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LIISA NEVALAINEN

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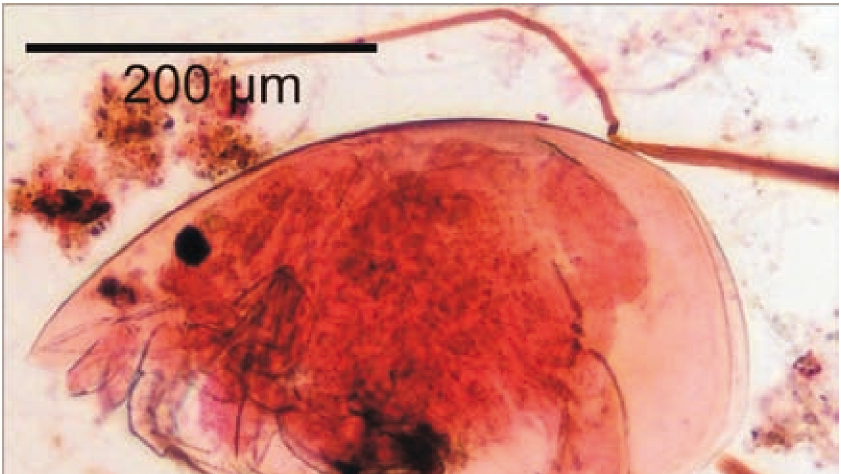

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Autumnal chydorid fauna (Anomopoda, Chydoridae) in Kevo region, northern Finnish Lapland

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Introduction

Water fleas of the family Chydoridae (Cladocera, Anomopoda) are microscopic crustaceans inhabiting different benthic habitats in littoral zones of lakes. Among Chydoridae (chydorids) some species live on submerged vegetation, whereas others are found on mud, sand or rocky substrata. Chydorids are an important part of the freshwater food web, consuming algae and detritus as grazers and being prey for predators. They are a very abundant and diverse family in all types of freshwater lakes, and several environmental variables, such as nutrients, pH, predators and habitat quality are known to influence their occurrence (e.g. Whiteside, 1970; Goulden, 1971; Sandøy & Nilssen, 1986; Hofmann, 1996). Because chydorids live in heterogeneous littoral habitats and are unevenly distributed in them their sampling for community analysis is difficult.

Zooplankton studies are quite common in Finland, but studies on littoral living chydorids are rather scarce and thus the modern distribution and occurrence of chydorid species around the nation is poorly documented. For example, Stenroos (1895, 1898) explored the occurrence of chydorid species in southern Finland during the late 19th century. During the 20th century Järnefelt (1915, 1956) investigated zooplankton communities in southern Finland providing observations on chydorids too. Purasjoki (1981) presented zoological and ecological observation on chydorids from south central Finland more than two decades ago. Latest contemporary ecological studies on cladocerans, including chydorids, in Finland were performed by Rautio (1998, 2001), who examined crustacean zooplankton communities in Kilpisjärvi region, northwest Finland.

Frey (1960) discovered that chitinous cladoceran and primarily chydorid body parts (carapaces, headshields, post-abdomens and ephippia) preserve as subfossils well and identifiable in lake sediments. Many studies on subfossil cladocerans have been performed since then in Finland, mainly concerning the development of lakes and their aquatic fauna from last glacial until present (e.g. Alhonen, 1970; Korhola, 1990; Sarmaja-Korjonen, 2002). Several studies on past environmental changes in northern lakes have included cladocerans (e.g. Hyvärinen & Alhonen, 1994; Sarmaja-Korjonen et al., 2006). Some researchers, e.g. Cotten (1985) and Korhola (1999) have studied the current distribution of cladocerans by their subfossil remains in surface sediments, since subfossil cladoceran communities from surface sediments are considered to represent their modern communities (cf. Frey, 1960).

Life cycle of chydorids alters between active and dormant stages and is controlled by environmental signals, such as shortening photoperiod and decreasing water temperature (Frey, 1982; Shan, 1974; Koksvik, 1995). In northern regions, the active period of chydorids lasts usually through the open-water season. During most of the open-water season chydorids reproduce by asexual reproduction (parthenogenesis) and their populations consist of parthenogenetic females. At the end of the active period, induced by unfavourable environmental conditions associated with winter, chydorids begin to reproduce sexually (gamogenesis). During the sexual reproduction period males and gamogenetic females appear into the communities and copulation results to resting egg production. Usually in northern regions chydorids overwinter as dormant resting eggs, but active individuals have been encountered under ice in Estonia and central Norway (Mäemets, 1961; Koksvik, 1995) and even in Signy Island, near Antarctica (Heywood, 1967). In spring, chydorids emerge from resting eggs after the dormancy, as environmental conditions are again favourable.

Since sexual reproduction and resting eggs are important phases in the life cycle of chydorids, perfect timing of gamogenesis is crucial. Initiating the process too early or too late may not lead to the optimal result, i.e. the optimal number of resting eggs (Kleiven et al., 1992). The length of the open-water season is extremely important in determining the timing and importance of sexual reproduction. In cold climates, e.g. in subarctic northern Finland, the open-water season is very short and chydorid populations must develop fast in order to produce resting eggs for the next winter (Poulsen, 1940; Sarmaja-Korjonen, 1999). Thus, the length of asexual reproduction period is restricted and sexual reproduction begins early during the open-water season. In milder climatic conditions, such as in southern Finland, the open-water season lasts considerably longer and also the length of the asexual reproduction period is longer (Nevalainen & Sarmaja-Korjonen, 2007).

The aim of the present study was to provide preliminary data of the occurrence of chydorids and their sexual reproduction during the early autumn in northernmost Finland. Therefore, chydorid communities and proportions of their sexual reproduction were studied in 16 small lakes in Kevo region, northernmost Finland, in the autumn of 2006. The study is part of a project, which investigates sexual reproduction of chydorids in Finland through sediment studies and ecological monitoring.

Sites

The 16 study lakes are located in Kevo region, northern Finnish Lapland, in a south-north transect from 69°22'N to 69°55'N (Figure 1). Climate in the northernmost Finland is subarctic. According to Kevo meteorological station in Utsjoki the mean annual air temperature in the area is +1.9 °C and mean July temperature is +13 °C. When altitude increases the lapse rate for air temperature is 0.6 °C per 100 m. Open-water season in the area lasts approximately 5 months, as ice-break usually occurs in early or mid-June and freezing in late October (Kuusisto, 1986). The lakes differed somewhat in their limnological conditions and also in their physical characteristics, such as in altitude and catchments vegetation (Table 1).

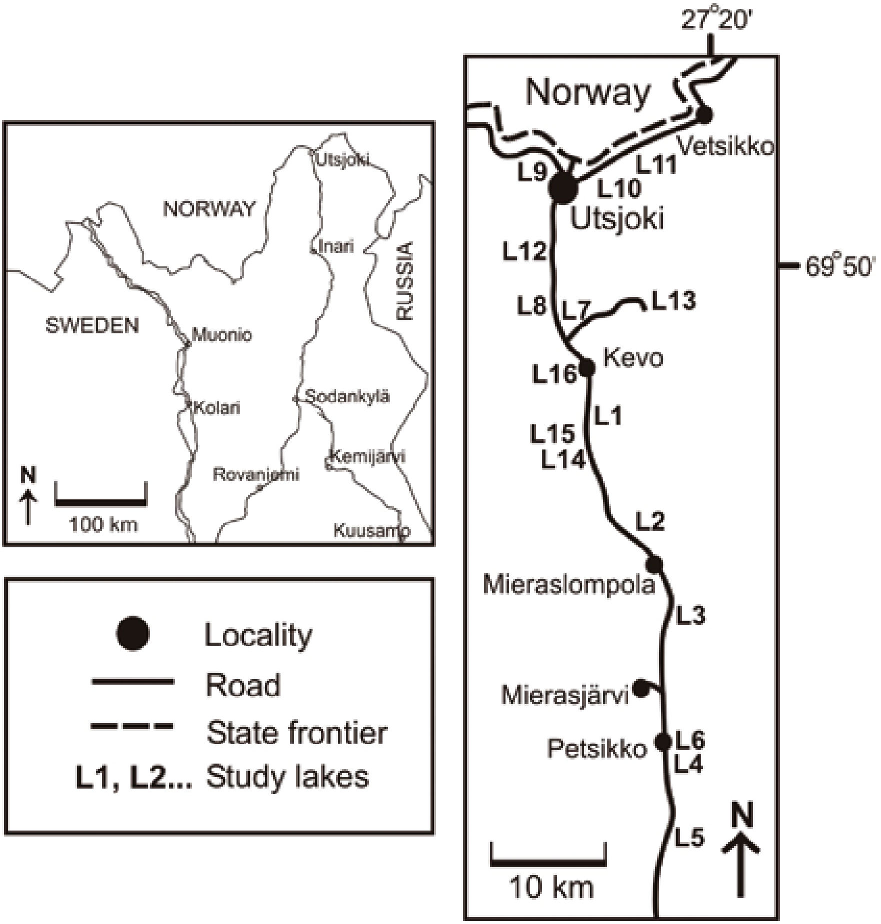

FIGURE 1. Locations of the 16 stydy lakes in northernmost Finland.

TABLE 1. Basic physical and chemical characters of the 16 study lakes. The lakes, where an adequate number of chydorids was encountered, are marked as bold. *Betula* (birch) is *B. pubescens* ssp. *czerepanovii* and *Pinus* (pine) is *P. sylvestris.*

Lake	Location	Altitude (masl)	T (°C)	pH	Cond. (µs/cm)	Catchment vegetation
L1	69°42’N, 27°03’E	114	13.0	7.53	20.1	*Pinus, Betula*
L2	**69°36’N, 27°10’E**	**141**	**11.6**	**7.57**	**20.8**	***Pinus, Betula***
L3	**69°33’N, 27°14’E**	**203**	**11.6**	**8.35**	**12.8**	***Pinus, Betula***
L4	**69°25’N, 27°15’E**	**259**	**10.4**	**8.70**	**24.0**	***Betula***
L5	**69°22’N, 27°14’E**	**236**	**11.4**	**7.22**	**58.0**	***Betula***
L6	69°26’N, 27°14’E	279	11.5	7.84	26.8	*Betula*
L7	69°46’N, 27°01’E	95	13.5	8.16	28.3	*Pinus, Betula*
L8	**69°48’N, 27°00’E**	**87**	**12.8**	**8.45**	**22.2**	***Pinus, Betula***
L9	**69°55’N, 26°57’E**	**118**	**13.4**	**8.26**	**24.0**	***Betula***
L10	**69°54’N, 27°04’E**	**74**	**12.9**	**7.87**	**17.13**	***Betula***
L11	69°55’N, 27°10’E	76	13.0	8.18	23.3	*Betula*
L12	69°50’N, 27°00’E	74	13.0	7.82	24.7	*Betula*
L13	69°48’N, 27°11’E	299	7.1	7.24	32.0	*Betula*
L14	69°40’N, 27°04’E	84	13.2	7.37	32.7	*Pinus, Betula*
L15	69°41’N, 27°04’E	174	8.4	7.24	21.7	*Pinus, Betula*
L16	**69°45’N, 27°00’E**	**70**	**12.3**	**7.04**	**27.5**	***Pinus, Betula***

Material and methods

Chydorids were sampled once during early September of 2006. The sampling dates were September 3rd and 8th. The samples were taken with a 100-µm sweep net from the shore. The net was swept back and forth over about 1 m of lakeshore in three different places. The samples were sieved through a 1290-µm mesh to distract large plant fragments, after which the residue was concentrated with a 100-µm mesh. The samples were stored in small jars with added ethanol. The littoral water temperature, pH and conductivity were measured from one of the sampling places of each lake (Table 1).

In the laboratory, the samples were mounted in glycerine on preparation slides and analysed under a light microscope at 100–200 X magnifications for precise identification. Chydorid individuals were counted until a minimum of 100 individuals was encountered or eight preparation slides (24 x 50 mm) were studied. Parthenogenetic females, gamogenetic females, and males were identified and marked separately. Relative proportions of each chydorid species as well as proportions of sexual individuals were calculated from the total amount of chydorids encountered. The chydorid nomenclature follows that of Røen (1995). *Chydorus sphaericus* is considered as *C. sphaericus sensu lato* (Frey 1986).

Results

Most of the study lakes were unnamed and therefore the lakes were coded (Table 1). In 8 of the 16 lakes sampled chydorids were extremely scarce and thus it was not possible to calculate relative proportions of species or sexual individuals in these lakes. The lakes, where an adequate number of chydorids was encountered are marked as bold in Table 1.

Figure 2 shows the relative proportions (%) of chydorid species in the lakes. *Alonopsis elongata* (Sars) (ca. 50 %) dominated in L2 together with *Acroperus harpae* (Baird) (> 40 %). *Alonella nana* (Baird) and *Alona affinis* (Leydig) occurred with low proportions. The dominant species in L3 were *A. elongata* (ca. 50 %) and *A. nana* (35 %), and *Chydorus sphaericus* s.l. and *Alonella excisa* (Fischer) were rarer. *Chydorus sphaericus* s.l. was most abundant species (> 50 %) in L4, together with *Alonopsis elongata* (ca. 30 %). In L5 *Alonella nana* (ca 50 %) and *Chydorus sphaericus* s.l. (ca. 30 %) dominated the community. *Alonopsis elongata* was most abundant (ca. 80 %) in L8 and *Chydorus sphaericus* s.l., *A. harpae, A. nana, A. excisa,* and *A.affinis* occurred with low proportion. *Acroperus harpae* was most abundant species in L9, where *C. sphaericus* s.l., *A. excisa* and *A. exigua* (Lilljeborg) were present at lower (< 20 %) abundances. The chydorid community in L10 was characterized by high abundances of *A. elongata, C. sphaericus* s.l., and *Eyrycercus lamellatus* (Müller). *Alonopsis elongata* and *Alonella excisa* dominated in L16 and *Alona rustica* Scott, *Alona*

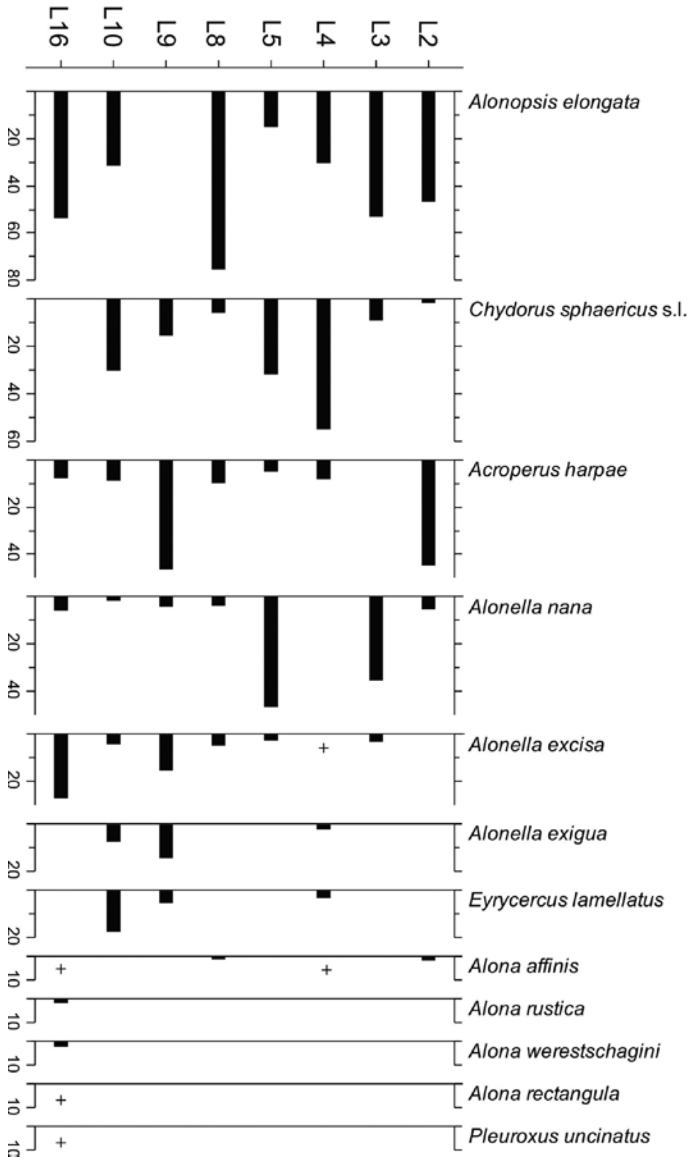

FIGURE 2. Relative proportions (%) of chydorid species in the lakes in the autumn of 2006. Plus (+) indicates < 1 % proportion.

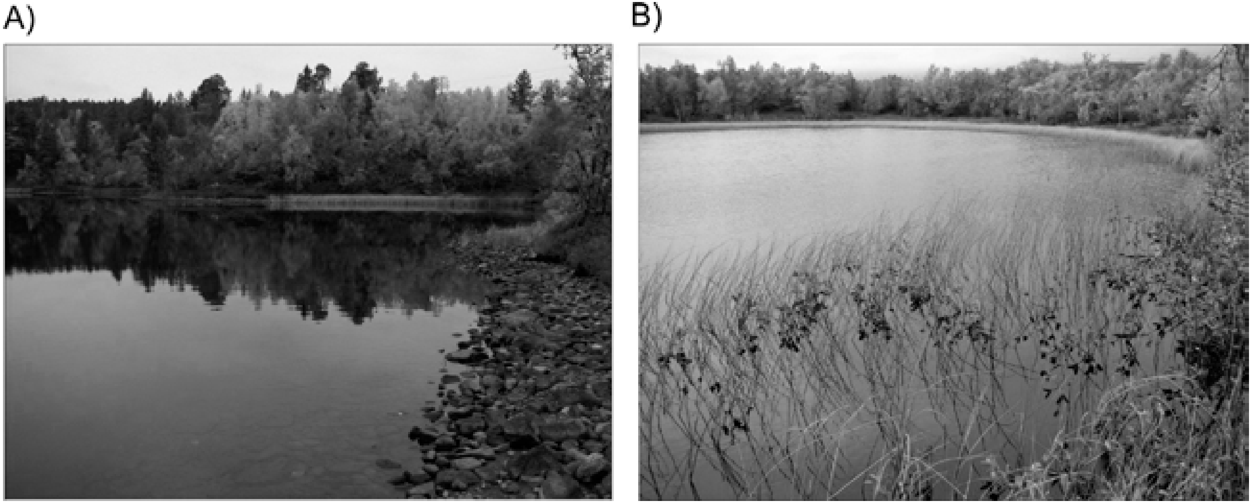

FIGURE 3. A) Rocky littoral zone in L14 and B) vegetation rich littoral zone in L9.

TABLE 2. Chydorid species encountered from the lakes in the autumn of 2006.

Species	Occurrences	Maximum	Mean	SD
Eyrycercus lamellatus (Müller)	3	17.1	3.1	5.6
Acroperus harpae (Baird)	7	46.5	16.2	17.2
Alona affinis (Leydig)	4	1.8	0.6	0.6
Alona rustica Scott	1	1.5	0.2	0.5
Alona werestschagini Sinev	1	2.2	0.3	0.7
Alona rectangula Sars	1	0.7	0.1	0.2
*Alonella excisa (*Fischer)	7	26.9	7.2	8.6
Alonella nana (Baird)	7	46.3	12.8	16.5
Alonella exigua (Lilljeborg)	3	14.1	2.9	4.8
Alonopsis elongata (Sars)	7	75.0	38.1	22.4
Pleuroxus uncinatus Baird	1	0.7	0.1	0.2
Chydorus sphaericus s.l.	7	54.9	18.5	17.7

werestschagini Sinev, *Alona rectangula* Sars and *Pleuroxus uncinatus* Baird were encountered with low proportions.

A total of 12 species of Chydoridae were encountered from the lakes. Table 2 shows all the species encountered and summarizes their occurrences in the 8 lakes. *Acroperus harpae, Alonella excisa, Alonella nana, Alonopsis elongata* and *Chydorus sphaericus* s.l. were most frequent and abundant, but their occurrences varied between the lakes. *Alona rustica, Alona werestschagini, Alona rectangula* and *Pleuroxus uncinatus* were rare and occurred only in one lake.

Highest number of species was encountered in L16 (Kevojärvi), and the highest Shannon-Wiener diversity index was found in L10 (Table 3). Proportions of total gamogenesis (males + gamogenetic females) varied from 30 % to nearly 80 %, being highest in L8 and lowest in L4 (Table 3). Males were most abundant in L8 (57 %) and gamogenetic females in L2 (38 %).

TABLE 3. Number of species, diversity index, and proportion of gamogenesis in the chydorid communities in the autumn of 2006.

Lake	Number of species	Diversity (H’)	Males (%)	Gamogenetic females (%)	Total gamogenesis (%)
L2	5	1.02	35.7	37.5	73.2
L3	4	1.02	26.5	8.8	35.3
L4	7	1.16	18.6	12.7	31.3
L5	5	1.24	22.0	12.2	34.2
L8	6	0.92	57.1	21.4	78.5
L9	6	1.49	34.0	12.0	46.0
L10	7	1.62	28.6	15.7	44.3
L16	9	1.31	34.8	11.9	46.7

Discussion

Chydorid fauna

Chydorids had almost deceased in 8 of the 16 lakes studied (Table 1). Usually chydorids are sampled during midsummer, since most chydorid species occur and are abundant during the summer months. The most reliable picture of chydorid communities is gained by ecological monitoring through the entire open-water season. In the present study the sampling was performed once in the autumn and thus many species had probably already produced resting eggs and deceased. The lakes, where chydorids had nearly died out, had rocky littoral zones and they lacked aquatic vegetation (L1, L7, L11, L12, and L14). A few of the lakes (L6, L15) were very shallow and one (L13) was situated at high altitude. It is likely, that due to some physical characters of these lakes, e.g. lack of suitable habitats in rocky littorals (Figure 3A) or low and daily varying temperatures in shallow lakes, chydorids had mostly died out earlier than in lakes with diverse habitats (Figure 3B).

As stated above, in all 12 species of chydorids were encountered from the lakes (Table 2). According to Silfverberg (1999) only *Alona affinis, Alonopsis elongata, Chydorus sphaericus* and *Eyrycercus lamellatus* have been recorded previously from the Inari Lapland biogeographical province. Thus, the present study widens considerably the list of chydorid species encountered from the region. The present study also widens the list of chydorid species encountered from Finland, because a recently described new and northern species *Alona werestschagini* (Sinev, 1999) was found in L16 (Figure 4). Firstly K. Sarmaja-Korjonen (personal communication) found subfossil remains of *A. werestschagini* in Utsjoki region, and the present study is the first to document this species as intact specimen from Finland. The findings of *Alona werestschagini* in L16 in Kevo region are not outstanding, because according to Sinev (1999), the species has formerly been found from northern localities in Kola peninsula, Russia and Finmark, Norway.

The autumnal chydorid communities in Kevo region were characterised by high abundance and frequency of *Alonopsis elongata* (Figure 2, Table 2). It was totally absent only in one lake (L9). The species is known to be common in oligotrophic and dystrophic lakes (Røen, 1995) and its occurrence is rather often connected with cold waters (Rautio, 1998; Korhola, 1999; de Eyto et al., 2002). Rautio (2001) found the species to be abundant in lakes in Kilpisjärvi region and observed it to increase towards autumn. Thus, the high autumnal proportion of *A. elongata* in the lakes in Kevo region may be caused by its seasonal population dynamics as it becomes more common during the late summer and autumn.

Also *Chydorus sphaericus* s.l. was a very common species in Kevo region, being absent only from one lake (L16) (Figure 2, Table 2). *Chydorus sphaericus* s.l. is a species complex (Frey, 1980; Duigan & Murray, 1987), consisting of very closely related species that are difficult to identify during a routine analysis. *Chydorus sphaericus* (Müller), i.e. *C. sphaericus sensu stricto* is a common species in all types of lakes and environments and it survives even in the arctic. Its high abundance is usually associated with high nutrient status and even pollution (Røen, 1995; de Eyto et al., 2002), although it cannot be classified to any particular environment. In the study of Rautio (2001), it was present in Kilpisjärvi region in low altitude ponds and became most abundant during late August.

Acroperus harpae, Alonella nana and *Alonella excisa* occurred in the autumnal communities in most of the lakes in Kevo region, but predominantly with low (< 10 %) proportions. These species prefer usually oligo- and dystrophic lakes (Whiteside, 1970; Røen, 1995), and therefore their occurrence in small lakes in Kevo region is reasonable.

The number of species was highest in L16 (Kevojärvi), as nine chydorid species were encountered from the autumnal samples in this lake (Table 3). *Alona rustica, Alona werestschagini, Alona rectangula* and *Pleuroxus uncinatus* were found only in this lake and with very low proportions. *Pleuroxus* species are usually associated with high nutrient status and warm climate (e.g. Røen, 1995; Sarmaja-Korjonen et al., 2003), and thus the occurrence of *P. uncinatus* in northernmost Finnish Lapland is interesting. Also *Alona rectangula* is usually found only in lakes with high nutrient status (Røen, 1995). However, K. Sarmaja-Korjonen (personal communication) found subfossil remains of both *P. uncinatus* and *A. rectangula* from surface sediments in Inari region and therefore their occurrence in northern Finland seems to be rather usual. Despite, they have not previously been observed in such northern locality as in this study. Rautio (1998) found *A. rectangula* in lakes in Kilpisjärvi region. In her study it occupied low elevation ponds with warmer waters. Kevojärvi is situated at a low altitude in the Utsjoki-river valley. The river valley probably stabiles water temperatures in Kevojärvi and provides suitable living conditions for *A. rectangula* in the northernmost Finland. However, only a few specimens of these species were found in the samples and more extensive sampling would be required to explain their distribution and commonness in northern areas.

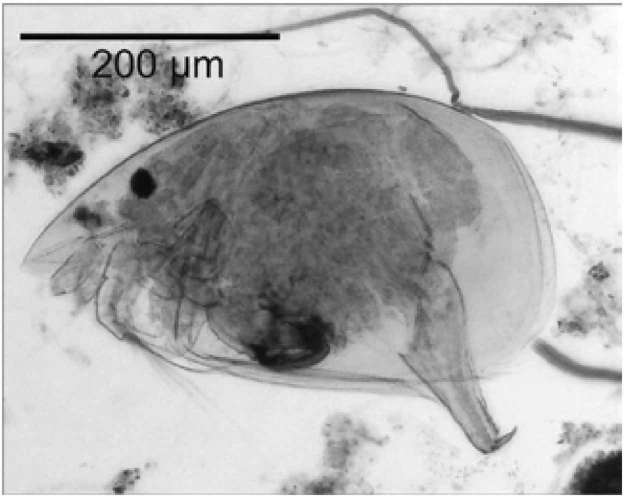

Figure 4. Male of *Alona werestschagini* from Kevojärvi.

Sexual reproduction

In the present study during the sampling in early September sexual individuals; males and gamogenetic females, were present in all of the lakes with rather high abundances (> 30 %) (Table 3). Proportions of males varied in different lakes between 18 % and 57 % and proportions of gamogenetic females varied between 9 % and 38 %. According to Nevalainen & Sarmaja-Korjonen (2007) highest proportions of males (ca. 10–40 %) in chydorid communities in southern Finland are found around mid-October and gamogenetic females (ca. 10–40 %) somewhat later. By that time, the lakes in Kevo region are already frozen. Because sexual reproduction develops as the proportion of sexual individuals, first males and later gamogenetic females increase progressively towards winter (Shan, 1969; Frey, 1982; Nevalainen & Sarmaja-Korjonen, 2007), the high proportion of sexual individual in Kevo region in early September indicates that sexual reproduction had been continuing for some time there. It also suggests that sexual reproduction in Kevo was at its latest phase with high proportion of sexual individual present, comparable to late October-early November in southern Finland.

Sexual reproduction of chydorids in southern Finland is usually initiated around mid-September with low proportion of gamogenetic individuals (Nevalainen & Sarmaja-Korjonen, 2007). According to present results (Table 3), it appears that sexual reproduction has started many weeks earlier in northern Finnish Lapland than in southern parts of the country, because such a high proportion of males and gamogenetic females were present in all the lakes in early September. Poulsen (1940) documented that sexual individuals of *C. sphaericus* were present in eastern Greenland from mid-July onwards, and thus it is likely that chydorid sexual reproduction started also in northern Finnish Lapland during late summer. Sarmaja-Korjonen (1999) and Frey (1982) stated that gamogenesis in chydorids may be initiated early and continue during most of the open-water season in northern regions, because it aims to maximise the production of resting eggs.

The present study does not reveal the stimuli for the earlier induction of gamogenesis in northern areas. The cause may be the low and abruptly decreasing water temperature during late summer or diurnal temperature changes in small lakes, since decreasing or changing water temperature acts as a stimulus for sexual reproduction (Kubersky, 1977; Frey, 1982). According to Korhonen (2002) highest water temperature (ca. 15 °C) is reached in Kevojärvi in late July-early August, after which it starts to drop rapidly. Similar trend in water temperatures occurs probably in all the lakes in Kevo region. Photoperiod is also considered to act as a stimulus for sexual reproduction (Shan, 1974; Frey, 1982). The day length in Utsjoki was still very long (ca. 15 hours) in early September, although it starts to decrease from late July onwards. Therefore the decreasing photoperiod probably also contributed to the induction of gamogenesis. However, further and more detailed studies on chydorids are needed to verify the induction time and cause for their sexual reproduction in northern areas.

Acknowledgements

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