PART II Chapter 3

BIOLOGY OF SNAIL INTERMEDIATE HOSTS OF SCHISTOSOMIASIS

3.1 A longitudinal study of snail intermediate hosts of trematode parasites in the Benue valley of North Cameroon.

Slootweg, R., E. van Rhijn, J.A. van Schijndel, M.J. Dijkstra & A.C. Colenbrander (1993). A longitudinal study of snail intermediate hosts of trematode parasites in the Benue valley of North Cameroon. *Journal of Medical and Applied Malacology* **5**: 45-59.

Throughout the northern Provinces of Cameroon, schistosomiasis is a public health problem. A recent nationwide survey revealed that *Schistosoma haematobium* and *S. mansoni* can reach high prevalences in individual villages in the North province (Ratard et al., 1990). Nation-wide malacological surveys carried out in Cameroon revealed that *Biomphalaria pfeifferi, Bulinus globosus, B. forskalii, B. senegalensis* and *B. truncatus* are possible intermediate hosts of human schistosomes from the Benue Valley (Same Ekobo, 1984; Same Ekobo et al., 1984; Greer et al., 1990; Mimpfoundi & Slootweg, 1991). The studies cited above have contributed significantly to the knowledge of the distribution of possible snail hosts, but the exact population dynamics of snails and the transmission dynamics of schistosomiasis are still in unclear. The construction in 1982 of a hydroelectric dam in the Benue near Lagdo, and the large scale development of irrigated agriculture on the former floodplains of the Benue valley further complicates the assessment of schistosomiasis transmission in the region. The hydrological characteristics of the area were dramatically altered and potential breeding sites for snail hosts have been created. To elucidate the dynamics of snail populations, a longitudinal study in and around the newly constructed irrigation scheme of Gounougou was conducted between April 1988 and March 1991. In 1987, this 200 ha irrigation scheme became operational; at the moment of writing an 800 ha extension is under construction near the villages of Ouro Doukoudjé and Bessoum. In 1986 the prevalence rates in Gounougou were 7% for intestinal and 21% for vesical schistosomiasis (Robert et al., 1989). Since cattle raising is one of the important economic activities in the region and fascioliasis among cattle is common (Cholet, pers. com.), data on the intermediate host snail *Lymnaea natalensis* are also included in this paper.

Snail sampling methods and sites

From April 1988 until March 1991, 13 sites were sampled monthly covering all available aquatic habitats around the village of Gounougou. Sites were sampled with dip-nets, but also hand collections were made. Search-time was taken as the standard measure to quantify the numbers of snails, as described by Olivier & Schneiderman (1956) and thus numbers of snails collected are expressed in numbers per man-hour search-time. Two persons searched for 2 x 15 minutes or one person for 30 minutes. The monthly samples were taken to the laboratory; snails were measured and exposed to sunlight, in order to detect possible cercarial shedding. On two sites with abundant numbers of snails, samples were taken weekly for several months in order to estimate the growth rates for *Bulinus forskalii, B. globosus* and *Lymnaea natalensis*. To avoid sampling errors, weekly sampled snails were measured and immediately replaced. In the aquaculture station, 24 ponds were sampled monthly, starting in May 1989. Here a fixed surface was inspected for snails; the concrete drainage device (monk) was searched with a dipnet. Thus a standard surface was inspected, taking only a few minutes per pond.

The collection sites are indicated in Figure 4; many of these sites are used intensively by inhabitants and may be considered as potential schistosomiasis transmission sites if snail hosts are present. A description of the observed water contact patterns is given in Slootweg et al. (1993a).

- **The Lagdo lake (artificial reservoir)**: the shore of the Lagdo lake at the East Dyke **(A)** is used intensively by fishermen from Gounougou. The lake was created in 1982 and reached its maximum filling level during the rainy season of 1988. The lake fills up between July and October; from November until June the shores recede.
- **The irrigation scheme**: the canals are constructed with laterite which does not allow much vegetation to develop. The primary irrigation canal **(B)** is permanently filled with varying water levels. The secondary **(C)** and tertiary irrigation canals **(D)** contain water only during irrigation and are regulated with valves. The field canals **(E)**, rice fields **(F)** and field drains **(G)** contain water during the entire growing season. Drainage water is disposed of through a tertiary **(H)** and secondary drain **(I)** into the depression of Gounougou. The drains are overgrown with aquatic weeds and are permanently filled with water. Clearing of weeds was done infrequently, and maintenance of the entire irrigation scheme was not optimal. Snail

sampling started less than one year after the scheme became operational. Two cycles of rice are grown per year; a dry season cycle between December and April and a rainy season cycle between June and November. One month after sowing, the rice seedlings are transplanted from sowing beds to the fields.

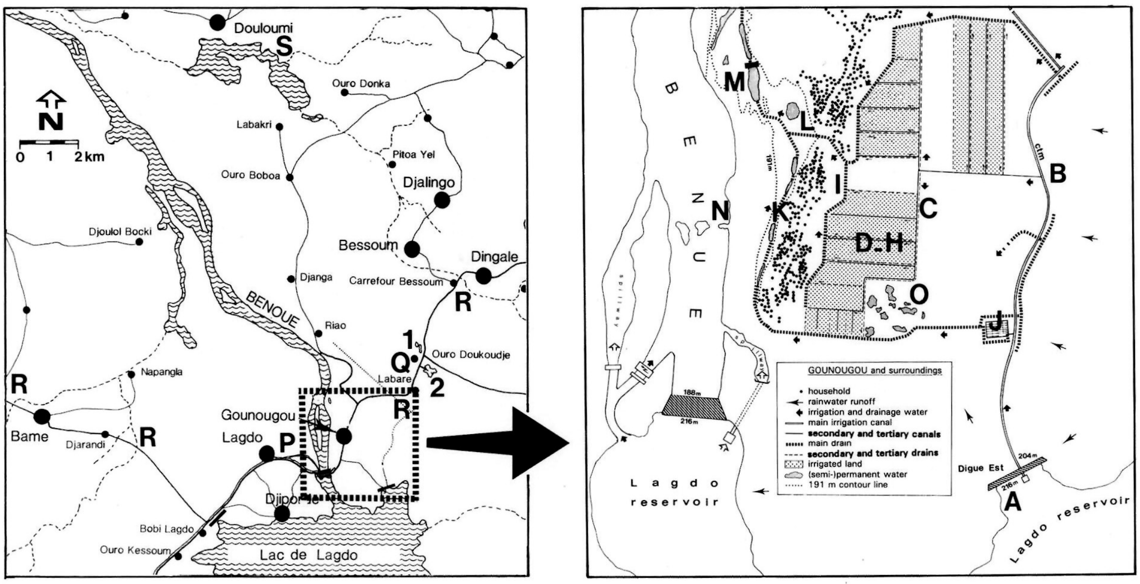


Fig. 4: Location of sampling sites in the Benue valley around the village of Gounougou; sampling sites in alphabetical order explained in the text.

- **The aquaculture station (J)** is located at 500 m from the inlet of the primary irrigation canal, and operational since June 1987. The relation between pond management, fish species and snail populations has been described by Slootweg et al. (1993b).
- **The depression of Gounougou**: this former floodplain depression now serves as primary drainage canal for drainage water of the Gounougou scheme (200 ha), and for the rainwater effluent. The ford in the middle of the depression **(K)**, the entrance of the secondary drain into the depression **(L)**, and a small basin **(M)** in the outlet towards the Benue were sampled.
- **The Benue river**: since 1988 the spillway of the Lagdo dam has been opened every year; during the remaining months the water flow is reduced to 60 m3/s released by the hydroelectric plant. The banks of the Benue have been cleared of vegetation by the spilling. An intensively used washing site was inspected monthly **(N)**.
- **Natural and artificial pools**: several isolated pools have been monitored on a regular or irregular basis. Monthly samples were taken in a clay quarry **(O)** south of the Gounougou scheme. These deep clay pits are used to water cattle in the dry season. Also samples where taken from a semi-natural pool on the left bank of the Benue, near Lagdo **(P)**. This permanent pool collected drainage water from a nearby vegetable garden. After one season of intensive snail sampling the vegetable garden was moved towards the river, and the pool dried completely. Several sites were visited irregularly: laterite quarries in Ouro Doukoudje **(Q)** and temporary streams in the Benue valley **(R)**.

Water temperature was measured weekly in several ponds of the aquaculture station at 8.00 h. and 16.00 h. during the entire research period. On nine sites, also hourly or bi-hourly measurements on water temperature and oxygen contents were carried from 6.00 h. to 18.00 h., with a WTW OXI 91 field kit at 15 cm water depth. Reliable meteorological data were available from 1984 until 1988 in a nearby research station at Karewa (9°10'N, 13°30'E, 200m altitude), located in the Benue valley at 20 km from Lagdo.

Results

Meteorological data and habitat measurements

Weather conditions.

The weather over the five-year period of measurement in the Benue valley is characterized by very high temperatures and evaporation, with lowest temperatures in December and January (Fig. 5) and highest in March and April. Differences between day and night temperatures were less pronounced in the rainy season compared to the dry season. Precipitation reached a mean of 913 mm, with maximal rainfall in August. Evaporation was more than double the precipitation with a mean value of 2327mm yearly, and a maximum in March. A combination of high temperature, low relative humidity and increasing wind speed was responsible for the enormous evaporation of 200mm - 300mm per month from February to May.

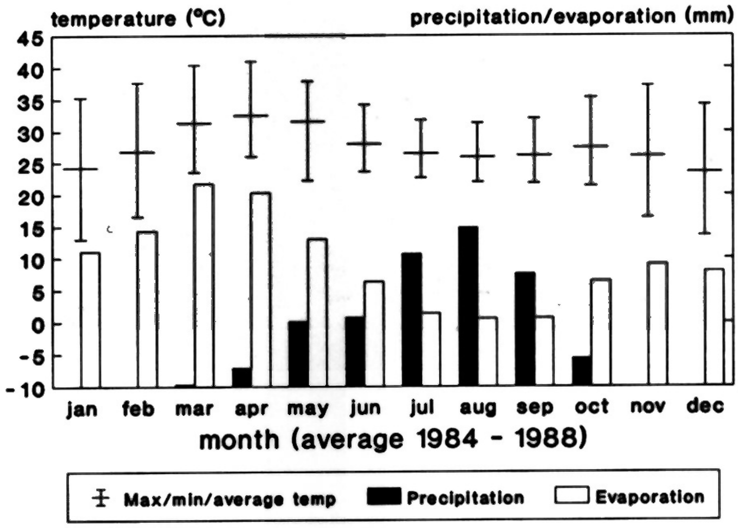


Fig. 5: Mean monthly air temperature, precipitation and evaporation for 1984 to 1988, measured at the experimental farm of Karewa.

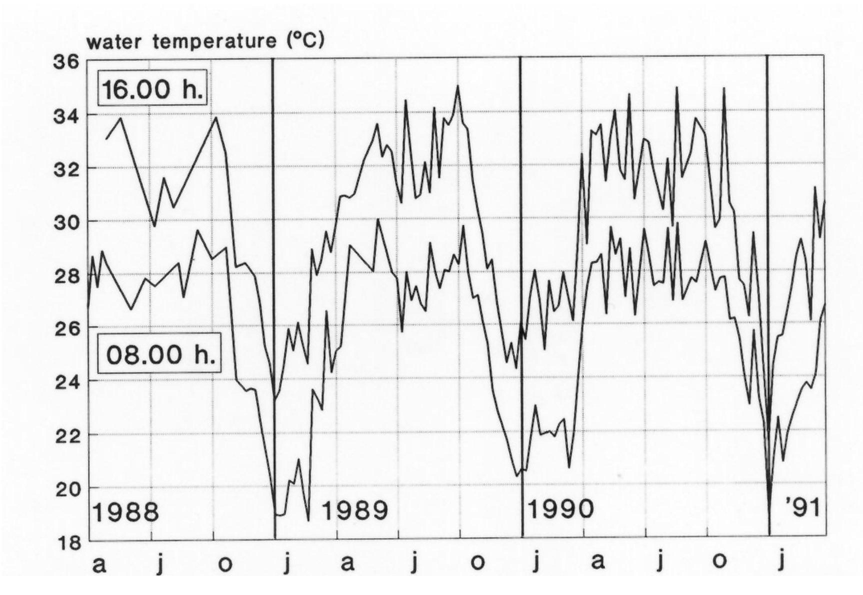


Fig. 6: Water temperatures at 8.00 h a.m. and 16.00 h p.m., measured weekly at the aquaculture station Gounougou between April 1988 and March 1991.

Seasonal water temperatures and snail densities

The water temperatures measured at the aquaculture station (Fig. 6) show remarkably high values in the rainy season between May and October, when the air temperature is relatively low. Morning temperatures (8.00 h.) during these months vary between 26°C and 30°C, and afternoon temperatures (16.00 h.) vary between 30°C and 35°C. Lowest morning water temperatures, measuring 19°C to 22°C, are registered between January and March when the cooling effect of evaporation is maximal. The length of the cool season can vary from one month in 1991 to four months in 1990. The combined effect of air temperature, relative humidity and evaporation results in water temperatures that seem contradictory to air temperatures. Similar results have already been discussed by Betterton (1984) for the Lake Chad region of Nigeria.

All but one of the correlations between water temperature and numbers of snails (Table 1) were negative, indicating that all three species are found in highest numbers when water temperatures are low or have been low in the previous months. Six correlation coefficients were significant; twice for B. forskalii at the fishculture station, and twice for both *B. truncatus* and *L. natalensis* in the drainage canals and clay quarry.

Table 1: Two-tailed test of crosscorrelation of ranks (Spearman) between average monthly water temperature as measured at the aquaculture station Gounougou and the numbers of snails encountered. Correlations were calculated for a time lag between 0 and 4 months; the time lag with highest correlation is given. Site codes refer to Figure 4.
Siginificance level: * $\alpha < 0.05$; ** $\alpha < 0.01$.

Sites (code)	snail species	crosscorrelation of ranks	time lag (months)	N	α
Fishculture station (J)	*B. forskalii*	- 0.52	2	20	*
	B. truncatus	- 0.39	2	20	-
Irrigation canals (B/C/D)	*B. forskalii*	- 0.15	0	35	-
Rice field (F)	*B. forskalii*	- 0.17	1	35	-
Field canal/ drain (E/G)	*B. forskalii*	- 0.46	1	35	**
	B. truncatus	+ 0.30	0	36	-
	L. natalensis	- 0.20	1	35	-
Drainage canals (H/I)	*B. forskalii*	- 0.29	0	36	-
	B. truncatus	- 0.43	0	36	**
	L. natalensis	- 0.44	1	35	**
Depression zone (K/L/M)	*B. forskalii*	- 0.32	0	36	-
	B. truncatus	- 0.23	1	35	-
	L. natalensis	- 0.16	1	35	-
Clay quarry (O)	*B. forskalii*	- 0.07	1	35	-
	B. truncatus	- 0.38	2	34	*
	L. natalensis	- 0.42	2	34	*

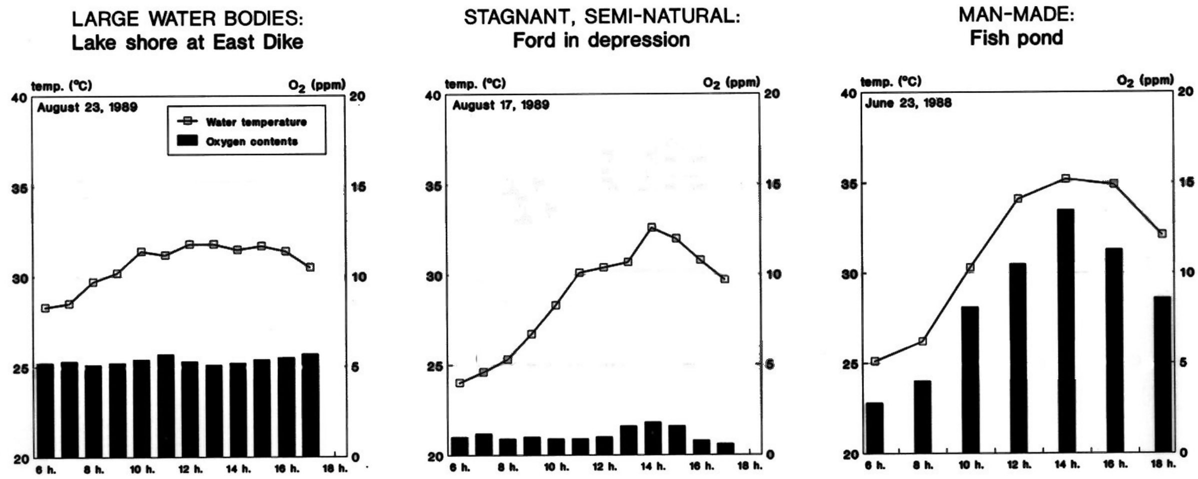
Habitat measurements

Temperature and oxygen measurements made from sunrise to sunset show that habitats can "behave" in a different way. Measurements were taken on sunny days in the rainy season, and thus not influenced by sudden showers. These data are presented to illustrate the variations during the day; data cannot be compared as measurements were taken on different days. Three main types of habitats can be recognized (for each habitat-type one representative figure is given in Figure 7):

1) Large water bodies with constant oxygen content and relatively low variation in water temperature (Fig. 7.1), i.e. the Lagdo reservoir (site A in Figure 4), the Benue river (N) and the primary irrigation canal (B) which receives water almost directly from the lake. These large volumes of water react very slowly to changes in the environment.

2) Stagnant semi-natural medium-sized water bodies. Water temperature rises sharply during the day, but oxygen content stays relatively low during the day (Fig. 7.2): i.e. the clay quarry (O), the ford (K) and drain entrance (L). These reservoirs are rather shallow (< 1.5m) and rapidly warm up. There is little turbulence and the exchange of oxygen with the air is low. The quantity of oxygen producing algae appeared low compared to the next habitat.

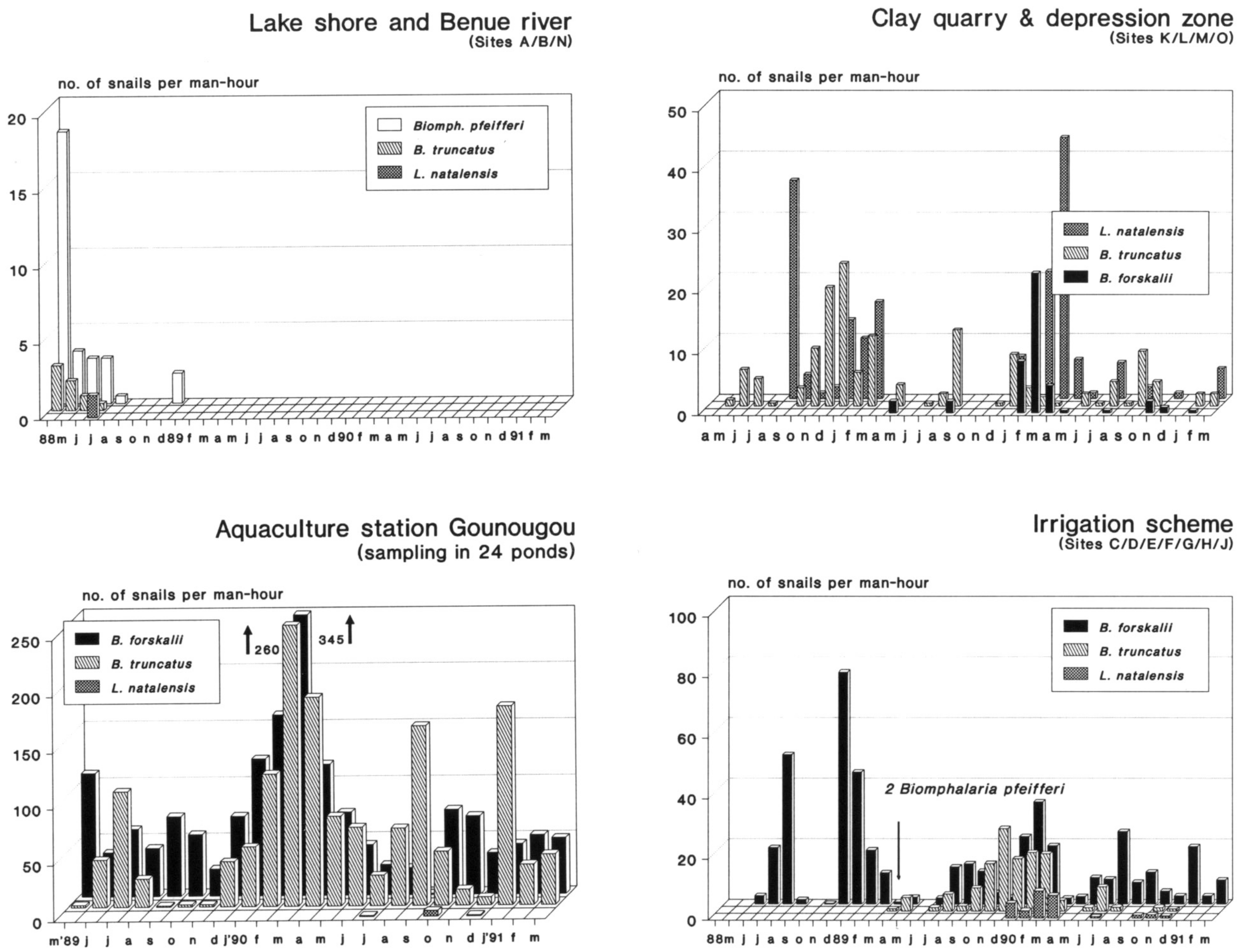
3) Man-made and man-managed small reservoirs. Water temperature and oxygen content rise sharply in morning hours. The oxygen content shows a large difference between minimal and maximal values (Fig. 7.3): rice field, secondary drain and fish pond. The algae living in this fertilized water (fertilizer from rice fields and fishfood in ponds) reach high concentrations and produce oxygen in sunlight, but consume oxygen during the night.



Figs. 7.1 - 7.3: Water temperatures and oxygen contents in different habitats during a clear day in the rainy season.

Sampling results

Only snail species of medical importance are discussed in this section, but several other species have also been encountered: *Pila wernei* (all over the irrigation system and the depression zone), *Lanistes ovum* (the irrigation system, depression and clay quarry), *Ceratophallus natalensis* (all sites except the river and the lake), *Cleopatra bulimoides*, and *Bellamya unicolor* (both in the Lagdo reservoir). We do not have the impression that competition between *P. wernei* or *L. ovum* and host snails occurs, but numbers are too low for statistical analysis. On the sites where P. wernei ever was recorded, this species was found 24 times in 288 samplings, 8 times in association with *B. forskalii*, 7 times with *B. truncatus* and 4 times with *L. natalensis*; *L. ovum* was registered 13 times in 144 samplings, 5 times in association with *B. forskalii*, once with *B. truncatus* and 4 times with *L. natalensis*. These results support findings by Madsen et al. (1988), who were not able to prove competitive exclusion between species in Sudanese irrigation schemes.



Figs. 8.1 - 8.4: Numbers of snails encountered per man-hour search-time during 36 months (23 months for the aquaculture station).

In 36 months of sampling no snails were found shedding cercariae of human schistosomes. (Numbers of snails tested: 6536 *Bulinus forskalii*, 240 *B. senegalensis*, 656 *B. globosus*, 2392 *B. truncatus*, and 74 *Biomphalaria pfeifferi*.)

1) **Large water bodies**

On the lake shore (site A) and in the Benue river (site N), very few snails were encountered (Figure 8.1). From April '88 until July '88, *B. pfeifferi* and *B. truncatus* were regularly encountered in the Benue and the lake in small numbers, but after the sudden rise in water level in the rainy season of 1988 and the subsequent opening of the spillways, no snail has ever since been recorded from the river and only once 2 *B. pfeifferi* have been found at the lake shore. Incidental sampling around Lagdo lake revealed several other temporary snail populations. In April '87 several dead shells and in June '88 living small *B. pfeifferi* (50/m2) were collected in Mai Djamba, a lake shore village with 29% prevalence of intestinal schistosomiasis (Robert et al., 1989). In April '90, *B. truncatus* was found in Mayo Boulel, a southwestern branch of the Lake, but in July of the same year, with rapidly rising water level, the population had entirely disappeared. It seems that the lake does not (yet?) harbour permanent snail populations.

The primary irrigation canal (site B) has always been free of snails, due to high water velocities and fluctuating water level.

2) Stagnant, semi-natural and medium-sized habitats (permanent or temporary).

The clay quarry (site O) and the depression zone (sites K/L/M) are characterized by strongly fluctuating populations of *B. forskalii, L. natalensis* and *B. truncatus* (Figure 8.2). Human interventions in the quarry were frequent, making it impossible to recognize a regular pattern in snail dynamics. The same applies to the depression zone where interventions to improve water management started in 1988. The effects of these interventions are described in detail by Slootweg & Keyzer (1993c).

The Lagdo pool (site P) was sampled weekly between November '88 and April '89 (see next paragraph). By then the pool was entirely dry for the first time in years because the inflow of drainage water had ceased. Populations of *B. globosus* and *L. natalensis* vanished completely and never reappeared in the following rainy seasons of '89, '90 and '91, in spite of the presence of water between June and February.

In the laterite quarries in Ouro Doukoudje (sites Q1 and Q2) a population of *B. senegalensis* appeared in the site Q1 in June, and disappeared before the end of the rainy season; the site entirely dried by the end of December. In the site Q2, both *B. senegalensis* and *B. globosus* were found during the rainy season; moreover, a small amount of water remained during the dry season and *B. globosus* had a second appearance.

Seasonal streams and pools (sites R1-R5) harboured either *B. forskalii* or *B. senegalensis*, but never mixed (Mimpfoundi & Slootweg, 1991). Weekly observations are now being made on snail dynamics in these habitats (Vroeg & Tsafack; pers. com.).

3) Man-made and man-managed habitats

One year after the aquaculture station Gounougou (Figure 8.3) was put into operation the first *B. forskalii* were recorded in November 1988 and by the end of January 1989 *B. truncatus* had also established itself. From May '89 until March '91 all ponds were sampled. *B. forskalii* and *B. truncatus* were found every month in varying numbers; *Lymnaea natalensis* was recorded for the first time in July '90 and has since been encountered sporadically. High numbers of snails were found during the dry season in the first half of 1990, during and shortly after a prolonged cool period of four months (Fig. 7).

All data from 7 sampling sites in the irrigation scheme have been combined in Figure 8.4. In the first year of sampling only *B. forskalii* was recorded. From shell characteristics it appeared that the population might be mixed with *B. senegalensis*, but iso-enzyme electrophoresis of samples taken in December '88 and July '90 revealed only *B. forskalii* (Mimpfoundi & Slootweg, 1991; Mimpfoundi, 1992). We consider the latter data more reliable since shell morphology of snails in the *B. forskalii* group is highly variable and confusing. In April '89, at the end of the fourth rice cycle since the scheme became operational, *B. truncatus* and *B. pfeifferi* were recorded for the first time in the field canals. *B. truncatus* has succeeded in establishing itself, but *B. pfeifferi* has been found only once. In January '90, at the sixth rice cycle, *Lymnaea natalensis* was obtained for the first time in the scheme, and has since been recorded several times in low numbers. The dynamics of *B. forskalii* populations reflects the irrigation schedule with peaks in the second or third month of an irrigation cycle.

The irrigation scheme provides habitats with different characteristics so it seems therefore useful to go into some detail. The secondary and tertiary irrigation canals (sites C and D) are often dry and do not constitute a favourable habitat for snails. Only *B. forskalii* was found occasionally, probably introduced with rice seedlings which were temporarily stored in the canals after being taken from the seedbeds. In the rice field (site F) the only species present during each cycle of rice is *B. forskalii; B. truncatus* and *L. natalensis* were found rarely in 1990. Both field canal and field drain (sites E and G) harbour populations of *B. forskalii, B. truncatus* and *L. natalensis*. In the third year of sampling *B. forskalii* was permanently present. In the secondary and tertiary drainage canals (sites H and I), *B. forskalii* was partially replaced by *B. truncatus* and *L. natalensis* in the second year of sampling. Due to cleaning and dredging in the drainage system this population was eradicated in the third year.

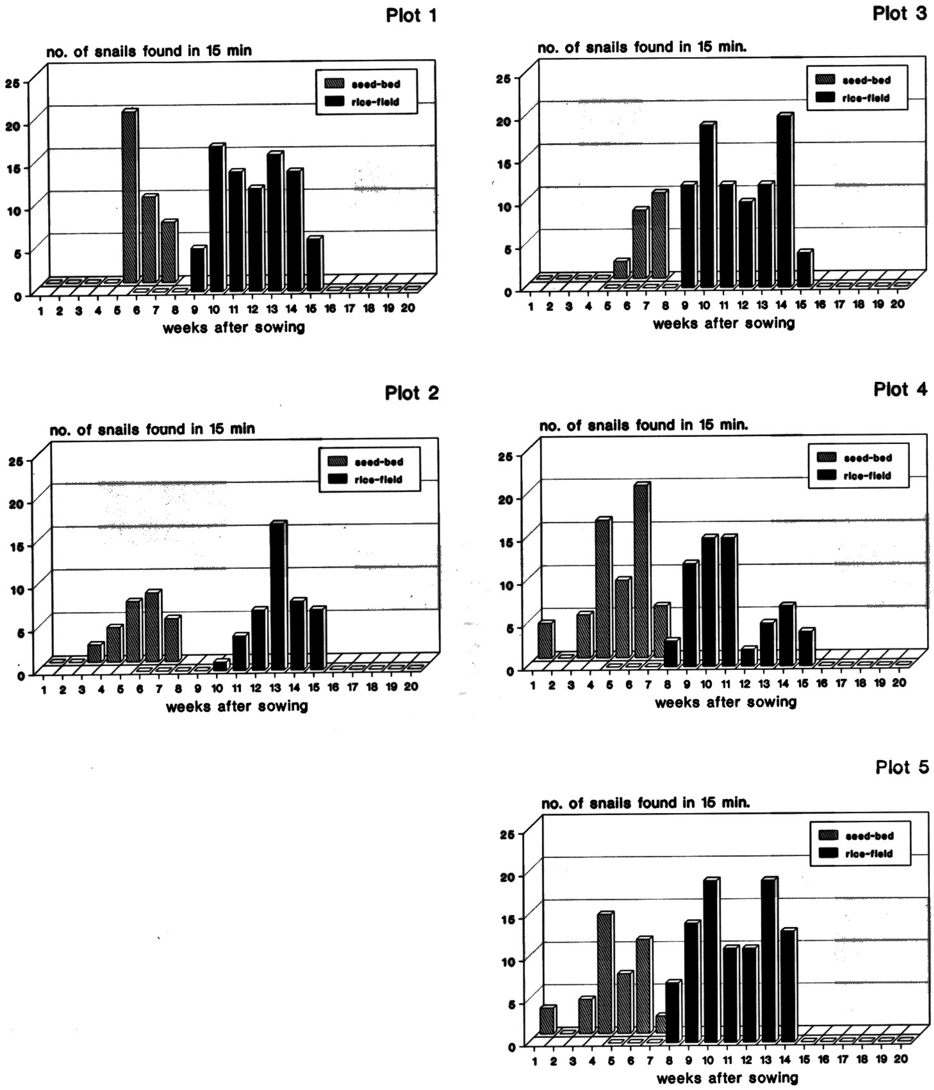


Fig. 9: Weekly sampling of *B. forskalii* populations in rice fields. The shaded bars in the background show numbers of snails found on the seedbeds; in the foreground black bars show the numbers of snails on corresponding fields where seedlings were planted. Small squares on the bottom of the graph indicate the periods when seedbeds and fields were inundated.

Bulinus forskalii in rice fields

During one entire cycle of dry season rice, the development of *B. forskalii* was followed weekly between November '90 and April '91 in eight plots. Sampling started in the seedbeds and continued at the rice fields corresponding to the seed beds (Figure 9). The development of snails in the seedbeds does not show a consistent pattern. On the rice fields the first snails appear in the fourth or fifth week after replanting; within two or three weeks a first peak in numbers occurred (plots 1,3,4,5), with a second peak 3-4 weeks later. In plot 2 the development of the population was a little slower and only one peak appeared after 7 weeks, coinciding with the second peak on the other plots. Snails completely disappeared 5 to 6 weeks before the fields were drained and dried; the presence of *B. forskalii* never lasted more than 8 weeks.

The mean size of snails in the first week of appearance was 3.1mm (SD 1.1) for the seedbeds, and 3.1mm (SD 1.6) for the rice fields. Length-frequency diagrams showed a constant appearance of juveniles, making it impossible to distinguish between generations. Hence it was impossible to construct a growth curve.

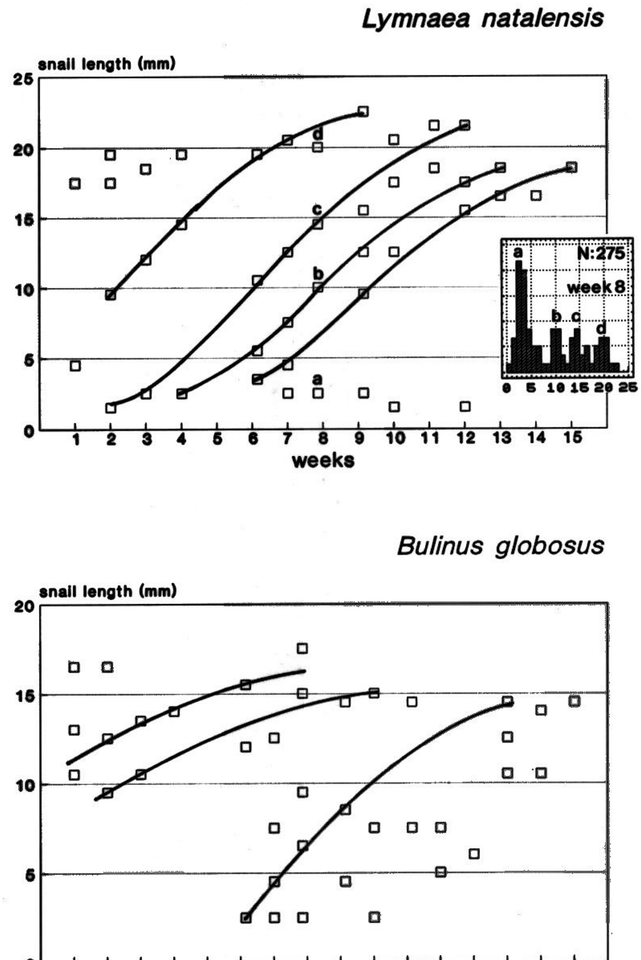


Fig. 10: Plotted peaks in length frequency distribution per week for *L. natalensis* and *B. globosus* The inset shows the length frequency histogram for week 8. The peaks a-d in the histogram correspond to points a-d in the figure.

***Bulinus globosus* / *Lymnaea natalensis* in the Lagdo pool**

Length-frequency histograms of the weekly samples of *B globosus* and *L. natalensis* showed that different generations existed simultaneously, reflected in different peaks in the histogram. In Figure 10 these peaks are plotted per week. Different generations of snails can be distinguished for *L. natalensis*, making it possible to draw a growth curve. In about 10 weeks this species grows from 1.5mm to 22.5mm. Between weeks 9 and 12 (January and February) the largest maximum size is attained. After week 7 newly hatched snails do not seem to survive since only the smallest size class is found.

The data for *B. globosus* are difficult to interpret. Several very speculative growth curves are shown suggesting that young 3.5mm snails reach 10mm in less than 4 weeks. Hatching occurs between week 6 and week 10 which coincides with the coolest water temperatures during the observation period, with afternoon temperature ranging from 23°C to 26°C (Fig. 7).

Discussion and conclusions

General remarks

The relation between water temperature and snail populations is complex, and factors indirectly linked with temperature, such as oxygen saturation and primary production will also influence snail densities, reflected in snail populations lagging one or two months behind the temperature minima. Nevertheless it appears that water temperatures generally exceed the optimal temperature for all three snail species *B. truncatus, B. forskalii* and *L. natalensis*, judging from the negative correlation between temperature and snail numbers.

Of the three habitat types described, the large water bodies hardly harbour any snail populations. It is noteworthy that *Biomphalaria pfeifferi* has only been found in some numbers in this habitat type with very constant temperatures and oxygen levels. The other two habitat types, stagnant semi-natural and man-managed water bodies, harbour permanent or seasonal populations of *B. forskalii, B. truncatus*, and *L. natalensis*, but *Biom. pfeifferi* is absent. The eutrophic man-made habitats harbour the largest numbers *B. forskalii* and *B. truncatus* snails, which corroborates the general opinion that availability of food is one of the crucial factors determining the density of snail populations (Brown, 1980; Slootweg et al, 1993), and that these species are capable of resisting large fluctuations in temperature and oxygen content. Behavioural studies have shown that snails are capable of escaping unfavourable conditions during the day, so habitat measurements do not necessarily reflect the actual conditions experienced by the snails (viz. Shiff, 1964a; Brown, 1980: pp.359-62).

Succession in the irrigation scheme and the artificial lake

The construction of a new irrigation scheme gave us the possibility to study the introduction and succession of snail species. *B. forskalii* was the first pioneering species to be encountered in the new habitat, followed by *B. truncatus* after two years of operation and *L. natalensis* after three years. *Biom. pfeifferi* and *B. globosus* were not found in the scheme. In the Logone valley of the Extreme Northern Province of Cameroon, Wibaux-Charlois et al. (1982) found large numbers of *B. forskalii* and few *B. truncatus* in the SEMRY II scheme, 11 and 23 months after the scheme became operational. In the SEMRY I scheme, which already was operational for over 10 years, *Biom. pfeifferi, B. truncatus, B. globosus* and very few *B. forskalii* were found. In the Gounougou scheme a similar succession pattern is seen, and since *Biom. pfeiferi* and *B. globosus* are present in the surroundings of Gounougou the establishment of these species in the irrigation scheme is to be expected. Examples from other areas in the soudano-sahelian climatic zone show a similar species composition. In the South Chad irrigation project Betterton (1984) described the presence of *B. truncatus, B. forskalii, B. globosus* but also *B. senegalensis* in the irrigation canals. As in the SEMRY area, *L. natalensis* was only present in the lake and also in the intake channel. In the Gezira irrigation scheme in Sudan, already operational for many years, Madsen et al. (1988) found *Biom. pfeifferi, B. truncatus, B.*

forskalii and *L.natalensis*. Contrasting in this respect is the Senegal delta where Diaw et al. (1991) only found large numbers of *Biom. pfeifferi* in March in irrigation canals several years after construction (no exact date is given). It appears that the presence of *Biom. pfeifferi* is most difficult to predict. Possibly high water temperatures in the Sudanian and Sahelian zones are unfavourable for this species, which prefers temperatures between 18°C and 25°C (Sturrock, 1966; Appleton, 1977; Kloos et al., 1988). Microclimatic conditions may determine whether *Biom. pfeifferi* will become established.

Sampling in the Lagdo lake was not extensive. Only the site near the East Dyke was sampled regularly showing initial populations of *Biom. pfeifferi* and *B. truncatus*, which were washed away by the sudden rise in water level in 1988. Irregular sampling revealed temporary populations of the same species. Paperna (1969) showed that in Lake Volta *B. forskalii* was omnipresent in the first year after filling of the lake; in the subsequent years this species was gradually replaced by *B. truncatus*. The dynamics of Lagdo lake seem to be less suitable for the establishment of permanent snail populations.

Bulinus forskalii

B. forskalii was the most common snail species in the area around Gounougou and was found in all habitats except the Benue river and Lagdo lakes. This species rapidly colonizes new habitats as shown by its immediate appearance in the rice fields and irrigation system. Similarly, Greer et al. (1990) found that *B. forskalii* was the most common species in Cameroon, occurring more frequently in flowing than in standing water and in smaller rather than larger reservoirs. Wibaux-Charlois et al. (1982) also found *B. forskalii* to be the most common species in the SEMRY irrigation scheme in the Extreme Northern Province of Cameroon, and the only species occurring in temporary pools. However, collections in the SEMRY study only were made in the dry season, probably overlooking many typical *B. senegalensis* habitats.

B. forskalii apparently prefers dynamic and unstable habitats were it has a competitive advantage over other species. In more permanent and stabilized habitats *B. truncatus* and other species outcompete *B. forskalii* as shown by the succession in the irrigation scheme of Gounougou in this study and in other studies (Paperna, 1969; Wibaux-Charlois, 1982). Furthermore it seems that this species prefers clean water; the onset of rains as well as flooding or the start of an irrigation season all stimulate the reproduction of the snail, but usually the species disappears after some time even if water is still present (McCullough, 1957; Teesdale, 1962; Cridland, 1967; Malaisse & Ripert, 1977; Betterton, 1984); in this study the snails all disappeared from rice fields within 8 weeks without any possible competitor snail being present.

The average size of emerging snails in the seed beds and in the rice fields was 3.1mm, which is remarkably similar to the size of emerging *B. senegalensis* reported by Goll & Wilkins (1984) in rainfed pools in Gambia. The authors state that viable aestivating snails are immature and remarkably constant in size; this apparently also holds for *B. forskalii* in the Benue area, although other authors also describe large adult snails emerging after aestivation (Malaisse & Ripert, 1977).

The rates of growth and reproduction are so fast that even weekly sampling did not allow the construction of a reliable growth curve. Only a mark and recapture technique as applied by Lévêque (1968), could give more detailed information. Lévêque showed that a generation cycle of *B. forskalii* lasts five weeks in alluvial pools in the Sahelian zone of Chad; maximal numbers of snails were encountered 2 months after filling of the pool (2½ months in Malaisse & Ripert, 1977). In the strongly eutrophic rice fields, water quality apparently deteriorates more rapidly compared to rainfed pools and *B. forskalii* disappears earlier. Apart from this it must be noted that it is not sure if Lévêque's study concerns *B. forskalii* and not *B. senegalensis*.

A negative correlation with water temperature was found, indicating that high temperatures limit this species. However, sometimes the snail populations lag 2 months behind temperature, indicating that snail populations are indirectly linked to temperature, with complex intermediary factors.

Bulinus senegalensis

The Benue valley is the southernmost area where *B. senegalensis* has been identified so far (Greer et al., 1990; Mimpfoundi & Slootweg, 1991). The species is only present during the rainy season in temporary streams and laterite pools. As Goll (1981) and Greer et al. (1990) indicated, this species has been overlooked in sampling programmes because of its limited presence in time and the difficulty of collecting during the rainy season. This underrepresentation in sampling programmes can lead to the false conclusion that *B. senegalensis* does not play any significant role in schistosomiasis transmission (e.g: Sellin et al., 1980). Betterton et al. (1983) found that this species disappears from pools even before *B. forskalii.* For the Sahelian zone it is clear now that this species is a principal intermediate host of *S. haematobium*, and that *B. forskalii* is not involved in transmission in this zone. As Mimpfoundi & Slootweg (1991) pointed out, the geographical distribution of *B. senegalensis* is not entirely clear, and this species could yet be found even further south where there are temporary pools that satisfy its aestivating habits.

The report by Betterton (1984) of *B. senegalensis* being found in drainage canals is worrying for irrigation development in the West African region. The scheme studied by Betterton was in an early stage of development so it is imaginable that this species will disappear after some years of operation, when prolonged periods of drought in the canals may cease to occur.

Bulinus truncatus

Bulinus truncatus was most common in the irrigation scheme where in the third year of operation it became permanently established, and in the aquaculture station. In the SEMRY irrigation scheme (Wibaux-Charlois et al., 1984) as well as in the Gezira-Managil scheme in Sudan (Madsen et all, 1988) *B. truncatus* was also found to be the most common species. Greer et al. (1990) describe *B. truncatus* in Cameroon as a species of perennial, man-made habitats, being more frequent in standing than in flowing water. The snails can survive short periods of desiccation in the aquaculture station, but neither in floodplain pools and streams, nor in temporary laterite quarries has this species been found. Very dynamic environments are also disadvantageous for these snails as shown by the disappearance of *B. truncatus* from the Lagdo lake and the Benue river after the rapid rise in water level and the opening of the spillways.

It is remarkable to describe *B. truncatus* as a species of perennial habitats while many field studies have shown this species to be able to survive droughts, especially in the Middle East (Watson, 1958; Malek, 1958; Chu et al. 1967; Appleton, 1978). Betterton et al. (1988) describe *B. truncatus* as poorly adapted to prolonged periods of severe drought (*B. rohlfsi*, later determined as *B. truncatus* by Jelnes, 1985). The complex genetic structure of this species and the possible existence of local strains perhaps explain the contradicting observations in the field.

Although *B. truncatus* can be found in every month of the year and is known to be very tolerant of temperature fluctuations (Watson, 1958) the snail populations show a negative correlation with water temperature; they show highest densities in the coolest months around January. Similar results were found in Volta Lake by Klumpp & Chu (1977) and in northern Nigeria by Betterton (1984). Demian et al. (1972) showed that egg production stopped and mortality increased when water temperatures were highest in Egypt (26-30°C).

Bulinus globosus

B. globosus was found in two semi-permanent water bodies in the Benue valley: in one of the laterite quarries near Ouro Doukoudjé and in the pool near Lagdo. When the latter pool dried completely after the permanent water supply had ceased to exist, this species did not reappear in three following rainy seasons. From these data we conclude that *B. globosus* survives drying of its habitat to a certain extent, but does not resist complete desiccation. In the literature *B. globosus* has often been described as a species of temporary habitats, capable of aestivation during prolonged periods of drought (Greer et al., 1990; Malaisse & Ripert, 1977; Cridland, 1967; reviewed by Appleton, 1978), although the species is not as resistant to desiccation as *B. forskalii* or *B. senegalensis*. Sellin et al. (1980), Betterton (1984) and Greer et al. (1990) state that in the Sudanian zone of West Africa this species is at its northernmost limit. In wetter areas this snail is the most common schistosomiasis intermediate host of permanent habitats. Several authors have described two forms of survival strategies for *B. globosus* or even two distinct morphs (Smithers, 1956; Shiff, 1964b; Hira, 1968; Betterton, 1984; Betterton et al., 1988; Okafor, 1990; Ngonseu et al., 1991). It is imaginable that different strains of *B. globosus* inhabit these different habitats and that the one in the Benue valley prefers permanent habitats with peak reproduction in the cool dry season months. The literature on the biology of *B. globosus* is rather confusing in this respect.

Studies by Shiff (1964a,b) and Woolhouse & Chandiwana (1990) show that *B. globosus* is limited by low water temperatures in Zimbabwe, and achieves its highest intrinsic rate of natural increase at a temperature of 25°C. In the Lagdo pool reproduction was limited to the cool months of January and February when afternoon water temperature did not exceed 26°C, indicating that this species is limited by high temperatures. Similarly, O'Keeffe (1985) found in Kenya that reproduction in *B. globosus* stopped when mean water temperatures exceeded 28.5°C. The temperature tolerance as determined by Shiff (1964a) in the laboratory relates well with observations under field conditions.

Data from the Lagdo pool indicate that the growth rate is much higher than the one calculated by O'Keeffe. The maximum size attained is also larger, 18mm vs. 12mm. The observation that only adult snails remained at the moment of drying of the pool corresponds to observations from the Extreme Northern Province of Cameroon (Ngonseu et al., 1991).

Lymnaea natalensis

This species was found in permanent bodies of water in sometimes high numbers (Lagdo pool and clay quarry), and appeared in man-made habitats shortly after *B. truncatus* became established. In the latter, numbers were never high and no permanent populations were observed. Also *L. natalensis* showed a negative correlation with temperature and was most abundant in the coolest months. The species does not resist desiccation, as shown in the Lagdo pool were snails did not reappear after the interruption of regular water supply. This is in accordance with Cridland (1967) who found that *L. natalensis* performed worst in comparison to *B. globosus* and *Biom. pfeifferi*, and could not survive more than 30 days of drought.

Consequences for transmission of schistosomiasis

Since no infected snails were found in three years of snail collections it is obvious that transmission of schistosomiasis has not intensified dramatically in the first years after creation of the Lagdo reservoir and the introduction of irrigated agriculture. Populations of snails did not reach such high densities as known from other irrigation schemes and many populations were only temporarily present. The impression is that schistosomiasis haematobium transmission may still be limited to seasonal sites where *B. senegalensis* and *B. globosus* are the principal intermediary hosts, as has been suggested by Betterton et al. (1983) and Greer et al. (1990). A detailed analysis of these seasonal sites is at present being carried out in order to assess their transmission potential. The establishment of *B. truncatus* in the irrigation scheme will in the near future increase transmission risks, although in several areas it has been shown that *B. truncatus* does not necessarily play a significant role in transmission of urinary schistosomiasis. Therefore experiments on the susceptibility of various potential intermediate host species will additionally be carried out to understand the transmission dynamics in the Benue valley. A further question that remains to be answered is whether *Biom. pfeifferi*, the intermediate host for intestinal schistosomiasis, will become permanently established in the newly created habitats around the Lagdo reservoir and in the irrigation scheme. Schistosomiasis is still a minor and localized public health problem that can be handled by the existing public health facilities, but there is reason for caution since it is probable that larger and permanent populations of snail intermediate hosts will eventually become established in the drainage systems in the Benue valley if no special preventive measures are taken.

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3.2 Further observations on the distribution of Bulinus senegalensis Müller in Cameroon

R. Mimpfoundi & R. Slootweg (1991). J*ournal of Molluscan Studies* **57**: 487-489.

Since 1956 when Smithers demonstrated that *Bulinus senegalensis* Müller 1781 was an important intermediate host for *Schistosomosa haematobium* in the Gambia, more information has been sought concerning its distribution. *B. senegalensis* was first reported from the type-locality Podor in Senegal by Adanson (1757). Its distribution range is now known to extend to Gambia (Smithers, 1956), Mauretania and Chad (Wright, 1959), Nigeria (Betterton, et al., 1983) and Cameroon (Mimpfoundi & Greer, 1990; Greer, et al., 1990). All the sites where *B. senegalensis* has been collected in those countries are temporary habitats located in the sub-Saharan belt across Africa. In Cameroon, based on shell characters, Greer et al. (1990) reported that species from two sites located in the wetter sudanian region. But as Betterton et al. (1983) stated, identification of *B. senegalensis* from shell material alone is difficult because of its often close resemblance to the related *Bulinus forskalii*.

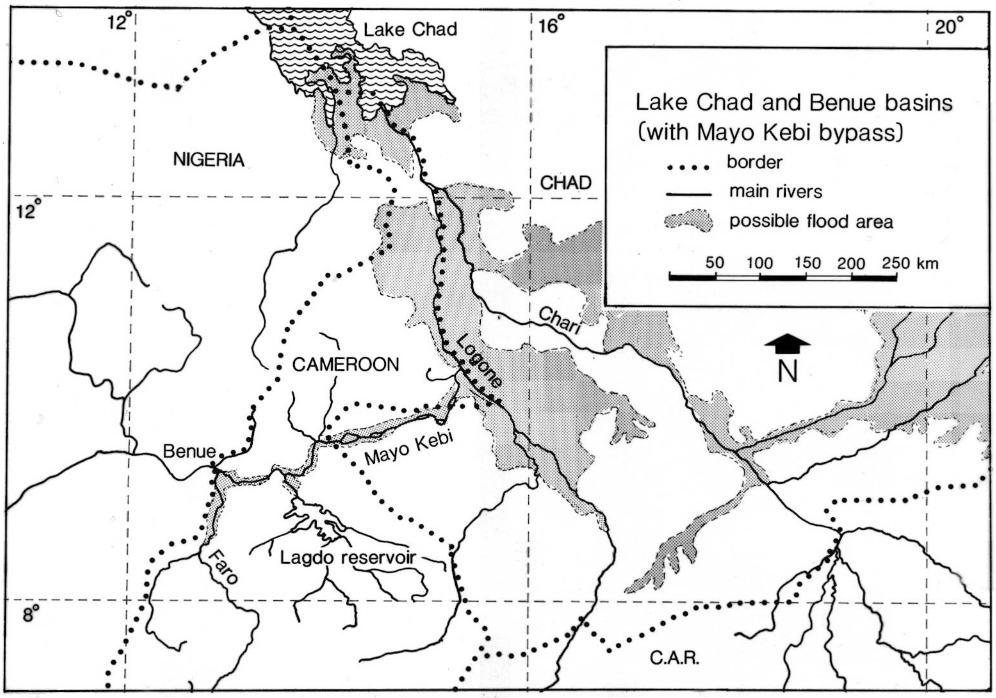

Fig. 11: Map of the Lake Chad and Benue basins.

This study was undertaken to confirm by the use of allozyme electrophoresis the occurence of *B. senegalensis* in the sudanian region in Cameroon.

The area surveyed in our study lies in the North Province of Cameroon, just above 9°N, from 13°33' to 13°36' East, in the valley of the river Benue (Fig.11). Northwards, the valley is connected to the Chad Plain by the Mayo Kebi valley. Westwards, the Benue flows into the Niger, the most important river in West Africa. Southeastwards, a reservoir at Lagdo overflooded most of the former valley. From Lagdo to the Niger, the Benue valley is of alluvial deposits, flat, with an altitude less than 200 metres. The climate in this area is sudanian, with an annual rainfall averaging about 1000mm. The rainy season extends from April to October, and the mean annual temperature is 28.1°C

Location of villages and waterbodies are detailed in Fig. 12. Eighteen sites were visited in July 1990 and examined for the presence of Bulinus. The majority of villagers are farmers and fishermen. Downstreams of the Lagdo dam a scheme for irrigated agriculture is under construction, with 200 hectares already in operation (mainly rice culture).

To investigate the southern occurence of snails resembling B. senegalensis, some sites on the road to Ngaoundere were visited at Garwawo, Nahari and Gouna (Mayo Salah), the last site being located some 120 kilometers south of Garoua (Fig. 12), but no specimen of Bulinus was found.

Snails were picked from emergent vegetation in aquatic habitats with a long-handled net, and initially identified from the shell. Living snails were brought back to the Experimental Taxonomy Unit, Cameroon Schistosomiasis Project, IMPM, Yaounde, and electrophoresis of enzymes was performed on starch gels. Techniques used in enzyme analysis, allozyme systems investigated, and the expression of their mobility are the same as in a previous study (Mimpfoundi & Greer, 1989).

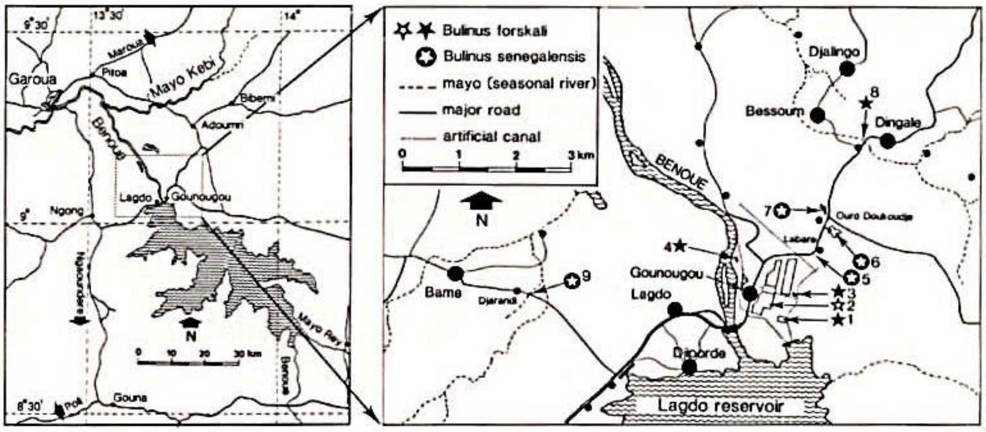

Fig. 12: Map of the study area showing localities where *Bulinus forskalii* and *B. senegalensis* occurred in July 1990. (Numbers correspond to Table 2).

Table 2: Sites, numbers investigated (N) and allozyme mobilities for polymorphic loci among populations of the *Bulinus forskalii* group in Lagdo.

Site		N	ACP	α-GPD	GPI	HBDH	PGM
1a	Fishculture station, pond 21	10	80	70	100	70	100
1b	Fishculture station, pond 22	10	80	70	100	70	100
2	Rice fields	15	80	70	100	70	100
3	Laterite quarry near "CTM"	10	80	70	100/90	70	100
4	Temporary pool near Benue	10	80	70	100	70	100
5	Ford near Labare	15	100	100	100	100	80
6	O. Doukoudje, laterite quarry	12	100	100	100	100	80
7	O. Doukoudje temporay pool	8	100	100	100	100	80
8	Mayo Bessoum	15	80	70	100	70	100
9	Mayo Djarandi	15	100	100	100	100	80

ACP = acid phosphatase; α-GPD = alpha glycerophosphate dehydrogenase;
GPI = glucose-phosphate isomerase; HBDH = hydroxybutyrate dehydrogenase; PGM = phosphoglucomutase.
Migrations are expressed relative to *Bulinus forskalii* from Edea as a reference (Mimpfundi & Greer, 1989; 1990). "/" seperating alleles indicates polymorphism in the sample.

Snails of the *B. forskalii* group were collected from 9 sites. From allozyme mobilities observed in ACP, α -GPD, HBDH and PGM (Table 2), we could identify *B. forskalii* by the allele combination ACP^{80}/ α-GPD^{70}/$HBDH^{70}$/PGM^{100} in the ponds of the fish breeding station (1), the rice fields (2), the laterite quarry near "CMT" (3), the temporary pool near the Benue (4) and the Mayo Bessoum (8). All these populations exhibited the GPI^{100} allele, except for (3) where it occured mixed with the GPI^{90}, without heterozygotes. *B. senegalensis*, identified by the allele combination ACP^{100}/ α-GPD^{100}/$HBDH^{100}$/PGM^{80} were collected near Labare (5), in the laterite quarry and temporary pool at Ouro Doukoudje (6,7) and in Mayo Ndjarandi (9). Mixed populations of *B. forskalii* and *B. senegalensis* were not found in that area, nor did we find the $HBDH^{50}$ allele of *B. forskalii* previously reported in the extreme-north of the country (Mimpfoundi & Greer, 1989). No snail was found shedding mammalian schistosome cercariae.

Based on shell characters alone, we collected *Bulinus globosus* in locality (6), and *Bulinus truncatus* in (1).

Information on the distribution of *B. senegalensis* is of importance, as this snail has been found to transmit *S. haematobium* in Gambia (Smithers, 1956), Nigeria (Betterton et al., 1983, 1988) and Cameroon (Mimpfoundi & Greer, 1989); undetected populations of this snail may be of epidemiological significance (Wright, 1959). In Cameroon, this snail has been identified on shell characters alone from as far south as Poli and Tchollire (Greer et al., 1990) located just under 8°30'N. But until now the occurrence of *B. senegalensis* has been confirmed using allozyme electrophoresis only in localities north of 10°N.

In the present report, we confirm the occurence of *B. senegalensis* in Lagdo, a village located 9°N, south of Garoua. The geographical features of that area are low altitude (<200m.), annual rainfall around 1000 mm in six months, and high temperatures (around 28°C), favouring temporary bodies of water suitable to the estivating habits of *B. senegalensis*. Identifications performed by Greer et al. (1990) from shells collected at Poli and Tchollire remain to be confirmed by further analysis; Tchollire is located in the Benue valley, and Poli in the Faro valley, a tributary of the river Benue. South of Lagdo along the road to Ngaoundere, the area is mostly hilly, raising rapidly to the Adamawa Plateau (1000m.). The few ponds in laterite quarries found in that area seem too temporary to be suitable to snails.

The occurence of *B. senegalensis* at Lagdo can be explained by interconnections between the Benue valley and the Chad plain were that snail is very common (Greer et al.,1990). The low altitude of those regions and general flooding during the rainy season favour temporary bodies of water and population migrations through the Mayo Kebi valley. This method of dispersal could explain the colonization of all the Benue and Faro valleys by this snail. Further investigations including all the Niger basin will be necessary in order to find out how far the distributions of *B. senegalensis* extend southwards.

The finding of the GPI^{90} allele in the *B. forskalii* population from site (3) is worthy a comment. In a previous study (Mimpfoundi & Greer, 1990), we found that allele only in populations collected from sites located in the evergreen forest of the equatorial and subequatorial regions where annual rainfall is higher than 1500 mm. The Benue flows into the Niger, the largest west african river linking the sahelian regions in the north to the equatorial regions in the south. We propose that snails with GPI^{90} allele migrated from the equatorial regions to Lagdo through the Niger-Benue river systems, as did *B. senegalensis* from the sahelian regions to the wetter sudanian regions.

Our theory on the distribution of *B. forskalii* in this region does not explain the absence of the $HBDH^{50}$ allele among the populations sampled in the Lagdo area, since it is connected to the Chad Plain through the Mayo Kebi. The climate in that area is tropical semi-arid. Thus, the $HBDH^{50}$ allele seems limited to the sub-sahelian part of the Logone valley, or it recently derived in that area from the common $HBDH^{70}$. Further investigations including snails from all the Logone valley remain necessary to better assess the geographical distribution of these alleles.

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