Supporting information

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

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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[1]:

$$\frac{r(C)}{r(0)} = \frac{\left(-\ln\left(1+\left(\frac{C}{LC50}\right)^{1/\beta}\right) - \ln\left(1+\left(\frac{C}{EC50}\right)^{1/\beta}\right)\right)}{\ln(R(0))} + 1 \qquad \text{(Eq. S1)}$$

with $1+(C/LC50)^{1/\beta} = 1/f_L$ (Eq. S2)

and $1+(C/EC50)^{1/\beta} = 1/f_E$ (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

$$\frac{r(S)}{r(0)}$$

$$= \frac{\left(-\ln\left(\frac{1}{f_{L,T}}\right)\cdot\left(\frac{1}{f_{L,S}}\right)\cdot\left(\frac{1}{f_{L,\mathrm{Chl\,a}}}\right)\cdot\left(\frac{1}{f_{L,Cd}}\right)\cdot\left(\frac{1}{f_{L,Cu}}\right)\cdot\left(\frac{1}{f_{L,Zn}}\right) - \ln\left(\frac{1}{f_{E,T}}\right)\cdot\left(\frac{1}{f_{E,S}}\right)\cdot\left(\frac{1}{f_{E,\mathrm{Chl\,a}}}\right)\cdot\left(\frac{1}{f_{E,Cd}}\right)\cdot\left(\frac{1}{f_{E,Cu}}\right)\cdot\left(\frac{1}{f_{E,Zn}}\right)\right)}{\ln(R(0))} + 1$$

$$= \frac{\left(-\ln\left(\prod_{n=1}^{i}\frac{1}{f_{L,i}}\right) - \ln\left(\prod_{n=1}^{i}\frac{1}{f_{E,i}}\right)\right)}{\ln(R(0))} + 1 \qquad \text{(Eq. S4)}$$

Table S1. Measured values for *Eurytemora affinis* abundance (ind.$\cdot$m^{-3}), temperature (°C), salinity (‰), chlorophyll *a* (µg chl *a*$\cdot$L^{-1}), metal concentrations (mg$\cdot$kg^{-1} dry weight) and total organic carbon (% TOC) in the SE and the DZE from 2003 through 2006

Variable	SE			DZE		
	mean	range	n	mean	range	n
E. affinis adults	996.5	20 – $5.3\cdot10^{3}$	32	$3.6\cdot10^{3}$	0 – $5.3\cdot10^{4}$	142
Temperature	14.0	4.7 – 25.2	106	10.3	-0.6 – 25.2	$1.4\cdot10^{3}$
Salinity	9.8	2.8 – 15.4	47	6.2	2.8 – 12.0	$1.4\cdot10^{3}$
Chlorophyll *a*	5.9	1.0 – 28.0	106	50.6	11.1 – 124.1	$1.4\cdot10^{3}$
Cd	4.0	0.9 – 7.1	105	0.5	0.5 – 0.6	6
Cu	66.5	46.5 – 214.4	105	32.8	17.1 – 42.0	6
Zn	399.8	310.0 – 598.0	105	182.4	144.0 – 207.0	6
TOC	3.8	2.9 – 4.9	105	6.2	5.5 – 6.8	7

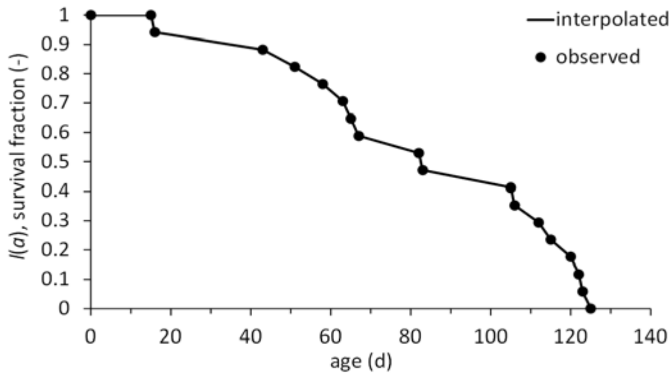
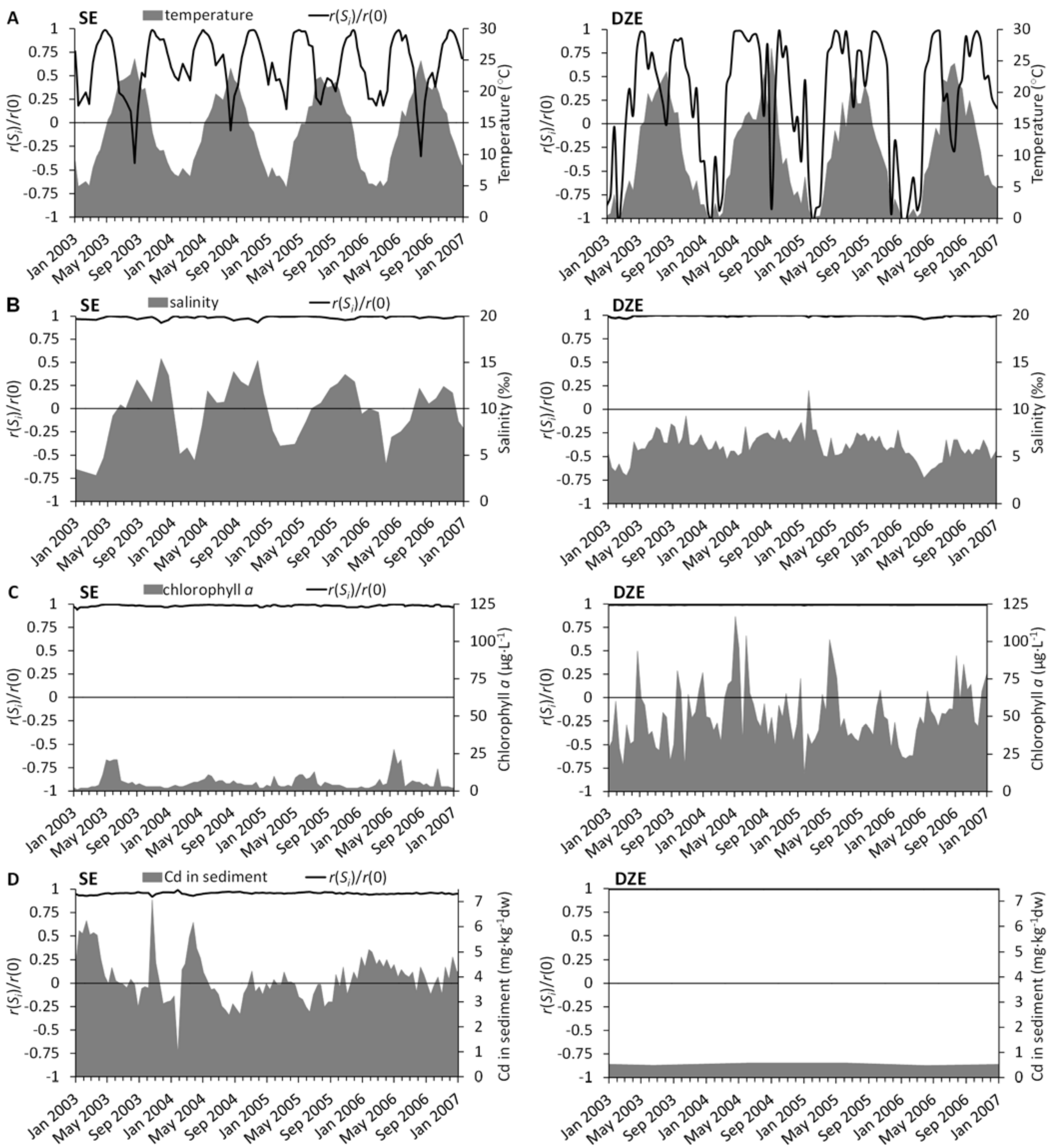


Figure S1. The observed survival fractions by Devreker et al.[3] and the interpolated survival fractions.


A
SE
temperature
r(S_i)/r(0)
Temperature (°C)
DZE
B
SE
salinity
Salinity (‰)
DZE
C
SE
chlorophyll a
Chlorophyll a (µg·L-1)
DZE
D
SE
Cd in sediment
Cd in sediment (mg·kg-1dw)
DZE
Jan 2003
May 2003
Sep 2003
Jan 2004
May 2004
Sep 2004
Jan 2005
May 2005
Sep 2005
Jan 2006
May 2006
Sep 2006
Jan 2007

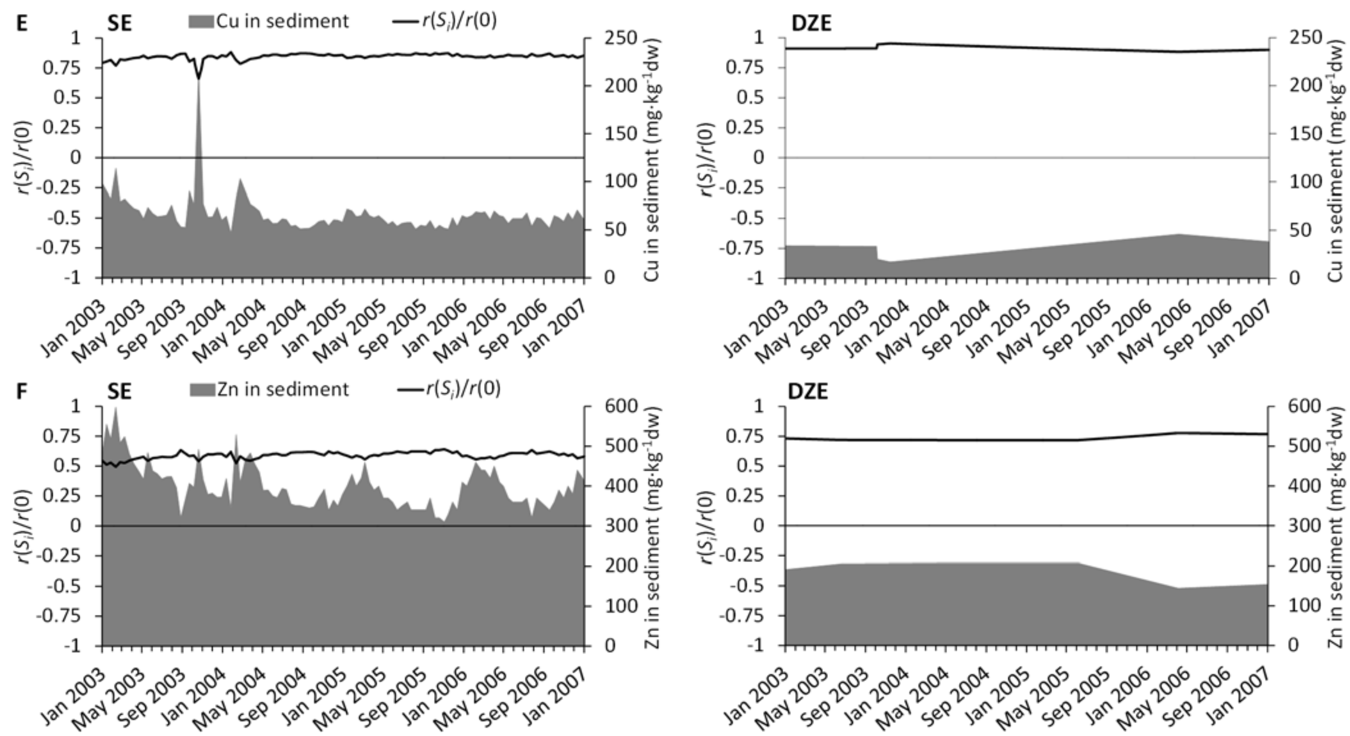


Figure S2. The ratio of increase rates of the population $r(S_i)/r(0)$ calculated for the Scheldt Estuary (SE) and the Darß-Zingst Estuary (DZE) as a function of (A) temperature, (B) salinity, (C) chlorophyll *a*, (D) cadmium, (E) copper, and (F) zinc.

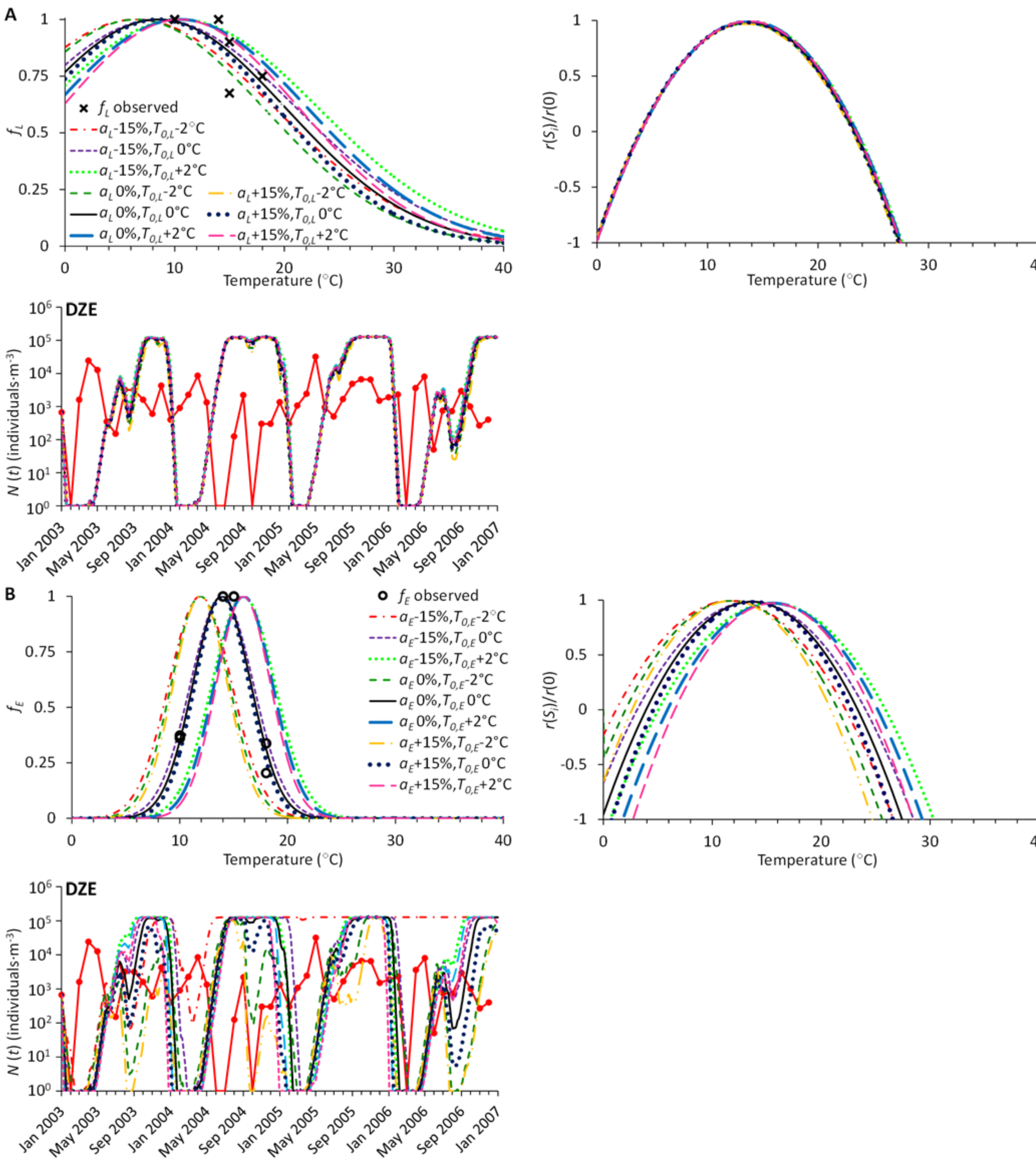


Figure S3. Results of the sensitivity analysis with changes in (A) survival parameters (reproduction parameters unchanged) and (B) reproduction parameters (survival parameters unchanged). The value of the slope of the curve *a* was changed by -15%, +15% and 0%, representing higher, lower and no change in tolerance to temperature, respectively. The optimal temperature T_0 was changed by -2°C, 2°C and 0°C.

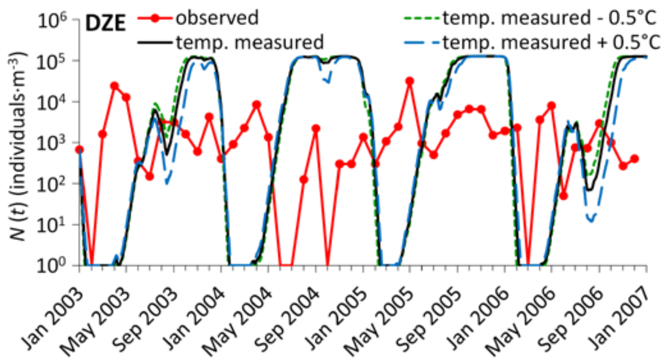


Figure S4. The effect of a 0.5°C change in water temperature on the population density $N(t)$ in DZE.

References

(1) Hendriks, A. J.; Enserink, E. L. Modelling response of single-species populations to microcontaminants as a function of species size with examples for waterfleas (*Daphnia magna*) and cormorants (*Phalacrocorax carbo*). *Ecol. Model.* **1996,** *88* (1-3), 247-262.

(2) Sibly, R. M.; Williams, T. D.; Jones, M. B. How environmental stress affects density dependence and carrying capacity in a marine copepod. *J. Appl. Ecol.* **2000,** *37* (3), 388-397.

(3) Devreker, D.; Pierson, J. J.; Souissi, S.; Kimmel, D. G.; Roman, M. R. An experimental approach to estimate egg production and development rate of the calanoid copepod *Eurytemora affinis* in Chesapeake Bay, USA. *J. Exp. Mar. Biol. Ecol.* **2012,** *416*, 72-83.