Supporting information

Modelling the impacts of multiple environmental stress factors on estuarine copepod populations

John C. Korsman* †, Aafke M. Schipper†, Lisette De Hoop†, Benoit Mialet §∥⊥, Tom Maris#,
Micky L.M. Tackx§∥, A. Jan Hendriks†

† Institute for Water and Wetland Research, Department of Environmental Science, Radboud University Nijmegen, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

§ EcoLab (Laboratoire Ecologie Fonctionnelle et Environnement), UPS, INP, Université de Toulouse, 118 Route de Narbonne, 31062 Toulouse, France

∥ EcoLab, CNRS, 31062 Toulouse, France

⊥ LIENSs (Littoral Environnement et Sociétés) UMR 7266, Université de La Rochelle-CNRS, 2 rue Olympe de Gouges, 17 000 La Rochelle, France

# Ecosystem Management Research Group, Department of Biology, University of Antwerp, Universiteitsplein 1C, B-2160 Wilrijk, Belgium

*Corresponding author *Phone: 0031-62-152-8190; e-mail: johnkorsman@hotmail.com
Contents supporting information:

**Text section S1**  
Derivation of equation 3.

**Table S1**  
Arithmetic mean values, ranges and numbers of measurements for the environmental stressor data.

**Figure S1**  
Measured and interpolated survival rates.

**Figure S2**  
The ratio of increase rates $r(S_i)/r(0)$ as a function of each individual stressor in the SE and the DZE, including the underlying environmental stressor data.

**Figure S3 and S4**  
The results of the sensitivity analyses.

**References**

**Number of pages**  
10
**Text section S1. Derivation of equation 3**

The ratio between the rates of increase of the population under contaminated conditions \( r(C) \) and reference conditions \( r(0) \) is calculated as:

\[
\frac{r(C)}{r(0)} = \left\{ \frac{-\ln\left(1 + \left(\frac{C}{LC_{50}}\right)^{\frac{1}{\beta}}\right) - \ln\left(1 + \left(\frac{C}{EC_{50}}\right)^{\frac{1}{\beta}}\right)}{\ln(R(0))} \right\} + 1 \quad \text{(Eq. S1)}
\]

with \( 1 + (C/LC_{50})^{\frac{1}{\beta}} = 1/f_L \) \quad \text{(Eq. S2)}

and \( 1 + (C/EC_{50})^{\frac{1}{\beta}} = 1/f_E \) \quad \text{(Eq. S3)}

where \( f_L \) and \( f_E \) represent the survival and reproduction under contaminated conditions, respectively, relative to the survival and reproduction rates in reference conditions.

Under the assumption that the effects of the various anthropogenic and natural stress factors included in this study are purely additive\(^2\), the ratio of increase rates of the population under multiple stress conditions \( r(S)/r(0) \) can be related to temperature \( T \), salinity \( S \), chlorophyll \( a \), and sediment concentrations of cadmium (Cd), copper (Cu) and zinc (Zn) according to

\[
\frac{r(S)}{r(0)} = \left\{ \frac{-\ln\left(1 + \frac{1}{f_{LT}}\right) - \ln\left(1 + \frac{1}{f_{LS}}\right) - \ln\left(1 + \frac{1}{f_{LCa}}\right) - \ln\left(1 + \frac{1}{f_{LCu}}\right) - \ln\left(1 + \frac{1}{f_{LZn}}\right) - \ln\left(1 + \frac{1}{f_{ET}}\right) - \ln\left(1 + \frac{1}{f_{ES}}\right) - \ln\left(1 + \frac{1}{f_{ECa}}\right) - \ln\left(1 + \frac{1}{f_{ECu}}\right) - \ln\left(1 + \frac{1}{f_{EZn}}\right)}{\ln(R(0))} \right\} + 1 \quad \text{(Eq. S4)}
\]
**Table S1.** Measured values for *Eurytemora affinis* abundance (ind·m\(^{-3}\)), temperature (°C), salinity (‰), chlorophyll *a* (µg chl *a*·L\(^{-1}\)), metal concentrations (mg·kg\(^{-1}\) dry weight) and total organic carbon (% TOC) in the SE and the DZE from 2003 through 2006

<table>
<thead>
<tr>
<th>Variable</th>
<th>SE</th>
<th>DZE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>range</td>
</tr>
<tr>
<td><em>E. affinis</em> adults</td>
<td>996.5</td>
<td>20 − 5.3·10(^3)</td>
</tr>
<tr>
<td>Temperature</td>
<td>14.0</td>
<td>4.7 − 25.2</td>
</tr>
<tr>
<td>Salinity</td>
<td>9.8</td>
<td>2.8 − 15.4</td>
</tr>
<tr>
<td>Chlorophyll <em>a</em></td>
<td>5.9</td>
<td>1.0 − 28.0</td>
</tr>
<tr>
<td>Cd</td>
<td>4.0</td>
<td>0.9 − 7.1</td>
</tr>
<tr>
<td>Cu</td>
<td>66.5</td>
<td>46.5 − 214.4</td>
</tr>
<tr>
<td>Zn</td>
<td>399.8</td>
<td>310.0 − 598.0</td>
</tr>
<tr>
<td>TOC</td>
<td>3.8</td>
<td>2.9 − 4.9</td>
</tr>
</tbody>
</table>
Figure S1. The observed survival fractions by Devreker et al.\textsuperscript{3} and the interpolated survival fractions.
Figure S2. The ratio of increase rates of the population $r(S_i)/r(0)$ calculated for the Scheldt Estuary (SE) and the Darß-Zingst Estuary (DZE) as a function of (A) temperature, (B) salinity, (C) chlorophyll $a$, (D) cadmium, (E) copper, and (F) zinc.
Figure S3. Results of the sensitivity analysis with changes in (A) survival parameters (reproduction parameters unchanged) and (B) reproduction parameters (survival parameters unchanged). The value of the slope of the curve $a$ was changed by -15%, +15% and 0%, representing higher, lower and no change in tolerance to temperature, respectively. The optimal temperature $T_R$ was changed by -2°C, 2°C and 0°C.
Figure S4. The effect of a 0.5°C change in water temperature on the population density $N(t)$ in DZE.
References

