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# Factors affecting seasonal abundance of gastropods of public health importance found at Agulu Lake shorelines in Nigeria

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## ABSTRACT

*Agulu Lake is one of 366 geo-referenced Schistosomiasis endemic foci in Nigeria. There is a dearth of publication on the gastropod intermediate hosts for larval stages of Schistosoma haematobium that cause urinary Schistosomiasis in Agulu. Gastropod abundance was determined by sampling eight stations on Agulu Lake shorelines from November 2012 to October 2013, using scoop net sampling and hand picking techniques, supplemented by 20 minutes manual search over aquatic plants and suspended materials in each sampled quadrat. Total abundance of gastropods encountered was 6866, which comprised Bulinus globosus 1957(28.5%), B. truncatus 1832(26.7%), B. forskalii 964(14%), Lymnaea natalensis 2089(30.4%) and Melanoides tuberculatus 24(0.4%). Mean seasonal density of gastropod/m$^2$ was 4.81±3.07 for dry season and 3.77±2.63 for rai ny season while spatial density for Agulu and Nri arms of the lake were 5.1±4.43 and 3.48±2.3, respectively. Generally, gastropod density was strongly and positively correlated with calcium ions but negatively correlated with water transparency, depth, dissolved oxygen and pH. However, water temperature showed little influence on gastropod abundance. Further work on molecular identification of the gastropods and their Schistosome infectivity status is needed because of human-water-contact activities in Agulu Lake and its environs.*

***Keywords:*** *Agulu Lake, water parameters, Gastropod density, Schistosomiasis*

## INTRODUCTION

Schistosomiasis is a parasitic infection that is endemic in 76 countries of the world[1], and second to malaria in terms of socio – economic and public health significance particularly in 44 endemic countries in Africa including Nigeria[2] where large populations of children are infected by the age of fifteen[3,4]. Gastropods have diverse habitats in freshwater, marine and terrestrial environments[5]. It has been stated that without snails there can be no Schistosomiasis and because Schistosome transmitting snails occur in very particular ecological circumstances that are subject to rapid change in an increasingly human – dominated world, understanding the future of this neglected yet persistent human diseases require experiences on how snail species are being affected by global changes in climate, increased pollution of aquatic habitats, continued transport of exotic and invasive species, construction of dams and irrigation systems, mass movement of humans and changes in human population density and standard of living[6].

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Human interventions in developing water systems have affected ecology of aquatic environments creating favorable conditions for aquatic fauna, and have greatly increased the prevalence of gastropods and trematode infections in several countries[7]. Parasitic trematodes and their gastropod intermediate hosts are integral parts of the freshwater ecosystem in which their distributions appear to be focalized. *Bulinus, Biomphalaria and Onchomelania* species have been associated with specific Schistosome parasites of man. Genus *Bulinus* host *Schistosoma haematobium* and *S. intercalatum* while *Biomphalaria* and *Onchomelania* species transmit *S. mansoni* and *S. japonicum* respectively[8]. Water temperature, transparency, pH, dissolve oxygen and calcium ion concentration are among water parameters known to operate in lake ecosystems[9]. The depth of water bodies and transparency are found to affect distribution of freshwater invertebrate dwellers. These factors combine to determine water quality and generally affect the population of freshwater gastropods[10]. Rainfall appears to pose the greatest influence on freshwater snails' distribution and population dynamics. In Nigeria, there are profound periods of dry and rainy seasons and gastropods are able to aestivate during unfavorable conditions especially in the temporary waters systems. The presence of freshwater gastropods suggests possibility of parasites transmission in an area. Therefore targeting the intermediate hosts remains an essential component of the integrated control strategies in a Schistosomiasis endemic area because of the cost effectiveness of other control methods, and the fact that certain water-associated activities like washing, swimming and fishing which are essential for the transmission of the disease are not likely to change with health education or provision of treated portable water[11]. The prevalence of urinary Schistosomiasis in Agulu community have been extensively studied[12,13,14,15,16,17] but there is dearth of information on the abundance of freshwater gastropods that are intermediate hosts of human and animal trematodes that cause urinary Schistosomiasis in the area. The aim of the present study on abundance of freshwater gastropods of public health importance in Agulu Lake area of Anambra State Nigeria was to identify the gastropods, determine their seasonal and spatial distributions and establish any relationship between their density and some water parameters of Agulu Lake shorelines.

## MATERIALS AND METHODS

**Study area:** Agulu (latitude 6º06˙N and longitude 7º03˙E) has an outstanding terrain that rises from the Niger valley in the West to a height of about 1000 feet above sea level. Agulu Lake in is one the 366 Schistosomiasis haematobium Geo-referenced endemic foci in Nigeria[18]. The lake is approximately 81 hectares and stretches for about 2 kilometers, and is the Head-stream of Idemili River which is tributary of the River Niger. It is bounded by three communities of Agulu, Nri, and Adazi-Nnukwu whose inhabitants utilize the lake for washing, drinking, fishing, swimming, cassava fermentation, and for isolated ritual purposes. Many commercial outfits including a National Diagnostic Centre and a University Faculty of Pharmaceutical Sciences are located in around the area.

**Sample stations and snail sampling technique:** Eight (8) sample stations were selected along the arms of Lake; 4 each on the Agulu- and Nri-arms, respectively (Figure 1).

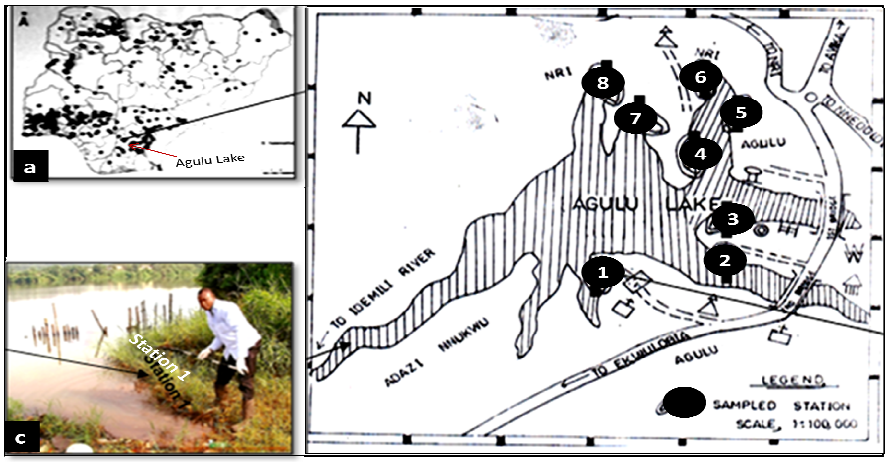


**Fig. 1: (a)** The 366 Schistosomiasis haematobium Geo-referenced endemic foci in Nigeria [18] include Agulu Lake, **(b)** The 8 stations sampled for gastropods along Agulu Lake shorelines **(c)** Human activity at Station 1 of Agulu Lake.

A quadrat of $20m^2$ along the shoreline was delineated from each of the 8 stations and sampled for gastropods once monthly from November 2012 to October 2013 hydrologic year, using scoop net and hand picking technique for collection of snails as described by[19,20,21]. All snails recovered were kept in pre-labeled plastic containers[22] which were taken to the laboratory for counting and identification[5]. Relative size measurements of the identified species were depicted centimeters.

**Analysis and measurements of water parameters:** Water samples from each station were analyzed for pH, Dissolved Oxygen (DO), and Calcium ion using standard laboratory procedures. Water temperature, transparency and depth were also recorded *in situ*.

**Statistical analysis:** Descriptive statistics were computed for all relevant data. Chi square ($\chi^2$) analysis was used to compare the association among groups for statistical significance. Correlation analysis was also used to compare relationship between gastropod density and values determined for water parameters of the lake.

## RESULTS AND DISCUSSIONS

Five species of fresh water gastropods namely, *Bulinus globosus*, *Bulinus truncatus*, *Bulinus forskalii*, *Lymnaea natalensis* and *Melanoides tuberculatus* were encountered in Agulu Lake shorelines and their comparative sizes and characteristic shapes are shown in Figure 2. Co-existence of *M. tuberculatus* with other trematode vectors like *B. globosus*, *B. truncatus* and *Lymnaea natalensis* has been reported in several water bodies by other workers[19,23].

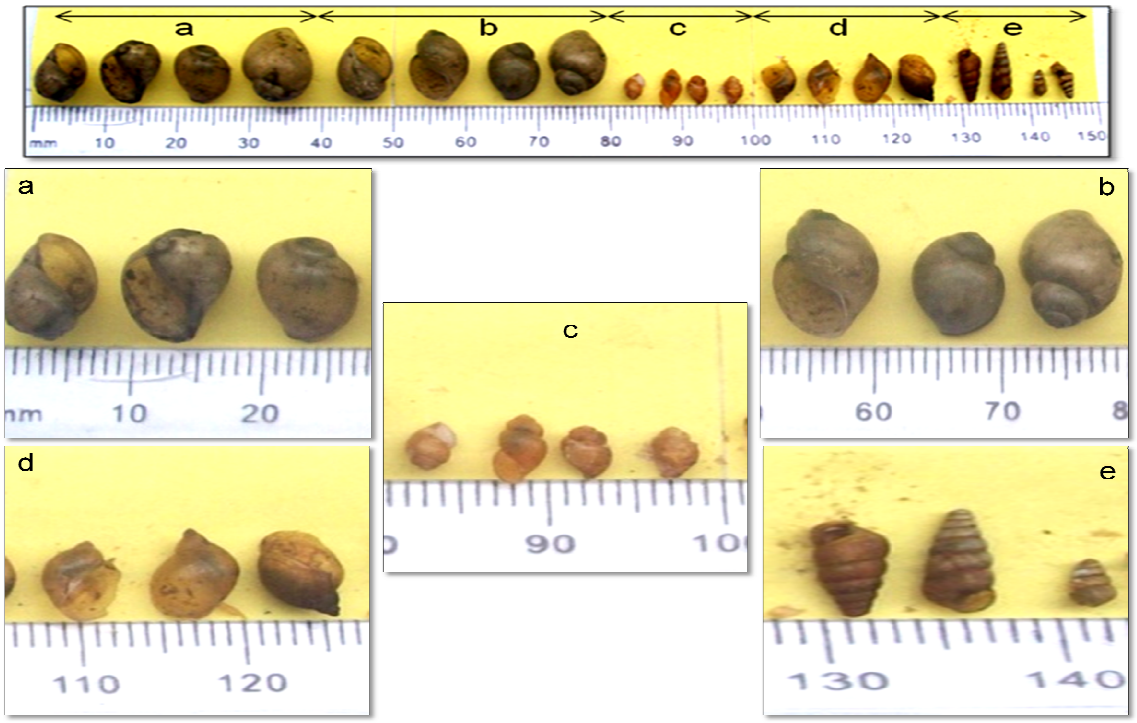


**Fig. 2:** Relative scale measurements (millimeters) of representative samples of fresh water Gastropods recovered from shorelines of Agulu Lake. **(a)** *Bulinus globosus*; **(b)** *Bulinus truncatus*; **(c)** *Bulinus forskalii*; **(d)** *Lymnaea natalensis*; **(e)** *Melanoides tuberculatus*.

Tables 1 showed the seasonal variations in abundance and density of the 5 species of freshwater gastropod encountered in Agulu Lake shorelines. The higher abundance of gastropods in dry season than rainy season is in agreement with the report[20] that snails' population expands in dry season and contracts during the rainy season. A seasonal trend in species population with high population peak during and or shortly after the rainy season was also reported[9]. However, seasonal fluctuations in snails' density has been tagged to seasonal rainfall pattern and habitat volume[25]. *M. tuberculatus* in Agulu lake shorelines had similar pattern with other widely

documented reports[26,27,28,29,30,31]. Lower gastropod density in late wet season of July to October (Figure 3) indicated that most snail species would be washed to different places or into the lake where they died easily but *L. natalensis* which mostly implicated in Fasciolosis in ruminants in the area and which attached to elephant grasses, showed higher density in rainy season (Figure 4). Generally, rainfall possesses greatest effect on freshwater snails' population dynamics[11,32] as heavy flooding that usually accompanied rainfall aided in the dispersal of aquatic fauna including gastropods, thereby decreasing their density in the given foci. Flooding does not support high density of snail species, and low snail density during the peak rainy season has been attributed to flushing out of snails by flood waters[33,34,35,36]. Dry season has been associated with high rates of biological activities as well as increased frequency of snails' occurrence[36]. The prevailing ecological conditions during dry season is therefore regarded as being more favorable to snails than those of rainy season[37].

**Table 1. Seasonal variations in freshwater gastropod abundance in Agulu Lake shorelines**

| Season | *Bulinus globosus* (n=1957) 28.46% | *Bulinus truncatus* (n=1832) 26.68% | *Bulinus forskalii* (n=964) 14.03% | *Lymnaea natalensis* (n=2089) 30.42% | *Melanoides tuberculatus* (n=24) 0.35 % | *Abundance (n=6866) 100% | ‡Density |
|---|---|---|---|---|---|---|---|
| **Dry season:** | | | | | | | |
| Nov-2012 | 404 | 357 | 198 | 265 | 0 | 1224 | 7.65 |
| Dec- 2012 | 386 | 409 | 186 | 224 | 0 | 1205 | 7.53 |
| Jan-2013 | 276 | 257 | 22 | 100 | 0 | 655 | 4.09 |
| February | 133 | 146 | 31 | 94 | 2 | 406 | 2.54 |
| March | 101 | 113 | 63 | 78 | 0 | 355 | 2.22 |
| *Abundance | 1300 | 1282 | 500 | 761 | 2 | 3845 | |
| ‡Density | 8.12 | 8.01 | 3.13 | 4.76 | 0.0125 | Mean± SD=4.81±3.07 | |
| Relative % | 18.90 | 18.67 | 7.28 | 11.08 | 0.03 | 56 | |
| **Rainy season:** | | | | | | | |
| April 2013 | 32 | 99 | 74 | 109 | 0 | 314 | 1.96 |
| May | 105 | 136 | 169 | 412 | 11 | 833 | 5.21 |
| June | 217 | 108 | 83 | 443 | 7 | 858 | 5.36 |
| July | 93 | 15 | 8 | 127 | 3 | 246 | 1.54 |
| August | 60 | 17 | 82 | 51 | 0 | 210 | 1.31 |
| September | 45 | 74 | 12 | 78 | 0 | 209 | 1.31 |
| Oct-2013 | 105 | 101 | 36 | 108 | 1 | 351 | 2.19 |
| *Abundance | 657 | 550 | 464 | 1328 | 22 | 3021 | |
| ‡Density | 4.11 | 3.43 | 2.9 | 8.3 | 0.1375 | Mean± SD=3.77±2.63 | |
| Relative % | 9.56 | 8.01 | 6.75 | 19.34 | 0.32 | 44 | |

* Abundance = Total individuals, ‡Density of Gastropod/$m^2$ = Abundance ÷ (no. of quadrats x area of each quadrat)[24].

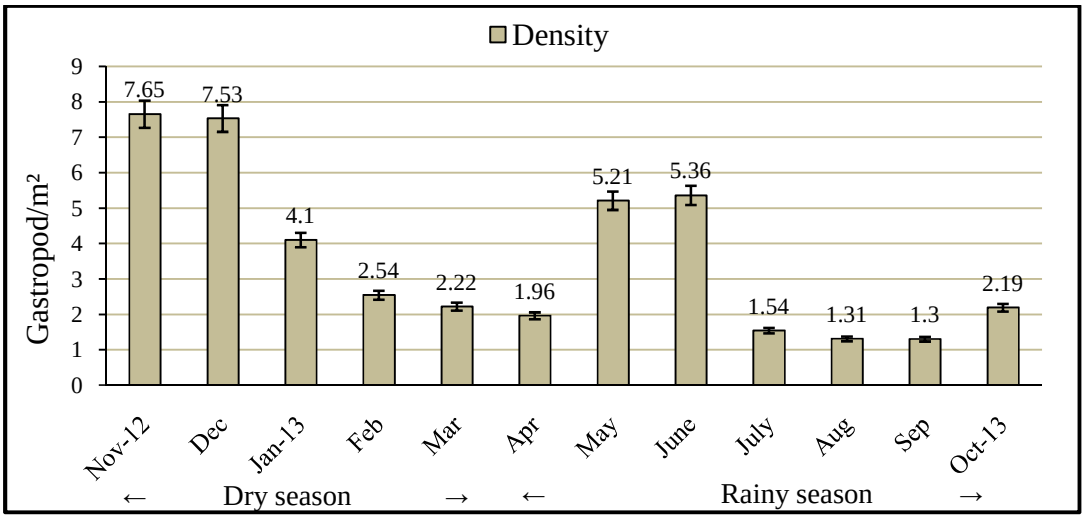


**Fig. 3:** Monthly\ seasonal trends in gastropod density in Agulu Lake shorelines

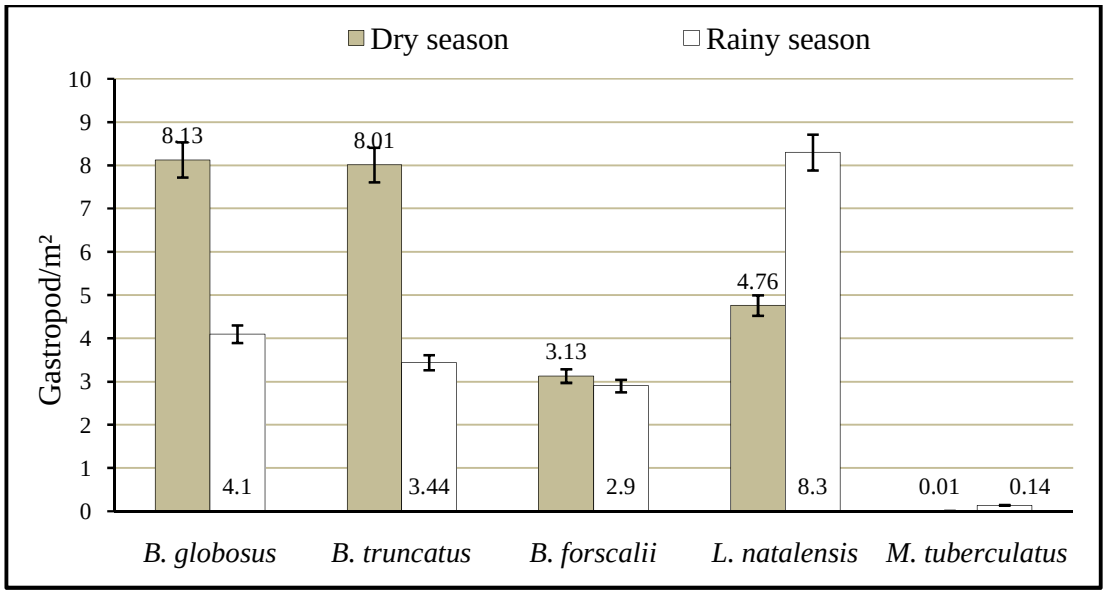


**Fig. 4:** Seasonal density of individual gastropod species in Agulu Lake shorelines

Table 2 showed the spatial variations in abundance of the 5 species of freshwater gastropod in Agulu Lake shorelines. *B. globosus* and *B. truncatus* were present at all stations against others that were absent from one or more stations. *B. forskalii* was not encountered at stations 1 to 5 while *L. natalensis* was absent from stations 6 to 8. The co-existence of the sub-class Pulmonata in same foci signified they have same ecological niche but the absence of *L. natalensis* from two stations 6, 7 and 8 located at Nri arm of the lake could mean that the species dispersal is moving northward from Agulu arm or that limnological conditions there were not favourable for the species survival. *Physa acuta* was observed in Agulu Lake area where it co-existed with *Bulinus* species[16]. However we did not recover *Physa* species; perhaps *P. acuta* had gone into extinction since[16] also reported that only six *Physa acuta* were identified out of hundreds of other snails collected by them. *Bulinus* species were collected from sub-merged plant vegetations at the water shores, while most of the lymnaeid snails were observed attaching themselves to floating materials on the peripheral surface of water near the bank. This observation is a confirmation to the report of that freshwater lymnaeid seemed to prefer peripheral sites of water bodies[24]. Spatial distributions of the freshwater gastropods also differ significantly between the stations (Figure 5).

Variations in gastropods' density at sampled stations could be linked with nature and level of human-water contact activities. Human activities like fetching of water, washing of farm tools and produce, bathing, swimming and fishing observed in Agulu Lake were also reported in River Ulasi in southern Nigeria[2] and in Opa Reservoir and Research Farm Pond[23], where mean duration of individual contact ranged from 1 minute of washing limbs to more than 5 hours of fishing. Higher numbers of snails collected from stations 1, 2, 5, and 7 (Figure 5) were thought to be related to increased frequency of contacts due to human activities at these sites which apparently created favourable microhabitats for the gastropods[38]. Zones of different human activities have been referred to as shallow shocked areas where one would collect aquatic organisms[39]. Definitely polluted Agulu Lake is a still water body, the kind which would necessitate the establishment of snail species[40]. The overall low density of *M. tuberculatus* observed in both Agulu and Nri arms of the lake (Figure 6) could be due to their habitats at edges of river beds and stream banks where water current is high[30,31,41] as well as their nocturnal behavior[42].

**Table 2. Spatial variations in freshwater gastropod abundance in Agulu Lake shorelines**

| Stations | *Bulinus globosus* (n=1957) 28.5% | *Bulinus truncatus* (n=1832) 26.7% | *Bulinus forskalii* (n=964) 14% | *Lymnaea natalensis* (n=2089) 30.4% | *Melanoides tuberculatus* (n=24) 0.4% | *Abundance (n=6866) 100% | ‡Density |
|---|---|---|---|---|---|---|---|
| Agulu Arms: | | | | | | | |
| Station 1 | 481 | 517 | 0 | 1012 | 10 | 2020 | 12.63 |
| Station 2 | 413 | 393 | 0 | 685 | 6 | 1497 | 9.35 |
| Station 3 | 101 | 98 | 0 | 109 | 1 | 309 | 1.93 |
| Station 4 | 83 | 146 | 0 | 25 | 3 | 257 | 1.6 |
| *Abundance | 1078 | 1154 | 0 | 1831 | 20 | 4083 | |
| ‡Density | 6.74 | 7.21 | 0 | 11.44 | 0.125 | Mean± SD=5.1±4.43 | |
| Nri Arms: | | | | | | | |
| Station 5 | 204 | 314 | 0 | 258 | 3 | 779 | 4.87 |
| Station 6 | 110 | 67 | 109 | 0 | 0 | 286 | 1.79 |
| Station 7 | 486 | 216 | 682 | 0 | 1 | 1385 | 8.66 |
| Station 8 | 79 | 81 | 173 | 0 | 0 | 333 | 2.08 |
| *Abundance | 879 | 678 | 964 | 258 | 4 | 2783 | |
| ‡Density | 5.49 | 4.24 | 6.03 | 1.61 | 0.025 | Mean± SD=3.48±2.3 | |

* Abundance= Total individuals; ‡Density (Gastropod/$m^2$) = Abundance ÷ (no. of quadrats) x (area of each quadrat) [24]

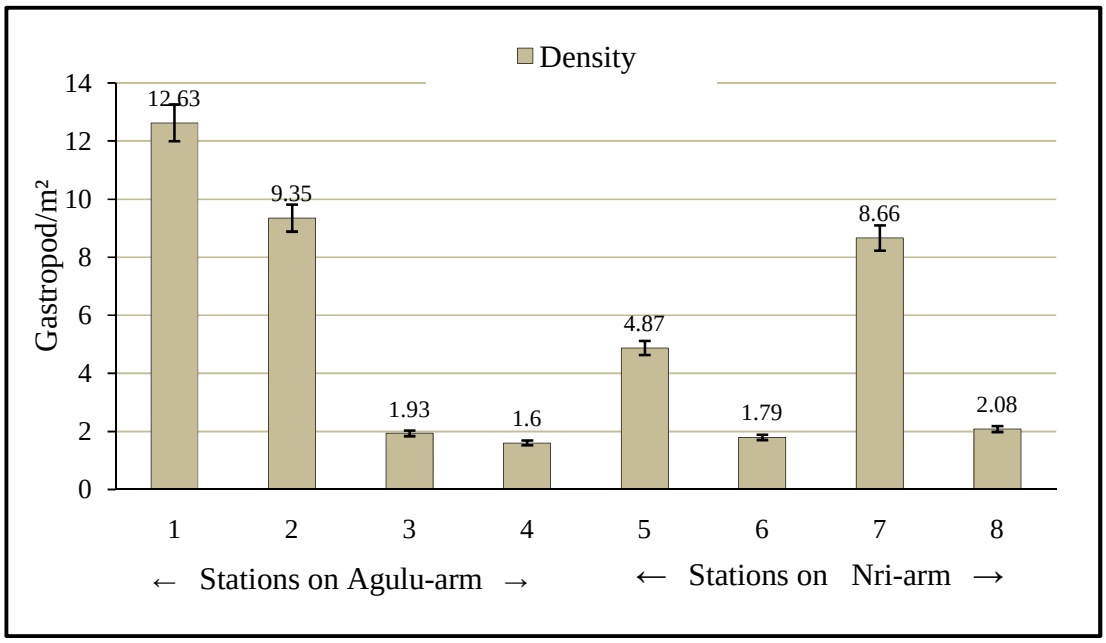


**Fig. 5:** Overall gastropod density at Stations in Agulu Lake shorelines

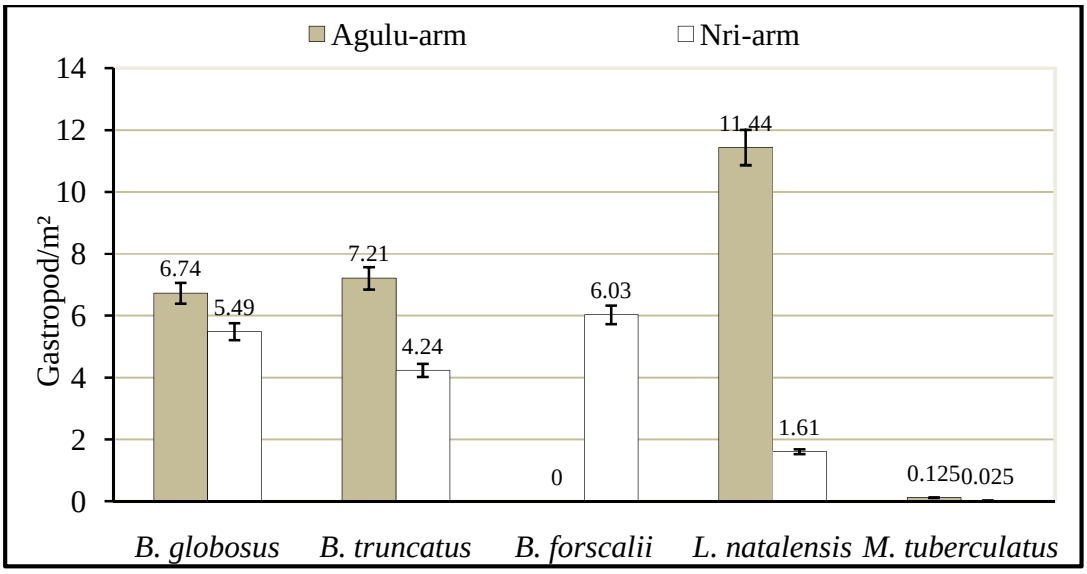


**Fig. 6:** Specific gastropod density in Agulu-arm and Nri-arm of Agulu Lake shorelines

The recent attack and killing of a school pupil by a crocodile in Agulu Lake has made the lake a high risk area. The incidence had drastically reduced the frequency of human-water contacts. However, wary local farmers still plant vegetables at the banks, while fishermen and raffia-palm wine tappers who visited the lake were watchful of crocodile attack, being ignorant of potential risk of Schistosomiasis transmission. Reduced frequency of visit to the lake by children implied that prevalence of Schistosomiasis among that age-group would decrease.

It had been observed that pronounced seasonal variations in temperature and rainfall in tropical systems influence other physicochemical characteristic of water bodies[20,42].

Variations in some physical and chemical water parameters of sample stations in Agulu Lake shorelines thought to affect gastropod abundance such as temperature, transparency, depth; dissolved oxygen (DO), calcium ion ($Ca^{++}$) and hydrogen ion (pH) concentrations are shown in Table 3 while correlation between gastropod density and these water parameters are presented in Figure 7.

**Table 3:** Variations in spatial gastropod density and water parameters of Agulu Lake

| Stations | Density (Gastropod/$m^2$) | Temperature ºC | Transparency cm | Depth cm | DO mg/L | $Ca^{++}$ mg/L | pH |
|---|---|---|---|---|---|---|---|
| 1 | 12.62 | 26.6 | 8.4 | 13.1 | 5.4 | 8.5 | 7.5 |
| 2 | 9.35 | 27.6 | 10.1 | 14.8 | 5.6 | 8.6 | 7.8 |
| 3 | 1.93 | 31.0 | 27.1 | 33.6 | 7.1 | 6.5 | 9.4 |
| 4 | 1.61 | 30.8 | 24.6 | 28.8 | 6.7 | 4.1 | 9.2 |
| 5 | 4.87 | 27.2 | 14.5 | 16.8 | 6.6 | 6.7 | 8.4 |
| 6 | 1.78 | 25.2 | 24.1 | 26.7 | 6.7 | 4.0 | 9.0 |
| 7 | 8.66 | 27.7 | 11.7 | 17.8 | 6.2 | 8.3 | 7.5 |
| 8 | 2.08 | 25.4 | 24.8 | 36.1 | 6.9 | 5.4 | 9.0 |
| Averages | | 27.68 | 18.16 | 23.46 | 6.4 | 6.51 | 8.47 |

Water temperature range of 25.2-30.8$^0$C obtained for Agulu Lake (Table 3) was closely related to those reported from water bodies in other endemic areas in Nigeria such as 23-33$^o$C in Imo State[20] and 22-28$^o$C for Moro Lake in Kwara State[44], both in Nigeria. However, water temperature showed little influence on gastropod density but we observed that high temperature beyond 30$^o$C (Figure 7a) would be lethal to gastropod development. As fewer snails were encountered in hotter periods of March and April and at Stations 3 and 4 with higher temperatures.

Water transparency decreased with rains as flooding washed down suspended materials and mud soil into the Lake which brought about turbidity\mixing that led to decrease in the clearness of the lake. This kind of report had been noted by[44] who described lower Secchi disc value due to washing of suspended particles into Moro Lake. Transparency was also known to facilitate the penetration of sunlight to the bottom of water particularly in the littoral zone encouraging the establishment and proliferation of aquatic weeds.

Water depth varied according to habitat stations and such variations accounted for the differences in the number of snails collected from various stations. The more polluted the water is, the less transparent it becomes and such zones favour snails existence. Thus, habitats with high depth maintained minimal snail populations while those with low depth had maximum numbers of snails (Table 3). The same situation was reported at Opa Reservoir and Research Farm pond Ile-Ife, Nigeria by investigators who observed that *Bulinus* snails inhabit the shallow part of the water bodies[45]. This showed that freshwater snails only colonize the ecological shorelines of the water bodies which were regarded as the shallowest part. There was a linear relationship between transparency and water depth (Figure 7b&c), with strong negative correlation between gastropod density, in line with[25] who attributed seasonal fluctuations in snails' density to variations in habitats' volume and rainfall.

Variations in Dissolved oxygen (DO) with temperature observed during this research supported that DO tended to reduce with increased temperature[20]. Low range of DO observed in Agulu Lake was closely related to the range of 3.2-6.8mg/l reported from Moro Lake[44] but was far lower than 17-35mg/l reported for Light House Beach and polluted Creeks in Lagos[46]. However, low oxygen level has been linked to slow flowing nature of waters which could limit oxygen level[47]. Relatively higher DO at Stations 3 and 8 could be attributed to lesser use of these sites for microbial activities because such places were not known as refuse dumping sites neither were ritual materials found around the area which would have necessitated serious microbial putrefaction. The lower values of DO at Stations 2, 5 and 7 were thought to be due to cumulative human activities in these areas and dumping of ritual materials. In such polluted areas, oxygen would be greatly utilized during microbial metabolic processes. There was a negative correlation between DO and gastropod density (Figure 7d) as the gastropods clustered at a range of 5.4-7mg/l, similar to 5.1–6.4mg/l at Opa Reservoir and Research Farm Pond[45], suggesting that DO showed little correlation with snails' density. It had been observed that density of pulmonates increased with increasing DO while that of prosobranchs decreased[21]. Mostly *L. natalensis* but not other pulmonates were seen in the open water at Nri-arm of Agulu Lake (Figure 6) which suggested that they needed high oxygen. This exertion agrees with reports that *Lymnaea* snails float on water surface because they require high oxygen concentration[48,49].

Calcium ion concentration in Agulu Lake was found to vary according to sampled stations and could be dependent on nature and rate of inflow of materials containing Calcium compounds from adjoining farms. Cement substances, chippings and other dusts from nearby COTAB Construction Company were also flooded into the lake and could raise its $Ca^{++}$ level. Calcium in Agulu Lake may be important for snails' growth, egg laying and shell building as calcium was important in shell formation and regulation of tissue permeability according to workers who also reported that $C_9^{++}$ in freshwaters was reasonably high to support snail's survival in Jos[28]. More gastropods were collected from Stations 1, 2, 5 and 7 (Figure 5) where Calcium levels were high (Table 3), an indication that the Calcium level was probably up to the range for supporting snails' survivals, growth and reproduction. A strong positive correlation existed between Calcium ion concentration and gastropod density (Figure 7e).

Average pH 8.47 of surface waters of sampled stations in Agulu Lake was in line with earlier reports in Agulu Lake[50,51] of high pH of 8.45 and 9.00, which conclusively showed that the lake witnesses an alkaline environment. Though some authors maintain that pH was

rarely a factor limiting snails distribution[21,51], our finding was similar to pH ranges of 6.8-7.95 and 7.0-8.0 reported from Upper Egypt[22] and Brazil[32] respectively, as optimally normal for development of aquatic molluscs. The pH 9.01 and 9.58 for Obutu and Agbu Lakes respectively in Anambra State[20] indicate that lakes in this part of the country have alkaline pH. More snails were encountered in sites with slightly alkaline pH than those with pH values above 9.0 (Table 3). A negative correlation occurred between pH and gastropod density (Figure 7f) and such condition appeared to be constant as pH range was slightly above the neutral point, and a good number of gastropods were collected from stations where pH ranges from 7.5 to 8.4.

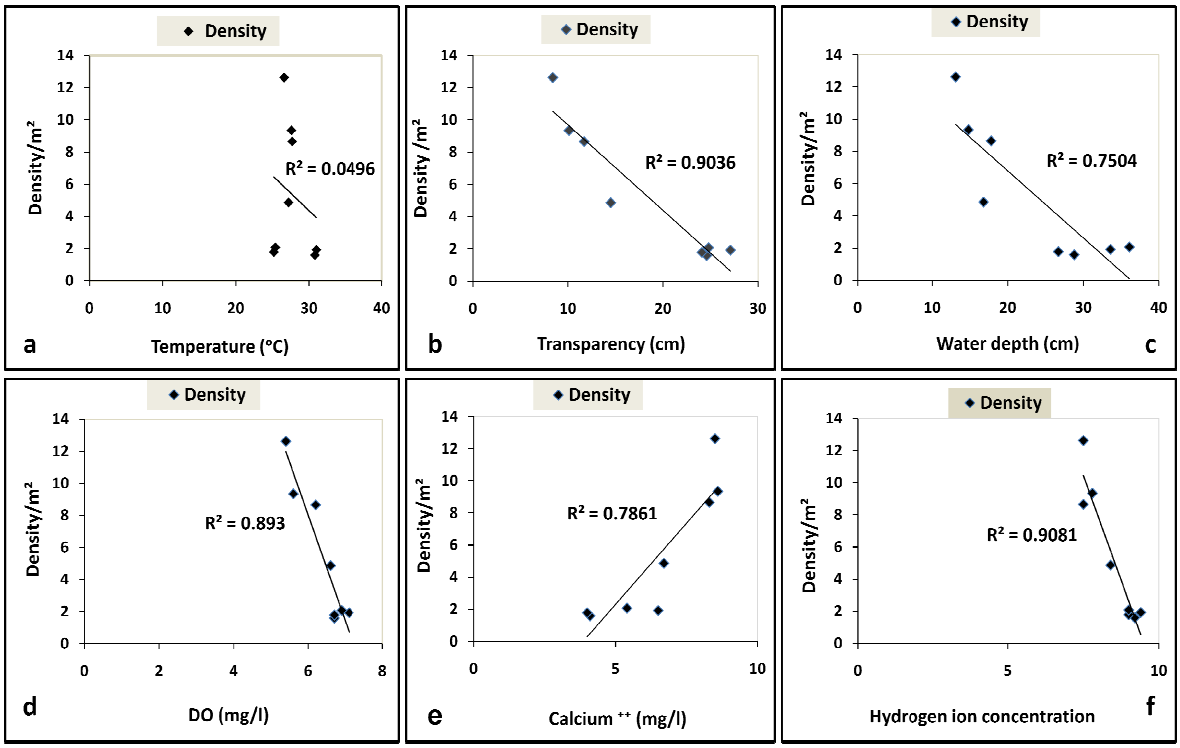


**Fig.7:** Correlation between gastropod density and water parameters at Stations in Agulu Lake shorelines. Water temperature **(a)**, Transparency **(b)**, Depth **(c)**, Dissolved oxygen **(d)**, $Ca^{++}$ **(e)**, and pH **(f).**

## CONCLUSIONS

This study identified 5 fresh water gastropod species and determined water parameters that influence their population abundance and distribution in Agulu Lake shorelines, the most important being rainfall and calcium ion concentration as well as human interventions. Generally, gastropod density was strongly and positively correlated with calcium ions but negatively correlated with water transparency, depth, dissolved oxygen and pH. It is recommended that further studies be carried out to investigate the extent at which each of the environmental factors would be manipulated under natural and laboratory conditions to control the population of the gastropods. Further research on the molecular phylogeny of *Bulinus* snails of Agulu Lake using DNA characterization will differentiate and conclusively identify the gastropods and investigate their cercarial infection rates.

**Conflict of interests:** The authors declare that there is no conflict of interests regarding the publication of this paper.

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