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Individual-based modelling of the recovery of *Chaoborus crystallinus* in aquatic mesocosm pond studies

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Introduction

The recovery time of chemically stressed populations in aquatic outdoor mesocosms studies is important for the risk assessment of pesticides.
Emerging insects like the phantom midge *Chaoborus crystallinus* can recover from inside the polluted ponds (autochthonous recovery), and by immigration of adults insects emerged from uncontaminated ponds (allochthonous recovery). In both mechanisms, the recovery time depends on the strength of toxic effects, population density and spatial vicinity of other undisturbed populations.

The merolimnic dipteran *Chaoborus crystallinus*, a pelagic invertebrate predator, is known as a frequently very sensitive organism to insecticide toxicity with increasing sensitivity of earlier instars.
To analyse the recovery time after pesticide application, an individual-based simulation model for *Chaoborus crystallinus* was developed to compare the recovery behaviour of isolated and connected populations following pesticide stress.

Materials and Methods

With an individual based simulation model, the population dynamics of the phantom midge *Chaoborus crystallinus* was simulated depending on start densities, food conditions, temperature and photo period.
Whole populations of ponds with a volume of 3.1 m³ were modelled. Population dynamics emerge from the behaviour of the individuals (Fig.1 and Fig.2).

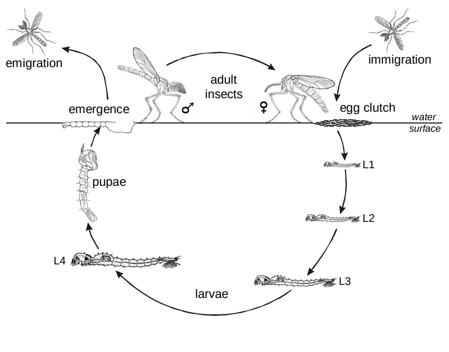


Fig. 1: Life cycle of *Chaoborus crystallinus*

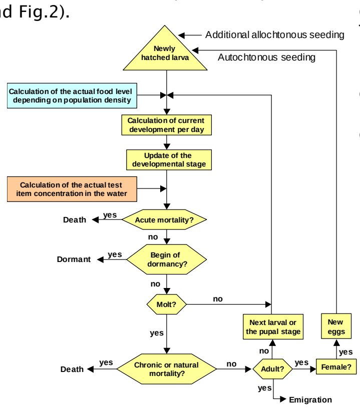


Fig. 2: Modelled life history of *Chaoborus*

For the treatments, the well known pyrethroid insecticide **α-Cypermethrin** was choosen as a model substance because of the strong effects on *Chaoborus*, its high dissipation rate (DT_{50} of 2.4 days), and the weak effects on other zooplankton groups (cladocerans, rotifers) which guaranteed undisturbed food ressources for the insects.
The used EC_{50} levels for the *Chaoborus* larvae (available from outdoor and laboratory findings) are: $EC_{50,acute}$ 0.07 µg/L, $EC_{50,chronic}$ 0.01 µg/L.
In the simulations, two applications with α-Cypermethrin took place on day 165 and 180 of the year (Fig.5 and Fig.6).
Full recovery of the treated population was assumed after reaching 70 % of the control population abundance for at least 7 days.

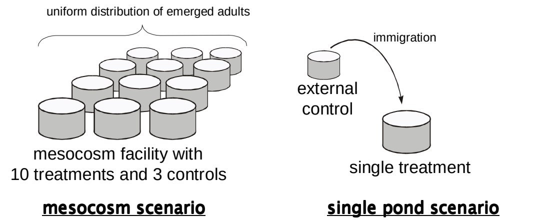


Fig. 3: Spatial arrangement of ponds in the model for different scenarios (Fig. 5, 6)

Simulation Results

The simulated population dynamics of Chaoborus crystallinus agree satisfyingly with the experimental data from an aquatic outdoor mesocosms study (Fig. 4).
In comparison with isolated treatments, the treated populations within a mesocosm study show a clear recovery, but never reach the abundance of the external control pond. The mesocosm control populations are negatively affected by the loss of individuals to the treatments (Fig. 5). The recovery potential of a treated population increases with the allochthonous input by migrating adult insects (Fig. 6).

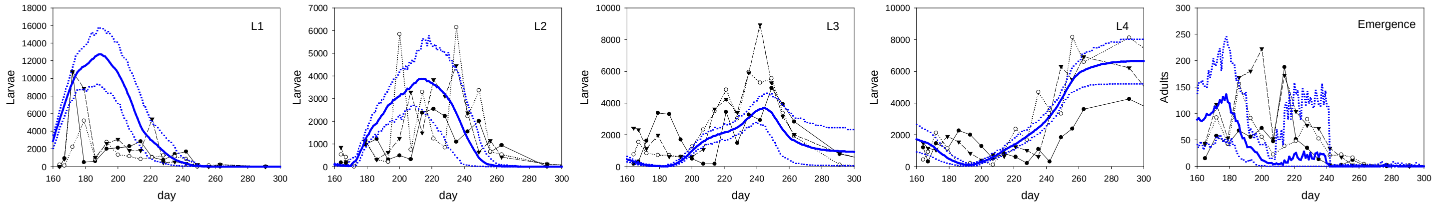
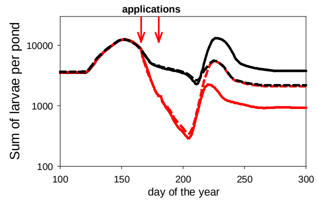


Fig. 4: Measured and simulated populations dynamics of the four larval stages (L1-L4) and adult insects (experiments without pesticides).
▼ ○ ● mesocosm field data of control ponds — mean of 40 simulations ······ minimum / maximum of simulations



external control — single treatment
mesocosm control ······ mesocosm treatment

Fig. 5: Exemplary simulations at 0.02 µg α-Cypermethrin/L for different scenarios (single control and treatment, combined controls and treatments within a mesocosm facility)

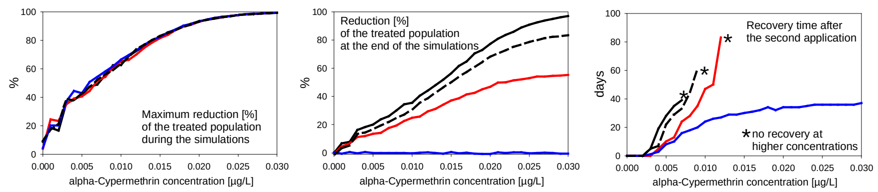


Fig. 6: Concentration dependence of the short term (left) and long term (middle) effects, and the recovery time (right) for a treated population compared to either external or mesocosm control populations.

— single treatment compared to the external control
······ single treatment compared to the external control with 5% immigration
— mesocosm treatment compared to the external control
— mesocosm treatment compared to the mesocosm control

Conclusions

⇒ The individual based model is suitable to predict the population dynamics of *Chaoborus crystallinus.*

⇒ Isolated populations show a lower recovery potential compared to treated populations within a mesocosm study site due to the lack of immigration from outside.

⇒ Untreated populations within a mesocosm study also decreased in population density due to the loss of emerged adults to the treated ponds.

⇒ The present simulation approach makes it possible to assess the influence of pesticides on populations in consideration of the number and spatial distribution of undisturbed populations in the landscape.