Survival of *Bulinus africanus* (Krauss), *Bulinus globosus* (Morelet) and *Biomphalaria pfeifferi* (Krauss) at constant high temperatures

P.H. Joubert, S.J. Pretorius, K.N. de Kock and J.A. van Eeden

Snail Research Unit of the SAMRC and Department of Zoology, Potchefstroom University for CHE, Potchefstroom

The survival of the freshwater snail species *Bulinus africanus*, *Bulinus globosus* and *Biomphalaria pfeifferi* at extreme high temperatures was experimentally investigated. Snails were exposed to temperatures in the range from 34°C to 40°C and their survival was noted daily. The results showed that the survival of the cohorts of all three species decreased with increased temperatures. It was also found that *B. globosus* survived longer at high temperatures than *B. africanus* and *B. pfeifferi*. There was no marked difference between the survival of the latter two species.

S. Afr. J. Zool. 1986, 21: 85–88

Die oorlewing van die varswaterslakspesies *Bulinus africanus*, *Bulinus globosus* en *Biomphalaria pfeifferi* by uiterste hoë temperature is eksperimenteel ondersoek. Slakke is aan temperature in die reeks 34°C tot 40°C blootgestel en hulle oorlewing is daagliks aangeteken. Die resultate toon dat die oorlewing van die kohorte van al die slakspesies afgeneem het met toenemende temperatuur. Daar is ook gevind that *B. globosus* langer geleef het by hoë temperature as *B. africanus* en *B. pfeifferi*, wat op hul beurt in hierdie opsig goed ooreengestem het.

S.-Afr. Tydskr. Dierk. 1986, 21: 85–88

P.H. Joubert* and S.J. Pretorius
Snail Research Institute of the SAMRC,
Department of Zoology, Potchefstroom University for CHE,
Potchefstroom, 2520 Republic of South Africa

K.N. de Kock and J.A. van Eeden
Department of Zoology, Potchefstroom University for CHE,
Potchefstroom, 2520 Republic of South Africa

*To whom correspondence should be addressed

Received 18 February 1985; accepted 4 September 1985.

A number of opinions are held on the relative importance of the various physical and chemical factors that may affect freshwater snails. However, it is generally accepted that temperature is one of the most important enviromental factors which can, amongst others, determine the geographical distribution of organisms (Stuckenberg 1969). In order to assess the effect of temperature on the organism, it is essential to investigate experimentally the effect of optimum as well as extreme temperatures on vital functions such as survival, egg production and growth rate.

The optimum temperatures for the various vital functions of freshwater snails have been investigated (Shiff 1962, 1964, 1966; De Kock 1973; De Kock & Van Eeden 1981), while others concentrated on investigations of the survival of snails at extreme temperatures (Chitramvong, Upatham & Sukhapanth 1981; El-Emam & Madsen 1982; Joubert 1984).

Measurements of water temperatures carried out by various researchers in this field such as Pitchford & Visser (1969) and O'Keeffe (1985) indicated that temperatures of 30°C and higher are not unusual in the endemic areas of *Bulinus globosus* (Morelet) and *Biomphalaria pfeifferi* (Krauss). Thus, during the summer high temperatures occur that can have a negative effect on the survival of some snails. There is a need to be able to evaluate the possible establishment of economically important snail species in certain areas and to assess the reasons for the existing distribution of the snails. The present distribution is well documented, but the factors influencing distribution as yet unknown. Therefore, it became necessary to obtain information on the survival of snails at extreme temperatures.

In this paper the survival of *Bulinus africanus* (Krauss), *B. globosus* and *B. pfeifferi* at constant high temperatures of 34°C to 40°C is reported. These snails were selected for our investigation because they are intermediate hosts for *Schistosoma* spp., the organism causing bilharzia in man.

Method

An aquarium system similar to that described by De Kock & Van Eeden (1980) and Joubert (1984), was used for the breeding and maintenance of experimental animals. The temperature in the aquaria was thermostatically controlled at a constant level by either heating or cooling as needed. The aquaria in which the snails were exposed were covered with perspex lids to prevent excessive evaporation owing to the high temperatures, and a consequent rise in electrical conductivity of the water.

Borehole water that had been biologically conditioned in a pond in a nearby botanical garden was filtered through a fine gauze net before being used in the aquaria. This water was continuously aerated to ensure that oxygen was not limiting for survival. In this way the oxygen saturation was kept above 70% which is more than sufficient for the survival of freshwater snails (Van Aardt & Frey 1980). The electrical conductivity of the water in the aquaria was controlled between 350–500 μS by the periodic addition of conditioned borehole water. It is known that the electrical conductivity in this range is favourable for these three snail species (De Kock 1973; Jennings 1976).

Eggs laid in the laboratory by snails obtained from a veld habitat were collected and the hatchlings reared to maturity. The parental snails of *B. africanus* originated from one of the springs of the Mooi River on the farm Gerhardminnebron 139 in the district of Potchefstroom (26°28'S/27°08'E). Those of *B. globosus* were obtained from outdoor holding tanks of the Research Institute for Diseases in a Tropical Environment of the South African Medical Research Council at Nelspruit (25°28'S/30°58'E). The parental snails of *B. pfeifferi* were collected from a pond in the Game Breeding Farm of the National Zoological Gardens of South Africa,

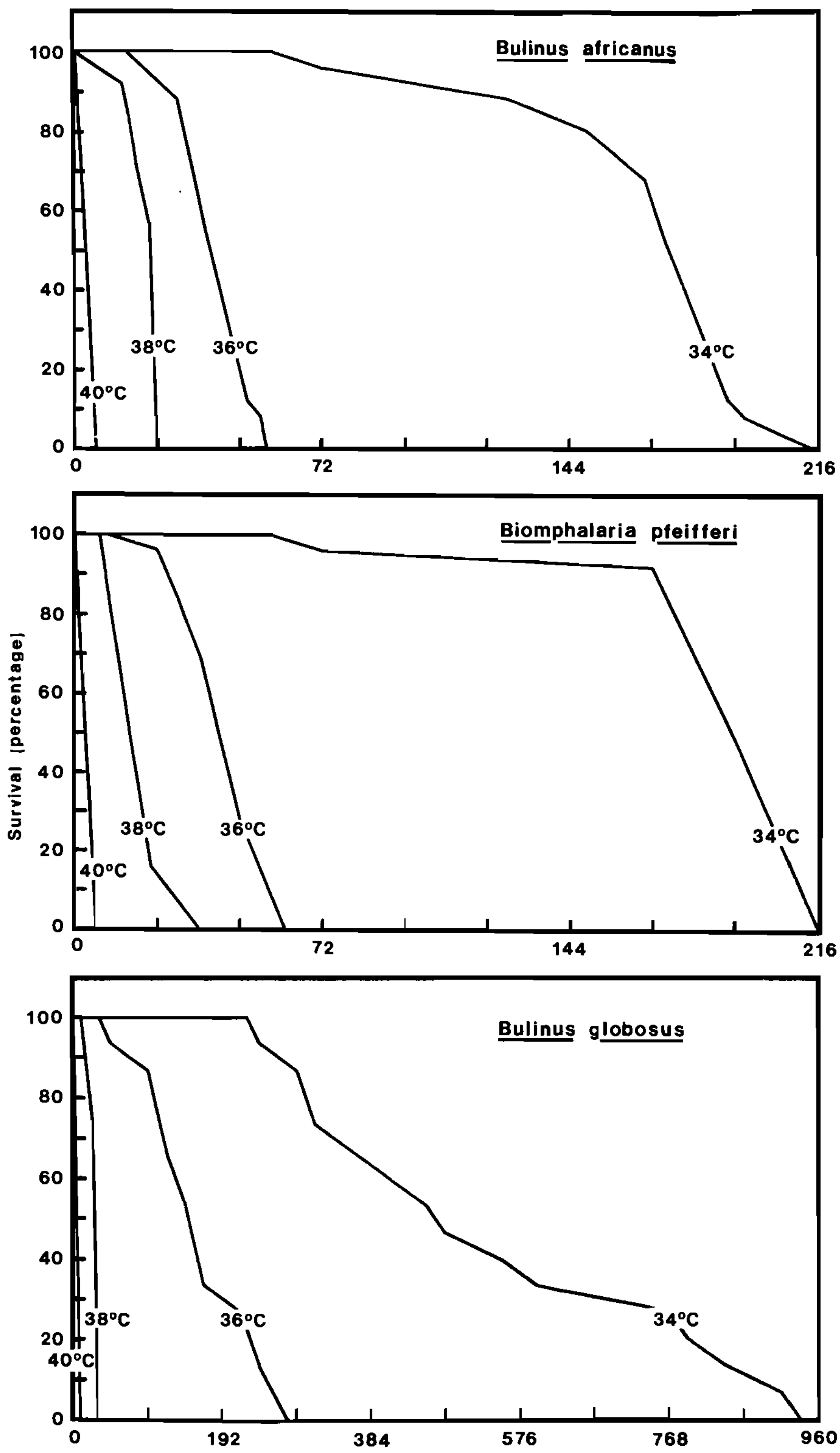

Figure 1 Percentage survival of *B. africanus*, *B. pfeifferi* and *B. globosus* after sustained exposure to various high temperatures.

situated in the municipal area of Lichtenburg (26°08′S/ 26°10′E).

Snails were put into a 1 000 ml glass beaker filled with water at 24°C. The beaker was then floated in an experimental aquarium where it gradually assumed the higher temperature over a period of about 2 h. The snails were then transferred to a polythene container with a fine gauze bottom which was suspended in the water of the experimental aquarium. By following this procedure the physiological shock of a sudden transfer at the start of the experiment was reduced. In this manner cohorts of 15 snails in the case of *B. globosus* and 25 snails of the other two species were continuously exposed to temperatures of 34°C, 36°C, 38°C and 40°C. During all experiments a control cohort of snails was kept at a favourable temperature of 24°C to ensure that deaths were the result of high temperature and not any other cause.

Criterium of death was taken as the absence of response to mechanical stimuli (Joubert 1984). If examination under the microscope revealed movement the snail was returned to the experimental aquarium. Snails judged as dead were placed in optimal conditions (24°C) to confirm initial observations. In only a few instances snails judged as dead proved otherwise. To evaluate the performance of the snails under these extreme conditions the regression between survival and extreme temperatures was calculated and compared.

Results and Discussion

The survival curves of *B. africanus*, *B. pfeifferi* and *B. globosus* when subjected to the various high temperatures, are shown in Figure 1. From this it can be seen that the lifespans of the cohorts of all three species shortened as the temperature rose. About 2–3 h after exposure to 40°C began, all the specimens were in an apparent heat coma, with most of the snails protruded far out of their shells. After 6–8 h had elapsed, all the snails were dead. This survival time was so short that it can be accepted that the vital functions of the snails are terminated almost immediately on exposure to 40°C. It was therefore impossible to determine accurately at which moment the first snails died at this temperature. The cohorts exposed to 38°C did not survive significantly longer than those exposed to 40°C. In the case of *B. globosus*, however, there was a marked increase in the survival time at 36°C and 34°C. It was clear that the temperatures used in the experiment were almost always more unfavourable for *B. africanus* and *B. pfeifferi* than for *B. globosus*. At 34°C for example, the cohort of *B. globosus* survived almost four times longer than those of *B. africanus* and *B. pfeifferi* (Figure 1).

In order to depict the overall survival of the various snail species at sustained high temperatures, the length of time that all the snails in each cohort survived (100% survival) was plotted in Figure 2, while the length of time until the cohorts died out (0% survival) was plotted in Figure 3 for each temperature and snail species in the experiment. Regression lines were drawn through the co-ordinate points of 100% as well as 0% survival and the equations are given in Table 1. The fit obtained ($100R^2$) shows that these regressions describe the survival of the snails at high temperatures satisfactorily (the lowest being 74%). From these two figures it is clear that *B. africanus* and *B. pfeifferi* can be grouped together because their survival curves were virtually identical, while the curves of *B. globosus* differed markedly from them.

Bulinus africanus and *B. pfeifferi* evidently die off at temperatures where *B. globosus* can survive successfully and therefore it can be assumed that *B. globosus* is better able to deal with high temperature conditions. Although this observation implies that the distribution of the three species should differ throughout the country, Brown (1980) showed

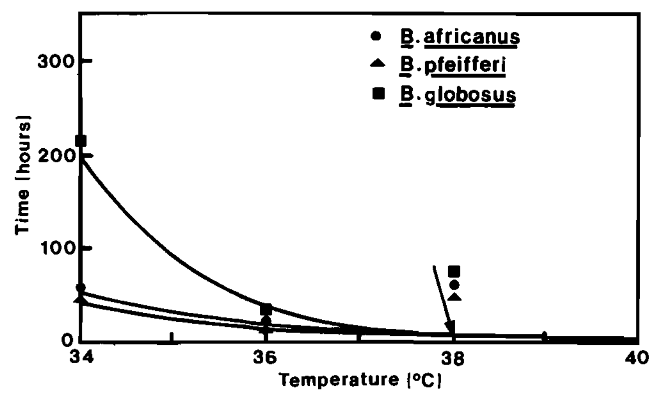

Figure 2 The relation between the time survived by all the snails (100% survival) and the temperatures to which they were continually subjected.

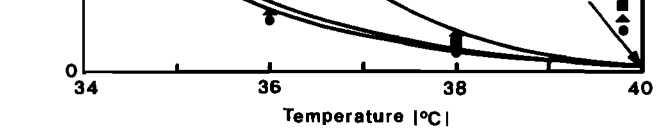

Figure 3 The relation between the time survived by none of the snails (0% survival) and the temperatures to which they were continually subjected.

Table 1 The regression between survival and extreme temperatures. Survival time = $Ke^{C \cdot \text{temperature}}$ and K, C = regression coefficients

	Low temperatures						High temperatures					
	100% survival			0% survival			100% survival			0% survival		
	K	C	$100R^2$	K	C	$100R^2$	e^K	C	$100R^2$	e^K	C	$100R^2$
B. africanus	21,615	0,167	91	51,387	0,181	97	18,474	−0,431	100	24,995	−0,578	99
B. pfeifferi	10,808	0,222	76	31,315	0,195	99	20,241	−0,486	75	24,579	−0,564	96
B. globosus	6,660	0,328	92	33,300	0,229	88	33,303	−0,824	99	34,928	−0,823	99

that all three do occur in the hotter parts of the country wherever suitable habitats exist. The exceptions are *B. pfeifferi* in the north-eastern tropical parts of Natal and KwaZulu where it has an erratic existence according to Appleton (1977), and *B. africanus* which is absent in this area (Brown 1966). These exceptions are most probably due to the restriction that high temperatures place on survival. On the other hand, *B. globosus* survives successfully in these parts. An additional explanation for the absence of *B. africanus* in these hot northern parts may be deduced from the population statistics of this snail species (De Kock 1973). His results show that the reproduction of *B. africanus* will be adversely affected at temperatures above 26°C, while *B. globosus* is only adversely affected at temperatures above 29°C, since the highest r_m value (inborn ability to reproduce) for *B. globosus* was determined at this temperature.

From the information in Figures 2 and 3 the survival of the three snail species at temperatures between 34°C and 40°C can be calculated on a theoretical basis. The results of the survival of the three snail species at high temperatures were analysed in the same way as the results on the survival at low temperatures reported by Joubert, Pretorius, De Kock & Van Eeden (1984), and the data are shown in Table 1. These calculations of survival at low and high temperatures now make it possible to assess the survival of snails at environmental temperature extremes. It is, however, not justified to give an explanation of the geographic distribution of the snail species on the basis on these calculations alone. Information on aspects such as the acclimatization of the snails, the sensitivity of snails of different ages to extreme temperatures, the effect of extreme temperatures on egg production and eggs as such, as well as the possible weakening of snails by parasites is of cardinal importance to shed light on the population dynamics of the snails. Nevertheless, this study can make a valuable contribution towards evaluating the chances of permanent occupation of the snail species investigated in areas where extremely high and low temperatures can occur.

Acknowledgements

The financial support of the South African Medical Research Council and the University of Potchefstroom for CHE, is gratefully acknowledged. We thank Mrs J.M. Barnes of the division of scientific publications of the SAMRC for reading and translating the manuscript.

References

APPLETON, C.C. 1977. The influence of temperature on the life-cycle and distribution of *Biomphalaria pfeifferi* (Krauss, 1848) in south-eastern Africa. *Int. J. Parasit.* 7: 335–345.

BROWN, D.S. 1966. On certain morphological features of *Bulinus africanus* and *B. globosus* (Mollusca: Pulmonata) and the distribution of these species in south eastern Africa. *Ann. Natal Mus.* 18,2: 401–415.

BROWN, D.S. 1980. Freshwater snails of Africa and their medical importance. Taylor & Francis Ltd, London, 487pp.

CHITRAMVONG, Y.P., UPATHAM, E.S. & SUKHAPANTH, N. 1981. Effects of some physico-chemical factors on the survival of *Bithynia siamensis siamensis*, *Radix rubiginosa* and *Indoplanorbis exustus*. *Malacological Review*. 14: 43–48.

DE KOCK, K.N. 1973. Die bevolkingsdinamika van vyf medies en veeartsenykundig belangrike varswaterslakspesies onder toestande van beheerde temperatuur. D.Sc. thesis, Potch. Univ. for CHE. Rep. of S.A. 388pp.

DE KOCK, K.N. & VAN EEDEN, J.A. 1980. Life-table studies on freshwater snails: Culture system and method. Wetenskaplike bydraes van die PU vir CHO Reeks B: Natuurwetenskappe, nr. 105: 1–9.

DE KOCK, K.N. & VAN EEDEN, J.A. 1981. Life-table studies on freshwater snails. The effect of constant temperature on the population dynamics of *Biomphalaria pfeifferi* (Krauss). Wetenskaplike bydraes van die PU vir CHO Reeks B: Natuurwetenskappe, nr. 107: 1–17.

EL-EMAM, M.A. & MADSEN, H. 1982. The effect of temperature, darkness, starvation and various food types on growth, survival and reproduction of *Helisoma duryi*, *Biomphalaria alexandrina* and *Bulinus truncatus* (Gastropoda: Planorbidae). *Hydrobiologia*. 88: 265–275.

JENNINGS, A.C. 1976. Studies on the influence of total dissolved solids on the biology of certain freshwater molluscs. D.Sc. thesis, Potch. Univ. for CHE. Rep. of S.A. 282pp.

JOUBERT, P.H. 1984. Die oorlewing van ses ekonomies belangrike varswaterslakspesies by uiterste temperature. D.Sc. thesis. Potch. Univ. for CHE. Rep. of S.A. 192pp.

JOUBERT, P.H., PRETORIUS, S.J., DE KOCK, K.N. & VAN EEDEN, J.A. 1984. The effect of constant low temperatures on the survival of *Bulinus africanus* (Krauss), *Bulinus globosus* (Morelet) and *Biomphalaria pfeifferi* (Krauss), *S. Afr. J. Zool.* 19,4: 314–316.

O'KEEFFE, J.H. 1985. Population biology of the freshwater snail *Bulinus globosus* on the Kenya coast. I. Population fluctuations in relation to climate. *J. appl. Ecol.* 22: 73–84.

PITCHFORD, R.J. & VISSER, P.S. 1969. The use of behaviour patterns of larval schistosomes in assessing the bilharzia potential of non-endemic areas. *S. Afr. Med. J.* 43: 983–995.

SHIFF, C.J. 1962. Aspects of the ecology of the intermediate host snail of bilharziasis, *Bulinus (Physopsis) globosus*. *Bull. Wld Hlth Org.* 27: 45–48.

SHIFF, C.J. 1964. Studies on *Bulinus (Physopsis) globosus* in Rhodesia. I. The influence of temperature on the intrinsic rate of natural increase. *Ann. trop. Med. Parasit.* 58,1: 94–105.

SHIFF, C.J. 1966. The influence of temperature on the vertical movement of *Bulinus (Physopsis) globosus* in the laboratory and in the field. *S. Afr. J. Sci.* 62,7: 210–214.

STUCKENBERG, B.R. 1969. Effective temperature as an ecological factor in southern Africa. *Zool. Afr.* 4, 2: 145–197.

VAN AARDT, W.J. & FREY, B.J. 1980. Oxygen-binding characteristics of the haemolymph of the freshwater snail *Bulinus (Physopsis) globosus*. *S. Afr. J. Zool.* 16: 1–4.