The use of species sensitivity distributions and monitoring to predict the ecological effect of longitudinal training dams

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Introduction

Currently, longitudinal training dams (LTDs) are constructed in the river Waal near the city Tiel (The Netherlands). Traditional groynes are removed and replaced by LTDs which lie parallel to the river edge (Fig. 1). The LTDs are expected to positively influence navigation, maintenance costs and safe discharge of water and ice. Due to the parallel nature of LTDs, they are also expected to create refuges from dynamics caused by water displacements and waves of passing ships, possibly exerting a positive influence on species assemblages. Moreover, several parameters (e.g., oxygen, temperature) may become more favourable for riverine species due to decreased dynamics in flow velocity.

Figure 1: Cross section of a river with on the left bank traditional groynes and on the right bank a longitudinal training dam.

In order to fully understand, and even predict, the effect of these changing river conditions on species assemblages, species sensitivity distributions (SSDs) are being constructed. SSDs describe the variation among species in their sensitivity to an environmental factor. Using SSDs spatial and temporal predictions of the biodiversity can be made if data is available on 1) the limitation of species' resilience, and 2) the actual level of limiting environmental factors. Here, we present a spatio-temporal effect prediction of temperature, desiccation and salinity on native and non-native mollusc assemblages in the littoral zone of the river Rhine.

Extremely low discharge events and high water temperature events in north-western European rivers are expected to become more frequent and intense due to climate change (Van Vliet et al., 2013). In addition, the salinity of river water may increase due to lower discharges and stronger tidal influences in estuarine areas caused by sea level rising (Verbrugge et al. 2012). These changing conditions affect riverine biodiversity. This can be either a shift from cold-water to thermophilic species or, depending on the conditions, mortality of aquatic species due to desiccation induced by air exposure (Collas et al., 2014).

The mollusc assemblages of the river Rhine are dominated by non-native mollusc species. These non-native species have had a profound impact on biodiversity and ecosystem functioning. Understanding the responses of native and non-native species to changing river conditions will enable model predictions of climate change impact on riverine biodiversity and ecosystems.

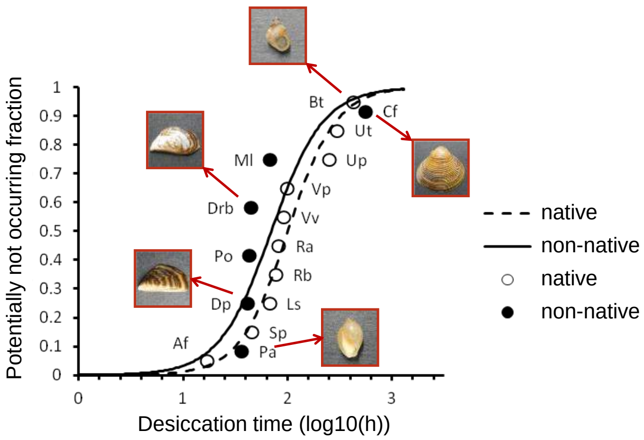

Figure 2. SSD based on the desiccation sensitivity of mollusc species, Abbreviations: Af: Ancylus fluviatilis; Pa: Physella acuta; Dp: Dreissena polymorpha; Drb: Dreissena rostriformis bugensis; Sp: Stagnicola palustris; Ls: Lymnaea stagnalis; Ml: Mytilopsis leucophaeata; Rb: Radix balthica; Ra: Radix auricularia; Vv: Viviparus viviparus; Vp: Valvata piscinalis; Up: Unio pictorum; Ut: Unio tumidus; Bt: Bithynia tentaculata, and Cf: Corbicula fluminea. (adapted from Collas et al., 2014).

Method

Mollusc SSDs were derived for desiccation, temperature and salinity (Collas et al. 2014; Verbrugge et al. 2012; Fig. 2). The mean and standard deviation of the derived SSDs were used to analyse the spatiotemporal trends of desiccation, water temperature, salinity and their combined effect on mollusc species in the littoral zone of the river Rhine (i.e., a groyne field near Lobith).

These effects were expressed as the potentially not occurring fraction (PNOF) of species. The combined effects of desiccation, temperature and salinity were calculated according to eq. 1:

$$(1) \quad PNOF_{DTS} = 1 - (1 - PNOF_D) * (1 - PNOF_T) * (1 - PNOF_S)$$

where *D*, *T* and *S* indicate desiccation, temperature and salinity, respectively. Subsequently, a model was constructed that depicts the spatiotemporal variation of combined effects of these stressors on potential species occurrence in the littoral zone. The water level, temperature and salinity data used in the model were obtained from a web-based portal (www.waterbase.nl; Fig. 3).

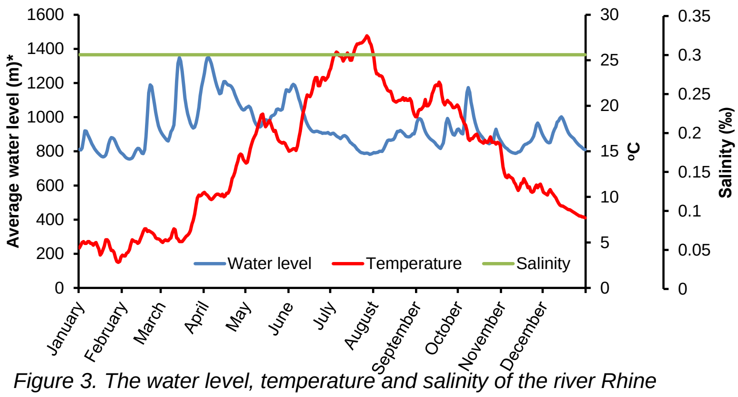

Figure 3. The water level, temperature and salinity of the river Rhine at Lobith during the year 2006 (Above average sea level).*

Results and discussion

Comparisons of the model predictions with field data on species occurrence during the period 1988-2003 revealed that the combined PNOF explained 62 and 80% of the actual not occurring fraction for native and non-native species, respectively (data not shown).

Predictions for a year with extremely low river discharges show that the combined effect of desiccation, temperature and salinity frequently limits the mollusc species occurrence in the littoral zone of the river Rhine at Lobith. However, this effect is due to desiccation and temperature limitation since there was no salinity based limitation at this location. The combined effect is higher for native species than for non-native species.

Native molluscs were additionally limited during June, July and August (Fig. 4A) opposed to non-native species (Fig. 4B). This difference is caused by the lower water temperature tolerance of native molluscs compared to non-native species (Verbrugge et al., 2012). A comparison of the combined PNOF results (Fig. 4) with the water level throughout 2006 (Fig. 3) reveals that the combined PNOF follows the same pattern as the water level. This similar pattern between the combined PNOF and water level indicates that desiccation is the primary environmental factor that determines diversity and composition of native and non-native mollusc assemblages.

The next step is to include other environmental factors (e.g. flow velocity, oxygen availability) and other species groups in the SSD-model. Moreover, field

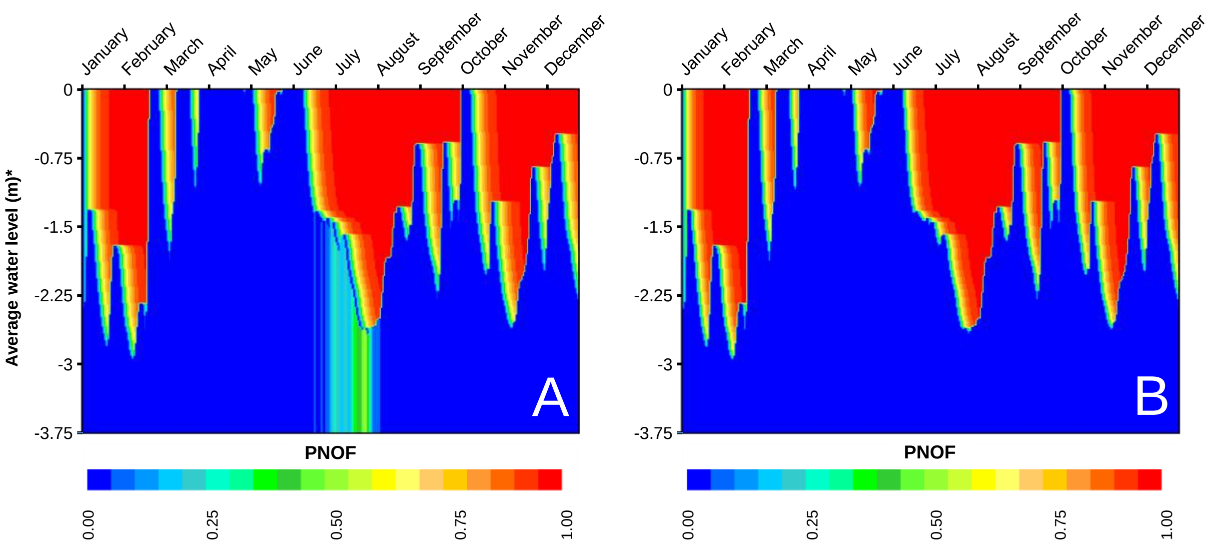

Figure 4. Potentially not occurring fraction (PNOF) due to the combined effect of desiccation, temperature and salinity on (A) native and (B) non-native molluscs in the littoral zone of the river Rhine at Lobith in the year 2006).

measurements of environmental factors and species occurrence will enable additional validation of the spatial and temporal model. Therefore, an extensive field monitoring campaign will be initiated in river sections with LTDs.

The focus of this campaign is twofold: 1) environmental factor measurements near sampling sites of species; 2) measurements of environmental factor levels throughout a year. Species will be sampled at a total of 12 sites of which 6 are located near an LTD. The other 6 sites are situated near other river structures (e.g. side channels, groynes and rip-rap banks; Fig. 5). At each site as many different habitats as possible will be sampled to get a good idea of the total species richness. The focus of the monitoring campaign is based on fish, snails, mussels, crayfish and amphipods. Flow velocity, water temperature, sediment concentration and type, water level, depth, oxygen availability and salinity will be monitored.

Conclusion

- The combined PNOF has a high explanatory value, indicating that SSDs are a useful tool to model species assemblages.
- Desiccation is the primary environmental factor that determines diversity and composition of the mollusc species pool in the littoral zone of the River Rhine.
- Throughout a year, native species are more limited by the three environmental factors than non-native species.
- The SSD approach can be used to predict the effect of climate change for the entire river continuum (from head waters to estuaries) or to determine the relative importance of each environmental factor at different river sections.
- The concept can also be applied for other river systems when river specific tolerance data of species are available.

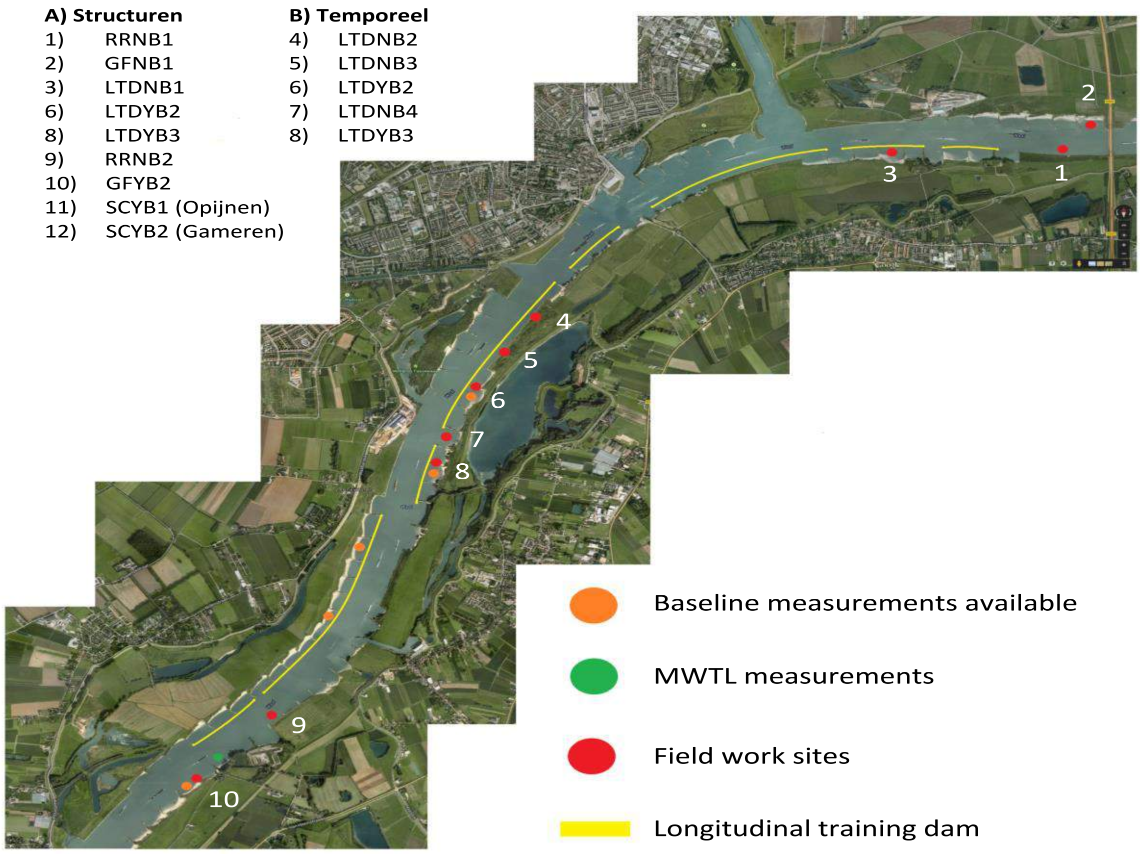

Figure 5. Overview of the different monitoring sites that will be monitored during the monitoring campaign.

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The results of this study have also been presented at the 2nd edition of the I.S. Rivers conference in Lyon (France).

References

Collas, F.P.L., Koopman, K.R., Hendriks, A.J., Van der Velde, G., Verbrugge, L.N.H., Leuven, R.S.E.W. (2014) Effects of desiccation on native and non-native molluscs in rivers. Freshwater Biology 59: 41-55.

Van Vliet, M.T.H., Franssen, W.H.P., Yearsley, J.R., Ludwig, F., Haddeland, I., Lettenmaier, D.P., Kabat, P. (2013) Global river discharge and water temperature under climate change. Global Environmental Change 23: 450-464.

Verbrugge, L.N.H., Schipper, A.M., Huijbregts, M.A.J., Van der Velde, G., Leuven, R.S.E.W. (2012) Sensitivity of native and non-native mollusc species to changing river water temperature and salinity. Biological Invasions 14: 1187-1199.