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FACTORS CONDITIONING THE HABITAT AND THE DENSITY OF *BIOMPHALARIA TENAGOPHILA* (ORBIGNY, 1835) IN AN ISOLATED SCHISTOSOMIASIS FOCUS IN RIO DE JANEIRO CITY

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The present work was carried out in a watercress garden in Alto da Boa Vista, in the city of Rio de Janeiro, Brazil. The investigation was carried out in two phases. The first one (1985-86) involved the sampling of Biomphalaria tenegophila *in two areas to determine its relative populational densities. The results showed that the populations presented similar densities and dynamics. The second phase (1988-89) involved the study of the influence of some environmental factors on the establishment of* B. tenagophila *in watercress garden. Two factors were identified as responsible for the establishment of* B. tenagophila *in the garden: (1) the quality of the water entering the irrigation system, to which domestic sewage is added, and (2) alterations in the nature of the substrate, due to inadequate fertilization techniques, which employ organic matter from adjacent pigsties. Aquatic plants and hydrological parameters of the irrigation system were subsidiary factors to the establishment of* B. tenagophila *in the garden.*

Key words: ecology – schistosomiasis – *Biomphalaria tenagophila* – watercress garden – environmental factors

In the Brazilian southeast, particularly in Rio de Janeiro and São Paulo states, the schistosomiasis transmission is partly associated with small and large scale irrigated cultivated areas as sugarcane, rice and watercress (Piza et al., 1960; Pessoa, 1978). Watercress gardens are particularly important transmission foci (Pinto, 1945; Bradley, 1968; Schall et al., 1985; among others). This is what occurs in Alto da Boa Vista region in Rio de Janeiro city where an isolated focus of schistosomiasis is closely linked to an irrigated watercress culture. The continuated presence of schistosomiasis in the region has being recently confirmed by Schall et al. (1985); Silva et al. (1986) and Baptista et al. (1989). The main characteristic of these irrigated cultures is that they are excellent habitats for the vector snails of *Schistosoma mansoni*. However, in spite of its relevance, there is little information on the environmental characteristics of these modified ecossystems concerning to the vector snails.

The present work aims to contribute to the knowledge of these modified lothic ecossystems, by investigating some parameters in the irrigation system of these cultures, including chemical and biological parameters related to the density and populacional dynamics of the snails.

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MATERIALS AND METHODS

Distribution pattern of B. tenagophila – A preliminary sampling of the main river basin (Rio das Furnas) in the study area had indicated the presence of *B. tenagophila* only within a group of four watercress gardens (Fig. 1). In all of these gardens *B. tenagophila* was microspatially present but with a heterogeneous distribution in the beds, that is, beds with high population densities and beds with total absence of snails.

The areas for snail sampling, which were taken to measure the populational densities (C1, C2 and C3), were selected according to the distribution pattern of the snails in the garden (A) as well as to the three different fertilization techniques of the watercress culture in the region, as presented in diagram of Fig. 2.

Collection method – A 5 m^2 square frame subdivided into 80 portions, 40 of wich were picked at random using a table of aleatory numbers, was used to collect snails. The 40

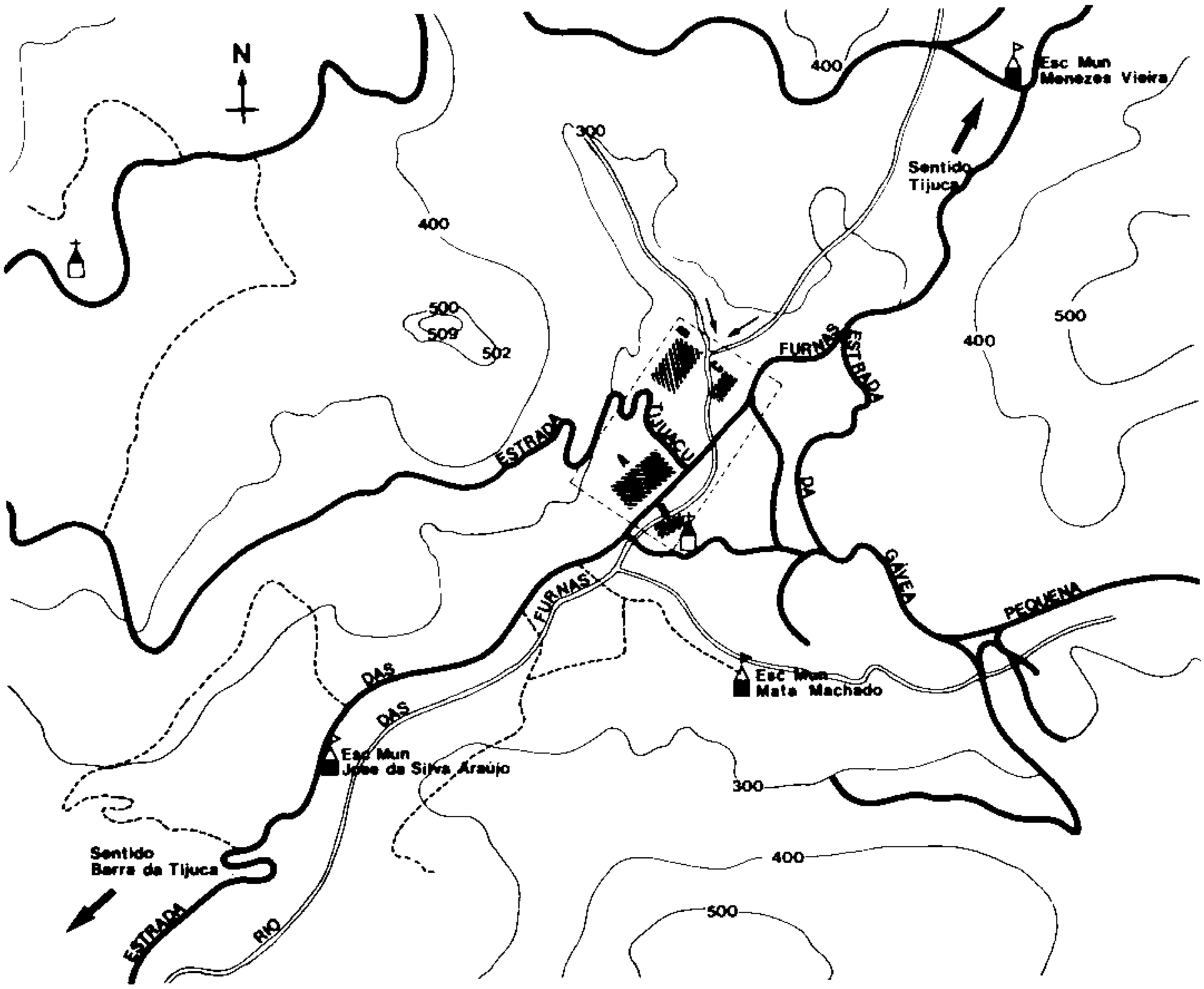

Fig. 1: schematic map of the region of Alto da Boa Vista, Coordinats: (22° 58'S; 43° 17'W) with the indication of the watercress gardens.

SCHOOL ==== WATER COURSE —— ROAD GARDEM - - - - PATH —500— HYPSOMETRIC LINE

CHURCH → WATER FLOW DIRECTION

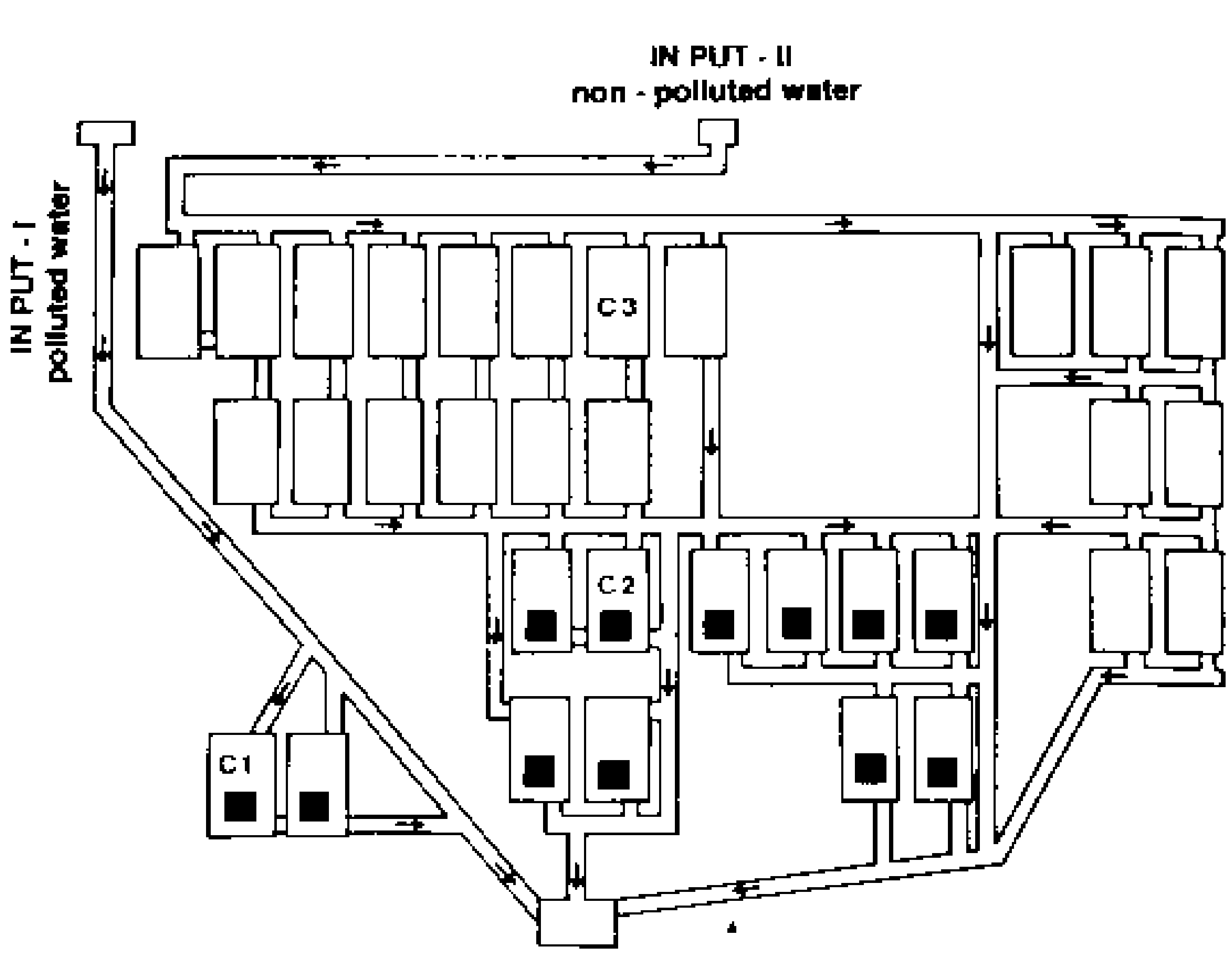

Fig. 2: diagram of the irrigation system in garden A, showing the sampling areas (C1, C2 and C3) and the distribution pattern of *Biomphalaria tenagophila* (black squares) with the respective fertilization techniques in the watercress garden (C1: water with domestic sewage; C2: non-polluted water fetilization with pigsties refuses (non-degrated organic matter); C3: non-polluted water fertilized with degraded organic matter.

portions corresponded to 2.5 m^2, i.e. 5% of the total area of each plateau (50 m^2). In each of these 40 portions, all snails found on the surface, in the sediment or on the water cress leaves were collected with tweezers. Since C3 was found to be free from *B. tenagophila*, snail collection was limited in the areas C1 and C2. After examination in the laboratory, 90% of the snails were returned to the field within approximately 4 days. Meteorological data were obtained from the Alto da Boa Vista Station of Instituto Nacional de Meteorologia.

Sampling procedure of the environmental factors – Garden A was chosen for the comparative quantification of the following factors in colonized (C1 and C2) and non-colonized (C3) areas.

Chemical quality of the water – The following parameters were examined: pH, conductivity, chlorides, alkalinity, Ca^{++} and Mg^{++}

concentrations, nitrate, organic nitrogen, Kjeldahl nitrogen and ammonium nitrogen. The analyses were carried out according to FEEMA (1979).

Hydrology of the irrigation system – Water flow, time of draining and water volume were examined. A 10 l plastic bucket was employed to measure water flow. Time of draining was the time taken to completely replace the water volume at the bed outlet after interruption in the supply of water. The water volume in the beds results from the multiplication of time of draining by water flow.

Aquatic plants – Comparative analyses of plant biomass of *Potamogeton striatus* and *Spirogyra* sp. were carried out in areas C2 and C3, since these plants were not observed in C1. Plant material was collected in the water entry of the beds, within quadrats 10 x 10 cm^2 (Pip & Sutherland-Guy, 1987). The collected material was dried in an oven at 60 °C until constant weight was attained.

Nature of the substrate – Three 15 cm deep samples were collected in each of the three areas (C1, C2 and C3) by using a plastic collector of vertical pressure. The samples were frozen to –10 °C upon collection and brought to the laboratory, where they were immediately dried at 60 °C for 72 hr. This material was sent to the Secretaria de Agricultura do Estado do Rio de janeiro – Serviço de Análises do Solo, where the following parameters were examined: pH, concentration of calcium, magnesium, phosphorus, potassium and sodium, total organic matter and soil texture.

RESULTS

Meteorological factors – The garden in question, which is located at an altitude of approximately 300 m in the Alto da Boa Vista region, is not subject to periods of drought. The highest rainfall indices were recorded between November and February, which was the time when the snail population suffered a reduction, and the frequency of adults increased.

Populational dynamics – As showed in Fig 3, the number of snails did not present significant differences between C1 and C2 areas every month ($T = 3$; $N = 12$; $P > 0{,}05$). Besides that, both populations presented a negative correlation between their densities and the normal rainfall (Spearman correlation coefficient = –0,673; $N = 10$; $P < 0.005$) in of the region. The period between April and October corresponded to higher snail numbers and its average densities were of 1183 (C1) and 1152 (C2). The average shell diameters there were of 7.5 and 8.0 mm, respectively.

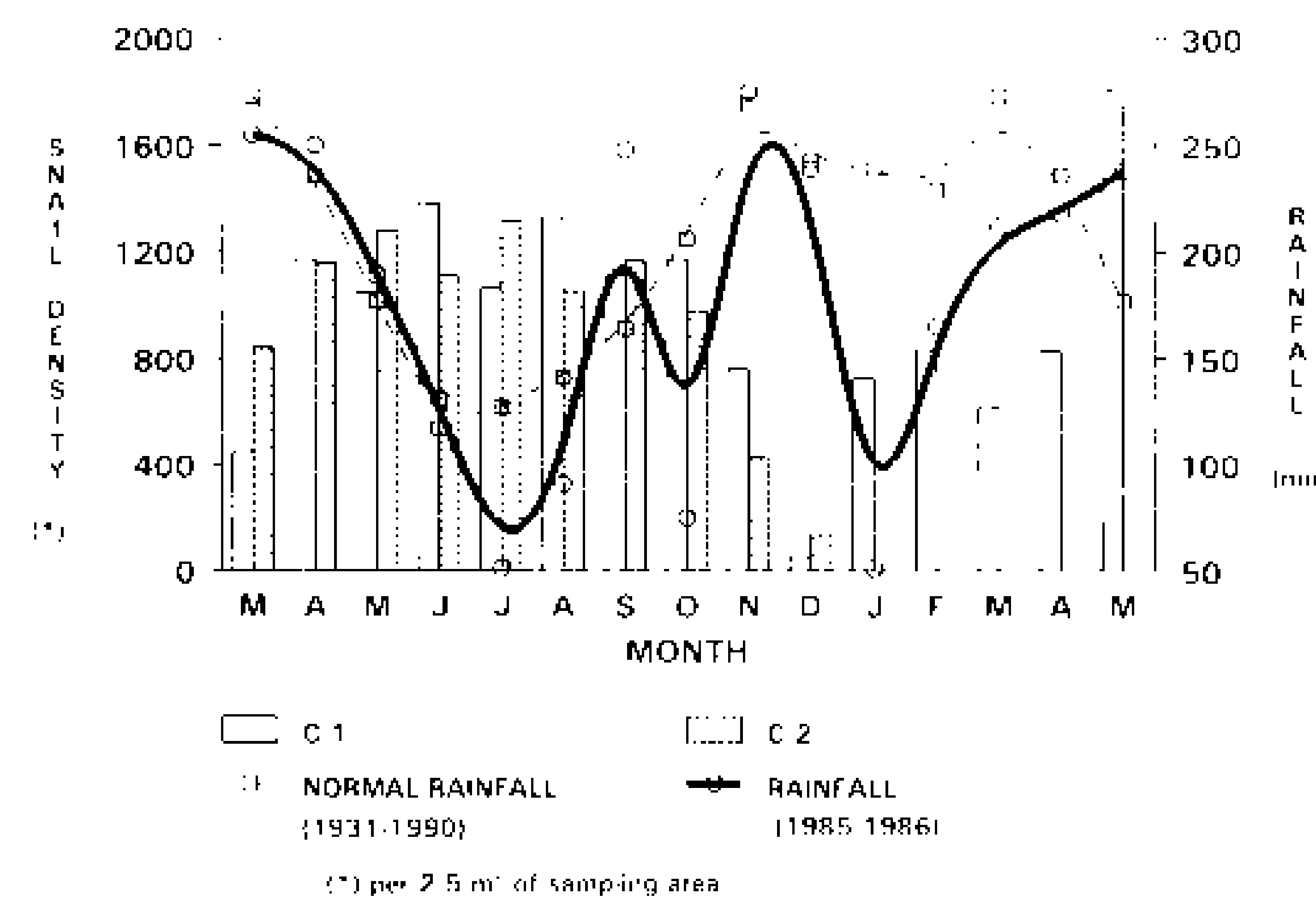

Fig. 3: monthly variation of snail density (number of snail per 2.5 m^2 of the sampling area) in the C1 and C2 areas and monthly rainfall (mm) between March 1985 and May 1986. The normal monthly rainfall at Alto da Boa Vista region between 1931 and 1990 is also showed.

Water quality – The results of areas C1, C2 and C3 were compared through the analysis of variance (ANOVA) statistical test. Significant differences between the three areas were detected for the following parameters: pH, conductivity, chlorides, alkalinity, organic nitrogen, Kjeldahl nitrogen, ammonium nitrogen and nitrates (Table I).

Hydrology of the irrigation system – The water that supplies the garden originates from the overflow of a dike at Rio das Furnas. Irrigation of the beds is achieved by an intermittent and unidirectional water flow through primary and secondary open channels. The natural inclination of the terrain is responsible for the water flow. No significant difference was detected between colonized and non-colonized areas by *B. tenagophila* when water flow, volume and draining time are considered (Table II).

Aquatic plants – No significant difference was observed in *P. striatus* and *Spirogyra* sp. biomass in C2 and C3 (Table III). However, both species show a seasonal growth cycle, with maximum abundance in the gardens in summer and in autumn (maximum availability of live plant tissue) and minimum abundance in winter (maximum availability of senescent plant tissue). Repopulation of the gardens occurred in spring and in the following summer the plants attained maximum abundance.

TABLE I

Analysis of the chemical parameters of water from a watercress garden in the Alto da Boa Vista region

Parameters	Area						Variance analysis	
	C_1		C_2		C_3			
	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	(F)	P
Total hardness ($mg/l\ CaCO_3$)	28,74	4,63	25,57	4,19	27,5	3,71	2,71	> 0,05
Ca total hardness ($mg/l\ CaCO_3$)	14,14	1,67	12,69	2,54	13,3	0,82	1,44	> 0,05
Mg hardness ($mg/l\ CaCO_3$)	15,80	3,67	15,58	3,71	15,5	5,01	0,014	> 0,05
Ca concentration (mg/l)	5,72	6,64	4,98	1,00	5,0	1,02	2,26	> 0,05
Mg concentration (mg/l)	3,73	0,85	3,38	1,30	3,32	1,13	0,71	> 0,05
Chloride (mg/l)	17,58	2,31	13,27	1,68	13,11	1,62	25,95	< 0,001
pH	6,43	0,31	6,51	0,45	6,56	0,38	0,51	> 0,05
Conductivity ($mhos\ cm^{-1}$)	108,00	9,48	85,00	10,54	84,10	11,69	17,45	< 0,001
Alcalinity (mg/l)	22,10	4,90	13,18	3,85	13,12	3,89	19,73	< 0,001
Nitrate (mg/l)	0,063	0,02	0,015	0,003	0,02	0,011	62,59	< 0,001
Concentration of HCO_3–(mg/l)	24,47	3,65	15,96	3,73	15,46	3,50	17,27	< 0,001
Organic Nitrogen (mg/l)	278,98	82,31	78,65	4,73	84,43	7,32	34,16	< 0,001
Kjeldhal Nitrogen (mg/l)	284,33	85,18	89,30	25,35	131,28	32,29	21,21	< 0,001
$N\text{-}NH_4$ (mg/l)	4,66	3,25	0,11	0,04	0,12	0,06	10,53	< 0,001

$\bar{X}$: mean; s: standard deviation; F: fration; P: probability.

TABLE II

Hydrological parameters in the irrigation system in a watercress garden in Alto da Boa Vista

Parameters	Area												Variance analysis	
	C_1				C_2				C_3					
	$\bar{X}$	s	Min.	Max.	$\bar{X}$	s	Min.	Max.	$\bar{X}$	s	Min.	Max.	(F)	P
Water flow (l/10s)	18,2	4,13	10	30	17	3,74	9	26	17,4	8,2	10	28	1,63	> 0,05
Volume (ℓ)	670,0	86,00	456	864	634	84,00	412	796	640,0	76,0	440	762	2,98	> 0,05
Time of draining (min)	6,21	0,71	4,8	7,8	6,24	0,71	5,1	7,9	6,5	0,8	5,2	7,6	0,02	> 0,05

$\bar{X}$: mean; s: standard deviation; Min: minimum value; Max: maximum value; F: fration; P: probability.

Nature of the substrate – ANOVA of the chemical constituents of the sediment indicated significant differences among the three beds in pH, concentration of Ca^{++} and Mg^{++}, K^{+} and Na^{+}. ANOVA of biological constituents indicated significantly higher organic matter contents in C1 and C2, both colonized by *B. tenagophila,* than in the non-colonized area C3 (Table IV). As regards the physical component of the substrate, all areas had a sand-clay soil texture.

DISCUSSION AND CONCLUSIONS

Populational dynamics – As seen before in the present work the C1 and C2 areas, although subjected to different environmental factors (especially concerning to the fertilization techniques), are able to sustain permanent colonies of *B. tenagophila.* An evaluation of the population dynamics in these areas also indicated that the population fluctuation is closely related to the annual precipitation regimen in the region, which characterizes a density-independent regulation of the population. However, between April and October, we can also suggest some intrinsic density-dependent mechanism since the malacological densities in both areas oscillate month by month, probably due to the carrying capacity of the population.

Chemical quality of the water – In the studied watercress garden, there occur some differences among the beds in the density of snails, with complete absence of snails in some cases. An attempt was made to investigate the causes of this phenomenon. Statistically different pH values were recorded for C1, C2 and C3; nevertheless, pH values observed in breeding sites of *B. glabrata* varied from 5.6 to 9.1 (Pieri, 1985), suggesting that the present differences do not seem to be directly relevant to colonization by *B. tenagophila.*

As regards chlorides, significant differences were observed among the three areas, the highest value being recorded in C1 (17.6 mg/l). However, variations of 13.1 mg/l and 13.3 mg/l observed in C3, C2, respectively, do not represent critical values to this species, since it is found in places with chloride concentrations between 10.0 mg/l and 2562 mg/l. Some places colonized by *B. glabrata* have even more extreme values of 1.0 mg/l to 3500 mg/l (Grisolia & Freitas, 1985).

TABLE III

Plant biomass of *Potamogeton striatus* and *Spirogyra* sp. in watercress beds with (C2) and without (C3) *Biomphalaria tenagophila* in Alto da Boa Vista

Parameter	Area				Variance Analysis	
	C_2		C_3			
	$\bar{X}$	s	$\bar{X}$	s	(F)	P
Dry weight (g)	10,32	0,10	10,29	0,06	0,859	> 0,05

$\bar{X}$: mean; s:standard deviation; F: fration; P: probability

TABLE IV

Chemical analysis of the sediment in a watercress garden in Alto da Boa Vista

Parameters	Area						Variance analysis	
	C_1		C_2		C_3			
	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	(F)	P
pH	6,00	0,53	5,6	0,32	5,4	0,17	5,41	< 0.05
Con Mg^{++} Ca^{+} (mg/l)	2,71	0,71	1,93	0,46	2,46	0,64	4,22	< 0,05
P Concentr. (mg/l)	50,70	17,23	51,40	14,28	57,0	20,75	0,34	> 0,05
K^{+} Concentr. (mg/l)	99,20	19,90	55,10	11,77	62,62	18,08	19,23	< 0,001
% of Organic matter	2,01	0,59	1,34	0,22	1,06	0,31	13,01	< 0.001
Na^{+} Concentr. (mg/l)	43,00	9,27	29,46	8,04	56,83	6,93	10,28	< 0,001

X: mean; s: standard; F: fration; P: probability.

The high concentrations of the nitrogen series compounds observed in C1 are in accordance with observations which frequently relate organic pollution to occurrence of snails (Ndifon, 1979; Thomas & Tait, 1984). However, as C2 is colonized by *B. tenagophila* and is not supplied with polluted waters, it is possible that either the presence of the snails in the beds may be related to more than one factor or that this species does not depend much on organic matter deposition on the habitat.

No significant differences among the three areas were detected when the average values of the following parameters were considered: Ca^{++} and Mg^{++} concentrations, as well as Ca^{++} and Mg^{++} hardness. These results are furthermore comparable to values observed in other *B. tenagophila* breeding sites by Andrade et al. (1955) and Grisolia & Freitas, (1985). It can be concluded that, with the exception of the concentration of nitrogen compounds, the physico-chemical factors of the water were probably not an important factor in determining the establishment of the molluscs in the garden. A positive relationship was observed between degree of water pollution and abundance of snail colonies, as already mentioned by Pinto, (1945) and Bradley, (1968).

Hydrology of the irrigation system – Although no differences in water flow were verified between colonized (C1 and C2) and noncolonized (C3) areas, there is some evidence that an increase in this variable, chiefly during the period of torrential rain storms, is an important regulation factor of the malacological population, for they decrease after the storms. Experimental manipulations should thus be carried out, in order to assess the effect of water flow increase on the malacological population and on viability of *Nasturtium officinale* production.

The absence of molluscs in the irrigation channels calls for no engineering intervention of a hydraulic nature on the physical structure of channels, such as lining of the canals with cement, closing them, or affecting the hydraulic gradient in order to increase water flow speed.

Aquatic plants – The absence of significant differences in aquatic plant biomass between areas C2 (WP/WB – with plant/with *Biomphalaria*) and C3 (WP/NB – with plant/without *Biomphalaria*) indicates that the presence and abundance of aquatic plants associated to *N. officinale* cultivation are not essential to the establishment of *B. tenagophila* in the garden. The snail-plant relationship can thus be understood as neutral.

It was demonstrated that *B. tenagophila* is not a direct consumer of live tissues of the plant species considered, since no snails were observed either in C3 (WP/NB) or in the beds of the same category during summer and autumn, when the plant species attained maximum densities. In the period of minimum plant densities (winter), when availability of decomposing plant material was highest, *B. tenagophila* was absent from C3, as well as in other beds of this category. It is possible that the establishment of this species in C2 is influenced by a quantitative or qualitative variation in periphyton associated to aquatic plants in the bed because additional organic nutrients are introduced in C2 from adjacent pigsties.

Nature of the substrate – The observed variation among areas C1, C2 and C3 in the concentration of Ca^{++}, Mg^{++}, K^{+} and Na^{+} in the substrate might be attributed to the influence of polluted waters entering C1. The high levels of organic matter observed in these waters generate alterations in the concentrations of elements of geological origin, which is a widely reported phenomenon in irrigation ditches in cultivated areas (Andrade, 1959). However, the observed variations do not seem to have any biological value, since they comply with the limits established by other authors to snail hosts in other localities (Andrade, 1959; Andrade et al., 1955).

The highest values of the organic component of the sediment found in colonized areas (C1 and C2) follow other data on correlation between increase in planorbid abundance and increase in organic matter of the medium (Malek, 1958; McMullen et al., 1973; Thomas, 1987).

The high organic matter contents in colonized areas (C1 and C2) should be specifically due to anthropogenous action, either through the introduction, in entry I, of organic mater in the form of polluted waters (C1), or organic refuse from adjacent pigsties (C2). The conditions thus provided seem to include sufficient organic substrate to the development of saprophytic bacteria and other microorganisms. In the non-colonized beds, which are only subject to fertilization by degrated liquid excrements, the number of saprophytic bacteria does not seem to be enough to sustain planorbids.

The periodic abundance rhythm of molluscs is evidently related to meteorological phenomena, the abundance curve following the annual rainfall pattern. On the basis of these observations it is suggested that the ideal moment for application of control measures of the molluscan population in the region should be the beginning of the rainy season (November/December).

The results obtained in the present study do not indicate any influence of aquatic plants on the establishment of *B. tenagophila* in the gardens. No measure is thus indicated, which deals with removal of these plants in order to control the malacological population.

Although no differences in hydrological parameters were detected between colonized and non-colonized areas, some experimental manipulations involving the collaboration of civil engineers should be carried out in order to promote a physical stress capable of excluding the malacological population within a reasonable cost-benefit scheme.

Taking the above points into account the following measures should be put into practice in order to attain control of the malacological population: (1) interruption of admittance of organic material from the pigsties into the gardens through sanitation, including septic tanks; (2) elimination of water sources with high organic pollution levels; (3) surveillance of the water quality of the Rio das Furnas in order to keep pollution level low through a sanitary reform in the region.

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