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DENSITY-DEPENDENT COMPENSATION OF TOXIC EFFECTS IN *CHAOBORUS CRYSTALLINUS* POPULATIONS – AN INDIVIDUAL-BASED SIMULATION STUDY

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Introduction

The recovery time of chemically stressed populations in aquatic outdoor mesocosms studies is essential for the risk assessment of pesticides. Density-dependent processes like cannibalism or emigration are important factors for the regulation of population density in many species which have high reproduction rates and exceed their carrying capacity temporarily. The organism we investigated was the aquatic phantom midge *Chaoborus crystallinus*, which is a common pelagic invertebrate predator in ponds. *C. crystallinus* is a multivoltine species, producing up to several hundred eggs per female and is frequently very sensitive to insecticide toxicity. In experimental studies we found, that at high larval density there was a high mortality rate of more than 80 % mainly caused by cannibalism. With an individual-based population model for *Chaoborus crystallinus*, scenarios with varying initial population densities, food conditions and insecticide concentrations have been analysed to assess the density-dependent population sensitivity to insecticides and its recovery time.

Modeling approach

Population dynamic of *Chaoborus crystallinus* was simulated depending on larval starting densities, food conditions, water temperature and photo period. Whole populations of isolated treated and control ponds (volume: 3.1 m³) were modelled under outdoor weather conditions. Population dynamics emerge from the behaviour of the individuals.

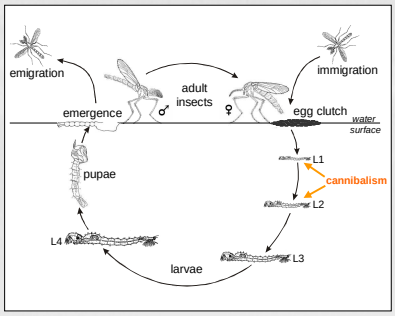

Fig. 1: Life cycle of *Chaoborus crystallinus*

- **Food saturation** level of the larvae: 30 % and 70 %, respectively
- **Start density** of fourth instar larvae in spring: 0.15 (low density) and 1.5 (high density) larvae/L, respectively
- Insecticide **application** on Day 140
- **DT50** of the insecticide: 2.5 days
- **EC50** for acute mortality of all larval stages: 0.1 µg/L
- A full **recovery** of a population was assumed if the mean deviation between treatment and control larval densities was < 20 % for at least 7 days
- 50 Monte Carlo simulations for each scenario

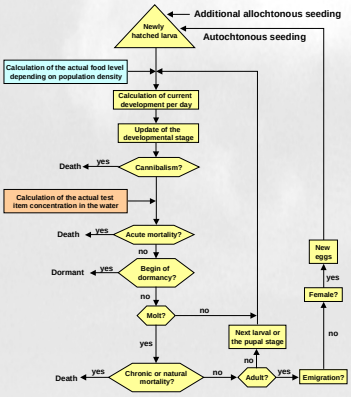

Fig. 2: Modelled life history of *Chaoborus*

Results and Discussion

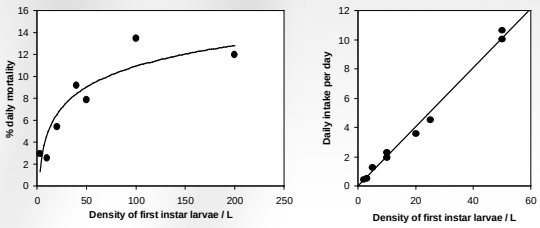

Fig. 3: Results of cannibalism experiments in the laboratory.
Left: Only L1-larvae. **Right:** Daily intake of L4-larvae feeding on L1-larvae

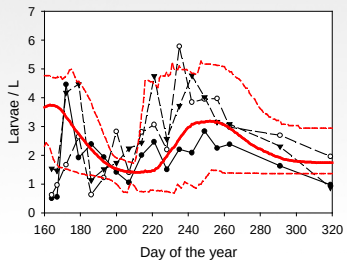

Fig. 4: Measured and simulated population dynamics without pesticides (sum of all larval stages).
●○▼ mesocosm field data of control ponds
mean of 50 Monte Carlo simulations
min/max of simulations

The carrying capacity of the modelled *Chaoborus* population is determined only by the density-dependent cannibalism rates (Fig. 3).
The simulated population dynamic of *Chaoborus crystallinus* fits in well with the experimental data from an aquatic outdoor mesocosms study (Fig. 4).

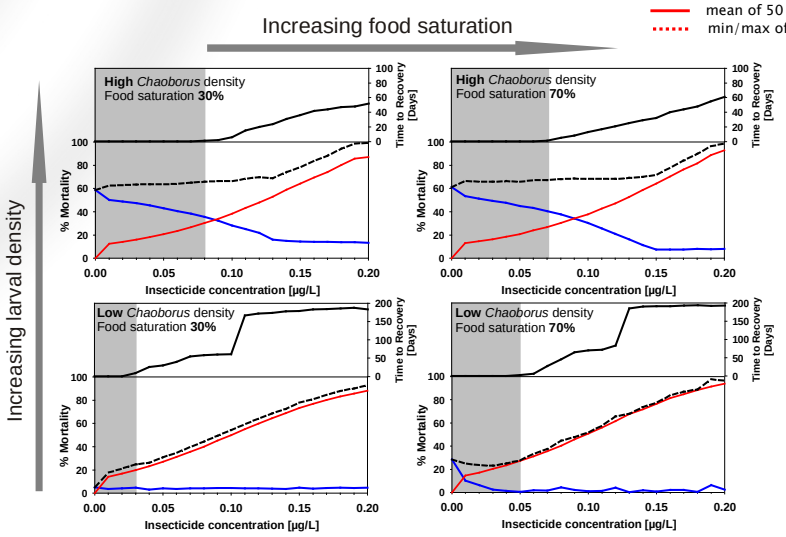

Fig. 5: Simulation results of the accumulated mortality for the *Chaoborus* populations over a period of 7 days after application and of the recovery time.
cannibalism — mortality by the toxicant ····· total mortality;
time to recovery; no significant toxic effect on the population level

At **high population densities**, a moderate insecticide effect is compensated by decreasing cannibalism over a wide concentration range resulting in an almost unchanged overall mortality compared to control populations without insecticide (Fig.5, upper figures).

At **low larval densities**, *Chaoborus* populations show lower mortality due to cannibalism and therefore are more sensitive to insecticide exposure (Fig.5, lower figures).

Thus, **increasing population densities** result in an increase of the population NOEC and shorten the time to recovery.

An **increase of the food level** generally increases the population density and therefore reduces the sensitivity of the population. But this could only be detected in the scenario "populations with low densities" which are considerably below their carrying capacity.

Conclusions

1. For species with high reproduction rates (r-strategists), a density-dependent mortality (e.g. cannibalism) might be an important antagonist to pesticide-related mortality with respect to the regulation of their population density under toxic stress.
2. The recovery time of insects such as the phantom midge *Chaoborus crystallinus* depends on the strength of toxic effects, their actual population density and the food availability.
3. These results indicate that in risk assessment studies using high population densities may underestimate the risk caused by toxic substances compared to populations with low densities.