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Direct and delayed effects of low temperature on the freshwater snail *Indoplanorbis exustus* (Deshayes, 1934), intermediate host of schistosomiasis

B. D. Parashar & K. M. Rao
Defence Research & Development Establishment, Gwalior 474 002, India

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Abstract

The direct and delayed effect of short-term exposure to low temperature (17.5 °C) on growth, reproduction and longevity of adolescent and mature freshwater *Indoplanorbis exustus* Deshyes (Mollusca: Gastropoda) was studied in the laboratory. We found that growth and reproduction were retarded, but were enhanced when later they were returned to ambient temperature.

Introduction

Temperature affects the growth and reproduction of fresh water snails (Van der Schalie & Berry, 1973; El-Hassan, 1974; Harris & Charleston, 1977; Parashar *et al.*, 1983). *Indoplanorbis exustus* Deshayes, 1984, a common fresh-water snail inhabiting south and southeast Asian countries, is an intermediate host of *Schistosoma nasalis* Rao, 1932, *S. spindale* Montgomery, 1906 and *S. indicum* Montgomery, 1906 (Malek & Cheng, 1974). In tropical countries like India, populations of this snail are exposed to low temperatures from December to February, but the effects of this are not known. The present study examines the effect and after-effect of low temperature exposure on growth, reproduction and survival of two age-groups of *I. exustus* under laboratory conditions.

Materials and methods

Snails were maintained in the laboratory at 30 ± 2 °C or at 17.5 ± 1 °C to simulate tropical and cool season conditions. *I. exustus* survives at 20 °C but does not breed, whereas at 15 °C, it dies (Parashar & Rao, 1985). Snails were kept in enamel dishes (30 cm diam.) containing 400 ml of tap water per snail. Spinach leaves were provided as food *ad libitum* and water in the dishes was replaced on alternate days. Increase in diameter of the shell at intervals of 2 weeks was recorded as an indicator of growth. Fecundity, mortality and the number of eggs per egg capsule were also recorded in all dishes. Dead snails were discarded daily and a proportionate amount of water was removed.

Two age-groups of snails were used in the experiments: mature snails, 29 days old which had laid on average 12 eggs before the start of an experiment, and adolescent snails, 14 days old and not having laid any egg. Although adolescent snails attained maturity during experiments they are still referred to as the adolescent group to differentiate them from other groups of snails.

Twenty adolescent snails (three replicates) and 20 mature snails (three replicates) were kept at 17.5 ± 1 °C for 12 weeks in separate enamel bowls. The surviving snails were then grown at ambient temperature of 30 ± 2 °C and observations i.e. increase in diameter of the shell at intervals of 2 weeks, fecundity, mortality and the number of eggs per egg capsule were recorded.

Data were analysed to determine growth rate, longevity and weekly and total egg production. Information on minimum, average and maximum number of eggs per egg capsule was also collected. Values for all these variables were subjected to one way analysis of variance for the determination of the value of variance ratio (F) and minimum significant range (K) from studentized range test (Goldstein, 1964). Population parameters were determined after the method of Howe (1953) and Andrewartha & Birch (1954).

Results

Effect of low temperature exposure

Activity and food uptake of both age groups of snails was reduced. The growth rates of adolescent snails (0.3 mm/fortnight) and mature snails (0.2 mm/fortnight) were lower than their respective controls but there was no mortality.

After-effect of low temperature exposure

Growth patterns are shown in Fig. 1. There was no significant difference in the growth rate of adolescent and mature snails in the controls (Table 1a). The growth rate of adolescent snails during low temperature exposure and at ambient temperature was significantly ($P < 0.05$) lower than in the other two groups of snails (Table 1a).

Both adolescent and mature snails started laying eggs within a week of their return to ambient temperature (30 ± 2 °C). The weekly

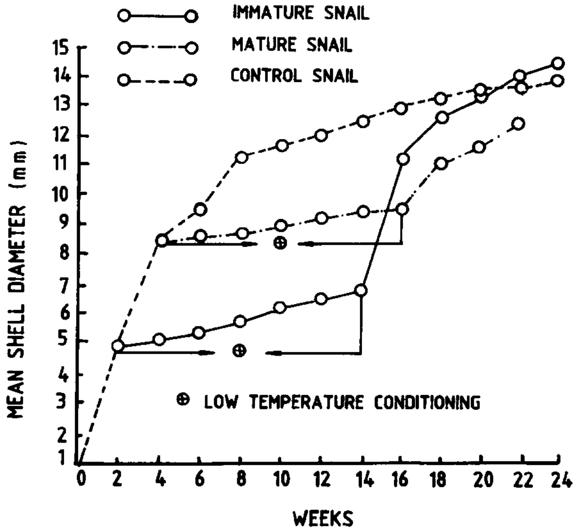

Fig. 1. Effect and after-effect of low temperature on growth of *Indoplanorbis exustus.*

and total egg production per snail was now higher in the adolescent snails than in the controls (Table 1b, 1c). Analysis of variance showed significant differences in egg production of the three groups of adolescent, mature and control snails ($P < 0.05$); but differences between adolescent and mature controls were not significant. The

Table 1a. Direct and delayed effect of low temperature conditioning on growth of *I. exustus.*

	Adolescent snail	Mature snail	Control snail
Growth (mm/fortnight)	0.88	0.42	0.83

Analysis of variance

Source	df	SS	MS	F	K
Regimen	2	0.3822	0.191	191	0.07
Error	6	0.0060	0.0010		

P <0.05.
F = variance ratio.
K = minimum significant range.

Table 1b. Delayed effect of low temperature conditioning on egg production/week of *I. exustus.*

	Adolescent snail	Mature snail	Control snail
Egg production/week/ snail	208.13	38.57	149.63

Analysis of variance

Source	df	SS	MS	*F*	*K*
Regimen	2	44 507.17	22 253.58	120.46	34.02
Error	6	1 108.41	184.73		

$P < 0.05$.

Table 1c. Delayed effect of low temperature conditioning on total egg production/snail of *I. exustus.*

	Adolescent snail	Mature snail	Control snail
Total gg production/ snail	2081.38	231.42	1047.41

Analysis of variance

Source	df	SS	MS	*F*	*K*
Regimen	2	5 156 824.29	2 578 412.14	193.65	289.13
Error	6	79 888.29	13 314.71		

$P < 0.05$.

Table 1d. Delayed effect of low temperature conditioning on average number of eggs in egg capsule of *I. exustus.*

	Adolescent snail	Mature snail	Control snail
Average No. of eggs in egg capsule	29.66	16.28	27.06

Analysis of variance

Source	df	SS	MS	*F*	*K*
Regimen	2	301.99	150.99	175.56	2.25
Error	6	5.2	0.86		

$P < 0.05$.

Table 1e. Delayed effect of low temperature conditioning on minimum number of eggs in egg capsule of *I. exustus.*

	Adolescent snail	Mature snail	Control snail
Minimum No. of eggs in egg capsule	24.20	10.32	19.24

Analysis of variance

Source	df	SS	MS	*F*	*K*
Regimen	2	296.82	148.41	98.94	3.03
Error	6	9.01	1.5		

$P < 0.05$.

minimum, average and maximum number of eggs per egg capsule was significantly ($P < 0.005$) higher in adolescent than in mature snails (Table 1d, 1e, 1f).

There was no significant difference ($P = 0.05$) in average longevity of adolescent, mature and control groups of snails (Table 1g). Minimum and maximum longevity differed significantly between adolescent and mature snails and also between adolescent snail and controls ($P < 0.05$) (Table 1h, 1i). There were no significant difference ($P = 0.05$) in average, minimum and maximum longevity of adolescent and mature groups of control snails.

The values of intrinsic rate of natural increase, net reproductive rate and mean generation time are summarized in Table 2. The adolescent snails exhibited the highest value for intrinsic rate of natural increase. The net reproductive rate for adolescent snails was 3.7 times higher than for control snails and about 20 times higher than for mature snails. The adolescent and mature groups

Table 1f. Delayed effect of low temperature conditioning on maximum number of eggs in egg capsule of *I. exustus*.

	Adolescent snail	Mature snail	Control snail
Maximum No. of eggs in egg capsule	43.60	23.64	34.80

Analysis of variance

Source	df	SS	MS	*F*	*K*
Regimen	2	664.65	332.32	179.63	3.38
Error	6	11.12	1.85		

$P < 0.05$.

Table 1g. Direct and delayed effect of low temperature conditioning on average longevity of *I. exustus*.

	Adolescent snail	Mature snail	Control snail
Average longevity	147.80^{NS}	136.80^{NS}	138.2^{NS}

Analysis of variance

Source	df	SS	MS	*F*	*K*
Regimen	2	717.06	358.53	0.031	60.10
Error	6	6908.80	1151.46		

$P < 0.05$.

Table 1h. Direct and delayed effect of low temperature conditioning on minimum longevity of *I. exustus*.

	Adolescent snail	Mature snail	Control snail
Minimum longevity (days)	119.00	115.00^{NS}	114.00^{NS}

Analysis of variance

Source	df	SS	MS	*F*	*K*
Regimen	2	42	21	10.5	2.89
Error	6	12	2		

$P < 0.05$.

Table 1i. Direct and delayed effect of low temperature conditioning on maximum longevity of *I. exustus*.

	Adolescent snail	Mature snail	Control snail
Maximum longevity	174.00	157.00^{NS}	164.00^{NS}

Analysis of variance

Source	df	SS	MS	*F*	*K*
Regimen	2	438	219	9.8	8.33
Error	6	134	22.33		

$P < 0.05$.

Table 2. The effect of low temperature on population parameters of *I. exustus*.

Stage of snail	Intrinsic rate of natural increase (rm)	Net reproductive rate (Ro)	Mean generation time (in weeks) (M.G.T.)
Adolescent	0.4706	2217.77	18.82
Mature	0.2354	113.71	20.11
Control	0.3508	601.09	18.23

of control snails exhibited similar value for all parameters.

Discussion

The results indicate that low temperature retards growth of *I. exustus*. The growth rate of mature snails was lower than that of adolescent snails at 17.5 °C. The control group of snails demonstrates that growth decreases after the snails attain maturity (Fig. 1). Sturrock (1966) and Sturrock & Sturrock (1972) reported that the growth rate of *Biomphalaria pfeifferi* Krauss, 1948 and *B. glabrata* Say, 1818 decreased at low temperature (19–20 °C) after attainment of sexual maturity. *B. alexandrina* Ehrenberg, 1831 and *Bulinus truncatus* Audouin, 1927 exhibited similar features of growth at 15 °C and 20 °C (El-Hassan, 1974). During the cool season in tropical countries, when temperature decreases below 20 °C, there will thus be little growth of adolescent or mature snails in the field.

Within the first two weeks of return to ambient temperature (30 °C), the adolescent snails grew by more than half their original size and this rapid growth continued in the subsequent two weeks. The mature snails increased only by about a quarter of their original size during the same period and their cumulative growth was the lowest of all the groups. These findings suggest that after low temperature exposure, the temperature fluctuation to ambient temperature promotes the growth of adolescent snails. This is further supported by the higher average shell size of adolescent snails compared to mature and control groups of snails (Fig. 1) during the latter part of the experiment after low temperature conditioning.

Reproduction was completely suppressed at 17.5 °C and this species is not likely to breed in the field during cool season conditions, like the other Indian species, *Lymnaea luteola* which also does not breed (Parashar *et al.*, 1983).

It was observed that after low temperature exposure, adolescent snails laid nine times more eggs than mature snails and twice as many as control snails. Temperature fluctuation to ambient temperature exposure had a triggering effect in the reproductive capacity of adolescent snails which showed a high rate of fecundity in the field during early spring, a phenomenon so far not known. This temperature fluctuation also affected the number of eggs in egg capsules with increase in the case of adolescent snails, and decrease in the mature snails.

The enhancement of reproduction due to exposure of low temperature has been reported in other cold blooded animals, especially insects. In the case of the rust-flour beetle, *Tribolium confusus*, low temperature caused a considerable increase in the rate of oviposition (Rockstein, 1964).

The increase in biotic potential of adolescent snails was also confirmed by high values of net reproductive rates and intrinsic rates of natural increase. The high intrinsic rate of natural increase of adolescent snails coupled with short mean generation time strongly suggest the possibility of a short-term increase in snail population in the field.

Survival of *I. exustus* was unaffected by low temperature exposure and all the groups showed insignificant differences in their average longevity. Similar observations on survival of snails at low temperature have been reported with *Lymnaea truncatula* Muller, 1974 (Kendall, 1953), *Lymnaea tomontosa* (Boray, 1969) and *Bulinus truncatus* (El-Hassan, 1974).

Since the reproductive potential of adolescent snails increases more than that of mature snails after exposure to low temperature, they will in the field be mainly responsible for increasing the population of overwintered *I. exustus*. The ratio of adolescent to mature *I. exustus* in a particular habitat during the cool season is therefore a useful predictor of the magnitude of the snail population in the next spring.

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