JOURNAL OF PLANKTON RESEARCH | VOLUME 32 | NUMBER 6 | PAGES 961–966 | 2010

SHORT COMMUNICATION

Interaction between *Hexarthra intermedia* (Rotifera) and *Bosmina longirostris* (Cladocera): a case of opportunistic nutrition or interference competition?

JUAN CARLOS JARAMILLO-LONDOÑO[1]* AND RICARDO MOTTA PINTO-COELHO[2]

[1]GRUPO GAIA, UNIVERSIDAD DE ANTIOQUIA, GRUPO DE INVESTIGACIONES Y MEDICIONES AMBIENTALES, FACULTAD DE INGENIERÍAS, UNIVERSIDAD DE MEDELLÍN, APARTADO AÉREO 1983, MEDELLÍN, COLOMBIA AND [2]LABORATÓRIO DE GESTÃO AMBIENTAL DE RESERVATÓRIOS, INSTITUTO DE CIÊNCIAS BIOLÓGICAS, UNIVERSIDADE FEDERAL DE MINAS GERAIS, BELO HORIZONTE, BRAZIL

*CORRESPONDING AUTHOR: jcjaramillo@udem.edu.co

Received December 14, 2009; accepted in principle February 3, 2010; accepted for publication February 7, 2010

Corresponding editor: John Dolan

This study describes a new ecological association between two typical components of tropical freshwater zooplankton: the cladoceran (*Bosmina longirostris*) and the rotifer (*Hexarthra intermedia*), which, unlike those reported in the literature, led to mortal damage to the cladoceran.

KEYWORDS: *Hexarthra intermedia*; *Bosmina longirostris*; zooplankton interaction; zooplankton feeding; Rotifera; Cladocera

Many studies have revealed the inverse relationship between the abundance of crustacean and rotifer zooplankton in several freshwater environments (Edmondson and Litt, 1987; Gilbert, 1988a; May and Jones, 1989; Lampert and Rothhaupt, 1991; May *et al.*, 1993; Conde-Porcuna *et al.*, 1994; Fussmann, 1996). There is good evidence that rotifer species are differentially influenced by crustacean predation and competition. Cyclopoid copepods have often been described as effective predators of rotifers (Williamson, 1983; Williamson and Butler, 1986; Schulze and Folt, 1990). Rotifers play important roles as grazers, suspension feeders and predators within the zooplankton community; consequently, they are often important components structuring this community (Herzig, 1987).

Generally, cladocerans are considered to be the most effective grazers among the crustaceans, tend to eliminate "edible" algae from the plankton and appear to compete strongly with rotifers for the resources they share (Dodson, 1974; Gilbert, 1988b). Moreover, some rotifer are swept into the branchial chamber of larger cladocerans (interference competition or mechanical interference), which may result in mortal damage to the rotifer (Gilbert and Stemberger, 1985; Burns and Gilbert, 1986; Gilbert, 1989; MacIsaac and Gilbert, 1989, 1990, 1991; Pace and Vaqué, 1994; Sarnelle, 1997; Conde-Porcuna, 1998).

Here we provide evidence of an inverse and antagonistic relationship between rotifers and cladocerans (Fig. 1). The investigation was undertaken in the

doi:10.1093/plankt/fbq020, available online at www.plankt.oxfordjournals.org. Advance Access publication March 2, 2010

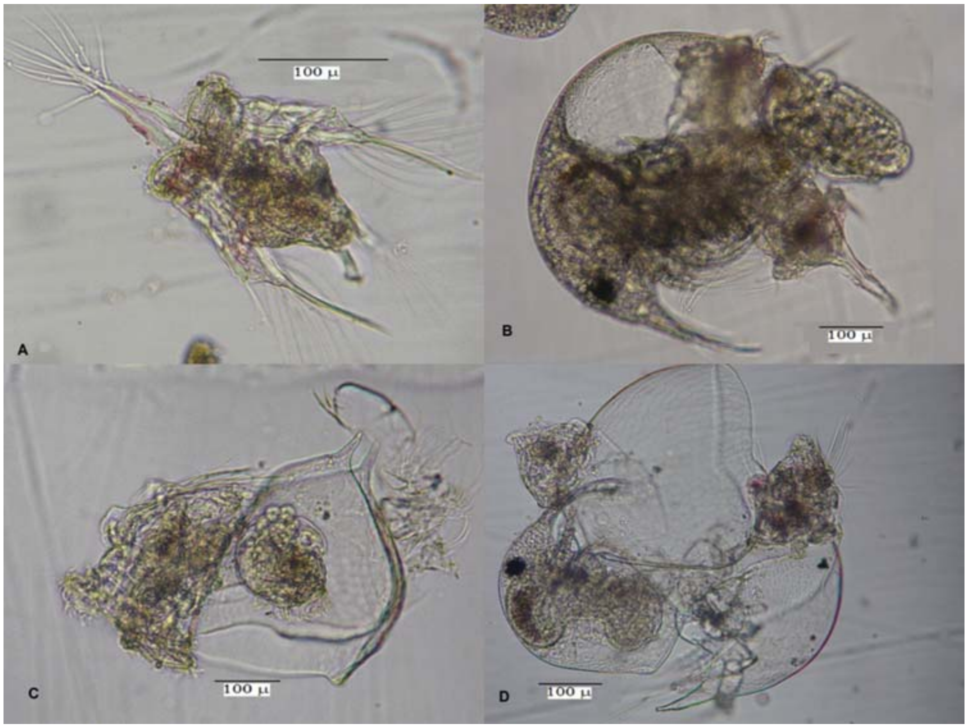

Fig. 1. *Hexarthra intermedia* (**A**) and different phases of *H. intermedia* intrusion on *B. longirostris* (**B, C** and **D**). A color version of this figure is available online.

Vargem das Flores Reservoir (19°55′ S, 44°10′ W). This is a mesotrophic water body located ~20 km southwest of Belo Horizonte, Minas Gerais, Brazil (2.5 Mio. Inh.). A COPASA operated facility treats most of the output water of this reservoir to provide the bulk of drinking water for the city of Belo Horizonte. An intensive sampling program included 27 stations where samples were collected for physical, chemical and biological analyses (Fig. 2). This survey was carried out in late October 2009 (20 October 2009). This survey was originally conceived to evaluate the spatial patterns in the distribution of phytoplankton and zooplankton communities, and to associate these patterns with existing inputs of organic pollution and silting areas.

At each station, depth, Secchi transparency, temperature, electrical conductivity, dissolved oxygen and pH were measured *in situ*. Water samples were transferred into 5 L plastic containers for measuring turbidity (DIGIMED model M-3), suspended solids (gravimetric, Clesceri *et al*., 1998), total organic nitrogen (semi-micro Kjeldahl, Clesceri *et al*., 1998) and phosphorus (ascorbic acid reaction, Clesceri *et al*., 1998) in the laboratory. In the water column at the central (deepest region) station, vertical profiles of temperature, electrical conductivity, dissolved oxygen and pH were taken using a Yellow Springs YSI 556 probe.

The zooplankton samples were collected by vertical hauls covering the entire water column, with a 68 µm mesh plankton net. All samples were preserved in 4% formalin for further laboratory processing. The samples were counted in a 1 mL Sedgwick-Rafter counting chamber under a Leica DMLB microscope at ×100 magnification, equipped with a SONY CCD Video CAM and a SIGMASCAN processing image software.

In order to establish a relationship between the densities of *Bosmina longirostris* and *Hexarthra intermedia* and any of the measured variables, a multiple correlation analysis was performed using the linear correlation coefficient of Pearson (r), since it is independent of the scales of the variables.

Vargem das Flores Reservoir is a typical mesotrophic reservoir. In this study, the mean values of total phosphorus (TP) and total organic nitrogen (TON) were 0.317 and 45.9 µM, respectively (Table I). The conductivity ranged between 137 and 156 µS cm^{-1}, dissolved oxygen oscillated between 6.0 and 8.7 mg L^{-1} and pH values tended to be very low in the bottom layer (14 m). The shallowest depth (1 m) was found at stations 15 and 25 and the deepest point ($Z_{max} = 12$ m) at station 8. The phytoplankton was dominated by small coccoid algae.

Hexarthra intermedia and *B. longirostris* were collected at all the sampling points in the reservoir. *Hexarthra*

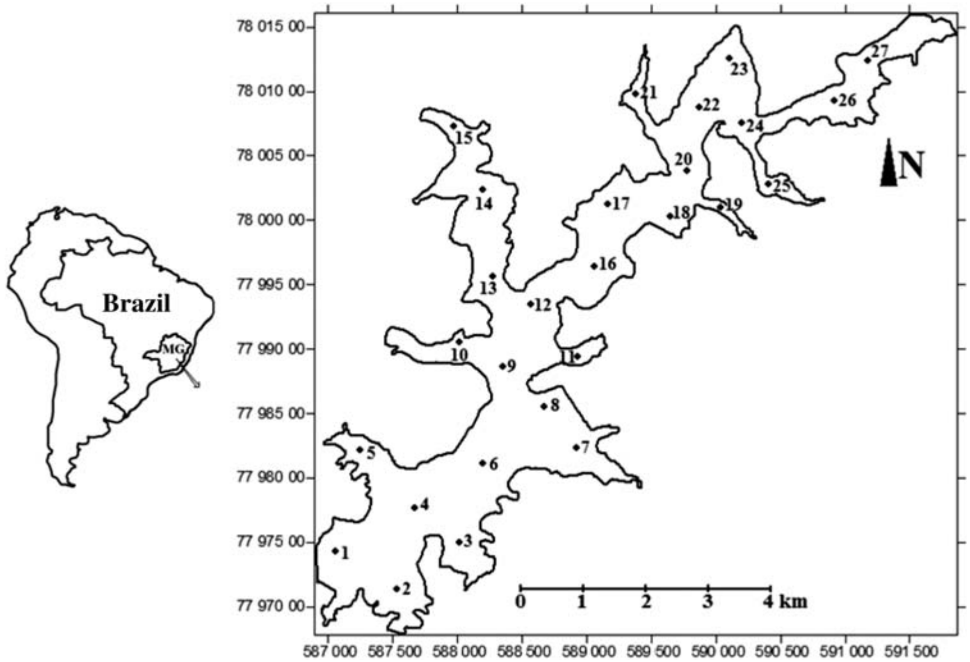

Fig. 2. Location of Vargem das Flores Reservoir and sampling stations.

Table I: Physical and chemical variables measured at 27 sampling stations in the Vargem das Flores Reservoir

Variables	Average	Minimum	Maximum
Temperature (°C)	25.5	20.9	26.0
Transparency (m)	1.41	0.50	2.00
Conductivity (μS cm^{-1})	151	137	167
Turbidity (NTU)	7.25	3.44	27.00
pH	9.2	2.3	9.6
Dissolved oxygen (mg L^{-1})	6.13	5.57	8.72
Total solids (mg L^{-1})	5.66	3.05	15.58
Nitrate (μM NO_3)	11.27	6.35	15.07
Total phosphorus (μM P)	0.317	0.192	0.859
Total organic nitrogen (μM N)	45.09	17.79	88.37

intermedia showed a mean density of 8.4 ind. L^{-1} (minimum of 0.4 ind. L^{-1} at station 12 and a maximum of 72.1 ind. L^{-1} at station 15). *Bosmina longirostris* had a mean density of 15.7 ind. L^{-1}. These densities ranged from <1.8 ind. L^{-1} at station 3 to a maximum 62.6 ind. L^{-1} at station 22. The mean density of empty carapaces of *B. longirostris* was 5.0 carapaces L^{-1}. It was common to detect up to four well-preserved individuals of *H. intermedia* inside empty bodies of *B. longirostris*.

On average, 22.9% of *B. longirostris* showed clear signs of intrusion by *H. intermedia* (Fig. 3). The mean proportion of *H. intermedia* that were found within *B. longirostris* carapaces was 59.9% (values ranging from a minimum of 2.9% at station 15 to a maximum of 100% at station 24). The density of *H. intermedia* was positively correlated with the density of *B. longirostris* containing *H. intermedia* ($r = 0.58$, $P = 0.001$), and with the occurrence of carapaces of *B. longirostris* containing *H. intermedia* ($r = 0.46$, $P = 0.015$) (Fig. 4). These results and correlations suggest not only the existence of a recurrent association between these two species, but also the possible impact of *H. intermedia* intrusions on death rates of *B. longirostris*.

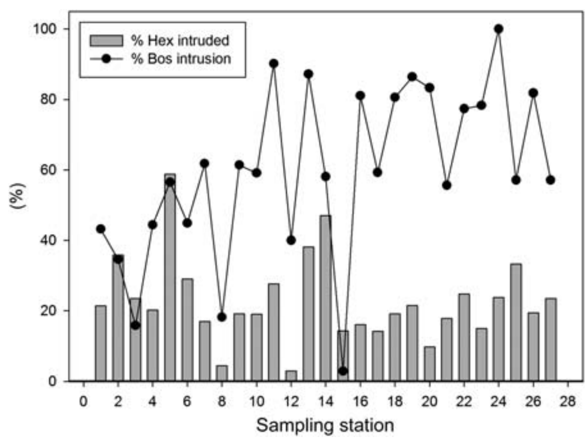

Fig. 3. Percentage of *B. longirostris* intrusion by *H. intermedia* and percentage of *H. intermedia* intruded to *B. longirostris* in Vargem das Flores Reservoir.

The density of *H. intermedia* was negatively correlated with depth and transparency ($r = -0.45$, $P = 0.019$;

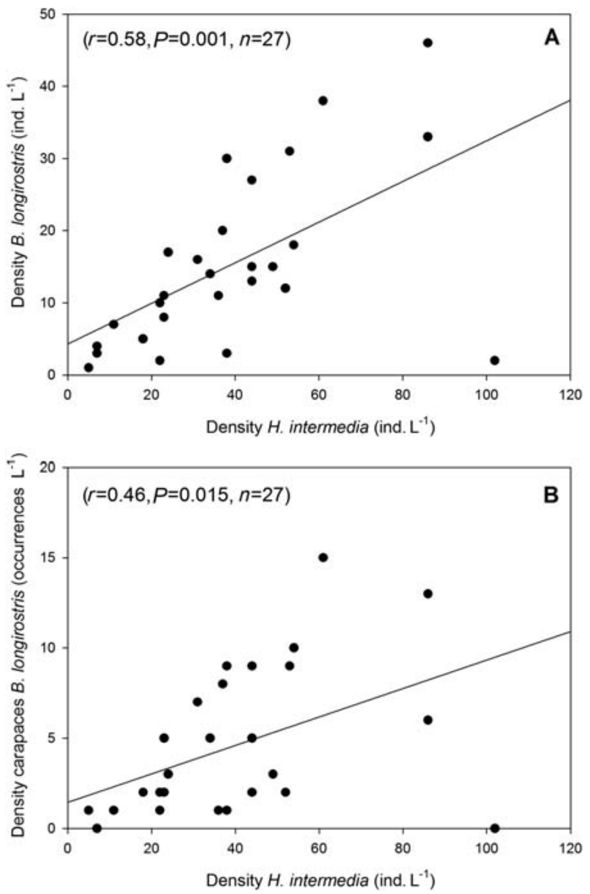

Fig. 4. Correlations between *H. intermedia* and density of *B. longirostris* intruded by *H. intermedia* (**A**), and density of *H. intermedia* and occurrence of carapaces of *B. longirostris* intruded by *H. intermedia* (**B**).

$r = -0.49$, $P = 0.008$, respectively), and positively with total solids and turbidity ($r = 0.59$, $P = 0.002$; $r = 0.61$, $P = 0.001$, respectively). This can be interpreted as a reflex behavior of *H. intermedia*. Possibly, this rotifer forms denser populations in turbid waters as a refuge from predators. Also, a correlation was found between the density of *B. longirostris* and the depth ($r = -0.43$, $P = 0.025$).

We found no evidence in the literature describing similar interactions between *H. intermedia* and *B. longirostris*. However, several studies have reported *Asplanchna* spp. as one of the top predators in freshwater ecosystems (Hofmann, 1983; Fernando *et al.*, 1990; Kappes *et al.*, 2000; Kumar and Ramakrishna, 2001; Jin and Niu, 2008; Pociecha and Wilk-Wozniak, 2008). *Bosmina* is frequently their potential prey (Matveeva, 1989). *Bosmina longirostris* is a slowly moving zooplankter, but it has a hard and resistant carapace (Jamieson, 1980; Williamson, 1986; Roche, 1990; Hellsten *et al.*, 1999; Chang and Hanazato, 2005).

Hexarthra intermedia has a mastax with malleoramate trophi (Ruttner-Kolisko, 1974), and prefers particles smaller than 6 μm (Pagano *et al.*, 1999). Its darting movements offer some protection against predation (Herzig and Koste, 1989; Ramakrishna and Kumar, 2002), and so *B. longirostris* becomes an easy prey to capture.

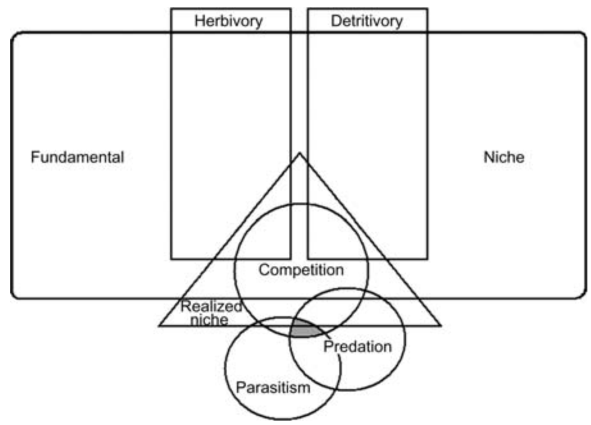

Fig. 5. Niche model proposed for *H. intermedia* based on the interaction with *B. longirostris*.

Considering these observations, we are proposing a previously undescribed feeding strategy for the rotifer *H. intermedia*. As previously mentioned, the water of this reservoir contains sufficient food for most zooplankton grazers, since the phytoplankton is composed mainly of small coccoid cells. *Hexarthra intermedia* is somehow able to find additional resources by exploiting a new ecological niche.

Considering the existing literature, the fundamental trophic niche of *H. intermedia* can be described as a typical microherbivore. The filtering apparatus of this rotifer clearly indicates that this species is specialized in filtering small particles such as phytoflagellates, small coccoid algal cells and possibly detrital food particles. It is a quite possible that this fundamental niche is substantially reduced as a result of ecological interactions such as competition and even predation. However, the present study provides information that allows us to add a new dimension to the ecological niche of *H. intermedia*. The intrusion of individuals of *H. intermedia* in the filtering chamber of *Bosmina* is not a trivial feature, since it reveals signs of a new ecological relationship that could be seen as a fusion of parasitism with interference competition. This kind of ecological relationship probably opens new possibilities to increase the fitness of this species in highly eutrophic waters. It represents a new potential to exploit food resources as well as to obtain extra protection against predators. Nevertheless, since it causes noticeable damage to the “hosts”, this relationship also approaches some form of parasitism (Fig. 5). *Hexarthra intermedia* is using food resources that are concentrated in the filtering apparatus of *B. longirostris*, which, in turn, appears to be noticeably negatively affected by this interaction.

The final question regarding the effects of *H. intermedia* on *B. longirostris* is the potential impact of this interaction on *Bosmina* populations. Resolving this question will require a more exhaustive study.

ACKNOWLEDGEMENTS

We thank Cid A. Morais-Jr and Simone P. Santos for their assistance in chemical analysis and for their help in the fieldwork. We also thank Dr Thales H. Viana and the COPASA staff at Vargem das Flores for providing logistical support. Finally, we express our gratitude to Dr Janet W. Reid, not only for language revision but also for substantial improvements in earlier versions of this manuscript.

REFERENCES

Burns, C. W. and Gilbert, J. J. (1986) Effects of daphnid size and density on interference between *Daphnia* and *Keratella cochlearis*. *Limnol. Oceanogr.*, **31**, 848–858.

Chang, K. H. and Hanazato, T. (2005) Prey handling time and ingestion probability for *Mesocyclops* sp. predation on small cladoceran species *Bosmina longirostris*, *Bosminopsis deitersi* and *Scapholeberis mucronata*. *Limnology*, **6**, 39–44.

Clesceri, L., Greenberg, A. E. and Eaton, A. D. (1998) *Standard Methods for Examination of Water and Wastewater*, 20th edn. APHA, AWWA, WEF, Baltimore, MD, USA.

Conde-Porcuna, J. M. (1998) Chemical interference by *Daphnia* on *Keratella*: a life table experiment. *J. Plankton Res.*, **20**, 1637–1644.

Conde-Porcuna, J. M., Morales-Baquero, R. and Cruz-Pizarro, L. (1994) Effects of *Daphnia longispina* on rotifer populations in a natural environment: relative importance of food limitation and interference competition. *J. Plankton Res.*, **16**, 691–706.

Dodson, S. I. (1974) Zooplankton competition and predation: an experimental test of the size efficiency hypothesis. *Ecology*, **55**, 605–613.

Edmondson, W. T. and Litt, A. H. (1987) *Conochilus* in Lake Washington. *Hydrobiologia*, **147**, 157–162.

Fernando, C. H., Tudorancea, C. and Mengestou, S. (1990) Invertebrate zooplankton predator composition and diversity in tropical lentic waters. *Hydrobiologia*, **198**, 13–31.

Fussmann, G. (1996) The importance of crustacean zooplankton in structuring rotifer and phytoplankton communities: an enclosure study. *J. Plankton Res.*, **18**, 1897–1915.

Gilbert, J. J. (1988a) Suppression of rotifer populations by *Daphnia*: a review of the evidence, the mechanisms and the effects of zooplankton community structure. *Limnol. Oceanogr.*, **33**, 1286–1303.

Gilbert, J. J. (1988b) Susceptibilities of ten rotifer species to interference from *Daphnia pulex*. *Ecology*, **69**, 1826–1838.

Gilbert, J. J. (1989) Competitive interactions between the rotifer *Synchaeta oblonga* and the cladoceran *Scapholeberis kingi* Sars. *Hydrobiologia*, **186/187**, 75–890.

Gilbert, J. J. and Stemberger, R. S. (1985) Control of *Keratella* populations by interference competition from *Daphnia*. *Limnol. Oceanogr.*, **30**, 180–188.

Hellsten, M., Lagergren, R. and Stenson, J. (1999) Can extreme morphology in *Bosmina* reduce predation risk from *Leptodora*? An experimental test. *Oecologia*, **118**, 23–28.

Herzig, A. (1987) The analysis of planktonic rotifer populations. A plea for long-term investigations. *Hydrobiologia*, **147**, 163–180.

Herzig, A. and Koste, W. (1989) The development of *Hexarthra* spp. in a shallow alkaline lake. *Hydrobiologia*, **186/187**, 129–136.

Hofmann, W. (1983) Interactions between *Asplanchna* and *Keratella cochlearis* in the Plußsee (north Germany). *Hydrobiologia*, **104**, 363–365.

Jamieson, C. D. (1980) The predatory feeding of copepodid stage III to adult *Mesocyclops leuckarti* (Claus). In Kerfoot, W. C. (ed), *Evolution and Ecology of Zooplankton Communities*. University Press of New England, Hanover, NH, pp. 518–537.

Jin, X. W. and Niu, C. J. (2008) Predatory rotifer *Asplanchna brightwelli* mediated competition outcome between *Brachionus calyciflorus* and *Brachionus patulus* (Rotifera). *Hydrobiologia*, **610**, 131–138.

Kappes, H., Mechenich, C. and Sinsch, U. (2000) Long-term dynamics of *Asplanchna priodonta* in Lake Windsborn with comments on the diet. *Hydrobiologia*, **432**, 91–100.

Kumar, R. and Ramakrishna, T. (2001) Effect of the cyclopoid copepod *Mesocyclops thermocyclopoides* on the interactions between the predatory rotifer *Asplanchna intermedia* and its prey *Brachionus calyciflorus* and *B. angularis*. *Hydrobiologia*, **453/454**, 261–268.

Lampert, W. and Rothhaupt, K. O. (1991) Alternating dynamics of rotifers and *Daphnia magna* in a shallow lake. *Arch. Hydrobiol.*, **120**, 447–456.

MacIsaac, H. J. and Gilbert, J. J. (1989) Competition between rotifers and cladocerans of different body sizes. *Oecologia*, **81**, 295–301.

MacIsaac, H. J. and Gilbert, J. J. (1990) Does exploitative or interference competition from *Daphnia* limit the abundance of *Keratella* in Loch Leven? A reassessment of May and Jones (1989). *J. Plankton Res.*, **12**, 315–1322.

MacIsaac, H. J. and Gilbert, J. J. (1991) Discrimination between exploitative and interference competition between Cladocera and *Keratella cochlearis*. *Ecology*, **72**, 924–937.

Matveeva, L. K. (1989) Interrelations of rotifers with predatory and herbivorous Cladocera: a review of Russian works. *Hydrobiologia*, **186/187**, 69–73.

May, L. and Jones, D. H. (1989) Does interference competition from *Daphnia* affect populations of *Keratella cochlearis* in Loch Leven, Scotland? *J. Plankton Res.*, **11**, 445–461.

May, L., Bailey-Watts, A. E. and Kirika, A. (1993) The ecology of *Synchaeta kitina* Rousselet in Loch Leven, Scotland. *Hydrobiologia*, **255/256**, 305–315.

Pace, M. L. and Vaqué, D. (1994) The importance of *Daphnia* in determining mortality rates of protozoans and rotifers in lakes. *Limnol. Oceanogr.*, **39**, 985–996.

Pagano, M., Sain-Jean, L., Arfi, R. *et al*. (1999) Zooplankton food limitation and grazing in a eutrophic brackish-water tropical pond (Côte d'Ivoire, West Africa). *Hydrobiologia*, **390**, 83–89.

Pociecha, A. and Wilk-Wozniak, E. (2008) Comments on the diet of *Asplanchna priodonta* (Gosse, 1850) in the Dobczycki dam reservoir on the basis of field sample observations. *Int. J. Oceanogr. Hydrobiol.*, **37**, 63–69.

Ramakrishna, T. and Kumar, R. (2002) Patterns of prey selectivity in the cyclopoid copepod *Mesocyclops thermocyclopoides*. *Aquat. Ecol.*, **36**, 411–424.

Roche, K. (1990) Some aspects of vulnerability to cyclopoid predation of zooplankton prey individuals. *Hydrobiologia*, **198**, 153–162.

Ruttner-Kolisko, A. (1974) Plankton rotifers. Biology and taxonomy. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart. *Die Binnengewässer*, **XXVI/1** (Suppl.), 146.

Sarnelle, O. (1997) Daphnia effects on microzooplankton: comparisons of enclosure and whole-lake responses. *Ecology*, **78**, 913–928.

Schulze, P. C. and Folt, C. L. (1990) Food resources, survivorship and reproduction of the omnivorous calanoid copepod *Epischura lacustris*. *Ecology*, **71**, 2224–2240.

Williamson, C. E. (1983) Invertebrate predation on planktonic rotifers. *Hydrobiologia*, **104**, 385–396.

Williamson, C. E. (1986) The swimming and feeding behavior of *Mesocyclops*. *Hydrobiologia*, **134**, 11–19.

Williamson, C. E. and Butler, N. M. (1986) Predation on rotifers by the suspension-feeding calanoid copepod *Diaptomus pallidus*. *Limnol. Oceanogr.*, **31**, 393–402.