Institute for Environmental Research

MODELLING TOXIC EFFECTS ON *DAPHNIA MAGNA* POPULATIONS UNDER NATURAL FIELD CONDITIONS

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Introduction

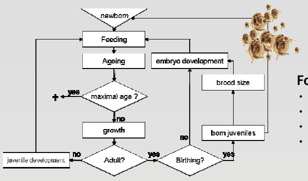
Daphnia magna is one of the most important aquatic test organisms for ecological risk assessment of pesticides, biocides, and industrial chemicals. Despite the large amount of data available on the effects of various toxicants on *D. magna*, it is often difficult to extrapolate from laboratory results to complex field situations.

To assess the relevant ecological impact on this species we developed a mechanistic population modelling approach to simulate the seasonal dynamics of the daphnids under more realistic field conditions. The individual based *Daphnia magna* population model (IDamP) was coupled with a complex lake model (Stoichiometric Lake Model, StoLaM). Both models were implemented and validated independently, but no further calibration of the coupled model was conducted.

IDamP-Model

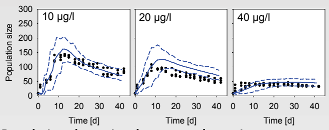
The IDamP model (Preuss et al. 2009):

- calibrated on individual level
- tested on individual and population level for
  - different food concentrations & scenarios
  - constant exposure (3,4-dichloroanline, nonylphenol)

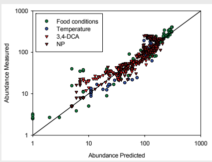


Forcing functions:
- Food
- Density
- Temperature
- Toxicant

Conceptual diagram of the asexual life-cycle of *Daphnia magna* in the IDamP model



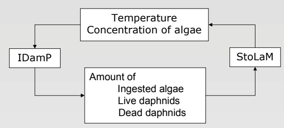
Population dynamics depent on the various concentrations of 3,4-dichloroanline at constant exposure



Predicted vs. measured abundance as dependent on various forcing functions. Dots show average abundance at each time point, for controls and all treatments (i.e. concentrations of the test item)

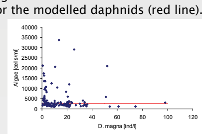
Interface

- In contrast to the laboratory studies with daily feeding of the daphnids, the food supply in the field and in the model depends on the dynamic growth of the algae.
- **In the coupled model, the food web complexity has been reduced to only one algae species (*Desmodesmus subspicatus*) and the daphnid population.**
- Algal growth depends on weather conditions, nutrient supply and daphnid grazing pressure. The population dynamics of the daphnids is controlled by water temperature and algal productivity.



Data exchange between IDamP and StoLaM

Laboratory microcosm studies implicate that daphnids can not use the total amount of suspended algae, one dataset is shown (Weyermann 1992). Even at high daphnid densities a low concentration of algae still remains in the water column. Therefore a minimum algae concentration of 2600 cells ml^{-1} was assumed unavailable for the modelled daphnids (red line).

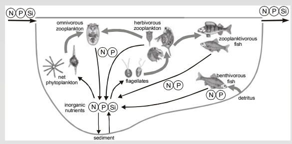


Correlation of measured daphnid density and algae concentration in laboratory microcosms

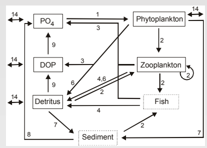
StoLaM-Model

The StoLaM model (Strauss 2009) comes as a one-dimensional hydrodynamic-ecological lake model to predict nutrient cycling and plankton succession in ponds and lakes, including

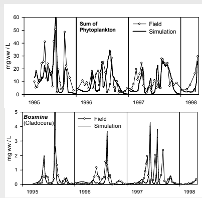
⇒ a hydrodynamic module to simulate underwater light climate and water temperature from measured weather data
⇒ up to 10 phytoplankton and zooplankton species in terms of biomass
⇒ complex nutrient cycles for nitrogen, phosphorus and silicon



Schematic of the food web interactions implemented including the main nutrient fluxes within the water column

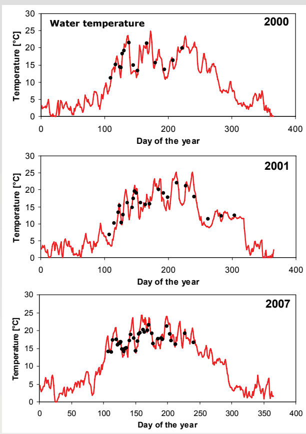


Nutrient cycle of phosphorus
1: assimilation; 2: grazing;
3: excretion; 4: egestion;
6: mortality; 7: sedimentation;
8: sediment release;
9: remineralisation;
14: in- and outflow.



Exemplary validation data:
Measured and simulated population dynamic of a zooplankton species (*Bosmina longirostris*) and the sum of phytoplankton in a eutrophic shallow lake (means for the epilimnion in 0-2 m water depth over a three-year period)

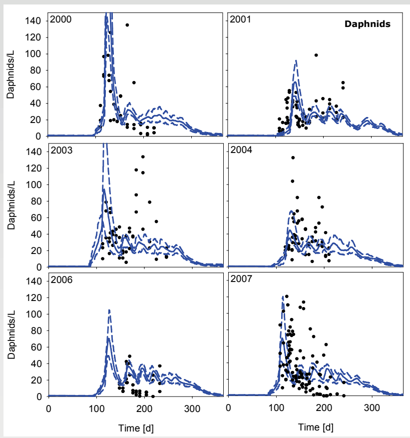
Simulation Results



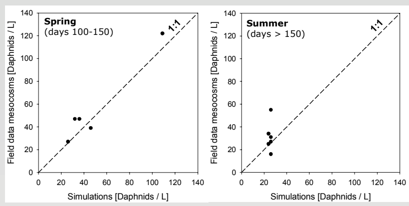
Simulated and measured water temperatures in control mesocosms of three specific years
(mesocosm facilities at the RWTH Aachen University)

- The model was tested using mesocosm data to show its applicability in the prediction of the general *Daphnia* population pattern found in outdoor ponds.
- **Simulations of specific years differ only in the measured weather scenarios and in the trophic state (phosphorus release rates) of the sediment.**

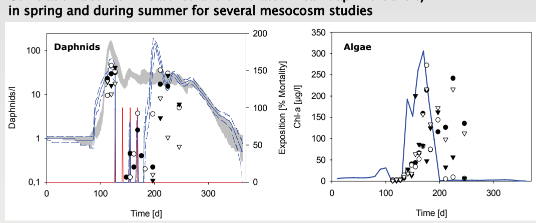
Mesocosm facility at gaiac, RWTH Aachen University, Germany



Simulated and measured daphnid abundance for control mesocosms
The measured concentration of daphnids in the controls of the mesocosm facility in Aachen during six specific years (three replicates each year) are shown as black dots and the simulation results, average and 95%-confidence limits, as blue lines.



Correlation between measured and simulated mean daphnid density in spring and during summer for several mesocosm studies



Comparison of simulation and measured data for direct and indirect effects of insecticide-treated mesocosms (4 high dose replicates)
Each of the two replicates for the two highest concentrations are shown as symbols, the exposure as red lines, and the simulation as blue lines (average and 95% confidence limit). The simulation of the control range is shown in grey

Conclusions

⇒ The prediction of water temperature indicates a realistic simulation of the physical environment in the mesocosms in terms of light, temperature and turbulence.
⇒ Despite the simplicity of the food web in the model, the predicted daphnid abundance is in good accordance with the general population dynamics measured under field conditions.
⇒ The presented model is able to reproduce both the general pattern of a toxic adverse effect on daphnids and time to recovery.
⇒ Also the indirect effect on algae biomass caused by grazing pressure, weather conditions, and nutrient availability was captured by the model for most of the replicates.

Outlook

This model approach has proven to be a useful tool in the extrapolation of acute and chronic effects from standard biotests in the laboratory (OECD 202 & 211) to populations of *D. magna* under natural field conditions.

Preuss et al. (2009), Ecol. Model. 220, 310-329
Strauss (2009): PhD-Thesis, RWTH Aachen
Weyermann (1992): Diploma Thesis, RWTH Aachen