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Ecology of Freshwater Snails in Opa Reservoir and Research Farm Ponds at Obafemi Awolowo University Ile-Ife, Nigeria

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Abstract: In a 12 month study, the ecology of freshwater snails in Opa Reservoir (OR) and Research Farm Ponds (RFPs), in Obafemi Awolowo University, Ile-Ife, Nigeria, was studied. During each monthly visit, eleven sites (seven sites in OR and four sites in RFPs) were sampled for relative snail density, vegetation cover and physicochemical properties of the water bodies. The data were analysed using non-parametric statistical methods. A total of 7,524 snails (4081 in OR and 3443 in RFPs) belonging to ten species were collected. The species and their overall relative proportions are: *Bulinus globosus* (1.5%), *B. truncatus* (1.7%), *B. forskalii* (0.2%), *Biomphalaria pfeifferi* (11.0%) *Potadoma moerchi* (36.0%), *P. freethi* (6.9%), *Melanoides tuberculata* (40.0%), Lanistes *libycus* (0.9%), *Lymnaea natalensis* (0.7%) and *Gyraulus costulatus* (1.1%). The density of the snails varied seasonally and spatially according to a pattern common to most species. The seasonal pattern was basically unimodal with peak in either November/December or March/April for most species. Factors identified as affecting focal and seasonal distribution of snails were rainfall, pH, oxygen concentration, conductivity and presence or absence of macrophytes. Out of a total of 11 dominant macrophytes identified, only *Ludwigia erecta* served as indicator species for the presence of *B. globosus*, which is the established intermediate host of urinary schistosomiasis in Ile-Ife area. *Fuirena umbellata* and *Commelina africana* suspected to have some molluscicidal effect correlated negatively with *B. truncatus* (in RFPs) and *Lanistes libycus* (in OR), respectively. The likelihood of *M. tuberculata* as competitor snail against *B. pfeifferi* is discussed.

Key words: *Bulinus*, competition, distribution, physicochemical properties, irrigation, water bodies

INTRODUCTION

The various economic and social benefits derived from the damming of rivers cannot be over emphasized. These include irrigation, fishing, sporting, recreation, navigation and hydroelectric power generation. No wonder in Nigeria, for example more than 300 reservoirs were established since 1973 following the devastating effect of the Sahel drought (Ofoezie, 2002).

However, damming of rivers and streams to create reservoirs gives rise to significant alterations in the natural ecology of the original water bodies. For instance, it creates new biotopes which are more conducive than hitherto for the breeding of freshwater snails including the intermediate host species and vectors of important human and animal diseases such as malaria, trypanosomiasis, schistosomiasis etc. (Waddy, 1975; Gilles, 1980; Hunter *et al.*, 1993; Jewsbury and Imevbore, 1988; Ofoezie, 2002). Sometimes, these changes occur in areas where some of these diseases especially schistosomiasis were previously unknown (Ofoezie *et al.*, 1991, 1997).

Several factors are considered as affecting the ecology of snails and other intermediate hosts of diseases, hence their focal and seasonal distributions. These include physical factors such as water current, temperature, turbidity, transparency and distribution of suspended solids, chemical factors such as ion concentration and dissolve gases in water as well as biological factors such as availability of food, competition and predator-prey interactions (Williams, 1970; Ofoezie, 1999).

Besides, aquatic macrophytes have been shown to play vital roles in the distribution of snails in different parts of Africa (Ofoezie, 1999). The macrophytes are believed to provide both food and shade and to provide breeding sites for the snails. However, the importance of different ecological factors vary significantly from one ecological zone to the other and even from one water body to the other, suggesting local investigations to identify important factors in each zone or water bodies (Dazo *et al.*, 1966; Klumpp and Chu, 1977; 1980; Imevbore *et al.*, 1988; Ofoezie, 1999).

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This study was therefore designed and executed to provide such important information on the ecology of freshwater snails in Opa Reservoir and Research farm ponds. Both the reservoir and the ponds are located within the Obafemi Awolowo University (OAU) where they serve multipurpose needs including water supply, recreation, fishing and agricultural production. It is hoped that knowledge of the ecology of the snails in the water bodies will contribute significantly to future control strategies against disease transmitting species.

MATERIALS AND METHODS

Study areas: This study was carried out in Opa Reservoir (OR) and Research farm ponds (RFPs) both in O.A.U Ile-Ife located between Lat 7° 30^1-7° 35^1 N and Long 4° 30^1-4° 35E^1. According to Akinbuwa and Adeniyi (1996), Opa Reservoir (Fig. 1) was established in 1978 by the impoundment of Opa River which took its source from Oke Opa Hills. It has a catchment area of about 116 km^2 which is characterized by a rainy season of about eight months (March-October) and a dry season of about four months (November-February), a mean annual precipitation of 1000-1250 mm (Oguntoyinbo, 1982) and a mean annual temperature of about 27°C (Ndifon and Ukoli, 1989). The reservoir was primarily created to supply potable water to the university community for which reason fishing activities were permitted only for recreational and research purposes.

The RFPs are located at the University Teaching and Research farm, about 4 km from the central campus (Fig. 2). There are two ponds in the farm, here identified as Ponds A and B. Pond A was formed by the impoundment of Elerin and Omifunfun streams in 1967 (Adeniyi, 1971) while Pond B was established downstream of Pond A in 1981. The primary purpose of the ponds was to supply water for agricultural activities of the farm such as irrigation, fisheries, poultry and cattle watering.

Methods

Sampling stations: A total of eleven sampling stations (1-4) in the RFPs and seven (5-11) in OR were selected for this study on the basis of accessibility and variations in site ecology. Each sampling station covered about 25 m along the shoreline and 2 m in-shore. Stations 1, 2, 5, 6, 7, 8 and 11 were human contact sites and were therefore easily assessable while 3, 4, 9, 10 though not easily accessible varied in ecological characteristics including macrophyte coverage, presence of dead decaying organic materials, characteristics of the substratum etc.

Snail sampling: Each of the eleven sites was sampled once every month for twelve months (July 2002-June 2003). Sampling in each site involved 30 passes of kitchen scoops supplemented by a manual search for 30 person-minute (WHO, 1985; Ofoezie, 1999). The scoop, attached to a 2 m pole, was usually dragged from the 2 m mark towards the researcher. The 30 passes were systematically thrown at about 1m distance along the 25 m stretch of each site. Each scoop was thoroughly searched and all snails present collected and kept in pre-labelled plastic containers containing damp and decaying leaves. The containers were later covered with perforated lids and returned to the laboratory where they were sorted, identified to species according to Brown and Kristensen (1993) and Brown (1994) and counted to determine the number of each snail species collected per site per month.

Physicochemical characterization of water: Surface water samples were collected once per month in each of the eleven stations in 2 L plastic containers by the simple dip method. Dissolved oxygen samples were collected in glass stoppered light reagent bottles and immediately fixed with Winklers reagent (KI and $MnCl_2$) in the field and titrated in 0.0125 N sodium thiosulphate (APHA *et al.*, 1992). Samples for Biochemical Oxygen Demand (BOD_5) were determined in the same way except that it was collected in dark reagent bottles and fixed after incubation in the dark for 5 days. The atmospheric temperature and temperature of the surface water in each site were measured directly with ordinary mercury in glass thermometer. Transparency and depth were determined with the aid of a secci disc attached to a calibrated cord. pH and conductivity were determined using a pH comparator (Lovibond comparator) and an electric conductivity meter (Model 7020), respectively. Total alkalinity was determined by titration with standard sulphuric acid (N/50 H_2SO_4) using mixed indicators (methyl red and bromocresol green).

Aquatic macrophytes: Aquatic macrophytes were sampled as described by Ofoezie (1999). All types of marginal, emergent and floating macrophytes found in each site were collected, properly labelled and identified to species level at the O.A.U. herbarium. Subsequently, each vegetation type was monitored every month in each site for presence, coverage and relative association with snails. Coverage was determined by a simple estimation of the proportion of a site covered by each species and scored as 1 for < 5%, 2 for 6-25%, 3 for 26-50%, 4 for 51-75% and 5 for > 75%.

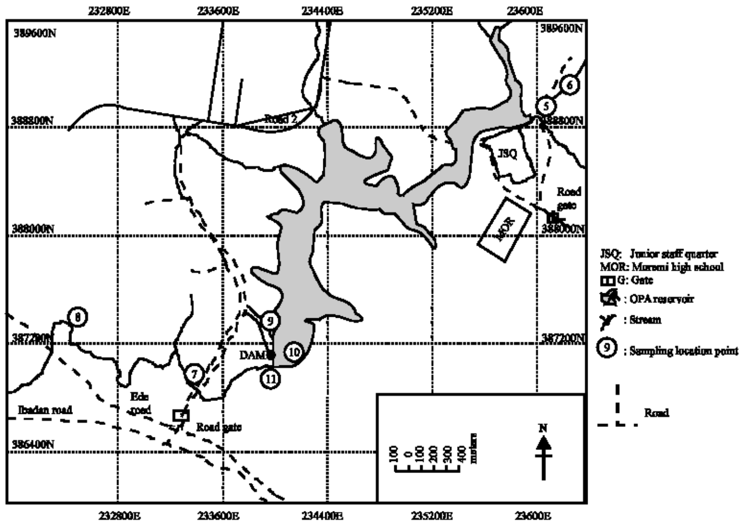

Fig. 1: Opa reservoir, Obafemi Awolowo University, Ile-Ife

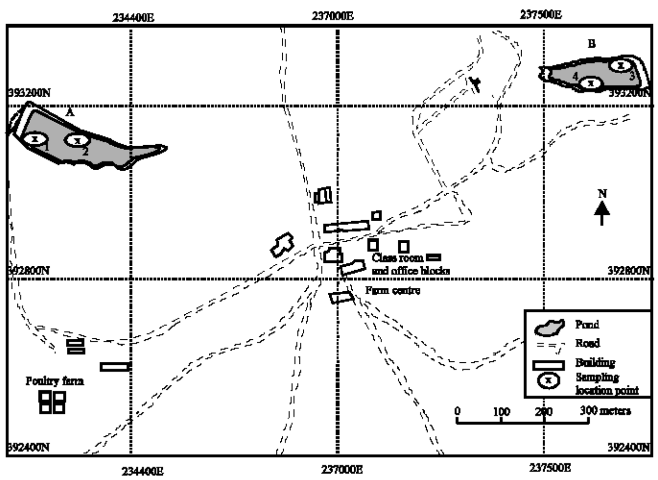

Fig. 2: Teaching and research farm showing the ponds and sampling stations

Statistical analyses: All statistical analyses were performed using non parametric tests since none conformed to normal distribution even after transformations (Siegel and Castellam, 1988). Differences in snail density among stations were determined using the Friedman two-way analysis of variance and between OR and RFPs by the Wilcoxon matched pairs sign ranked test. The strength of correlation between snail species and between snail density and environmental parameters were determined using spearman ranked order correlation coefficient. All analyses were performed using SPSS version 10.

RESULTS

General summary of findings: The general summary of important findings of this study is presented in Table 1. A total of ten snail species comprising two subclasses, four families and seven genera were collected in the reservoir and ponds during the study period. These were *Bulinus globosus* (Morelet, 1866), *B. truncatus* (Audouin, 1827), *B. forskalii* (Ehrenberg, 1831), *Biomphalaria pfeifferi* (Krauss, 1848) *Potadoma moerchi* (Reeve, 1859) *P. freethi* (Gray, 1831) *Melanoides tuberculata* (Reeve, 1859), *Lanistes libycus* (Morelet,

1848) *Lymnaea natalensis* (Krauss, 1848) and *Gyraulus costulatus* (Krauss, 1848). Four (*B. truncatus*, *B. forskalii*, *B. pfeifferi* and *P. moerchi*) were found in RFPs while all except *P. moerchi* were found in OR.

Seasonal and spatial variation in snail density: Table 2 presents the total number of snails of each individual species collected from each of the eleven stations over the study period of 12 months. Three of the four snail species found in RFPs were collected from each station although station 1 appear the most preferred. In contrast, all snail species in OR focally distributed except *M. tuberculata* which was found in all stations. However, statistical analysis showed that only *M. tuberculata* was significantly distributed in RFPs while all species were significantly distributed in OR except *P. freethi* (Table 2). *Bulinus globosus*, the local intermediate host of *Schistosoma haematobium* were found only in stations S5, S6, S7 and S8 which are small tributary streams of the reservoir. Thus, they were not found in either the reservoir or in the ponds.

Figure 3 showed the monthly variations in the mean number of each snail species collected in the water bodies. The figure reveals a pattern of temporal variation, which is common for most species. Thus, all the species showed unimodal distribution with peak in November/December for *B. globosus, B. truncatus* and *G. costulatus*; March/April for *B. pfeifferi*, *P. moerchi* and *P. freethi*, June for *M. tuberculata* and *L. natalensis* while *B. forskalii* showed no discernible pattern but with peak in June. No relationship was seen between temperature and any of the snail species while rainfall was seen to affect the density of *B. pfeifferi* but not the other snail species.

Snail distribution in relation to physicochemical factors: The mean and range values of physicochemical properties of water in the sampling stations are shown in Table 3. Generally, water in the RFPs stations is slightly acidic while that in OR is slightly alkaline. Conductivity and alkalinity are lower in the RFPs than in OR.

Table 4 presents the result of the statistical analysis of the relationship between the physicochemical characteristics of the stations on one hand and between snail distribution (seasonal and spatial) and the physicochemical parameters on the other hand. In general, all the parameters investigated varied significantly among the four sites on RFPs and among the seven sites on OR except BOD and pH which were comparable in RFPs and OR stations, respectively. However, a comparison of these properties using their overall means at the four sites in RFPs and the seven sites in OR and also the eleven sites put together showed that all but DO differed significantly between OR and RFPs.

Table 1: The general summary of snail and plant species found in Opa Reservoir and Research Farm Ponds, (July 2002-June 2003)

	Opa reservoir	Research farm ponds	Total
No. of monthly site visits	12	12	12
No. of stations sample/month	7	4	11
No. of snail species found	9	4	10
Total number of snails collected	4081	3443	7524
Snail species	Total distribution (%)		
Bulinus globosus	2.71	0.00	1.5
Bulinus tuncatus	1.89	0.67	1.7
Bulinus forskalii	0.27	0.02	0.2
Biomphalaria pfeifferi	3.70	7.00	11.0
Potadoma moerchi	0.0	36.00	36.0
Potadoma freethi	12.79	0.00	6.9
Melanoides tuberculata	73.68	0.00	40.0
Lanistes libycus	1.64	0.00	0.9
Lymnaea natalensis	1.35	0.00	0.7
Gyraulus costulatus	1.96	0.00	1.1
Total	100	100	100
Checklist of aquatic macrophytes			
Marginal			
Achornea sp.	x		x
Ageratum conyzoides	x		x
Acroceras zizanioides	x	x	x
Altemanthera senssilis		x	x
Aspilia africana			x
Commelina africana		x	x
Cynodon dactylon	x	x	x
Desmodiumgiganticum		x	x
Eclipta prostata		x	x
Emilia coccinia	x		x
Ludwigia decurrens	x	x	x
Ludwigia erecta	x	x	x
Panicum maximum		x	x
Paspalum polystachyum	x		x
Paspalum vaginatum	x		x
Phaulopsis banteri		x	x
Rhynchospora corymbosa		x	x
Shrankia leptocarpa	x		x
Sida corymbosa		x	x
Sphenoclea zeylanica	x		x
Starchytarpheta sp.	x		x
Urena nobata		x	x
Vernonia sp.			x
Emergent			
Coix lachryma-jobi		x	x
Cyclosorus dentatus		x	x
Cyperus digitatus	x	x	x
Fuirena umbrellata	x		x
Pentodon pentadrus	x	x	x
Polygorum lanigerum	x		x
Impatiens irvingii		x	x
Typha australis		x	x
Floating			
Azolla africana	x		x
Pistia stratioites		x	x

x-means present

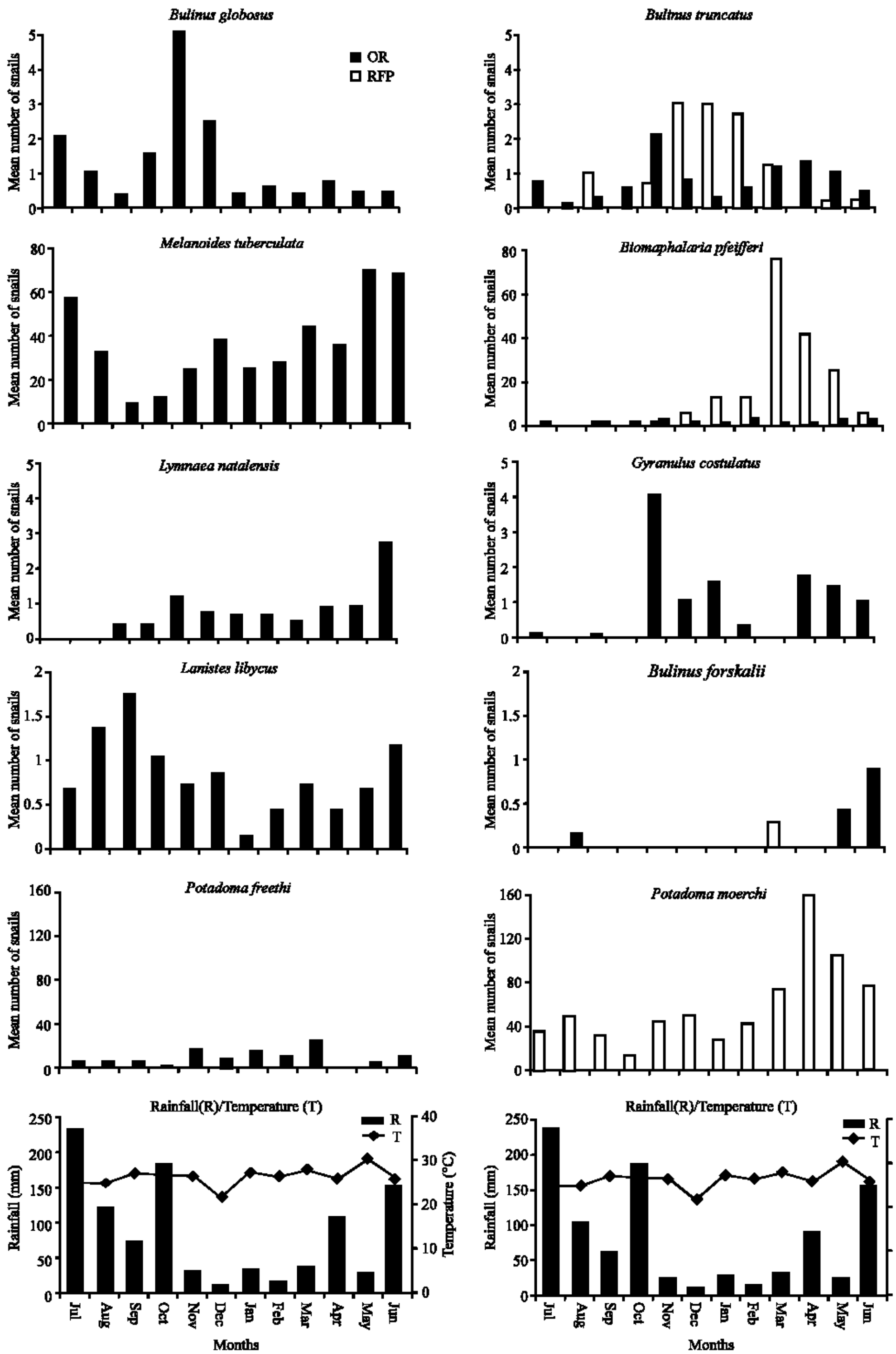

Fig. 3: Mean monthly variation in density of snail collected from Opa Reservoir (OR) and Research Farm Ponds (RFP) in relation to rainfall and temperature at Obafemi Awolowo University, Ile Ife (July 2000-June 2003)

Table 2: Distribution and density of snails collected from eleven sites on Opa Reservoir and Research Farm ponds, O.A.U., Ile-Ife (July 2002-June 2003)

Snail sp.	*Bulinus globosus*	*Bulinus truncatus*	*Bulinus forskalii*	*Biomphalaria pfeifferi*	*Potadoma moerchi*	*Potadoma freethi*	*Melanoides tuberculata*	*Lanistes libycus*	*Lymnaea natalensis*	*Gyraulus costulatus*	Total	Overall total (%)
S1	0	13	0	573	1069	0	0	0	0	0	1655	22.0
S2	0	12	1	94	1275	0	0	0	0	0	1402	18.5
S3	0	3	0	10	317	0	0	0	0	0	330	4.4
S4	0	1	0	4	51	0	0	0	0	0	56	0.7
p-value+	*	ns	*	ns	0.000	*	*	*	*	*		
Sub-total	*	49	1	681	2712	0	0	0	0	0	3443	45.8
S5	90	0	0	0	0	93	4	20	0	1	208	2.8
S6	18	0	0	0	0	426	129	31	0	1	605	8.0
S7	1	0	0	0	0	0	227	10	0	0	238	3.2
S8	2	0	0	4	0	3	351	4	0	1	365	4.9
S9	0	32	0	38	0	0	142	0	24	21	257	3.4
S10	0	40	10	94	0	0	106	2	31	56	339	4.5
S11	0	5	1	15	0	0	2048	0	0	0	3069	27.5
p-value+	0.025	0.000	0.046	0.000	*	ns	0.022	0.000	0.000	0.003		
Sub-total	111	77	11	151	0	522	3007	67	55	80	4081	54.2
Total	111	126	12	832	2712	522	3007	67	55	80	7524	100
Overall total (%)	1.5	1.7	0.2	11.0	36.0	6.9	40.0	0.9	0.7	1.1		

+ Friedman two way analysis of variance for differences in monthly snail counts. * Statistics cannot be computed because one of the variables is constant

Table 3: Median and range values of the physicochemical characteristics of water collected from seven sites from Opa reservoir and four sites from Research Farm (July 2002-June 2003)

Parameter	Air temperature (°C)	Water temperature (°C)	Depth (cm)	Transparency (cm)	DO (Mg/L O_2)	BOD_5 (Mg/L O_2)	pH	Conductivity µmhos cm^{-1}	Alkalinity (mg/L $CaCO_3$)
S1	25(15.5-28)	28.6(23.5-31.5)	36(34-40)	32.5(28-38)	6.1(2.8-8.5)	2(0.7-4.4)	6.9(6.6-7.3)	83(73-110)	34(20.5-38)
S2	25.2(18-27.5)	28.8(23.8-32)	42(38-51)	37.5(29-41)	6.2(3.2-8.4)	1.8(0.6-3)	6.8(6.5-7.7)	84(71-104)	32.4(26.8-39)
S3	27.9(22.5-33.8)	29.7(26-34)	41.5(26-50)	37(19-46)	6.4(3.6-14.2)	3.9(1.2-7.6)	6.8(6.5-7.5)	76(61-115)	29(22-42)
S4	28(23.5-31)	29.8(26-32)	42(27-50)	36.5(18-46)	5.9(4.6-1.4)	2.4(0.8-3.2)	6.8(6.7-7.2)	77.5(66-116)	29.8(23-35)
S5	29.9(23-31.5)	26.5(22-28)	58.5(34-76)	40(18-72)	5.9(3.5-12.7)	4.3(0.2-6.7)	7.3(6.9-7.4)	246(144-575)	94.5(63.3-102)
S6	28.9(21.7-33.5)	26.5(22-29)	50(28-76)	41.5(26-59)	5.3(3.1-9.2)	2.5(0.3-3.8)	7.4(6.9-7.5)	298(189-630)	110.5(77-221)
S7	23.6(17.2-33.5)	27.7(26-29.5)	46.5(31-63)	37(29-60)	6.0(4.2-8.0)	2.7(0.6-5.4)	7.3(6.9-7.5)	176.5(131-196)	71.5(51.5-96)
S8	24.5(18.3-26.9)	26.5(25-29.2)	45.5(21-66)	41.5(19-58)	6.2(3.5-8.0)	2.6(0.9-4.8)	7.3(7.0-7.5)	184(128-290)	73(59-90)
S9	25.8(20.5-30)	28.1(26-30.1)	50.5(31-63)	47.5(29-60)	5.1(2.3-7.6)	2.4(1-4.9)	7.2(6.9-7.4)	187(136-196)	80.3(56-102)
S10	26(25.2-30)	28.5(26.8-30.2)	42(35-52)	40(33-48)	5.6(2.4-7.2)	1.8(0.4-4.3)	7.3(6.9-7.4)	190(140-300)	81.3(60-101)
S11	26.4(23.5-29.5)	28.7(25-30.2)	47(32-81)	45(30-75)	5.8(4.5-8.6)	2.7(1.8-4)	7.3(6.8-7.5)	183.5(138-310)	75.4(56-104)

Values in parenthesis represent the range of the parameters

Table 4: The result of statistical analysis of temporal variation in some physicochemical and biological (relative snail density) parameter measured at four sites in Research Farm Ponds and seven sites in Opa Reservoir, O.A.U. Ile-Ife (July 2002-June 2003)

	Independent test of monthly records between				Correlation of monthly records at X		
	4 sites at RFPs+	7 sites at OR+	RFPs and OR*	All site+	RFPs	OR	All sites
Physicochemical properties							
Air temperature	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Water temperature	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Depth	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Transparency	0.000	0.000	0.000	0.000	0.000	0.000	0.000
pH	0.000	ns	0.000	0.000	0.000	ns	0.000
Alkalinity	0.000	0.000	0.000	0.003	0.000	0.000	0.000
Conductivity	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DO	0.000	0.000	ns	0.000	0.000	0.000	ns
BOD	ns	0.000	0.000	0.000	ns	0.000	0.000
Snail density							
Bulinus globosus		ns	ns	0.025		0.025	0.025
Bulinus tuncatus	ns	0.00	0.000	0.002	ns	0.00	0.002
Bulinus forskalii	too few	0.046	0.043	0.025		0.046	0.025
Biomphalaria pfeifferi	ns		ns	0.006	ns	0.000	
Potadoma moerchi	0.000		0.000	0.000	0.000		
Potadoma freethi		ns	0.017	ns		ns	ns
Melanoides tuberculata		0.022	0.000	0.022		0.022	0.022
Lanistes libycus		0.000	0.000	0.000		0.000	0.000
Gyraulus costulatus		0.003	0.004	0.003		0.003	0.003
Lymnaea natalensis		0.000	0.000	0.000		0.000	0.000

+ Friedman analysis of variance, * Wilcoxon signed pair rank test, X-Kendall's coefficient of concordance, ns = not significant

Table 5: Correlation coefficient matrix between snail species and physicochemical properties of water in Opa reservoir and Research farm ponds, O.A.U., Ile-Ife (July 2002-June 2003)

	Bulinus globosus	*Bulinus truncatus*	*Bulinus forskalii*	*Biomphalaria pfeifferi*	*Potadoma moerchi*	*Potadoma freethi*	*Gyraulus costulatus*	*Lanistes libycus*	*Melanoides tuberculata*	*Lymnaea natalensis*
OR										
Air temperature (°C)	0.058	-0.157	-0.156	-0.055		0.325	-0.109	0.358	0.111	-0.208
Water temperature (°C)	-0.089	0.243	0.234	0.251		0.133	0.462	-0.122	0.225	0.017
Depth (cm)	0.192	-0.379	0.639	-0.121		-0.347	-0.357	0.095	0.049	-0.058
Transparency (cm)	0.198	-0.358	0.639	-0.076		-0.160	-0.362	-0.061	0.071	-0.055
PH	0.065	0.288	-0.917	-0.086		0.443*	0.119	0.105	0.088	-0.268
DO (mg/L O_2)	0.387	0.128	0.078	-0.270		-0.240	0.061	-0.232	0.150	-0.035
BOD (mg/L O_2)	-0.079	-0.390*	-0.126	-0.609**		0.360	-0.474	-0.127	-0.020	-0.247
Alkalinity (mg/L $CaCO_3$)	-0.153	0.063	0.309	-0.123		0.028	-0.228	-0.042	-0.119	-0.337
Conductivity (μmhos cm^{-1})	-0.224	0.052	0.455	0.023		0.620**	-0.130	0.263	-0.059	-0.051
RFPs										
Air temperature (°C)		-0.319	a	-0.051	-0.316*					
Water temperature (°C)		-0.539	a	0.073	0.041					
Depth (cm)		0.228	a	-0.284	-0.075					
Transparency (cm)		0.328	a	-0.198	0.095					
PH		-0.253	a	0.359	0.009					
DO (mg/L O_2)		-0.335	a	0.036	0.095					
BOD (mg/L O_2)		-0.289	a	0.048	-0.146					
Alkalinity (mg/L $CaCO_3$)		0.368	a	0.203	0.064					
Conductivity (μmhos cm^{-1})		0.141	a	0.339	0.155					

* Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level, a- Cannot be computed because at least one of the variable is constant

Table 6: Correlation coefficient matrix between snail species pairs in Opa reservoir and Research farm ponds (July 2002-June 2003)

	Bulinus globosus	*Bulinus truncatus*	*Bulinus forskalii*	*Biomphalaria pfeifferi*	*Potadoma moerchi*	*Potadoma freethi*	*Gyraulus costulatus*	*Lanistes libycus*	*Melanoides tuberculata*	*Lymnaea natalensis*
RFPs										
Bulinus tuncatus										
Bulinus forskalii		a								
Biomphalaria pfeifferi		-0.390	a							
Potadoma moerchi		-0.509	a	0.359						
OR										
Bulinus globosus										
Bulinus tuncatus	a									
Bulinus forskalii	a	-0.886	a							
Biomphalaria pfeifferi	a	0.427*	0.396							
Potadoma moerchi	a									
Potadoma freethi	-0.287	a	a	a						
Gyraulus costulatus	a	0.726**	-0.893	0.594*		a				
Lanistes libycus	- 0.81	a	a	1.000**		0.38	a			
Melanoides tuberculata	-0.314	-0.318	-0.791	-0.355*		-0.245	-0.124	-0.316		
Lymnaea natalensis	a	0.145	0.918	0.400		a	0.714*	a	-0.125	

* Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level, a- cannot be computed because at least one of the variable is constant

The result of the correlation analysis between physicochemical parameters and the snail species densities are presented in Table 5. In RFPs, all the snail species correlated positively with alkalinity and conductivity, negatively with air temperature but only *P. moerchi* and air temperature correlated to a statistically significant level ($p<0.01$). In OR, of the 81 correlations performed, 38 were positive and 43 were negative although only 4 were of statistical significance. These include *P. freethi* which correlated positively and significantly with both pH and conductivity and *B. truncatus* and *B. pfeifferi* each of which correlated negatively and significantly with BOD_5

Table 6 presents the correlation matrix between the snail species. In the RFPs, all the snail species were negatively correlated with one another except *P. moerchi* and *B. pfeifferi*, which correlated positively. None however correlated to a statistically significant level. In OR, of the 22 correlation values, 12 were negative while 10 were positive. However, none of the negative correlations were significant except that between *M. tuberculata* and *B. pfeifferi*. Of the 10 positive correlations, 5 were significant while the rest were not. The 5 significant correlations were *B. pfeifferi* and *L. libycus* ($r = 1.00$, $p<0.01$, *B. pfeifferi* and *B. truncatus*, ($r = 0.427$, $p<0.05$); *B. pfeifferi* and *G. costulatus* ($r = 0.594$, $p<0.05$),

Table 7: The frequency and relative coverage (represented as scores) of aquatic macrophytes at eleven sites in OR and RFPs (July 2002-June 2003)

Macrophytes	S1 N(CO)	S2 N(CO)	S3 N(CO)	S4 N(CO)	S5 N(CO)	S6 N(CO)	S7 N(CO)	S8 N(CO)	S9 N(CO)	S10 N(CO)	S11 N(CO)	Mean N(CO)
Achornea sp.			1(10)			1(6)						2(1.5)
Ageratum conyzoides				1(24)								1(2.2)
Acroceras zizanioides		1(10)			12(72)	12(71)	11(24)	12(25)	12(30)	9(12)	9(17)	8(23.7)*
Altemanthera senssilis						1(6)						1(0.5)
Aspilia africana			1(6)									1(0.5)
Commelina africana	5(8)	6(9)				3(20)		1(24)	8(8)	7(8)		6(7)*
Cynodon dactylon	6(36)		4(39)	5(34)	3(32)							4(13)*
Desmodiumgiganticum										1(5)		1(0.5)
Eclipta prostata									1(6)			1(0.5)
Emilia coccinia	1(6)	2(5)										2(1)
Ludwigia decurrens			1(5)	1(14)			1(6)	1(6)				4(5.5)
Ludwigia erecta		2(8)	1(10)		6(16)	2(28)		2(10)	12(15)	12(14)	1(10)	8(10)*
Panicum maximum					12(62)	1(6)	7(31)	7(26)	1(6)	2(5)		6(12.9)*
Paspalum polystachyum	1(24)	5(53)										2(7)*
Paspalum vaginatum	4(6)	3(4)										2(0.9)
Phaulopsis banteri							1(5)	1(5)		1(5)		3(1.3)
Rhynchospora corymbosa										12(28)		1(2.5)
Shrankia leptocarpa			2(18)									1(1.6)
Sida corymbosa						1(10)						1(0.9)
Sphenoclea zeylanica			1(10)	4(24)								2(3.1)
Starchytarpheta sp.		3(8)	2(15)	3(20)								3(3)
Urena nobata								1(16)				1(1.5)
Vernonia sp.						1(6)						1(0.5)
Coix lachryma-jobi											6(26)	1(2.4)
Cyclosorus dentatus										12(20)		1(1.8)
Cyperus digitatus	1(6)	2(4)	2(10)	2(36)								4(5.1)
Fuirena umbrellata	1(6)		6(58)	5(34)								3(8.9)*
Pentodon pentadrus	1(6)	1(6)	5(43)	4(39)								4(9.1)*
Polygorum lanigerum	2(8)	3(5)	2(75)									3(8)*
Impatiens irvingii									12(72)	12(68)		2(0.5)
Typha australis												2(12.7)*
Azolla africana			1(75)	1(6)								2(7.4)*
Pistia stratioites									6(8)	6(16)		2(2.2)
Total Coverage	3.8	3.4	11.3	0.7	5.5	4.6	2.2	3.4	5	4.9	1.8	

N = Frequency of occurrence, CO = Coverage, * = Dominant macrophyte based on a cutoffcoverageof7.0)

Table 8: Correlation coefficient matrix between snail species and dominant aquatic macrophyte in Opa reservoir and Research Farm Ponds, O.A.U., Ile-Ife (July 2002-2003)

	Bulinus globosus	*Bulinus truncatus*	*Bulinus forskalii*	*Biomphalaria pfeifferi*	*Potadoma moerchi*	*Potadoma freethi*	*Gyraulus costulatus*	*Lanistes libycus*	*Melanoides tuberculata*	*Lymnaea natalensis*
RFPs										
Cynodon dactylon		-0.468	a	-0.013	-0.092					
Fuirena umbrellata		-1.000**	a	0.569	-0.655*					
Pentodon Pentadrus		a	a	-0.500	-0.290					
Ludwigia erecta		a	a	a	1.000**					
Acroceras zizanioides		a	a	a	a					
Commelina africana		-0.424	a	-0.353	0.677*					
Polygorum lanigerum		a	a	-0.688	-0.084					
Paspalum polystachyum		0.000	a	0.029	-0.254					
Azolla africana		a	a	a	a					
OR										
Pentodon Pentadrus	-0.814	a	a	a		a	a	-0.344	a	a
Panicum maximum	-0.133	0.442	a	0.067		0.284	-0.705	0.415	-0.218	-0.333
Ludwigia erecta	1.000**	-0.231	0.866	0.025		0.624	-0.544	-0.192	-0.164	-0.191
Acroceras zizanioides	0.115	-0.312	a	-0.088		0.310	-0.410	-0.212	-0.255	-0.361
Commelina africana	a	-0.300	a	-0.123		-0.982	-0.292	-0.965**	0.395	-0.442
Typha australis	a	0.176	a	0.083		a	0.245	a	-0.007	0.195

a- cannot be computed because one of the variable is constant, * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

G. costulatus and *L. natalensis* ($r = 0.714$, $p<0.05$).*G. costulatus* and *B. truncartus* ($r = 0.726$, $p<0.01$)

Snail distribution in relation to aquatic vegetation: The frequency of occurrence and relative coverage by site of the aquatic macrophytes in RFPs and OR are presented in Table 7. *Ludwigia erecta* and *Acroceras zizanioides* are the most frequently encountered but only *A. zizanioides* stands out as the densest. Based on a cut off point mean relative coverage of 7.0, eleven macrophytes were considered as dominant in the two water bodies. These plants which include *Cynodon dactylon*, *Fuirena umbellata*, *Pentodon pentadrus*, *L. erecta*, *A. zizanioides*, *Commelina africana*, *Polygorum lanigerum*, *Paspalum polystachyum*, *Azolla africana*, *Panicum maximum* and *Typha australis* were also correlated with snail species (Table 8). In RFPs, of the 17 correlations computed only 5 were positive and 4 statistically significant. They include *P. moerchi* which correlated positively with two macrophytes (*L. erecta* and *C. africana*) and negatively with *F. umbellata*, as well as *B. truncatus* which correlated negatively and significantly with *F. umbellata*.

In OR, of the 39 correlations computed, 13 were positive but only one (*B. globosus* and *L. erecta*) was significant ($r = 1.000$, $p<0.01$). There was also a highly significant negative correlation between *C. africana* and *L. libycus* ($r = -0.97$, $p<0.001$).

DISCUSSION

This study has identified a total of ten snail species namely *B. globosus*, *B. truncatus*, *B. forskalii*, *Biomphalaria pfeifferi*, *Potadoma moerchi*, *P. freethi*, *M. tuberculata*, *L. natalensis*, *L. libycus* and *G. costulatus* in Opa Reservoir and Research farm ponds. According to Barclay, (1958), this is an indication of stable coexistence found only in habitats, which are capable of supporting mutually exclusive and conducive niches for different species population. Out of the 10 snail species collected in the reservoir and ponds, 6 are pulmonate snails while 4 are prosobranch snails. Out of the 6 pulmonate snails; 5 are known intermediate hosts of animal and human diseases. *L. natalensis* is host to *Fasciola gigantica* in many parts of Africa (Brown, 1994), *B. forskalii* transmits *Schistosoma intercalatum* in Nigeria (Arene *et al*., 1989) Cameroun (Wright *et al*., 1972) and Gabon (Brown *et al*., 1984) and *B. pfeifferi* is host of *S. mansoni* in Nigeria (Cowper, 1973; Adewunmi *et al*., 1990) *B. globosus* and *B. truncatus* are known intermediate hosts of *S. haematobium* in Nigeria (Adewunmi *et al*., 1990) and other parts of Africa (Doumenge *et al*., 1987). However, *B. globosus* is the major host of *S. haematobium* in the area south of 9° north including the present study area (Sellin *et al*., 1980).

The distribution of *B. globosus* is patchy and found only in small streams tributaries of the reservoir and not the pool itself. Fagbola (1989) had demonstrated the invasion of the dam by *B. truncatus* and *B. pfeifferi* since 1989. This situation has remained so even after 14 years. Moreover, a complimentary investigation had shown that only *B. globosus* shed the human schistosome cercariae in the tributary streams (Owojori, 2004) and this is an indication of imminent risk of schistosomiasis transmission in the reservoir. The observed relative abundance of *B. pfeifferi* in the RFPs is also very worrying in the light of recent southward movement of the species and risk of *S. mansoni* transmission previously restricted above 9°N (Sellin *et al*., 1980). Most of the snails in the ponds and reservoir showed marked seasonal variation in density, the pattern of which is common in all species. In spite of this, peak abundance of the snails were recorded in November/December for *B. globosus*, *B. truncatus* and *G. costulatus*, March/April for *P. moerchi*, *P. freethi* and *B. pfeifferi*, May/June for *B. forskalii* and *M. tuberculata* and September for *L. libycus*. This trend agrees with the report of several workers from the southwest Nigeria (Hira, 1969a; Hira and Muller, 1966) and Igwun, eastern Nigeria (Udonsi, 1990). It however contrasts with bimodal pattern seen in Yola, northern Nigeria (Akogun and Okin, 1993) Oyan, southwest Nigeria (Ofoezie, 1999), Lake volta, Ghana (McCullough, 1957; Klumpp and Chu, 1977) and lake Kariba, Zambia (Hira, 1969b). According to these reports, snail maxima are determined by local physicochemical and biological conditions of particular ecosystems. In this study area, it appears the overriding factors include rainfall, pH, oxygen concentration, electrical conductivity and presence or absence of aquatic macrophytes.

On the basis of significant correlations, it can be inferred that in OR, there is close positive association between *B. pfeifferi* and the trio of *L. libycus*, *B. truncatus* and *G. costulatus* as well as between *G. costulatus* and the duo of *B. truncatus* and *L. natalensis*. It should however be noted that these associations were not supported by field observations. In spite of this, the observed statistical correlations agree with the findings of Thomas and Tait (1984) in Ibadan where *L. libycus* coexisted with *B. globosus* and *B. pfeifferi* and the works of Madsen (1985) both of which support the likelihood of species overlap.

The only significant negative correlation observed in this study occurred between *M. tuberculata* and *B. pfeifferi* signifying probable interspecific competition between them. Inter specific competition among freshwater snails is well established and *M. tuberculata* has been suggested as an important agent for biological control of intermediate hosts especially *Biomphalaria glabrata* (Dupouy *et al*., 1980; Kawazoe *et al*., 1980; Brown, 1982; Pointier, 1986; 1993; Pointier *et al*., 1989; 1991; Pointier and Guyard, 1992; Schlegel *et al*., 1997). Although the relationship between this species and *B. pfeifferi* is not well documented, the negative association found in this study is a clear indication that *B. pfeifferi* probably does not thrive well in the presence of *M. tuberculata*. However, further studies may be required to substantiate the extent at which this species could be used to control *B. pfeifferi* in tropical Africa and elsewhere.

Apart from DO, all other physicochemical variables investigated by this study varied between OR and RFPs. This confirms the report that water chemistry varies among water bodies and does influence snail distribution at the regional and sectoral levels (Williams, 1970; Okwuosa and Ukoli, 1980; Ndifon and Ukoli, 1989). For instance, physicochemical factors were not correlated with snail density at RFPs while at OR, BOD_5 was negatively correlated with the densities of *B. truncatus* and *B. pfeifferi* while pH and conductivity were positively correlated with *P. freethi*. Other workers have suggested that in Nigeria, snail density is not significantly affected by water turbidity, temperature, alkalinity, acidity and presence of major ions but is significantly limited by conductivity, DO and BOD_5 (Okwuosa and Ukoli, 1980; Ofoezie, 1999). The present study while supporting the above did not show significant correlation between snail density and DO. Although this study did not include cations and anions, these parameters have been well studied in Opa Reservoir (Eludoyin *et al*., 2004). Most of these parameters were within limit except SO_4 which was fairly high.

The strong snail-plant association observed in this study is consistent with reports from many parts of Africa. The most important aquatic macrophytes in RFPs and OR were *Fuirena*, *umbellata*, *Ludwigia erecta* and *Commelina africana*. In RFPs, the density of *P. moerchi* was positively correlated with *Ludwigia erecta* and *Commelina africana*. A similar trend was seen in OR where a strong association was found between *B. globosus* and *L. erecta*. Similar trends have been reported in many parts of Africa (Paperna, 1969; Odei, 1973; Klumpp and Chu, 1980; Hillali *et al*., 1985; Madsen *et al*., 1988; Ofoezie, 1999). For instance, in lake Volta, *B. rohlfsi* was found in association with *Ceratophylum demersum* (Paperna, 1969; Odei, 1973; Klumpp and Chu, 1977) in Egypt, *Potamogeton crispus* and *Eichornia crassipes* were positively correlated with *B. truncatus* and *Bulinus alexandrina* (Dazo *et al*., 1966) and in Oyan Reservoir, *Impatiens irvingii* significantly correlated with all snails species and especially *Indoplanorbis exustus*, a recently introduced species to that area (Ofoezie, 1999).

Some significant negative association were also recorded during this study especially between *Fuirena umbellata* and the duo of *B. truncatus* and *P. moerchi* in RFPs and *C. africana* with *L. libycus* in OR. Although, it is difficult to explain this negative association, studies have shown that where this situation exists, such plants could have some molluscicidal effect and could be used to reduce the density of the snails involved. This however requires further investigation.

CONCLUSIONS

This study has thus provided baseline data in fashioning out control strategies for vector snails in this ecological zone. It has also suggested that focal distribution of snails in OR and RFPs could be attributed to chemical factors of water such as pH, conductivity and BOD_5 and to snail plant association. It is also recommended upon confirmation that *M. tuberculata* may be used in biological control of *B. pfeifferi* while *L. erecta*; a marginal plant may be cleared around water bodies in this ecological zone to reduce snail population.

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