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BEHAVIORAL RESPONSES TO LIGHT BY THE SNALL *BIOMPHALARIA* TENAGOPHILA (ORBIGNY, 1835)

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(With 5 text-figures)

RESUMO

Comportamento do Caramujo *Biomphalaria tenagophila* (Orbigny, 1835) em relação à luz

Em um ambiente de escolha (labirinto em Y) foi estudada a resposta à luz de populações albinas procedentes de Joinvile (SC) e melânicas de São José dos Campos (SP) do caramujo *Biomphalaria tenagophila.* O comportamento foi estimado pela distância(cm) percorrida por hora e a localização (horizontal e vertical) do animal no labirinto. Os dados foram comparados entre as amostras de animais de diâmetro grande e pequeno estudadas em grupos e isoladamente. Todas as amostras responderam positivamente à luz, entretanto, ocorreram diferenças no tempo de aproximação do estímulo, o qual variou com o diâmetro da concha e a condição social dos animais.

Os resultados foram comparados aos da espécie *B. glabrata* e *B. straminea* estudadas em condições semelhantes e discutidos quanto à relação com a resposta à luz do parasito *Schistosoma mansoni.*

Palavras-Chave: Biomphalaria tenagophila; comportamento; luz.

ABSTRACT

Biomphalaria tenagophila snails placed in a Y-shaped aquarium were studied in terms of their behavioral response to light. Albino populations from Joinvile (State of Santa Catarina, Brazil) and melanic populations from São José dos Campos (State of São Paulo) were used. Snail behavior was measured by the distance (cm) covered per hour and location of the animal in the aquarium. Data obtained for animals with a small shell diameter were compared to those obtained for animals with a large shell diameter studied both as groups and separately. All samples studied were attracted to light, but differences were observed in time of aproximation to the stimulus, which varied with shell diameter and social condition of the animal.

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The results were compared to those obtained for *B. glabrata* and *B. straminea* in previous studies under similar conditions, and discussed in terms of the responses to light by the parasite *Schistosoma mansoni*.

Key-Words: Biomphalaria tenagophila, behavior; light.

INTRODUCTION

The snail *Biomphalaria tenagophila* is considered to be one of the intermediate host species of *Schistosoma mansoni* (Sambon, 1907), as demonstrated by Paraense (1956, 1963, 1978, 1981) among others, and has wide geographical distribution in the Central, Southeastern and Southern regions of Brazil, as well as in some other countries in South America (Paraense, 1972, 1981).

Few ecological and behavioral studies have been published on this species. Investigations of this nature may result in better knowledge of the mechanisms of survival and distribution of the animal in its habitat and also affect its control.

In a situation of free choice, the effect of light was investigated on same behavioral aspects of *B. tenagophila*, such as the existence of positive attraction, the time of approximation to the stimulus source by the animals, the reactions of orientation (kinesia or taxis) in the presence of the stimulus, and the possible interference of group factors with orientation to light.

The ethological approach of behavioral observation proposed by Carthy (1969) and Cunha (1974) and the reviews by Fraenkel & Gunn (1961) and Hinde (1966) on the types of orientation reactions were taken as reference points for the present investigation.

MATERIAL AND METHODS

1. Animals

Noninfected *Biomphalaria tenagophila* mollusks were raised from specimens kindly provided by Dr. W.L. Paraense (Department of Malacology, Instituto Oswaldo Cruz, Rio de Janeiro). Albino animals originated from Joinvile (SC) and melanic animals from São José dos Campos (SP).

The snails were reared and maintained in the laboratory under conditions similar to those described by Schall, Jurberg & Vasconcellos (1985).

The sample consisted of large specimens having a diameter of 11 ± 1.3 mm and considered adults according to the data reported by Brumpt (1941) and Rey (1956), and of small specimens having a mean shell diameter of 5.5 ±0.7 mm. Forty large and 40 small animals were studied, each group consisting of 20 albino (Joinvile, SC) and 20 melanic (S.J. Campos, SP) snails, using a Repeated Measurement scheme (Miller, 1977). Using an independent group scheme, 20 melanic animals also from S.J. dos Campos were studied as well. All animals tested in groups were marked as previously described by Schall, Jurberg & Vasconcellos (1985).

2. Material

The experimental room, the equipment used (3 Y-shaped aquaria), the lighting scheme and control of possible interfering variables have been described by Schall, Jurberg & Vasconcellos (1985) in a study on *B. glabrata*.

Water quality was controlled by periodical analyses of conductivity (72 ± 8.8 μmho.cm^{-1}), dissolved oxygen (7.5 ± 0.1 mg/l) and pH (7.2 ± 0.3) in the aquaria.

At the beginning and at the end of each testing session, water temperature was measured at four different points in the aquarium, i.e. in the central confluence and at the end of the three arms. Water temperature was maintained at 22.0 ± 0.7°C throughout the experiments. On average, no variations above 0.5°C were recorded during the same experimental day.

In the Control Situation, light intensity was 350 lux in all 3 arms of the aquarium, and in the Experimental Situation it varied from 0.17 to 350 lux, and was 2.8 to 350 lux in the lighted arm.

3. Procedure

The 80 specimens were tested in groups of 10 (5 albino and 5 melanic animals) by the Repeated Measurement Plan (Miller, 1977) and submitted to 2 experimental situations, i.e. Control Situation (CS) and Experimental Situation (ES), in the following order:

PHASE 1: 1st – Control Situation (CS)
2nd – Experimental situation with the light focus on the left side of the "Y" (LES), or,
– Experimental Situation with the light focus on the right side of the "Y" (RES).
PHASE II: Other specimens were submitted to the same procedure as in PHASE I, but with the sequence of situations inverted (1st LES or RES, 2nd CS).

Two Y-shaped aquaria were used in each experimental session, each containing 10 animals tested in the Control Situation (CS) or in the Experimental Situation (ES), with a group submitted to LES and another to RES in the latter. The use of the light focus on the left side (LES) or on the right side (RES) permitted to determine a possible tendency of the animal towards fixation on one side more than on another due to a cause other than the stimulus under study.

Recordings were performed on 4 consecutive days of the same week at alternate hours between 9:00 and 16:00 h on the lst day and from 9:00 to 10:00 h on the following day, with 5-minute intervals between observations and with the animals remaining in the experimental environment for 25 hours.

A study session was also carried out with melanic animals of large diameter using the independent sample plan, i.e. each group of animals was tested in only one of the experimental situations. Twenty melanic animals were used in this session, 10 of which were tested in LES and 10 in RES on 2 consecutive days, following the methodology described above.

In another session, 12 melanic animals of large diameter were tested separately, i.e. a single animal in each aquarium, with 3 animals tested in the 3 respective aquaria on the same day. In this sample, 3 animals were tested in LES and 3 in RES. Six animals were used for the control situation (SC) and tested on 2 different days. This session was used as a control for possible group variables that may interfere with the response to the stimulus.

No food was supplied to the animals during the 25 hours of the experiment in order to avoid competition between the light and food stimulus.

Data recording was started at the time when the animals were placed in area 1 of the aquarium at 9:00 a.m. Data quantification and behavior recording were performed by the methods described by Schall, Jurberg & Vasconcellos (1985).

RESULTS

Using the Repeated Measurement Plan, the occurrence of a behavioral change was demonstrated in the animals when tested in the aquarium for the 2nd time, both under control or experimental conditions. This effect indicates that some interfering process may occur, such as habituation or learning, for example. When animal distribution in the 3 arms of the aquarium per hour is compared, it can be observed that for the samples tested for the first (Fig. 1), the frequency of location in one of the side arms was 60% in CS and 80% in ES for adult animals (both melanic and albino). In contrast, for the great number of animals tested for the second time in the aquarium (Fig. 2),these frequencies did not reach 40% either in CS or ES for adult animals throughout the experimental period (25 hours). Thus, there was a drop in the response of exploration of the side arms for animals tested for the second time in this environment, which may be explained as due to previous experience in this environment. This effect also occurred for young animals, although the difference was not of the same proportion as for the adults (Figs. 1 and 2).

In view of this occurrence, only the results obtained for animals tested in CS or ES for the 1st time were used for analysis, i.e. following an independent sample plan. These results are presented below.

a) *Response to light:*

On the basis of animal location in the arms of the aquarium both in the experimental (ES) and control (CS) situation (Fig. 1), the attractive effect of light was confirmed for the various samples studied. Statistical comparison of the left and right arm by the chi-square test in CS (for the last recording hour) showed similar distribution in the two arms with no significant difference for large and small melanic animals and for small albino animals (Table I). Large albino animals, however, were located on the right side at significantly higher frequency than on the left side. Comparison of the left and right sides for ES when only one arm was lighted revealed a significant difference for all groups studied (Table I).

Fig. 1 shows the distribution of albino and

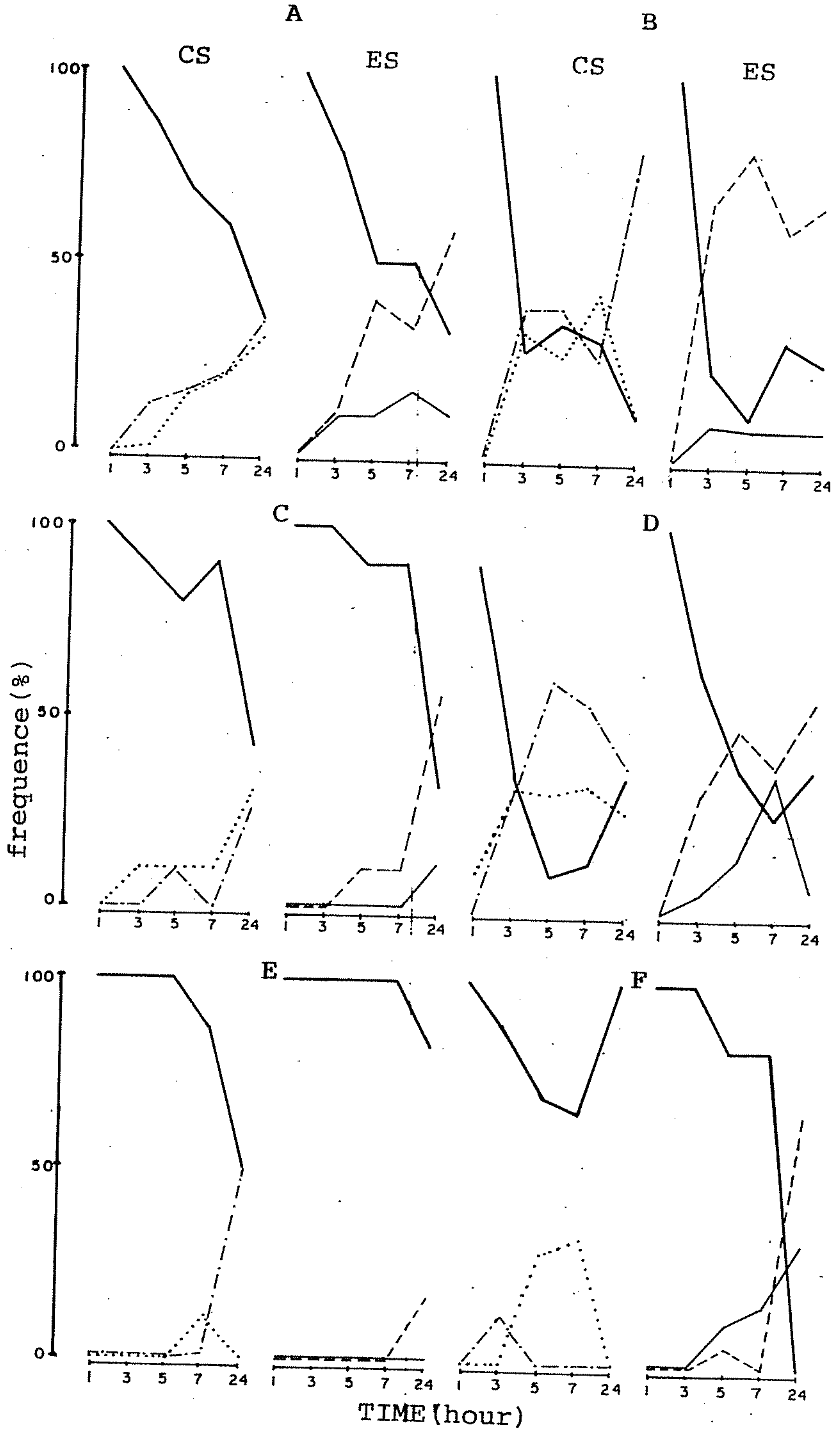

Fig. 1 – Location frequence (%) of *B. tenagophila* tested for the first time in the arms of the Y – shaped aquarium: central arm (———); left side arm (. . . . .); right side arm (—·—·—); illuminated side arm (– – – –); dark side arm (———), during the five hours of register. A-small albino; B-large albino; C-small melanic; D-large melanic; E-separately albino; F-separately melanic. CS-control situation and ES-experimental situation.

melanic animals tested individually in CS and ES in the 3 arms of the aquarium. By analysing the last time interval, it can be observed that in CS there was a massive frequency of albino animals in the right, with a significant difference (Table I), whereas no difference was observed for the melanic animals (Fig. 1 and Table I). In ES, the location of both albino and melanic animals was more frequent in the lighted arm (LA) than in the dark arm (DA), the difference being significant (chi-square test, Table I).

The frequency of animal location in the various areas of the aquarium (areas 5 of the central compartment, 6 to 13 – left side, and 14 to 21 – right side) was analyzed when the left or right arm was lighted, during ES for the last recording hour (25th hour). A similar procedure was carried out for CS with the 2 side arms equally lighted. Since no significant difference was detected by the Kruskal-Wallis test among the samples studied (small albino, SA, small melanic, SM, large albino, LA, and large melanic, LM) with respect to animal dispersal through the areas, the data were studied as a whole both for CS ($H = 0.198$; d.f. = 3; $p > 0.05$) and ES ($H = 2.827$; d.f. = 3; $p > 0.05$).

The frequency of animal distribution in the areas analyzed both in CS and ES when the animals were tested in groups (Fig. 3A) was higher in the last area of the side arms (13 and 21) both for CS and ES. In ES, frequency was double than in CS, a fact that might have been associated with incident light. The low frequencies for the remaining areas indicate that these are transition areas for the animals, which tend to fix in the last one, as clearly observed for ES. When the animals were tested separately, the frequencies in all areas were always lower than 20%, and the effect of fixation in the last areas as observed for group samples did not occur (Fig. 3B).

b) *Locomotion*

Locomotion was estimated on the basis of the distance (cm) covered for the 9:00, 11:00, 13:00 and 15:00 h time intervals on the lst day of the experiment and for the 9:00 h time interval on the following day. Fig. 4A shows the locomotion of large albino and melanic animals in CS and ES (an average of 10 animals in each situation). Maximum locomotion by the albino group occurred at 11:00 hs (CS and ES), and maximum locomotion by the melanic group occured at 13:00 h (CS) and 15:00 h (ES). Also, locomotion was significantly greater in CS for the melanic group (Mann-Whitney U test $U = 3$; n_1 and $n_2 = 5$; $p < 0.05$). Locomotion by the albino animals was greater in ES although not

TABLE I

Mean location frequence(f) and percentage(%) of the samples studied: large albino (LA); large melanic(LM); small albino(SA); small melanic(SM); separately tested albino(STA) and separately tested melanic(STM) in the control situation(CS) and experimental situation(ES). LA(left side arm); RA(right) side arm; IA(illuminated side arm); DA(dark side arm). (* = $p < 0,05$; d.f. = 1, chisquare test)

		LA		LM		SA		SM		STA		STM	
		LA	RA	LA	RA	LA	RA	LA	RA	LA	RA	LA	RA
CS	f	12	96	32	46	36	42	36	33	0	36	0	0
	%	10	80	27	38	30	35	20	20	0	50	0	0
	X^2	65.3*		2.5		0.4		0.13		324.0*		0.0	
		LA		LM		SA		SM		STA		STM	
		IA	DA	IA	DA	IA	DA	IA	DA	IA	DA	IA	DA
ES	f	81	9	67	8	70	12	67	14	12	0	48	24
	%	68	8	56	7	58	10	56	12	17	0	67	33
	X^2	57.6*		46.4*		41.0*		34.7*		36.0*		24.0*	

significantly so (U = 8.5; n_1 and n_2 = 5; $p > 0.05$).

Fig. 4B shows the locomotion rate of small albino and melanic animals in CS and ES. When the locomotion rate of these animals was compared between CS and ES, no significant difference was observed for albino snails (U = 8.5; n_1 and n_2 = 5; $p > 0.05$) or for melanic snails (U = 6.5; n_1 and n_2 = 5; $p > 0.05$).

Comparative analysis of locomotion among all groups (LA, LM, SA and SM) by the Kruskal-Wallis test showed a significant difference both in CS (H = 16.32; d.f. = 3; $p < 0.05$) and ES (H = 16.27; d.f. = 3; $p < 0.05$). A subsequent comparison by the Dunn procedure revealed that the significance of the difference in CS concerned only LM and SM animals, and in ES, only LA and SM animals. In both cases, the locomotion rate of the SM group (CS = 5.8 ± 6.9 cm/h, and ES = 11.8 ± 8.7 cm/h) was significantly lower than that of the LM group (CS = 82.2 ± 32.9 cm/h, and ES = 43.6 ± 25.2 cm/h) and of the LA group

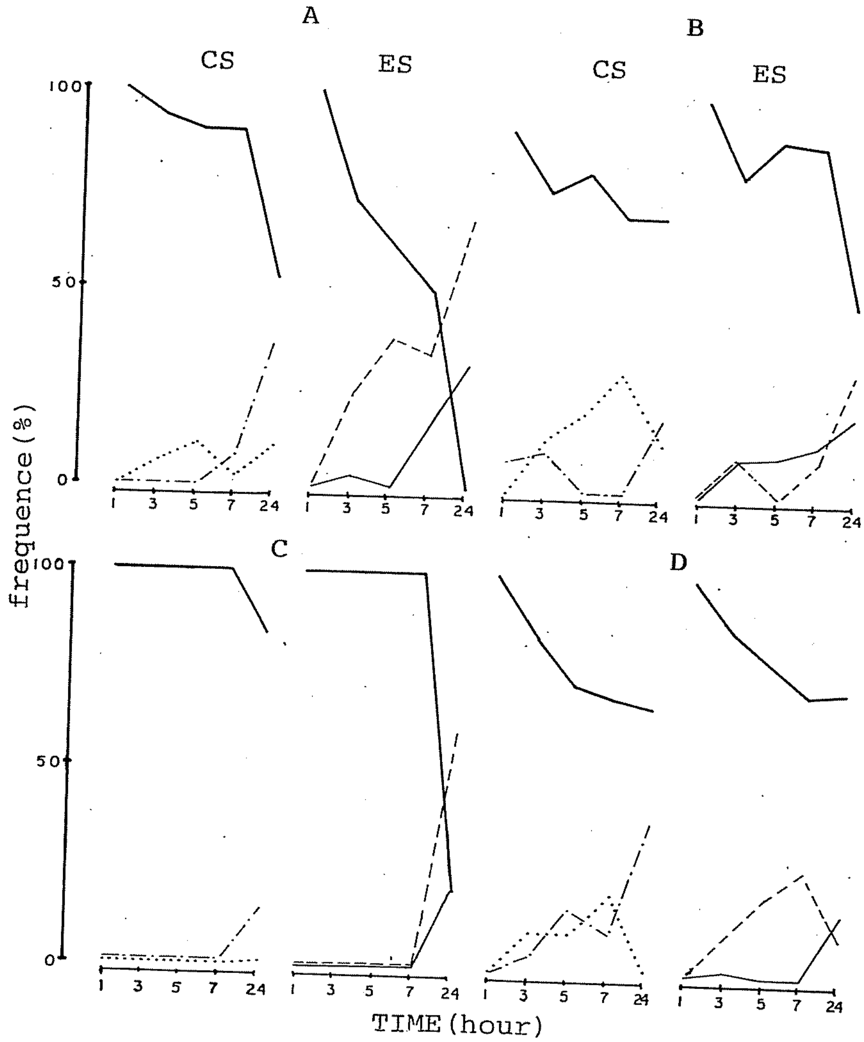

Fig. 2 – Location frequence (%) of *B. tenagophila* tested for the 2nd time in the arms of the Y-shaped aquarium: central arm (———); left side arm (. . . . . .); right side arm (—·—·—); illuminated side arm (– – – –); dark side arm (———), during the five hours of register. A-small albino; B-large albino; C-small melanic; D-large melanic. CS-control situation and ES-experimental situation.

(CS = 55.6 ± 27.0 cm/h, and ES = 62.8 ± 13.0 cm/h). The locomotion rate of small albino animals (CS = 38.0 ± 21.4 cm/h, and ES = 25.2 ± .? 4 cm/h) was lower than that of large animals (LA and LM), although not significantly so.

Locomotion by isolated animals was reduced (Fig. 4C) in relation to group samples, i.e. 6.2 ± 6.4 cm/h for isolated albino animals (IA) in ES, and 6.8 ± 8.7 cm/h in CS, and 8.2 ± 2.4 cm/h for isolated melanic animals (IM) in ES, and 31.6 ± 13.9 cm/h in CS. When the hourly rates in CS and ES were compared for the IA sample by the Mann-Whitney U test, no significant difference was detected ($U = 12$; n_1 and $n_2 = 5$; $p > 0.05$, whereas for IM, locomotion was significantly greater in CS ($U = 0$; n_1 and $n_2 = 5$; $p < 0.05$). When the data for each situation (CS and ES) were compared for IA and IM, no significant differences were detected between the two samples in ES ($U = 9.5$; n_1 and $n_2 = 5$; $p > 0.05$), with locomotion by IM being significantly greater than locomotion by IA in CS ($U = 1$; n_1 and $n_2 = 5$; $p < 0.05$).

When mean locomotion values in both CS and ES were related to each testing condition, i.e. isolated animals (1), groups of animals having a small diameter (2) and groups of animals having a large diameter (3), a 0.77 correlation coefficient (ρ of Spearman) was obtained. The test of significance of the correlation coefficient gave $t = 3.816$ for d.f. = 10, demonstrating a positive correlation with significance at the 1% level between animal condition and locomotion, a correlation that tended to grow from the isolated animal in the direction of grouped animals of small diameter and consecutively towards animals of large diameter (Fig. 5).

c) *Analysis of animal position*

Six reference points were used to determine the position of the animal's cephalopodal mass (cpm): floating on the surface of the water (F); on

TABLE II

Mean ($\bar{X}$) and standard deviations(S) of the time of permanence in the central arm(CA in minutes) in the control situation(CS) and experimental situation(ES) for large albino(LA); large melanic(LM); small albino(SA); small melanic(SM); separately tested albino(STA); separately tested melanic(STM)

ANIMALS	CS		ES	
	$\bar{X}$	S	$\bar{X}$	S
LA	173.0	74.9	157.0	18.4
LM	105.0	31.1	230.0	100.4
SA	322.0	2.8	299.5	34.6
SM	372.0	16.9	354.0	93.3
STA	412.5	10.6	420.0	0.0
STM	340.8	29.5	390.0	42.4

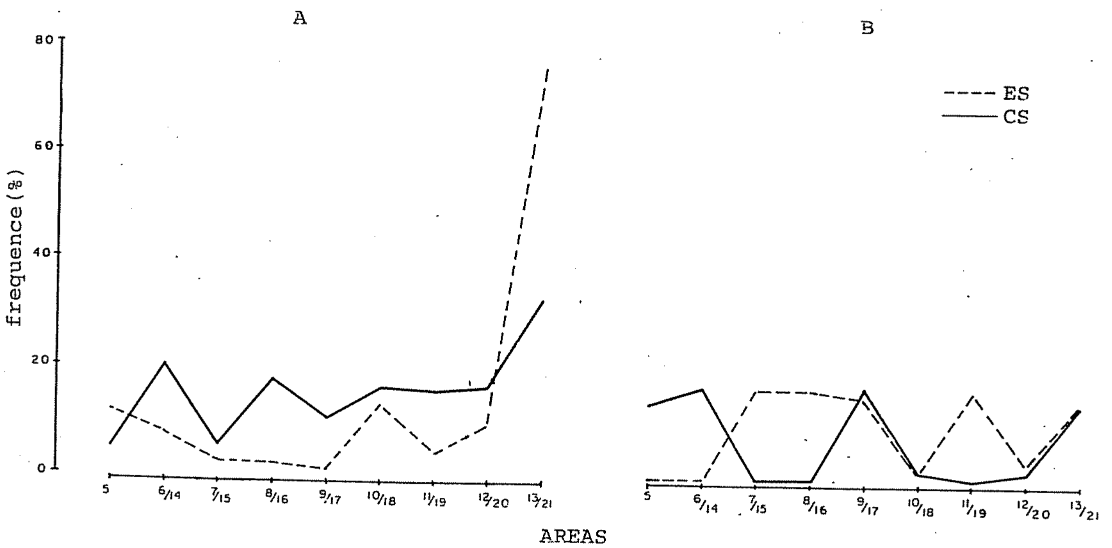

Fig. 3 – Location frequence (%) of. *B. tenagophila* in the areas of the Y-shaped aquarium in the 25th hour of register (9:00 AM of the 2nd day of experiment). A-snails tested in group; B-separately tested animals.

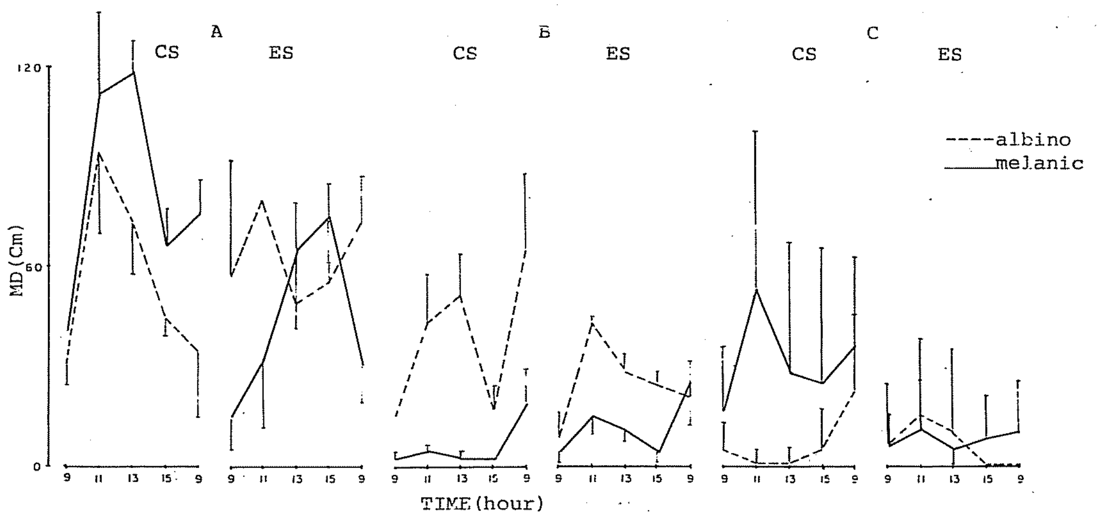

Fig. 4 – Locomotion (mean distance covered per hour – MD – in cm) in the control situation(CS) and experimental situation(ES). A-large animals; B-small animals; C-separately tested animals.

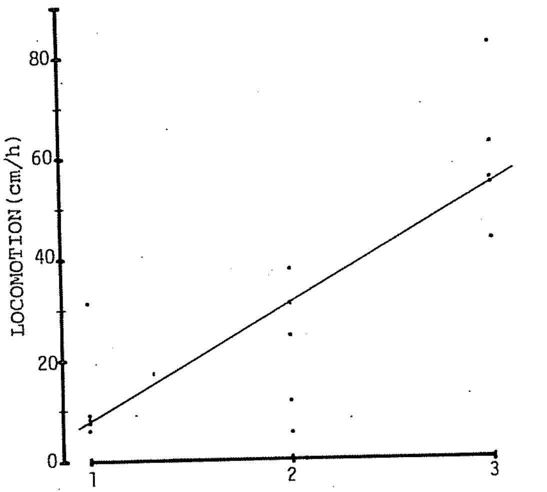

Fig. 5 – Mean locomotion (cm/h) of *B. tenagophila* as related to experimental condition: condition 1: separately tested large snails; condition 2: small snails tested in group; condition 3: large snails tested in group. (Spearman's p = 0,77; p < 0,01).

the bottom of the aquarium (B); on the wall (W); on the acrylic wall (aW); on the wall-surface (Ws): = cpm resting on the wall and head above the surface of the water; on top of the shell of another animal (OTO) (Fig. 6).

When the hourly data for the animals tested in groups (LA, LM, SA and SM) were pooled, animals of large diameter (LA and LM) were found in the B position at high frequency both in the control (43.3%-LA, and 40.5%-LM) an in the experimental (42.5%-LA and 35%-LM) situation, as well as in W (sum of W+aW+Ws) in the control (40.8%-LA and 48.8%-LM) and in the experimental (40.3%-LA and 53.3%-LM) situation. The remaining locations, about 20%, were subdivided into F and OTO.

Animals of small diameter (SA and SM) were found at high frequency in the B position both in the control (49.6%-SA and 44%-SM) and in the experimental (39.7%-SA and 43.4%-SM) situation, as well as in W, in the control (39.5%-SA and 53.4%-SM) and in the experimental (50%-SA and 52.5%-SM) situation. The distribution of F and OTO was below 10% for SA and SM both in CS and ES. Percent values in CS and ES were similar for positions B and W for both large and small animals. Comparison of the absolute values for each category (F, B, W, aW, Ws, and OTO) in CS and ES by the Mann-Whitney U test showed no significant differences for any of them. Thus, for animals tested in groups, there seemed to be no relation between the animal's position in the various levels of the "Y" and the position of the light source (vertical in CS and horizontal in ES).

When the animals were tested separately, higher frequencies were detected in W (sum of W+aW+Ws) both in the control (76.5%-IA and 63.8%-IM) and in the experimental (77.0%-IA and 42.0%-IM) situation. The frequency of position B was 14.8% for IA and 36.1% for IM in the control situation, and 14.2% for IA and 39.5% for IM in the experimental situation, with no statistical differences between the two situations (chi-square test). The frequency of position F was 8.7% (IA) and 0.0% (IM) in the control situation, and 9.0% (IA) and 16.8% (IM) in the experimental situation, the latter value being significantly higher than in CS (chi-square test).

DISCUSSION

Analysis of the data demonstrated that the *B. tenagophila* samples studied respond positively to the light intensity tested. However, the locomotion rate of melanic animals of large diameter (adults) studied as a group (82.2 cm/h) was 8.3% lower than that of *B. glabrata* and 51% lower than that of *B. straminea* melanic adults studied under similar conditions (Schall, Jurberg & Rosemberg, 1983; Schall, Jurberg & Vasconcellos, 1985). Thus, the approximation of *B. tenagophila* to the light source is more delayed in relation to the other two species mentioned. If we consider the 50% index of individuals that reach the lighted area in the chosen environment, this is obtained during the 1 st hour of the experiment for *B. straminea,* during the 2nd hour for *B. glabrata,* and only during the 5th hour for *B. tenagophila.*

Other behavioral characteristics were also observed, such as: a) a tendency on the part of the animals to fix themselves on the right side of the Y-shaped aquarium, which was quite clear for animals of large diameter and significant for albino animals when exposed to homogeneous illumination (Control Situation); b) a locomotion gradient increasing in the following direction: isolated animals – a lower rate than for animals of small diameter, and a lower rate for both in relation to animals of large diameter; c) a significantly greater locomotion rate for large melanic animals under homogeneous (control) than differential (experimental) lighting conditions.

Even though a positive orientation towards light was detected, it is not yet possible to classify it in terms of the criteria indicated by Fraenkel & Gunn (1961) and Hinde (1966) as kinesia or taxis, since during the observing times on the first day of recording the number of animals that responded to the stimulus was small and therefore did not permit us to determine the predominant type of mechanism. The option for the lighted arm of the aquarium was demonstrated with significance during the 24th hour of observation on the day after the beginning of the experiment. Thus, the absence of recording during the night prevented us from analyzing the mechanism of orientation that occurred during this interval, when large numbers of animals responded to the stimulus, with more than 50% of them being located in the lighted arm of the aquarium during the 24th hour. The samples of large animals studied as groups, which reacted more rapidly to light, never did so during the 1st hour of the experiment, and the recording interval during the 2nd and 4th hours once again prevented us from detecting the type of mechanism shown by the animals in their response to light. This was not the case in the study of *B. glabrata* and *B. straminea* (Schall *et al.*, 1983, 1985), since the behavior of the former was recorded continuously during the first two hours of the experiment (when more than 50% of the animals responded to the stimulus) and most specimens of the latter species promptly responded to light, i.e. during the first hour of the experiment. Thus, for these two species it was possible to determine the occurrence of the orientation mechanism denoted positive phototaxis, whereby the animals move directly towards the stimulus. New experimental designs for *B. tenagophila* using continuous filming of the experimental sessions may help elucidate this matter.

The significantly higher locomotion rate of large melanic snails under homogeneous 350 lux illumination (control) than under experimental conditions (2.8 to 350 lux in the lighted arm only) suggests the occurrence of high photo-orthokinesia, whereby the locomotion rate increases with increasing light intensity. This mechanism was also detected in large melanic specimens of *B. glabrata* (Schall, Jurberg & Vasconcellos, 1985). This variation in locomotion rate in relation to the variation in light intensity permits the animal to fix itself in regions that are most adequate for its survival, remaining for longer times in the areas in which it moves more slowly.

Social factors that may interfere with the response to light in samples studied as groups should also be considered, since the animals are not only attracted to a favorable site, but also to one another (Eibl-Eibesfeldt, 1974). Simpson *et al.* (1973) demonstrated in the laboratory that *B. glabrata* is highly social, thus confirming field observations of agglomerations of *B. glabrata* in nature. Thus, keeping in mind that the process of social attraction may interfere with the response to light, the study of separate animals in a clean environment permitted us to evaluate the action of the stimulus without any social interference or effects of chemical residues, since water containing extracts of lyophilized *Biomphalaria* is an attractant for individuals of the same species (Uhazy *et.al.*, 1978). The results obtained here for isolated animals showed that a significant response to light occurs even under these conditions. This evidence, however, was clear only during the 24th hour of the experiment, no positive response to the stimulus being observed during the 7 hours of observation on the 1st day. Under isolation conditions, the animals remained in the central arm of the aquarium for more than 6:30 hours, whereas when studied as groups, at least 50% of them were already in the lighted arm by the 3rd or 5th hour. When isolated, *B. tenagophila* moves little, with consequent longer permanence in the central arm and a longer time needed to reach the lighted arm.

According to Willows (1973), under normal conditions, most gastropods move about looking for food and for mating or to escape from noxious stimuli. It has been demonstrated that *B. glabrata*, though a hermaphrodite species, prefers crossed fertilization (Paraense, 1955) and that there is attraction between individuals of the same genus which is mediated by substances such as specific amino acids that may act as pheromones (Uhazy *et al.*, 1978; Thomas *et al.*, 1980). In addition, Townsend (1974) demonstrated that *B. glabrata* individuals are able to follow the mucous trails left by other animals of the same species. In the present study, considering the absence of food in the experimental environment, the greater locomotion of grouped animals in relation to isolated animals may have been associated with social stimuli, which may have acted as factors facilitating environmental exploration and consequently more rapid approximation to the light transition area (area 5), where the option for the lighted arm occurred. A growing gradient (significant positive correlation) was observed from the isolated condition to animals of small diameter studied as groups and from them to animals of large diameter. This evidence suggests the hypothesis that the greater locomotion of grouped animals is related to the mating stimulus, which is absent in the isolated situation, is not so frequent among groups of animals of small diameter (although a direct relationship between size and age cannot be established for this species, the probability that some animals of small diameter have not yet reached sexual maturation should be considered, since the animals were reared in the laboratory under homogeneous conditions, a fact that makes the diameter-age relationship more probable) and is certainly present in groups of animals of large diameter. This locomotion gradient has a corresponding gradient of time of approximation to the stimulus, with a more delayed response by isolated animals.

It should be pointed out that there are no studies of the circadian rhythm of activity of these animals, which may be clarified in terms of the periodicity of locomotion for grouped and isolated animals. Data on the snail *Helisoma trivolis* (Kavaliers, 1981) have demonstrated that, at constant temperatures, the activity of isolated animals is nocturnal and shows a twilight pattern in grouped individuals. Thus, the reaction to environmental stimuli should also exhibit a rhythmic pattern and therefore the recording periods for each social condition could be adapted as a function of this periodicity, thus permitting clearer observation of the phenomenon under study.

The evidence for greater animal fixation on the right arm of the Y-shaped aquarium under homogeneous conditions of stimulation suggests a few questions that deserve specific investigation, such as: (1) whether this occurrence may be related with some type of magnetic orientation; (2) whether the spatial conformation of the shell may have any effect on the direction of motion, and (3) whether there is any adaptative factor linked to the geographic origin of the species. As far as hypothesis 2 is concerned, the shell of *B. tenagophila* in general has a deeper excavation on the left, whereas the shells of *B. glabrata* and *B. straminea* have more depth on the right (Paraense, 1970) and these two species, in contrast to *B. tenagophila*, show a tendency to fix themselves predominantly on the left side of the aquarium. However, Paraense (personal communication) questions this type of relationship, since later observations have indicated great variability of these external traits of the shell.

As to the geographic origin of the strains studied, the *B. tenagophila* specimens from Joinvile-SC (albino) showed a tendency for fixation on the right arm of the aquarium which was more significant than that shown by animals from São José dos Campos-SP (melanic). Tendency towards the left side is more expressive in *B. straminea* (Picos-PI) than in *B. glabrata* (Touros-RN). However, to establish a type of relation of a geographic nature, it would be necessary to repeat the experiment with animals of the same species and with the same kind of pigmentation, varying only the origin, and taking into account a fixed magnetic orientation in the testing place. In addition, it is possible to perform experiments in which the magnetic field is artificially altered, a fact that would permit discussing the possibilities indicated above.

Another point to be experimentally investigated is the relation between the effect of lighting on the behavior of the host *B. tenagophila* and the behavior of the parasite (cercaria and miracidia) *S. mansoni*. In this respect, it should be pointed out that, according to several authors, the first orientation of the miracidium is towards the environment as a reaction to one or more physical stimuli, and this orientation leads the miracidum to the type of environment where the hosts are found (Wright, 1959, 1966; Smyth, 1966). The importance of illumination as one of these stimuli has been experimentally demonstrated in the relationship miracidium (*Schistosoma*) x host (mollusk) (Faust, 1924; Takahashi *et al.*, 1961; Chernin & Dunavan, 1962; Wright, 1962). From this point of view, we may suggest that one of the three host species of *Schistosoma mansoni* studied, *B. tenagophila*, *B. glabrata* and *B. straminea*, may be evolutionarily more vulnerable to contact with the parasite in terms of the type of response to environmental illumination, exhibiting a behavioral pattern that is more similar to that of the miracidium and therefore being more frequently located by the latter. This hypothesis should be tested experimentally.

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