Changes of plankton community structure in pond and stream mesocosms caused by the herbicide metazachlor

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Introduction

Fig. 1: *Acropercus harpae*

A mesocosm study was conducted in the indoor pond and stream mesocosm system of the German Federal Environmental Agency (Mohr et al. 2005) in order to study effects of the herbicide metazachlor on macrophytes and plankton communities. Metazachlor disturbs the synthesis of very long chain fatty acids (VLCFA; >18 C) by an irreversible inhibition of the VLCFA elongation enzyme (Eckermann et al. 2003).

The herbicide is toxic to almost all higher plants but algae seem to react very heterogenously with EC 50 ranging from 0.031 mg/L for *Pseudokirchneriella subcapitata* to 1.63 mg/L for *Chlorella* sp. (FAO 1999).

In contrast to higher plants, some algae are capable of replacing the missing VLCFAs in membranes by others or have different fatty acid compostions with few VLCFAs (Schmalfuß et al. 1998; Napolitano 1998).

Direct toxic effects on zooplankton or protozoans are rather unlikely since these groups are generally unable to synthesise fatty acids. Zooplankton or protozoan populations would rather be impacted by the resulting differences in food quality and quantity. In this study we investigated whether

- algae with high amounts of VLCFAs are more sensitive to metazachlor than algae with less VLCFAs
- mesocosm studies are suitable to detect sensitive plankton species

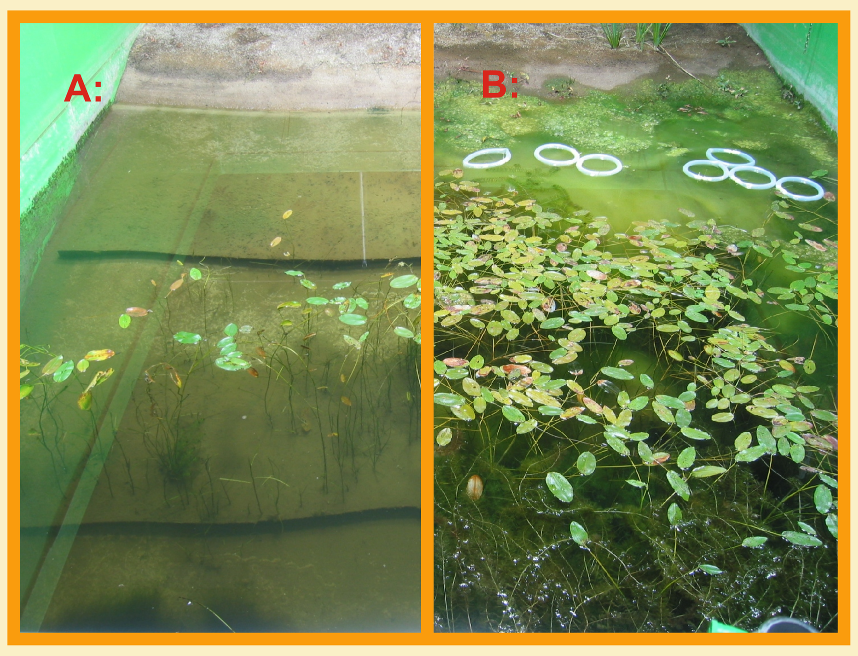

Fig. 2: Indoor ponds after application of metazachlor (Oct. 2003) - A: 200 µg/l dosage, B: control

Materials and Methods

Characteristics of the Mesocosm System

	Streams	Ponds
Size:	circular system of 106 m	690 x 325 x 250 cm (L x W x H)
Water volume:	40 m^3	15 m^3
Flow velocity:	0.12 m/s	
Max. light intensity:	7,000 lx	13,000 lx
Alkalinity:	1.7 - 2.5 mM/l	0.5 - 1.6 mM/l
Turbidity:	0 - 1.7 NTU	0.4 - 1.5 NTU
Nutrient level:	0 - 0.01 mg/l PO_4-P	0 - 0.025 mg/l PO_4-P
	0.02 - 0.35 mg/l NH_4-N	0 - 0.2 mg/l NH_4-N
	0 - 1.1 mg/l NO_3-N	0 - 0.9 mg/l NO_3-N

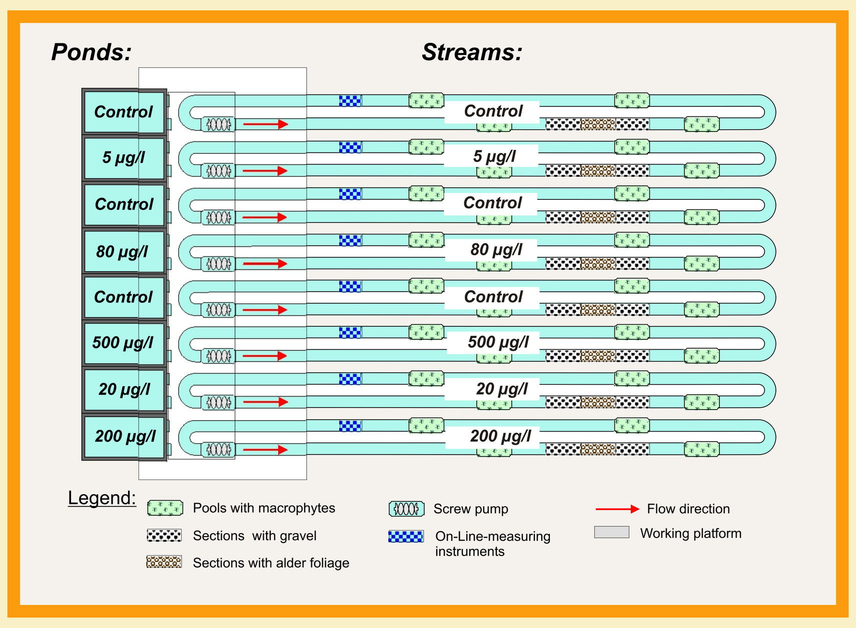

Fig. 3: Application scheme of the indoor pond and stream mesocosm system

Experimental Design

- Contamination of 5 ponds and 5 streams with 5, 20, 80, 200, and 500 µg/l Metazachlor (single application), three systems served as control (Fig. 2 and 3)
- Duration of experiment: 20 - 22 weeks (start 3rd June 2003, end October 2003)
- Biweekly measurements of physico-chemical and biological parameters
- Water sampling for plankton: depth integrated at different positions in the ponds and at a depth of 0.1 m (one position) in the streams
- Phytoplankton and protozoans were fixed with Lugol's solution and counted according to Utermöhl (1958)
- Zooplankton was fixed in formaldehyde at a final concentration of about 4% and counted under a stereoscope
- Plankton community response was analysed by principle response curve (PRC) analysis using CANOCO (version 4.5)

Results: Streams

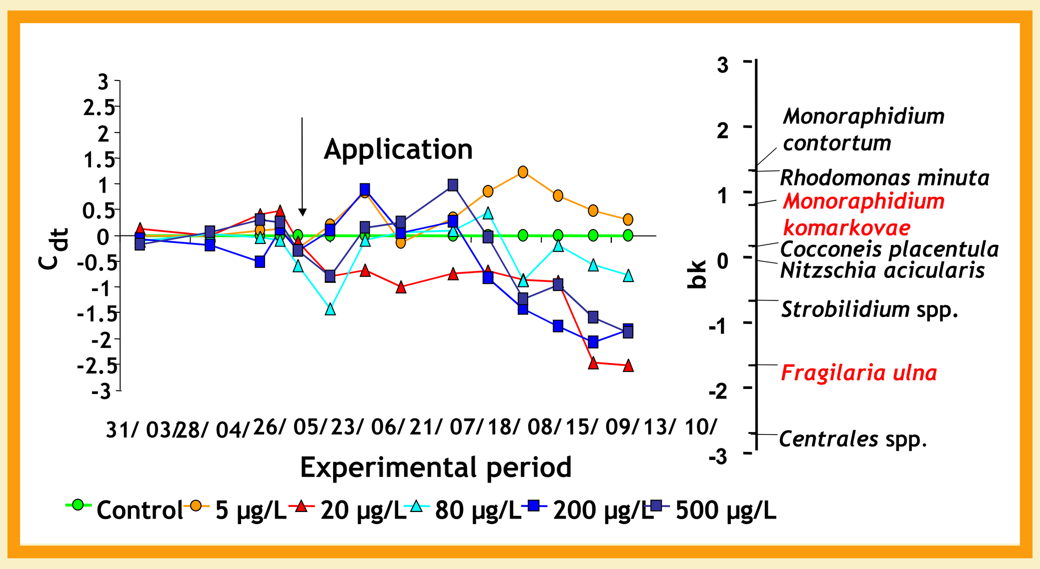

Fig. 4: PRC-analysis of the reduced phytoplankton data set in the stream mesocosms. Of total treatment variance (21.1 %), 30.5 % is explained by the PRC diagram. Species weight = bk value, arrow indicates date of application.

- Overall, density of pyhtoplankton and protozoans was very low (<5000 Ind./mL) with few species dominating the systems at each sampling date
- PRC revealed no clear concentration response relationship (Fig. 4)
- Species like *Monoraphidium komarkovae* (green algae) reacted with a decrease in abundance (Fig. 4, positive species weights; Fig. 5), while species like *Fragilaria ulna* (diatom) reacted with an increase in abundance (Fig. 4, negative species weights; Fig. 5)
- *M. komarkovae* directly decreased after Metazachlor application even at lowest concentration (5 µg/L)

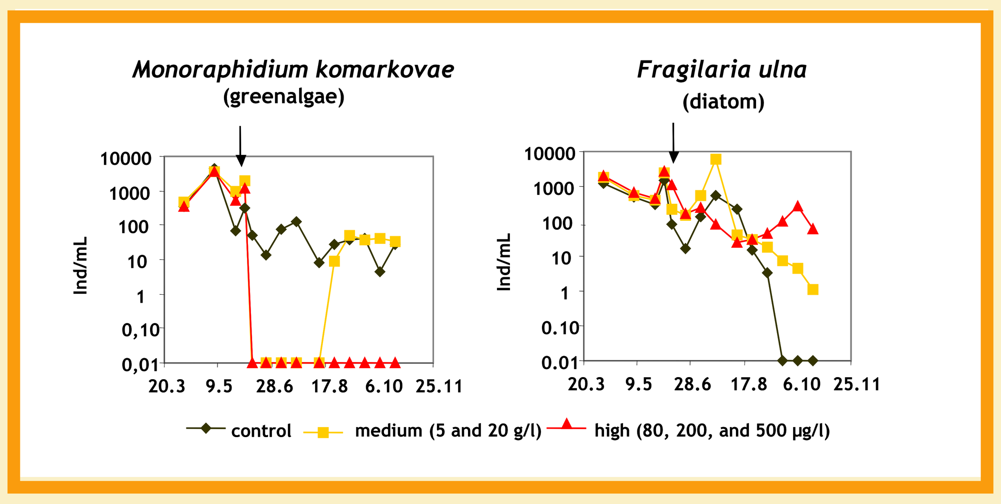

Fig. 5: Dynamics of two phytoplankton species in the stream mesocosms during the investigation period. For better overview, the dynamics in the low (5 and 20) and high (80, 200 and 500) Metazachlor concentrations were grouped into "medium" and "high".

Results: Ponds

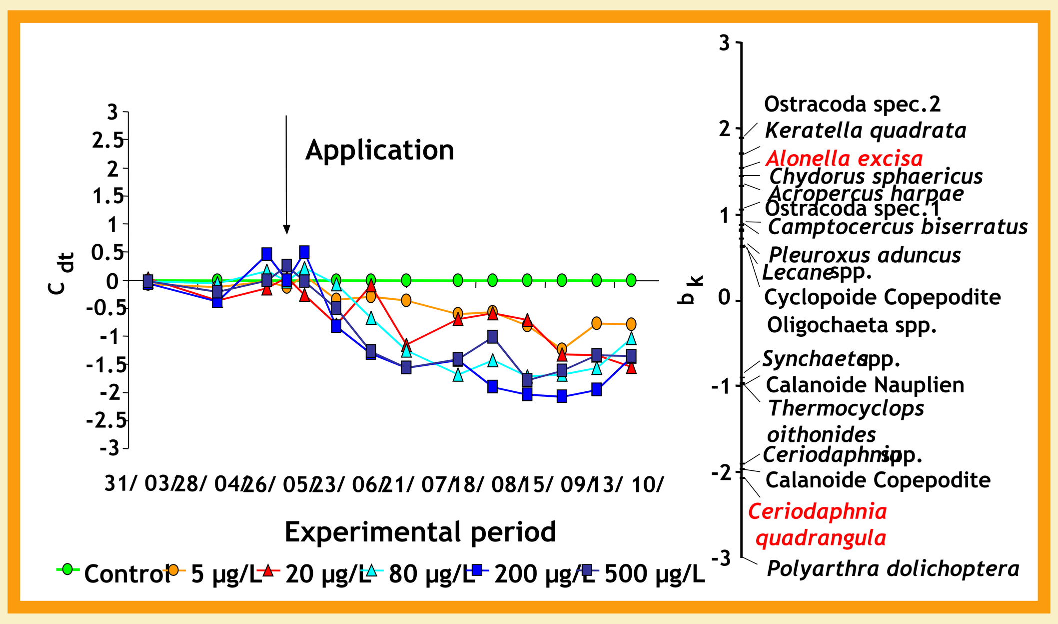

Fig. 6: PRC-analysis of the reduced zooplankton data set in the pond mesocosms. Of total treatment variance (33.91 %), 31.6 % is explained by the PRC diagram. Species weight = bk value, arrow indicates date of application.

- PRC revealed no clear concentration response relationship (Fig. 6), but significant differences between the controls and the different treatments were found for 6 sampling dates (permutation test, p > 0.05)
- Especially phytophile species like *Alonella excisa* or (*Acropercus harpae*, Fig. 1) reacted with a decrease in abundance (Fig. 6, positive species weights; Fig. 7) while free-swimming species like *Ceriodaphnia quadrangula* or *Polyarthra dolichoptera* reacted with an increase in abundance (Fig. 6, negative species weights; Fig. 7)

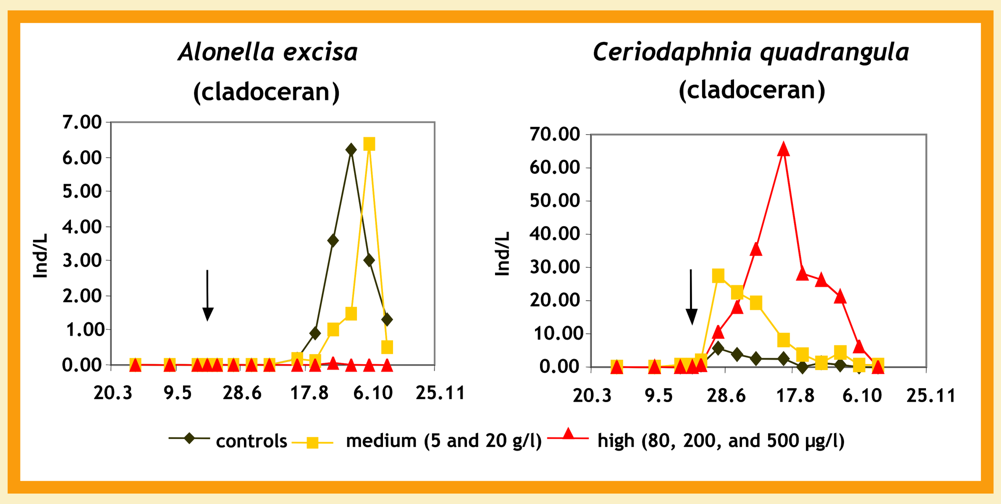

Fig. 7: Dynamics of two zooplankton species in the pond mesocosms during the investigation period. For better overview, the dynamics in the low (5 and 20) and high (80, 200 and 500) Metazachlor concentrations were grouped into "medium" and "high".

Discussion and Conclusions

In this study green algae, which have generally high amounts of VLCFAs (Napolitano 1998), were more sensitive than diatoms and cryptophytes with less amounts of VLCFAs. However, generalisations concerning the sensitivity of different groups or even species are difficult. Even within one species sensitivity towards metazachlor may vary strongly. Schmalfuß et al. (1998) found that a *Scenedesmus acutus* mutant was highly resistant to metazachlor while the wild type was very sensitive. Only the mutant was able to replace the missing VLCFAs in essential membranes or cell wall components with <C18 fatty acids. The fact that in this study most algal species reacted insensitive or increased in abundance may at least partly result from this capability.

Indirect effects like altered habitat structure, changes in competition conditions and food availability were most likely responsible for the changes in the zooplankton communities of the pond mesocosms.

The absence of phytophile species like *A. excisa*, *Acropercus harpae* or *Camptocercus biserratus* in the highly contaminated ponds was caused by the strong reduction of macrophyte biomass (Fig. 2), while free swimming species like *P. dolichoptera* and *C. quadrangula* increased in abundance.

The occurrence of many indirect effects on the plankton community was probably the reason why the PRC analysis did not reveal a clear concentration response relationship.

General Conclusions

Standard laboratory toxicity tests with few algal species may not be sufficient to cover the whole range of effects of metazachlor on algae since the reactions of algae seem to be very heterogeneous due to the special mode of action of this herbicide. Consequently, for risk assessment mesocosm studies should become a standard in testing chloracetamides or single species tests should be restricted to algae with a high share in >C18 VLCFA.

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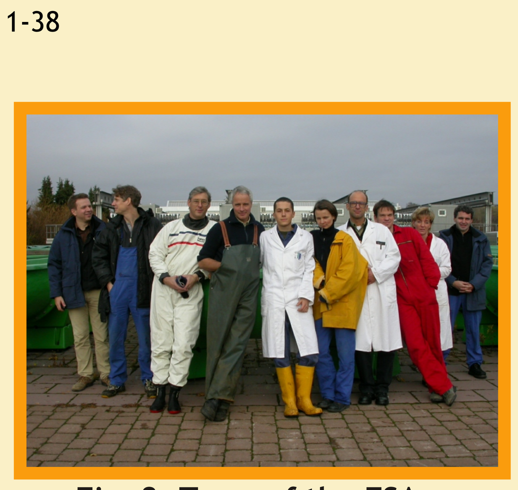

Fig. 8: Team of the FSA