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THEME SECTION

Advances in the ecology of freshwater mysids

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Introduction

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ABSTRACT: Mysids can be considered the krill of lakes. These crustaceans are relatively small (<30 mm), omnivorous, perform extensive vertical migrations, are a major food source for fishes, and can be the dominant species by mass in lakes. This Theme Section comprises 4 papers that represent significant advances in the study of these ecologically important animals, including techniques that were not available 20 years ago, such as DNA:RNA:protein ratios, fatty acids and stable isotopes as growth indicators, quantitative analysis of acoustics data and vertical migration models. The Theme Section thus represents a step forward towards better understanding long-term zooplankton time series, mysid omnivory, and the mysid ecological role in lake food webs.

KEY WORDS: *Mysis relicta* · *Mysis diluviana* · Zooplankton · Lakes · Food web

Mysids, or opossum shrimps, are members of the mostly marine order Mysidacea. There are some 30 species occurring in freshwater lakes and rivers, and the group has a worldwide distribution. Of these species, members of the *Mysis relicta* species complex have received the greatest attention because of their high abundance in some lakes (reported densities >1000 ind. m^{-2}), their importance as a food source for fishes, and their sometimes large effect on food web dynamics. The *Mysis relicta* species complex consists of

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4 species, 1 in North America (*M. diluviana*) and 3 in Eurasia (*M. relicta, M. segerstralei, M. salemaai*) (Audzijonyte & Väinolä 2005). The complex is a glacial relict with circumpolar distribution in deep, cold lakes of the Northern Hemisphere. The biomass of mysids can exceed that of planktivorous fishes, with which they compete for zooplankton prey (Gal et al. 2006). Their potential effect on food webs was not fully appreciated until they were introduced into new lake habitats in an attempt to promote fish growth. Mysids often had strong negative effects on zooplankton and their introduction led to decreases in some of the fish species they were supposed to enhance (Lasenby et al. 1986, Nesler & Bergersen 1991). Effects can cascade through ecosystem food webs to top predators such as bears and eagles (Spencer et al. 1991).

Mysid growth rate is a key component in calculating productivity of the mysid population and mysid consumption of various prey items (Johannsson et al. 2003), which are needed for inferences on the role of mysids in the food web. Growth rates vary widely, and are highest in highly productive lakes. Growth rates range from 0.2 mm mo^{-1} in Lake Tahoe to 1.5 mm mo^{-1} in mesotrophic lakes (review in Rudstam 2009), but they are difficult to measure *in situ*, especially when generations overlap. Johannsson et al. (2008) used nucleic acids and protein ratios as indicators of mysid growth and condition in laboratory experiments. Johannsson et al. (2009, this Theme Section) use this method to investigate inter-annual and spatial growth rate differences in Lake Ontario. The indices demonstrate differences in condition and growth rate, and suggest that certain essential fatty acids may be limiting in Lake Ontario.

Mysis spp. perform diel migrations at dusk and dawn from their daytime refuge in dark, deep water to the meta- or epilimnion, where they feed on zooplankton and algae. These migrations can be over 100 m and are limited by temperatures above 12 to 16°C and light levels above 10^{-4} lux, i.e. light levels that limit fish visual feeding. Boscarino et al. (2009a, this Theme Section) show that the actual distributions, not just the mean depth, can be predicted from the response of mysids to these variables in the laboratory (Boscarino et al. 2007, 2009b). Including the distribution of mysid prey and predators did not improve the predicting ability of the models. Because most of the interactions between mysids and their prey and predators likely occur at the edges of their vertical distributions, a better understanding of the whole distribution, not only the mean depth, is essential for adding a spatial dimension and more realism to predator–prey models. Diel vertical migrations are common in zooplankton (DeMeester 2009), and the approach by Boscarino et al. should also be useful for understanding the distribution of other migrating organisms.

Mysids are omnivores and capable of both filter-feeding and raptorial feeding. Mysids also feed on benthic prey, detritus and sediment during the day (Van Duyn-Henderson & Lasenby 1986). Diets of mysids can vary greatly between neighboring lakes (Nordin et al. 2008). Whall & Lasenby (2009, this Theme Section) examined the trophic role of *Mysis diluviana* in 2 neighboring lakes, one in which the introduction of mysids was associated with the collapse of kokanee salmon *Oncorhynchus nerka* (Okanagan Lake), and the other, in which it was not (Kalamalka Lake). They predicted that zooplankton would form a greater proportion of the diet of mysids in Okanagan Lake, where they were expected to compete more strongly with kokanee for zooplankton prey. However, comparison of mysid diets and clearance rates together with stable isotope signatures suggested that this was not the case. The study by Whall & Lasenby (2009) shows how these different techniques can be combined to investigate mysid prey choice. The reason for the different food web effects in the 2 lakes, however, remains unknown.

Mysids were introduced in 1949 to Kootenay Lake, BC, Canada, and are thought to be responsible for a large increase in growth rate of kokanee salmon and the spectacular fishery that developed after the introduction. After this reported success, mysids were introduced to many lakes and reservoirs in North America and Scandinavia to increase fish growth and production. However, results were not often those intended, as mysid predation caused declines in cladocerans, in particular in *Daphnia*. Koksvik et al. (2009, this Theme Section) show that an initial decline in cladocerans can be a transitory phenomenon. In Lake Lille Jonsvatn, the cladocerans returned after a period of 11 yr with depressed *Daphnia* abundance. Koksvik et al. (2009) think that this may be due to increased water clarity, which limits mysid migration into shallower water and provides a refuge for cladocerans in the epilimnion. This study highlights the importance of long-term studies.

The contributions to this Theme Section represent the state of the art in mysid ecology. The papers are based on a symposium on mysid biology organized by Lars Rudstam, Ora Johannsson and Michael Arts at the International Society of Limnology meeting in Montreal in 2007. The mysid symposium represented an update of similar symposia held in the 1980s and 1990s (Morgan 1982, Nesler & Bergersen 1991). The contributions to the present Theme Section include the use of techniques that were not available 20 years ago, such as DNA:RNA:protein ratios, fatty acids and stable isotopes as growth indicators, as well as quantitative analysis of acoustics data and vertical migration models, and thus represent a step forward towards better understanding the ecology of mysids in freshwater systems.

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