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Effect of Temperature and Atmospheric Pressure on the Eggs of the Intermediate Snail Hosts of *Schistosoma mansoni* and *S. haematobium*

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Introduction

Factors such as geographical altitude, amount of rainfall, stream geology, and water verocity, depth, temperature and chemistry, affect the distribution of schistosomiasis vector snails. These factors were elucidated primarily by observations of snail populations in their natural habitat and by examining snail fecundity in the laboratory. To our knowledge, little detailed information is available regarding the accelerating and limiting factors involved in the embryonic development of the snail eggs. Nojima (1973) and Nojima and Katamine (1976) reported the effect of temperature, the amount of water and of mineral salts on the eggs of *Oncomelania* spp., the intermediate hosts of *Schistosoma japonicum*. The temperature represents a limiting factor in the embryonic development of the eggs of *Biomphalaria* spp. transmitting *S. mansoni* (Sturrock, 1966; Sturrock and Sturrock, 1972; Mousa and El-Hassan, 1972) and the effect of temperature on the eggs of *Bulinus truncatus* transmitting, *S. haematobium* has also been studied (El-Gindy and Radhawy, 1965; Mousa and El-Hassan, 1972).

To examine the effect of temperature and atmospheric pressure on the life span and geographical distribution of vector snails, eggs were experimentally exposed to these factors.

Materials and Methods

Adult Puerto Rican *Biomphalaria glarata,* Kenyan *Biomphalaria pfeifferi* and Kenyan *Bulinus globosus* snails were maintained in aquariums (24×45×30 cm deep), at the four insides of which polyethylene strips had been placed. The water temperature in these aquariums was maintained at 25±0.5 C. Egg masses laid during a 24-hr period were removed from the strips and counted under a dissecting microscope. Approximately 200 eggs each were placed into 15 cm diameter petri dishes containing 200 ml of dechlorinated tap water, the temperature of which was maintained at 10, 15, 20, 25, 30, 32, or 35 C. Multiple, identical experiments were done. Alternatively, approximately 40 eggs each were placed into 10 ml of vaccine bottles con-

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Table 1 Effect of temperature on hatching rates of *Biomphalaria glabrata*, *B. pfeifferi* and *Bulinus globosus* eggs

Water temps.	No. of snails hatched / No. of eggs examined (Hatching rate: %)		
	Biomphalaria		*Bulinus*
	glabrata	*pfeifferi*	*globosus*
35 C	0/605 (0)	0/213 (0)	0/233 (0)
32 C	573/678 (84.4)	271/318 (85.2)	170/515 (33.0)
30 C	389/419 (92.8)	228/238 (95.8)	41/121 (33.9)
25 C	651/721 (90.3)	491/544 (90.3)	308/532 (57.9)
20 C	425/345 (93.4)	233/261 (89.3)	96/344 (27.9)
15 C	303/327 (92.7)	257/282 (91.1)	57/593 (9.6)
10 C	0/237 (0)	0/211 (0)	0/150 (0)

taining 3 ml of the water. They were sealed with rubber stoppers and the air pressure inside the bottles was adjusted to 1/4, 1/3, 1/2, 1, 2, 3, or 4 atm by injecting or withdrawing the proper amount of air with a syringe. The water temperature in the atmospheric pressure experiments was maintained at 25 C.

Egg masses maintained in petri dishes at a constant water temperature of 10 C were examined once a week, and all others were observed daily under a dissecting microscope. The number of hatched snails was recorded until no more viable embryos could be detected. No tap water in any of containers was changed through the experimental period.

Results

1. Effect of temperature

a) Growth and hatching rate

In all three species examined, the critical upper and lower temperature for hatching were 35 C and 10 C, respectively (Table 1). At a water temperature of 10 C, none of the eggs from the three species hatched. At 35 C, *B. pfeifferi* and *B. globosus* egg embryos ceased their development at early cleavage, while those of *B. glabrata* barely reached the early veliger stage.

At water temperatures between 15 C and 32 C, the hatching rates in *B. glabrata* and *B. pfeifferi* were 84.4 to 93.4% and 85.2 to 95.8% respectively, and higher than those in *B. globosus* (9.6 to 57.9%). Within the temperatures, about 90% of the eggs of *Biomphalaria* spp. hatched; on the other hand, in *B. globosus* the maximum hatching rate was 57.9% at 25 C.

b) Incubation period

Examination of the hatching patterns at water temperatures between 32 C and 15 C showed that in all three species the incubation period was shorter at the higher temperatures. Furthermore, at identical temperatures, the incubation periods of *B. glabrata* were shorter than those of the other species (Fig. 1).

2. Effect of atmospheric pressure

a) Hatching rate

At atmospheric pressure of up to 4, almost all *Biomphalaria* spp. eggs hatched. However, only 7.4% of *B. globosus* eggs hatched at an atmospheric pressure of 4, as compared to about 40% at an atmospheric pressure range between 1/2 and 3. In all three species, a decrease in atmospheric pressure brought about a decrease in the hatching rates (Table 2), although the eggs of *B. globosus* exhibited a greater tolerance for reduced atmospheric pressures than the eggs of *Biomphalaria* spp.

b) Incubation period

Examination of the hatching patterns at a constant water temperature of 25 C and

Table 2 Effect of atmospheric pressure on hatching rates of *Biomphalaria glabrata*, *B. pfeifferi* and *Bulinus globosus* eggs

Atmospheric pressure	No. of snails hatched / No. of eggs examined (Hatching rate: %)		
	Biomphalaria		*Bulinus*
	glabrata	*preifferi*	*globosus*
4 atm.	42/45 (93.3)	28/28 (100.0)	2/27 (7.4)
3 atm.	36/36 (100.0)	27/28 (96.6)	15/41 (36.6)
2 atm.	41/42 (97.6)	48/49 (98.0)	14/34 (41.2)
1 (control)	44/45 (97.8)	35/36 (97.2)	12/29 (41.4)
1/2 atm.	17/31 (54.8)	17/40 (42.5)	12/32 (37.5)
1/3 atm.	10/41 (24.4)	2/30 (6.6)	11/35 (31.4)
1/4 atm.	0/38 (0)	0/27 (0)	3/40 (7.5)

The water temperature: 25 C

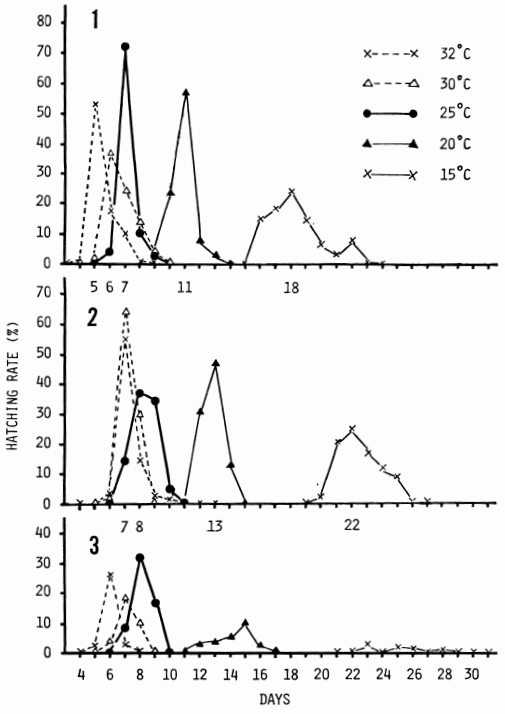

Fig. 1 Hatching patterns of the eggs of (1) *Biomphalaria glabrata*, (2) *B. pfeifferi* and (3) *Bulinus globosus* at different temperatures.

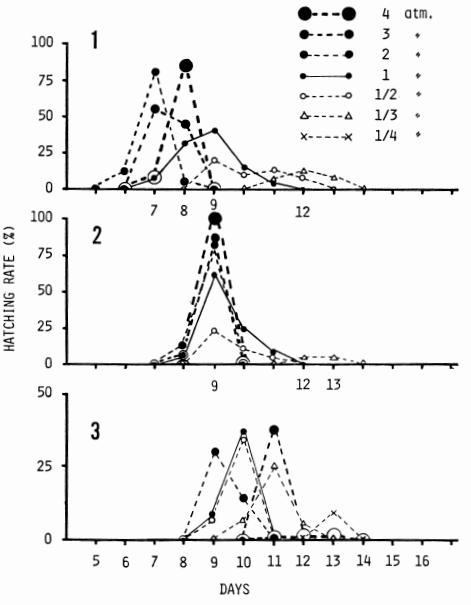

Fig. 2 Hatching patterns of the eggs of (1) *Biomphalaria glabrata*, (2) *B. pfeifferi* and (3) *Bulinus globosus* at different atmospheric pressures. The water temperature during the observation periods was maintained at 25 C.

at an atmospheric pressure range from 1 (control) to 4, showed that in *Biomphalaria* spp. there was no remarkable difference in the incubation period. In *B. globosus*, the incubation period increased at the atmospheric pressure of 3 and 4. In all species, the incubation period increased as the atmospheric pressure decreased below 1 atm, and in *Biomphalaria* spp., this increase was remarkable (Fig. 2).

Discussion

Although there have been many field and laboratory observations on the growth and hatching of *Biomphalaria* and *Bulinus* snail eggs, there are only a few reports on controlled temperature experiments. The hatching rates and incubation periods for *B. glabrata* and *B. pfeifferi* eggs in the present study are similar to those reported partly by Perlowagora-Szumlewics (1958), Ritchie *et al.* (1966), Sturrock (1966), Sodeman (1970), Sturrock and Sturrock (1972), Mousa and El-Hassan (1972), Kawazoe (1976, 1977), Appleton (1977) and Chieffi *et al.* (1977). On the other hand, the present hatching rates for *B. globosus* at the temperature range between 15 C and 32 C were much more lower than those for *B. truncatus* by El-Gindy and Radhawy (1965) and Mousa and El-Hassan (1972). The possibility that damage of some eggs during the process of removing the eggs from the polyethylene strips might affect our results cannot be ruled out. However, it should seem that there is a difference in hatching rates between *Bulinus* species. The incubation periods of *B. globosus* noted in the present study coincide with those in earlier reports (Standen, 1948; Barlow and Muench, 1951; Najarian, 1960; El-Gindy and Radhawy, 1965; Mousa and El-Hassan, 1972; Sodeman and Dowda, 1973).

Snails of the *Biomphalaria choanomphala* group are known to live in some African lakes with both shallow and deep water (12 m: Mandahl-Barth, 1949). *B. pfeifferi ruppellii* and *B. truncatus sericinus* has been noted to live at altitude of up to 2,610 m and 2,880 m respectively in Ethiopia (Brown, 1964). A water depth of 12 m corresponds to an atmospheric pressure of 2.2; an altitude of 2,880 m, 2/3. Furthermore, a highland form of *B. truncatus sericinus* has been reported in Ethiopia and South Arabia (Mandahl-Barth, 1965), and *Bulinus* spp. populations (hexaploid and octoploid, including *B. truncatus sericinus*) are thought to a clear preference for the habitat at the altitudes over 2,100 m (Brown and Wright, 1972). On the other hand, adult Puerto Rican *B. glabrata* used in this study had been well established in the laboratory for 12 years or more, while *B. pfeifferi* and *B. globosus* used were transported from Kenya to our laboratory one year before the present experiments and they were considered not to be well established laboratory colonies.

Our study clearly indicated that *Biomphalaria* spp. eggs have a tolerance for higher, while *Bulinus globosus* eggs have a tolerance for lower atmospheric pressures. This difference in tolerance for atmospheric pressures may be of congenital origin and may explain the geographical distribution of these species.

Summary

Hatching rates and incubation periods of *Biomphalaria glabrata, B. pfeifferi* and *Bulinus globosus* eggs were examined at different water temperatures and different atmospheric pressures. At 10 C and 35 C, none of the eggs hatched and at the temperatures between 15 C and 32 C, about 90% of the *Biomphalaria* spp. hatched, while the maximum hatching rate for *Bulinus globosus* was 57.9% at 25 C. In all three species, the higher the water temperature, the shorter the incubation period. *Biomphalaria* spp. eggs showed a tolerance for higher, while *B. globosus* had a tolerance for lower, atmospheric pressures. In all three species, the lower the atmospheric pressure, the longer the incubation period.

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マンソン及びビルハルツ住血吸虫の中間宿主貝類の卵子に及ぼす温度と気圧の影響

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マンソン住血吸虫症を媒介する *Biomphalaria glabrata*, *B. pfeifferi*, ビルハルツ住血吸虫症の *Bulinus globosus* の卵子の発育，孵化に及ぼす温度と気圧の影響をみ，媒介貝類の地理的分布に関与する物理的要因の水温，気圧，水深について考察した．得られた結果は以下のとおりである．

いずれの種も 10C 以下の低温，35C 以上の高温では卵子の発育，孵化はない．15C～32C では *Biomphalaria* 属の卵子で 90% 前後の高い孵化率をみたが，*Bulinus globosus* の卵子で 25C で最高 57.9% の孵化率を得たに過ぎず，*Bulinus* 属の他種の報告例と比較しても低い孵化率であった．いずれの種でも産卵から孵化に要する時間は高温になる程に，短期間になる．

卵子の発育，孵化に及ぼす気圧の影響を *Biomphalaria* 属と *Bulinus globosus* で比較すると，前者は高気圧に対しより耐性があり，後者は低気圧に，より耐性があった．いずれの種でも，気圧が低くなればなる程，産卵から孵化に要する時間が延長した．