

Depth effects on the abundance, survivorship rate and size of *Melanooides tuberculatus* (Prosobranchia: Thiaridae) in Dom Helvécio Lake, Minas Gerais, Brazil

Efeito da profundidade sobre a abundância, sobrevivência e tamanho de *Melanooides tuberculatus* (Prosobranchia: Thiaridae) no Lago Dom Helvécio, Minas Gerais, Brasil

Vasconcelos, MC.¹, Espírito-Santo, MM.² and Barbosa, FAR.³

¹Programa de Pós-graduação em Ecologia, Departamento de Ecologia, Instituto de Biociências, Universidade Federal do Rio Grande do Sul – UFRGS, Av. Paulo Gama, 110, CEP 90040-060, Porto Alegre, RS, Brazil
e-mail: castro_bio@yahoo.com.br

²Departamento de Biologia Geral, Centro de Ciências Biológicas e da Saúde – CCBS, Universidade Estadual de Montes Claros – UNIMONTES, CP 126, CEP 39401-089, Montes Claros, MG, Brazil
e-mail: marioesanto@yahoo.com.br

³Departamento de Biologia Geral, Instituto de Ciências Biológicas – ICB, Universidade Federal de Minas Gerais – UFMG, Av. Antônio Carlos, 6627, Pampulha, CEP 31270-901, Belo Horizonte, MG, Brazil
e-mail: barbosa@icb.ufmg.br

Abstract: Aim: The effects of lake depth on the abundance, survivorship and size of the freshwater snail *Melanooides tuberculatus* in the Dom Helvécio Lake, at Rio Doce State Park, Minas Gerais were determined; **Methods:** In order to sample the snails, the sediment was collected every meter from the margin until 1 meter in depth along three transects. At each transect, the number of *M. tuberculatus* was counted for each sample and their survivorship determined. A linear regression analysis was used to determine the depth effects on abundance and volume. A Chi-squared goodness-of-fit test was used to verify the depth effects on snail survivorship; **Results:** Snail abundance did not show a clear pattern with depth, probably due to an aggregate pattern of spatial distribution of this species in the lake. The survivorship rate of *M. tuberculatus* was generally low (33.9%), but higher at intermediate depths (0.25-0.75 m), considering the depth range evaluated in this study. The snail volume was higher at the shallow parts of the lake (to 0.5 m); **Conclusions:** These results suggest that the narrow depth variation assessed here is sufficient to affect the performance of *M. tuberculatus*. This snail is probably indirectly influenced by light availability, since it reduces the amount of organic matter to the snails at deeper parts of the lake.

Keywords: benthos, *Melanooides tuberculatus*, freshwater snail, tropical lakes.

Resumo: Objetivo: O objetivo deste estudo foi avaliar o efeito da profundidade na abundância, sobrevivência e tamanho de *Melanooides tuberculatus* no lago Dom Helvécio, Parque Estadual do Rio Doce, Minas Gerais; **Métodos:** Para a amostragem dos moluscos, três transectos foram demarcados. Em cada transecto, o sedimento foi coletado a cada metro de distância a partir da margem até atingir 1 m de profundidade. O número de moluscos foi contado em cada amostra e sua sobrevivência determinada. Por meio de regressão linear simples, avaliou-se o efeito da profundidade sobre a abundância e volume de *M. tuberculatus*. A sobrevivência foi avaliada através de qui-quadrado; **Resultados:** A abundância não mostrou um padrão claro com a profundidade, provavelmente devido a um padrão de distribuição agregado para esta espécie no lago. A sobrevivência de *M. tuberculatus* foi geralmente baixa (33,9%), mas alta nas profundidades intermediárias (0,25-0,75 m), considerando a profundidade avaliada neste estudo. O volume do caramujo foi maior nas partes rasas do lago (até 0,5 m); **Conclusões:** Estes resultados sugerem que a variação estreita da profundidade avaliada aqui é suficiente para afetar o desempenho do *M. tuberculatus*. Este provavelmente é influenciado indiretamente pela disponibilidade de luz, uma vez que esta determina uma diminuição da quantidade de matéria orgânica disponível para estes indivíduos nas partes mais profundas do lago.

Palavras-chave: bentos, *Melanooides tuberculatus*, caramujos de água doce, lagos tropicais.

1. Introduction

Freshwater snails are benthic animals encountered in several environments such as streams, lakes and wetlands. They live within the euphotic zone and are usually found on the margin of lakes (Russel-Hunter, 1978). A multitude of factors influences the distribution of these organisms among which salinity, substrate type (e.g., aquatic plants in lakes and cobbles in streams) (Tian and Resh, 1997; De Marco, 1999; Wen et al., 2002), water speed, salt content in water, evolutionary state of the lake and depth (Duggan, 2002; Silva and Barros, 2001; Muli and Muvuti, 2001) deserve attention. Among these factors, depth is especially important for the distribution and abundance of pulmonate freshwater snails. Depth affects water temperature, oxygen concentration and the light availability, which determine photosynthetic rates and, consequently, food availability (Russel-Hunter, 1978; Tian and Resh, 1997; Muli and Muvuti, 2002).

Melanoides tuberculatus Müller (1774); (Prosobranchia: Thiaridae) is a freshwater snail native from Asia but with a wide distribution in tropical and subtropical regions (Pointer, 1999). *M. tuberculatus* is an exotic species in many parts of the world, commonly found throughout the American continent (Murray, 1984; De Marco, 1999), and possesses parthenogenetic breeding and detractive feeding strategies (Pointer and McCulloch, 1989). The first record of *M. tuberculatus* in Brazil was in the city of Santos, State of São Paulo, in 1967 (Vaz et al., 1986). Since 1986, this snail has been found in almost all states from southeast to central-west regions (Carvalho, 1986; França et al., 2007; Suriani et al., 2007). The first record of this snail in the Rio Doce State Park was in 1999, in Dom Helvécio Lake, when De Marco (1999) found an established population, breeding in places with high human perturbations. This snail has been also studied for biological control purposes due to its potential competitive exclusion of *Biomphalaria glabrata* Say (1818), (Planorbidae), the major vector of schistosomiasis in tropical regions (Thomas and Tait, 1984; Pointer et al., 1994; Guimarães et al., 2001; Giovanelli et al., 2002, 2005).

In this study, we examined the effects of lake depth on the abundance, survivorship and size of *Melanoides tuberculatus* in an area of Dom Helvécio Lake under intense human impact.

2. Material and Methods

The study was conducted in Rio Doce State Park (RDSP) (19° 29' 24"-19°48'18" S and 42° 28' 18"-42° 38' 30" W). The RDSP constitutes the largest remnant of the Atlantic Rain Forest in the State of Minas Gerais, with 36,000 ha and more than 42 lakes in different states of evolution (IEF, 1994). The RDSP exhibits altitudes between 230 and 515 m above the sea level and an Aw climate type in

Koppen's classification, with an average annual precipitation of 1,300 mm and an average temperature of 23 °C. The main vegetation type is seasonally semi-deciduous forest (Gilhuis, 1986). The Dom Helvécio Lake is the largest lake within the park, with 687 ha and 32.5 m depth, presenting oligotrophic conditions (Tundisi and Saijo, 1997; Petrucio and Barbosa, 2004). The most important physical and chemical variables are shown in Table 1.

Samplings were conducted in December/02, at a peninsula of approximately 80 m long in Lake Dom Helvécio, an area under considerable anthropogenic pressure. In some parts of the peninsula, the habitat was extremely altered by artificial sand deposition and macrophytes exclusion. Three transects were delimited during the study, in different positions of the peninsula. The slopes of each transects were different, due to depth variations at each part of the lake.

At each transect, sediment samples were collected each meter from the margin, until 1 m depth. Each sediment sample was taken at approximately 5 cm depth from the lake bed, using a hand net of 0.25 × 0.25 cm². This material was stored in plastic bags and, in the laboratory, all individuals of *M. tuberculatus* were counted. For each sampling site, lake depth was recorded. Regression analyses were used to verify the effects of depth on the snail's abundance and average volume per sampling point. The abundance data was log-transformed to meet the requirements of normality and homocedasticity. Shell volume was estimated as a cone ($\frac{1}{3}\pi r^2 h$, where r is half the shell width and h is shell length), which is approximately the shape of *M. tuberculatus* shells. These measures were taken for each individual with a caliper (0.1 mm). Snails volume was log+1 transformed, since the data were not homocedastic. To determine the effect of depth on the survivorship of *M. tuberculatus*, the

Table 1. Physical and chemical characteristics of Dom Helvécio Lake in December/02.

Depth	Meters	0.0	0.25	0.5	0.75	1.0
pH	-	6.38	6.68	6.92	6.96	7.09
Conductivity	µS.cm ⁻¹	34.00	35.00	35.00	35.00	35.00
Disolved oxygen	mg.L ⁻¹	8.00	8.00	8.10	8.10	8.10
Temperture	°C	30.10	30.10	29.90	29.00	29.70
TDS	mg.L ⁻¹	20.00	20.00	20.00	20.00	20.00
Redox potential	mV	61.00	47.00	43.00	42.00	41.00
Alcalinity	meq.L ⁻¹	0.027	-	-	-	-
Chlorophyll-a	µg.L ⁻¹	11.76	-	-	-	-
P-tot	µg.L ⁻¹	7.50	-	-	-	-
PO ₄ ³⁻	µg.L ⁻¹	2.90	-	-	-	-
N-tot	µg.L ⁻¹	368.20	-	-	-	-
NH ₄ ⁺	µg.L ⁻¹	18.20	-	-	-	-
NO ₃ ⁻	µg.L ⁻¹	1.00*	-	-	-	-
NO ₂ ⁻	µg.L ⁻¹	2.50*	-	-	-	-
Silicate	mg.L ⁻¹	2.40	-	-	-	-

samples collected at the depths of 0, 0.25, 0.5, 0.75, 1 m at each transect were analyzed. To verify the survivorship of *M. tuberculatus*, each individual in these samples was analyzed under an inverted magnifying glass and considered alive if the snail was found inside the shell. For empty shells, the snail was considered dead. Survivorship rates were compared between the five depths through a Chi-squared goodness-of-fit test. The expected values were calculated using the proportion of live snails among all individuals analyzed, regardless of depth.

3. Results

A total of 2,511 individuals of *M. tuberculatus* were collected along the three transects in the peninsula of the Dom Helvécio Lake. Due to differences in declivity, the number of samples differed between transects ($n = 19, 23$ and 9 for transects 1, 2 and 3, respectively). The abundance of snails was not affected by lake depth ($F_{(1,48)} 1.71, p = 0.19, R^2 = 0.01, n = 50$). The average volume of *M. tuberculatus* was $1.2 \pm 0.01 \text{ cm}^3$ ($n = 332$) in the studied population. The snail size was affected by lake depth, decreasing significantly after 0.5 m in depth ($F_{(1,48)} 53.07, p < 0.001, R^2 = 0.51, n = 50$) (Figure 1).

We analyzed 332 specimens for survivorship and, as a whole, only one-third of the snails were alive (33.9%). The snail survivorship was size-independent; varying from 30% to 40% for almost all volume classes (Table 2). In contrast to the observed for snail abundance, the survivorship rates were clearly influenced by lake depth. The survivorship was higher in intermediate depths, considering the range comprised in this study (Figure 2). At 0.25 and 0.50 m, the survivorship rates were higher than the expected, though only significant at 0.5 m ($\chi^2 = 6.43, DF = 1, p < 0.01$). The survivorship was lower than the expected at 0 and 0.75 m, though this difference was significant only at 0 m ($\chi^2 = 6.57,$

$DF = 1, p < 0.01$). No significant differences were found between observed and expected values at 1.0 m depth.

4. Discussion

The abundance of *M. tuberculatus* in the Dom Helvécio Lake was not affected by lake depth. It is possible that our depth range was not broad enough to detect such effects. Freshwater snails are benthic organisms of the eutrophic zone rarely occurring below 4 m depth (Hussel-Hunter, 1978), as demonstrated by SUDECAP (1990) in the eutrophic Pampulha Reservoir in Belo Horizonte, State of Minas Gerais, where *M. tuberculatus* occurred in great abundance until 2 m. However, França et al. (2007) and Suriani et al. (2007) studying six reservoirs in the Tietê River, in São Paulo State recorded high snail abundances down to 22 m. Moreover, these authors suggested *M. tuberculatus* was not influenced by any physical and chemical parameters

Table 2. Abundance and survivorship rate of *Melanoides tuberculatus* at different class volumes in Dom Helvécio Lake, Minas Gerais.

Volume classes (cm^3)	Abundance	Survivorship (%)
0-0.025	32	31.3
0.025-0.05	32	9.4
0.05-0.075	42	38.1
0.075-0.1	39	35.9
0.1-0.125	54	38.9
0.125-0.15	33	36.4
0.15-0.175	26	30.8
0.175-0.2	24	45.8
0.2-0.225	10	30.0
0.225-0.25	6	50.0
0.25-0.275	7	28.6
0.275-0.3	6	33.3
>0.3	10	40.0

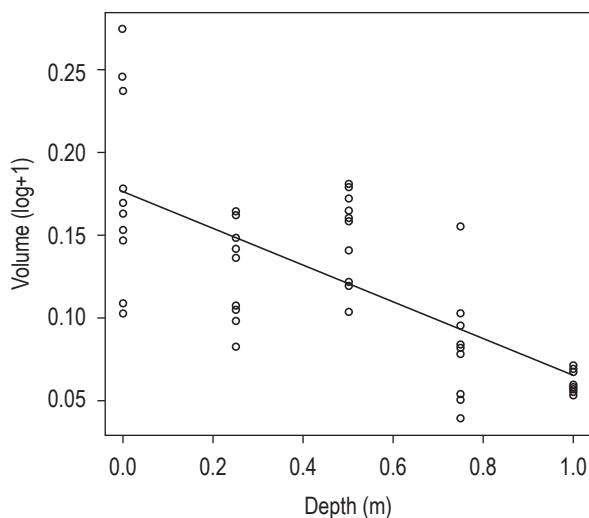


Figure 1. Relationship between the average volume ($\text{Log} + 1$) of *Melanoides tuberculatus* and depth at Dom Helvécio Lake.

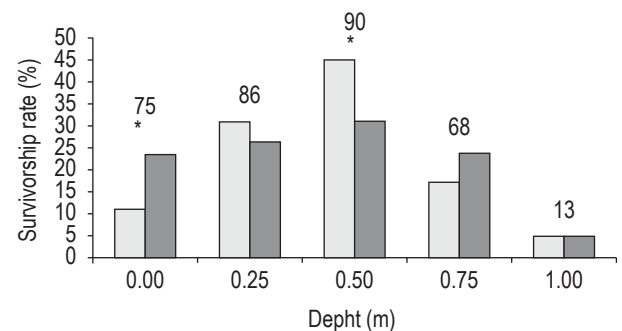


Figure 2. Survivorship rate of *M. tuberculatus* along 5 depth classes in Dom Helvécio Lake, Minas Gerais. Empty bars represent the observed survivorship rate and filled bars represent the expected survivorship rate for the population at each depth class. Asterisks indicate statistical differences (Chi-squared goodness-of-fit test, $p < 0.05$). Numbers above bars represent the number of snails analyzed at each depth class.

and that they did not find a clear abundance pattern with depth across the reservoirs. In the present study, the lack of a clear pattern of variation in abundance with depth is probably a consequence of an aggregated distribution pattern of *M. tuberculatus* in Lake Dom Helvécio, as also recorded in Pampulha Reservoir where higher abundance was higher recorded in fine sediment (Bedê, 1992). Furthermore, Dudgeon (1982, 1983) observed that, in the Plover Cove Reservoir, individuals of this species aggregated at sites with marginal vegetation recently inundated, rich in organic matter. The areas sampled in Lake Dom Helvécio had no vegetation cover, thus *M. tuberculatus* may aggregate at micro-sites of fine sediment with higher organic matter availability.

Despite the absence of depth effects on *M. tuberculatus* abundance, our results suggest that the performance of this snail is affected by lake depth. In the deeper parts of the transects (0.75-1 m), the prevailing lower light availability may reduce algae biomass, decreasing the amount of food to the snails and negatively affecting their survivorship and volume. In the shallow parts of the lake (0-0.25 m), the snails may be very exposed to both intense light and predation by birds. Thus, within the depth range considered in this study, it seems that the optimal environmental conditions for *M. tuberculatus* are between 0.25-0.75 m depth.

The high mortality rate observed for *M. tuberculatus* in Dom Helvécio Lake may be a consequence of anthropogenic use of the peninsula mainly by swimmers, what is reinforced by the size-independent survivorship observed for this population. The disruption of the snails shells by swimmers may cause random mortality in relation to snail size, contrasting with predation by fishes and birds, which are usually size-selective (i.e., larger individuals) (Bedê, 1992).

These results may be helpful to biological control strategies of *M. tuberculatus* since this species is exotic to the Dom Helvécio Lake and can cause direct and indirect effects on populations of native snails and macrophytes, among other organisms. Moreover, in this lake the snail distribution seems to be restricted to the studied peninsula where human activities may increase their mortality and limit population growth and spreading. However, comparative studies including people-free areas of the lake as control are necessary to confirm this hypothesis. Further studies should be made in order to understand the invasive behavior of this species, its impact on native communities and its potential to occupy other lakes in the area, as well as its possible use as controlling agent of Planorbidae mollusks, which are important schistosomiasis vectors in tropical regions.

Acknowledgements

We thank the Graduate Program in Ecologia, Conservação e Manejo da Vida Silvestre of the Universidade Federal de Minas Gerais for logistical support and the

Instituto Estadual de Florestas (IEF) for allowing us to work within the Rio Doce State Park. We are grateful to Aline Duarte, Emilia Recla and Aline Marcia for their help during fieldwork.

References

- BEDÊ, LC. *Dinâmica populacional de Melanoides tuberculata (Prosobranchia: Thiaridae) no reservatório da Pampulha, Belo Horizonte, MG, Brasil*. Minas Gerais: Universidade Federal de Minas Gerais, 1992. [Dissertação de Mestrado].
- CARVALHO, OS. Ocorrência de tiarídeo (Mollusca) no lago da Pampulha, Belo Horizonte, MG, Brasil. *Rev. Bras. Med. Trop.*, 1986, vol. 19, no. 1, p. 57.
- DUDGEON, D. The effects of water level fluctuation on a gastropod community in a rocky marginal zone of Plover Cove reservoir, Hong Kong. *The Veliger.*, 1982, vol. 24, no. 3, p. 267-271.
- DUDGEON, D. The effects of water level fluctuation on a gently shelving marginal zone of Plover Cove reservoir, Hong Kong. *Arch. Fur Hydrob.*, 1983, vol. 65, p. 163-196.
- DUGGAN, IC. First record of a wild population of the tropical snail *Melanoides tuberculata* in New Zealand natural waters. *N. Z. J. Mar. Fresh. Res.*, 2002, vol. 36, p. 825-829.
- FRANÇA, RS., SURIANI, AL. and ROCHA, O. Composição das espécies de moluscos bentônicos nos reservatórios do baixo Rio Tietê (São Paulo, Brasil) com uma avaliação do impacto causado pelas espécies exóticas invasoras. *Rev. Bras. Zoo.*, 2007, vol. 24, p. 41-51.
- GIOVANELLI, A., VIEIRA, M. and SILVA, CLPAC. Interaction between the intermediate host of Schistosomiasis in Brazil *Biomphalaria glabrata* (Planorbidae) and a possible competitor *Melanoides tuberculata* (Thiaridae): I Laboratory experiments. *Mem. Inst. Osw. Cruz.*, 2002, vol. 97, no. 3, p. 363-369.
- GIOVANELLI, A., SILVA, CLPAC., LEAL, GBE. and BAPTISTA, DF. Habitat preference of freshwater snails in relation to environmental factors and the presence of the competitor snail *Melanoides tuberculatus* (Müller, 1774). *Mem. Inst. Osw. Cruz.*, 2005, vol. 100, no. 2, p. 169-176.
- GILHUIS, JP. *Vegetation survey of the Parque Florestal Estadual do Rio Doce, MG, Brasil*. Wageningen: Agricultural University Wageningen, 1986. [Dissertação de Mestrado].
- GUIMARAES, CT., SOUZA, CP. and SOARES, DM. Possible competitive displacement of planorbids by *Melanoides tuberculata* in Minas Gerais, Brazil. *Mem. Inst. Osw. Cruz.*, 2001, vol. 96, p. 173-176.
- Instituto Estadual de Florestas - IEF. *Pesquisas prioritárias para o Parque Estadual do Rio Doce, Brasil*. Belo Horizonte: IEF, 1994. 35 p.
- MARCO, P. Jr. Invasion by the introduction aquatic snail *Melanoides tuberculata* (Müller, 1774) (Gastropoda: Prosobranchia: Thiaridae) of the Rio Doce State Park, Minas Gerais, Brazil. *Stud. Neotr. Faun. Environ.*, 1999, vol. 34, p. 186-189.

- MULI, JR. and MAVUTI, KM. The benthic macrofauna community of Kenyan waters of Lake Victoria. *Hydrobiologia*, 2001, vol. 458, no. 1, p. 83-90.
- MURRAY, HD. *Tarebia granifera* and *Melanooides tuberculata* in Texas. *Am. Malacol. Union Inc.*, 1984, vol. 15, p. 16.
- PETRUCIO, MM. and BARBOSA, FAR. Diel variations of phytoplankton and bacterioplankton production rates in four tropical lakes in the middle Rio Doce basin (southeastern: Brazil). *Hydrobiologia*, 2004, vol. 513, no. 1, p. 71-76.
- POINTER, JP. Invading freshwater gastropods: some conflicts aspects for public health. *Malacologia*, 1999, vol. 41, p. 403-411.
- POINTER, JP., INCANI, RN., BALZAN, C., CHROSCIECHOWSKI, P. and PRYPCHAN, S. Invasion of the rivers of the littoral central region of Venezuela, by *Thiara granifera* and *Melanooides tuberculata* (Mollusca: Prosobranchia: Thiaridea) and the absence of *Biomphalaria glabrata*, snail host of *Schistosoma mansoni*. *The Nautilus*, 1994, vol. 107, no. 4, p. 124-128.
- RUSSEL-HUNTER, WD. Ecology of freshwater pulmonates. In FRETTER, V. and PEAKE, J. (Eds.). *Pulmonates: systematics, evolution and ecology*. London: Academic Press, 1978. p. 335-383.
- SILVA, MJM. and BARROS, M. Occurrence and distribution of freshwater molluscs in the Riacho Fundo Creek Basin, Brasilia, Brazil. *Rev. Bio. Trop.*, 2001, vol. 49, no. 3, p. 865-870.
- Superintendência de Desenvolvimento da Capital - SUDECAP. *Estudos ecológicos na represa da Pampulha*. Belo Horizonte: SUDECAP, 1990. 130 p. (Relatório Final do Convênio SUDECAP-Ecologia).
- SURIANI, AL., FRANÇA, RS. and ROCHA, O. A malacofauna bentônica das represas do médio rio Tietê (São Paulo, Brasil) e uma avaliação ecológica das espécies exóticas invasoras, *Melanooides tuberculata* (Müller) e *Corbicula fluminea* (Müller). *Rev. Bras. Zoo.*, 2007, vol. 24, p. 21-32.
- THOMAS, JD. and TAIT, AI. Control of the snail hosts of *Schistosomiasis* by environmental manipulation: a field and laboratory appraisal in the Ibadan area, Nigeria. *Phil. Transc. Royal. Soc. London*, 1984, vol. 305, no. 1123, p. 201-253.
- TIAN, LHT. and RESH, VH. Abundance and microdistribution of freshwater gastropods in three streams of Moorea, French Polynesia. *Ann. Limnol.*, 1997, vol. 33, no. 4, p. 235-244.
- TUNDISI, JG. and SAIJO, Y. *Limnological studies on the on the Rio Doce valley lakes, Brazil*. Rio de Janeiro: Brazilian Academy of Sciences, 1997. 513 p.
- VAZ, JF., TELES, HS., CORRÊA, MA. and LEITE, SPS. Ocorrência no Brasil de *Thiara (Melanooides) tuberculada* (O. F. Muller, 1774) (Gastropoda: Prosobranchia), primeiro hospedeiro intermediário de *Clonorchis sinensis* (Cobbold, 1875 (Trematoda: Platyhelminthes)). *Rev. Saude Publ. São Paulo*, 1986, vol. 20, no. 4, p. 318-322.
- WEN, KJ., TREMBLAY, R. and BOURGET, E. Ontogenetic changes in hyposaline tolerance in the mussels *Mytilus edulis* and *M. trossulus*: implications for distribution. *Mar. Ecol. Prog. Ser.*, 2002, vol. 228, p. 143-152.

Received: 13 July 2009

Accepted: 17 November 2009

