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Ecology of freshwater snails in south-western Nigeria. I: Distribution and habitat preferences

G. T. Ndifon* & F. M. A. Ukoli
*Department of Zoology, University of Ibadan, Ibadan, Nigeria; *present address: Department of Biological Sciences, Bayero, University, Kano, Nigeria*

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Abstract

Dry and rainy season investigations of diverse freshwater habitats in south-western Nigeria revealed fourteen species of snail comprised of nine pulmonates: *Biomphalaria pfeifferi* Krauss, *Bulinus globosus* Morelet, *Bulinus rohlfsi* Clessin, *Lymnaea natalensis* Krauss, *Physa (≈ Aplexa) waterloti* Germain, *Bulinus forskali* Ehrenberg, *Gyraulus costulatus* Krauss, *Ferrissia* sp, *Segmentorbis* sp. and five prosobranchs namely, *Lanistes libycus* Morelet, *Lanistes ovum* Peters, *Pila wernei* Philippi, *Potadoma moerchi* Reeve and *Melanoides tuberculata* Müller.

The influence of diverse chemical and physical properties of water on their occurrence as well as interspecific and snail-plant relationships are discussed and maps showing the distribution of the species encountered are presented. Among the intermediate hosts of *Schistosoma*, *B. globosus* was widely distributed and common, *B. pfeifferi* was also widely distributed but infrequent and *B. rohlfsi* was rare.

Introduction

Investigations of freshwater snails in Nigeria include those of Hira (1966) and Asumu (1975) for Ibadan City and its environs, Okwuosa (1979) for Lagos, Ogun and Oyo States, Ukoli, F. M. A., D. I. Asumu, V. N. Okwuosa & G. T. Ndifon (unpublished) for Bendel State, Ukoli & Asumu (1979) for the New Federal Capital Territory, Ukoli, F. M. A., D. I. Asumu & G. T. Ndifon (unpublished) for the Kainji Lake Basin, Ebele (1981) for Zaria City, Dupont & Lévêque (1968), Lévêque (1967a & b, 1972) and Betterton *et al.* (1983) for the Lake Chad area, Betterton, C. & G. T. Ndifon (in press) for Kano State and Thomas & Tait (1984) for the Ibadan area. Together all these studies deal with only a small part of over 900000 km^2 of territory (Nigeria) which is characterised by marked variations in climate, vegetation and hydrology. Thus, little is known of the snail fauna of a greater part of the country apart from sporadic reports on the occurrence of intermediate hosts of *Schistosoma* by various workers (Gordon, 1932 in Kano; Taylor, 1932 in Kagoro; Ramsay, 1934 in Zaria, Kankia, Bauchi and Pankshin; Aletor, 1971 in Igarra; Donges, 1972 in the Abeokuta area; Walsh & Mellink, 1970 and Dazo & Biles, 1972 in the Kainji Lake Basin; Pugh *et al.*, 1980 in Malumfashi and Smith, 1982 in Zaria for example).

The investigations reported in this paper were carried out during the period from January 1976 to November 1977. The aim was to collect base-line information on the composition and geographic distribution of freshwater gastropods particularly those of medical and veterinary importance.

Description of the study area

The study area is situated between longitudes 2° E and 5° E and latitudes 7° N and 10° N and includes parts of Kwara, Ogun and Oyo States of Nigeria. Its northern part lies within the middle climatic belt of Nigeria experiencing a dry season of about seven months (October to April) and a rainy season of about five months (May to September) while the southern part lies in the southern climatic belt which is characterised by a long rainy season of about eight months (March to October) and a dry season of about four months (November to February). The north receives a mean annual rainfall of from 1 140 mm to 1 525 mm while in the south, the corresponding range is from 1 140 mm to over 2 540 mm (Perkins & Stembridge, 1966). As with rainfall, relative humidity decreases progressively from south to north being greatest during the rainy season due to the south-west winds and least during the dry season owing to the north-east winds (harmattan). A slight fall in temperature is experienced during the rainy season but otherwise, temperatures are generally high over the entire area with an annual mean of 24–27° C. Both annual and daily ranges of temperature increase progressively from south to north.

Soils of the area are generally moderately to strongly leached and low in humus content. They are characterised by weakly acidic (pH 5.5–7.0) to neutral surface layers and moderately to strongly acid sublayers and fall within the 'Ibadan Group' consisting of friable porous sand and sandy clays. The clay fraction is usually less than 40% and consists chiefly of inactive kaolin while the silt fraction is usually less than 10%. The area overlies metamorphic rocks of the basement complex ranging from coarse pegmatites to fine-grained schists and from acid quartzites to basic amphiboles (Smyth & Montgomery, 1962).

It is situated within the derived savanna vegetation zone. This zone is predominantly the result of man's activity especially over-cultivation and over-burning, and is characterised by a gradual transition from more or less continuous forest in the south to more or less continuous savanna in the north (Hopkins, 1974). The Plateau of Yorubaland with an average altitude of about 485 m (range, 300–900 m) above sea-level occupies most of the study area and from it the land surface slopes north-east into the River Niger basin and south-west to less than 120 m above sea-level.

The northern sector of the area is drained by Rivers Moshi, Osin, Oyi and Awun which empty into the River Niger, while the southern one is drained by Rivers Ofiki, Oshun, Oyun which empty into the Atlantic Ocean. Most of these rivers flow all year round but the network of streams supplying them flow only during the rainy season. However, in exceptionally dry years, the rivers also dry out completely or become reduced to pools maintained by subsurface flow (Smyth & Montgomery, 1962).

Materials and methods

A 10 to 15 min. snail search was carried out in each freshwater body by two persons using long-handled snail nets. Where nets could not be used as in the case of shallow or stony water bodies, a careful visual examination of debris and aquatic vegetation was conducted. Every attempt was made to examine as many freshwater bodies as possible throughout the area and snails found were transferred to plastic containers for later examination, identification and enumeration in the laboratory. Subsequently, preserved specimens were sent to the British Museum (nat. Hist.), London for confirmation of the species.

Since the purpose of the investigation was mainly to determine the composition and geographic distribution of the snail fauna, emphasis was on a widespread and intensive search and snail population densities were not rigorously investigated. Notes were made of the types of waterbody and their degrees of pollution, aquatic and subaquatic macrophytes and the proportion of the habitat receiving shade from floating, emergent and fringe vegetation. A wide range of physical and chemical properties of water and substratum as well as other habitat characteristics were also measured and will be discussed in a later publication.

The term 'habitat' used in this study is after Ökland (1969) who considered it to be a place where snails were searched for and certain ecological factors measured; for large water bodies such as lakes and rivers it consisted of about 200 m of shoreline while entire small pools and ponds each represented a habitat.

In analysing the results, frequency deviation histograms were constructed following the method used by Ökland (*loc. cit.*) and based on his assumption. An advantage of this method is that essentially qualitative data can be interpreted in simple quantitative terms thereby avoiding what Appleton (1978) referred to as 'annecdotal descriptions' that characterise literature on intermediate hosts of schistosomiasis.

Results

1. Snail fauna of the area

Altogether 404 freshwater bodies were investigated in the area, 153 (37.9%) during the dry season (September 1976 to January 1977) and 251 (62.1%) during the rainy season (April to August 1977). Of the 404, 190 (44%) were positive for various species of snails as shown in Table 1.

Bulinus globosus Morelet, *Bulinus forskali* Ehrenberg, and *Gyraulus costulatus* Krauss were predominant among the pulmonates as were *Melanoides tuberculata* Müller and *Lanistes libycus* Morelet among the prosobranchs. These and all other species found in the area i.e. *Potadoma moerchi* Reeve, *Lanistes ovum* Peters, *Pila wernei* Philippi, *Bulinus rohlfsi* Clessin, *Biomphalaria pfeifferi* Krauss, *Lymnaea natalensis* Krauss, *Physa (= Aplexa) waterloti* Germain, *Ferrissia* sp. and *Segmentorbis* sp. are typical of the known freshwater gastropods of the West African subregion (M-Barth, 1973; Brown 1974 & 1980).

2. Composition of the snail community according to:

2.1. Type of habitat

A variety of lotic and lentic freshwater bodies was encountered in the study area; the former consisted mainly of streams and rivers while the latter group was largely made up of pools as can be seen from Table 2. A significant proportion of these water bodies was directly or indirectly manmade; for example, disused quarries, excavations, and blocked culverts and bridges became filled with rainwater and gave rise to the majority of rainy season pools found in the area. An even more important variety of pool from the point of view of disease transmission was that made by scooping out holes in river beds during chronic spells of dry weather when rivers had dried out completely as was the case during the present investigation. Though very few in number, such pools were observed to be centres of concentrated human and animal activity as they were often the only surviving source of water available for many kilometers around. Table 2 shows that in general lenthic water bodies were more commonly inhabited by snails than lotic ones and in this respect, dams were the most favoured as 88.9% of them were colonised by one species of snail or the other. Also highly favoured were fishponds and springs 82.4% and 66.7% respectively of which harboured various species of snail. The only canal investigated contained snails during both dry and rainy season surveys.

Relative frequencies of occurrence of snail species in relation to types of water body are presented in Fig. 1. from which it can be seen that only *B. globosus*, *B. forskali*, *G. costulatus M. tuberculata* and *L. libycus* were encountered in all the five types of water body under consideration, all the other species being absent in one or more of them. Among the pulmonates, *Bulinus globosus* occurred most frequently in streams and was nearly as frequent also in pools but showed a decreased frequency of occurrence in both rivers and fish ponds and was least frequent in the later. However, frequencies of occurrence of *B. globosus* in all types of water body in the area were close to

Table 1. Types and relative frequencies of occurrence (among 404 water bodies) of freshwater snail species in south-western Nigeria.

Order	Family	Species	Positive habitats	Frequency (As % of 404)
PULMONATA	PLANORBIDAE	*Bulinus globosus* Morelet	81	20.0
		Bulinus rohlfsi Clessin	2	0.5
		Bulinus forskali Ehrenberg	31	7.7
		Biomphalaria pfeifferi Krauss	16	4.0
		Gyraulus costulatus Krauss	39	9.4
		Segmentorbis sp.	2	0.5
	LYMNAEIDAE	*Lymnaea natalensis* Krauss	5	1.2
	PHYSIDAE	Physa (= *Aplexa*) *waterloti* Germain	16	4.0
	ANCYLIDAE	*Ferrissia* sp.	4	1.0
PROSOBRANCHIA	THIARIDAE (= MELANIIDAE)	*Melanoides tuberculata* Müller	48	11.9
		Potadoma moerchi Reeve	7	1.7
	PILIDAE	*Lanistes libycus* Morelet	71	17.6
		Lanistes ovum Peters	1	0.3
		Pila wernei Phillipi	7	1.7

Table 2. Relative frequencies of occurrence (%) of various water body types in south-western Nigeria (total number investigated was 404).

Group	Type	Number investigated	Frequency (% of 404)	% Positive for snails
LOTIC	a. Stream	161	41.8	41.0
	b. River	67	16.6	47.8
	c. Canal	1	0.3	100.0
	a + b + c	229	56.7	43.2
LENTIC	a. Fishpond	17	4.2	82.4
	b. Dam	9	2.2	88.9
	c. Spring	3	0.7	66.7
	d. Pool	14.6	36.1	44.5
	a + b + c	175	43.3	50.9

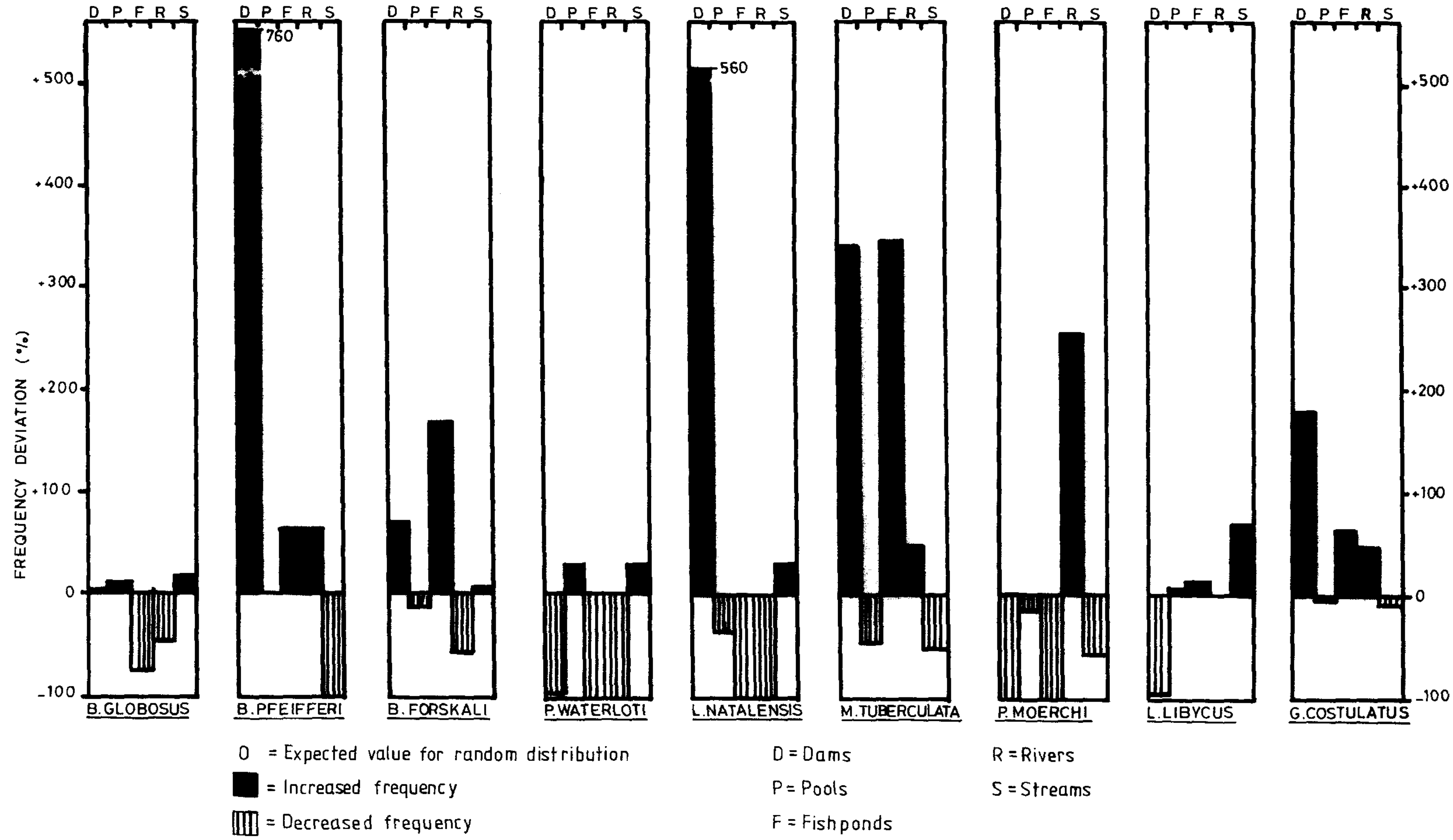

Fig. 1. Occurrences of nine species of freshwater snail in relation to type of water body.

the expected values for random distribution. *B. pfeifferi* preferred permanent bodies of water such as dams while *P. waterloti* occurred in streams and pools with almost equal frequencies and was not found in any other type of water body except the dam at Shaki. *G. costulatus*, one of the commonest gastropods of the area though mostly found in dams was also quite frequent in fishponds and rivers. Similarly, although fishponds appeared to be the preferred habitats for *B. forskali*, it was also often seen in dams. *B. rohlfsi* was only found in two fishponds while *Ferrissia* sp. was found in a dry season pool of River Ogun at Shepeteri as well as in three streams located at Oyo, Iseyin and Oluku villages. One specimen of *Segmentorbis* sp. was collected from Owo River at Owo, and six others were also collected from a stream at Efue.

Among the prosobranchs, *M. tuberculata* was most frequently encountered in dams and was nearly as frequent also in fishponds. Of the fourteen species encountered, only *M. tuberculata* was often present in large numbers, the mean number per habitat being 456 specimens compared with all the other species for which it was less than 50. *L. libycus* appeared to prefer streams particularly muddy ones containing thick growths of subaquatic macrophytes while *P. moerchi* seemed to prefer fast flowing, heavily shaded streams and rivers with gravelly or rocky substrates. Specimens of *L. ovum* were encountered at Bacita in a clayey canal drawing its water from the River Niger while *P. wernei* was found in the canal as well as in rivers and streams within the Niger basin as far south as Ilorin.

2.2 *Degree of shade*

The degree of shading of habitats by marginal, floating and emergent vegetation varied from 0% (negligible) to 100% (total cover). Referring to Fig. 2, it will be seen that *P. waterloti*, *G. costulatus*, *L. libycus*, *B. globosus* and *B. forskali* could all be encountered in negligibly (0%) to completely (100%) shaded water bodies although *B. globosus* appeared to prefer those with moderate (50–75%) shade and *G. costulatus*, *P. waterloti* and *L. libycus* were most frequent in high shade ones. In contrast, *B. pfeifferi* and *L. natalensis* both seemed to prefer minimal (0–25%) shade in their habitats. The prosobranchs, *P. moerchi* and *M. tuberculata* both preferred moderately shaded habitats but were often also found in low (25–50%) shade ones while all the water bodies in which *Segmentorbis* sp, *Ferrissia* sp. and *B. rohlfsi* were encountered were substantially shaded.

2.3 *Degree of pollution*

Soaps and detergents encountered in water bodies during the present study resulted mainly from washing, bathing and laundry activities which in rural areas especially during the dry season are more frequently undertaken directly in water bodies. Also frequently undertaken in water bodies during the dry season were fermentation of cassava tubers and washing of seeds of *Parkia clappertoniana* Keay which both cause serious fouling of water bodies especially stagnant ones. But with the availability of rainwater at home during the rainy season, there was a significant reduction in the frequency of these activities at water bodies and consequently also of the pollution which they cause. Human and animal excrements as well as domestic wastes were also frequently encountered especially in water bodies situated in densely populated human settlements while oil probably of a petro-chemical nature was often seen on the surfaces of water bodies that were situated at, or near motor vehicle repair sites. Although the frequency of oil pollution was low (1.5%), its effects appeared to be quite dramatic and long lasting as evidenced by the near total devastation of aquatic and subaquatic macrophytes and the slow recovery rates of the affected habitats.

B. globosus, *B. forskali*, *G. costulatus* and *P. moerchi* were most frequently encountered in water bodies polluted by cassava fermentation while *L. natalensis* and *P. waterloti* appeared to prefer those polluted with domestic wastes (see Fig. 3). Organic pollution in general seemed to favour *B. globosus* since its frequency of occurrence increased in habitats polluted with vegetable matter and domestic wastes but decreased signifi-

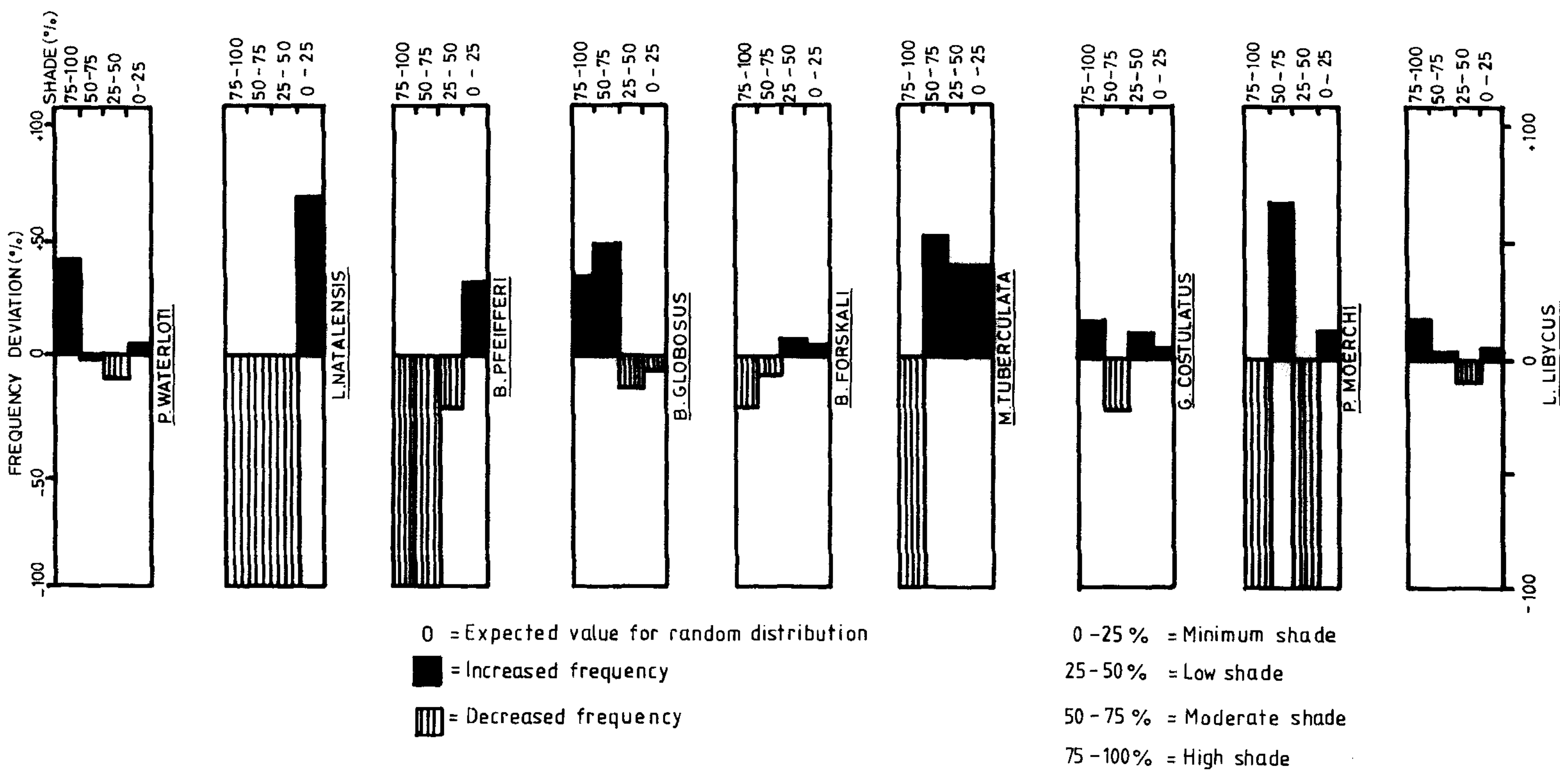

Fig. 2. Occurrences of nine species of freshwater snail in relation to shade.

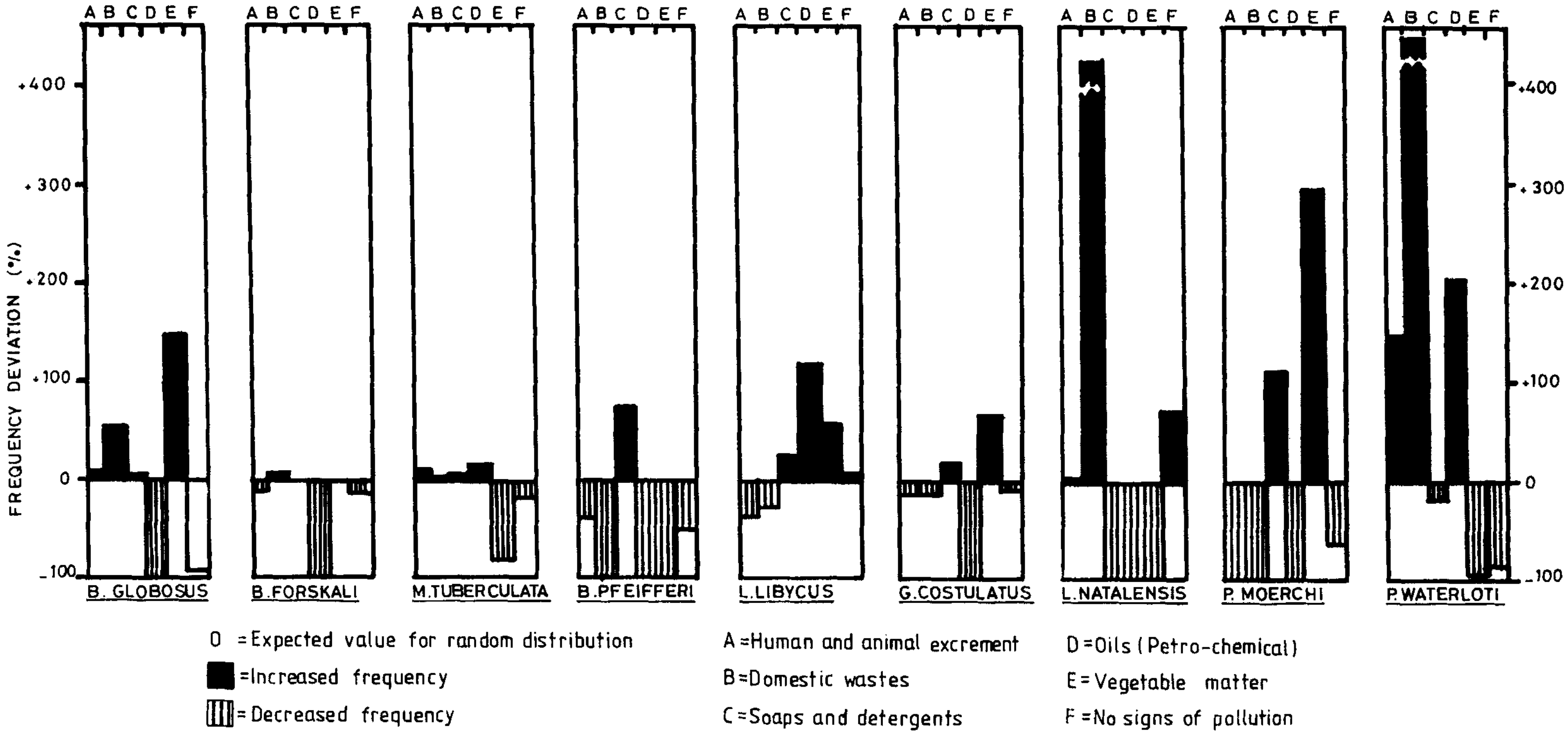

Fig. 3. Occurrences of nine species of freshwater snail in relation to types of pollution.

cantly in those showing no signs of pollution while preferred habitats of *P. waterloti* seemed to be those situated in densely populated human settlements which in the present area are often associated with severe pollution with human feces and domestic wastes. In sharp contrast to all the above snail species, *B. pfeifferi* showed a decreased frequency of occurrence in habitats containing polluting amounts of organic matter and an increased frequency in those polluted with soaps and detergents. Quite often, only *L. libycus* and *M. tuberculata* were found in habitats polluted with oil; indeed, it was not unusual to find *L. libycus* in sluggish streams or pools whose surfaces were completely covered by a film of oil while the snail appeared non-the-worse for this condition.

2.4 Type of Aquatic and Subaquatic Vegetation
Species of aquatic and subaquatic macrophytes encountered during the present study are shown in Table 3. All 190 water bodies which harboured snails also contained various aquatic and subaquatic macrophytes thus suggesting that these plants may be of some importance to snails. Subaquatic macrophytes of the study area were dominated by *Acroceras zizanioides* (Kunth) Dandy, *Alternanthera sessilis* Linn., *Commelina* sp. *Ludwigia leptocarpa* Nutt and other members of the family Graminiae mainly *Paspalum* spp.

Table 3. Relative frequencies of occurrence (%) of various species of aquatic/subaquatic macrophytes among 190 snail-positive water bodies.

Order	Family	Species	Number of positive habitats	Frequency (As % of 190)
AQUATIC	Lamnaceae	*Lemna pausicotata* ex Engelm	10	5.3
	Lentubulariaceae	*Utricularia reflexa* Oliv.	6	3.2
	Avaceae	*Pistia stratiotes* Linn.	1	0.5
	Salvinaceae	*Salvinia nymphellula* Desv.	5	2.6
		Heteranthera sp.	2	1.1
	Nymphaceae	*Nymphaea lotus* Linn.	8	4.2
SUBAQUATIC	Gramineae	*Acroceras* zizanioides (Kunth) Dandy	83	43.7
		Paspalum spp.	32	16.8
		Croix lacryma-jobi	18	9.5
		other Graminiae	31	16.3
	Commelinaceae	*Commelina* sp.	84	44.2
	Polygonaceae	*Polygonum salicifolium* ex Willd.	14	7.4
	Amaranthaceae	*Alternanthera sessilis* Linn.	52	27.4
	Onograceae	*Ludwigia leptocarpa* Nutt.		
		Cyclosorus sp.	10	5.3
		Ipomaea aquatica Forsk.	14	7.4

while aquatic forms were dominated by *Lemna pausicostata* ex Engelm and *Nymphaea lotus* Linn. It was observed that while some subaquatics e.g. *A. zizanioides* and *Commelina* sp. were more or less permanent features of the water bodies in which they were found and did not alter significantly in abundance seasonally, the aquatics *N. lotus*, *Pistia stratiotes* Linn., *Salvinia nymphellula* Desv., *Utricularia reflexa* Oliv. and the subaquatics *A. sessilis* and *L. leptocarpa* usually underwent pronounced seasonal changes in form and amount thereby, probably altering the characteristics of habitats and consequently affecting snails. It appears that subaquatic macrophytes are more important than aquatic ones as, X^2 analyses for association between snails and macrophytes revealed that out of nine positive and statistically significant associations six i.e. *B. globosus*/*A. sessilis*, *B. globosus*/*Commelina* sp., *B. forskali*/*A. sessilis*, *B. forskali*/*Paspalum* spp., *B. pfeifferi*/*Paspalum* spp., and Graminiae involved subaquatic macrophytes while only one i.e. *B. forskali*/*L. pausicostata* involved aquatic macrophytes (see Table 4).

2.5 Seasons

Seasonal variations in characteristics of aquatic habitats in the area were chiefly in form of increased growth of algae, decreased amount of suspended solids, decreased current speeds and lower turbidities during the dry season compared

Table 4. X^2 Values for Association Between Some Plants and Snail Species. Asterisks (*) indicate significant associations ($P \leqslant 0.05$).

Plant	Snail species		
	B. globosus	*B. pfeifferi*	*B. forskali*
Commelina sp.	6.4549*	0.0025	0.4915
Alternanthera sessilis Linn.	3.2782*	0.3364	14.3104*
Paspalum spp.	1.3848	5.9210*	8.7514*
Other Graminiae	1.9791	6.5748*	0.8249
Lemna pausicotata ex Engelm	1.9531	2.2465	6.4795*
Filamentous algae	13.5435*	0.1785	4.3042*

with their rainy season levels. Also, as the dry season intensified, some aquatic and subaquatic macrophytes either significantly reduced in amount or disappeared altogether. Significant differences between dry and rainy season water chemistry and between dry and rainy season substratum chemistry and physical properties were also observed. The observed differences in seasonal frequencies of occurrence of the individual snail species shown in Fig. 4 probably reflect such changes in the characteristics of the habitats. Apart from *B. forskali* which showed an increased frequency of occurrence during the rainy season, all of the others were more frequently encountered during the dry season. Furthermore, although population numbers were not rigorously estimated it was observed that all of the species except *B. forskali* were more abundant during the dry than during the rainy season. However in the case of *B. globosus*, both dry and rainy season frequencies of occurrence were close to values expected for random distribution probably because this species can tolerate wide ranges of ecological factors.

3. Intra-communal relationships

Relative concurrences of the more commonly occurring snail species of the present study area are presented in Table 5 which on examination reveals that the maximum number of snail species co-habiting a water body at any given time was 5 and that *B. globosus*, *B. pfeifferi*, *P. waterloti*, *L. libycus*, *M. tuberculata*, *G. costulatus*, *P. moerchi* and *L. natalensis* each tolerated up to 4 other species in their habitats. In general, frequencies of occurrence dropped markedly as numbers of species involved in the associations increased say, beyond 3 except, in the case of *L. natalensis*.

X^2 tests (Bailey, 1980) for degrees of association between pairs of some of the snail species are presented in Table 6 and the results show that all the associations were positive and that for the pairs *B. globosus*/*B. pfeifferi*, *B. globosus*/*B. forskali*, *B. globosus*/*P. waterloti*, *B. globosus*/*L. liby-*

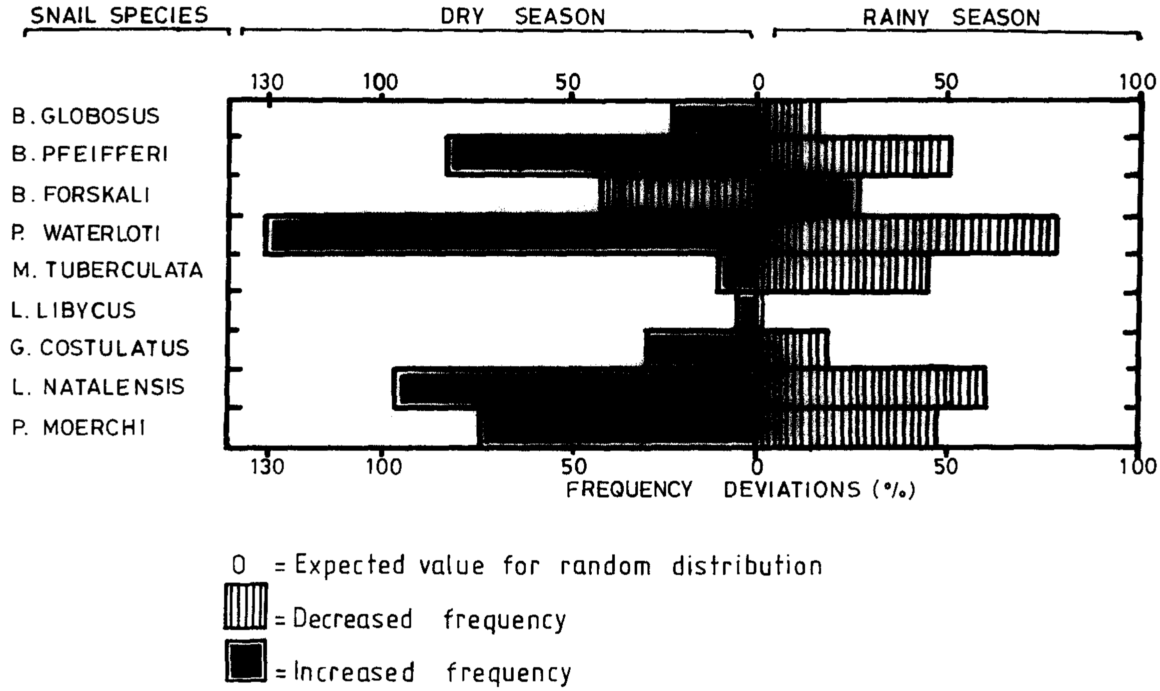

Fig. 4. Occurrences of nine species of freshwater snail in relation to climatic seasons.

Table 5. Concurrences of snail species in south-western Nigeria expressed as a percentage of the total number of snail-positive habitats (190).

SNAIL SPECIES	*B. globosus*	*B. pfeifferi*	*B. forskali*	*P. waterloti*	*L. libycus*	*M. tuberculata*	*G. costulatus*	*P. moerchi*	*L. natalensis*
Occurrence									
Alone	30.8	14.3	23.3	33.3	47.1	48.8	21.1	0	0
With 1 other species	30.8	21.4	26.7	20.0	27.1	24.4	26.4	50.0	25.0
With 2 other species	26.9	42.9	36.7	20.0	18.6	12.2	31.6	33.3	25.0
With 3 other species	9.0	7.1	13.3	20.0	4.3	7.3	13.2	0	25.0
With 4 other species	2.6	14.3	0	6.7	2.9	7.3	7.9	16.7	25.0
With 5 other species	2.6	14.3	0	0	0	0	0	0	0

Table 6. X^2 values for degree of association between snail species. Asterisks (*) indicate significant associations ($P \leqslant 0.05$).

B. globosus						
5.7102*	*B. pfeifferi*					
46.6364*	1.0260	*B. forskali*				
0.5792	12.5151*	0.0588	*M. tuberculata*			
9.8168*	0.5100	0.0223	7.4381*	*P. waterloti*		
18.8030*	0.6381	1.0804	0.0012	0.7380	*L. libycus*	
27.6236*	3.7305	26.7965*	1,3098	0.4053	3.4042	*G. costulatus*

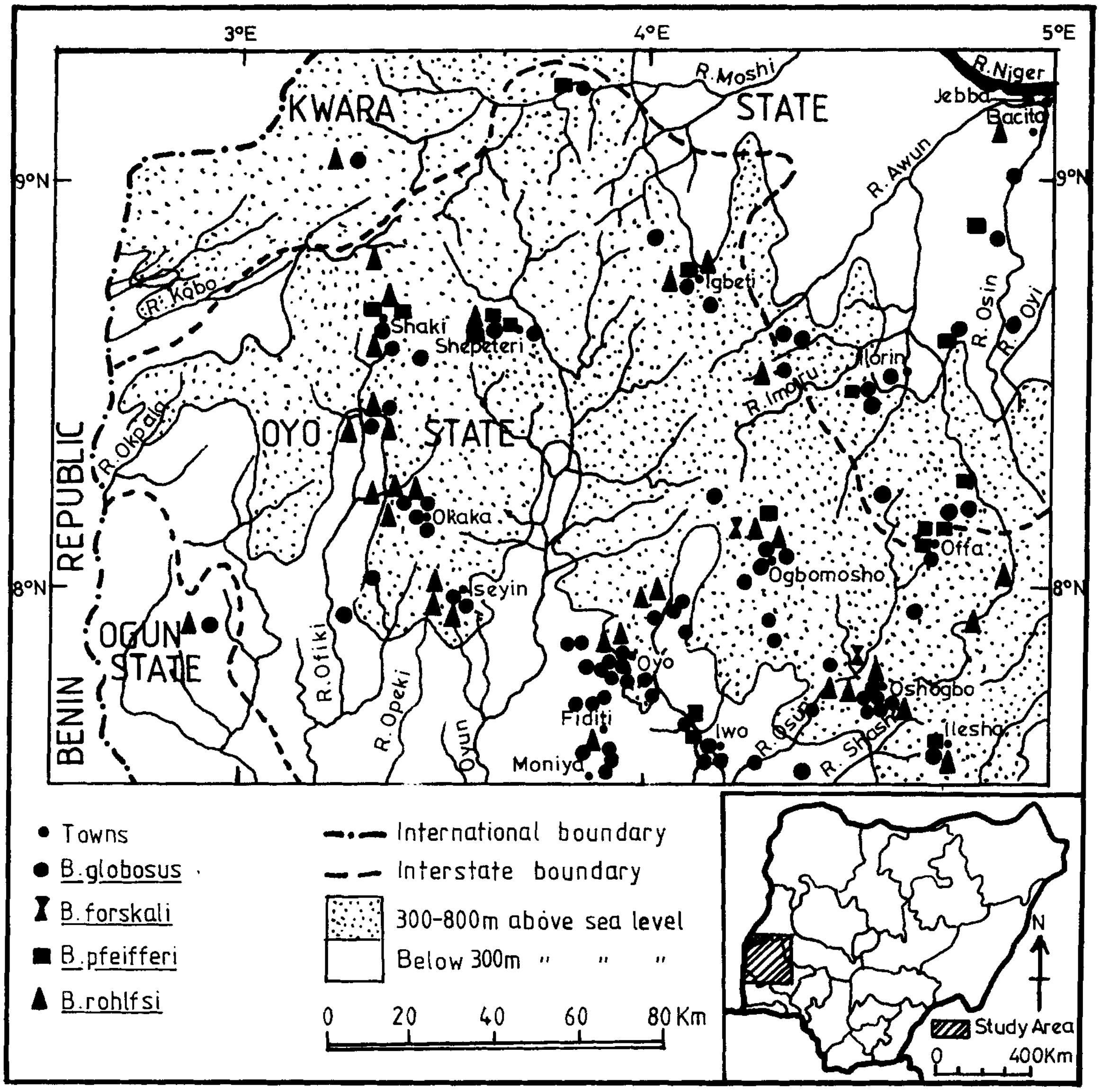

Fig. 5. Geographic distribution of pulmonates of medical/potentially medical importance in South-Western Nigeria.

cus, *B. globosus*/*G. costulatus*, *B. pfeifferi*/*M. tuberculata*, *B. forskali*/*G. costulatus* and *M. tuberculata*/*P. waterloti* the associations were statistically significant ($P < 0.05$). Of interest is *B. globosus*, the intermediate host of *Schistosoma haematobium* Bilharz that, showed the highest number of significant associations which no doubt is another indication of its ability to tolerate a wide range of environmental conditions.

4. Geographic distribution

In general, the geographic distribution of each of the pulmonate snail species in the study area was scattered as shown in Figs. 5 & 6. *B. globosus* and *G. costulatus* were however the only species that could be described as ubiquitous in the area. Fishponds constituted the only type of waterbody in which *B. rohlfsi* was encountered and this may be the reason why this species was rare in the area.

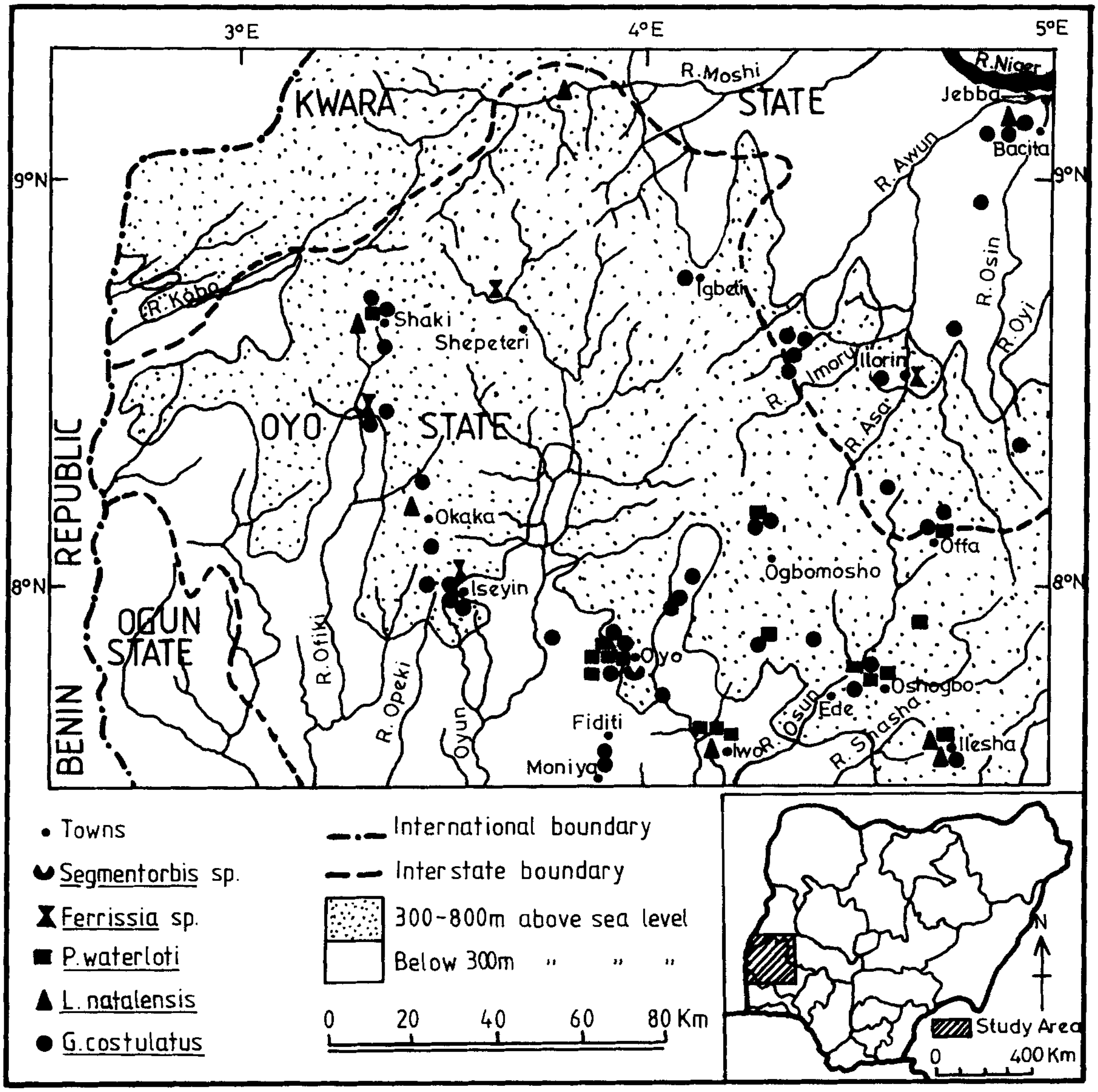

Fig. 6. Geographic distribution of other pulmonates in south-western Nigeria.

It is quite possible that the distribution of *Ferrissia* is wider than results of the present study would appear to indicate because the usual method of snail sampling using a net was found to be very ineffective in dislodging it from debris and vegetation to which it usually adheres very firmly. *B. pfeifferi* was chiefly found in permanent water bodies that were mostly situated on the Plateau of Yorubaland (300–900 m above sea-level) and was seldom encountered elsewhere. Similarly the distribution of *P. waterloti* closely followed that of densely populated human settlements most of which were on the same plateau.

Among the prosobranchs, *M. tuberculata* and *L. libycus* were the most widely distributed in the area as shown in Fig. 7 while the others were restricted in distribution with *P. moerchi* being confined to the eastern third of the area in fast flowing, well shaded, rocky or gravelly streams and rivers while *P. wernei* was confined to the north-eastern corner in the Niger basin. The canal from the River Niger was the only habitat from

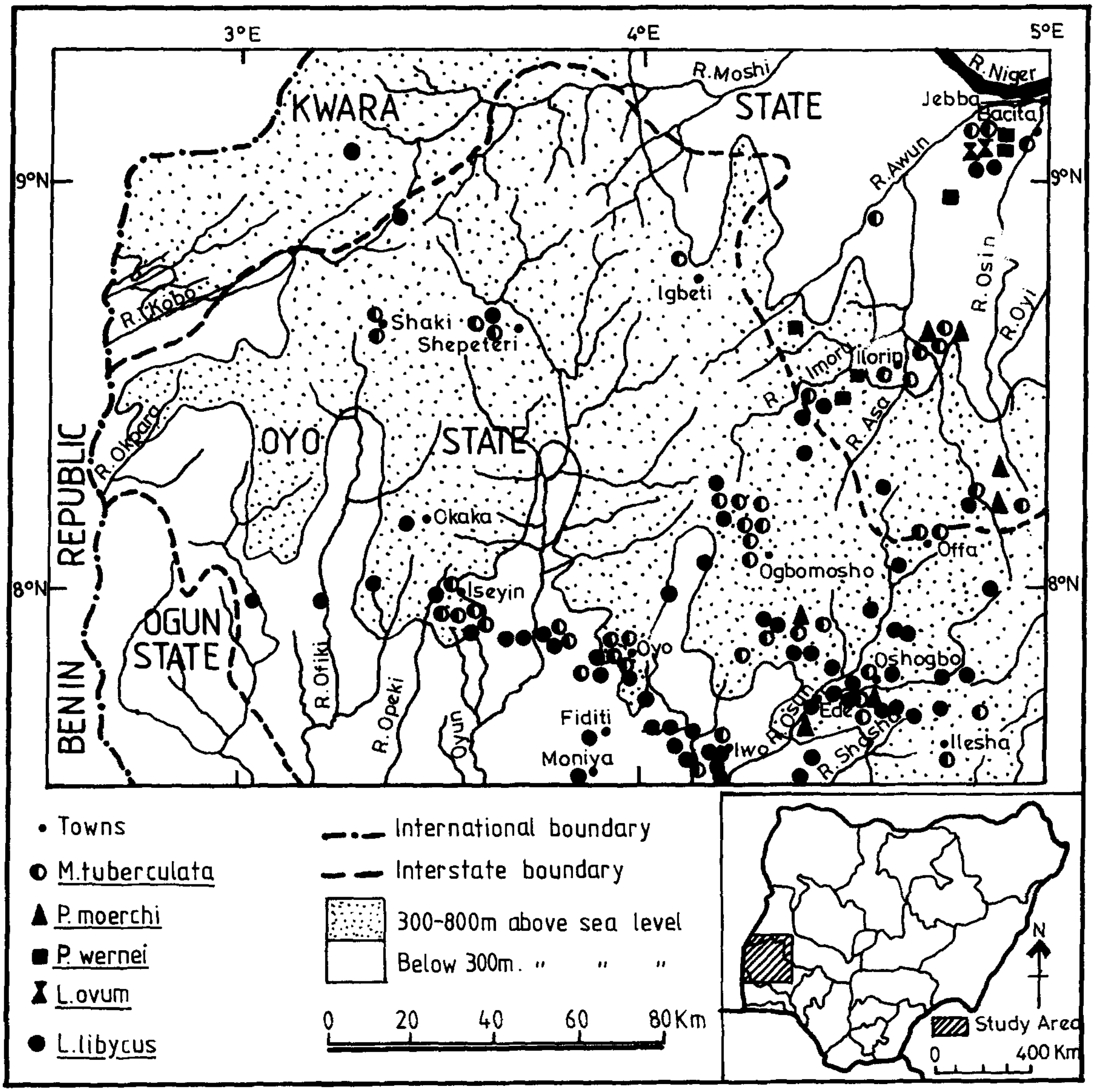

Fig. 7. Geographic distribution of prosobranchs in south-western Nigeria.

which *L. ovum* was collected during the present study and it is conceivable that the specimens may have originated from the River Niger since this species has previously been recorded by Walsh & Mellink (1970) in Lake Kainji.

Discussion

1. Type of water body

Freshwater types encountered in the present study area ranged in size from under 1 m to over 200 m diameter and included pools, dams, fish-ponds, rivers, streams, springs and a canal. Pools and streams predominated and constituted 41.8% and 36.1% respectively of the 404 habitats investigated. It was however apparent that the choice of any particular water body type by any of the encountered snail species did not depend on its frequency of occurrence and this is taken to imply the existence of other perhaps more important factors influencing snail preferences for water bodies. Thus, although the order of decreasing frequencies of occurrence of water types in the area was: streams > pools > rivers > fishponds > dams > springs > canal, *B. pfeifferi*, *L. natalensis*, *G. costulatus* were most frequently encountered in dams while *M. tuberculata* was most frequent in dams and fishponds, *L. libycus* in streams, *P. waterloti* and *B. globosus* in streams and pools, *P. moerchi* in rivers and *B. forskali* in fishponds. Indeed, Boycott (1936) observed that what matters to molluscs is not the topographical type of water body but its rate of flow, nature of substratum and the quality of the water and Brown (1980) similarly considered the effect of size of a water body to be overridden by other factors such as salinity and water level.

Flooding of water bodies which was observed to be a regular feature of the study area would appear to be the most important single local factor responsible for the spread of snails into newly established water bodies although other means of dispersal such as birds and human agency (Wright, 1977) are probably also involved. Betterton (1980) also considered rain water run-off to be an important factor in the spread of snails into newly created water bodies in the South Chad irrigation project area.

2. *Snail species of the study area*

All the snail species i.e. the pulmonates: *B. globosus*, *B. pfeifferi*, *L. natalensis*, *P. waterloti*, *G. costulatus*, *B. rohlfsi*, *B. forskali*, *Ferrissia* sp., *Segmentorbis* sp. and the prosobranchs: *P. moerchi*, *L. libycus*, *L. ovum*, *P. wernei*, *M. tuberculata* encountered in the present study area have been recorded from various parts of the West African region as a whole (Brown, 1980; M. Barth, 1973) and Nigeria in particular (Gordon, 1932; Taylor, 1932; Ramsay, 1934; Cowper, 1959; Purser, 1959; Cowper & Woodward, 1960; Okpala, 1961; Gilles *et al.*, 1980; Hira, 1966; Lévêque, 1967a & b, 1972; Walsh & Melink, 1970; Donges, 1972; Asumu, 1975; Okwuosa, 1979; Ukoli & Asumu, 1979; Brown, 1974; Pugh *et al.*, 1980 and Ebele, 1951). The present results further emphasize the uniformity of 'soudanian' aquatic fauna attributed (Beadle, 1974) to the intermittent linking of the water systems of the region during the pleistocene.

Although snail numbers were not rigorously estimated during the present study, mean numbers per habitat based on two-man 10 to 15 minute searches were low being less than 50 for all the species except the parthenogenetic and viviparous prosobranch, *M. tuberculata* for which a mean of 456 specimens per habitat was recorded. The mode of reproduction of this species as well as its detritivorous habit (Beadle, 1974; Thomas & Tait, 1984) provide possible explanations for the widespread occurrence and high population numbers of this species. Lévêque (1973) reported collecting about 1 500 m^{-2} *M. tuberculata* specimens in Lake Chad, northern Nigeria and Thomas & Tait, (1984) collected up to 9 800 m^{-2} of this species in Ibadan, southern Nigeria but much lower numbers (less than 100 m^{-2}) for other species.

Another feature of the snail fauna of the present study area was the low species diversity (mean, 1.7) per habitat probably owing to the highly seasonal nature of most of the water bodies in the area which is evidenced by the drop in number of habitats investigated, from 251 in the rainy season to 153 in the dry season. Thus, species having low tolerances to dessication are likely to be less frequent in habitats which frequently dry out. Besides, even when the water bodies do not dry out completely, the marginal vegetation could lose contact with water resulting in an exposure of the snails to predators, dessication, and other hazards and also to a reduction in the number of biotopes available to them. Since the number of snail species living in a water body is generally related to the variety of conditions (Brown, 1980) it could be expected that such a reduction in the number of biotopes would lead to a drop in the number of species colonising each habitat. This has been shown to be the case in East Africa where, (Brown 1980) observed the mean species diversity for ephemeral water bodies to be 2.0 per habitat while those for large swamps and stony beaches of Lake Victoria both of which had greater varieties of biotope were 5.4 and 6.5 respectively.

The widespread distribution and high frequency of occurrence (20%) of *B. globosus* observed during the present study are probably attributable to the ability of the species to tolerate wide ranges of ecological factors (Brown, 1980). Compared with *B. pfeifferi* and *B. rohlfsi* which occurred in only 4% and 0.5% respectively of all the habitats investigated, *B. globosus* would appear to be the most important intermediate host of schistosomiasis in South-western Nigeria, a position it is already believed to occupy in West Africa (Cowper, 1963; Hira & Muller, 1966; M. Barth, 1973; Brown, 1980). This species is known to have the greatest range of distribution among all members of its group, being found in most of Africa South of the Sahara as far north as Senegal and Southern Sudan (M. Barth, 1973) and south to Angola (Wright, 1963a) and Eastern South Africa (Brown, 1966). *B. rohlfsi* has been implicated in the transmission of a minor strain of *S. haematobium* in Ibadan, Nigeria (Cowper, 1959 & 1963). Investigations in the Lake Chad Basin (Betterton *et al.*; Betterton, 1984) and Kano State (Betterton & Ndifon, in press) have shown that during the dry season, *B. rohlfsi* is widespread and common in irrigation schemes and dams and is probably the main carrier of *S. haematobium* in Northern Nigeria during this period. The known distribution of *B. rohlfsi* is from Chad to Ivory Coast and Mali (M. Barth, 1973) but the species has also been collected from the Barombi Lakes in Cameroun (Wright, 1965) the Congo (McCullough (1964), Zaire (M. Barth *et al.*, 1974) and Angola (Wright (1963a).

In the present area as elsewhere in Nigeria (Walsh & Melink, 1970; Asumu, 1975; Ukoli & Asumu, 1979; Betterton, 1984; Betterton & Ndifon, in press and Thomas & Tait, 1984) *B. pfeifferi* was seldom recorded from temporary habitats thus, suggesting that habitat permanence may be an important factor in its occurrence. This apparent restriction to permanent habitats may be due to its poor aestivative ability (Brown, 1980) although water temperature probably also plays an important role in the distribution of this species since even in permanent but small fishponds, mass mortalities of its populations were often observed at the peak of the dry season when the ponds probably attained higher temperatures owing to the small amount of water left in them. According to Brown (1980), *B. pfeifferi* is excluded from large areas of East and West Africa because of its narrow ecological tolerance. This species also appears to prefer areas of higher altitude: 300–800 m (mean 550 m) above sea-level in the present study area, 655–823 m South Africa (Appleton, 1975), 600 mm and above in Kenya (Teesdale, 1954) and has been excluded from the Awash valley (Brown & Lemma, 1970) and the area from Somalia to Northern Mozambique by 'too warm climatic conditions' (Sturrock, 1965) while being absent from most of South Africa due to cool winter temperatures and low rainfall (Brown, 1980). It is however known to be widespread in the area south of the line passing through Asmara, Ethiopia (Brown, 1965) and has also been collected from the Nile in the Sudan (Malek, 1959), Lake Chad (Lévêque, 1967a & b; Betterton *et al.*, 1983, Betterton, 1984), Senegal (Brown, 1980), the Plateau of Southern Angola (Wright, 1963a), and North-west Transvaal (Van Eeden & Combrinck, 1966).

Both *B. forskali* and *G. costulatus* which were widely distributed and common in the present study area are known to be widespread throughout tropical Africa (Brown, 1980, M. Barth, 1973) and have been widely reported from Nigeria (Lévêque, 1967a & b; Betterton, 1984; Betterton & Ndifon, in press in the north, Hira, 1968; Asumu, 1975; Okwuosa, 1979; Thomas & Tait, 1984 in the south and Walsh & Mellink, 1970; Ukoli & Asumu, 1979 in the middle belt). *Ferrissia* sp. and *Segmentorbis* sp. were rarely encountered during the present study. However, *Ferrissia eburnensis* Binder is known to occur from Lower Zaire to Côte d'Ivoire and *Ferrissia chudeaui* Germain from Mali to Sierra Leone (M.

Barth, 1973). *Ferrissia* appears to be widely distributed in Nigeria being found from north (Betterton & Ndifon, in press) through the middle belt (Walsh & Mellink, 1970; Ukoli a Asumu, 1979) to south (Asumu, 1975) in all cases being reported as a minor faunistic element only. Both *Segmentorbis angustus* Jickeli and *Ferrissia kanisaensis* Preston are widespread in most of tropical Africa (M. Barth, 1973). In Nigeria, *S. kanisaensis* has been recorded from Lake Chad in the north (Betterton, 1984), the Kainji lake and Federal Capital Territory in the middle belt (Walsh & Mellink, 1970; Ukoli and Asumu, 1979) and Ibadan in the south (Asumu, 1975) although usually also as a minor faunistic element only.

P. waterloti has hitherto been known to occur from Ghana, Togo and Ibadan, Nigeria (Brown, 1980). The present findings therefore constitute an extension of the known geographic range of this species in Nigeria and also shows that all but one of the water bodies in which it was encountered fall south of latitude 8° 15° N i.e. in the south-western part of the study area. Although its fragile and very thin shell hence poor aestivative adaptation could be advanced to account for this restricted distribution, there may well be other reasons for the failure of this species to colonise permanent water bodies further north of the country.

L. natalensis which is known to be widespread throughout Africa (Brown, 1980), was also widely distributed though infrequent in the present study area being restricted in its occurrence to permanent water bodies. This species is among the most commonly recorded freshwater snails of Nigeria, occurring from south (Hira, 1966; Asumu, 1975; Okwuosa, 1979; Thomas & Tait, 1984) though the middle belt (Walsh & Mellink, 1970; Ukoli & Asumu, 1979) to north (Lévêque, 1967a & b; Ebele, 1979; Smith, 1982; Betterton, 1984; Betterton & Ndilon, in press).

Among the prosobranchs, *L. libycus* and *M. tuberculata* were widespread and frequent in the present study area but the frequencies with which both were encountered tended to decrease northwards. Walsh & Mellink (1970) also did not record them from the Kainji Lake which lies just a little further north of the present area while Ukoli & Asumu (1979) found *L. libycus* but not *M. tuberculata* in the latitudinally identical New Federal Capital Territory, and Betterton & Ndifon (in press) have not found either species in the Kano State. However, *M. tuberculata* and *L. ovum* are found in the Lake Chad (Lévêque, 1967& & b; Betterton, 1984) while further south, *L. libycus* and *M. tuberculata* are the commonest prosobranch (Hira, 1966; Asumu, 1975; Okwuosa, 1979; Thomas & Tait, 1984). *M. tuberculata* is not known to occur in habitats which frequently dry out and although it occurs in most of Africa, it is known to be infrequently encountered in West Africa and absent from the Zaire Basin (Brown, 1980). *L. libycus* is found in the coastal region of West Africa from Côte d'Ivoire to Gabon (Brown, 1980; M. Barth, 1973). *L. ovum* collected during the present study from the Bacita canal could conceivably have originated from the River Niger since this was the only natural habitat in which the species was encountered. This species has been recorded from Lake Kainji also on the Niger, Yola (Brown, 1980) and Lake Chad (Lévêque, 1967a & b; Betterton, 1984) while *P. moerchi* which during the present study was observed to be restricted to highly shaded stony or gravely streams in the south-western corner of the study area has previously also been known to occur from Ghana to Western Nigeria (Brown, 1980; M. Barth, 1973). The occurrence of *P. wernei* within the Niger Basin in the region from around Jebba to around Ilorin of the present study area is of interest since the species has not been reported from the nearby Lake Kainji although it is known to occur in the Niger at Mali (Pain, 1961). In Africa, *P. wernei* occurs from Somalia and Southern Sudan in the east to the Niger in the west and to Lower Zaire (M. Barth *et al.*, 1974) and North-east Namibia (Pain, 1961) in the south.

3. Pollution

Of the various types of pollution presently being considered, organic pollution in the form of decomposing algae and macrophytes, human and animal excrements and domestic wastes was the most frequent in the study area being encountered in 30.2% of the 404 investigated habitats. However, these materials were very infrequently encountered during the rainy season owing to flushing out by fast currents and floods but accumulated to significant levels during the dry season when water bodies were either slow-flowing or stagnant.

Differences in the frequencies of occurrence of various snail species with respect to different types of pollution observed during the present study differences in their behaviour and physiology. Thus, the pulmonates *G. costulatus*, *B. globosus*, *L. natalensis* and *P. waterloti* which possess vascularised mantles with which they can acquire atmospheric oxygen for respiration were most frequently encountered in organically polluted water bodies. In the case of *B. globosus*, this is not surprising since it has been shown (Van Aardt & Frey, 1981) that the oxygen retention capacity of its haemoglobin like that of *Biomphalaria sudanica* (Jones, 1964) is very high thus making it well suited for life in water bodies having low oxygen concentrations. Observations by Van Emden *et al.* (1974) that *B. glabrata* can survive an exposure of LC 100 24 h to detergents for up to 20 h and that biodegradable products of detergents in concentrations of up to 100 mg l^{-1} have no influence on its mortality would appear to account for the high frequency of occurrence of the closely related *B. pfeifferi* during the present study in water bodies polluted with soaps and detergents. Smith (1982) observed that in a sewage-polluted stream at Zaria, Nigeria, previously low populations of *L. natalensis* recovered before those of *B. globosus* and *B. pfeifferi* and *B. globosus* was more common near the sewage outfall than *B. pfeifferi*. The results of the present study form an interesting comparison to his findings as evidenced by the order of decreasing frequencies of occurrence of the snail species which was: *P. waterloti* > *B. globosus* > *G. costulatus* > *L. libycus* > *B. forskali* > *M. tuberculata* > *P. moerchi* > *L. natalensis* > *B. pfeifferi* for water bodies polluted with vegetable matter, *P. waterloti* > *L. natalensis* > *B. globosus* > *B. forskali* > *M. tuberculata* > *G. costulatus* > *L. libycus* > *P. moerchi* > *B. pfeifferi* for those polluted with domestic wastes and *P. moerchi* > *M. tuberculata* > *B. globosus* > *L. natalensis* > *B. forskali* > *G. costulatus* > *L. libycus* > *B. pfeifferi* > *P. moerchi* for those polluted with human and animal excrements.

Some workers (Watson, 1958 & Betterton *et al.*, 1983 for example) have noted that host snails of schistosomiasis are abundant in habitats polluted by organic matter; Watson (*loc. cit.*) was of the view that human excrement could serve as food for snails and also provide factors which stimulate their growth and reproduction while human urine may act as a fertilizer for algae which snails feed on. However, it has also been pointed out (Frank, 1963; Walsh & Mellink, 1970; Smith, 1982) that excessive organic pollution may harm them. Indeed, Frank (*loc. cit.*) confirmed this experimentally by demonstrating that moderate amounts of male human urine promoted growth of *Biamphalaria* while high amounts depressed its fecundity.

4. *Degree of shade*

Based on the degree of shading of the habitats in which they were most frequently encountered, snail species of the present study area can variously be described as shade intolerant, slightly or moderately shade tolerant and shade loving. In the first class are *B. pfeifferi* and *L. natalensis* which were most frequently encountered in water bodies having 0–25% of their surface areas shaded by marginal, floating or emergent vegetation; in the second is *B. forskali*, *P. moerchi* and *M. tuberculata* which preferred those with 50–75% shade and in the fourth are *P. waterloti* and *L. libycus* which were most frequently encountered in 75–100% shade habitats. However, there was no evidence to suggest that any of these snail species actively sought shade and avoided direct sunlight as claimed by some workers (Gerber, 1952; Zakaria, 1955; Hira, 1966; Asumu, 1975). Zakaria (*loc. cit.*) actually demonstrated experimentally that *B. truncatus* selected areas of light shade and moved away from bright areas or total darkness, probably owing to a direct influence of sunlight on the physiology of the snails. Also, it has been shown (Joy, 1971) that red light can cause lowered eggs production in *Biomphalaria glabrata* and according to Thomas & Tait (1984), UV light is lethal to albino *B. glabrata*. The present authors are of the opinion that under field conditions direct sunlight or the absence of it more significantly influences snail populations indirectly by influencing the amounts of micro- and macroflora as evidenced by the increased numbers of most species during the dry season when the flora was rich and varied compared with their low numbers during the rainy season when the opposite situation prevailed.

5. *Aquatic/subaquatic vegetation*

It could be concluded from the results of the present study that the presence of aquatic/subaquatic vegetation is a desirable feature of habitats of freshwater snails in South-western Nigeria since all the water bodies from which they were collected contained some form of such vegetation and all the vegetation types were positively associated with the snails some of them significantly as shown by X^2 tests for *B. globosus*, *B. forskali* and *B. pfeifferi*. Thomas & Tait (1984) also observed similar snail-plant associations in the Ibadan area, Nigeria. The present results have also revealed that being very common does not necessarily mean a plant species will be the more significantly associated with snails; thus, although it occurred very frequently (43.7%) in the area, *A. zizanioides* was not significantly associated with any of the snails investigated. Some workers (Wright, 1956; McCullough, 1956; Shiff, 1964; Hira, 1966) have observed that aquatic host snails of schistosomiasis prefer certain macrophytes for certain activities such as egg deposition. During the present study it was also observed that plants with smooth surfaces were favoured for egg deposition and resting while those with very hairy surfaces such as *Pistia stratiotes* were seldom used for either purposes. In particular *Commelina*, *Nymphaea lotus*, *A. sessilis* and *Paspalum* spp. if present were extensively used for egg deposition by *B. globosus*. In the course of laboratory investigations during the present study *B. globosus* exhibited a large appetite for fresh homogenates of *Commelina* and boiled leaves of *A. sessilis* and its egg production and growth and mortality rates were similar to those of snails fed boiled garden lettuce probably implying that decomposing forms of these plants could also serve as a food source for the snails.

6. *Other snails*

As evidenced by the trend of decreasing degree of association with increasing number of participating species, the present results suggest that snail species in South-western Nigeria tend to occur more frequently alone than with other snails, the optimum size of the association being two in most cases. Similarly, van Someren (1946) observed that in Kenya, *Lymnaea caillaudi* occurred more frequently alone than with any other species. One possible explanation for this could be that water bodies of the area present few biotopes for colonisation by the different species since according to Brown (1980) species diversity increases with increasing diversity of biotopes. In the present study area biotope diversity would be reduced say during the dry season owing to drying out of water and its consequent loss of contact with fringe vegetation. It could also be that some species utilise similar niches and so enter into competition with one another. Competition has been implicated in the unfavourable relationship between *B. globosus* on one hand and *P. waterloti* and *L. natalensis* on the other (McCullough, 1957) and between *Biomphalaria ugandae* and *Biomphalaria sudanica tanganyicensis* (Berrie, 1964). However, X^2 analysis in the present study do not provide any evidence in favour of competition between any of the species encountered. An interesting case is that of *L. libycus* and *B. globosus* which were highly positively significantly associated with each other. Laboratory observations during the present study revealed that *L. libycus* is a voracious macrophyte eater and a suggestion was made (Ndifon, 1979) that it probably ingested eggs of other snails such as *B. globosus* along with its food. This suggestion was based on the observation that whenever these two species occurred together, the numbers of *B. globosus* were usually rather low. Indeed, Thomas & Tait (1984) demonstrated experimentally that *L. libycus* preys on eggs and juveniles of *B. pfeifferi* although they also found that the two species were very strongly associated with each other. *L. libycus* thus resembles *Marisa cornuarieties* (Demian & Lufty, 1965a & b), *Pomacea* (Pauliniyi & Paulini, 1972) and Helisoma duryi (Fradsen & Madsen, 1979) which prey on planorbids.

7. *Seasons*

Judging by the increased frequencies of occurrence and higher numbers of most snail species observed in the present area during the dry season, it would appear that ecological conditions prevailing during the dry season are more favourable than those of the rainy season. The only exception to this general situation was *B. forskali* which was more frequent and numerous during the rainy season. Thus, the mean numbers per habitat for *B. globosus*, *B. pfeifferi* and *B. forskali* for example were 19, 11 and 3 respectively during the dry season and 12, 5 and 40 respectively also during the rainy season. Dry season conditions which would favour snails in the present study area include among others, low turbidities, reduced currents and substantial growths of algae and macrophytes. Hira (1966) and Asumu (1975) both recorded higher numbers of snails during the dry season in the Ibadan area while according to Hira (*loc. cit.*), Watson (1950) and Teesdale (1962) intermediate host snails of schistosomiasis prefer slow or stagnant water. Watson (*loc. cit.*) was of the opinion that *B. forskali* prefers fast flowing waters such as those found during the rainy season but Hira (1966) suggested that lowering of water temperatures during the rainy season may have triggered breeding in *B. forskali* and so accounted for the higher numbers of this species observed during the rains.

Conclusion

Dry and rainy season investigations of freshwater snails carried out from January 1976 to December 1977 in an area of South-western Nigeria including parts of Oyo, Ondo and Kwara States revealed fourteen snail species including *Bulinus forskali*, *Bulinus globosus*, *Gyraulus costulatus*, *Lanistes libycus*, and *Melanoides tuberculata* which were widely distributed and common, *Biomphalaria pfeifferi*, *Lymnaea natalensis*, *Physa waterloti* and *Potadoma moerchi* which were infrequent and *Bulinus rohlfsi*, *Pila wernei*, *Segmentorbis* sp., *Ferrissia* sp. and *Lanistes ovum* which were rare. All these species are typical of the West African gastropod fauna previously reported by other workers. Flooding of water bodies during the rainy season appears to be a major factor influencing snail dispersal in the area. All the species except *B. forskali* were more frequently encountered during the dry than during the rainy season.

Among the intermediate hosts of *Schistosoma* encountered, *B. globosus* but not *B. pfeifferi* appeared to be favoured by organic pollution such as human and animal excrements, domestic wastes and vegetable matter.

B. pfeifferi and *L. natalensis* preferred minimal shade in their habitats while *B. globosus*, *P. moerchi* and *M. tuberculata* preferred moderately shaded ones and habitats of *G. costulatus*, *P. waterloti*, *L. libycus*, *P. wernei*, *L. ovum*, *Ferrissia* sp. and *Segmentorbis* sp. were typically highly shaded.

With regards to schistosomiasis transmission important fresh water types in the present area are pools, streams and dams, the first two were the preferred habitats of *B. globosus* while the third was the preferred habitat of *B. pfeifferi* and *B. rohlfsi*. In general, lenthic habitats of the area were more frequently colonised than lotic ones.

The presence of macrophytes in habitats of freshwater snails in the studied area appears to be essential since all the water bodies in which snails were encountered contained various aquatic or sub-aquatic macrophytes all of which were positively associated with the snails. In the case of the intermediate hosts of schistosomiasis the associations were statistically positively significant for the pairs: *B. globosus/Commelina*, *B. forskali/A. sessilis*, *B. pfeifferi/Paspalum* spp., and *B. forskali/Lemna pausicotata*. It was also evident that being most common did not necessarily mean a plant species will be the most significantly associated with snails.

Concurrences of snail species of the present study area decreased with the increasing number of species involved in the association and in general, most species occurred most frequently alone. Statistically positively significant associations observed between the pairs: *B. globosus/P. waterloti*, *B. globosus/L. libycus*, *B. globosus/G. costulatus*, *M. tuberculata/P. waterloti*, *B. pfeifferi/M. tuberculata* and *B. forskali/G. costulatus* are suggestive of shared ecological requirements.

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