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Full Length Research Paper

Mapping of gastropods associated with urogenital schistosomiasis transmission in Agulu Lake area of Anambra State, Nigeria

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ABSTRACT

Urogenital Schistosomiasis had been diagnosed among pupils in Agulu Lake areas of Anambra State, Nigeria. The causative parasite, *Schistosoma haematobium*, and the snail intermediate hosts have been identified. Some water parameters of Agulu Lake that influenced gastropod abundance around the lake were also determined. Recent crocodile infestation of the lake has limited human-water contact activities in the lake but there has been an increase in market-gardening at the Nri-axis of the lake, which may expose women and children to increased risk of urinary schistosomiasis and soil-transmitted helminth infections in the area.

Keywords: Gastropod abundance, Urogenital schistosomiasis, Agulu Lake, physico-chemical parameters of water, water contact activities.

INTRODUCTION

Agulu Lake, the target area of study, is approximately eighty-one hectares and stretches for about two kilometers. It is the Head-stream of Idemili River which flows through Anaocha, Idemili North and South Local Government Areas, traversing Ogbaru Local Government Area and drains into the River Niger near Onitsha (Ikpeze and Obikwelu, 2016). Agulu Lake has six arms that spurred into neighbouring Communities of Nri and Adazi-Nnukwu but the two big arms are within Agulu. The lake's unique outline was probably due to its mode of origin from damming of perennial Idemili River with eroded materials from gullies to the south of the lake in the distant past. The lake and the surrounding freshwater bodies have been in use for various purposes like washing of domestic utensils and clothes, fishing, recreation (swimming), bathing, cassava fermentation, isolated rituals and sacrificial offerings as well as a source of drinking water by some members of the surrounding communities. The prevalence of urogenital schistosomiasis has been extensively studied among adolescent primary school-age boys in Agulu Lake area (Ekwunife *et al.*, 2009; Udeh *et al.*, 2009; Ekwunife *et al.*, 2008; Ekwunife and Okafor 2004; Emejulu *et al.*, 1994; Emejulu *et al.*, 1992) but there is a dearth of information on ecology of gastropods which serve as intermediate hosts for developmental stages of *Schistosoma haematobium* that cause urogenital schistosomiasis in the area. For the "Mapping of gastropods associated with urogenital schistosomiasis transmission in Agulu Lake Area" it was needful to study not only Gastropod abundance but also the Physico-chemical parameters of the Lake which influence gastropod density in the endemic area. The important physico-chemical parameters included that influence gastropod density include water temperature, depth, transparency, dissolved oxygen, pH, and calcium ion concentration (Ikpeze *et al.*, 2020).

Preliminary visit to Agulu Lake

On 26th May 2016, before the commencement of research, the Principal investigator called on the Chief Priest and Custodian of Agulu Lake at "Ogbuefi Ovuobu Temple" (Plate 1) for permission to conduct the research on gastropods that are the intermediate hosts of *Schistosoma haematobium* that causes Schistosomiasis within the Agulu Lake area. After a token was offered to Agulu Lake, the Chief Priest granted permission for the Research to commence. He expressed happiness that a Researcher deemed it appropriate to enquire before embarking on such an important project on Agulu Lake and its environs. He explained that urogenital schistosomiasis was introduced to the area by some refugees from certain endemic areas who settled in Agulu during the Biafra-Nigeria Civil War.

The Chief Priest of the lake also lamented that a section of the Awka-Ekwulobia major highway which passed over Agulu Lake has a massive concrete drainage that diverted floods and pollutants from the road, and other industrial effluents from TAMAD Quarry Company and COTABS Construction Company into the lake (Plate 2). Other sources of pollutants into the lake (Plate 3) included effluents from a Five-Star Hotel and a Hotel Resort, excrement from animals that grazed near the lake, as well as the Car-wash by the lake side. Geographic co-ordinates of these locations were captured with a GSM Mobile App.

Plate 1: Ogbuefi Ovuobu Temple at Agulu Lake-side (N6°7′47.01″:E7°2′0.27″)

Plate 2: Sources of pollutants and industrial effluents in Agulu Lake. [a] Section of Awka-Ekwulobia road (N6°7′47.01″:E7°2′0.27″), [b] Concrete drainage Awka-Ekwulobia road (N6°7′55.25″: E7°2′5.34″), [c] TAMAD Quarry (N6°8′2.5″:E7°2′5.18″), [d] COTABS Company (N6°7′55.25″: E7°2′5.34″).

Plate 3: Other sources of pollution in Agulu Lake. [a] Five-star Hotel, [b] Hotel Resort, [c] Animal grazing near the lake (N6°7′52.78″: E7°2′3.46″), [d] Car-wash near the lake (N6°7′56.47″: E7°2′0.21″).

PHASE I OF THE STUDY (JUNE 2017 - MAY 2018)

Gastropod abundance and some water parameters of Agulu Lake that influenced gastropod abundance

Eight gastropod sampling stations were purposively selected because of their preferences for human activities on Agulu Lake waterlines. Stations 1, 2, 3 and 4 were on the Agulu-axis of the lake while Stations 5, 6, 7, and 8 were on the Nri-axis of the lake (Figure 1). Eight quadrats, each measuring 20m along the waterlines and 1m width off-shores were delineated from each of the 8 sampling stations for gastropod and water measurements.

Each quadrant was sampled completely for freshwater gastropods between June 2017 and May 2018. Sampling was by means of scoop net and hand-picking technique for snail collection. The scoop net has a long handle 100cm long, with sieve net of mesh 3mm – 4mm (Idris and Ajanusi, 2002).

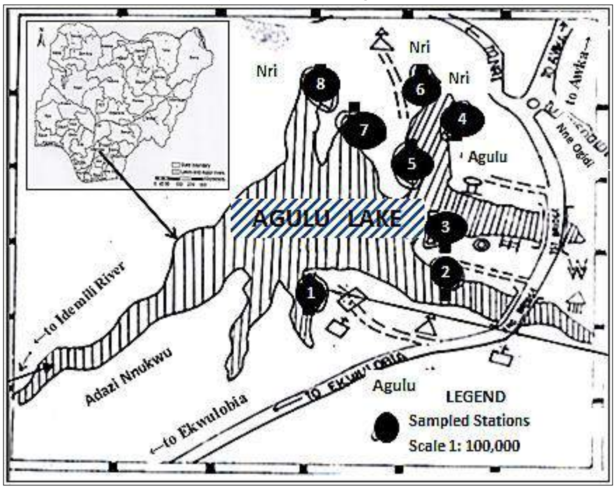

Figure 1: Agulu Lake showing the 8 gastropod sampling stations on Agulu Lake waterlines.

Pair of rubber boots and hand gloves were the personal protective equipment used to prevented infective water contact during the sampling process (Plate 4).

Plate 4: The scoop net for gastropod sampling

A 15-minutes sampling period was adopted (Njoku-Tony, 2011) when 40 passes were systematically thrown at consecutive 50cm distances along each $20m^2$ quadrant. Long forceps was used to retrieve the snails from scoop nets. The sampling was supplemented by 5 minutes manual search over vegetative cover and suspended materials. Gastropods recovered were washed thoroughly and cleared from mud and debris before being kept in pre-labeled plastic containers (Mohamed *et al*., 2011). The mouth of each container was covered with nylon nets to allow inflow of air. Some aquatic plant leaves associated with the gastropods were also collected and placed inside each container for the snails to feed on.

The pre-labeled containers with the contents were taken to the laboratory where the gastropods were identified using the Malacology Keys of Brown (1994) and their relative sizes compared by placing them alongside a meter rule. The circumferences (diameters) of some of the identified *Bulinus* species were measured in millimeters with Bow-calipers and transparent metric.

Physical parameters of water sampled

Physical water parameters determined at each gastropod sampling station was carried out at the same time of gastropod sampling between June 2017 and May 2018.

Water Depth was measured according to Mohamed *et al.* (2011) using a wooden metric rule of length 100cm (Plate 5a). The wooden structure was immersed into the water along the waterlines at each station at 12 monthly intervals of the hydrologic year of study. The calibrated values on the metric rule at which water levels outlined were recorded.

Water Transparency was measured with the aid of Secci disc of diameter 25cm attached to a calibrated cord (Owojori *et al*., 2006). Secci disc is a circular measuring device painted quarterly with white and black colours. It was thrown into water with the attached cord held firmly and released gradually. The instrument was monitored as it sank into water. Immediately the disc became invisible, the water level mark on the calibrated cord was recorded (Plate 5b).

Water Temperature was determined *in situ* by dipping ordinary mercury in glass thermometer into water (Plate 5c).

Plate 5: Measurements of the physical water parameters of Agulu Lake. [a] water depth, [b] water transparency, and [c] water temperature.

The lake was visited twice daily at 7.00am in the morning to measure the maximum temperature and at 6.00pm in the evening to measure the minimum temperature. The values of maximum and minimum temperatures were added together and the sum divided by 2 to obtain mean daily temperatures. Daily temperatures for each month were added and the sum divided by number of days in the month to obtain mean monthly temperatures.

Chemical parameters of water sampled

Water samples collections in pre-labeled white plastic containers were done concomitantly with monthly snail sampling from each station, and were taken to the laboratory of Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, for determination of dissolved oxygen (DO), calcium ions and hydrogen ions (pH) concentrations.

Dissolved Oxygen concentration was determined by the Azide method was employed, starting with pipetting 25ml of water sample into a conical flask and adding 4ml of potassium fluoride to it. This was followed by the addition of 2ml of manganese sulphate solution and shaken for several times. After few minutes, 2ml of alkaline iodide containing sodium Azide (NaN_3) was added followed by 2ml of H_2SO_4. A deep yellow colour was observed with continuous shaking. Two (2) ml of starch indicator was added to the solution to show the presence of oxygen when the set up turned blue-black. Then sodium thiosulphate standard solution ($Na_2S_2O_3$) was added to the solution to obtain a clear titer. The addition of alkine iodide, manganese sulphate and potassium fluoride worked in precipitating the oxygen; sodium thiosulphate standard solution performed the work of titrating oxygen, while starch indicator showed the presence of oxygen (Plate 6a).

Calcium ion concentration was determined by the titrimetric method when 0.01N EDTA solution prepared by weighing out 4g analytical reagent grade which was dissolved in distilled water and diluted to 1000ml. Ammonium buffer solution (pH 10) prepared by dissolving 6.8g of Ammonium Chloride (NH_4Cl) in 57ml of Ammonium hydroxide (NH_4OH) was made up to 100ml with distilled water.

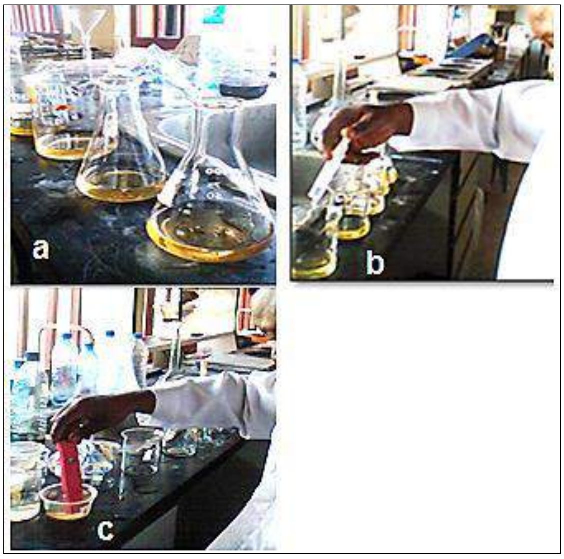

Plate 6: Determination of chemical parameters of water [a] DO, [b] Ca^{++}, and [c] pH

Erichrome black T dye with 0.5g of the dye was dissolved in 100ml of 2-methylmethanol. The underlining principle is that Ethylene diaminetetracetic acid and its sodium salt (EDTA) form a chelating soluble complex when added to a solution of a metallic cation. When small amount of the dye was added to the aqueous solution containing calcium and Magnesium ions at pH 10.0±0.1, the solution turned wine red. The EDTA was added to complex the Calcium and Magnesium ions after which the solution was observed to change from wine-red to blue-black marking the end point of titration (Plate 6b).

The pH of water samples was determined with digital pH meter which was dipped in water and monitored immediately (Plate 6c). The set-up was timed for 3-5 minutes pending when the reading on the digital meter began to fluctuate. The highest value on the scale was recorded as the pH for the sample. The procedure was repeated at monthly intervals.

PHASE II OF THE STUDY (JUNE – AUGUST 2018)

Impact of Crocodile in Agulu Lake on Gastropod Abundance

"Mapping of gastropods associated with urogenital schistosomiasis transmission in Agulu Lake Area" progressed to completion in 2018 when sudden infestation of the Agulu Lake by crocodiles occurred. During Phase Two of this study, however, the Agulu Lake proper had become 'a no-go area' due to threats by crocodiles whose chalky-white tracts of fecal droppings were visible on their afternoon-resting places by the lake-side (Plate 7).

Plate 7: Crocodile's chalky-white fecal droppings at crocodile's resting ground on Agulu Lake waterlines at Okachamma 2 (encircled). N6°7′56.47″: E7°2′0.21″

This led to unprecedented increase in females' participation in extensive vegetable gardening beyond the lake's waterlines to avoid direct confrontation with the crocodiles, hence exposing more women to risk of schistosomiasis.

Scientists are now focusing on female genital schistosomiasis, caused by an inflammatory reaction to schistosome eggs trapped in body tissue, leading to fibrosis and scarring of the female genital tract, with early signs of the disease manifesting as a burning sensation in the genitals, spot bleeding, abnormal discharge smell, bloody discharge, stress incontinence and lower abdominal pain (Galappaththi-Arachchige *et al*., 2016).

Female genital schistosomiasis can rapidly progress towards swellings or ulcerations of the vulva and vagina, causing genital bleeding, pain and dyspareunia, and the symptoms can gradually evolve towards reproductive organ damage, characterized by sub- or infertility, ectopic pregnancy, spontaneous abortion, premature birth and low birth weight. Engels *et al*. (2020) has linked female genital schistosomiasis to pain, bleeding and sub- or infertility, leading to social stigma, which is a common issue for women in schistosomiasis-endemic areas in sub-Saharan Africa. These authors (Engels *et al*., 2020) opined that the disease be recognized as another component of a comprehensive health and human rights agenda for women and girls in Africa, alongside human immunodeficiency virus (HIV) and cervical cancer.

On the other hand, absence of human-Agulu Lake water-contact activities due to the presence of crocodiles would likely cause a decline in gastropod abundance and extinction, implying that in the absence of snail intermediate host control of urogenital schistosomiasis would be achieved in the area. Therefore the additional three-month study was to access the "Impact of crocodile infestation on gastropod abundance in Agulu Lake area. We envisaged that the result of the present research will help Public Health Policy-makers in evidence-based decisions on integrated approach to disease intervention programmes for schistosomiasis and female genital schistosomiasis, cervical cancer, HIV and sexually transmitted infections in respect of infants and young girls under 5 years, primary school-age girls, adolescent girls between 12 and 19 years, and women over 20 years of age who are now observed to be actively engaged in market-gardening in the study area.

Gastropod and water sampling

Three quadrats, each measuring 20m along the waterline and 1m width offshore were delineated away from the crocodile infested axes of the lake at Nri axis (Figure 2) and studied from June to August 2018. No Station was selected from the Agulu-axis due to visible presence of crocodiles' faeces on the surroundings of the lake at Okachamma 2 (Plate 7). The three stations on the Nri axis of the lake were therefore sampled for gastropods while the physicochemical parameters of the waterlines at the stations were also determined as were done in Phase One of the study.

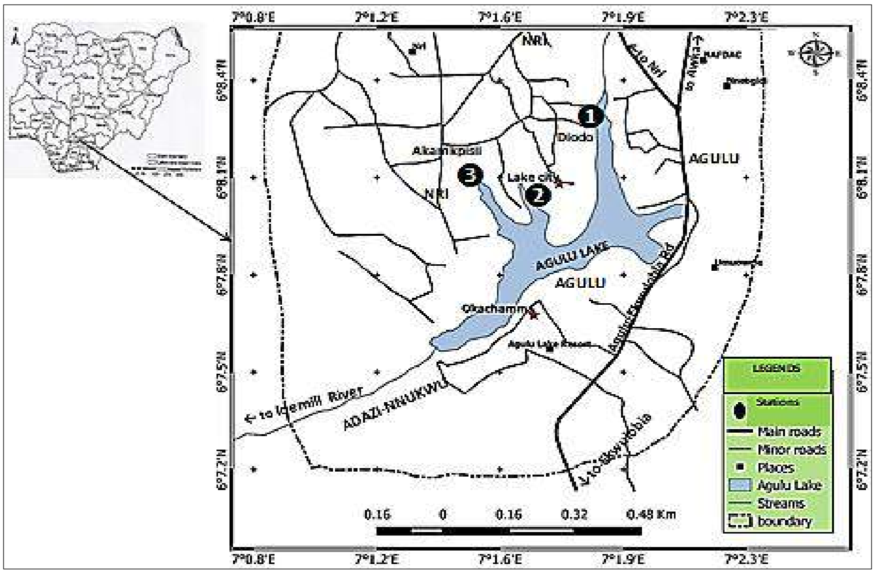

Figure 2: Nigeria (inset) showing location of Agulu Lake and the three sample sites ❶Diodo, ❷Ezu Ncheke (Lake City) and ❸Akamkpisi waterlines where human-water-contact activities had less risk of crocodile attack.

The surrounding freshwater bodies adjoining the Lake were in use for extensive vegetable gardening during this Phase Two of the study. The arms of the lake in these areas were approached with caution by members of the community who were always on the watch-out for any crocodile. GPS locations of major activities observed during this phase of the study were taken with the aid of an android cellular hand-set and recorded for further reference. Human-water contact activities where infective freshwater gastropods inhabit which usually predisposed the individuals to urogenital schistosomiasis (Okwelogu *et al*., 2012; Iwueze *et al*., 2018).

According to Ikpeze *et al.* (2020), the schistosome infection process can be visualized in the flow-chart (Figure 3) of the indirect life-cycle of *Schistosoma haematobium* showing the importance of snail as an intermediate host for the larval stages of the parasite. Human activities observed in the study area included Fish Farming besides Agulu Lake at Okachamma site (Plate 8), Clothe-washing at Akamkpisi 3 (Plate 9), Ritual performances at Akamkpisi 3 (Plate 10), Cassava processing and fermentation at Diodo (Plate 11), water-fetching by women at Ezu Ncheke (Plates 12 and 13), Vegetable gardening and children playing at Lake City Ezu Ncheke (Plates 14 and 15), and market-gardening and palm fruits harvesting and processing and vegetable garden at Diodo lake side (Plates 16, 17and 18).

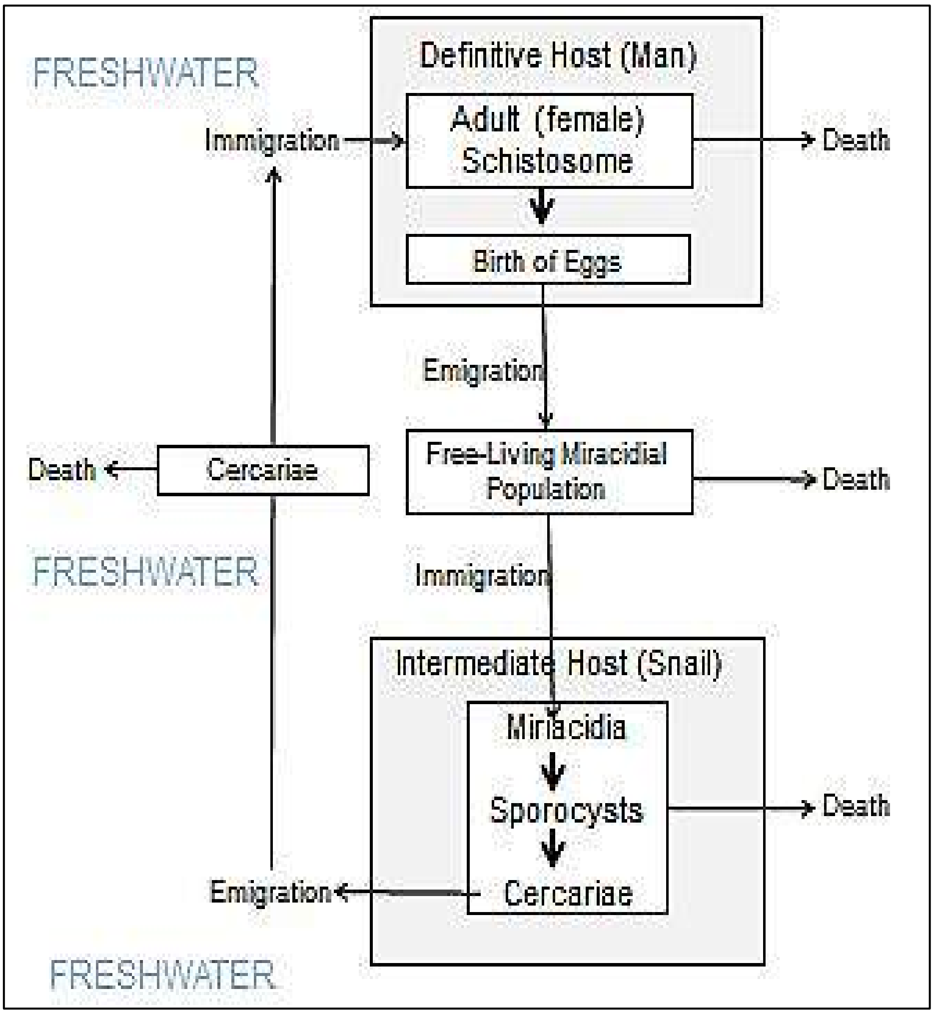

Figure 3: Flow-chart of the indirect life-cycle of *Schistosoma haematobium* showing the importance of snail as an intermediate host for the larval stages of the parasite Adult female schistosome lays eggs which are voided in urine of man. Eggs hatch in freshwater into a miracidium which penetrates the gastropod intermediate host. Larval populations of sporocysts and cercariae develop in the snail, and cercariae eventually bore out through the snail to infect the definitive host (human) to continue the life cycle but all sub-populations are subject to death processes (Ikpeze *et al.*, 2020).

Plate 8: “N6°7′56.47″: E7°2′0.21″. Fish Farming facilities besides Agulu Lake at Okachamma 2 [a[Water Pumping, [b, c] Two Concrete Fish ponds, [d] Harvested Fish for sale, [e] Tree-cutting to provide wood for fish-drying (woman taking stock of the fire-woods encircled), [f] Arrangement for open drying of harvested fish.

Plate 9: N6°7′34.23″: E7°1′16.92″. Clothe-washing at Akamkpisi 3 section of the Lake side

Plate 10: N6°7′34.23″: E7°1′16.92″. Ritual objects at Akamkpisi 3 section of the Lake side

Plate 11: N6°7′58.45″: E7°1′36.55″. Cassava fermentation at Diodo Lake side

Plate 12: N6°8′2.11″: E7°1′36.84″ Women fetching water from the Ezu Ncheke Lake City Nri-axis of Agulu Lake side

Plate 13: N6°8′0.69″: E7°1′33.50″ woman fetching water and irrigating a vegetable garden at Ezu Ncheke Lake City Nri-axis of Agulu Lake.

Plate 14: N6°8′8.12″: E7°1′34.82″. Vegetable gardens at Ezu Ncheke Lake City Nri-axis of lake side

Plate 15: N6°8′2.11″: E7°1′36.84″ Infants at vegetables nursery farms at Ezu Ncheke lake side

Plate 16: N6°8′0.69″: E7°1′33.50″ A typical household comprising an infant, 2 Primary school-age children, 2 adolescents and a woman working at their vegetable gardens at Diodo lake side.

Plate 17: N6°7′58.45″: E7°1′36.55″ Palm fruits harvesting and market gardening at Diodo

Plate 18: N6°7′58.45″: E7°1′36.55″ Market gardening by children and adult at Diodo.

RESULTS AND DISCUSSIONS (PHASE I: JUNE 2017-MAY 2018)

The gastropod species identified from the sampled stations were shown in Plates 19 and 20 while the monthly Gastropod abundance and physico-chemical parameters of water at gastropod sampling stations on the lake's waterlines were shown in Table 1.

Species of *Bulinus globosus*, *Bulinus truncatus*, *Bulinus forskalii*, *Melanoides tuberculata*, and Lymnaea *natalensis* at different growth stages were identified. The differences in ranges of the diameters of *Bulinus* species were as indicated in Plate 20 but *B. globosus* and *B. truncatus* appeared to be larger than *B. forskalii* in this environment. *The species of Melanoides tuberculata* and *Lymnaea natalensis* were longer than they were wide.

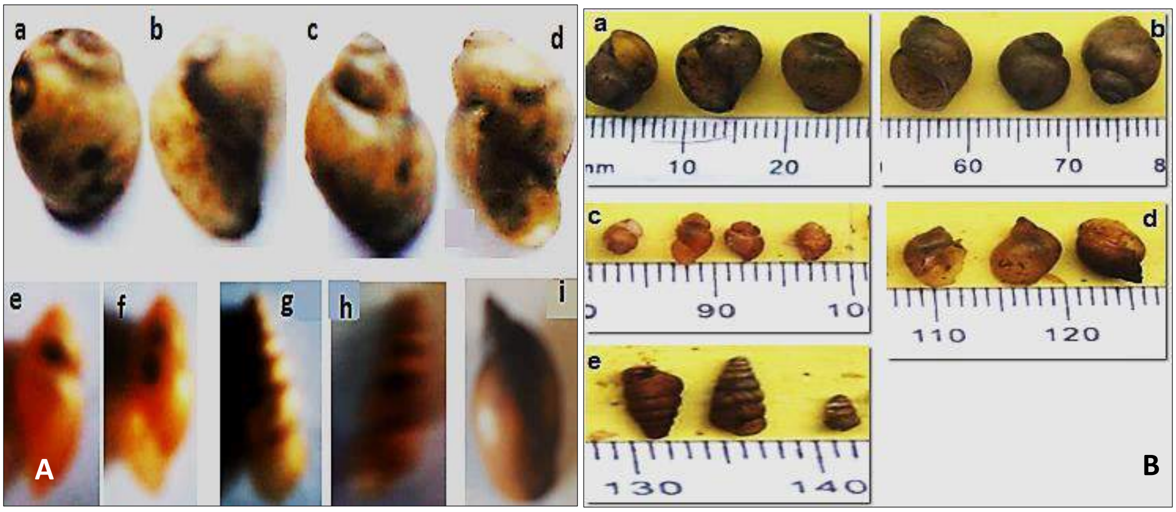

Plate 19: Freshwater gastropods identifies from Agulu Lake waterlines.
A: [a, b] *Bulinus globosus*, [c, d] *Bulinus truncatus*, [e, f] *Bulinus forskalii*, [g, h] *Melanoides tuberculata*, [i] *Lymnaea natalensis*.
B: Comparative sizes (millimeters) of representative specimens of the gastropods.
[a] *Bulinus globosus*, [b] *Bulinus truncatus*, [c] *Bulinus forskalii*, [d] *Lymnaea natalensis*, [e] *Melanoides tuberculata*.

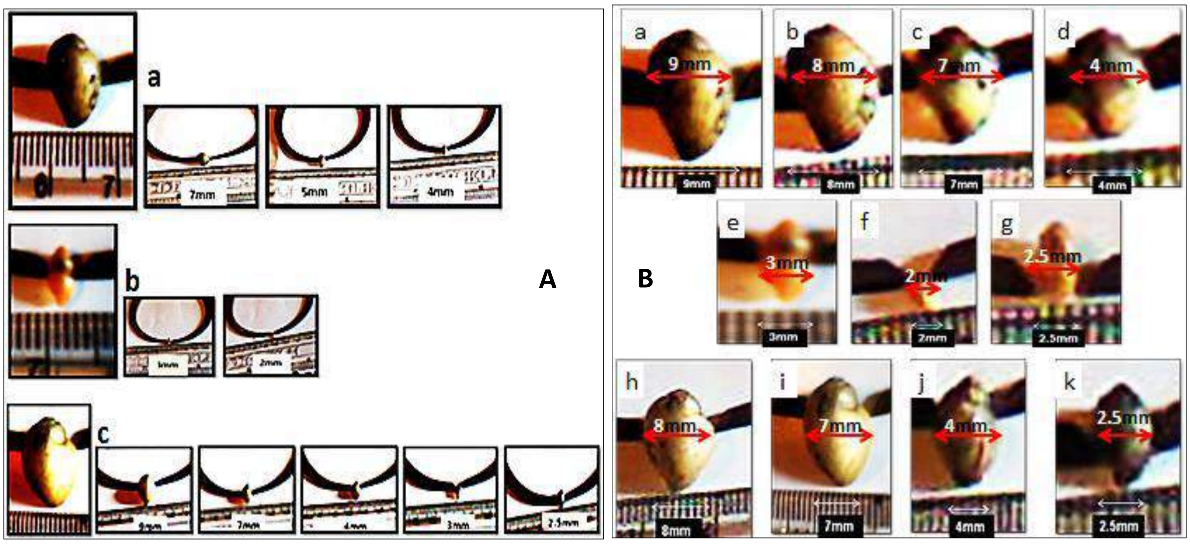

Plate 20: Comparative diameters of growth stages of *Bulinus* species.
A: Measured with bow caliper [a] *B. globosus*, [b] *B. forskalii*, [c] *B. truncatus*
B: Measured with transparent metric. [a, b, c, d] *B. globosus* (4-9mm), [e, f, g] *B. forskalii* (2-3mm), [h, I, j, k] *B. truncatus* (2.5-8mm).

Table 1: Seasonal Gastropod Abundance and Physico-chemical Parameters of lake water sampled (June 2017-May 2018)

Period	Gastropod	Depth	Transparency	Temperature	DO	Ca^{++}	pH
	No.	cm	cm	°C	mg/L	mg/L	
Wet season							
Apr. 2018	314	29.0	26.3	31.5	7.5	8.4	4.9
May 2018	829	29.7	26.5	26.3	8.8	7.3	4.7
June 2017	857	35.7	28.9	28.2	9.6	8.6	5.8
July 2017	246	42.1	30.9	24.6	3.6	10.0	7.9
Aug 2017	210	33.9	27.1	25.2	6.9	7.1	6.0
Sept 2017	209	27.8	23.0	26.3	5.7	8.1	4.1
Oct 2017	350	30.6	26.8	28.0	4.9	7.1	6.0
Total	3015						
Average	**430.7**	**32.7**	**27.1**	**27.2**	**6.7**	**8.1**	**5.6**
Dry season							
Nov 2017	1224	24.7	15.1	29.2	4.8	7.5	4.9
Dec 2017	1205	19.8	6.6	29.3	5.1	8.9	4.3
Jan 2018	655	20.1	11.0	30.2	5.1	9.1	4.2
Feb 2017	398	25.2	21.1	30.3	3.0	7.6	4.9
Mar 2017	355	20.4	11.1	32.1	4.8	8.6	4.0
Total	3837						
Average	**767.4**	**22.0**	**13.0**	**30.2**	**4.6**	**8.3**	**4.5**

The dry season had a higher average monthly abundance of 767.4 gastropods over the wet season with 430.7 gastropods (Table 1). This suggested that gastropods thrive better under the prevailing water parameters in the dry season, more especially in water temperature of about 30°C in shallow areas with higher transparency and calcium ion concentrations. Water pH appeared not to have less influence on gastropod abundance in both seasons of the year. However, the higher average gastropod abundance at Agulu-axis over the Nri-axis. of the lake (Table 2) seemed to confirm that higher abundance may be related to low water depth and high calcium ion but not to pH.

Table 2: Gastropod Abundance and physico-chemical parameters of water at locations

Location	Station	Gastropods	Depth	Transparency	Temperature	DO	Ca^{++}	pH
		No.	cm	cm	ºC	mg/L	mg/L	
Agulu axis	1	2010	13.1	8.4	26.6	5.4	8.5	7.5
	2	1497	14.8	10.1	27.6	5.6	8.6	7.8
	3	309	33.6	27.1	31.0	7.1	6.5	9.4
	4	779	16.8	14.5	27.2	6.6	6.7	8.4
	Total	4595						
	Average	**1148.7**	**19.6**	**15.0**	**28.1**	**6.2**	**7.6**	**8.3**
Nri axis	5	257	28.8	24.6	30.8	6.7	4.1	9.2
	6	286	26.7	24.1	25.2	6.7	4.0	9.0
	7	1381	17.8	11.7	27.7	6.2	8.3	7.5
	8	333	36.1	24.8	25.4	6.9	5.4	9.0
	Total	2257						
	Average	**564.2**	**27.3**	**21.3**	**27.3**	**6.6**	**5.4**	**8.7**

The overall seasonal abundance of the gastropod species identified during the study has been shown in Table 3 where *Bulinus globosus* and *B. truncatus* each had a greater abundance in the dry than in the wet season. *Melanoides tuberculata* was recovered in very small numbers, especially in the dry season. It could be that the environment was not favourable for it or it may be facing extinction in the area. We need further research to prove this. A cursory look at the abundance of gastropod species (Table 4) will reveal that *B. forskalii* and *M. tuberculata* were almost extinct at Agulu Agulu-axis while *L. natalensis* and *M. tuberculata* were also going extinct from Nri-axis. This should give concern to environmental ecologists.

Table 3: Overall monthly abundance of gastropod species sampled from Agulu Lake

Month	Gastropods	Gastropod species no.				
	No.	*L. natalensis*	*B. globosus*	*B. truncatus*	*B. forskalii*	*M. tuberculata*
Wet season						
April 2018	314	109	32	99	74	0
May 2018	829	412	105	136	165	11
June 2017	857	442	217	108	83	7
July 2017	246	127	93	15	8	3
Aug. 2017	210	51	60	17	82	0
Sept. 2017	209	78	45	74	12	0
Oct. 2017	350	108	104	101	36	1
Total	3015	1327	656	550	460	22
Average	**430.7**	**189.6**	**93.7**	**78.6**	**65.7**	**3.1**
Dry season						
Nov. 2017	1224	265	404	357	198	0
Dec. 2017	1205	224	386	409	186	0
Jan. 2018	655	100	276	257	22	0
Feb. 2018	398	94	133	138	31	2
Mar 2018	355	78	101	113	63	0
Total	3837	761	1300	1274	500	2
Average	**767.4**	**152.2**	**260.0**	**254.8**	**100.0**	**0.4**

Table 4: Abundance of gastropod species from Agulu and Nri axes

Location	Stations	Gastropods No.	Gastropod species No.				
			L. natalensis	*B. globosus*	*B. truncatus*	*B. forskalii*	*M. tuberculata*
Agulu axis	1	2010	1011	480	509	0	10
	2	1497	685	413	393	0	6
	3	309	109	101	98	0	1
	4	779	258	204	314	0	3
	Total	4595	2063	1198	1314	0	20
	Average	**1148.7**	**515.7**	**299.5**	**328.5**	**0.0**	**5.0**
Nri axis	5	257	25	83	146	0	3
	6	286	0	110	67	109	0
	7	1381	0	486	216	678	1
	8	333	0	79	81	173	0
	Total	2257	25	758	510	960	4
	Average	**564.2**	**6.3**	**189.5**	**127.5**	**240.0**	**1.0**

RESULTS AND DISCUSSIONS (PHASE II OF THE STUDY)

Freshwater gastropods recovered from sampled stations were shown in Plate 21. Gastropod abundance as well as the monthly gastropod abundance with physicochemical parameters of water determined has been presented in Tables 5 and 6, respectively. Table 7 also showed the abundance of gastropod species identified from sampled stations.

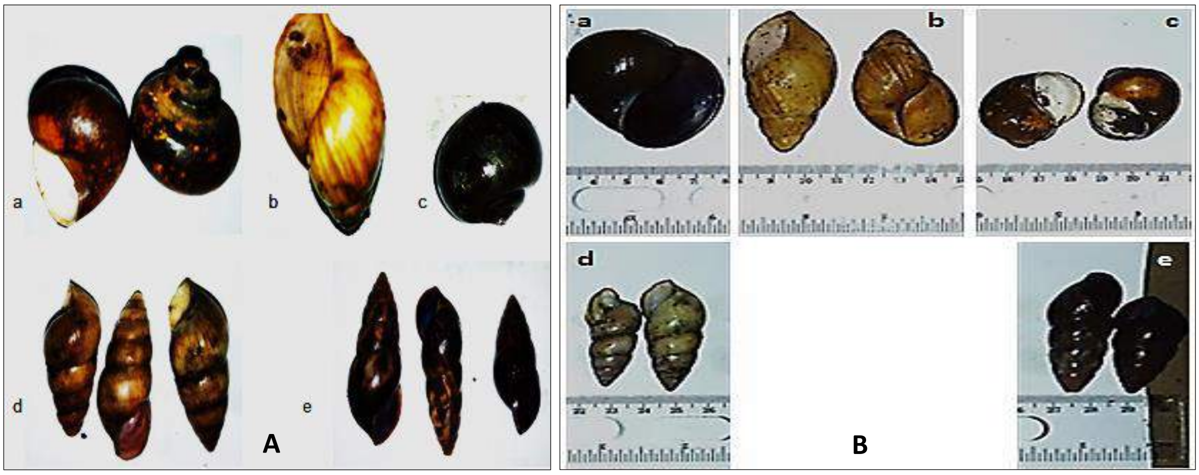

Plate 21: Representative specimens of freshwater gastropods recovered from sampled sites at Nri-axis of Agulu Lake. Plate 21A showed [a] *Bulinus globosus*. [b] *Lymnaea natalensis*, [c] *Bulinus truncatus*, [d] *Bulinus forskalii*, and [e] *Melanoides tuberculata*.
Plate 21 B indicated the **r**elative size measurements (millimeters) of the growth stages of the different species of the gastropods recovered [a] *B. globosus* 22.5x14mm, [b] *L. natalensis* 25x14.5mm, [c] *B. truncatus* 14.5x10mm, [d] *B. forskalii* 28mm long, and [e] *Melanoides tuberculata* 27mm long.

From Table 5, Diodo had a monthly average of 176 gastropods recovered from it, which was more abundant than Ezu Ncheke (Av. 122.3) and Akamkpisi (Av. 31.7). Also the month of June (Table 6) recorded the highest number of gastropods, perhaps before heavy rains swept them away in July and least number was recovered in August.

Other water parameters did not fluctuate noticeably within the three month period or between the stations. However, intense human activities were observed at Diodo and Ezu Ncheke, where extensive market gardening and cassava processing flourished. These activities may not be without risks of schistosomiasis since the species of gastropods identified in Table 7 are well-known intermediate hosts of the larval stages of *Schistosoma haematobium*. Out of the 990 gastropods recovered in three months, *Bulinus* species comprised 531 or about 53.6%.

The presence of *L. natalensis* (n=450) or about 45.5% of all gastropods collected portends serious danger because it is the intermediate host for Fasciola species that cause human and animal Fascioliasis, which is transmitted by consumption of edible raw vegetables containing encysted larvae of the giant liver fluke, *Fasciola gigantica*.

Table 5: Gastropod abundance and physico-chemical parameters of water at sample Stations

Stations	Gastropods		Depth	Transparency	Temperature	DO	Ca^{++}	pH
	No.		cm	cm	^{o}C	mg/L	mg/L	
Diodo	528		16.77	14.18	26.85	6.56	6.70	8.39
Ezu Ncheke	367		13.15	8.43	26.61	5.38	8.50	7.56
Akamkpisi	095		26.71	24.12	25.23	6.71	4.04	9.00
Total	990	Average	18.88	15.58	26.23	6.22	6.41	8.32
Average	330							

Table 6: Monthly gastropod abundance and physicochemical parameters of water determined

Month	Gastropods		Depth	Transparency	Temperature	DO	Ca^{++}	pH
	No.		cm	cm	^{o}C	mg/L	mg/L	
June	483		18.67	15.03	26.48	6.08	6.52	8.34
July	372		18.89	15.71	25.98	6.33	6.43	8.21
August	135		19.08	15.99	26.24	6.24	6.30	8.40
Total	990	Average	18.88	15.58	26.23	6.22	6.41	8.32

Table 7: Abundance of gastropod species identified from sampled stations

Stations	Gastropods	Gastropod species				
	No.	*L. natalensis*	*B. globosus*	*B. truncatus*	*B. forskalii*	*M. tuberculata*
Diodo	528	240	120	80	81	9
Ezu Ncheke	367	210	110	45	0	3
Akamkpisi	95	0	70	25	0	0
Total	990	450	300	150	81	12

CONCLUSION

Gastropod intermediate hosts for the larval stages of *Schistosoma haematobium* that causes Urogenital Schistosomiasis were identified from Agulu Lake area. Some physico-chemical water parameters of Agulu Lake that also influence gastropod abundance in the area were also determined. Recent crocodile infestation of the lake has limited human-water contact activities in Agulu-axis, but there has been an increase in market-gardening activities at the Nri-axis which may expose the women and children concerned to increased risk of urinary schistosomiasis and soil-transmitted helminth infections. This evidence-based research will help health-policy makers to mount urgent awareness programme and adequate health intervention in this community and elsewhere with similar circumstances in the country.

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