Hydrogen peroxide effects on Northern shrimp: dynamic modelling of mortality

Tjalling Jager[1], Jannicke Moe[2] , Dag Hjermann[2], Elisa Ravagnan[3] and Renée Bechmann[3]

[1] DEBtox Research, De Bilt, The Netherlands, [2] Norwegian Institute for Water Research (NIVA), Oslo, Norway

[3] NORCE Research Centre, Stavanger, Norway

Introduction

Hydrogen peroxide (H_2O_2) is used as anti-parasitic veterinary medicine in salmon farming worldwide. Since the treatment water is discharged to the sea, there are concerns about the potential effects on populations of the Northern shrimp (*Pandalus borealis*), an economically and ecologically important species in Norwegian fjords. As part of the PestPuls project, this study aims to extrapolate the results from laboratory toxicity tests to realistic field conditions using the toxicokinetic-toxicodynamic model GUTS (Jager *et al.*, 2011).

Fig. 1. Northern shrimp (Pandalus borealis).

Toxicity testing and model fitting

Adult shrimp were exposed to short pulses of H_2O_2, followed by a recovery period in clean seawater. The exposure concentrations represented 100, 1000 and 10000 times dilutions of the prescribed treatment concentration for salmon. In the two lowest dilutions, substantial and delayed mortality was observed.

The complete data set (survival over time, in all treatments) was modelled simultaneously using GUTS in Matlab, using BYOM (www.debtox.info/byom.html). One model adaptation was needed as the toxicant effects were observed to saturate at high exposure concentrations. The model fit is shown in Fig. 2. Clearly, mortality continues well after exposure stops, which could be reasonably-well captured by the model.

The details of the toxicity tests and model fitting have been published in Bechmann *et al.* (2019).

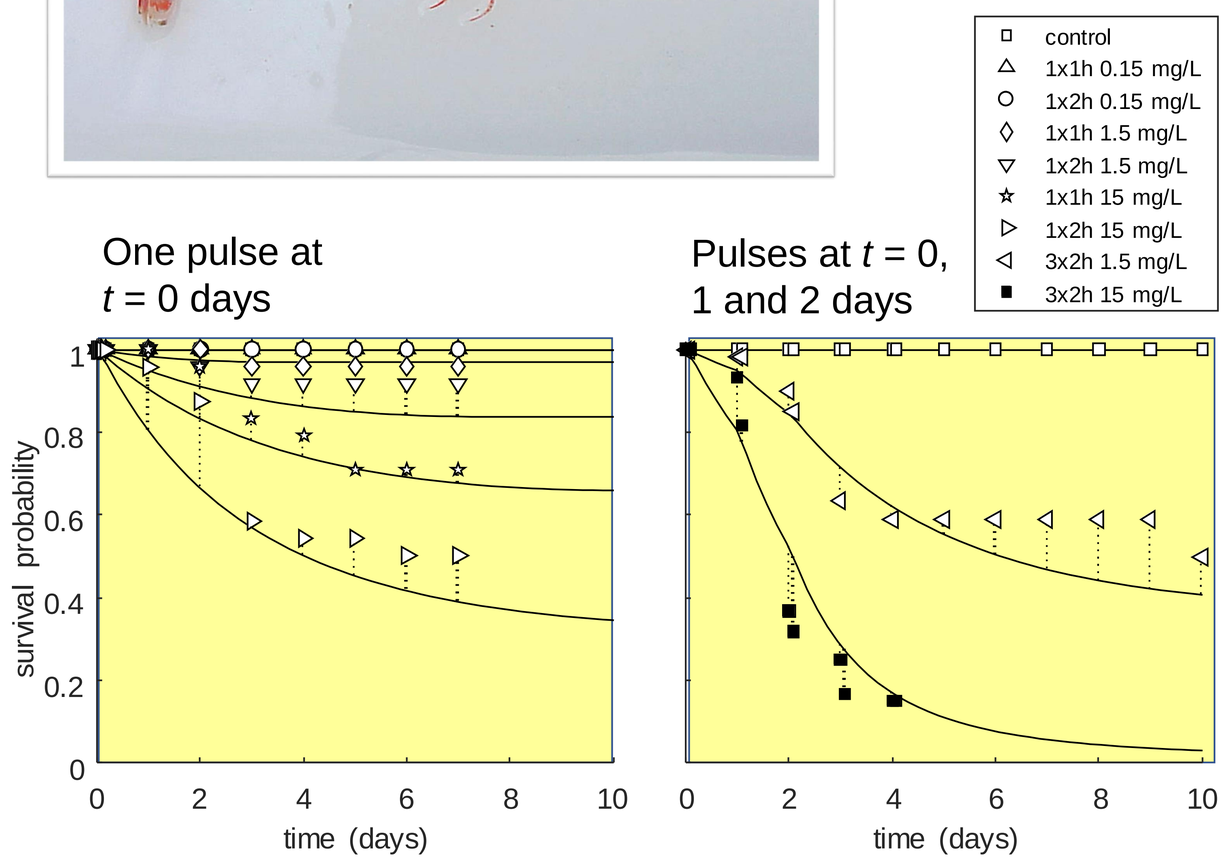

Fig. 2. Simultaneous model fit of GUTS (stochastic death) to the toxicity tests with pulsed exposure of H_2O_2.

Error propagation to model predictions

Next, we predict what happens under more realistic exposure conditions as may be encountered in a Norwegian fjord. Exposure profiles for H_2O_2 were generated using a dispersion model (Refseth *et al*, 2019). The parameter uncertainty from the fit in Fig. 2 was quantified in a Bayesian framework, generating a sample from the posterior distribution with MCMC analysis. The sample was subsequently used to generate credible intervals on the model predictions. One example is shown in Fig. 3.

In a different work package of the PestPuls project, population consequences for entire fjord systems are calculated. This is an extension of the shrimp population model of Moe *et al.* (2019), see presentation Jannicke Moe (ID 4.07.5). Mortality in the model is calculated using the calibrated GUTS model, for each grid cell on the map, using the local exposure conditions over time. The population model has a time step of 3 months; Fig. 4 shows the predicted survival probability from the GUTS model after this step.

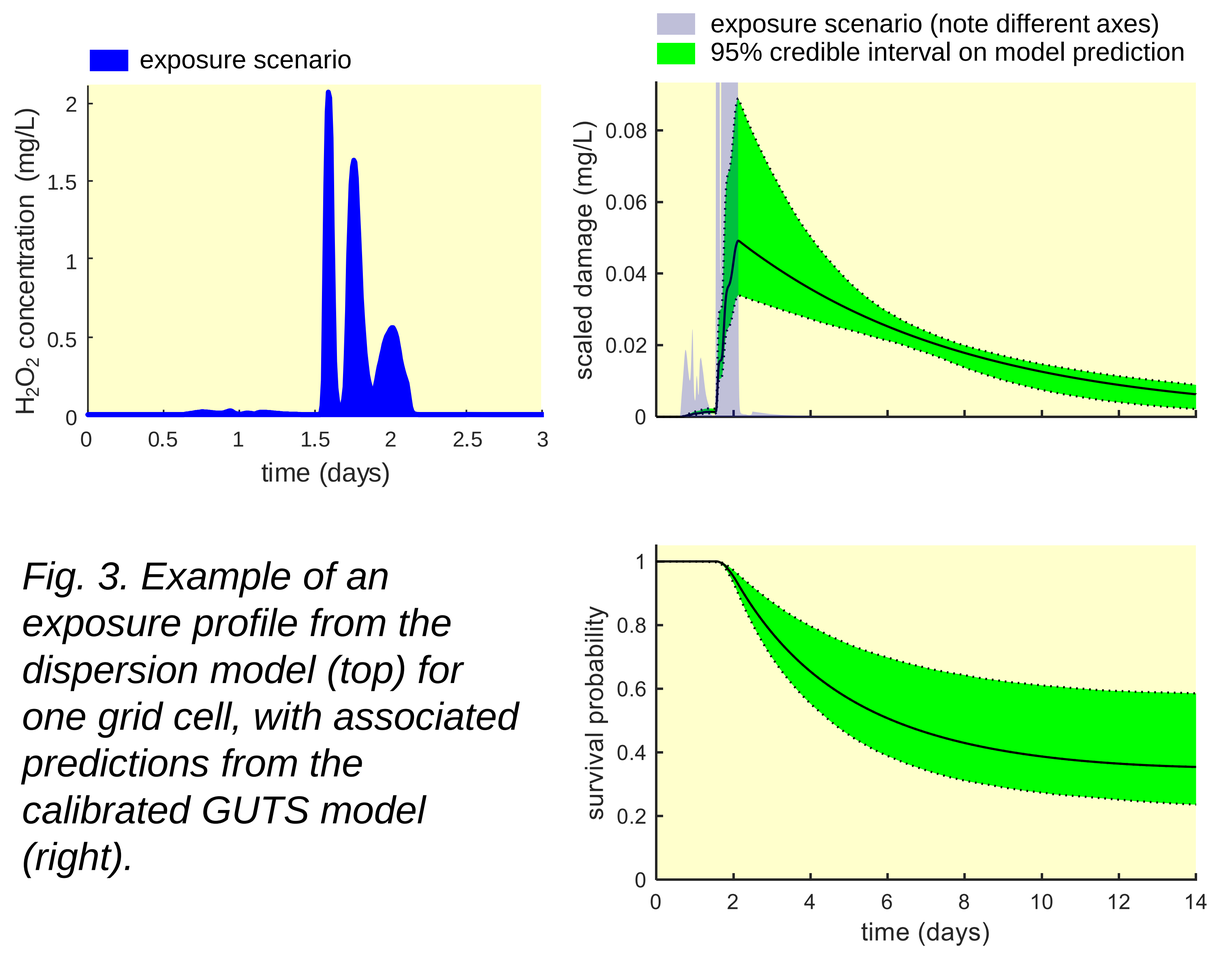

Fig. 3. Example of an exposure profile from the dispersion model (top) for one grid cell, with associated predictions from the calibrated GUTS model (right).

Conclusions

TKTD models such as GUTS allow for meaningful analysis of toxicity tests with time-varying exposure. Furthermore, these models support the urgently-needed translation of laboratory results to the field. Therefore, these models form a powerful link between lab-based toxicity testing and population modelling.

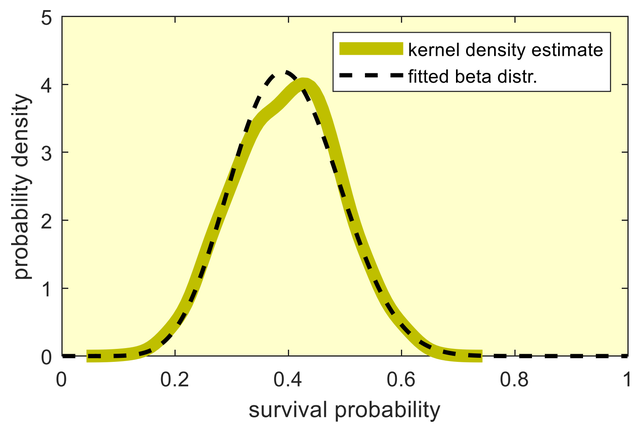

Fig. 4. Predicted survival probability at the end of a 3-month time step following the exposure event, as used for population modelling. The uncertainty in the estimate can be well described by a beta distribution

References

Bechmann *et al.* (2019). Ecotox. Environ. Saf. https://doi.org/10.1016/j.ecoenv.2019.05.045.
Jager *et al.* (2011). Environ. Sci. Technol. https://dx.doi.org/10.1021/es103092a.
Moe *et al.* (2019). Ecol. Modell. https://doi.org/10.1016/j.ecolmodel.2019.108833.
Refseth *et al* (2019). Akvaplan-niva Report 8948. https://www.fhf.no/prosjekter/prosjektbasen/901416/.

DEBtox Research

NIVA Norsk institutt for vannforskning

NORCE

Acknowledgements

This work was conducted as part of the PestPuls project, financed by the Research Council of Norway (grant no. 267746/E40).

The Research Council of Norway