Potential effects of water temperature and salinity on native and exotic mollusc species in the river Rhine

Laura N.H. Verbrugge, Aafke M. Schipper, Mark A.J. Huijbregts, Gerard van der Velde, A. Jan Hendriks & Rob S.E.W. Leuven; Institute for Water and Wetland Research; Radboud University Nijmegen, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands, e-mail: l.verbrugge@science.ru.nl

Abstract
We analyzed the effects of changes in water temperature and salinity on the species pool of freshwater molluscs in the river Rhine. Specific sensitivity distributions (SSDs) for maximum temperature and salinity tolerance were constructed for native and exotic mollusc species specific for the river Rhine. These SSDs were used to determine the potentially not occurring fractions (PNOFs) of each species group corresponding with the yearly maximum water temperature and salinity levels recorded in the river Rhine at Lobith over the last five decades. Rising river water temperatures turned out to have a much larger influence than changes in salinity levels on mollusc species occurrence. We also show that temperature rise disproportionally affects native compared to exotic mollusc species.

Introduction

Several large rivers in Western Europe show changing water temperatures and salinity, due to climate change and water pollution (control). Molluscs constitute a large share of the group of macroinvertebrates and play an important role in biogeochemical processes in rivers. This paper presents the results of a study on the influence of changes in water temperature and salinity on native and exotic mollusc species in the river Rhine (Verbrugge et al. submitted). We answer the following questions:

1. What are the temporal trends of the maximum water temperature and salinity of the river Rhine?
2. Which native and exotic mollusc species have been recorded in the river Rhine and what are their sensitivity distributions for temperature and salinity tolerance?
3. What are the impacts of changes in water temperature and salinity on the occurrence of both species groups?

Material and methods

Data on water temperature and chloride concentrations of the river Rhine at Lobith were obtained from www.waterbase.nl for the years 1910 to 2009 and 1950 to 2009, respectively. A list of freshwater mollusc species occurring in the river Rhine was compiled using field surveys (e.g., IKSR 2002; Leuven et al. 2009).

Photo 1. Mass deposit of exotic mollusc shells on the banks of the river Rhine in the Netherlands after flooding.

In total 34 native species and 10 exotic species were recorded. The database was completed with data on maximum temperature (T_{max}; ^{o}C) and salinity (S_{max}; ‰) at which these species were recorded in the field. A logistic distribution was used to calculate the PNOF (Eq. 1).

$$PNOF = \frac{1}{1 + e^{-(\frac{x-\alpha}{\beta})}} \quad (1)$$

where x represents the environmental stressor (T in °C or S in ‰) and the location parameter α equals the sample mean of the species-specific upper tolerance values. The scale parameter β of the logistic distribution depends on the sample standard deviation of the upper tolerance values (Aldenberg & Slob, 1993).

Results

The yearly maximum water temperature of the river Rhine increased over the period 1910-2009 (Fig. 1). The maximum chloride concentration shows an increase over the period 1950-1985 and a steep decline since the mid 1980s, as a result of effective water pollution control (i.e., international treaties concerned with a reduction in salt load of the river Rhine in 1976).

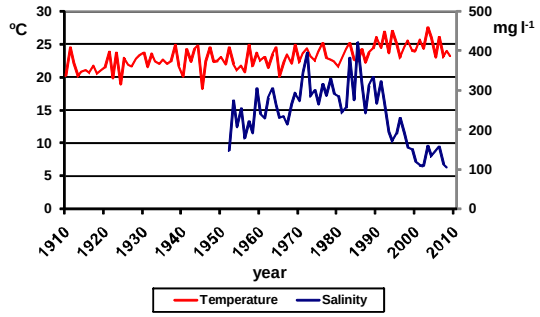

Figure 1. Maximum water temperature and chloride concentration of the river Rhine at Lobith.

Temperature tolerance data were found for 18 native and 8 exotic species, accounting for 53% and 80% of their species pools in the river Rhine, respectively. The maximum temperature tolerance of native species ranges from 24.0 to 32.0 °C. For exotic species this range is 29.5 to 37.0 °C (Fig. 2). The maximum temperature tolerance is significantly higher for exotic than for native species ($p < 0.01$). The SSDs for salinity were based on data for 33 native and 8 exotic species, constituting 97% and 80% of the species pools, respectively. Mean maximum salinity tolerance is not significantly different between native and exotic species ($p = 0.08$).

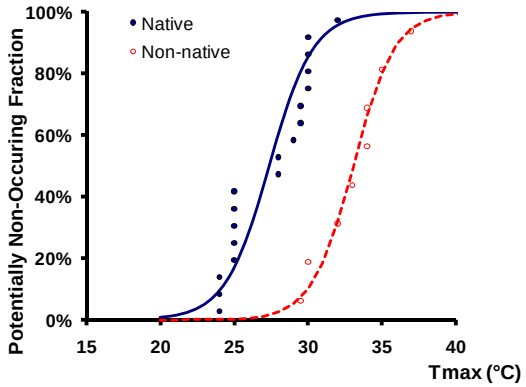

Figure 2. Example of species sensitivity distributions for maximum temperature tolerances of native and exotic molluscs specific of the river Rhine. The data points represent individual species' tolerances based on Hazen plotting positions.

Comparison of potentially not occurring fractions of species (PNOFs) reveal that temperature effects are greater than salinity effects (Table 1). Furthermore, the PNOFs for combined stress are higher for native species than for exotic species.

Discussion

Exotic mollusc species can tolerate higher maximum temperatures than native species. Increasing water temperature of the river Rhine has been attributed for 2/3 part to thermal pollution and for 1/3 part to global warming. The results of our study imply that reducing thermal pollution may mitigate loss of native biodiversity and species replacements in the river Rhine.

Furthermore, the construction and application of SSDs appeared a promising approach to address the separate and combined effects of changing abiotic conditions on species pools.

Table 1. Percentage potentially not occurring fraction (PNOF) of native and exotic mollusc species at Lobith, calculated using the yearly maximum water temperature, yearly maximum salinity and combined effect of both stressors under the assumption of additive effects.

Year	1960	1976	1990	2006
Temperature				
Native species	3.6	17.7	29.6	28.2
Non-native species	0.0	0.3	0.7	0.6
Salinity				
Native species	2.4	5.3	5.2	2.7
Non-native species	1.0	2.1	2.1	1.1
Combined				
Native species	5.9	22.0	33.3	30.2
Non-native species	1.1	2.4	2.7	1.7

Conclusions

- In total 44 mollusc species were recorded in the river Rhine, comprising 34 native species and 10 exotic species.
- Over the last five decades maximum water temperature of the river Rhine at Lobith increased with circa 0.5 ^{o}C per decade. Salinity levels at Lobith decreased since the mid 1980s.
- Exotic mollusc species tolerate higher maximum temperatures than native ones.
- Temperature appears to be a more important stressor than salinity in the river Rhine delta.
- Further increase in water temperature will deteriorate a higher percentage of native mollusc species than exotic ones.

References

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