Assessing the effects of pharmaceuticals on aquatic ecosystems

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Effects of pharmaceuticals in aquatic ecosystems

- Public awareness of the presence of pharmaceuticals in our environment grows.
- More sophisticated detection techniques detect more compounds...

- ...but what is the actual risk?
- $$risk = \frac{effect\ of\ a\ compound}{exposure\ to\ a\ compound} = \frac{EC_{50}}{concentration\ measured\ in\ environment}$$

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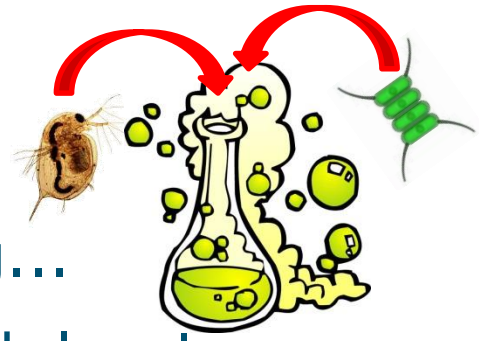

- What about effects? → standard lab testing...
- But once effects are found it's at rather high levels ...

Table 1
Examples of concentrations (ng L^{-1}) of non-steroidal anti-inflammatory drugs measured in different aquatic environments.

Compound	CAS number	Sample	Country	Analytical procedure	LOD (ng L^{-1})	Concentration reported (ng L^{-1})	Ref.	Taxon	Species	Toxicological endpoint	Ecotoxicity data	Ref.
Acetylsalicylic acid	50-78-2	Somes river water	Romania	SPE-GC–MS	30 (LOQ)	<30–37.2 (±4.6)	[20]	Algae	*D. subspicatus*	EC_{50} (growth inhibition)	106.7 mg L^{-1}	[95]
Acetylsalicylic acid		STP influent	Japan	SPE-GC–MS	10 (LOQ)	470–19,400	[86]	Crustacean	*D. magna*	EC_{50} (48 h) (immobilization)	88.1 mg L^{-1}	[95]
		STP effluent				38.0–111						
Salicylic acid	69-72-7	STP effluent	Canada	SPE-GC–MS/MS	0.1	554.3–2178.2	[17]	Bacteria	*V. fischeri*	EC_{50} (30 min)	90 mg L^{-1}	[83]
		River water				130.4–371.5						
		Lake water				286.7						
Salicylic acid		STP influent	Canada	SPE-GC–MS	10	2820–12,700	[18]	Algae	*Scenedesmus subspicatus*	EC_{50} (72 h)	>100 mg L^{-1}	[83]
		STP effluent				10–320						
								Crustacean	*D. magna*	EC_{50} (24 h) (immobilization)	118 mg L^{-1}	[83]
								Ciliates	*Tetrahymena pyriformis*	EC_{50} (48 h) (growth inhibition)	>100 mg L^{-1}	[83]
								Fish	*B. rerio (zebra fish)*	LC_{50} (48 h)	37 mg L^{-1}	[83]

Santos,et al (2010). Journal of Hazardous Materials **175**(1-3): 45-95.

- ...are there no effects out there?

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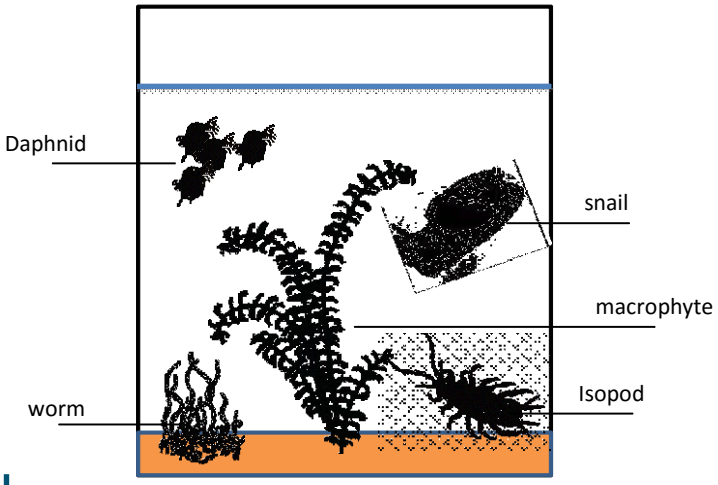
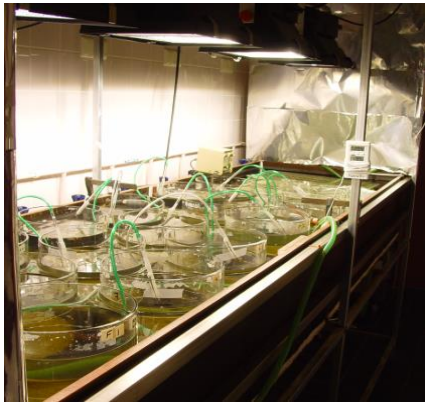
- 14 day indoor microcosm study
  - More realistic community
  - Chronic vs acute
  - Other processes like reproduction included
  - mimicking actual measured concentrations
  - Control, effluent and mix (spike of selected compounds)
  - 12L water with sediment layer (n=4)





Effects of pharmaceuticals in aquatic ecosystems

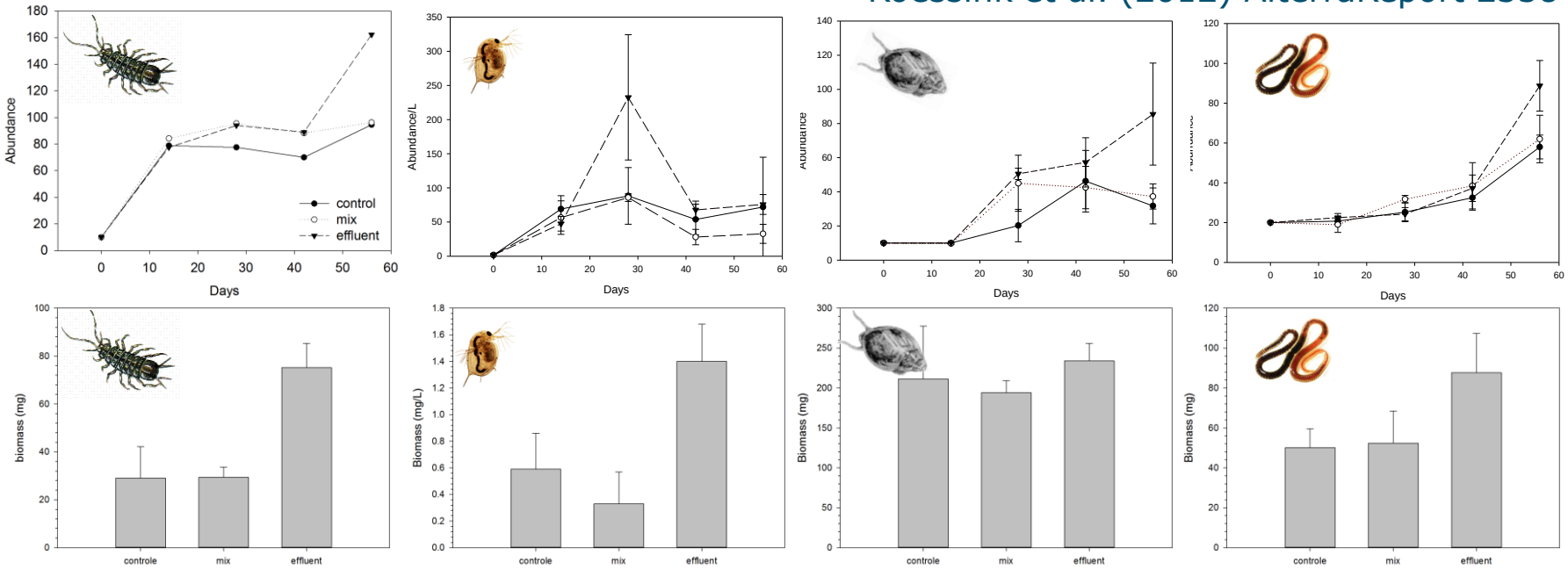
- Concentrations

Compound	Effluent start (µg/L)	Effluent eind (µg/L)	TWA effluent (14d)	Mix start (µg/L)	Mix eind (µg/L)	TWA mix (14d)
Diclofenac	0.7	0.28	0.46	0.5	0.07	0.22
Carbamazepine	0.9	0.70	0.76	0.5	0.27	0.36
Gemfibrozil	<0.5	0.38				
Hydrochlorothiazide	5.3	2.15	3.38	1.0	0.17	0.43
Irbesartan	3.2	0.44	1.09	2.5	0.89	1.56
Valsartan	<0.5	0.07	-			
Anhydroerythromycin A	0.2	0.09	0.14			
Azithromycin	0.2	<LOQ	-			
Clarithromycin	0.1	<LOQ	-			
Sotalol	4.1	1.85	2.87	1.5	0.40	0.80
Atenolol	0.3	<LOQ	-	0.5	0.05	0.23
Metoprolol*	2.5	0.58	1.00	2.5	0.44	0.83
Iohexol	0.4	0.54	0.24			
Ioxithalamic acid	0.3	0.35	0.31			
Ciprofloxacin	0.2	<LOQ	-			
Sulfamethoxazole	0.5	0.62	0.57			
Bisphenol A	<0.5	0.07	-			
Metformin	2.4	1.70	2.07	6.0	2.1	3.07
Guanyl urea	61.7	38.50	48.02	77.0	6.5	20.76

Effects of pharmaceuticals in aquatic ecosystems

- Results:

Roessink et al. (2012) AlterraReport 2338



- For all species abundances and/or biomass increases in the effluent treatment
- No negative effect observed → positive effect due to excess of nutrients?
- Is this the right way of looking at this topic?

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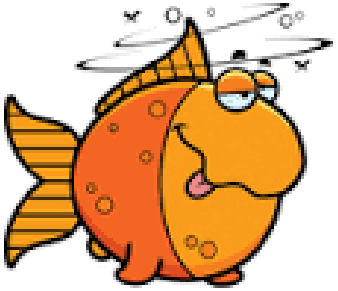
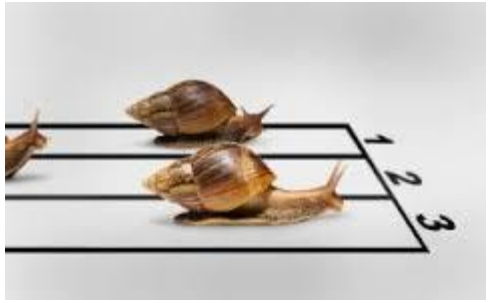
- Effects of pharmaceuticals: clear examples from estrogens e.g., impacting fish (Nash et al., 2004; Kidd et al., 2007).
- But what about other classes of pharmaceuticals? ... Their impact might actually be different → on behaviour/locomotion/ cognition (Brodin et al, 2013; Fong and Ford, 2014)





- Other types of investigations are required...

Nash, et al., 2004. Environmental Health Perspectives 112(17): 1725-1733.
Kidd et al., 2007. Proceedings of the National Academy of Sciences 104(21): 8897-8901.
Brodin et al., 2013. Science **339**(6121): 814-815.
Fong and Ford (2014). Aquatic Toxicology **151**: 4-13.

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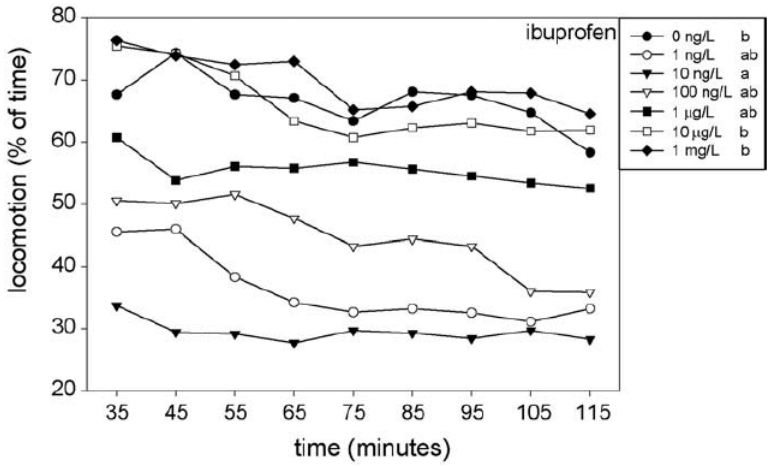
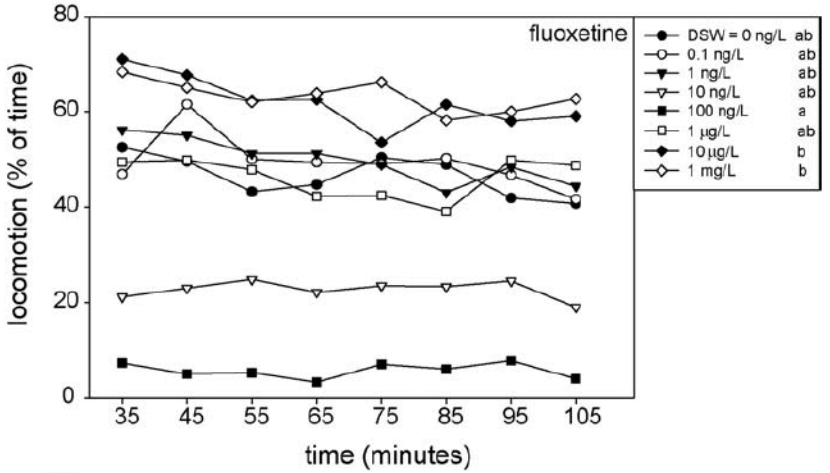
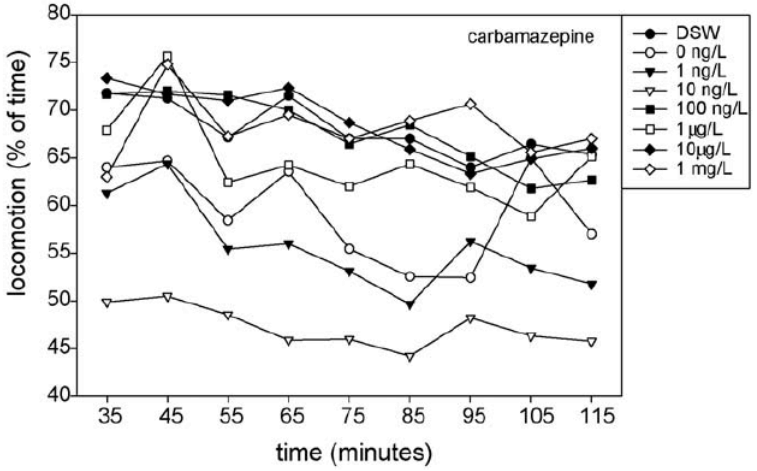
- Multispecies freshwater biomonitor
  - Chamber with electric field
  - Animal movement is detected in the field
  - Distinct patterns correlate with distinct behaviour (e.g., swimming, resting, ventilating)
- *Gammarus pulex* (crustacean)
- Ibuprofen, carbamazepine, fluoxetine, cetyltrimethylammonium bromide (CTAB)

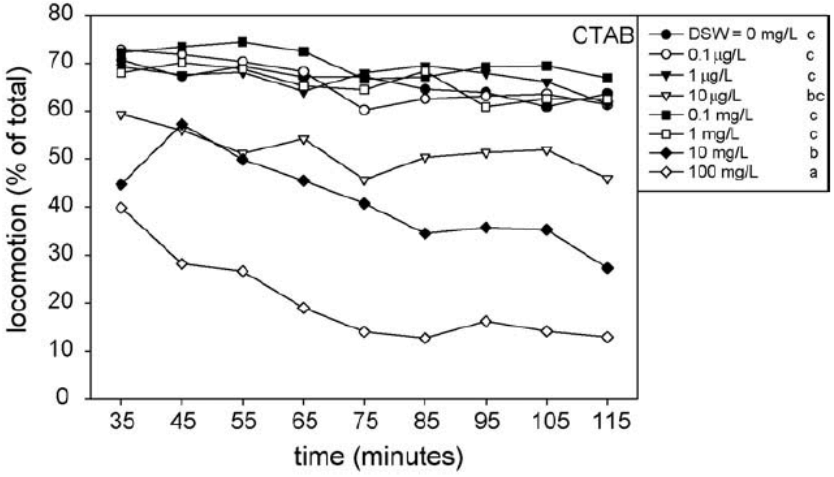
Effects of pharmaceuticals in aquatic ecosystems

- Results









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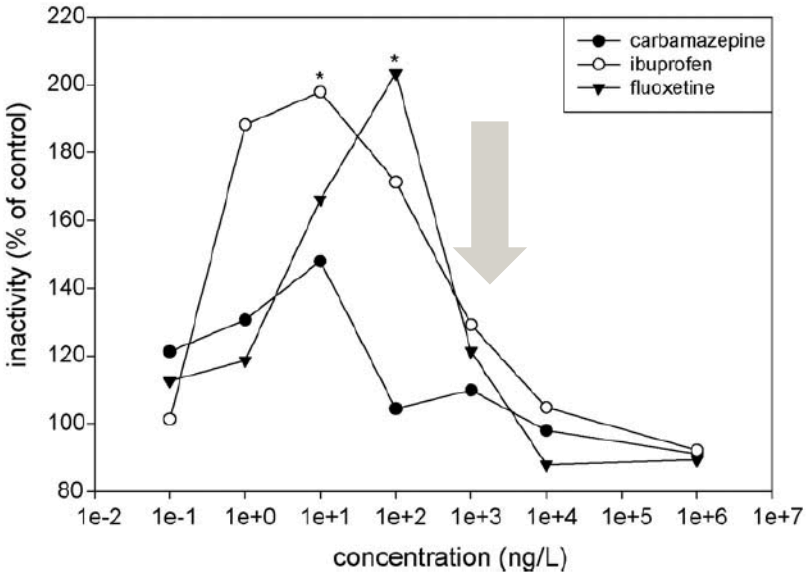
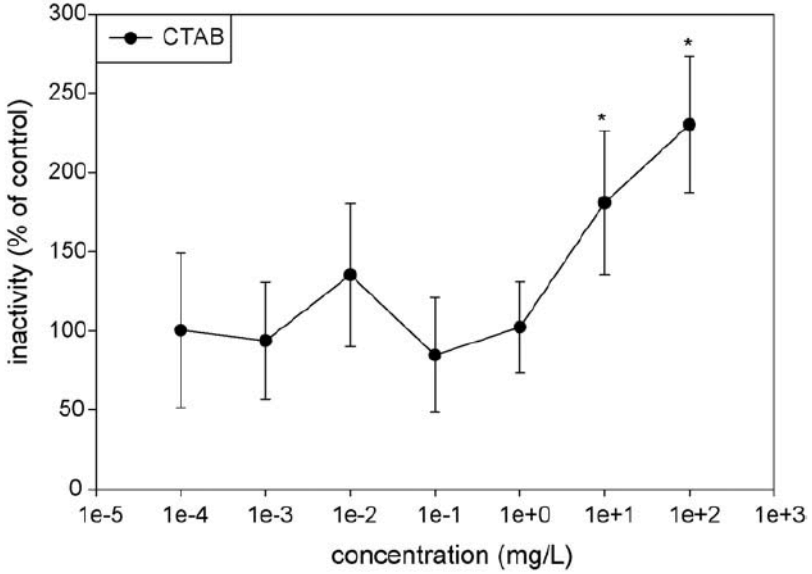
- Results





- Carbamazepine, ibuprofen & fluoxetine caused inactivity at low test concentrations, this effect disappeared at higher dosages
- The response to CTAB increased at increasing dosage

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- Pharmaceuticals:
  - Do not always follow the 'standard' ecotox rules (increasing dosage = increasing response)
  - Impact other endpoints than mortality or reproduction
- So what....?
  - Behavioural disturbances can have severe effects on populations
    - Inactivity = less food intake
    - Not recognizing predator cues
  - Effects occur at environmental relevant concentrations → potential risk

Effects of pharmaceuticals in aquatic ecosystems

- Thus...
  - Test not het highest concentration found in the environment, but the environmentally active concentration
  - When testing in (model) ecosystems such effects only become visible when multiple trophic levels are present (e.g., predator-prey interactions)

Thank you for your attention!

For further contact:

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