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Do signal crayfish *Pacifastacus leniusculus* harm freshwater pearl mussels? Some field observations

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Abstract

More than 90 % of the freshwater pearl mussel populations in Bavaria (Germany) are strongly overaged. In the course of managing adults of *Margaritifera margaritifera* in a small population during the spawning season in August 2007, individuals with injured shells were found. It was clear that the damage was not done by muskrat. Therefore we suspected that non-native signal crayfish *Pacifastacus leniusculus* were gnawing at the mussels.

Starting in June 2008, an inventory of the damaged mussel population and of signal crayfish was done. *P. leniusculus* specimens were sampled by setting traps at intervals of 100 meters. Within the stretch populated by pearl mussels a capture-recapture study was carried out in two 100 meter sections. Trapped crayfish were marked by cutting notches on their uropod. The data were analysed with a closed-population model using the statistics program MARK.

A total of 2,249 *Pacifastacus leniusculus* were captured in a river section of 6 km. The upper distribution is limited by low water temperature. Data loggers recorded a mean summer temperature of 12 ºC upstream of the crayfish population, as compared to 13.6 ºC within. For the 1.1 km-section populated by mussels the capture-recapture analysis estimated mean densities of 5.4 signal crayfish per m² corresponding to 13,000 individuals.

35 % of the pearl mussels showed varying degrees of shell damage. Damage exclusively occurred on the points of the shell and looked like abrasions. Badly damaged shells could not be closed properly. We suggest that the omnivorous signal crayfish might locally become an additional threat to declining pearl mussel populations.

Introduction

The freshwater pearl mussel *Margaritifera margaritifera* (L.) is undergoing substantial decline throughout its range from western Russia to the eastern seaboard of North America (Young *et al.* 2001). Particularly the deteriorations of habitat quality by e.g. eutrophication (Bauer 1983, 1988) and physical degradation (Cosgrove *et al.* 2000, Geist & Auerswald 2007) has led to increased mortality of all age classes and to a lack of juvenile mussels.

In this paper we report a study investigating some curious field observations that might indicate an additional threat to pearl mussel populations: In August 2007 we had found some mussels with injured shells in the Biberbach, a stream near the border between Germany and the Czech Republic (Schmidt *et al.* 2007). The shell abrasions look quite different from the damage caused by muskrat (Figure 1). We suspected the non-native signal crayfish *Pacifastacus leniusculus* caused the damage. This species had been introduced in 1996 by a fish farmer in some ponds draining towards the Biberbach. In the stream signal crayfish were first observed two years later in one single location (Schmidt & Wenz 1998).

Figure 1. Damaged pearl mussel shell (left), found in the Biberbach in August 2007, as compared to an intact shell (right).

Approximately 1.1 km of the Biberbach is currently inhabited by freshwater pearl mussels. The actual population size is about 370 individuals, compared to about 1.000 in 1990 (Schmidt & Wenz 1990). The population is overaged as well: The youngest specimens are between 40 and 50 years old. The main causes for the population decline are inadequate sewage treatment, pollution from fish farms and intensive agriculture. However, over the last decade water quality has improved due to conservation measures, for example the establishment of buffer zones.

The present study started in June 2008. The purpose was 1) to investigate the spatial distribution of signal crayfish in the river; 2) to calculate the total number of crayfish in the section inhabited by pearl mussels; 3) to survey the damage to the mussels; and 4). to look for evidence that signal crayfish were causing the damage.

Methods

To capture crayfish traps with wide openings at both ends were used, supplied with fresh ox liver as a lure (Figure 2).

Figure 2. Trap (model PIRAT) for the capture of crayfish.

The range and distribution of crayfish in the Biberbach was investigated by a longitudinal inventory. From June to September 2008, traps were set at intervals of 100 meters, covering a stream section of about 6 km and extending

to both upstream and downstream of the stretch inhabited by pearl mussels. All traps were installed in the afternoon and examined the next morning. For each trap the number, sexes and sizes of the captured crayfish were recorded.
Additionally at each trap site the physical stream structure was described according to Hahner (2002). Water temperature was recorded by data loggers (Syntec HOBO Water Temp Pro) exposed in the upper, middle and lower part of the investigated stream section.

In the stream section inhabited by mussels, the absolute number and density of crayfish was estimated by a capture-recapture study in August and September 2008. Two stretches of 100 meters were investigated, one in open meadow, one in forest. 80 traps were set simultaneously within each stretch. The catch was repeated 4 times at intervals of one week. All captured crayfish were marked by a punch mark at the uropod (Figure 3) and then put back into the stream. The population size of each of the two investigated stream stretches was estimated from the resulting crayfish encounter histories, using the closed-population approach (Otis *et al.* 1978) of the statistics program MARK (White & Burnham 1999).

Figure 3. Male signal crayfish, marked by a punch on the uropod.

Between July 2008 and July 2009 a complete survey of the pearl mussel population in the Biberbach was done. All mussels were measured and examined for shell damages.

Results

Although in former times the Biberbach was famous for its stock of noble crayfish *Astacus astacus,* in the longitudinal crayfish inventory only signal crayfish but no native species were caught. This was to be expected, as *Pacifastacus leniusculus* is highly competitive (Söderbeck 1995 and 1991) and a vector of the crayfish plague (Alderman 1997). A total of 2,249 *Pacifastacus leniusculus* were captured, with the highest numbers of crayfish recorded about 300 meters downstream of the fish farm that originally introduced the crayfish in 1996 (Figure 4).

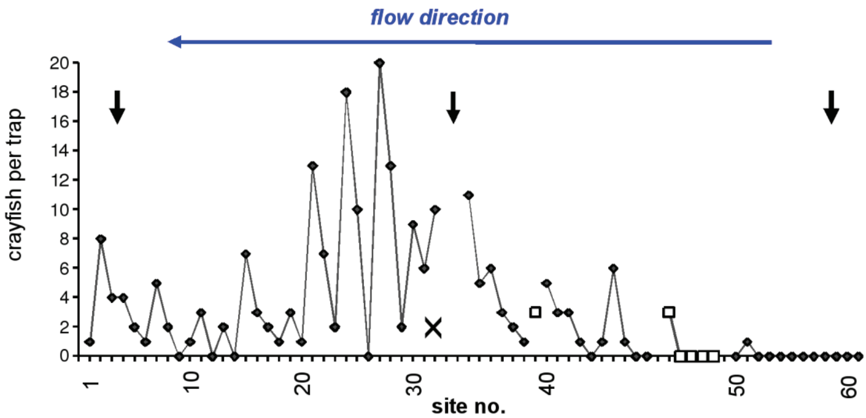


Figure 4. Number of crayfish per trap caught in the longitudinal inventory. Diamonds = main stream. Squares = millstream and tributary. x = location of the fish farm that introduced signal crayfish. Arrows = locations of the temperature data loggers.

Although certain morphological criteria of the river are essential for crayfish settlement (Bohl 1987), in this study no correlation was found between the number of crayfish caught and the recorded parameters of physical stream structure (e.g., shelter structures; Figure 5). However, the signal crayfish distribution is probably limited by water temperature: In the upper part of the investigated stream section, where no crayfish were caught, the mean day temperature did not reach 14 °C in the summer of 2008 (overall mean 12.0 ± 1.2 °C), whereas mean day temperatures of up to 17 °C were measured further downstream in the sections inhabited by the signal crayfish (middle part: overall mean 13.6 ± 1.2 °C; lower part: overall mean 14.4 ± 1.6 °C; Figure 6). This corresponds well with observations from other authors (Strätz *et al.* 2004, Capurro *et al.* 2007), who stated that 15 °C might be a critical threshold for signal crayfish.

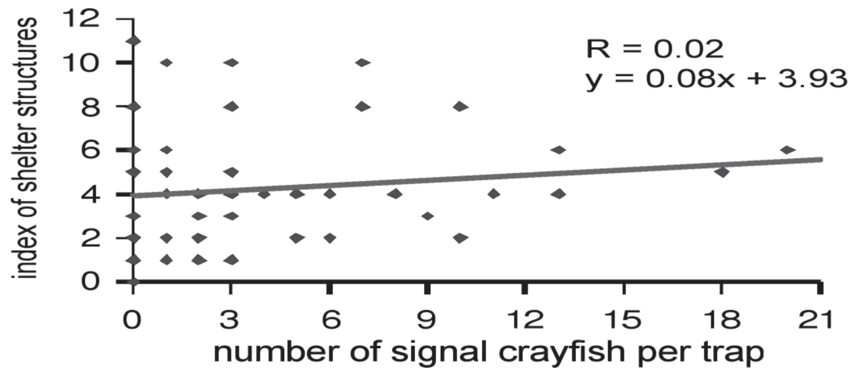
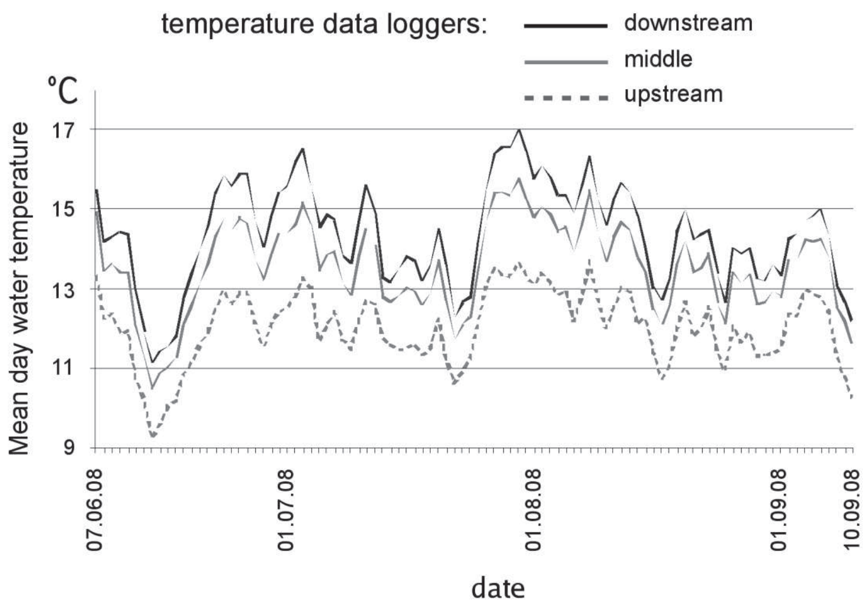


Figure 5. Scatter plot of the index of shelter structures on trap sites versus number of crayfish caught.



Fgure 6. Mean day temperatures of stream water calculated from data logger measurements at the three sites indicated in figure 4, from June to September 2008.

In the capture-recapture study again *Pacifastacus leniusculus* was the only crayfish species caught. In the catch the number of males was higher than that of females. Females are less active and hide for longer periods, especially when they are carrying eggs or offspring (Bohl 1987). In the course of the repeated captures the number of unmarked individuals in the traps did not decline, indicating that the real number of crayfish by far exceeds the number of caught specimen (Figure 7). Accordingly, from the encounter histories of 826 crayfish caught in the meadow-stream stretch a population of 1,462 was estimated with MARK (95 %-confidence limits: 1.196 to 1.943). In the forested investigation

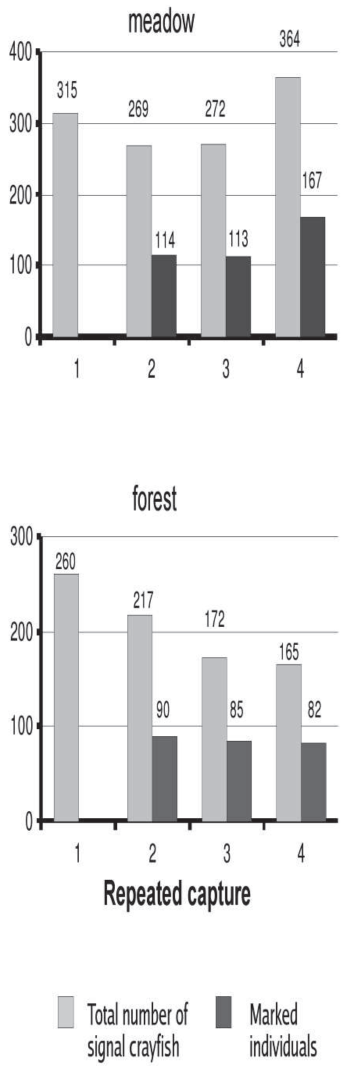


Figure 7. Capture - recapture inventory: Total number of crayfish caught at each of the 4 catches, and number of marked, that is, recaptured specimen.

site from 557 caught specimens a population of 890 animals was estimated (95 %-confidence limits: 738 to 1.178). From these figures for the 1.1 kilometre of the stream inhabited by pearl mussels a crayfish population of 13,000 is extrapolated, corresponding to 5.4 individuals per m². Some signal crayfish showed snapped claw points (Figure 8). This was exclusively found in the river section populated by mussels.

Figure 8. Crayfish claw with broken point.

The examination of the pearl mussel population revealed that 35 % of the animals show shell injuries. No correlation was found between mussel size and the occurrence of injuries (Figure 9). However, as no mussels with total length smaller than 80 mm are present in this population, the potential violability of young mussels is not known. Curiously, the damage was observed more often at the leading end of the mussels that normally is buried in the substrate (Figure

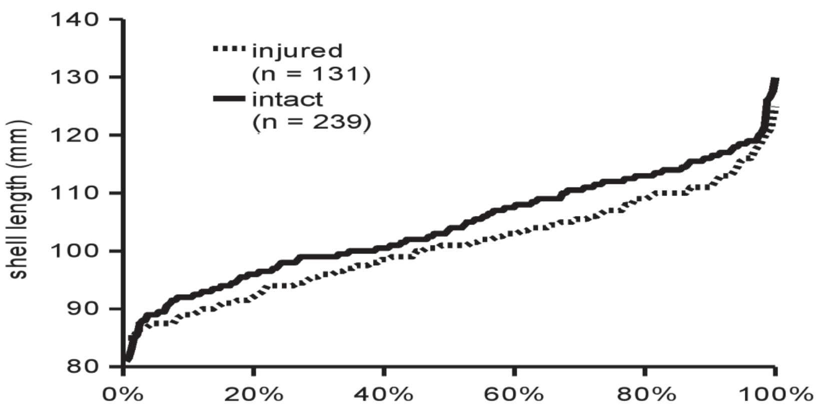


Figure 9. Cumulative distribution of the length of damaged and intact pearl mussel shells.

10). The reason might be that displaced or moving mussels will stretch out their foot at the leading end, which might attract predators. Some of the damage was so severe that the mussels were no longer able to close their shells (Figure 11). This is likely to be lethal in the long term.

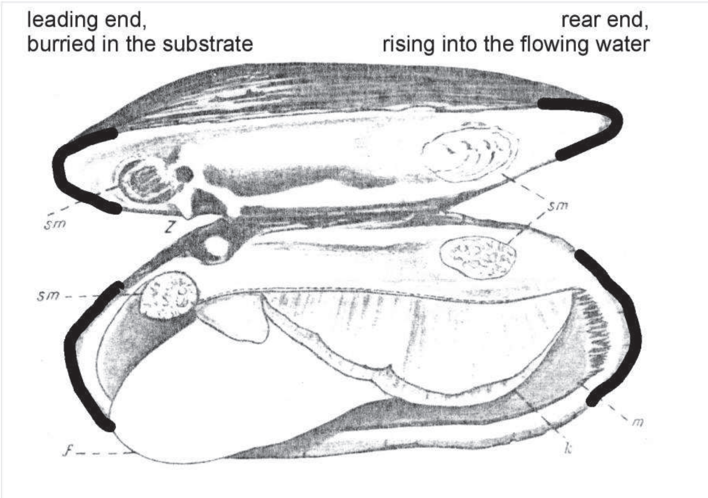


Figure 10. Dissected pearl mussel. Location of shell damages are marked black. From Korschelt 1926, supplemented.

Figure 11. Severely damaged mussel, showing shell injuries at the leading end.

Discussion

Considering the already depleted size of the freshwater pearl mussel population and its ongoing decline, the observed damage poses a serious threat to the remaining individuals. The question is, can the signal crayfish be held responsible for the observed damage to the mussels?

In a Swedish laboratory study Hylander (2004) found that signal crayfish attack juveniles of the mussel *Unio tumidus*. The crayfish used their mouth parts to gnaw on the edge of the shells to get inside.
In the present study there was no possibility to directly observe the action that injured the mussels. The snapped claw points might however be interpreted as evidence for crayfish involvement. Possibly the claw breaks when a disturbed mussel shuts its shell.

There is no doubt that the main impairment of freshwater pearl mussel populations is habitat degradation. The major task for mussel conservation therefore is the restoration of rivers, including the river catchments. Locally invasive species like muskrat (Zahner-Meike & Hanson 2001, Hochwald 1990) and signal crayfish seem to be an additional issue.

Irrespective of the possible impairment of mussels, signal crayfish were shown to have a strong negative impact on the stocks of native crayfish (Söderbeck 1991, Huber & Schubart 2005). They can also cause the degradation of macrophytes, aquatic insects and benthic fishes (Crawford *et al.* 2006, Guan & Wiles 1997, Nyström 1999).

For all these reasons precautions and alertness are needed to prevent further dispersal and spread of *Pacifastacus leniusculus*, particularly as no effective measure has been found to eradicate this non-native species from running waters (Peay *et al.* 2006, Hyatt 2008).

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