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Size-mass relationships of *Melanoides tuberculatus* (Thiaridae: Gastropoda) in a eutrophic reservoir

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ABSTRACT. This study evaluated the relationships of certain allometric measurements in *Melanoides tuberculatus* Muller, 1774, in order to develop a statistical model to estimate the biomass of this mollusc species. We measured the total length and aperture of 70 shells. These measurements were correlated with the biomass values to construct exponential and power-function models, and both models showed high coefficients of determination. The exponential model was the better biomass predictor, with a coefficient of determination over 93%. These proposed models may be an effective tool to determine the biomass of *M. tuberculatus* in eutrophic Brazilian reservoirs.

KEY WORDS. Allometry; dry mass; eutrophication; molluscs.

Reservoirs are artificial ecosystems that functions mainly to generate electricity and supply water for domestic and industrial processes. From the ecological point of view, reservoirs produce considerable alterations in aquatic ecosystems due to changes in the time of water residency, habitat fragmentation and exotic species invasion (Tundisi 2008, Agostinho *et al.* 2005). Eutrophication is also a serious threat, since the excessive growth of algae resulting from enrichment of the water, mainly with phosphorus and nitrogen, can modify the biodiversity and the distribution of organisms in these environments (Figueirêdo *et al.* 2007).

In tropical countries, both native mollusc species and exotic invasive species such as *Melanoides tuberculatus* Muller, 1774 occur in reservoirs. The Afro-Asian *M. tuberculatus* was originally reported in Brazil in 1967 in Santos (São Paulo), and spread to Brasília (Distrito Federal) and the states of Rio de Janeiro, Goiás, Paraíba and Espírito Santo (Fernandez *et al.* 2003, Vaz *et al.* 1986). *Melanoides tuberculatus* was first reported in the state of Minas Gerais in 1986, from Pampulha Reservoir in the city of Belo Horizonte (Carvalho 1986, Freitas *et al.* 1987). In a study begun in September of that same year at Soledade Lake in the Ouro Branco region, but not published until 1994, some individuals were also found (Silva *et al.* 1994). In 1996, the species was reported from Dom Helvécio Lake in the Rio Doce State Park (De Marco Jr 1999).

This invasive mollusc threatens the biodiversity of ecosystems where it is found, and it also represents a risk for human health since it hosts the trematodes *Paragonimus westermani* Kerbert, 1878 and *Clornorchis sinensis* Looss, 1907 species endemic to Asia that are able to parasitize humans (Souza & Lima 1990). The species is an r strategist, with parthenogenetic reproduction and the potential to maintain high population densities for long periods of time. It is easily transported and highly adaptable, establishing on all kinds of substrates (Pointier *et al.* 1993).

Because of all these reasons, *M. Tuberculatus* is found in many aquatic ecosystems with different levels of pollution and ranging from oligotrophic to hypereutrophic (Rocha-Miranda & Martins-Silva 2006, Callisto *et al.* 2005). Since *M. Tuberculatus* is a potential competitor of native planorbid species that host human parasites, it has been introduced into the American continent for purposes of biological control (Guimarães *et al.* 2001).

In studies on benthic aquatic insects, biomass estimates provide information to estimate growth, production, and feeding ecology (Benke *et al.* 1999, Johnston & Cunjak 1999). Similarly, information on biomass can be used to support inferences about the adaptation of *M. tuberculatus* in eutrophic environments and its effect on other species of molluscs (Pointier & Augustin 1999).

However, biomass estimation takes time and is prone to errors, especially when the organisms are preserved. Preservatives can produce significant losses of biomass and most are toxic (Wetzel *et al.* 2005). Because of these and other problems, that many studies on insects have used the size of body structures as biomass predictors (Genkai-Kato & Miyasaka 2007, González *et al.* 2002, Cressa 1999). However, the relationships between size and weight must be used cautiously since they may not account for environmental and geographical variations and are not exact for every taxon, i.e., there is a different relationship for each species (Johnston & Cunjak 1999).

Since *M. tuberculatus* was recorded in Brazilian waters, few studies have assessed the spread of this invasive mollusc in this country. The status of the species is still poorly known, as is its distribution and ecology (FERNADEZ *et al.* 2003). The size structure of a population of *M. tuberculatus* in a eutrophic reservoir might be an important tool to aid in the management of this alien species in southeastern Brazil.

The objective of the present study was to establish, through allometric relationships, a statistical model to estimate the biomass of *M. tuberculatus* populations.

MATERIAL AND METHODS

The Ibirité Reservoir (19°07'00"-20º02'30"S, 44°07'30-44º07'30"W) is fed mainly by the Ibirité River. The dam was construted in 1967 in order to supply water for the Gabriel Passos refinery (REGAP), one of the Petrobras refineries constructed along highway BR-381. The reservoir has a surface area of 2.8 km^2, a volume of 15.423.000 m^3 and a mean depth of 16 m (GARCIA *et al.* 2009).

The reservoir has undergone rapid artificial eutrophication because of human impacts in its drainage basin. This eutrophic state is characterized by high primary production, algal bloom episodes, and the presence of aquatic macrophytes (MORENO & CALLISTO 2006). During the study period the mean depth at the sampling stations was 2.6 m (± 1.65). Mean dissolved oxygen concentrations were about 7.3 mg/l (± 0.68), with a mean temperature of 27.83 °C (± 0.52), a slightly basic pH (7.4 ± 0.32) and high electrical conductivity (237.6 $\mu S\ cm^{-1}$ ± 23.16).

The molluscs were collected from the sediments during April 2009, by means of an Ekman-Birge sampler with a sampling area of 0.0225 m^2 (FREITAS *et al.* 1987). In all, 15 sampling points were selected along the shore of the reservoir, and three replicates were taken at each point (Fig. 1). The collected material was placed in plastic bags and transported, with no the added of preservatives, to the Laboratório de Ecologia de Bentos, Universidade Federal de Minas Gerais. At the laboratory, the samples were washed on sieves (0.5 mm mesh size) to separate the molluscs, on the same day of their collection.

The measurements of the total length of the shell (from the vertex to the farthest point on the opposite end) and the shell aperture were taken using a Vernier caliper with a precision of 0.05 mm. Each snail was weighed to obtain the total wet weight. The specimens were dried in the oven at 60°C until they reached a constant weight, approximately 48 hours, and then incinerated in a furnace at 500°C for four hours in order to estimate the weight of the mineral fraction. The biomass was obtained from the difference between the total dry weight and the weight of the mineral fraction. The results were expressed in milligrams and correlated with the length and shell aperture measurements in millimeters, in order to establish the relationship between weight and length (ELKARMI & ISMAIL 2007).

Dispersion diagrams were constructed, correlating the biomass (B) with the measurements of total length (TL) and shell aperture (SA). The method of least squares was used to produce the regression models. The validity of the equations was based on the regression significance (p), the coefficient of determination (R^2) and on the analysis of the residues (VIEIRA 2003).

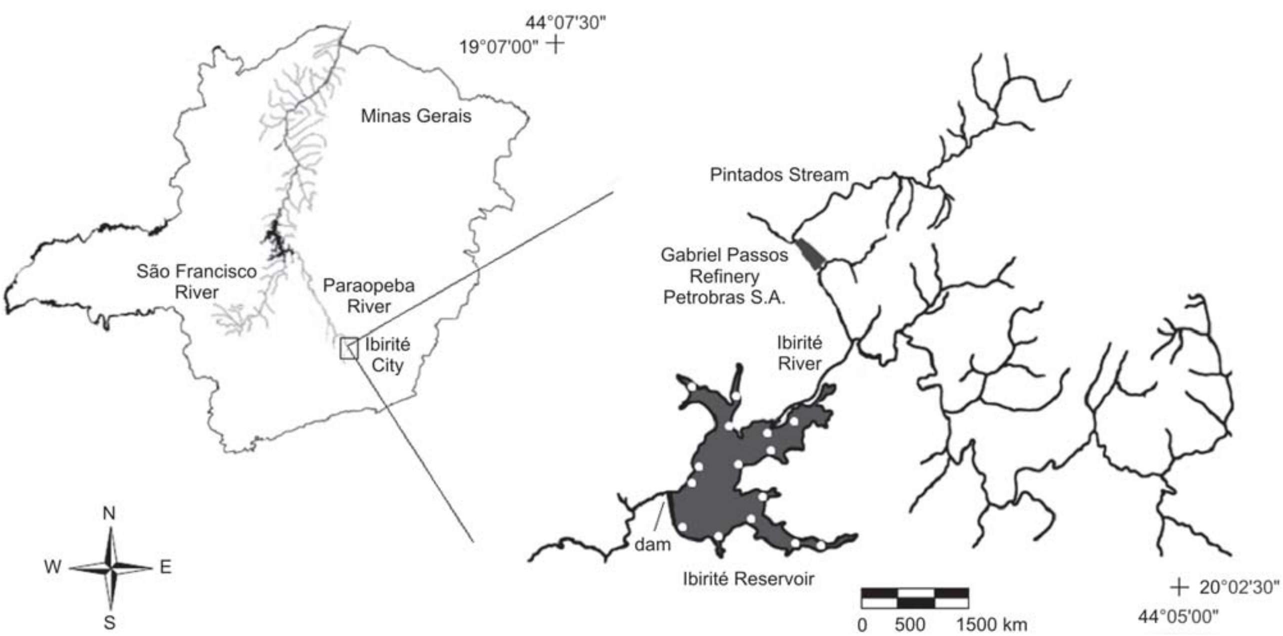


Figure 1. Distribution of sampling points in the Ibirité Reservoir, in the basin of the Paraopeba River, Minas Gerais. Modified from GARCIA *et al.* 2009.

RESULTS

The relationships between the measurements and the biomass of 70 individuals were used. The shell lengths ranged from 3.2 to 18.95 mm, with a mean of 10 mm (± 4.62). The shell apertures ranged from 0.75 to 5.9 mm, with a mean of 2.8 mm (± 1.47). The biomass ranged from 0.4 to 22 mg, with a mean of 5.76 mg (± 5.91).

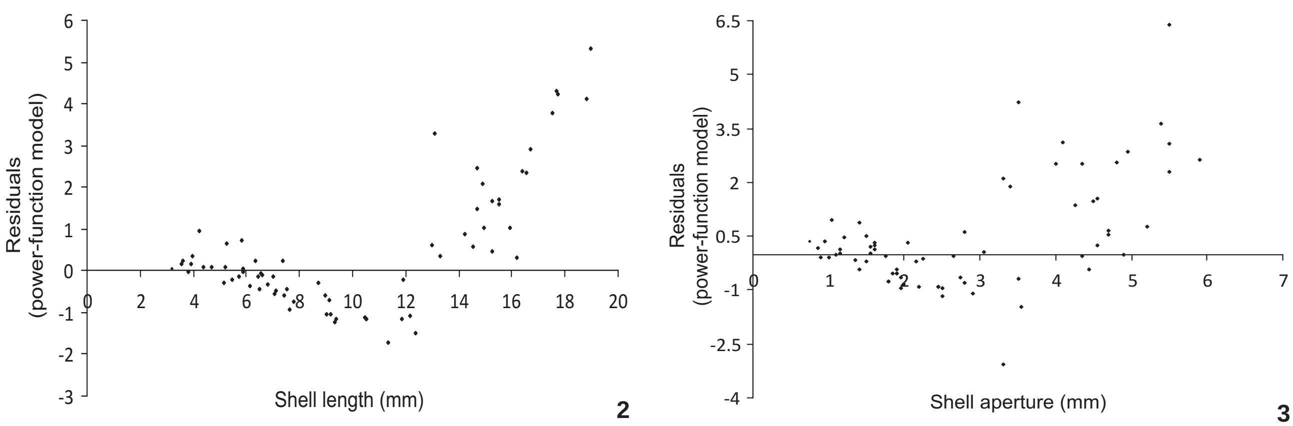
The exponential and power-function models presented significant correlations ($p < 0.001$). The coefficients of determination of the regressions (R^2) varied from 0.9206 to 0.9685 (Tab. I). The results indicated that the shell length produced the highest coefficient of determination in the regression analyses of the exponential and power- function models (R^2), 0.9685 and 0.9414, respectively.

DISCUSSION

The models showed high coefficients of determination, explaining from 92 to 96% of the biomass variation as a function of the measurements used. The coefficients of determination of the exponential model were slightly higher than the coefficients of the power-function model, showing that the exponential model better explained the data variation. The power-function model showed an irregular dispersal pattern of residuals for the measurements of both shell length and aperture (Figs 2 and 3) (VIEIRA 2003).

In practice, the interpretation of the exponencial model shows that *M. tuberculatus* has rapid growth, is well adapted to the eutrophic environment, and probably exerts competitive pressure on other species of molluscs, meeting the requirements of an invasive species (ELKARMI & ISMAIL 2007, EVERETT 2000, POINTIER *et al.* 1993). Previous studies have used these relationships to propose equations for the estimation of the growth rate and/or secondary production of benthic aquatic insects (GENKAI-KATO & MIYASAKA 2007, GONZÁLEZ *et al.* 2002, CRESSA 1999).

Some of the specimens collected were excluded from this study because of significant losses of the shell apex. A study in Pampulha Reservoir found it difficult to obtain allometric relationships because each individual had lost on average 20.53% of its estimated theoretical length, with larger individuals having lost more of the shell (FREITAS *et al.* 1987). This breakage may occur due to factors such as water temperature, pH, total hardness, alkalinity, availability of calcium ions, and dissolved salts. These factors can influence the demineralization process and consequently lead to the loss of the entire shell (ORONSAYE 2002, LANZER & SHAFER 1988).



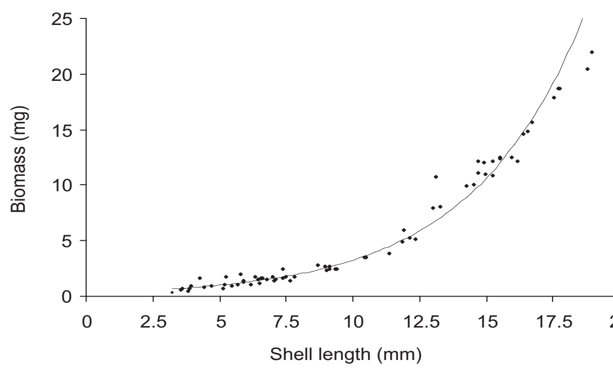
Figures 2-3. Graphs of residuals versus shell length (2) and residuals versus shell aperture (3) of the power-function model.

Table I. Regression equations and values found for each variable. The biomass is represented by B, and the shell total length (TL) and shell aperture (SA) of *M. tuberculatus* are represented by L. (a and b) regression constants, (R^2) coefficient of determination, (e) Euler's number (2.718).

Function	Equation	Conversion	A	b	R^2
Exponential	$B = a \cdot e^{(b \cdot L)}$	B → TL	0,3058	0,2365	0,9685
		B → SA	0,4172	0,7332	0,9353
Potential	B = a · Lb	B → TL	0,0287	2,1637	0,9414
		B → SA	0,5982	1,9136	0,9206

Individuals with shell length and aperture greater than 10 and 3 mm, respectively, showed greater biomass variations as a function of their size (Figs 4 and 5). This may be related to the onset of sexual maturity and the stage of the reproductive period, since embryos can remain in the brood pouch for three to five months before being released (Pointier *et al.* 1993, Dudgeon 1986).

Variations in the relationship between size and biomass in populations of a species from different geographical regions can be caused by differences in the physical and chemical factors and by fluctuations in their environmental conditions (González *et al.* 2002). This highlights the importance of selecting geographical regions with similar characteristics and preferably specific taxa, when carrying out studies that involve these kind of regressions. On the other hand, a study by Genkai-Kato & Miyasaka (2007) showed that seasonal variations did not significantly affect these relationships.



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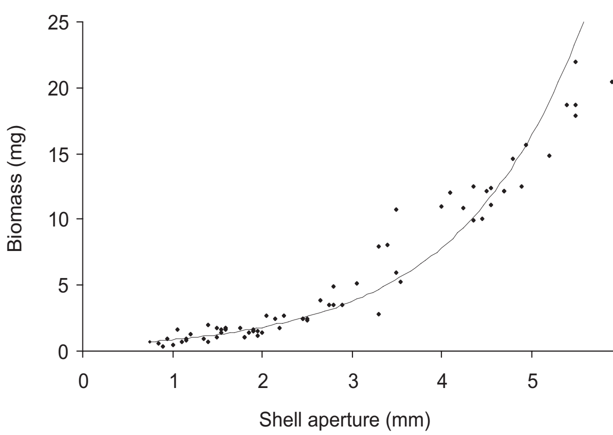

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Figures 4-5. Graphs of exponential regression model for biomass/shell length (4) and biomass/shell aperture (5) of *M. tuberculatus* in the Ibirité Reservoir, Minas Gerais (n = 70). The equation for the exponential model is: $B = a \cdot e^{(b \cdot L)}$.

In addition, the regression equations must be constructed using the data from fresh individuals, since preserved individuals can lose as much as 73.8% of their biomass during the first weeks, and this may lead to underestimation of the weight. The choice of preservative, ethanol or formaldehyde, does not seem to have a significant effect on loss of biomass, since both substances produce a large loss, mainly during the first three weeks following preservation (Wetzel *et al.* 2005).

The models presented here can be used to determine the biomass of *M. Tuberculatus*. The exponential model better described the relationship between size and biomass and the biological characteristics of the species. Because of the presence of numerous individuals lacking the shell apex, the use of the shell aperture measurement is a good alternative for the construction of the models to describe snail populations in Brazilian eutrophic reservoirs.

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LITERATURE CITED

Agostinho, A.A.; S.M. Thomaz; L.C. Gomes. 2005. Conservação da biodiversidade em águas continentais do Brasil. **Megadiversidade 1** (1): 70-78.

Benke, A.C.; A.D. Huryn; L.A. Smock; J.B. Wallace. 1999. Length-mass relationships for freshwater macroinvertebrates in North America with particular reference to the southeastern United States. **Journal of the North American Benthological Society 18** (3): 308-343.

Callisto, M.; P. Moreno; J.F. Gonçalves Jr; W.R. Ferreira; C.L.Z. Gomes. 2005. Malacological assessment and natural infestation of *Biomphalaria straminea* (Dunker, 1848) by *Schistosoma mansoni* (Sambon, 1907) an *Chaetogaster limnaei* (K. Von Baer, 1827) in an urban eutrophic watershed. **Brazilian Journal of Biology 65** (2):1-13.

Carvalho, O.S. 1986. Ocorrência de um tiarídeo (Mollusca) no lago da Pampulha, Belo Horizonte, MG, Brasil. **Revista da Sociedade Brasileira de Medicina Tropical 19** (1): 57.

Cressa, C. 1999. Dry mass estimates of some tropical aquatic insects. **Revista de Biologia Tropical 47**: 133-141.

De Marco Jr, P. 1999. Invasion by the introduced aquatic snail *Melanoides tuberculata* (Müller, 1774) (Gastropoda: Prosobranchia: Thiaridae) of the Rio Doce State Park, Minas Gerais, Brazil. **Studies of the Neotropical Fauna and Environment 34**: 186-189.

Dudgeon, D. 1986. The lyfe cycle, population dynamics and productivity of *Melanoides tuberculata* (Müller, 1774) (Gastropoda, Prosobranchia: Thiaridae) in Hong Kong. **Journal of Zoology 208**: 37-53.

Elkarmi, A.Z. & N.S. Ismail. 2007. Growth models and shell morphometrics of two populations of *Melanoides tuberculata* (Thiaridae) living in hot springs and freshwater pools. **Journal of Limnology 66** (2): 90-96.

Everett, R.A. 2000. Patterns and pathways of biological invasions. **Trens in Ecology and Evolution 15** (5): 177-178.

Fernandez, M.A.; S.C. Thiengo; L.R. Simone. 2003. Distribuition of the introduced freshwater snail *Melanoides tuberculatus* (Gastropoda: Thiaridae) in Brazil. **The Nautilus 117** (3): 78-82.

Figueirêdo, M.C.B.; A.S. Teixeira; L.F.P. Araújo; M.F. Rosa; W.D. Paulino; S. Mota; J.C. Araújo. 2007. Avaliação da vulnerabilidade ambiental de reservatórios à eutrofização. **Engenharia Sanitária e Ambiental 12** (4): 399-409.

Freitas, J.R.; L.C. Bedê; P. De Marco Jr; L.A. Rocha; M.B. Santos. 1987. Population dynamics of aquatic snails in Pampulha Reservoir. **Memórias do Instituto Oswaldo Cruz 82** (4): 299-305.

Garcia, F.C.; F.R. Barbosa; S. Braz; M.M. Petrucio; B. Faria. 2009. Water quality of na urban reservoir subjected to periodic applications of cooper sulphate: the case of Ibirité reservoir, southeast Brazil. **Acta Limnologica Brasiliensia 21** (2): 235-243.

Genkai-Kato, M. & H. Miyasaka. 2007. Length-weight relationships of four predatory stonefly species in Japan. **Limnology 8**: 171-174.

González, J.M.; A. Basaguren; J. Pozo. 2002. Size-mass relationships of stream invertebrates in a northern Spain stream. **Hydrobiologia 489**: 131-137.

Guimarães, C.T; C.P. Souza; D.M. Soares. 2001. Possible competitive displacement of Planorbids by *Melanoides tuberculata* in Minas Gerais, Brazil. **Memórias do Instituto Oswaldo Cruz 96**: 173-176.

Johnston, T.A. & R.A. Cunjak. 1999. Dry mass-length relationships for benthic insects: a review with new data from Catamaran Brook, New Brunswick, Canada. **Freshwater Biology 41**: 653-674.

Lanzer, R.M. & A. Shafer. 1988. Fatores determinantes da distribuição de moluscos dulceaquícolas nas lagoas costeiras do Rio Grande do Sul. **Acta Limnologica Brasiliensia 11**: 649-675.

Moreno, P. & M. Callisto. 2006. Benthis macroinvertebrates in the watershed of an urban reservoir in southeastern Brazil. **Hydrobiologia 560**: 311-321.

Oronsaye, C.G. 2002. The effect of transplantation experimento on the Shell morph of the Shell fish *Tympanotonus fuscatus fuscatus*. **Tropical Ecology 43** (2): 351-354.

Pointier, J.P. & D. Augustin. 1999. Biological control and invading freshwater snails. A case study. **Comptes Rendus de l'Académie des Sciences, Sciences de la Vie 322** (12): 1093-1098.

Pointier, J.P.; A. Théron; G. Borel. 1993. Ecology of the introduced snail *Melanoides tuberculata* (Gastropoda: Thiaridae) in relation to *Biomphalaria glabrata* in the marshy forest zone of Guadeloupe, French West Indies. **Journal of Molluscan Studies 59**: 421-428.

Rocha-Miranda, F. & M.J. Martins-Silva. 2006. First Record of the invasive snail *Melanoides tuberculatus* (Gastropoda: Prosobranchia: Thiaridae) in the Paranã river basin, GO, Brazil. **Brazilian Journal of Biology 66** (4): 1109-1115.

Silva, R.E.; A.L. Melo; L.H. Pereira; L.F. Frederico. 1994. Levantamento malacológico da bacia hodrográfica do Lago Soledade, Ouro Branco (Minas Gerais, Brasil). **Revista do Instituto de Medicina Tropical 36** (5): 437-444.

Souza C.P. & L.C. Lima. 1990. **Moluscos de Interesse Parasitológico do Brasil, Série de esquistossomose, 1**. Fundação Oswaldo Cruz, Centro de Pesquisas René Rachou, Belo Horizonte, 76 p.

Tundisi, J.G. 2008. Recursos hídricos no futuro: problemas e soluções. **Estudos Avançados 22** (63): 7-16.

Vaz J.F.; H.M.S. Teles; M.A. Correa; S.P.S. Leite. 1986. Ocorrência no Brasil de *Thiara* (*Melanoides*) *tuberculata* (O.F. Müller, 1774) (Gastropoda, Prosobranchia), primeiro hospedeiro intermediário de *Clonorchis sinensis* (Cobbold, 1875) (Trematoda, Plathyelmintes). **Revista Saúde Pública 20**: 318-322.

Vieira, S. 2003. **Biostatística: tópicos avançados.** Rio de Janeiro, Elsevier, 2nd ed., 212p.

Wetzel, M.A.; H. Leuchs; J.H.E. Koop. 2005. Preservation effects on wet weight, dry weight and ash-free dry weight biomass estimates of four common estuarine macroinvertebrates: no difference between ethanol and formalin. **Helgol Marine Research 59**: 206-213. doi: 10.1007/s10152-005-0220-z

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