Alien macro-crustaceans in freshwater ecosystems in Flanders

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1. Introduction

The introduction of invasive species has increased enormously during the past decades. Currently, eighteen alien macro-crustaceans have been found in freshwater ecosystems in Flanders. One of these invasive species, which is already widely distributed throughout Europe, is *Dikerogammarus villosus* (Bollache et al., 2004). Since 1997, *D. villosus* has been found in Flemish watercourses (Messiaen et al., unpublished data). *D. villosus* was first observed in the Albertcanal, while nowadays, it also occurs in other canals and other stagnant and running watercourses in Flanders. Lab experiments have been proven useful to determine the impact of *D. villosus* on a microcosm scale (Dick and Platvoet, 2000). A problem with these experiments is to translate these results to field situations. Therefore, it can be useful to draw conclusions based on lab experiments combined with field observations and data-driven models. This study aims to identify the most important variables determining the habitat suitability of *D. villosus* using decision trees. In addition, lab experiments were conducted to get more insight in the behaviour of *D. villosus*. In this way, models based on field observations can be used in combination with lab experiments to make useful predictions about the impact of the invasive species *D. villosus* on native macroinvertebrate communities.

2. Material and methods

Multiple as well as single prey experiments were conducted in glass aquaria filled with five litres of carbon filtered water. In the multiple prey experiments, five individuals of the predator *Dikerogammarus villosus* were released in the aquaria containing four individuals of five different prey (*Asellus aquaticus*, *Crangonyx pseudogracilis*, *Gammarus pulex*, *Cloeon*

dipterum and *Chironomus* species). Single species experiments with *A. aquaticus*, *C. pseudogracilis*, *G. pulex*, *G. tigrinus* or *C. dipterum* as prey were also conducted to study the interaction between prey and predator in the absence of other macroinvertebrates. In these experiments, five individuals of one prey species were exposed with five individuals of *D. villosus*. All experiments lasted 24 h after which the survival of the macroinvertebrates was checked. To check the influence of the substrate on the predation, all experiments were conducted three times: once on gravel, once on sand and once without substrate. All predator-prey experiments were replicated five times.

To determine the substrate preference of the invasive *D. villosus* and the native *G. pulex,* 10 individuals of one species were released in an aquarium filled with 10 litres of carbon filtered water. To assess if substrate preference changed if prey and predator occurred together, an additional experiment was conducted, where 10 individuals of both species were put together in one aquarium. The substrate preference was checked after 24 hours.

The dataset used to model the habitat suitability is based on the samples collected by the Flemish Environment Agency, which monitors a large number of sampling points scattered over the different stagnant and running water systems in Flanders. Environmental variables, hydro-morphological characteristics and data of other macroinvertebrates were available. In total, 232 presence or absence data were available with information on the hydro-morphological characteristics and physical-chemical variables. In 145 samples, *D. villosus* was absent, while in 87 other samples, the species was present. For the decision tree construction, the machine learning package WEKA – J 48 algorithm (Witten and Frank, 2000) was used.

3. Results

The multiple prey experiment showed a strong predation on all macroinvertebrates in the presence of *D. villosus* (Fig. 1), while all individuals of *D. villosus* survived. The highest survival of prey was usually found with gravel as substrate, except for *G. pulex*, which had the highest survival with sand as substrate. There was a significant difference in survival of the different prey ($p<0.001$) and a significant difference in survival when using different substrates ($p=0.039$). The single prey experiments (Fig. 1) showed a significant difference in survival of *A. aquaticus* ($p<0.001$), *C. pseudogracilis* ($p=0.012$) and *G. tigrinus* ($p<0.001$) when different substrates were used. As in the multiple prey experiment, survival was again highest on gravel.

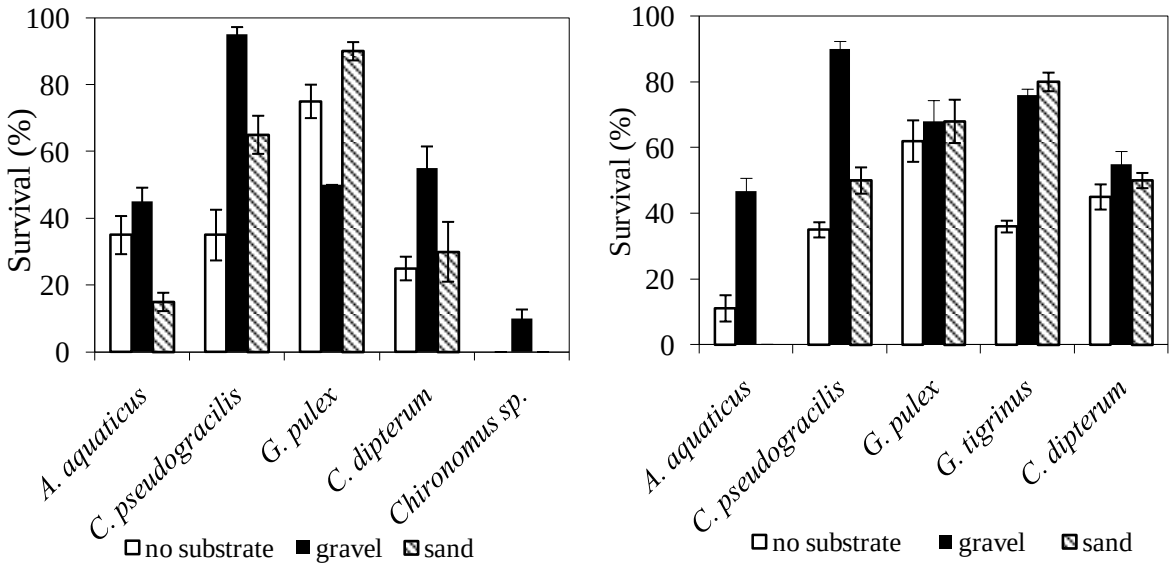

Figure 1 - Survival of the prey (*Asellus aquaticus, Crangonyx pseudogracilis, Gammarus pulex, Cloeon dipterum, Chironomus* species and *G. tigrinus*) after 24 h exposure to the predator *Dikerogammarus villosus* in the multiple (left) and single (right) prey experiments when exposed without substrate, on gravel and on sand.

The single species substrate preference experiments showed that *D. villosus* has a clear preference for gravel (p<0.001): after 24 h, 63.3 ± 1.9 % of the individuals were found between the gravel. When both species were exposed together, there was a significant shift in substrate preference of *G. pulex* (p<0.001) and *D. villosus* (p=0.006): more individuals of *D. villosus* and less individuals of *G. pulex* were present between the gravel.

A decision tree with 77 % CCI and a *K* of 0.5 was constructed. The most important variables determining the presence or absence of *D. villosus* were bank structure, oxygen saturation and conductivity. The model showed that *D. villosus* preferred canals with a high oxygen concentration and a low conductivity.

4. Discussion

Results of the predator-prey experiments showed a similar predatory behaviour of *D. villosus* compared to the results of previous studies (Dick and Platvoet, 2000; Krisp and Maier, 2005). Not only native species, but also the exotic species *G. tigrinus* and *C. pseudogracilis* originating from North America were predated. In this way, *D. villosus* can not only have an influence on native fauna, but also on exotic species, as was already observed in the river Rhine and the river Meuse (Josens et al., 2005; Van Riel et al., 2006). In the presence of *D. villosus*, a general decline in macroinvertebrate diversity and abundance in natural systems was observed (Van Riel et al., 2003). Despite its predatory behaviour, *D. villosus* should not

be seen as a strict carnivore: studies conducted by Platvoet et al. (2005), Maazouzi et al. (2007) and Mayer et al. (2008) showed that *D. villosus* is an omnivorous species able to eat plant as well as animal material. This diverse food spectrum probably contributes to the successful spread of this species.

The substrate preference experiment pointed out that *D. villosus* preferred gravel substrate, as was also found in previous lab studies (Van Riel et al., 2003; Kley and Maier, 2006). Studies conducted in the Moselle river (France) indicated that *D. villosus* was present on different types of substrates (Devin et al., 2003), however, there was a difference in preference based on the age and the size of the species. Juveniles were more often present between roots and macrophytes whereas adults had a preference for boulders and stones.

The developed habitat suitability model indicated that watercourses with an artificial bank structure, a high oxygen saturation and a low conductivity were preferred by *D. villosus*. *D. villosus* can thus invade artificial watercourses, however, the water quality regarding oxygen content and conductivity has to be good. The species avoided watercourses with a good biological water quality, which possibly means that natural systems with a high diversity of macroinvertebrates are more resistant to invasions than watercourses with a low diversity. However, according to Bollache et al. (2004), it is possible that in the near future, whole drainages of natural and semi-natural rivers, can be invaded by this species. Therefore, continuous monitoring of invasive species remains necessary.

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