

Bathymetric expansion of an invasive gammarid (*Dikerogammarus villosus*, Crustacea, Amphipoda) in Lake Léman

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ABSTRACT

After the arrival of *Dikerogammarus villosus* SOVINSKIJ in Lake Léman (2002) and its rapid expansion, the bathymetric distribution of gammarids was investigated in 2004-2005 at one location in the lake. *D. villosus* is able to colonize a wide range of substratum types (cobbles, gravel, sand/clay with *Dreissena* aggregates) down to a depth of 10 meters. Maximum abundance reached 235 ind. m⁻² in November 2004 between 0.5 and 1 m. The native gammarids (*Gammarus pulex* (LINNAEUS) and *G. fossarum* (KOCH)) were found in low numbers almost exclusively at a depth of 10 meters. The replacement of *G. pulex* and *G. fossarum* by *D. villosus* is confirmed as no more native species have been found since 2004 between 0 and 5 meters in sites where they were previously abundant. Even though the decline of invertebrate richness was not observed in the littoral zone, our results suggest that the native species are threatened.

Key words : Gammarids, invasive species, size classes, niche partitioning, depth, Switzerland

1. INTRODUCTION

After the spectacular spreading of the mussel *Dreissena polymorpha* (PALLAS) during the sixties (Binder 1965) and the more inconspicuous expansion of *Potamopyrgus antipodarum* (SMITH) in the seventies (Crozet *et al.* 1980), another species, the gammarid *Dikerogammarus villosus* SOVINSKIJ began to invade the Lake Léman littoral in 2002, from the Ponto-Caspian Region (Bollache 2004). This gammarid has invaded Central European waters over the last two decades and is currently widely distributed in the Danubian Basin. After the opening of the Danube-Main-Rhine canal in 1992 *D. villosus* has spread throughout Western Europe replacing native gammarids (e.g. Dick & Platvoet 2000; Müller *et al.* 2002; Kley & Maier 2003). In 1997, it was recorded, for the first time in the French hydrological system, in the Saone River (Devin *et al.* 2001; Bollache 2003) and in 1998, it was found in the Rhone (downstream of Lyon) and Meuse Rivers. Transport (boat displacement, fish stocking, etc.) might be the potential source of the Lake Léman invasion, because its first record in the Rhone River upstream of Lyon was confirmed later in 2004 (Castella *et al.* 2004). Currently, *D. villosus* has not been observed in the main tributaries of Lake Léman, although it was observed in Lake Neuchâtel, mainly on the North stony shore (Sept. 2003, depth 0.5 m: 260 ind. m⁻²; July 2005, depth 2 – 3 m: 125 ind. m⁻²) (P. Stucki, pers. comm.), in Lake Bienne (2005), in Lake Morat (2006) (Lubini *et al.*, in press) and in Lake Zürich (2006) (Steinmann *et al.* 2006). In 2003, while it was recorded for the first time in Southern Alps (Lake Garda) (Casellato *et al.* 2006), it was not

collected in Lake Maggiore or in Lake Lugano (V. Lubini, pers. comm.)

In many European countries, invasions of the Ponto-Caspian gammarids have been facilitated by habitat alteration, caused by the previous settlement of *D. polymorpha*, that is supposed to have helped the introduction of the co-evolved gammarid species (e.g. Simberloff & Von Holle 1999; Jazdzewski & Konopacka 2002). In many rivers and lakes, densities of invasive species are increasing rapidly (Bollache 2004; Bollache *et al.* 2004; Casellato *et al.* 2006; Mürle *et al.* 2003) and their expansion is considered a threat to the native fauna of the invaded ecosystems. Furthermore, *D. villosus* is known to be an efficient predator which has replaced native gammarids in many communities (e.g. Kinsler & Maier 2003; Krisp & Maier 2005).

In the present study, we investigate the bathymetric colonisation of the Pontogammaridae *D. villosus* and the native Gammaridae (*Gammarus pulex* (LINNAEUS) (Juguet 1958) and *G. fossarum* (KOCH) (Crozet 1984) in different substrates and depths. We expected that the predatory *D. villosus* would be spatially segregated from the other gammarid species.

2. STUDY SITE AND METHODS

The study site is located at "Rivaz gare" (46°28'10"N; 6°47'05"E) along the littoral zone of the Swiss part of Lake Léman, at a depth of 0 - 10 m. Substrate was composed of grain size 0.2 – 5 cm at a depth of 0 - 0.50 m. Cobbles with a diameter of 5 – 20 cm could be found down to a depth of 5 meters. At greater depth (10 m) a sandy/muddy bottom predominated. The 0.2 - 5 m depths were colonized by aquatic plants (*Zannichellia palustris* L., *Potamogeton crispus* L., *P. pecti-*

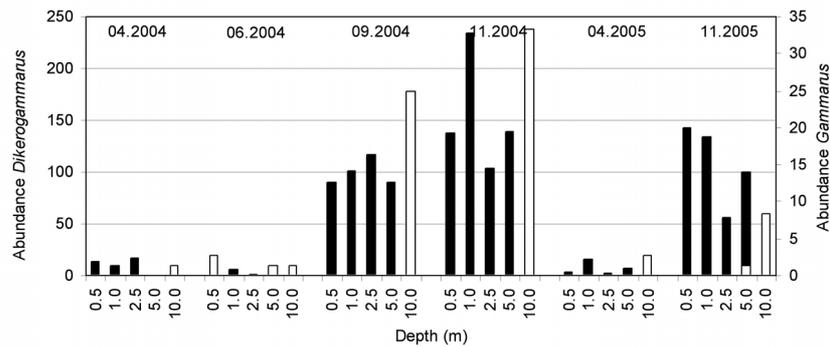


Fig. 1. Abundance (ind. m⁻²) of *Dikerogammarus villosus* (black boxes) and *Gammarus pulex* / *G. fossarum* (white boxes) at different depths and in different months in Lake Léman.

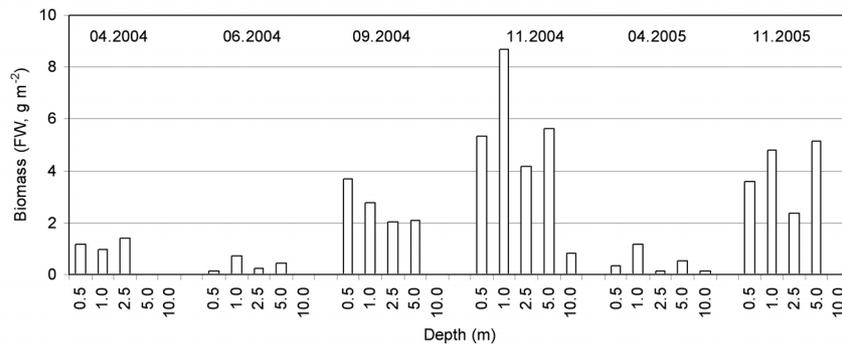


Fig. 2. Biomass of *Dikerogammarus villosus* at different depths in Lake Léman.

natus L., *P. perfoliatus* L. and *Miriophyllum spicatum* L.). The stony and sandy substrate was covered by *Dreissena polymorpha* shells at depths greater than 1 m. The slope was an average of 15%.

Gammarids were collected on six occasions every three months from April 2004 to April 2005 and in late autumn in November 2005 at five different depths (0.5, 1.0, 2.5, 5.0, 10.0 m). A Surber-type bottom sampler (0.07 m²; 300 µm mesh size) was used by a SCUBA diver and eight replicates were taken at each depth to provide an overall sample. The bulk of gammarids were sorted on the shore.

Abundance and biomass (fresh weight) were calculated by depth and date. Body length was determined by measuring from the tip of the rostrum head to the base of the telson. Results were distributed into four size classes (<6, 6-10, >10-15, >15 mm) and are displayed as histograms according to the percentage of the gammarid composition.

3. RESULTS

Dikerogammarus villosus was found from the lake shore to a depth of 5 m, colonizing either stony substrate or *Dreissena* aggregates of muddy sediments. Only a few individuals (8 ind. m⁻²) were found, on one occasion (November 2004), at a lower depth (10 m).

A marked seasonal trend was observed in the distribution of *D. villosus*, with higher abundance in autumn (Fig. 1). Maximum abundance reached 235 ind. m⁻² in November 2004 and 143 ind. m⁻² in November 2005 between 0.5 and 1 m.

Biomass of *D. villosus* (Fig. 2) followed the abundance trend throughout the seasons and in the depth ($R^2 = 0.945$, $P < 0.01$, $n = 30$).

A few of the native species *G. pulex* and *G. fossarum* were found, almost exclusively at lower depths than *D. villosus*, with maxima in autumn at 10 m (33 ind. m⁻²) (Fig. 1). Biomass was also low (max. 0.65 g m⁻² in autumn at 10 m).

The distribution of different size classes of *D. villosus* was also estimated (Fig. 3). Juveniles (length <6 mm) were found only in autumn. The other size classes were also present, but prevalent only in spring and summer.

4. DISCUSSION

The rapid spatial expansion of *D. villosus* all around Lake Léman has been confirmed. After the first observations along the French shore between Lugrin (2002), Thonon and Yvoire (spring and summer 2003) (Bollache 2004), we also found *D. villosus* on the Swiss shores in autumn 2003. Its bathymetric spreading is also

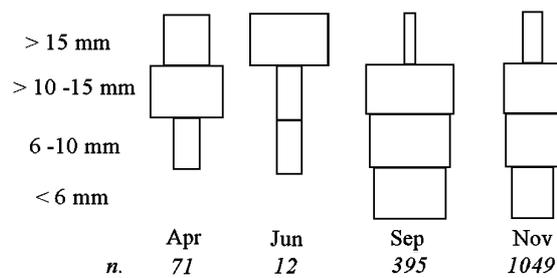


Fig. 3. Size frequency histograms (%) of *Dikerogammarus villosus* in 2004-2005; n = numbers of individuals.

evident, showing an high ability to disperse, to adapt to new habitats and to compete with other invertebrates down to a depth of 10 m. This spatial and bathymetric dispersion probably led to the displacement of the native gammarids species, *G. pulex* and *G. fossarum*, to a depth greater than 10 m. This confirms the studies by Mulattieri (2006) in Lake Léman, where *D. villosus* was the only gammarid found in large numbers (max. 500 ind. m⁻²) in 2004 on stony substrates between 0 and 5 m, and by Casellato *et al.* (2006) in Lake Garda (Italy), where *D. villosus* was found down to 11 m. It is possible that *G. pulex* and *G. fossarum* shifted from stony substrate to muddy sediment colonized by *Dreissena* aggregates to avoid contact with the predator *D. villosus*. Similar behaviour between these native and invasive species was observed by Kley & Maier (2005) in the River Danube.

In fact, the native species have not been found since 2004 in sites where they were previously abundant. In 1978-79, their abundance ranged from 21 to 3120 ind. m⁻² on stony substrate at a depth of 2 – 3 m (Crozet 1982) and from 50 to 770 ind. m⁻² in 1989 on a stony shore (Bänziger 1991). However, in spite of the invasion of *D. villosus*, the similarity of the invertebrate faunal composition in the littoral zone between 1978-79 (Crozet 1982) and 2004 (Mulattieri 2006) suggested that the invasive species primarily has a predatory impact on the native gammarids.

Reproductive periods for *D. villosus* in Lake Léman seem to be in summer and early autumn (Fig 3). Growth appears to continue during winter as no more juveniles were found in April. Piscart *et al.* (2003) specified that growth of females in winter was higher than that of males at temperatures below 15 °C.

The extremely widespread and abundant mussel *D. polymorpha* in the Swiss lakes has certainly enhanced the quick dispersion of *D. villosus*, which originated from the same endemic regions. It has already been shown that *D. polymorpha* favours *D. villosus* populations by increasing both the habitat complexity of the colonized substratum (potential refuges) and the abundance of invertebrates (potential prey for *D. villosus*) due to the exploitation of biodeposition by deposit feeders (Devin *et al.* 2003). Another invasive mussel, *Corbicula fluminea* (MÜLLER), a native of the Euphratean

River basin, was also observed in another Swiss lake (Lake Neuchâtel, 2003) (P. Stucki, pers comm.).

In Lake Léman, the displacement of native gammarids species to greater depths induced a niche partitioning between *D. villosus* and other gammarid species. An annual biomonitoring survey at the same sites and also in deeper waters is being carried out to follow its potential bathymetric expansion into different habitats.

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