

Dynamics of Snail Populations of *Biomphalaria glabrata* and *B. straminea* under Semi-Natural Conditions

Dinâmica das Populações dos Caramujos Biomphalaria glabrata e B. straminea em Condições Semi-Naturais

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Growth curves and mortality rates for populations of *Biomphalaria glabrata* and *B. straminea* bred under semi-natural conditions are reported. Snail populations of the above species were maintained for 220 weeks in indoor cement channels. Data were recorded at 20 week intervals. Crude densities are significantly different for each of the studied populations. *B. glabrata* showed the lower figure while *B. straminea* R3 strain showed the best performance. The latter is able to live in half the volume of water needed for *B. glabrata* when both are submitted to population pressure.

Keywords: Snail Population Dynamics; Competitive Displacement; *Biomphalaria*; Brazil

INTRODUCTION

There is strong and diversified evidence showing that *Biomphalaria straminea* is an efficient competitor against *B. glabrata* (Barbosa, 1973; Michelson & Dubois, 1979; Guyard & Pointier, 1979; Barbosa et al., 1981, 1984, 1985; Barbosa, 1987). Studies on interactions between the two species demand a knowledge of the factors that may influence the competitive process. Among these factors growth and reproduction are the most relevant. In the current paper the population dynamics of *B. straminea* and *B. glabrata* living under semi-natural conditions, as previously described (Barbosa et al., 1983), is presented. This study is limited to the presentation and discussion of data on population growth, size-group distribution and mortality rates.

MATERIALS AND METHODS

For the present observations, laboratory-reared strains of *B. glabrata* and *B. straminea* were used. The former (PA strain) originated from natural breeding places in the county of Paulista, about 40 Km from Recife, in the coastal forest region of the State of Pernambuco, Brazil. Two strains of *B. straminea* were used: an albino black-eyed strain (PT) partially resistant to infection with *Schistosoma mansoni*, originated from irrigation ditches in the county of Petrolândia, 420 Km west of the sea coast of the State of Pernambuco. The second one is a pure albino resistant strain, named R3. This strain originated from Sete Lagoas, State of Minas Gerais, Brazil, was sent to Dr. C. S. Richards (Biomedical Research Institute, Rockville, Md, USA) by Dr. W. L. Paraense (Fundação Oswaldo Cruz, Rio de Janeiro, Brazil). The albino R3 stock was obtained through exposure to infection and selection of the original Sete Lagoas strain (Richards, in letter to senior author, 1982).

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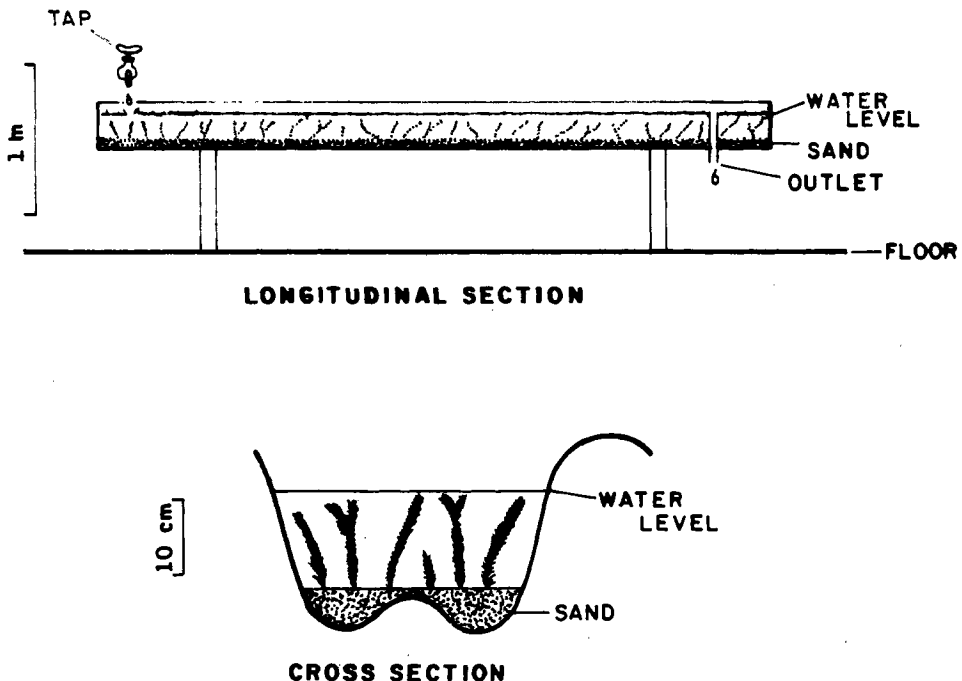
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The snail populations were observed for the period of 220 weeks in separate indoors channels measuring 4.5 m long. Cement roof covers of the trade mark *Kalheta* built by *Brasilit*, were fixed upside down on strong supports in such a way that the upper end of the channel was held at 95 cm over the floor. Both ends of the channels were closed with cement walls. At one end of each channel a tap was fixed at 16 cm over the water surface. At the opposite end, an outlet was placed to regulate the volume of the water inside the channel. (Figure 1). Each channel holds 140.6 (SD = 1.9) average liters of water.

Both indoor aquaria and channels receive natural day light through ordinary windows. Artificial lights placed in the snail rooms to increase the amount of light was only used during cloudy dark days. Tap water was used in the channels during the experiments. The water before arriving to the channels is dechlorinated through consecutive passages in two tanks placed at the roof of the building. The water drops continuously over the surface of the water and its input is regulated in such a way that the whole content of the channel is replaced every

thirty days. The water is kept at pH neutral point by using calcium carbonate powder. Sand is screened and washed in the laboratory before its use. The water temperature is kept at 22.4 C (SD = 1.77) by the use of air conditioning ordinary equipment which is only used in hot days during summer. Lettuce was the everyday food for the snails. In addition, on alternate weeks, the snails were offered cooked-leaves of stinging-nettle (*Fleurya aestuans*), fresh wheat germ and fish-food powder. *Elodea* sp. was the only species of aquatic plant introduced in the channels. Each colony was started by seeding with 250 mature snails. The snail population dynamics were studied by examination of a 20 per cent sample taken at intervals of 20 weeks. For each channel, three fixed collecting stations were established at regular intervals along the channels. Each station was made of a cross segment of a channel of the same size, and inserted as a lining sheet over the inner surface of the channels used in the experiments. The content of the three stations corresponds to 20 per cent of the whole volume of the channel water. At the moment of the sampling collection, both open sides of the stations are

FIGURE 1 - Longitudinal and Cross Section Views of a 4.5mm Long Channel (From Barbosa et al., 1983)



tightly closed with wooden walls kept in place by means of two clamps each. To avoid escaping of very young snail specimens the wooden pieces are set in a frame of soft rubber. At that moment, the whole channel segment (collecting station) is gently pulled up while the water content leaks through screened holes placed at the lateral surfaces of the wooden pieces. The whole content of the sample is then spread over a large shallow pan and the snails are counted and measured. Plants and sand are carefully examined under a low magnification stereoscope. After this operation, snails are put back in the channels.

In the experimental channels, it was observed that a variable number of snails gathered around air bubbles formed on the surface of the water resulting from the dropping of water from the feeding faucets. To avoid this inconvenience the faucets were closed 48h before the counting time. A similar phenomenon occurred with pieces of lettuce around which groups of snails used to gather. For this reason snails were not fed during 48h before sampling (Barbosa et al., 1983).

Snails were classified in four size (maximum diameter) groups as follow: *B. glabrata* ≥ 6.9 , 7.0—11.9, 12.0—16.9, and ≥ 17.0 mm; *B. straminea* ≤ 3.9 , 4.0—5.9, 6.0—7.9, and ≥ 8.0 mm. The relationship between age and size is very complex and variable. Although age cannot be determined precisely it was decided to divide snail populations in size-groups, for theoretical reasons and according to our own experience. The results obtained in the current studies seem to warrant this decision.

The statistical analysis was carried out on the following points: (1) stability of the survival proportions in the snail populations through the proportions trend test (Armitage, 1974); (2) estimation of the stability straight lines for the number of survivors; (3) hypothesis tests for the straight line b coefficients; (4) estimation of the common b coefficient to the stability straight line; and (5) covariance analysis for the straight line interceptions. The statistical analysis was carried out on the whole snail population samples, independent of their divisions into size-groups.

RESULTS

Descriptive results are shown in Tables 1 to 3 and Figures 2 to 5. Data from statistical analysis are presented in the text and in Figures 2 to 4. Tables 1 to 3 show the absolute numbers of snails per sample: mortality is shown in absolute numbers and percentages (in brackets).

In Figures 2 to 4, data on the absolute growth rates of the snail populations are plotted. At the bottom of these figures the percentage distribution of specimens according to size-groups, are seen.

The values of χ^2 in the proportions trend test (data from Tables 1 to 3) for the survival of the snail populations, indicate that the growth curves of the three studied populations follow similar patterns:

a) *Biomphalaria glabrata* population tends to become stable beginning the 60th week ($\chi^2_{7df} = 9.39$; $0.20 < P < 0.30$). Adjustment of the straight line for the stability period is represented by the equation $y = 150.1 + 0.31x$ (observation corresponding to 100th week was considered atypical);

b) for *B. straminea*, PT strain, the period of stability was attained at the 120th observation week ($\chi^2_{4df} = 5.04$; $0.20 < P < 0.30$). The stability straight line equation was estimated as $y = 224.5 - 0.10x$ (mortality rate at 160th week point was considered atypical);

c) the stability period of *B. straminea*, R3 strain, begins at 160th week ($\chi^2_{2df} = 0.51$; $0.70 < P < 0.80$) and the estimated stability line corresponds to the equation $y = 309.3 + 0.145x$.

The hypothesis test for the b coefficient of the three stability straight lines shows that the null hypothesis is not disproved in any of the snail populations studied ($t_{7df} = 0.34$; $0.70 < P < 0.80$ for *B. glabrata*; $t_{4df} = 0.71$; $0.50 < P < 0.60$ for *B. straminea* PT strain; and $t_{2df} =$

TABLE 1 - *Biomphalaria glabrata* (PA strain): Population Growth and Mortality According to Size Distribution — 1982/1986

Weeks	Size Class Intervals (mm)															All Size Groups		
	≤ 6.9			7 — 11.9			12 — 16.9			≥ 17			Totals					
	A	D	T	A	D	T	A	D	T	A	D	T	No	No	No	% Mortal.		
20	174	4	178	25	3	28	12	5	17	11	4	15	222	16	238	6.7		
	(2.2)		(10.7)			(29.4)			(26.7)									
40	64	4	68	55	3	58	59	4	63	9	5	14	187	16	203	7.9		
	(5.9)		(5.2)			(6.3)			(6.3)									
60	37	0	37	53	1	54	63	1	64	6	2	8	159	4	163	2.5		
	(-)		(1.9)			(1.6)			(1.6)									
80	31	0	31	39	2	41	53	9	62	9	5	14	132	10	142	7.0		
	(-)		(4.9)			(4.9)			(14.5)									
100	24	1	25	44	4	48	57	3	60	3	8	11	128	16	144	11.1		
	(4.0)		(8.3)			(8.3)			(5.0)									
120	62	0	62	45	2	47	39	0	39	13	13	26	159	15	174	8.6		
	(-)		(4.3)			(4.3)			(-)									
140	32	1	33	51	1	52	66	2	68	22	3	25	171	7	178	3.9		
	(3.0)		(1.9)			(1.9)			(2.9)									
160	35	0	35	35	0	35	52	2	54	22	6	28	144	8	152	5.3		
	(-)		(-)			(-)			(3.7)									
180	39	1	40	43	1	45	50	2	52	21	3	24	153	7	160	4.4		
	(2.5)		(2.2)			(2.2)			(3.8)									
200	29	2	31	51	1	56	62	2	64	8	4	12	150	9	159	5.7		
	(6.5)		(1.8)			(1.8)			(3.1)									
220	26	0	26	53	3	56	58	3	61	9	6	15	146	12	158	7.6		
	(-)		(5.4)			(5.4)			(4.9)									
Total	535	13	566	494	21	520	571	33	604	133	59	192	1751	120	1871	6.4		
	(2.3)		(4.0)			(4.0)			(5.5)									

A = Alive

D = Dead

T = Total

() = % Mortality

TABLE 2 - *Biomphalaria straminea* (PT strain): Population Growth and Mortality According to Size Distribution — 1982/1986

Weeks	Size Class Intervals (mm)															All Size Groups					
	≤ 3.9			4.0 — 5.9			6.0 — 7.9			≥ 8.0			Totals								
	A	D	T	A	D	T	A	D	T	A	D	T	No	No	No	%	%	%			
20	114	1	115	52	1	53	14	8	22	4	4	8	4	4	8	184	14	198	7.1		
40	35	12	47	73	10	83	62	8	70	6	8	14	6	8	14	176	38	214	17.8		
60	62	0	62	35	2	37	33	4	37	5	1	6	5	1	6	135	7	142	4.9		
80	147	0	147	64	7	71	38	16	54	8	4	12	8	4	12	257	27	284	9.5		
100	81	0	81	119	0	119	50	3	53	6	8	14	6	8	14	256	11	267	4.1		
120	32	0	32	55	4	59	107	5	112	10	3	13	10	3	13	204	12	216	5.6		
140	75	0	75	72	1	73	76	7	83	2	0	2	2	0	2	225	8	233	3.4		
160	31	2	33	67	6	73	81	16	97	16	18	34	16	18	34	195	40	235	17.0		
180	24	2	26	75	0	75	84	3	87	17	7	24	17	7	24	200	12	212	5.7		
200	28	3	31	84	1	85	80	2	82	20	3	23	20	3	23	212	9	221	4.1		
220	27	2	29	73	1	74	78	2	80	20	5	25	20	5	25	198	10	208	4.8		
Total	656	22	678	769	33	802	703	74	777	114	61	175	114	61	175	2242	188	2430	7.7		

A = Alive D = Dead T = Total () = % Mortality

TABLE 3 - *Biomphalaria straminea* (R3 strain): Population Growth and Mortality According to Size Distribution --- 1982/1986

Weeks	Size Class Intervals (mm)												All Size Groups						
	≤ 3.9			4.0 - 5.9			6.0 - 7.9			≥ 8.0			A		D		Totals		
	A	D	T	A	D	T	A	D	T	A	D	T	No	No	No	No	No	% Mortal.	
20	32	4	36	34	5	39	0	1	1	0	0	0	0	0	0	66	10	76	13.2
		(11.1)			(12.8)			(100.0)			(-)			(-)					
40	130	10	140	43	6	49	0	0	0	0	0	0	0	0	0	173	16	189	8.5
		(7.1)			(12.2)			(-)			(-)			(-)					
60	94	2	96	6	1	7	7	3	10	2	0	2	0	0	0	109	6	115	5.2
		(2.1)			(14.3)			(30.0)			(-)			(-)					
80	438	10	448	148	12	160	72	0	72	8	1	9	1	1	2	666	23	689	3.3
		(2.2)			(7.5)			(-)			(11.1)			(100.0)					
100	366	31	397	200	28	228	36	39	75	0	0	0	0	0	0	602	110	712	15.4
		(7.8)			(12.3)			(52.0)			(100.0)			(100.0)					
120	483	39	522	206	48	254	11	17	28	0	2	2	2	2	4	700	106	806	13.2
		(7.5)			(18.9)			(60.7)			(100.0)			(100.0)					
140	243	10	253	153	4	157	15	3	18	0	0	0	0	0	0	411	17	428	4.0
		(4.0)			(2.5)			(16.7)			(-)			(-)					
160	105	20	125	124	8	132	68	10	78	11	0	11	0	0	0	308	38	346	11.0
		(16.0)			(6.1)			(12.8)			(-)			(-)					
180	128	12	140	109	18	127	62	13	75	4	1	5	1	1	2	303	44	347	12.7
		(8.6)			(14.2)			(17.3)			(20.0)			(20.0)					
200	130	10	140	87	14	101	86	16	102	8	2	10	2	2	4	311	42	353	11.9
		(7.1)			(13.9)			(15.7)			(23.1)			(23.1)					
220	124	14	138	95	12	107	86	12	98	10	3	13	3	3	6	315	41	356	11.5
		(10.1)			(11.2)			(12.2)			(12.2)			(12.2)					
Total	2273	162	2435	1205	156	1361	443	114	557	43	21	64	21	21	42	3964	453	4417	10.3
		(6.7)			(11.5)			(20.5)			(32.8)			(32.8)					

A = Alive

D = Dead

T = Total

() = % Mortality

1.56; $0.20 < P < 0.30$ for *B. straminea* R3 strain). The common b coefficient for the three stability straight lines was estimated as $b_c = 0.0094$. So, the equations for the adjusted stability straight line with $b_c = 0.0094$, were as follows: *B. glabrata* $y =$

$105.1 + 0.0094x$; and *B. straminea*, PT strain, $y = 205.4 + 0.0094x$; and *B. straminea*, R3 strain, $y = 307.2 + 0.0094x$ (Figures 2 to 4).

Covariance analysis shows that the straight line intercepts differ significantly.

FIGURE 2 - *Biomphalaria glabrata* (PA strain): Population Growth and Size Distribution — 1982/1986

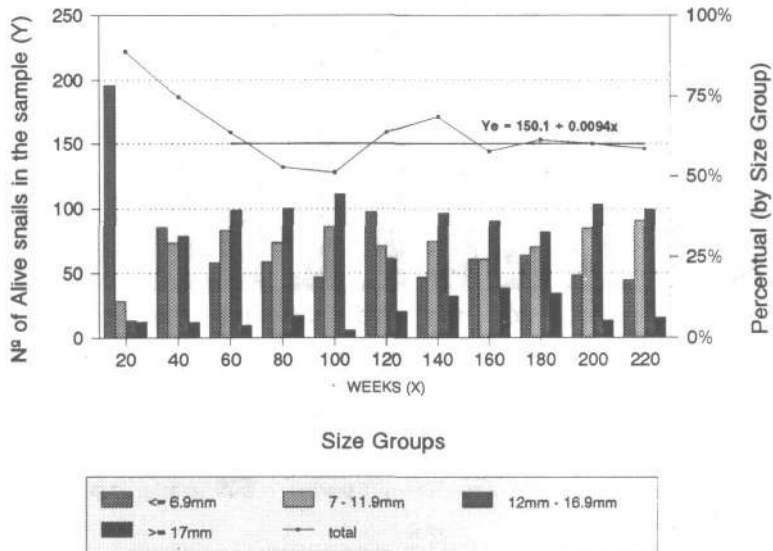


FIGURE 3 - *Biomphalaria straminea* (PT strain): Population Growth and Size Distribution — 1982/1986

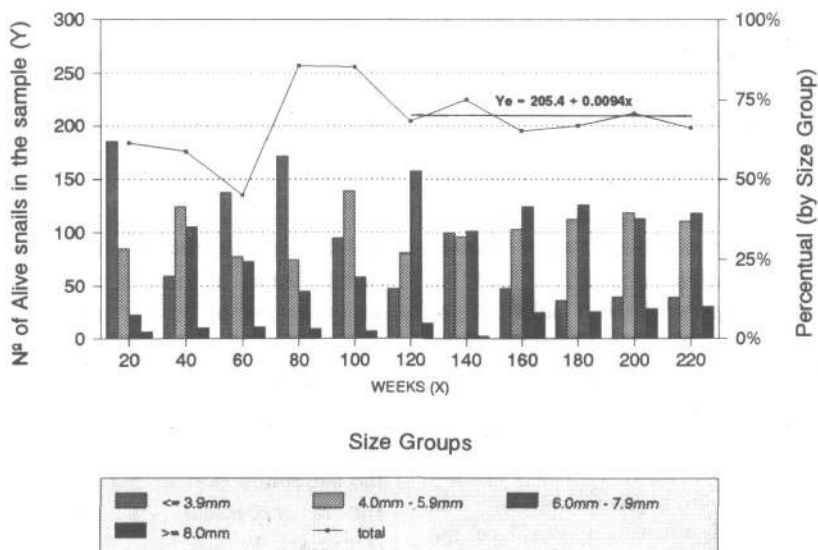


FIGURE 4 - *Biomphalaria straminea* (R3 strain): Population Growth and Size Distribution — 1982/1986

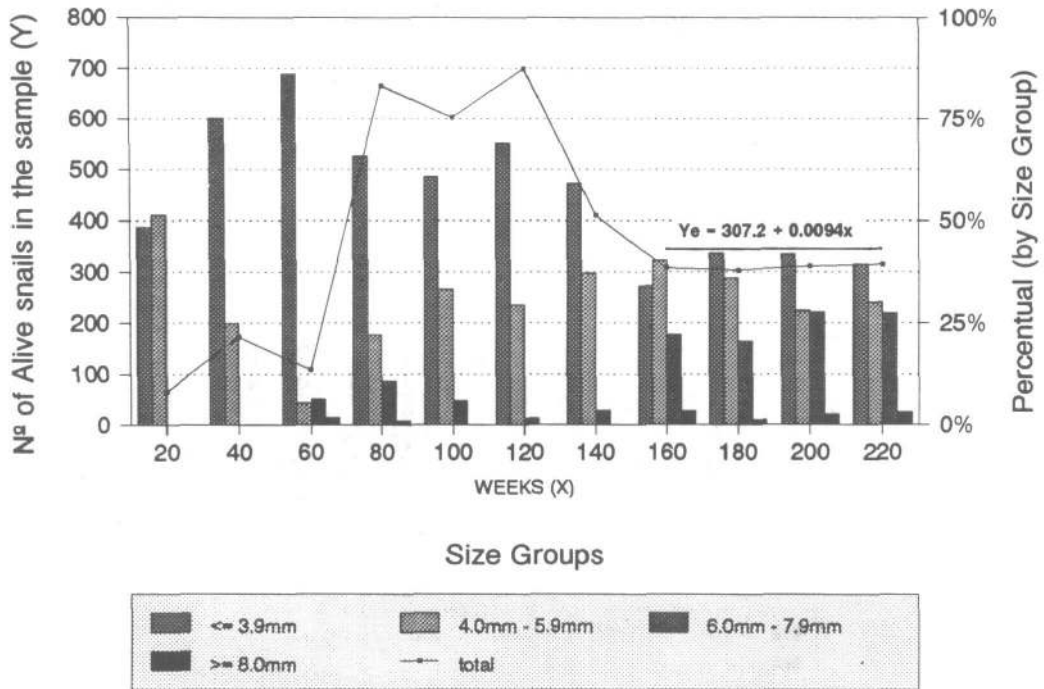


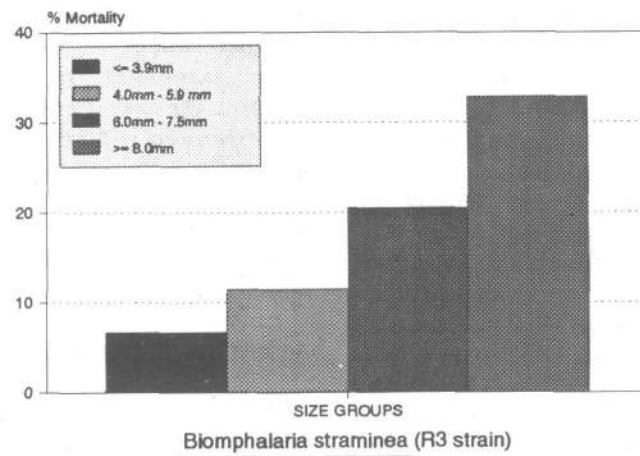
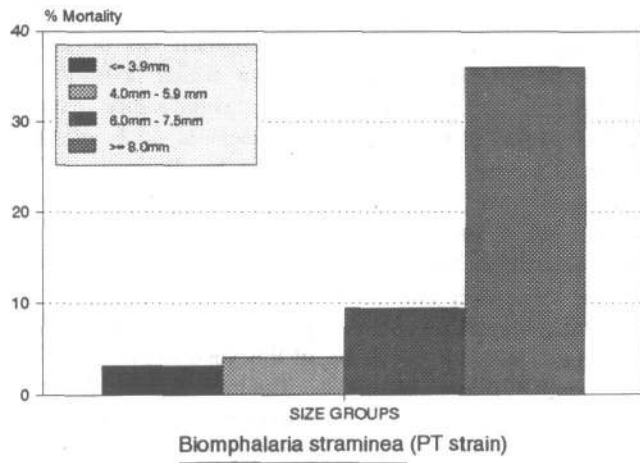
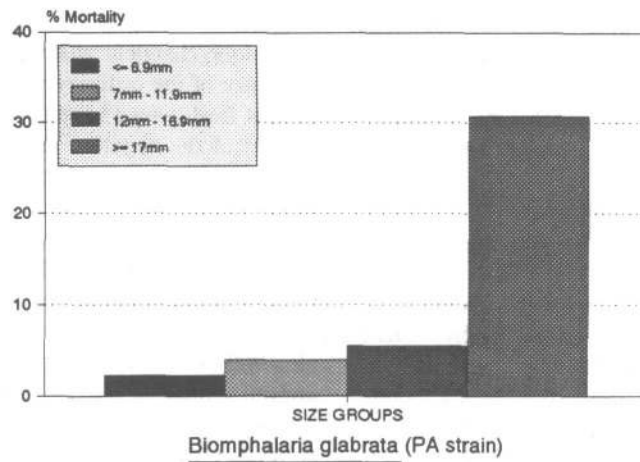
Figure 5 shows the comparative percentage mortality rates for each of the *Biomphalaria* strains studied, according to size-groups at the end of 220th week observation period.

The data analysis shows that the saturation (carrying capacity) level of the snail colonies is attained at the last countings when growth begins to oscillate between limits that could be considered as variations of the population size at a constant volume of water. Saturation level can be also ascertained by changes which occurred in the size-group distributions. As seen in the growth curves (Figures 2 to 4), the size-group distributions tend to show a regular balance among the four groups of "age" in which were divided, towards the end of the experiment.

There is marked variation among the species/strains of *Biomphalaria*, as expected. These variations are related to the number of snails as well as to the period in which they occur.

The values of y calculated through the stability straight lines represent the snail crude density for each species/strain population of the saturation period. Taking into account the whole volume of water per channel ($\bar{x} = 140.6$, SD = 1.9, liters) and the number of snails estimated as the crude density, it was possible to estimate the number of snails per liter of water during the saturation period: 5.5 for *B. glabrata*; 7.3 for *B. straminea*, PT strain; 10.9 for *B. straminea*, R3 strain.

FIGURE 5 - Mortality Rates According to Size Groups for the Total Observation Period — 1982/1986



DISCUSSION

Results show that populations of *Biomphalaria* can be maintained satisfactorily under semi-natural conditions for at least 220 weeks, and probably for much longer periods. We still have in our laboratory channels flourishing colonies of *B. glabrata* kept for six years.

This method opens perspectives for other types of studies such as snail ecology, genetics and related subjects.

We did not find any reliable procedure to calculate the biomass for each snail population. However, it was possible to estimate the higher snail population levels (crude density) in the channels at the periods in which the populations attained their greatest densities (saturation). These figures are significantly different for each of the studied populations. The lower figure for *B. glabrata* can be explained, in part, by the larger size attained by those individuals. *B. straminea* R3 strain population took 160 weeks. *B. glabrata* attained the same level at 60 weeks.

On the other hand, it was shown that under population pressure, the R3 strain of *B. straminea* attains higher density in the same volume of water than the two other studied snail populations. As a result, this strain is able to live in half the volume needed by *B. glabrata* when both are submitted to population pressure.

Mortality data presented in Tables 1 to 3 should be taken with caution. As snail countings were made at 20 week intervals, it is understandable that some snail shells, specially the juvenile ones, may disintegrate during the 140 day period between each sampling.

It was not possible to complete data on snail demography due to some technical difficulties. For instance, we did not find any reliable technique to estimate directly fertility by counting the number of snail eggs laid.

It is usually accepted that a stable population is kept in equilibrium by the balance between the limits to population growth imposed by the environment and the potential inherent growth of the population.

Particular situations were created in the so called "semi-natural" conditions. In the particular case of the current study, the snail

population cycles were independent of the cyclic fluctuations due to external environmental factors. Another factor to be mentioned is that the *Biomphalaria* snails bred in in-door channels were not submitted to the influence of the ordinary macro-fauna found in natural fresh-water habitats.

Most of the negative intraspecific effects on population growth reported in the literature were observed in snail kept in "closed" laboratory systems. As the experimental snails are generally maintained in laboratory glass aquaria under variable conditions this makes quantitative comparison difficult (Hairston et al., 1960). Comparisons with the present system are unfortunately not possible.

Results obtained in the current paper clearly show that different behavioral patterns emerged from the studied populations of *Biomphalaria* (Figures 2 to 4). This indicates that each species/strain has developed inherent growth patterns which favor *B. straminea*. This may have significance on the competitive displacement of *B. glabrata* by *B. straminea* studied by Barbosa (1973, 1987) and other Authors (Guyard & Pointier, 1979; Michelson & Dubois, 1979).

The presence of *B. straminea* in Hong Kong and its spreading to new regions of south China give a very good idea of the adaptative capacity of this species (Yipp, 1990).

The most promising method for the biological control of the snail vectors of schistosomiasis is the introduction of competitor non-susceptible snails (WHO, 1987). Madsen (1990), complemented by Coimbra (1991) covered most of the recent literature dealing with snail biological control.

The experiment by Barbosa-Figueiredo (1989), ... *the largest controlled and long-term field experiment so far conducted on congeneric competition in Biomphalaria ...* (Coimbra, 1991) shows that ... *biological control based on competitive displacement between close species holds important potential in the control of schistosomiasis* (Coimbra, 1991).

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RESUMO

BARBOSA, F. S.; SANCHES, O.;
 BARBOSA, C. S. & ARRUDA, F. **Dinâmica das Populações dos Caramujos *Biomphalaria glabrata* e *B. straminea* em Condições Semi-Naturais.** Cad. Saúde Públ., Rio de Janeiro, 8 (2): 157-167, abr/jun, 1992.

Curvas de crescimento e taxas de mortalidade para populações de *Biomphalaria glabrata* e *B. straminea*, criadas em condições semi-naturais, são descritas no presente trabalho. As populações dos caramujos foram observadas durante 220 semanas em canaletas de cimento montadas no laboratório. Dados foram coletados a cada intervalo de 20 semanas. As densidades brutas de crescimento foram significativamente diferentes para cada população estudada. *B. glabrata* mostrou crescimento inferior às duas cepas de *B. straminea*. A cepa R3 desta última espécie mostrou o melhor desempenho, sendo capaz de viver em metade do volume de água necessária a *B. glabrata* quando ambas estão submetidas a pressão populacional.

Palavras-Chave: Dinâmica de Populações de Caramujos; Deslocamento Competitivo; *Biomphalaria*; Brasil

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