The effects of pollution and foraging adaptation on the stability of ecological communities

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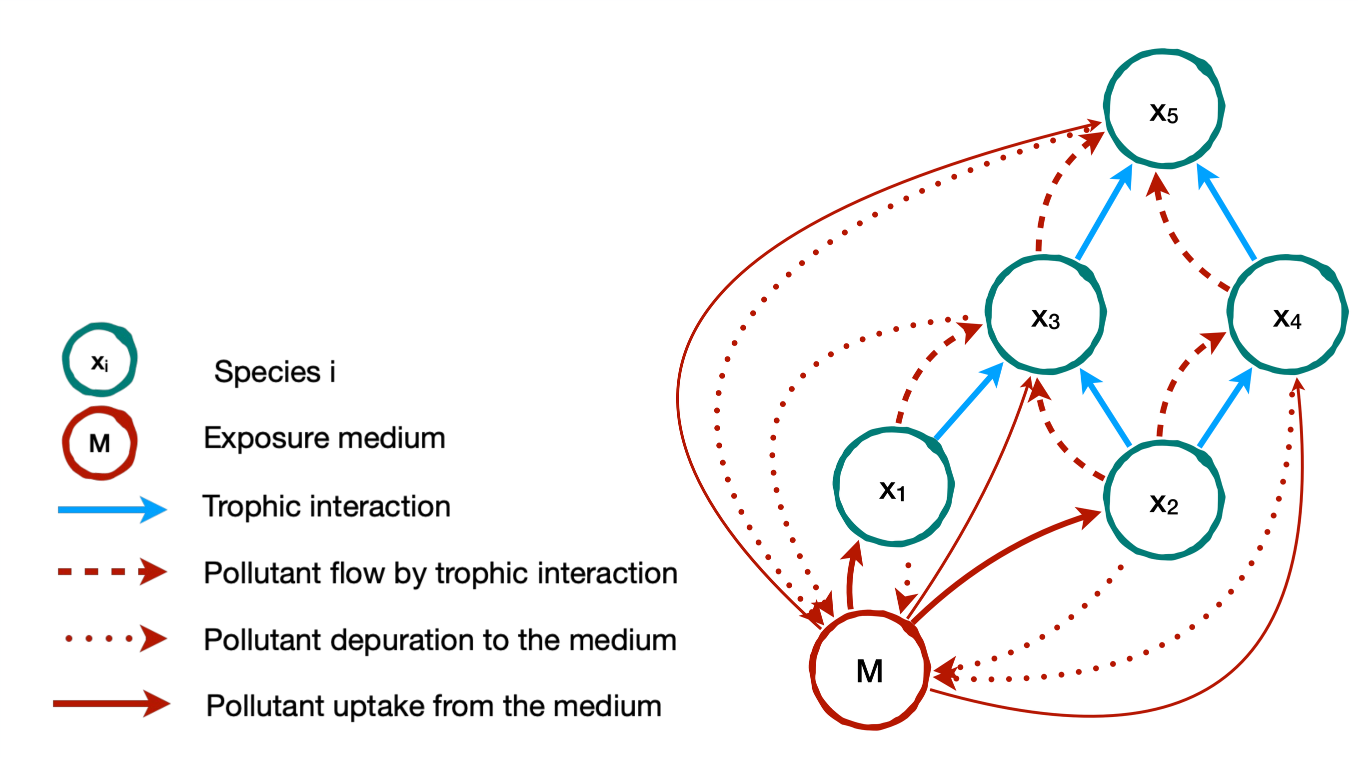
Introduction and research objectives

- **Adaptive foraging behaviour**, here considered as the capacity of living organisms to modify their prey preference, can limit pollutant transportation through trophic networks while still enabling the biomass flow.
- We assessed how **foraging behaviour can impact the stability of aquatic food webs in the presence of chemical pollution**, including its relationship with the topological properties of these webs (i.e., species richness and connectance), using a multi-species bioenergetic model.



Materials and methods

- We applied the **bioenergetic model** of Yodzis & Innes (1992), which was generalised for multispecies systems by Williams & Martinez (2004) and adapted for polluted environments by Garáy-Narváez et al. (2013), in order to model the temporal variation of biomass density (Eq. 1), bioaccumulation (Eq. 2), and pollutant concentration in the exposure medium (Eq. 3).
- To model alterations in prey preference over time, we applied a **replicator equation** (Eq. 4), which was dependent on the fitness profit of the predator species when consuming each of its prey species separately.

$$\frac{dB_i}{dt} = B_i r_i \kappa_i\left(1-\frac{B_i}{K_i}\right) - x_i B_i + B_i \kappa_i x_i \sum_{j\in\{preys_i\}} y_{i,j}F_{i,j} - \sum_{j\in\{consumers_i\}} \frac{B_j x_j y_{ji} F_{ji}}{\epsilon_{ji} f_{ji}} \quad (1)$$

$$\frac{dA_i}{dt} = \omega_i C B_i + B_i \kappa_i \sum_{j=prey} x_i y_{ij} G_{ij} - x_i A_i - \sum_{j=cons} \frac{B_j x_j y_{ji} G_{ji}}{\epsilon_{ji} f_{ji}} - \rho_i A_i \quad (2)$$

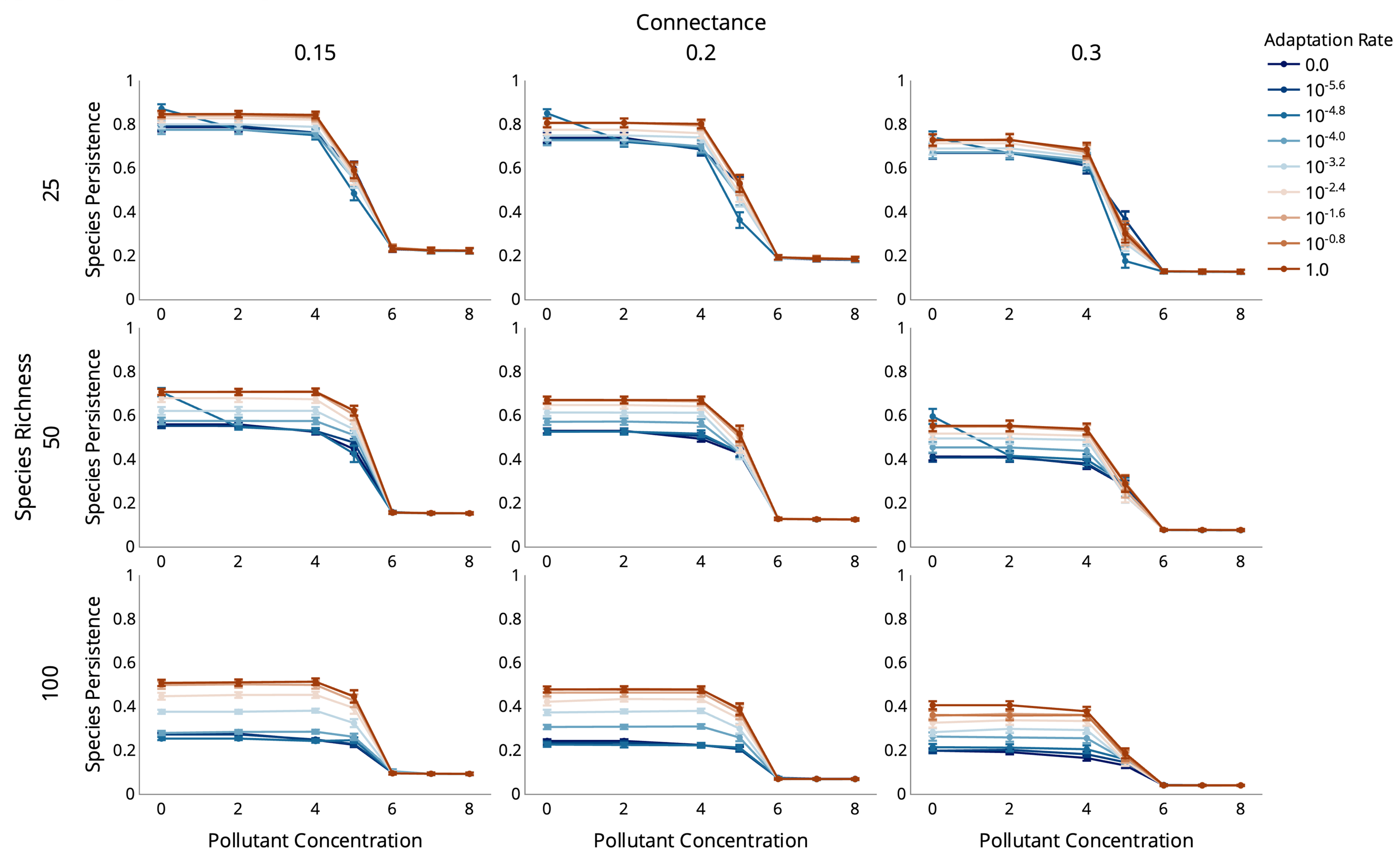
$$\frac{dC}{dt} = \Pi(t) + \sum_i \rho_i A_i - \sum_i \omega_i C B_i - \psi C \quad (3)$$

$$\frac{d\alpha_{ij}}{dt} = v_i \alpha_{ij}\left(Fit_{ij} - \overline{Fit_i}\right) \quad (4)$$

- The experiment included **8 pollutant concentrations** (dimensionless, including controls), **9 levels of feeding adaptive velocity** (between 0 and 1), and different network topologies: **species richness** ∊ [25, 50, 100]; and **connectance** ∊ [0.15, 0.2, 0.3]).
- Effects were evaluated on **species persistence** and on the difference in the **Shannon-Wiener diversity index ratio** (ΔH´) after 20,000 time-steps.
- Results were analysed with **Generalized Linear Models** (GLM) with a normal distribution.

Results

(A) Species persistence



(B) ΔH'

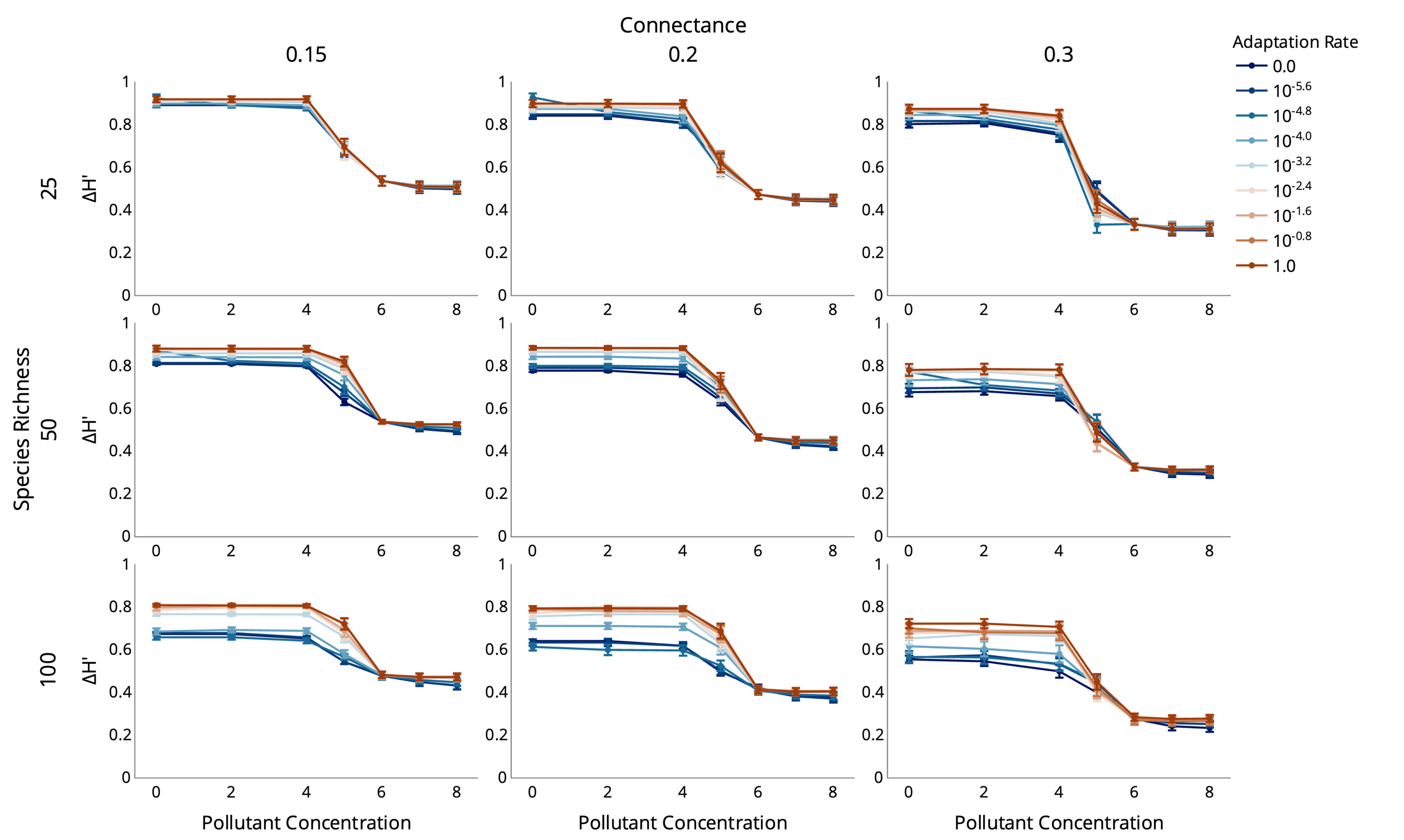


Figure 2. Effects of pollutant concentration and adaptation rate on species persistence (A) and ΔH' (B) for food webs with different topological structure: 25 (top), 50 (middle), and 100 (bottom) species, and connectance levels of 0.15 (left), 0.2 (middle), and 0.3 (right).

Figure 1. Illustrative example of changes of species' biomass density over time in response to a pulse-like entry of pollutant into the exposure medium after stability has been reached by the community.

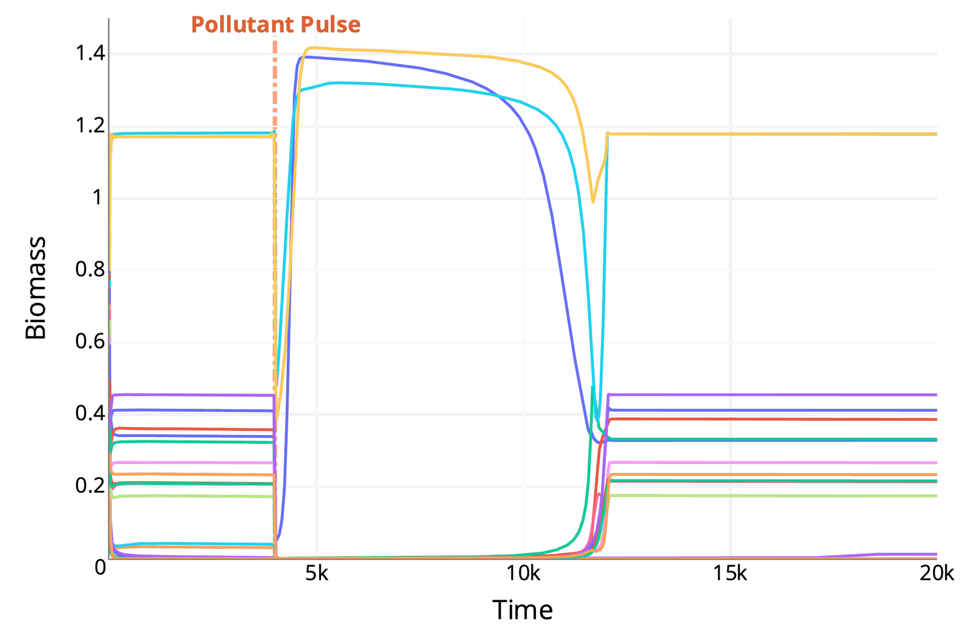


Table 1. Results of the GLMs for specie persistence and ΔH': parameter estimate, p-value and effect classification for single parameters (+: positive; -: negative) and the binary combinations (S+: positive synergistic; A+: positive antagonistic; A-: negative antagonistic; AD: additive).

Response variable	Parameter	Estimate	p-value	Effect
Species persistence	Intercept	1.27	<0.001	+
	Species Richness (S)	-0.007	<0.001	-
	Connectance (C)	-1.21	<0.001	-
	Pollutant (P)	-0.11	<0.001	-
	Adaptation rate (A)	0.11	<0.001	+
	S:C	0.004	<0.001	S+
	S:P	0.0006	<0.001	S+
	S:A	0.0007	<0.001	A+
	C:P	0.04	<0.001	S+
	C:A	-0.13	0.01	A-
	P:A	-0.02	<0.001	A+
ΔH'	Intercept	1.14	<0.001	+
	Species Richness (S)	-0.002	<0.001	-
	Connectance (C)	-0.50	<0.001	-
	Pollutant (P)	-0.05	<0.001	-
	Adaptation rate (A)	0.04	0.009	+
	S:C	-0.0007	0.19	AD
	S:P	0.0002	<0.001	S+
	S:A	0.0006	<0.001	A+
	C:P	-0.12	<0.001	A+
	C:A	-0.015	0.79	AD
	P:A	-0.008	<0.001	A+

Conclusions

- **Species richness, connectance, and pollutant concentration** have a **negative effect** on species persistence and diversity; while **adaptive behaviour** has a positive effect on species persistence and diversity.
- **Complex networks**, i.e. large and highly connected food webs, are **more stable than smaller and weakly connected networks** when exposed to low and intermediate pollutant concentrations (≤ 5).
- **Adaptive behaviour** has a **stabilising effect** on chemically exposed communities by meliorating the negative effect of pollution (A+).
- Further work will assess the effects of chemicals with different **mode of action** and **thermal regimes** on the stability of aquatic communities.

References:
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