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Short communication

The killer shrimp, *Dikerogammarus villosus* (Sowinsky, 1894), is spreading in Italy

Elena Tricarico, Giuseppe Mazza, Gabriele Orioli, Claudia Rossano, Felicita Scapini and Francesca Gherardi*

Dipartimento di Biologia Evoluzionistica "Leo Pardi", Università di Firenze, via Romana 17, 50125 Firenze, Italy
E-mail: elena.tricarico@unifi.it (ET), m.beppe81@libero.it (GM), gabri.orioli@gmail.com (GO), claudia_rossano@libero.it (CR), felicita.scapini@unifi.it (FS), francesca.gherardi@unifi.it (FG)
* *Corresponding author*

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Abstract

In 2008, the killer shrimp, *Dikerogammarus villosus*, native to the Ponto-Caspian region, was found for the first time in Central Italy, in Bilancino, an artificial lake situated in the watershed of the River Arno (Tuscany). This new record shows that this species' range is expanding in Italy. It is thus imperative to identify the pathways and vectors of spread of this species in order to halt this invasion process.

Key words: *Dikerogammarus villosus*, inland waters, Italy

Because of its predatory voracity and aggressive behaviour, *Dikerogammarus villosus* (Sowinsky, 1894) is called the ''killer shrimp''. It is a crustacean amphipod native to the Ponto-Caspian region. After the opening of the Danube-Main-Rhine canal in 1992, as the result of both natural expansion and transportation in ballast waters (Casellato et al. 2007), the species quickly invaded central and western Europe (Van den Brink and Van der Velde 1991; Dick and Platvoet 2000; Kinzler and Maier 2003; Kley and Maier 2003; Grabowski et al. 2007b).

Its progressive spread across Europe poses a serious threat to the diversity of indigenous amphipods and to the wider indigenous communities as well. *Dikerogammarus villosus* shows a number of life history traits typical of an invasive species, such as the short duration of embryonic development, rapid growth, short generation time, early sexual maturity, long reproductive period, and large reproductive capacity (Pöckl 2007, 2009). Besides being a shredder and detritus feeder, it is a voracious predator of both macroinvertebrates and the eggs, larvae, and adults of fish species (Dick et al. 2002; Devin et al. 2003; Casellato et al. 2007; Platvoet et al. 2009). It tolerates wide ranges of temperature, oxygen concentration, and salinity (Bruijs et al. 2001; Bij de Vaate et al. 2002; Devin et al. 2003; Brooks et al. 2009) and adapts to several types of substrate (Devin et al. 2003), favoured in this by its polymorphic pigmentation (Devin et al. 2004a). Its aggressive behaviour and voracity cause the replacement of indigenous gammarids (Dick and Platvoet 2000; Van Riel et al. 2006, 2007; Casellato et al. 2008; Leuven et al. 2009; Van der Velde et al. 2009) along with changes in the composition of the invaded communities and damages to the food webs of the recipient water bodies (Dick et al. 2002; Haas et al. 2002; Van der Velde et al. 2002). All these characteristics give this invader the potential of becoming widely distributed in inland water systems.

Since 2003, *D. villosus* has been reported in Northern Italy (Lake Garda, Po and Mincio rivers; Casellato et al. 2006, 2007, 2008). During 2008-2009, *D. villosus* was found in several samples of macrobenthos taken from the shoreline of the Lake Bilancino (40 km from Florence, Tuscany, Central Italy; 43°58'41"N, 11°16'54"E; altitude: 255 m above sea level; Figure 1).

Lake Bilancino is an artificial lake built in 1995 (but opened in 2002) to provide Florence with water and energy; it is located in an agricultural area, near a busy highway, and is an oligotrophic lake (total nitrogen TN: 0.83 mg/l;

nitric nitrogen NO_{3-}: 0.5 mg/l; chlorophyll *a*: 2.3 mg/m^3), with low dissolved oxygen saturation during summer in the hypolimnion stratum (<20%) and poor water transparency (on average 3.3 m) (data from the Regional Agency for the protection on the environment, ARPAT 2009). The lake has six influent rivers (Lora, Calecchia, Tavaiano, Sieve, Sorcella, and Stura) and only one effluent (Sieve).

Due to the large number of established alien species, this lake can be considered as a hot spot of xenodiversity. Since 2002, 14 alien species have become established in the lake: the Chinese freshwater jellyfish *Craspedacusta sowerbyi* Lankaster, 1880; the Ponto-Caspian zebra mussel *Dreissena polymorpha* (Pallas, 1771); the American bladder snail *Haitia acuta* (Draparnaud, 1805); the New Zealand mudsnail *Potamopyrgus antipodarum* (Gray, 1843); the Chinese pond mussel *Sinanodonta woodiana* (Lea, 1834); the red swamp crayfish *Procambarus clarkii* (Girard, 1852); the crucian carp *Carassius carassius* (Linnaeus, 1758); the carp *Cyprinus carpio* (Linnaeus, 1758); the black bullhead *Ictalurus melas* (Rafinesque, 1820); the channel catfish *Ictalurus punctatus* (Rafinesque, 1818); the pumpkinseed sunfish *Lepomis gibbosus* (Linnaeus, 1758); the largemouth bass *Micropterus salmoides* Lacépède, 1802; the wels catfish *Silurus glanis* Linnaeus, 1758; and the coypu *Myocastor coypus* (Molina, 1782) (Lori and Cianfanelli 2006; ARPAT 2009). Among the other alien species in the lake, *D. polymorpha*, recorded in Bilancino since 2005 (Lori and Cianfanelli 2006), is causing the strongest economic impact amounting to 20,000 Euro per year to clean pipes and tanks of the water treatment plant managed by the company Publiacqua (P. Grossi, pers. comm.).

Dikerogammarus villosus is the only gammarid in the lake, while the indigenous species *Echinogammarus veneris* is reported in the rivers of the same basin (Ruffo and Stoch 2005). During October 2008 and April 2009, we sampled four sites (two on the Northern side, two on the Southern one) along the littoral area of the lake. Sampling was performed up to 2 m from the banks and from 0 to 60 cm depth in areas where gammarids seemed most concentrated. Individuals were collected using a hand net (0.5 mm mesh size) in a square transect of 50×50 cm randomly sorted, and preserved in vials with 75% ethanol; then, in the laboratory, under a light microscope, their sex and maturation level were analyzed. The mean density did

Figure 1. View of Lake Bilancino (Tuscany, Central Italy). Photo by C. Rossano.

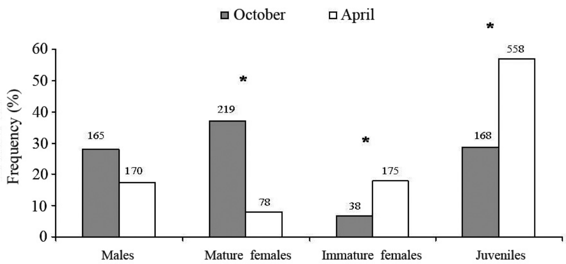

Figure 2. Frequency of males, mature females, immature females, and juveniles sampled in October 2008 and April 2009 in Lake Bilancino. The numbers over the bar indicate sample size. * denotes a significant difference after the G test with Williams' correction.

Figure 3. Two mating individuals of *Dikerogammarus villosus*: the male (the biggest and striped shrimp) is guarding the female. Photo by C. Rossano.

not change between October and April (independent samples Student's t-test: t=-0.81, df=6, P=0.45; October: 210±88 ind/m^2; April: 369±175 ind/m^2). From a total of 1571 individuals, the sex ratio was biased towards females (males=335, females= 510, G test with Williams' correction: G=36.49, df=1, P<0.001) without any significant difference between October and April (G=0.10, df=1, P>0.1; Figure 2). Our findings confirm previous studies on this species in different areas (e.g. Casellato et al. 2006; Pöckl 2009). In the invasion process, female-biased sex ratio could be advantageous since it increases the reproductive capacity of the population (Devin et al. 2004b). The number of ovigerous females was higher in October (85%) than in April (31%) (G=164.68, df=1, P<0.001), while the opposite was found for the juveniles (April 57% *vs* October 33%; G=220.81, df=1, P<0.001; Figure 2). In April, we also observed several matings (Figure 3). Similar to other species of Gammaridae, *D. villosus* is a multivoltine species with three generations reported per year (Devin et al. 2004b). In Austria, Pöckl (2009) found a reproductive resting period from October to December, and three peaks of juveniles in May-June, August-October, and January. Breeding typically lasts nine months, but it can extend for more than 10 months in warmer conditions (Grabowski et al. 2007a; Pöckl 2009). For example, in Lake Garda, Casellato et al. (2006) found ovigerous females all year round, with peaks between June and October, while juveniles were the most abundant component of the population particularly in October. Further samplings are needed in Bilancino to better understand the life cycle of the species in this newly invaded area.

In Lake Bilancino, *D. villosus* mostly occupies gravelly bottoms as in Lake Garda (Casellato et al. 2007); it also inhabits the clusters of *D. polymorpha*, which confirms the strong association between the two species. Indeed, in many European countries the invasion of the killer shrimp has been facilitated by the habitat alteration caused by previous introductions of *D. polymorpha* (Gonzales and Downing 1999; Simberloff and Von Holle 1999; Jazdzewski and Konopacka 2002). The invaded habitats are in fact physically modified by zebra mussel: its high-density and dense clusters provide suitable shelter to macroinvertebrates, including *D. villosus*. Moreover, zebra mussel faeces become an additional food source for the indigenous gammarids and for other detritivorous macroinvertebrates, which in turn provide prey for *D. villosus* (Ricciardi et al. 1997; Gonzáles and Downing 1999).

This is the first record of *D. villosus* for Central Italy and warns of the likely further expansion of this species' range across Italy. Similar to *D. polymorpha* (Lori and Cianfanelli 2006), *D. villosus* has the potential of colonizing the River Sieve, the effluent of Lake Bilancino, and subsequently the River Arno downstream of its confluence, whereas its dispersal upstream might be limited. *Dikerogammarus villosus* seems to have been introduced into Lake Garda by tourist boats from central Europe (Casellato et al. 2006, 2007), possibly in association with *D. polymorpha* (Quaglia et al. 2008); it might have been also released into Lake Bilancino as a contaminant of fish stocks. Obviously, further studies are needed to understand the exact pathways and vectors of this species in order to prevent and hopefully control its further spread across Central and Southern Italy.

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