Short Communication

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An Invader Along with an Invader: An Unusual Record of a Zebra Mussel *Dreissena polymorpha* (Pallas, 1771) (Bivalvia) Living Phoretically on a Killer Shrimp *Dikerogammarus villosus* (Sowinsky, 1894) (Amphipoda)

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Abstract: A zebra mussel specimen (*Dreissena polymorpha*) was recorded attached to the chitin cover of a killer shrimp (*Dikerogammarus villosus*). This is a rarely observed interspecies relationship (phoresis) between two of the top invasive aquatic macroinvertebrates in Europe. Thus, the zebra mussel obtains some opportunity for passive migration and probably this is one additional vector of its spread.

Key words: Ponto-Caspian invaders, phoresis, vectors of spread, Bulgarian inland waters

Introduction

The two species, zebra mussel *Dreissena polymorpha* (Pallas, 1771) and killer shrimp *Dikerogammarus villosus* (Sowinsky, 1894), are native to the Ponto-Caspian region, including the lower reaches of the Danube River (Valkanov 1936, Cărăuşu et al. 1955, Russev 1963, Mordukhai-Boltovskoi et al. 1969). Recently, they have been identified as 'top invaders' in many central and western European water basins (bij de Vaate et al. 2002, Karatayev et al. 2002, 2007, Rewicz et al. 2014, 2015). This high invasiveness is due to their biological traits: tolerance for a wide range of temperature and salinity, tolerance for low oxygen, very high rate of reproduction and growth, possibility of survival outside water, and opportunity for fast and efficient migration via river corridors or human transport (Bruijs et al. 2001, Karatayev et al. 2007, Brooks et al. 2008, Martens & Grabow 2008, Santagata et al. 2008, MacNeil & Platvoet 2011, Van Riel et al. 2011, Bacela-Spychalska et al. 2013).

In addition to these environmental advantages, some interspecies relationships could play a positive role in the successful introduction and spread of these two species, e.g., *D. villosus* becomes more abundant in the presence of *D. polymorpha* colonies because the zebra mussel provides suitable habitat and shelter (Kobak & Zytkowicz 2007, Kobak et al. 2013), concealment from predators (Kobak et al. 2014), and some food resources for the killer shrimp (Devin et al. 2003, Gergs & Rothhaupt 2008, Platvoed et al. 2009).

As a sessile species, the zebra mussel can spread primarily through its planktonic larval stages (veligers). The transport of adult mussels attached to some aquatic invertebrates also plays a specific role for their spread. This is often observed on less mobile (sessile and semi-sessile) macroinvertebrates, especially unionids and snails (Mackie 1991, Karatayev et al. 1997, Ricciardi et al. 1997, Lauer & McComish 2001). Similar relationships (called *phoresis*) between the zebra mussels and mobile macroinvertebrates, especially small in size, are less common. Phoretic relations between the zebra mussel and the spiny-cheek crayfish (*Orconectes limosus* Rafinesque, 1817) were reported by Anwand (1996). Only small individuals (between 1 and 2 years old) of mussels were found as 'colonisers'. This phoresis causes negative effects on the spiny-cheek crayfish (at least inconvenience). On the other hand, the zebra mussels receive good ecological

advantages as better feeding conditions, additional substrata and, most importantly for dispersal, increased activity radius. The attachment of mature zebra mussels to the carapace of a big crustacean (*Astacus leptodactylus* Eschscholtz, 1823) has been considered as an effective mechanism of upstream migration (Mordukhai-Boltovskoi 1960). A formation of a thick cover by zebra mussels on the carapaces of *A. leptodactylus* was reported also for Beloslav Lake, Bulgaria, by Bulgurkov (1961). The author assumed that the reason was deteriorated environmental conditions, in particular salinisation of lake water, which made the crayfish weak and less mobile.

Very rarely, the zebra mussel can be found as epizoon on some aquatic insects. Tucker & Camerer (1994) were the first to record one larvae of dragonfly (Odonata) with an attached zebra mussel. Weihrauch & Borcherding (2001) reported this phenomenon for ten different species of dragonflies, in particular for some relatively immobile species.

The zebra mussel is very rarely found attached on small crustaceans. Such records have been reported for the mysid *Paramysis ullskyi* (Mordukhai-Boltovskoi 1960), and the killer shrimp (Cărăuşu et al. 1955). In the latter case, a small-sized zebra mussel was found attached dorsally to the 2nd metasomal segment. Here we present a similar observation of an interspecies (phoretic) relationship between a zebra mussel specimen and a killer shrimp.

Materials and Methods

The observation was done on 19 November 2016 in the littoral zone of Gorni Dabnik Reservoir (N 43.36676; E 24.33521, Pleven District, Bulgaria). After sampling by a hand net, the individuals were stored in 70% ethanol and deposited in the hydrobiological collection of the Faculty of Biology, Sofia University 'St. Kliment Ohridski'. For easy visual demonstration of the zebra mussel byssal threads, colouration with chlorazol black was done.

Results and Discussion

In Bulgaria, the zebra mussel was reported initially from the Danube River and the Black Sea coastal lakes and river mouths (Valkanov 1936, Drensky 1947, Russev 1959, 1966). Recently, a rapid spread of this species in the Bulgarian inland waters has been observed, with more than 60 water bodies reported

Fig. 1. The killer shrimp, *Dikerogammarus villosus,* with a dorsally attached zebra mussel, *Dreissena polymorpha*, Gorni Dabnik Reservoir, 19.11.2016. Scale bar = 1 mm. Photo: Nikolay Simov (NMNH-Sofia, BAS, Bulgaria)

Fig. 2. Byssal threads (coloured with chlorazol black) of the zebra mussel *Dreissena polymorpha* (above) attached to the killer shrimp *Dikerogammarus villosus* (below). The arrows show some of the byssal thread plaques. Photo: Nikolay Simov (NMNH-Sofia, BAS, Bulgaria)

as infested (Trichkova et al. 2009, Trichkova et al., unpublished data). The killer shrimp is a common species in the Danube River and some Black Sea lagoons and river mouths in Bulgaria (Valkanov 1936, Russev 1959, 1966, Kovachev et al. 1999, Vidinova et al. 2016). We found the killer shrimp in Gorni Dabnik Reservoir for the first time in 2011 (Kenderov et al. 2017) and this is the farthest location from the Danube River (about 30 km upstream) currently recorded. This reservoir was heavily infested by zebra mussel (Trichkova et al., unpublished data), as well as another alien mussel species – *Corbicula fluminea* (O. F. Müller, 1774) (Hubenov et al. 2013).

Since 2011 up to now, we have found only one individual of the killer shrimp with an attached juvenile of the zebra mussel (Fig. 1). The shell width of the zebra mussel was 2.7 mm. Thus, the approximate age of the specimen could be estimated at about few months, regardless of the many environmental factors affecting the growth (according to Karatayev et al. 2006). The individual of the killer shrimp was about 1-3 months old (see Piscart et al. 2003, Devin et al. 2004, Rewicz et al. 2014) and probably early mature. Therefore, the phoretic relationships between the two individuals likely started at the beginning of their life cycle.

The zebra mussel was attached dorsally to the chitin cover of the 1st metasomal segment of the killer shrimp with 11 byssal threads. The fastening of the threads was strong, having their broad base (adhesive plaques) on the body of the killer shrimp (Fig. 2). This observation is very similar to the record of Cărăuşu et al. (1955).

Based on the record reported in this study, the following assumptions can be made:

1) The dorsal attachment of the zebra mussel to the metasome of the killer shrimp is probably only possible because of the mobility of the lower parts of the gammarid body (e.g. pereopods) and the entire mesosom (flexible in swimming or walking).

2) This attachment type and specific orientation of the zebra mussel is probably the most appropriate because of the negative role of hydrodynamic pressure during fast swimming of the killer shrimp, especially at the stage of the byssal thread formation.

3) The zebra mussel is likely to cause negative effects on its host: difficulty and energy consuming in crawling and swimming (we observed slow and irregular motion of the killer shrimp while swimming). Inability to hide in small shelters and microhabitats is also a possible effect of the attachment.

4) The larger overall dimensions and contrasting colour of the two bodies lead to easy visual recognition from predators.

5) The zebra mussel might get an additional opportunity to spread through mobile organisms, such as the killer shrimp, which is a good swimmer and migrant. In the sense of the 'invasion meltdown' theory, the negative impact of the zebra mussel could be exacerbated by interactions with the killer shrimp.

It is important to pay attention to phoresis as the one described in this study as a complementary factor for the spread of some invasive species. Furthermore, the design and implementation of different monitoring programmes, invasive management and protection strategies, river basin management plans, etc., are recommended for the prevention of introduction and spread of aquatic invasive alien species in the Bulgarian inland water bodies. At the local level, these may include biological control actions, community campaigns such as '*check, clean and dry*', different decontamination protocols, early detection programmes, and individual activities against transfer of aquatic invasive alien species.

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