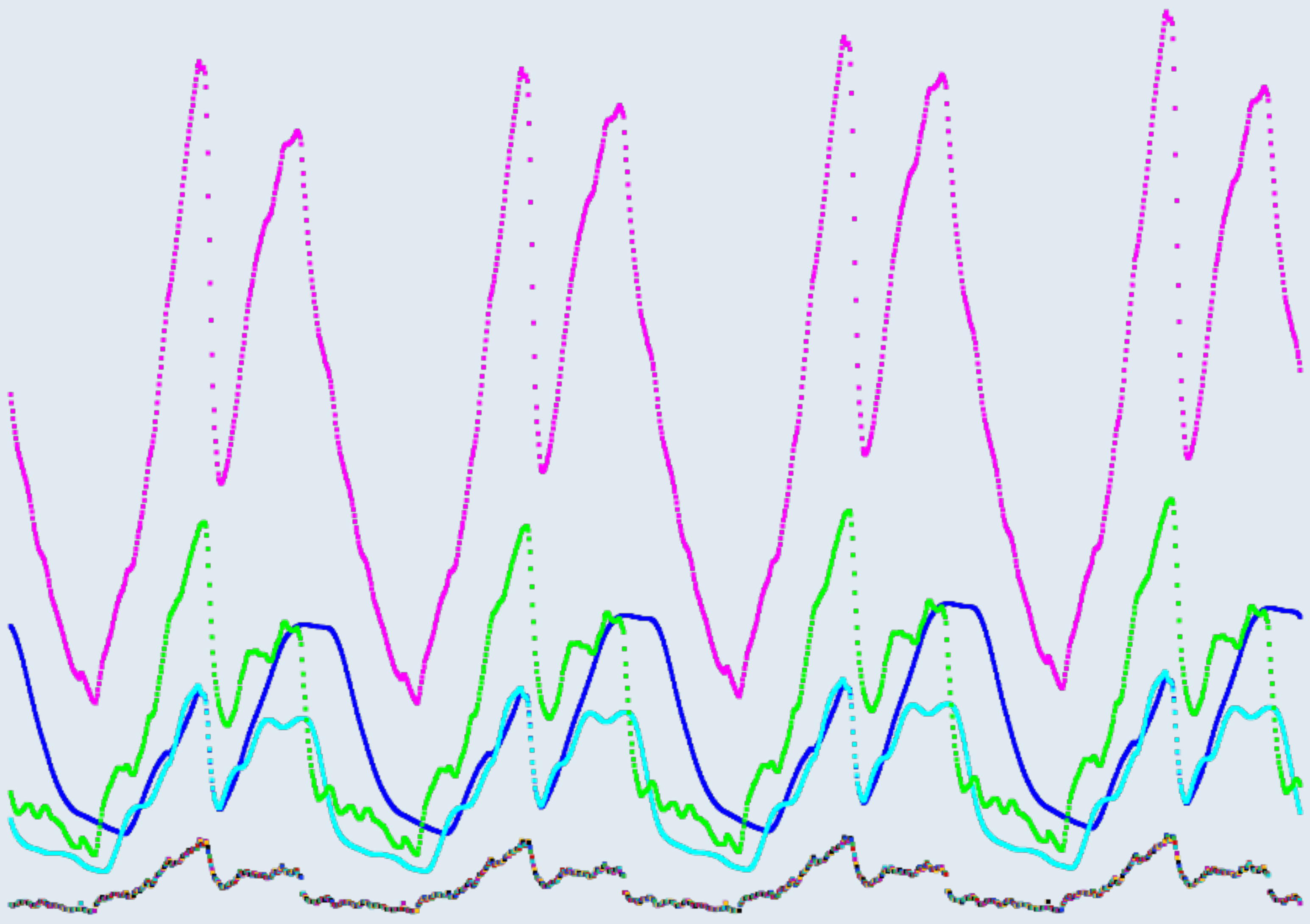

Effects of Climate change on Population interaction

Quantify the "who eats whom" in an aquatic food web under climate change scenarios and the uncertainties associated with it.

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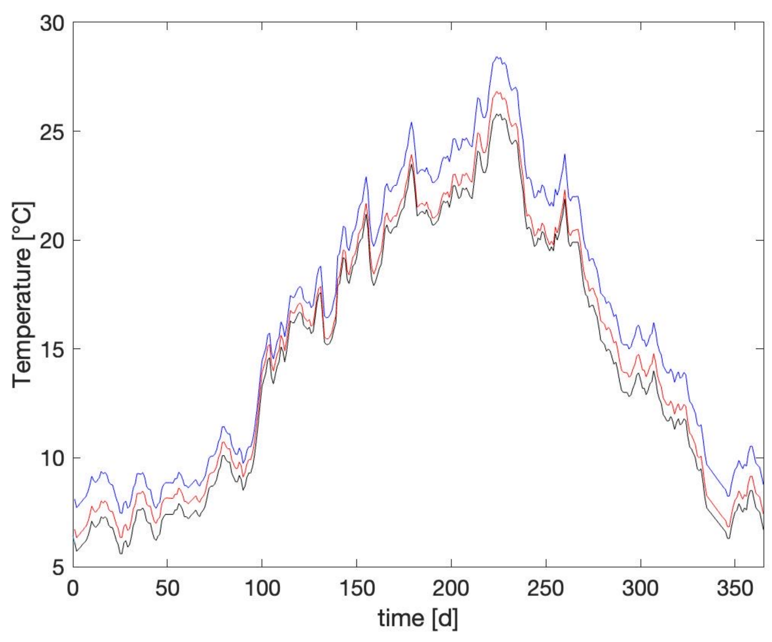
Introduction

If we are able to predict stability of food webs under environmental change, we can direct management to preservation of ecosystem services. As predator-prey relationships depend on individual size, all population models must be size-structured (Claessen et al., 2004). In the framework of a COMSOL® model, the range of individual size is represented as the geometry, and a transport-reaction equation is implemented for each species. The analysis presented here considers the interaction of perch *Perca fluviatilis*, round goby *Neogobius melanostomus*, and killer shrimp *Dikerogammarus villosus* in river Rhine. It is based on population specific analysis (Thapa, M. S., 2021; Minor R., 2020) and interaction analysis (Lazarev, K., 2021).

A fully coupled food web model combined with monitoring data should further explore these findings in future.

Methodology

FIGURE 1. Climate change scenarios for river Rhine were taken from Hardenbicker (2017). Salinity scenarios (not shown here) were communicated with Kirschbauer et al (2021).



For each species *j* a PDE on population density was solved balancing over growth ***G***, mortality *M* and reproduction *R* where each process depends on size *x* of the respective species, temperature *T* and salinity *s*.

The prey biomass due to predation ***P*** by perch was quantified.

Predator

$$\frac{\partial u_j}{\partial t} = \frac{\partial^2 (c\, u_j)}{\partial x^2} - \frac{\partial (G_j(T,s,x,\underline{u})\, u_j)}{\partial x} - M_j(T,s,x)\cdot u_j + R_j(T,s,x,u_j) - P_j(T,s,x,\underline{u})\cdot u_j$$

Intake *I*: Who eats how much?

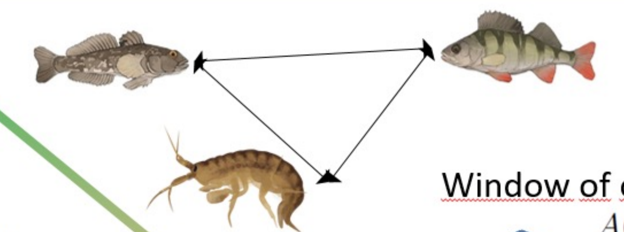
$$I(x,T) = \frac{\eta(x)\, r_C(T,x)}{1 + H(x)\,\eta(x)}$$

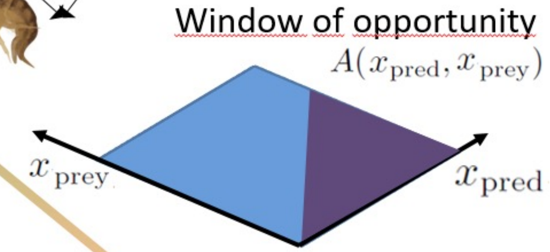
Encounter η

$$\eta(x_{\text{pred}}) = \int A(x_{\text{pred}}, x_{\text{prey}}) \cdot x_{\text{prey}} \cdot u_{\text{prey}}\, \mathrm{d}x_{\text{prey}}$$

Mortality μ: Who gets eaten?

$$\mu(x_{\text{prey}}, T) = \int \frac{A(x_{\text{pred}}, x_{\text{prey}})\, r_C(x_{\text{pred}}, T)\, u_{\text{pred}}}{1 + H(x_{\text{pred}}, T)\,\eta(x_{\text{pred}})}\, \mathrm{d}x_{\text{pred}}$$





Prey

$$\frac{\partial u_i}{\partial t} = \frac{\partial^2 (c\, u_i)}{\partial x^2} - \frac{\partial (G_i(T,s,x,\underline{u})\, u_i)}{\partial x} - M_i(T,s,x)\cdot u_i + R_i(T,s,x,u_i) - P_i(T,s,x,\underline{u})\cdot u_i$$

Results

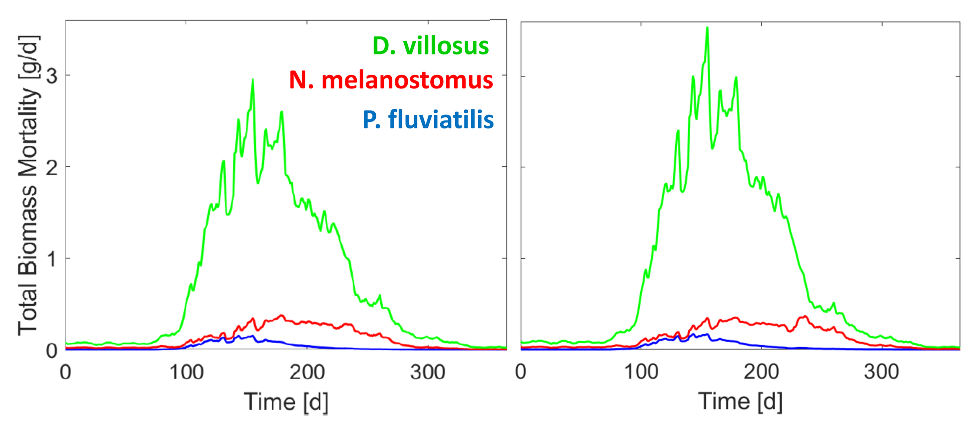
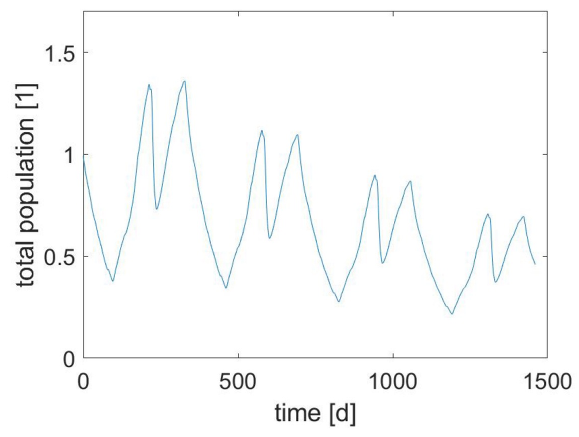


FIGURE 2. Total biomass undergoing predatory mortality by perch over time as quantified by interaction model, species-wise. Left: Reference conditions, right: near future climate change.

In a near future climate change scenario for Rhine, perch is not likely to experience a strong change in an assumed food composition of killer shrimp, round goby and own offspring.

For multiple stressors killer shrimps might reduce in number not due to direct lethal effects, but as growth gets too small for them to reach reproduction stage early enough to compensate for losses.

FIGURE 3. Total population of killer shrimp over a series of four years with an identical multiple stressor-scenario.



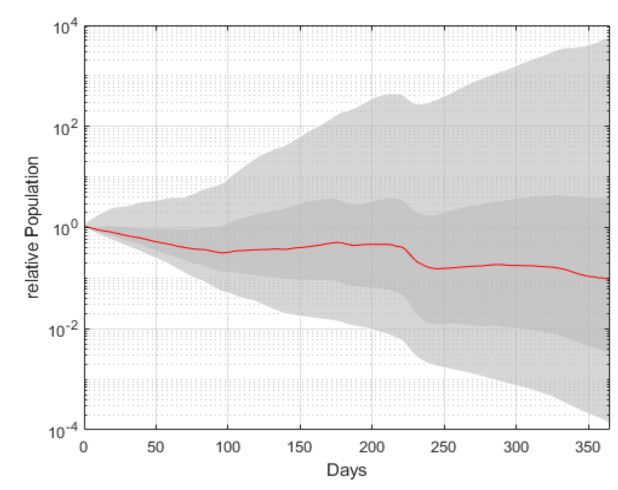


FIGURE 4. Total population of killer shrimp in reference year based on Monte Carlo simulations. Input is standard errors of parameters where known, and 10% elsewhere. Red: Median, Dark grey: 25 -25%, Light grey: 5% - 95 % quantiles.

If we take into account all parameter uncertainty stated in literature in a Monte Carlo simulation, total population of killer shrimp after one year in 5% - 95% quantiles spreads over eight orders of magnitude.

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