Impact of temperature on species sensitivity distribution in aquatic invertebrates

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Aim: Extrapolating toxic effects across temperatures by using the Arrhenius function and investigate the impact of temperature on a SSD with aquatic invertebrates.

Introduction

- Aquatic effect assessment uses results from laboratory experiments
- Test organisms are kept under constant environmental conditions which might differ across species (e.g. temperature)
- Results are used to statistically derive community level endpoints (e.g. HC5 from species sensitivity distributions (SSDs))
- LC_{50}s have been reported to depend on ambient temperature [1] → problems when comparing species sensitivities
- Changes in physiological rates at different temperature regimes can be described by the Arrhenius function [2].
- → Examine if the Arrhenius function is also able to predict TKTD model rates, such as GUTS [3], for different temperatures

Methods

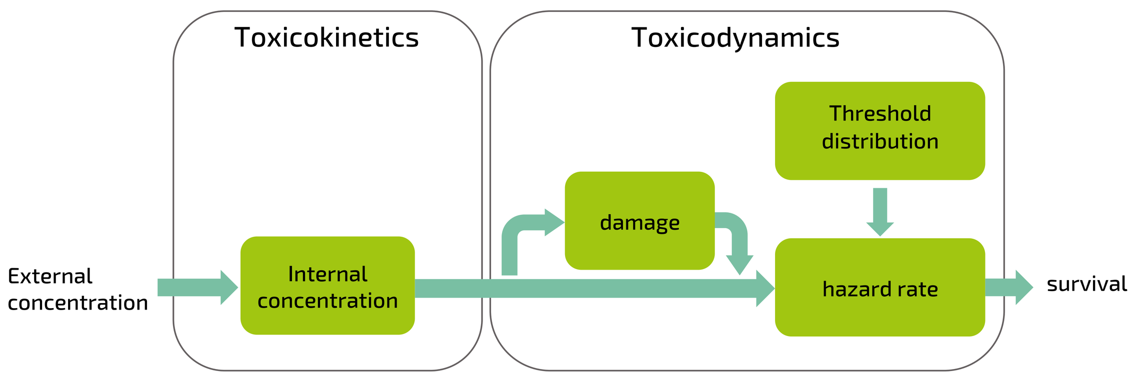
Species: *Asellus aquaticus*, *Daphnia magna*, *Ceriodaphnia dubia*, *Epeorus assimilis*, *Chaoborus crystallinus*, *Gammarus fossarum*, *Cloeon dipterum*, *Rhithrogena semicolorata*

- Temperature range 12-25°C
- Temporally resolved data from acute toxicity test with Chlorpyrifos (CPF) for all species, analysed with GUTS [3]

Model assumptions and parametrizations

- General unified threshold model of survival (GUTS)[3] with scaled internal concentration as dose metric and stochastic death as toxicodynamic assumption
- output: parameter values for k_e, k_k, z and modelled LC_{50} after 96h

GUTS



Schematic structure of GUTS according to Jager et al. 2011 [3]

Temperature correction

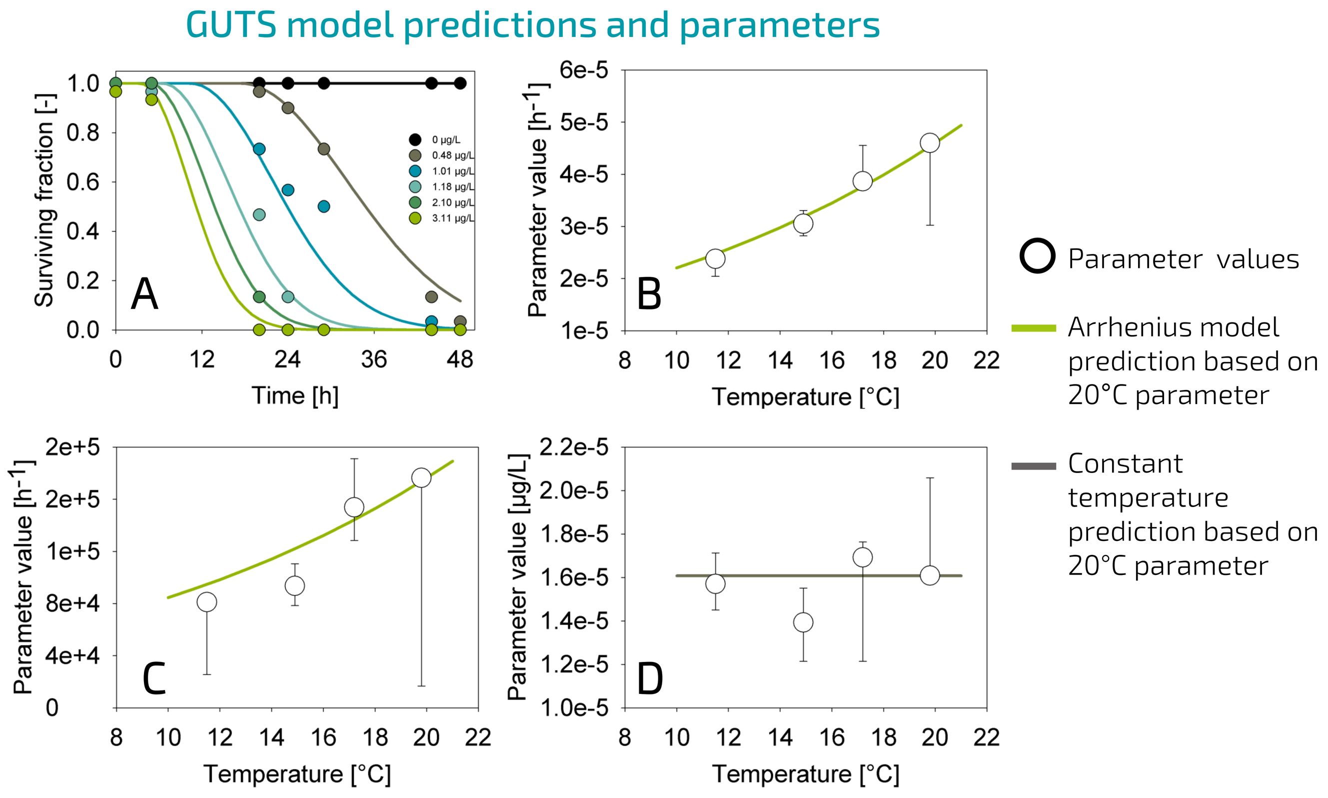
$$f_T := e^{\left(\frac{TA}{T_{ref}+273.15} - \frac{TA}{T+273.15}\right)}$$

T_{ref} : reference temperature (original test temperature)
TA : Arrhenius temperature (species specific)
T : desired temperature

Arrhenius temperature taken from species specific entries in Add-my-Pet database [4]

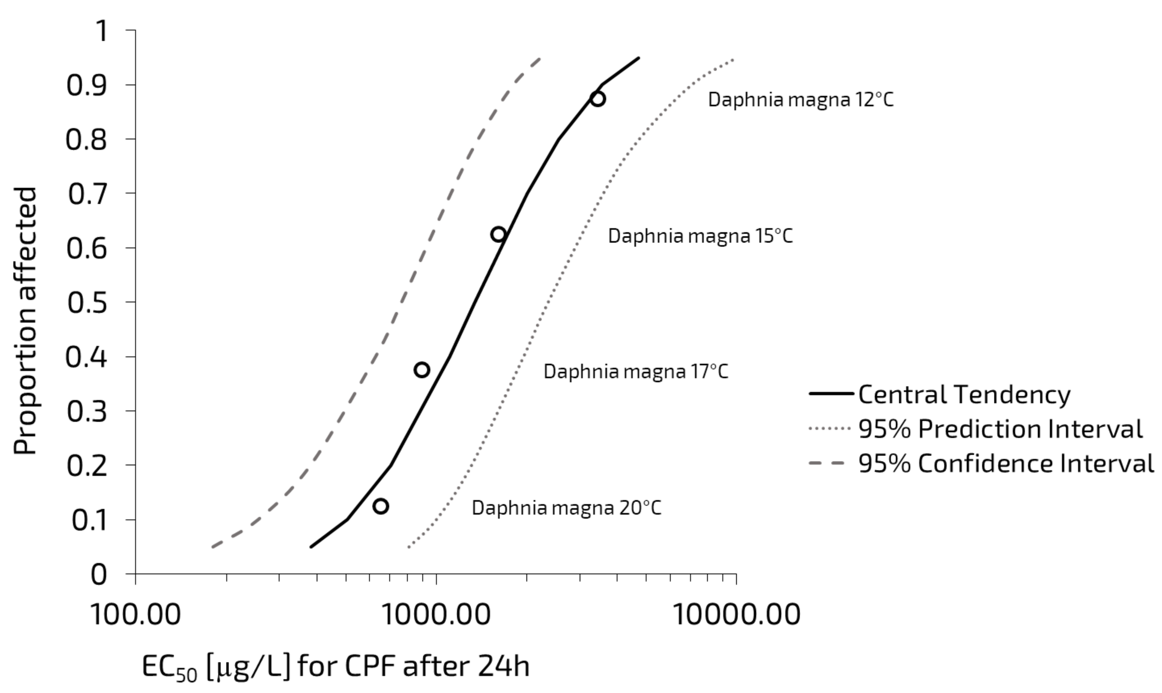
Results

GUTS model predictions and parameters



A GUTS model fit for 48 hours toxicity test with *Daphnia magna* and Chlorpyrifos at 17 °C.
B dominant rate constant k_e
C slope parameter k_k
D effect threshold z

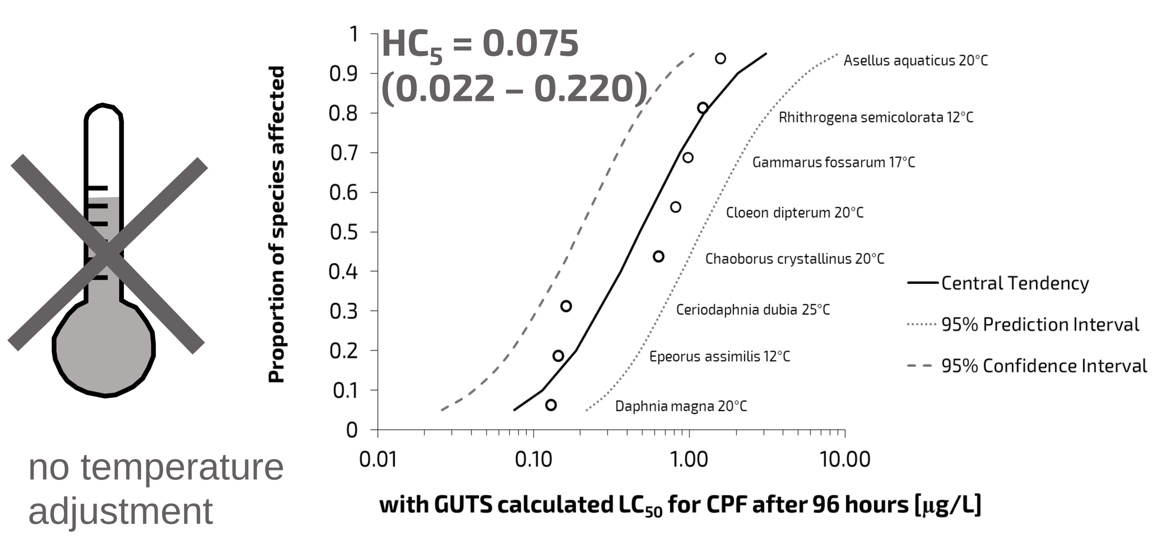
Temperature dependent EC_{50} values of *Daphnia magna*



Calculated EC_{50} 24h values from 4 acute toxicity tests with *Daphnia magna* at different temperatures

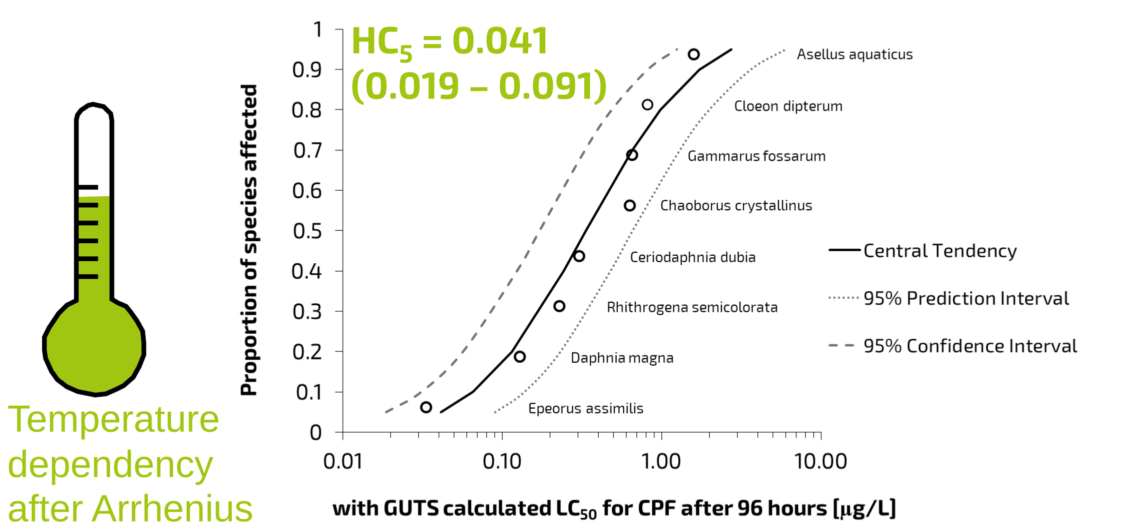
- GUTS is able to predict effects of acute toxicity tests
- The GUTS parameters k_e and k_k show temperature dependency which can be predicted by Arrhenius function for *Daphnia magna*
- GUTS parameter z is independent of temperature
- EC_{50} values of Daphnia magna show temperature dependency

SSD for 8 macroinvertebrate species



Species sensitivity distribution of 8 aquatic invertebrates regarding Chlorpyrifos based on LC_{50} 96h values calculated with GUTS. Measured concentration in microgram per litre (log-scale) and potentially affected fraction. Temperature range: 12—25°C

SSD for 8 macroinvertebrate species after temperature adjustment



Species sensitivity distribution of 8 aquatic invertebrates regarding Chlorpyrifos based on LC_{50} 96h values calculated with GUTS. Measured concentration in microgram per litre (log-scale) and potentially affected fraction. Temperature range: 12—25°C

species	Original test temperature	LC_{50} 96h	LC_{50} 96h after temperature correction to 20°C	Tendency of effect concentration
Ceriodaphnia dubia	25°C	0.162216	0.305388	↗
Chaoborus crystallinus	20°C	0.634113	0.634113	-
Cloeon dipterum	20°C	0.816305	0.816305	-
Daphnia magna	20°C	0.12906	0.12906	-
Epeorus assimilis	12°C	0.143746	0.033371	↘
Gammarus fossarum	17°C	0.978526	0.655052	↘
Rhithrogena semicolorata	12°C	1.22474	0.229457	↘
Asellus aquaticus	20°C	1.58924	1.58924	-

- Temperature adjustment of the GUTS parameters k_e and k_k resulted in different LC_{50}s (the higher the temperature the more sensitive is the organism to a toxicant) which then induced a shift in the SSD
- HC_5 from SSD is affected, noticeable in a lower value and smaller range of the confidence intervals

Conclusions

- With temperature correction the SSD are different, because the ranking of species is affected
- A comparison of toxic effects over different species and temperatures is now possible assuming the same temperature dependency as for *D. magna*
- Especially for the lower temperatures the adjustment is necessary→ otherwise risk of underprediction of effects
- Useful for the risk assessment in order to set reliable No effect thresholds

[1] Cairns J, Heath AG, Parker BC. 1975. The effects of temperature upon the toxicity of chemicals to aquatic organisms. Hydrobiologia 47(1):135-171
[2] Kooijman SALM. 2010. Dynamic energy budget theory for metabolic organization. Cambridge University Press, Cambridge. 514p.
[3] Jager et al. 2011. General unified threshold model of survival—a toxicokinetic–toxicodynamic framework for ecotoxicology. Environ Sci Technol 45:2529–2540
[4] Add-my-Pet, 2018. Database of code, data and DEB model parameters (bio.vu.nl/thb/deb/deblab/add_my_pet/index.html
SSD generator: *water.rutgers.edu/TMDLs/SI/SSD_Generator_V1.xls*

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