Influence of stock origin and environmental conditions on the survival and growth of juvenile freshwater pearl mussels (*Margaritifera margaritifera*) in a cross-exposure experiment

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Introduction

The freshwater pearl mussel is a highly specialized, sensitive freshwater bivalve. The most sensitive life stage seems to be the early post-parasitic phase. As the species is highly endangered throughout its distribution range, captive rearing programs have been implemented in several countries. In semi-artificial breeding, juveniles are kept in mesh cages and exposed in the free-flowing water of rivers, serving as bioindicators for ambient water quality at the same time. Their suitability as bioindicators is still discussed controversely due to methodological differences and potential local adapatations. In this contribution, we therefore tested the influence of freshwater pearl mussel stock and study stream conditions on juvenile mussel performance (i.e. growth and survival) in a standardized cross experiment. Specifically the following hypotheses were tested:

1) **environmental factors determine growth and survival rates independent of mussel stock,**
2) **the probability of winter survival increases with mussel shell length,**
3) **stocks are locally adapted and juvenile mussels from native stocks exposed to the streams of parental origin exhibit higher growth and survival rates than non-native stocks and**
4) **freshwater pearl mussel juveniles are suitable bioindicators separating high and low quality habitats.**

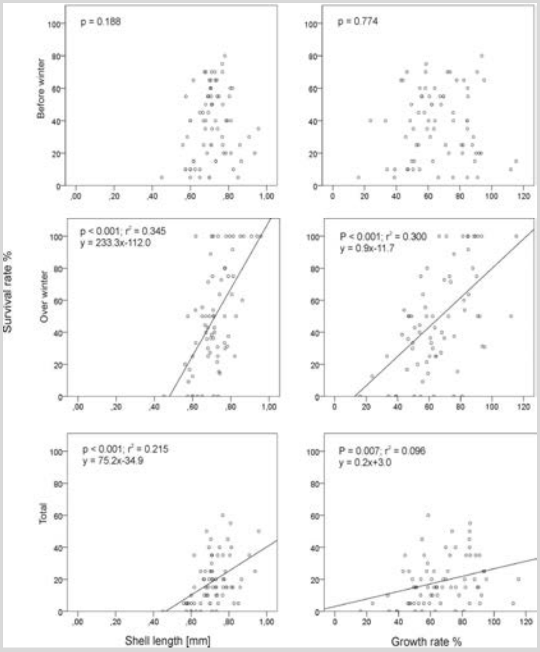

Figure 2: Before winter, over winter and total survival rates as a function of juvenile mussel shell length and growth rate.

Materials and Methods

During the cross experiment, performance (survival and growth) of four mussel stocks originating from the three main drainages in Central Europe, the Rhine, Danube and Elbe was investigated (Fig. 1). The juveniles were exposed in five study streams which were selected to integrate pearl mussel streams of different water qualities and recruitment status of the mussel population. Per study stream, five standard mesh cages containing an equal number of 20 (10 x 2) juvenile pearl mussels per stock in separate chambers were installed. Survival and growth rates of juveniles were checked after three months (i.e. before their first winter) and after nine months (i.e. after their first winter).

In addition, water temperature and food quality during exposures were analyzed. Water temperature was continuously monitored by temperature loggers. Detritus samples were collected from each stream and organic carbon, stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) and C/N ratios were measured.

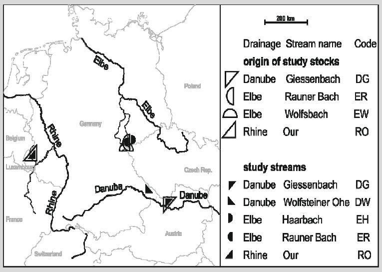

Figure 1: Location of mussel stock origin and study streams in relation to major Central European drainage areas. Codes are composed of initial letters of major drainage (first code letter) and mussel stock origin or study stream, respectively (second letter).

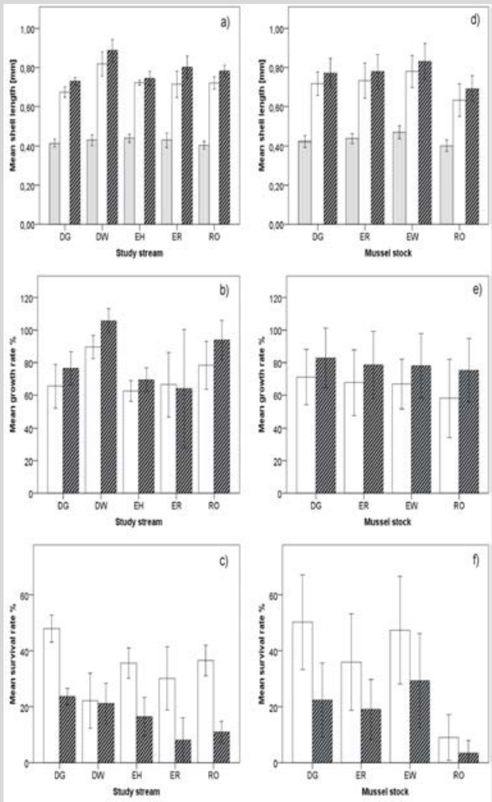

Figure 3: Study stream specific (a-c) and mussel stock-specific (d-f) initial (dotted bars), before winter (white bars) and total (shaded bars) mean shell lengths, growth rates and survival rates with standard deviations.

Results

Hypothesis 1:
Univariate general linear models revealed that study stream significantly influenced growth of juvenile mussels. However, with 40.9% (p<0.001) the variation in total survival was mainly expained by mussel stock compared to 15.0% (p=0.034) attributed to study stream conditions.

Hypothesis 2:
Total and over winter survival clearly increased with mussel shell length before winter as revealed by linear regression analyses (Fig. 2). Mussel shell length tended to be higher in streams with high growth rates of juvenile mussels.

Hypothesis 3:
No clear pattern was detected concerning local adaptation. Population DG performed best in its native stream and better than did non-native stocks in river DG. However, stock RO performed worse in its native habitat than was the case for non-native stock DG. Furthermore, trends in local adaptation depended on sampling time and could differ between sampling 1 and 2.

Hypothesis 4:
Based on the results in this study, juvenile mussels are suitable bioindicators as juvenile performance allowed to discriminate between habitats with higher and lower quality. Performance was best in streams DW and DG, which still hosted the biggest and healthiest mussel populations of the study streams (Fig. 3). Additionally, they revealed most favourable conditions concerning water and food quality as indicated by specific conductance, water temperature, organic carbon content and C/N ratios, respectively.

Conclusions

Mussels are suitable bioindicators as long as a careful consideration of stock-specificity is ensured to avoid false interpretation of bioindication results, especially when comparing results of different studies with various stocks. Some stocks performed better outside than inside their native habitats. Consequently, rearing of juveniles in non-native habitats is recommendable in case of low breeding success in native habitats to bridge the time which is needed to restore the stream and for the purpose of risk spreading.

Further readings

Denic M, Taeubert JE, Lange M, Thielen F, Scheder C, Gumpinger C, Geist J (2014) Influence of stock origin and environmental conditions on the survival and growth of juvenile freshwater pearl mussels (*Margaritifera margaritifera*) in a cross-exposure experiment. Limnologica: in press. DOI: 10.1016/j.limno.2014.07.005