermanni* (Zimmermann 2017). *Echinostoma luisreyi* and *Echinostoma paraensei* are intermediate hosts for *P. marmorata* despite the fact that physid snails are typically overlooked as helminth intermediate hosts (Valadão et al. 2023). Schistosomiasis is controlled via mass treatment of populations at risk, safe water access, improved sanitation, hygiene promotion, and snail control (WHO 2020) Controlling snail populations is a crucial part of national and international programs to eradicate schistosomiasis. For the prevention and control of snail-borne diseases, it is essential to pinpoint the variables that affect the distribution and habitat preferences of the intermediate hosts, which are the snails. Because the development of an effective control strategy necessitates the study of population dynamics of the intermediate hosts and their relationship to environmental factors, it is necessary to understand the period of highest relative abundance if control measures are to be successfully implemented (Hussein et al. 2011). Physicochemical characteristics cannot be neglected in their significant role in deciding whether a species will survive or perish in its breeding habitat. There is a paucity of information on the physicochemical characteristics of snails of public health importance in these Delta State rivers and streams. Therefore, this study was designed.

2. MATERIALS AND METHODS

2.1. Study Area

This study was conducted in Ndokwa West Local Government Area (LGA), Delta State, Nigeria. The sample communities included Utagba-uno (Latitude: 5.525008oN and Longitude: 6.233211oE), Ndemili (Latitude:

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6.011817oN and Longitude: 6.164809oE), Ogbe-ogume (Latitude: 5.434711oN and Longitude: 6.165410oE), Umusam (Latitude: 5.411409oN and Longitude: 6.244128oE), Olieogo-umuseti (Latitude: 5.410374oN and Longitude: 6.252145oE), Abbi (Latitude: 5.404563oN and Longitude: 6.123992oE), and Ugiliamai (Latitude: 5.514307oN and Longitude: 6.263314oE) as shown in Fig. 1. Ndokwa West LGA has a land mass area of 816 km² and an estimated population of 149,325 as noted by the National Population Census of 2006. Farming, trading, artisan jobs, and civil service jobs are common occupations among residents with their sources of water including wells, rivers, streams, and borehole water. The study locations were primarily chosen based on ecological differences and secondarily due to the intervention activities ongoing in some quarters of the local government to reduce the prevalence rate of urinary infection by Primary Health Care Centre (PHCC). In the LGA, two villages were chosen based on information from the health unit, and in each of the quarters; schools were randomly selected from the list of schools provided by the educational district offices. Open defecation and urination were observed in most of the schools because of a lack of functional toilets and portable water supply.

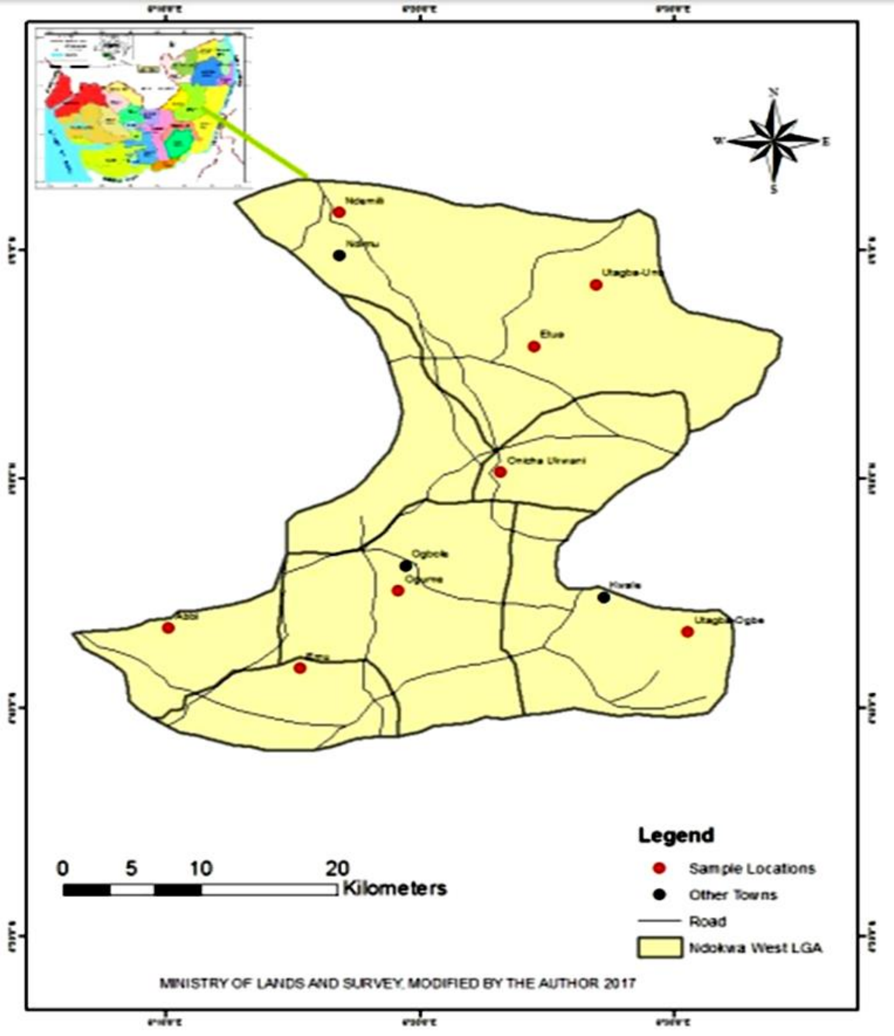

Fig. 1: Map of Ndokwa West Local Government Area showing sampled communities.

2.2. Snail Survey

Snails were sampled from three rivers and two streams selected from Ndokwa West Local Government Area of Delta State (Fig. 2). A long metal handled spade with wire gauze net (Fig. 3) was used for snail sampling in the open water while snail species along the banks of the stream or submerged in vegetation were handpicked. Sampling was done once a month for six months (May to October 2017). Species richness was computed by dividing the total number of species minus 1 by the total number of individual species collected. Two sampling techniques were used, namely the hand-net method described by Pesigan et al. (1958) and the handpicking technique described by Ofoezie (1991). Snail collections were taken to the Zoology Laboratory, University of Benin, Benin City, Nigeria in Red cap and wide-mouthed plastic containers with perforated lids (Brown 1994). The snails were counted and preserved in 10% formalin. Snail identification was done with an aided standard key by Pan American Health Organization (1968).

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Fig. 2: Various rivers where samples were collected.

A B

Fig. 3: A) Long metal handle spade with wire gauze and B) handpicking of snails with forceps from a scoop net.

2.3. Collection of Flora

Floras collected at study sites were stored in a plant press, made up of a wooden frame (for rigidity), corrugated cardboard ventilators (to allow air to flow through the press), blotter paper (to absorb moisture) and folded paper, typically a newspaper (to contain the plant material). The plant press was tightened using straps with buckles or bolts with wing nuts. The objective of pressing plants is to extract moisture in the shortest period of time, while preserving the morphological integrity of the plant and to yield material that can be readily mounted on herbarium paper (an acid-free cardstock) for long-term storage. (Ndifon and Ukoli 1989).

2.4. Physicochemical Parameter

Water sample analysis was done using physical and chemical approaches. Water samples were collected from rivers and streams in each community surveyed using standard methods. Qualitative data of the water was measured on each visit to the water bodies. The waterbodies were stratified into three sampling stations for convenience of sampling and served as replicates for the sampling.

2.4.1. Temperature: Air and water temperatures were measured with 10-100°C mercury in a glass thermometer which was thoroughly dry. The thermometer was allowed to equilibrate for 5min before readings were taken and recorded in °C.

2.4.2. Water Flow Velocity: The float method was used to measure the current velocity of the water. In each station, two points were marked, and the time taken for the Ping-Pong ball (a tennis ball) to transport itself between these

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two points was recorded with the use of a stopwatch (triplicate). The flow velocity can be calculated or gotten from the relation:
Velocity (m/s) = (Distance)/Time

Distance is expressed here between two points measured with the use of a measuring tape.

***2.4.3. Water Depth*:** Water depth was measured using a calibrated rope with a metal attached to its end. The metal is lowered to the bottom (the bed) of the river and the measurement was read from the calibrated rope, this was carried out at various site of the river (various stations) and recorded in meters (m).

***2.4.4. Transparency*:** Transparency was determined using a Secchi disc. The Secchi disc is a black and white colored disc of about 25cm in diameter. The disc was observed while it was carefully lowered into the water. The depth at which the Secchi disc appears from sight when hauled is recorded. The average of both depths was also recorded in centimeters (cm). Electrical Conductivity was measured using a conductivity meter. The meter was set to zero point. The water sample to be tested was poured into the Sproul. The knob of the meter was pressed and the reading was thus taken. This was expressed in micro-ohms/cm.

***2.4.5. Hydrogen ion concentration (pH)*:** A washed bottle, rinsed with river water was used to collect water samples for pH determination. It was corked, labeled and taken to the laboratory for analysis.

***2.4.6. Dissolved oxygen (DO)*:** Water samples for DO were taken by immersion to fullness into a well washed 250ml reagent bottle which was fixed immediately by adding 1ml of Winkler solution A (manganese sulphate) followed by Winkler solution B (azide-iodine solution) to each bottle. The resolving precipitate was dissolved in the laboratory by adding 2ml of concentrated H2SO4 (tetraoxosulphate (VI) acid) to form a gold brown solution. Dissolved oxygen was determined using titrimetric method. 200ml of the treated sample was transferred using pipette into a conical flask placed on a white surface. This was titrated with sodium thio-sulphate. The flask was rotated during titration until the sample became (faint) pale yellow in color. 1mL of the starch solution was added as the sample turned blue-black. The titration continued until the blue color first disappeared. The volume of the thiosulphate used was recorded:
Oxygen concentration= vx8x10/(volume of sample)

Where V = Volume of sodium thiosulphate used in titration and result was expressed in mg/L.

***2.4.7. Phosphate-Phosphorus (Ph-P)*:** The auto analysis was used to determine the phosphate-phosphorous content in two samples. 2mL of water was put into the sampling corks and placed on a tray. The reagent L – Ascorbic acid and ammonium molybdate in tetraoxosulphate (VI) was put into two different conical flasks. The water sample was passed through a proportionate pump. The sample together with the reagent was passed to the mixer and the calorimeter were the color developed light blue from the calorimeter, they were taken in part per million (mg/L).

***2.4.8. Nitrate-Nitrogen (Ni-N)*:** The nitrate in the water samples was determined using a brucine calorimeter method. 10mL of water sample was put into 250mL of volumetric flask. Brucine (2mL) reagent was added rapidly into 10mL of concentrated tetraoxosulphate (VI). The solution was mixed for about 30s and allowed to cool for 15min. The mixture was made up to mark with distilled water after color development (purple) absorbance was measured at 470m wavelength in the spectrometer.

2.5. Data Analysis

Data was entered into MS Excel Spread Sheet and checked before analysis. Descriptive statistics were used in the presentation of results. Water parameter analysis was done as per the sampled rivers and streams while the three stations served as replicates of the rivers. Analysis of Variance (ANOVA) test was done to ascertain the level of significance in water parameters and were significant at $P<0.05$. Pearson correlation analysis was done to ascertain the relationship between the water parameters and snail abundance. All analysis was done using IBM Statistical Software version 22 and Microsoft Excel Windows application. Graphical presentations were carried out with Microsoft Excel to illustrate the findings.

3. RESULTS

3.1. Physicochemical Characteristics of Snail Breeding Sites

The physicochemical characteristics of snail breeding sites in Ndokwa West, Delta State is presented in Table 1. Mean values of air and water temperature were at optimum levels to support snail community, and this ranged between 24 and 26.8oC, and 18.3 and 23.6oC, respectively. The rivers and streams were shallower in depth and slightly turbid, with ranges from 0.43 to 1.65m, and 1.73 to 8.33NTU, respectively. Conductivity in the stream and river sampled was low (ranges between 20.9 and 49.9µs/cm). Hydrogen ion concentration wasmoderate and slightly alkaline in nature (ranges between 7.3 and 8.4). Dissolved oxygen (DO) was high in the sampled water bodies and ranged from 4.7 to 8.1. Nitrate and Phosphate were between 0.6 and 8.4mg/L, and 0.3 and 0.9mg/L, respectively (Table 1). Air and water temperature, depth, turbidity, conductivity, and nitrate were significantly different (P<0.05) whereas others were not (Table 1). The highest values of physicochemical parameters were recorded in different rivers and streams. Air and water temperature, nitrate, DO and phosphate were highest in the Umoni River. More so, turbidity, flow velocity, and pH were highly recorded in the Ase River while the depth of the Adofi River was higher than other rivers sampled. Similarly, the lowest values of physicochemical parameters were recorded in different rivers and streams. Air and water temperature, depth and flow velocity were lowest in the Atama stream. Conductivity, DO, and nitrate were lowest in the Atuode stream. Turbidity, pH, and phosphate were the lowest in Adofi River, Umoni River, and Ase River, respectively.

Table 1: Physicochemical characteristics of snail breeding sites in Ndokwa West, Delta State

Parameters	River Umoni	River Ase	River Adofi	Atama stream	Atuode stream	F-ANOVA	P value
Air temperature (oC)	26.83±1.08 (20-38)	24.32±0.58 (20-29.1)	24.65±0.64 (20.12-29)	23.97±0.50 (20.15-28.15)	24.32±0.23 (23.1-26.73)	2.66*	0.038
Water temperature (oC)	23.56±0.76 (20-31)	23.24±0.58 (20-29)	22.49±0.48 (19.73-25.7)	18.25±1.96 (0.53-24.1)	21.80±0.35 (18.93-24.0)	4.45*	0.003
Depth (m)	0.48±0.04 (0.22-0.76)	0.65±0.03 (0.42-0.86)	1.65±0.09 (1.2-2.45)	0.43±0.04 (0.19-0.71)	0.52±0.04 (0.23-0.83)	8.65*	<0.05
Turbidity (NTU)	7.24±0.57 (5-15)	8.33±0.25 (5.9-10.3)	1.73±0.20 (0.33-3.47)	1.74±0.26 (0.09-3.7)	3.30±0.53 (0.52-6.3)	62.54*	<0.0001
Flow velocity (m/s)	0.38±0.02 (0.22-0.51)	0.45±0.02 (0.32-0.62)	0.33±0.03 (0.17-0.59)	0.29±0.02 (0.15-0.41)	0.30±0.03 (0.06-0.5)	2.1	0.09
Conductivity (µs/cm)	49.34±1.77 (39-63)	49.92±2.09 (36-71)	25.96±1.58 (19.6-44.2)	31.04±3.26 (9.12-58.12)	20.91±1.85 (3.9-32.1)	37.68*	<0.0001
pH	7.3±0.2 (5.7-8.9)	8.4±0.1 (7.6-8.9)	7.6±0.2 (6.24-8.7)	7.5±0.1 (6.45-8.3)	7.6±0.2 (6.58-8.8)	1.76	0.23
Dissolve oxygen (mg/L)	8.1±1.9 (4.1-9.2)	5.1±1.7 (4.6-7.1)	5.7±0.3 (3.2-8.0)	5.5±0.7 (3.27-9.3)	4.7 ±0.4 (2.03-8.19)	1.19	0.35
Nitrate (mg/L)	8.07±0.62 (4.1-13.3)	6.71±0.59 (1.2-10.8)	1.23±0.26 (0.029-3.8)	2.11±0.81 (0.029-10)	0.61±0.15 (0.028-1.92)	39.03*	<0.0001
Phosphate (mg/L)	0.91±0.54 (0.03-10)	0.25±0.05 (0.04-0.7)	0.46±0.10 (0.04-1.37)	0.61±0.33 (0.005-6.01)	0.38±0.10 (0.028-1.21)	0.76	0.56

Values are presented as mean±SE and values in parentheses are ranges of field data. *Shows significance at P<0.05.

3.2. Snail Abundance and Associating Flora

Snail species recovered from the sampled rivers in Ndokwa West Local Government Area is shown in Table 2. Achatina sp. was the predominant species encountered in all sampled water bodies and was found to be larger compared to others (Fig. 5). This was closely followed by *Bulinus globosus* which was found in four out of the five water bodies that were sampled. *Biomphalaria pfeifferi* was the smallest encountered snail in the sampled water bodies. Snails were highly occurring in Atuode stream located in Onicha-ukwani, a partially shaded and slow-flowing stream (Fig. 4). This was closely followed by Adofi River which is located in Abbi, slow-flowing and unshaded. River Umoni located in Ndemili and Ase in Utagba-Ogbe have the lowest snail abundance. As shown in Table 3, both rivers are fast-flowing. However, Ase river is partially shaded and Umoni river not shaded. Atama stream located in Utagba-Unor is slowly flowing. Several associating florae present in the sampled rivers and streams are shown in Fig. 6. Almost all plants were present collectively in the sampled rivers and streams.

4. DISCUSSION

Physicochemical parameters of snail breeding habitat are important determining factors for the sustenance of the occurrence or mortality of species. The determination of physicochemical characteristics has been done in several studies involving the breeding habitat of mosquitoes, the dumpsites of electronics, and many others (Ojianwuna et al. 2021; Oluwagbemi et al. 2023). This study illustrates the significance of physicochemical factors in the spatial distribution of snails as human schistosomiasis intermediate hosts. These factors include conductivity, dissolved oxygen and its saturation, pH, and water flow velocity. The air and water temperature of snail breeding

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Table 2: Monthly abundance of snails in water bodies surveyed in Ndokwa West LGA, Delta State, Nigeria

Snail species	May	June	July	August	September	October	Abundance
Achatina sp.	97	82	49	22	17	12	279
Bulinus globosus	72	51	28	16	5	1	173
Oncomelania hupensis	39	33	9	7	3	0	91
Biomphalaria pfeifferi	1	0	1	0	0	0	2
Pila sp.	16	9	5	0	3	1	34
						Total	579

Table 3: Characteristics of water bodies and organisms encountered in Ndokwa West LGA of Delta State, Nigeria

Waterbody	Location	Type of shade	Flow velocity	Flora collected	Snail species present
River Umoni	Ndemili	No shades	Fast	Acanthaceae *Commelina diffusa*, *Eichhornia crassipes*, Nymphaeaceae (water lily)	*Oncomelania hupensis*, *Bulinus globosus*, *Achatina* sp.
Ase River	Utagba-Ogbe	Partially shaded	Fast	*Conoclinium coelestinum Eupatorium coelestinum Solenostemon monostachyus Eichhornia crassipes*	*Oncomelania hupensis*, *Bulinus globosus*, *Pila ampullaceal*, *Achatina* sp., *Biomphalaria pfeifferi*
Atama stream	Utagba-Unor	Partially shaded	Slow	*Phyllanthus amarus* Nymphaeaceae *Eichhornia crassipes Alternanthera brasiliana*	*Bulinus globosus*, *Pila ampullaceal*, *Achatina* sp
Atuode stream	Onicha-ukwani	Partially shaded	Slow	Arnica (*Colocasia esculenta*) Nymphaeaceae (water lily)	*Oncomelania hupensis*, *Achatina* sp. (P)dentifera ,*Achatina*
Adofi river	Abbi	No shades	Slow	*Ageratum conyzoides*, *Eichhornia crassipes* Nymphaeaceae *Cleome viscosa* L. (*Arivela viscosa*)	*Achatina* sp. *Bulinus* sp. *Oncomelania hupensis*

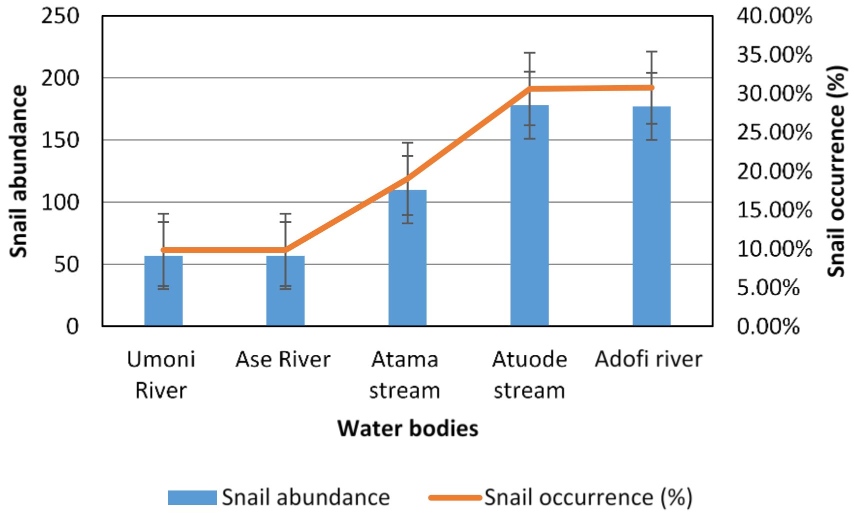

Fig. 4: Abundance and occurrence of snails in some water bodies in Ndokwa West LGA, Delta State.

habitat was higher in the Umoni River than in other rivers, and it was observed to be within tolerable limits for snail biological activities. The air and water temperatures recorded in this present study disagree with the findings of Ejoh et al. (2018), carried out in Udu LGA, Delta State, Nigeria, where the mean temperature varied from 25C to 34°C. The average temperature (23.56°C) obtained in this study is within the acceptable limits (<35°C) set by the Federal Ministry of Water Resources (2016). High temperatures cause thermal stress in snail vectors and also reduce the dissolved oxygen content of water bodies. Most of the snails recorded in all the water bodies visited tolerated the average temperature (air temperature 28°C, water temperature 27.2°C) in their natural habitats. Snails were found attached to water lettuce (Eichhornia crassipes) in all water bodies surveyed. The population dynamics of snails are said to have a direct effect on parasite transmission. Pearson correlation revealed no significant relationship between the water temperature and the abundance of snails throughout the season, with a significance level of 0.268 (P>0.05). This is in contrast to the findings of Okoye et al. (2022) who recorded great abundance due to their endurance of a relatively high temperature. The high temperature recorded in this study can be attributed to the absence of shades in the Umoni and Adofi rivers, while in others there were partial shades. The freshwater ecosystem found in other areas is less exposed to light due to its highly developed eutrophication, which accounts for the low temperatures recorded in those rivers, especially the Atama River.

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Fig. 5: Snails collected from surveyed water bodies with a measuring device.

Fig. 6: Some floras collected in and around the surveyed area in Ndokwa West LGA of Delta State.

The average depth of rivers in this area is 0.75 meters and this corroborates the finding of Arimoro et al. (2007) in the Ase River. Pearson correlation revealed no significant relationship between the water depth and the abundance of snails throughout the season with a significance level of 0.819 (P>0.05). Fluctuations in turbidity in the sampled rivers varied from 1.73 NTU to 8.33 NTU with the highest recorded in the Ase river. This range does

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not correspond to the study of Agedah et al. (2015) done at Wilberforce Island, Bayelsa state, Nigeria in 2015, who reported a turbidity range of 103.752-117.252 NTU. Pearson correlation revealed no significant relationship between the turbidity and the abundance of snails in all the rivers with a significance level of 0.093 (P>0.05). Monthly variations in flow velocity for this study ranged from (0.29-0.45m/s). The highest flow velocity was recorded in river Ase (0.45m/s) (0.62m/s) in May and the lowest was recorded in Atama River Atuode river (0.29m/s) (0.02m/s) in August. The flow velocity is consistent with the results of the study of Arimoro et al. (2007). Pearson correlation revealed a significant negative correlation between the water flow velocity and the abundance of snails throughout the rivers with a significance level of 0.038 (P<0.05). The Ase River has been reported to have a high rate of water conduction; snails were uncommon at this sampling point. Speed may be the cause of this low abundance of snails. A water current above 0.3m/s will physically prevent snails from being abundant in a river (Nwoko et al. 2022). In the sampled rivers, the electrical conductivity, which is a measure of an aqueous solution's capacity to conduct electrical current, varies monthly and ranges from 20.91–49.92S/cm. The Atuode River had the lowest electrical conductivity (20.91S/cm), and the Ase River had the highest (49.92S/cm). The significant contributions of organic matter in the water, which led to their greater mineralization, are what account for the high levels of electrical conductivity at the Ase River. This finding is in disagreement with Okoye et al. (2022), in a similar study in the Anambra River (Nigeria) during the rainy season, who reported a low electrical conductivity range of 8.25 S/cm to 10.7 S/cm. Based on the study of Tchakonte et al. (2014), increased electrical conductivity affects the maturity and survival of snails and increases their abundance. From this study, the values of conductivity obtained at Ase (49.92µS/cm) have no impact on the density of snails as the low values of conductivity observed do not significantly correlate with intermediate host populations. Pearson correlation revealed no significant relationship between the electrical conductivity and the abundance of snails throughout the rivers with a significance level of 0.064 (P>0.05). Monthly changes in pH for this research ranged from 7.3–8.37. The result corroborates the findings of Okoye et al. (2022), who reported a pH range of 7.8–8.4 for a similar study in Anambra State. The mean pH (7.3) obtained in this study is within the acceptable limits of 6.5-8.5 by the Federal Ministry of Water Resources (Andong et al. 2019). Hydrogen ion concentration is a significant parameter that determines the snail distribution. High pH is associated with increased calcium content, and these habitats are discovered around draining streams in calcareous catchments (Okoye et al. 2022). Based on the study of Chang (2008), environments populated with industries are characterized by higher pH levels because of their likelihood to use wastewater-alkaline products while residential areas with higher pH also utilize alkaline detergents. According to the study of Okoye et al. (2022), a pH range of 7-5 encourages biological productivity, whereas a pH below 4 is detrimental to aquatic life.

The DO of the water sampled ranged from 4.7mg/L in the Atuode River to 8.1mg/L in the Umoni River. The average DO of the rivers (5.82mg/L) disagrees with a similar study conducted in River Nworie, Imo State, Nigeria, which reported a DO range of 2.27–3.89mg/L (Verla et al. 2020). DO of the rivers in this study are somewhat below the Federal Ministry of Water Resources' recommended limits of 7.5- 8.3mg/L except for river Umoni which is in line. Pearson correlation revealed no significant negative correlation between the Dissolved Oxygen and the abundance of snails throughout the rivers with a significance level of 0.851 (P<0.05). Snails can adapt to various conditions by reducing the oxygen demand. Snails can also lower their need for oxygen by lowering their food intake and reducing mobility, extending siphons or palps, reducing their depth of burial, and floating in waters with increased DO. Sewage disposal into river bodies has been discovered to be the contributing factor to the organic content of water, hence lowering the availability of oxygen to snails (Obiakor et al. 2014). Dissolved oxygen played a significant role in the diversity of snail species represented in this study where high diversity was recorded in station three of Umoni River. The reason for this could be due to the high or large surface area of the station which exposes the site to air and sunlight which favors the photosynthetic activities of aquatic plants which in turn leads to a higher diversity of organisms. Similar observations were also recorded by Edema et al. (2002) in Niger State, Nigeria in a magnifying stream. The values of dissolved oxygen obtained during the study ranged from 5.5-8.1mg/L in the two stations with the mean values of 4.21 and 5.10mg/L, respectively. Pearson correlation revealed a significant negative correlation between the Dissolved Oxygen and the abundance of snails throughout the rivers with a significance level of 0.049 (P<0.005). These species are very sensitive to reductions in dissolved oxygen and are sometimes not found in areas where oxygen levels are considerably low. Dissolved oxygen played a significant role in the diversity of snail species represented in this study where high diversity was recorded in station three of Umoni River. The reason for this could be due to the high or large surface area of the station which exposes the site to air and sunlight which favors the photosynthetic activities of aquatic plants which in turn leads to higher diversity of organisms.

Nitrate is one of the parameters derived from human sources and inorganic fertilizers used in agriculture. The monthly values of nitrate ranged from 0.61-8.07mg/L; the lowest value was found in the Atuode stream at station one in October, while the highest value was found in the Umoni rivers. The nitrate concentration is consistent with

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the study by Ejoh et al. (2018). Pearson correlation revealed no significant correlation between the nitrate and the abundance of snails throughout the rivers with a significance level of 0.061 (P>0.05). Phosphate ranged from 0.25mg/L to 0.91mg/L. The highest value was observed in the Umoni River, and the lowest value was recorded in the Ase River. This conflicts with comparable studies in Otuocha, Otunsugbe, and Ukwubili (Okoye et al. 2022). Phosphate originates from agricultural land (leaching of fertilizers by rainwater) and also from home activities for which women use different detergents and antiseptics.

Pearson correlation revealed no significant correlation between the phosphate and the abundance of snails throughout the rivers with a significance level of 0.797 (p<0.005).

In this present study, Umoni River and Ase River were found to have higher populations of snail species. The dominant snail species that harbor the infection encountered in this study was Bulinus globosus which accounted for 42.5% this is in agreement with Omudu and Iyough (2005) who reported 44.78% in the ecological studies of gastropod fauna of River Benue. Bulinus globosus has been known to play a significant role in the complex life cycle of several species of parasitic trematodes including liver flukes and lung flukes Wingard et al. (2008). A study by Igbinosa et al. (2015) reported that these snails compete with native snails particularly hydrops that may carry Schistosoma infection. Related studies conducted in similar freshwater bodies in Nigeria (Edema et al. 2002) have associated the presence of these organisms in a site with lean water conditions. This work revealed that a high density of snail species populations was encountered in the open water area which may have been influenced by an unexplained abundance of aquatic macrophytes in the open waters in the study areas. Snail abundance was typically high during the rains. This finding is consistent with Nwoko et al. (2023) who attributed the increase of snail population to the onset of rains. The findings of this study have revealed that the water bodies of Ndokwa West Local Government Area are good habitats for freshwater snails. The physicochemical parameters across each stream showed no significant difference with the abundance of snails indicating that snails found were more tolerant and adapted to a reasonable range of physico-chemical conditions.

5. Conclusion and Recommendation

The physicochemical qualities of the water from the snail breeding sites were at optimum for snail abundance and distribution. It is therefore predicted that snail abundance is directly linked to parasite transmission. Bulinus sp. was the major intermediate host of S. haematobium probably for their high adaptation to local ecological factors such as rainfall pattern, topography, and inflow due to a lack of drainage system. There is a need to reinforce the control of snails of public health importance or regulate their abundance through manipulation of physicochemical characteristics of water before infections go beyond the tolerable levels.

Authors' Contribution

CC designed the study and carried out the field sampling, all authors wrote and approved the final manuscript.

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