Functional endpoints in ecotoxicology: A case study in freshwater indoor microcosms

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Background

Little is known about the influence of toxicants on the function of freshwater sediments. To better understand these effects, a microcosm experiment was carried out with Cadmium (Cd) as a model pollutant (50 and 400 mg Cd kg^{-1} dry sediment). In a 7-month study the effect of Cd was examined on biomass (B), secondary production (P) and its relationship (P/B) of the zoobenthos. The results can provide new insights into benthic community disturbances and the functional consequences thereof.

Materials and methods

The secondary production of the benthic community was studied in indoor microcosms over seven months with monthly sampling at eight occasions (T0 - T7; T0: initial value, T1 - T7: experimental time). The temperature was maintained at 20 °C under a 12:12 h light:dark regime. The overlying water was skimmed to sediment surface level after which a 1-L aqueous Cd solution (as $CdCl_2 \cdot 1H_2O$, dissolved in deionized water) was added to final nominal low (LC) and high (HC) concentrations of 50 and 400 mg kg^{-1} dry sediment, respectively. For the control, 1 L of deionized water was added. Five replicates were set up for the control and each of the two Cd concentrations (= 15 microcosms). The Cd-spiked sediments were gently mixed using a large plastic comb. Skimmed water was refilled up to 10 cm one day later. Abundance, biomass and secondary production was determined as outlined below:

Bacteria

- Abundace was determined by direct counts using DAPI (Porter and Feig, 1980; Schallenberg et al., 1989)
- Biomass was calculated after Bratbak and Dundas (1984)
- Secondary production was measured using the ^3H marked thymidine method of Findlay (1993)

Protozoans

- Abundace was determined by direct counts (Gasol, 1993)
- Biomass was calculated after Finlay (1978)
- Secondary production was indirectly estimated from biomass data using the method of Calkorskaja as cited in Finlay (1978), taking into account temperature and cell size

Metazoans

- Abundace was determined by direct counts following Ludox extraction from sediment
- Biomass was calculated using taxon specific methods (Faupel et al., 2011)
- Secondary production was determined either by the size-frequency method (Benke, 1979), by direct measurements (oligochaeates) or following Vranken et al., 1986 (nematodes)

Results

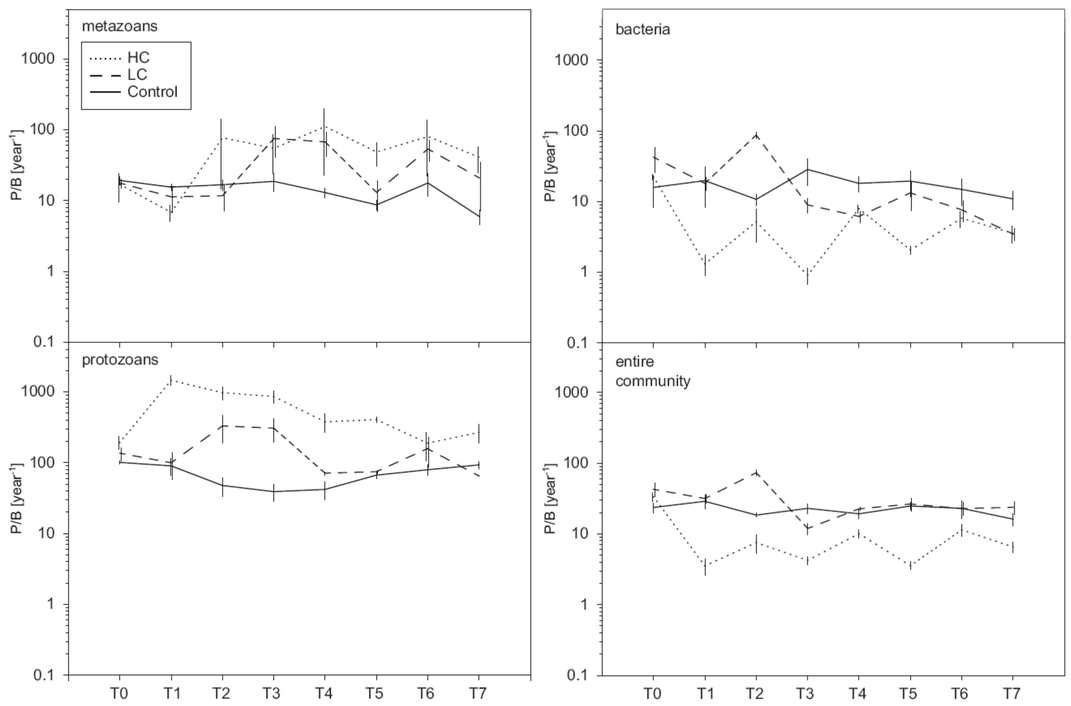

Fig. 1: Succession of estimated P/B ratios of metazoans, protozoans, bacteria and the entire community under three conditions (control, LC = 50 mg Cd kg^{-1} dry sediment, HC = 400 mg Cd kg^{-1} dry sediment; mean ± SE, n=5).

Tab. 1: Biomass, secondary production and the corresponding P/B ratio of metazoans, protozoans, bacteria and the entire community in microcosms over seven months (T1-T7) under three treatment conditions (control, LC, HC; mean ± SD, n=5). Asterisks indicate level of significance (rmANOVA with post-hoc 2-sided Dunnett or GameseHowell).

Taxon	Biomass [mg C m^{-2}]			Secondary production [mg C m^{-2} y^{-1}]			Sec. production/Biomass [y^{-1}]		
	Treatment			Treatment			Treatment		
	CN	LC	HC	CN	LC	HC	CN	LC	HC
Metazoans	0.50 ± 0.11	0.1 ± 0.03*	0.05 ± 0.04**	5.34 ± 2.19	1.53 ± 0.87*	0.63 ± 0.26***	13.65 ± 4.76	35.68 ± 27.75	58.93 ± 32.65*
Proztozoans	0.34 ± 0.12	0.21 ± 0.16*	0.01 ± 0.02***	18.26 ± 6.95	13.83 ± 10.66	1.81 ± 0.85***	65.41 ± 22.90	156.38 ± 113.03**	647.32 ± 464.50*
Bacteria	0.70 ± 0.14	0.56 ± 0.44	0.77 ± 0.23	8.41 ± 1.22	6.37 ± 6.39	2.55 ± 1.74**	17.46 ± 6.11	20.71 ± 29.8	3.83 ± 2.61**
Entire community	1.54 ± 0.14	0.87 ± 0.49***	0.83 ± 0.22***	32.01 ± 7.55	21.73 ± 9.98*	4.98 ± 2.14***	22.22 ± 4.36	30.75 ± 20.06	6.80 ± 3.22***

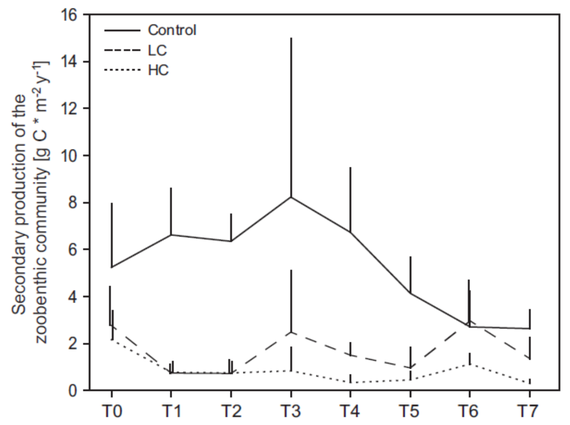

Fig. 2: Secondary production of the zoobenthic community under three treatment conditions (control, LC = 50 mg Cd kg^{-1} dry sediment, HC = 400 mg Cd kg^{-1} dry sediment; mean ± SE, n=5).

Tab. 2: Secondary production of benthos in response to three different treatments over 7 months (CN, LC, HC; $mean_{T1\text{-}T7}$ ± SD; n=5). Asterisks indicate level of significance (rm ANOVA with post-hoc GameseHowell).

Taxon	Secondary production [mg C m^{-2} y^{-1}]		
	Treatment		
	CN	LC	HC
Nematoda	635 ± 125	87 ± 52***	32 ± 18***
Rotifera	463 ± 190	1255 ± 930	220 ± 95
Harpacticoida	118 ± 139	26 ± 68	46 ± 38
Cyclopoida	275 ±345	9 ± 24	15 ± 39
Ostracoda	1862 ±1404	73 ± 105**	303 ± 186**
Platyhelminthes	583 ±694	5 ± 8	0.1 ± 0.4*
Cladocera	20 ±15	1 ± 1***	3.2 ± 2***
Oligocheata	1386 ±435	79 ± 26***	7.4 ± 18***
Entire community	5342 ±2185	1534 ± 874***	627 ± 258***

* Significance level: $p < 0.05$
** Significance level: $p < 0.01$
*** Significance level: $p < 0.001$

Discussion

- Strong effects on biomass, secondary production and their relationship P/B
- Strong differences among taxa. Relatively fast reproducers within metazoans and protozoans (r-strategists) are able to thrive under LC condition.
- Increased P/B ratio under Cd stress of bacteria and protozoans (fast reproducers)
- Functional endpoints (secondary production, P/B) provide new insights into community disturbance and appear to be sensitive endpoints with acceptably low variance of data.
  - → Increasing the evaluation options of microcosms
  - → Extending the available information for ecotoxicological risk assessments

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