

The Temporal Response Surface:

A novel method for the assessment of delayed and time - cumulative aquatic ecosystem risk



Full article



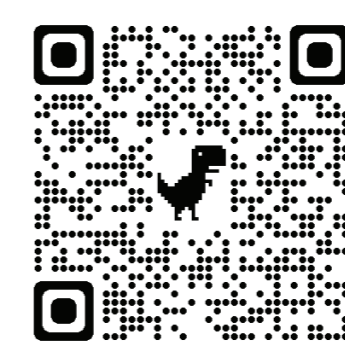
Reef Catchments Science Partnership
DATA TO CHANGE



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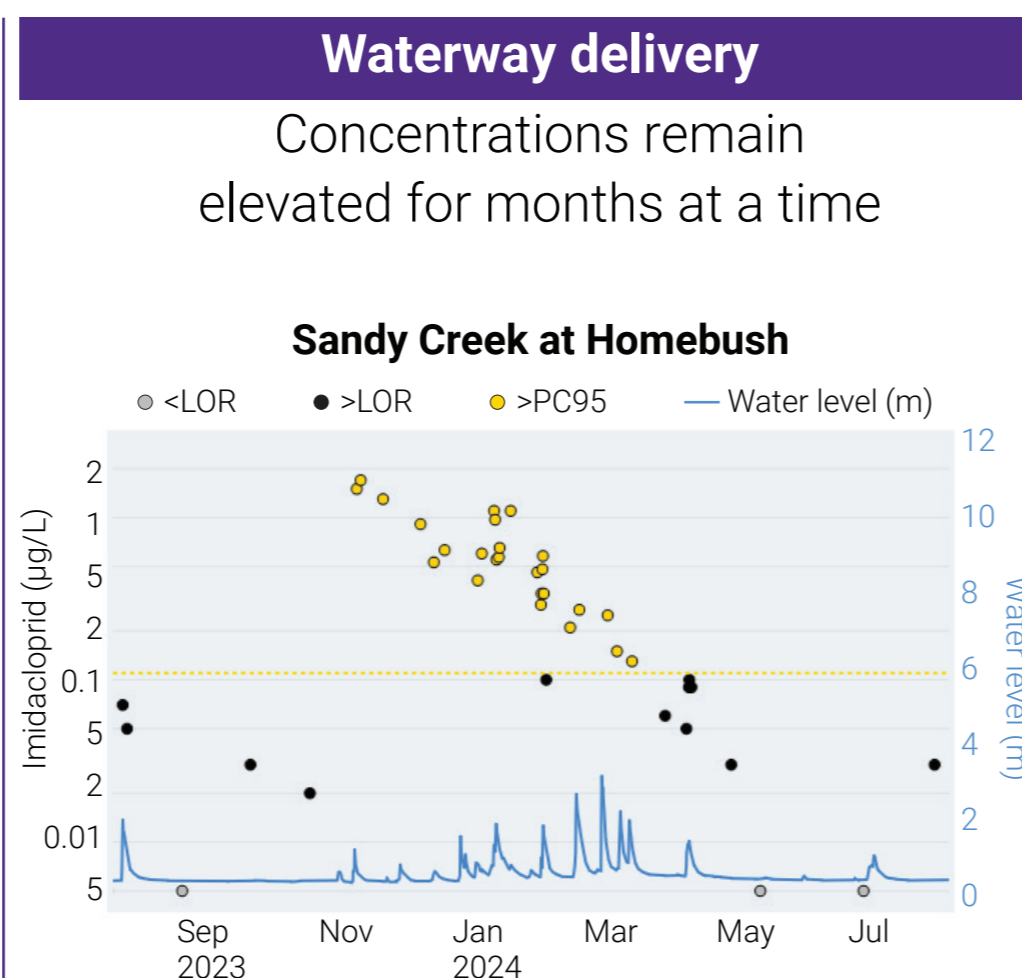
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RCSP website

Application

Imidacloprid is widely used for agriculture in the Great Barrier Reef catchment area



Impact

Cumulative toxicity affects aquatic insects and crustacea

Introduction

Traditional guideline methods may provide insufficient ecosystem protection.

Imidacloprid binds to the neural receptors in aquatic insects and crustaceans. As more receptors become bound lower concentrations trigger toxicity, leading to more severe effects over time. Ecosystem protection guidelines are derived using relatively short-duration toxicity tests that may not account for delayed and time-cumulative toxicity. The Temporal Response Surface (TRS) provides a practical solution that accounts for the effects of delayed and cumulative toxicity in the setting of ecosystem protection guidelines.

Method

A third axis (exposure duration) is incorporated into the imidacloprid species sensitivity distribution.

Regression models were developed for Insecta, Malacostraca, and Branchiopoda (Figure 1A):

$$\ln(\text{Time}) = \alpha + \beta \ln(\text{Concentration})$$

Where α is the model intercept and β is the slope. Effect concentration was then predicted at daily time steps from 1 - 100 days (Figure 1B). Temporal adjustment factors (TAFs) were then applied to each organism in the imidacloprid SSD to estimate toxicity at different time points (Figure 1C):

$$\text{TAF} = \frac{EC(\text{modelled}_x)}{EC(\text{measured}_y)}$$

where EC_{modelled_x} is the predicted effect concentration on Day x , and EC_{measured_y} is the measured (observed) effect concentration for each toxicity datum in the species sensitivity distribution (SSD). An SSD was then derived for each temporally adjusted data set and plotted in temporal order to form the 3-dimensional TRS.

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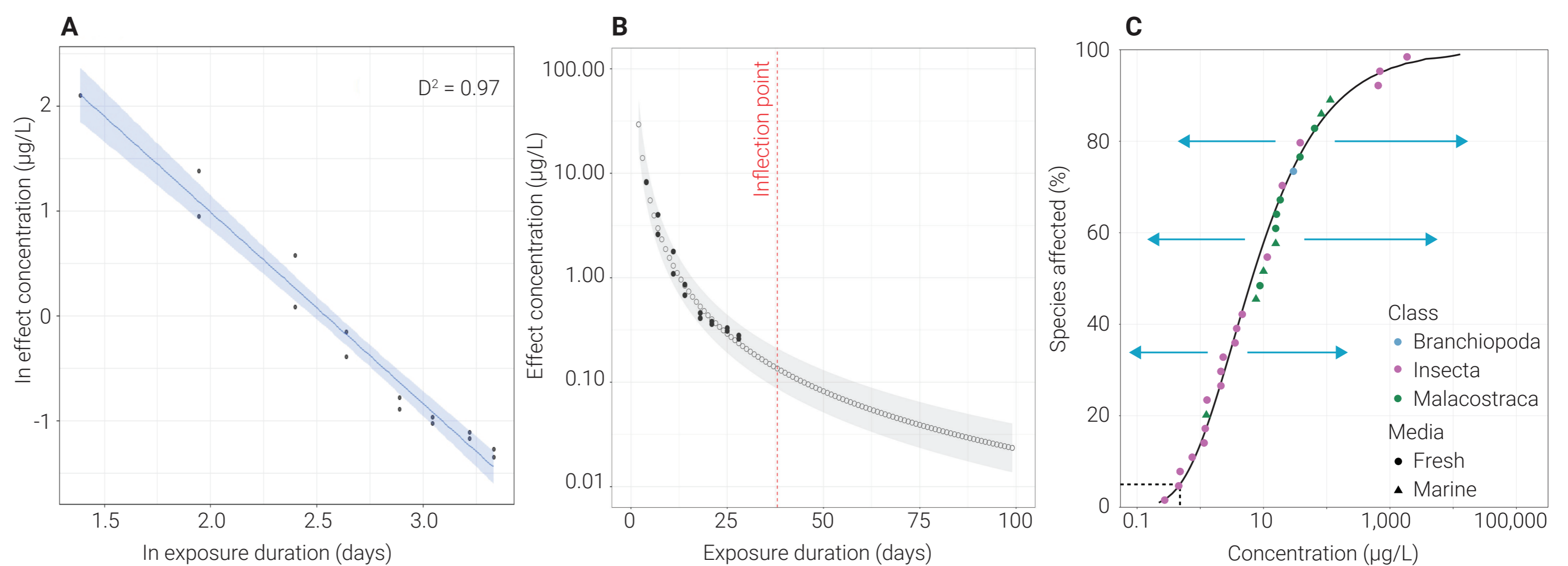


Figure 1A. Gaussian Generalised Linear Models (GLMs) were fitted to toxicity data for *Daphnia magna*, *Deleatidium* sp. (pictured), and *Hyalella azteca*, resulting in D-squared values of 0.99, 0.97, and 0.99, respectively. 1B The models were used to predict the imidacloprid effect concentration for each species from 1 to 100 days of exposure (black dots are observed values, hollow circles are predicted values). 1C Temporal Adjustment Factors (TAFs) were then applied to each species in the imidacloprid SSD based on which organism class they belonged to, effectively 'shifting' the toxicity data to represent different exposure durations.

Results

Applied to imidacloprid, the TRS reveals that ecosystem protection thresholds drop quickly within the first 30 days of exposure then continue to decline over time. The concentration that is protective of 95% of the ecosystem for a period of 21 days is an order of magnitude lower than current Australian guidelines, at 0.012 µg/L.

The Temporal Response Surface enables risk assessment under conditions that are virtually impossible to test for.

The TRS method aligns with Australian and international regulatory frameworks and allows for risk assessment of chemicals with delayed or cumulative toxicity. Future research may apply approach to other toxicants (e.g., organophosphates, neonicotinoids, mercury) or combinations of stressors (e.g., water temperature versus toxicity).

Imidacloprid Temporal Response Surface

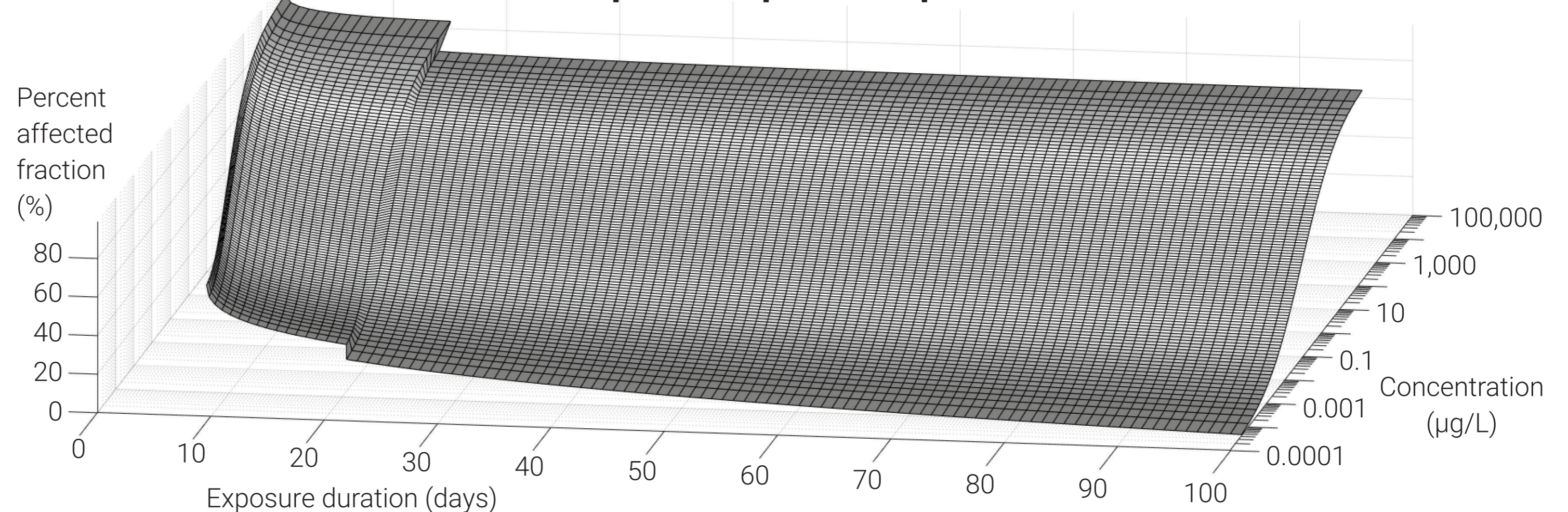


Figure 2 The Temporal Response Surface for imidacloprid. All SSDs in this plot were produced using ssdtools, the vertical 'wobble' in the surface is due to a change from log Gumbel to log normal distribution type at day 18.