Linking ecology and the identification of priority environmental contaminants: lessons learned from river biofilms

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Multiple stressors affect river structure and function

Anomalous water temperature

Simplified habitat

Poorer water quality than under natural conditions

Multiple stressors affect river structure and function

Rising pressure on water resources

Intensive management: weirs, dams, channels…

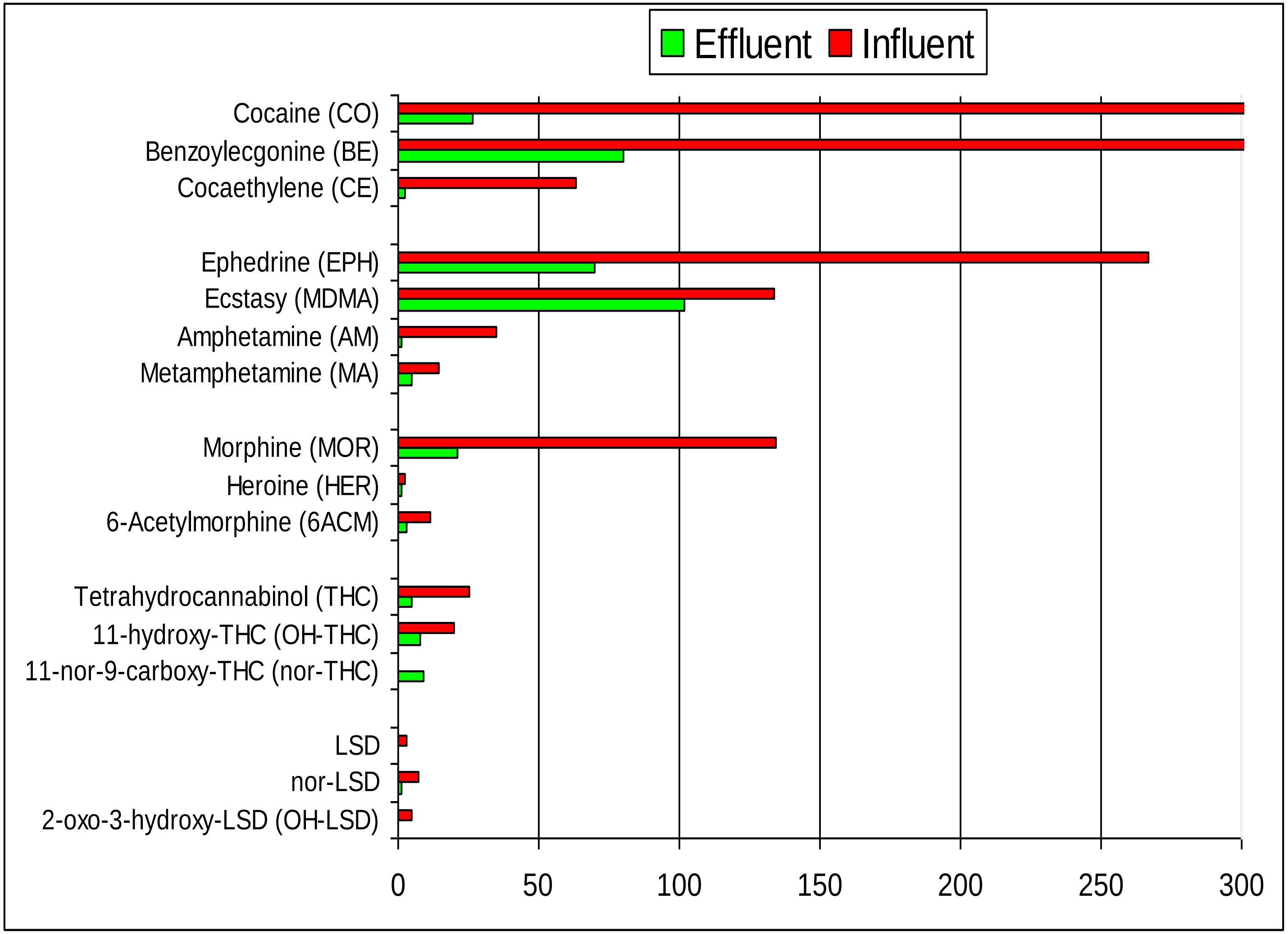
Impact on biodiversity

Arrival of invasive species

Multiple stressors affect river structure and function

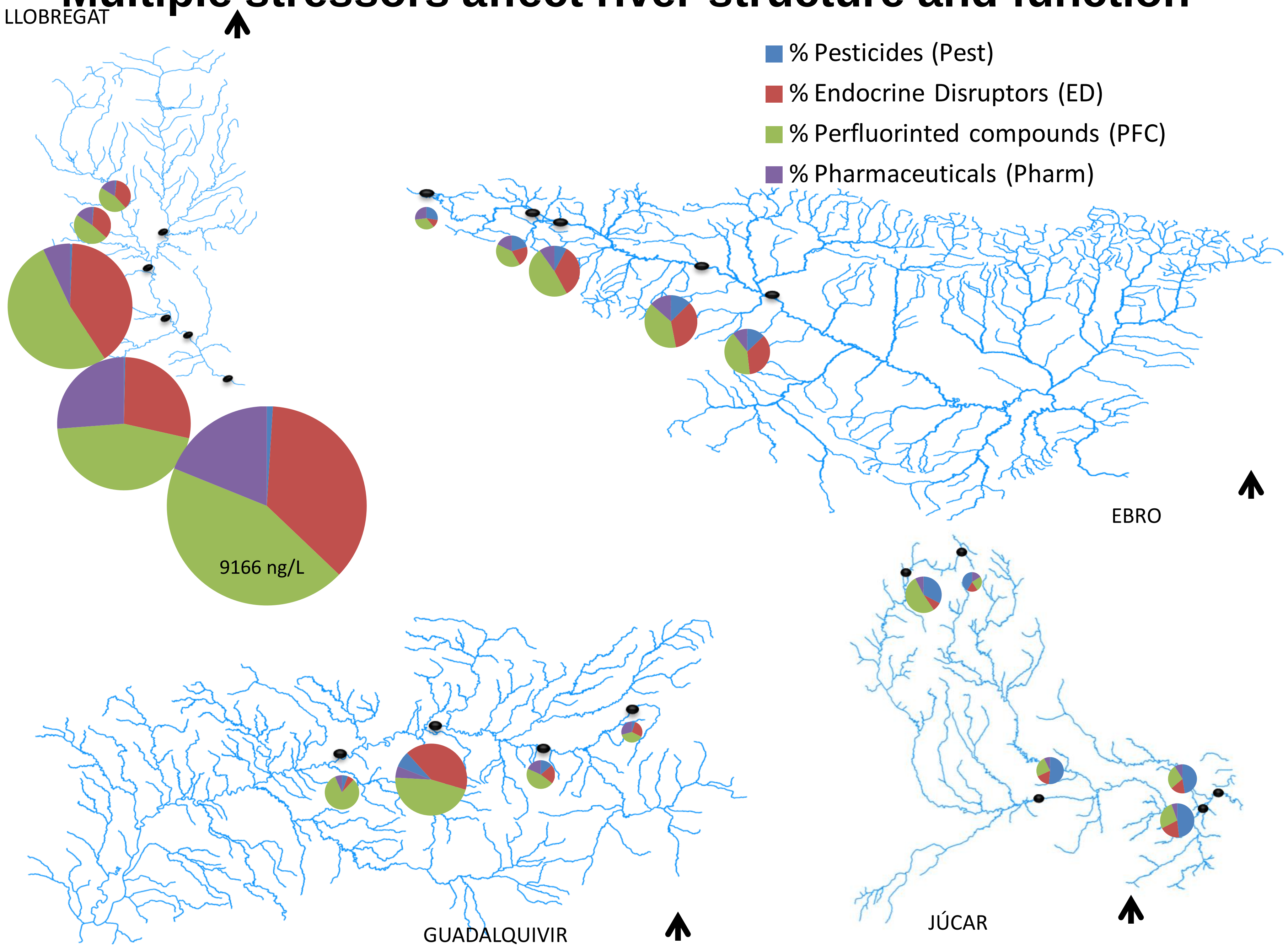
•CEC come along with:

- Nutrients
- DOM
- Priority pollutants



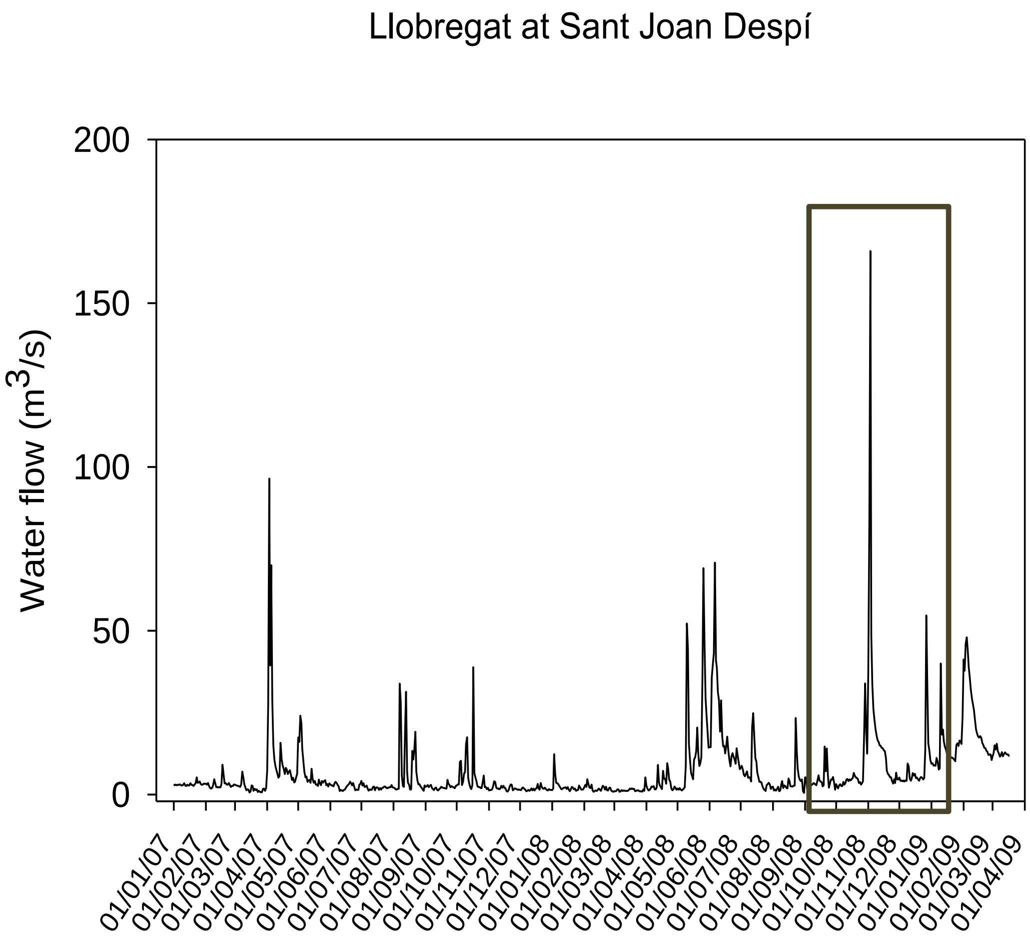
Postigo et al. 2009

Multiple stressors affect river structure and function



Multiple stressors affect river structure and function

Hydrograph of the Llobregat River (NE Spain) (daily values)

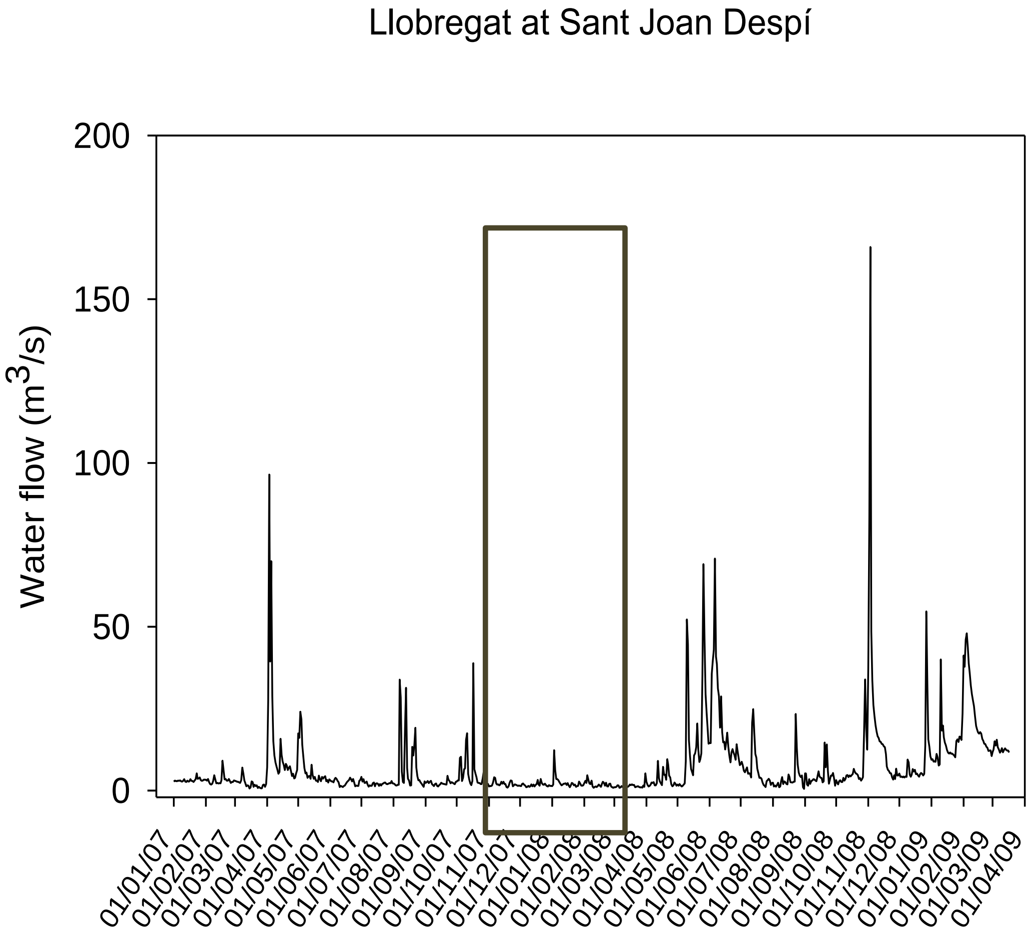


-Sediment mobility: associated mobility of CECs
-Biological resetting
-…..

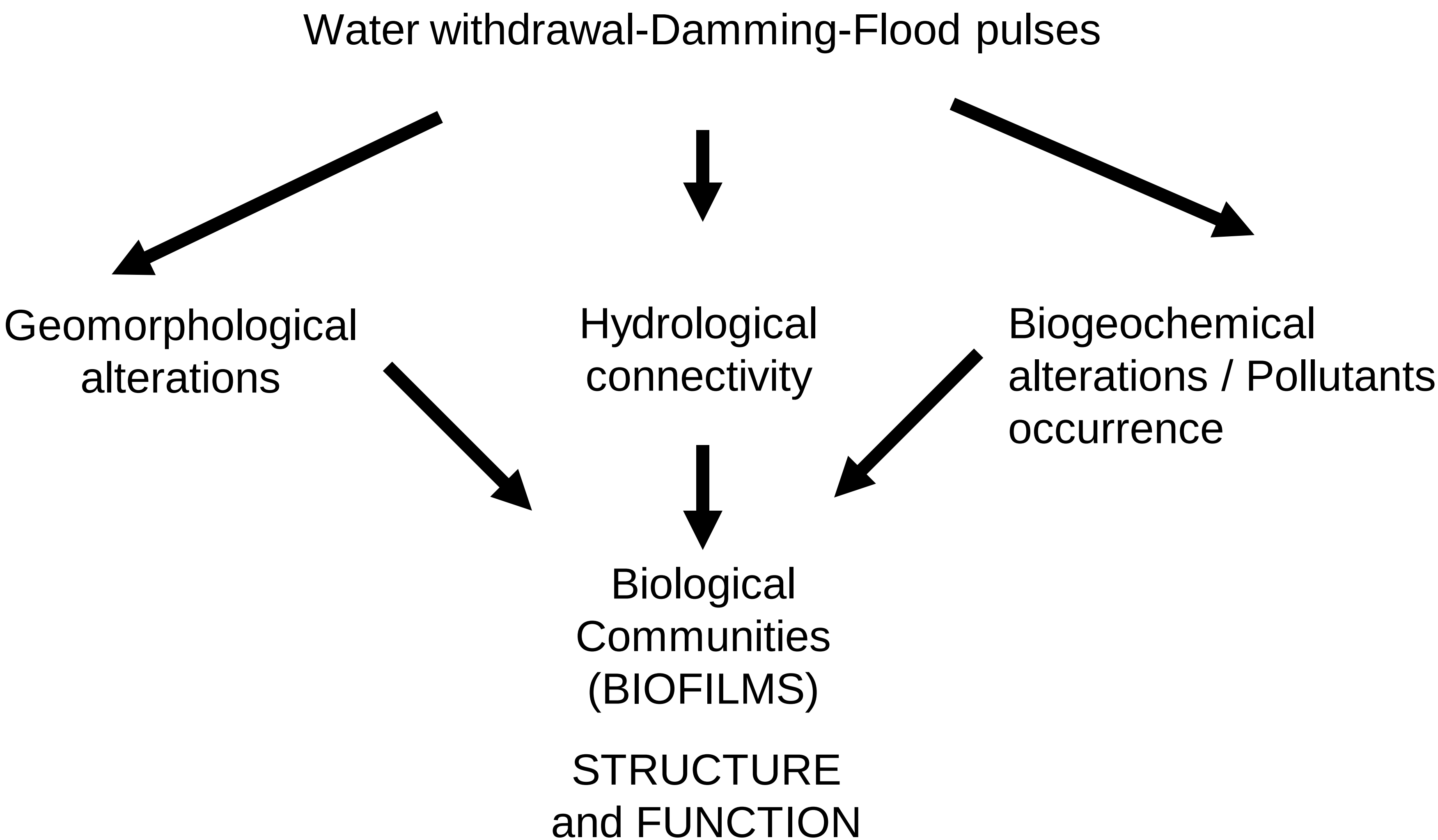
Multiple stressors affect river structure and function

Hydrograph of the Llobregat River (NE Spain) (daily values)

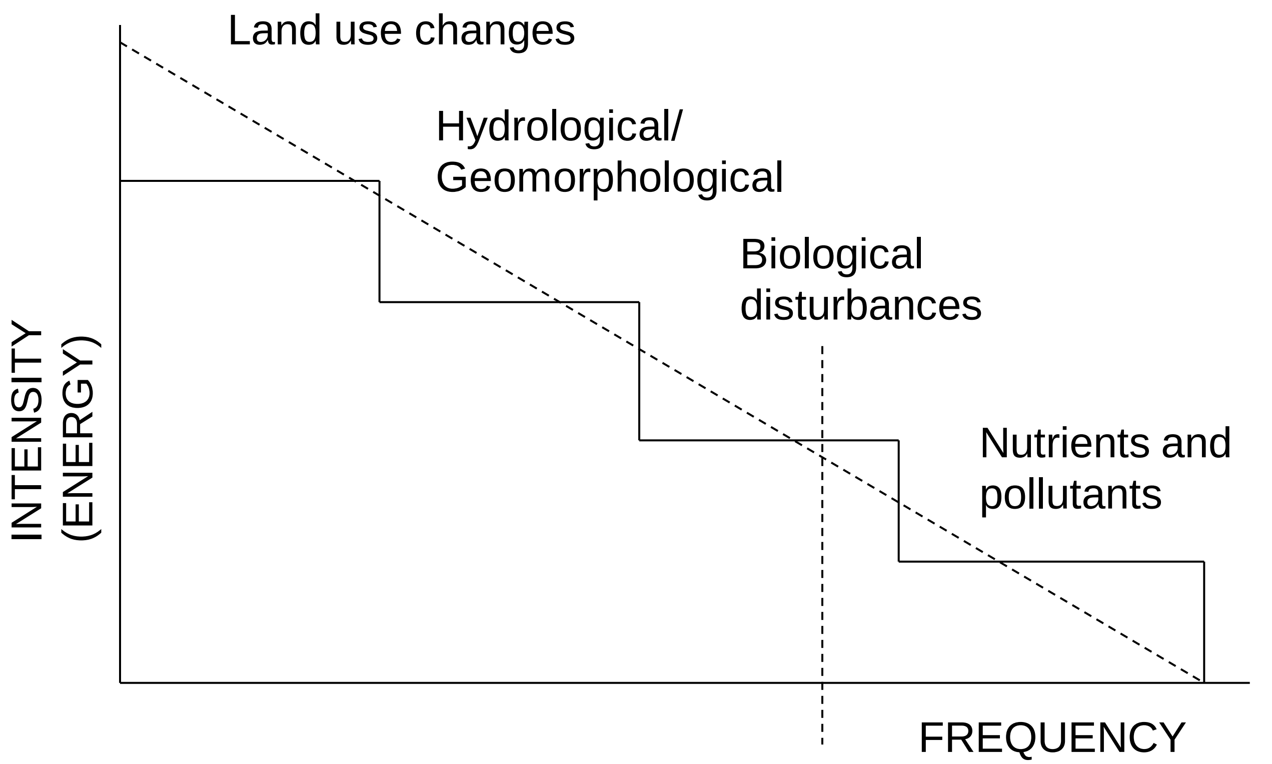
-lower dilution and higher concentration of CECs
-Higher biological complexity
-…..



A hierarchy of stressors



Intensity and reversibility of stressor effects



Intensity and reversibility of stressor effects

Most intense and irreversible effects

Hydrological and Physical- driven

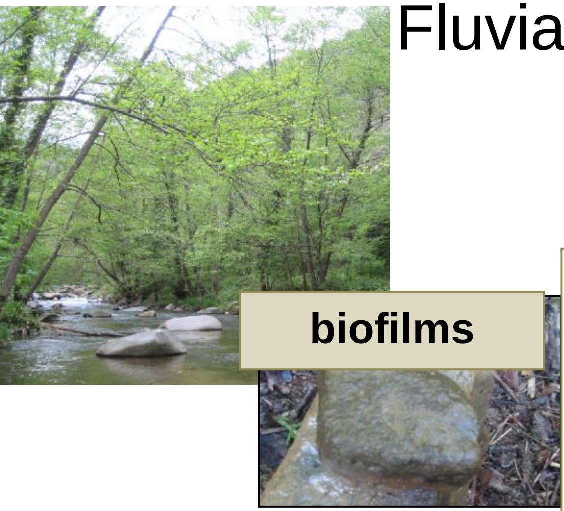
- Alterations of the hydrological cycle
  - Water abstraction
  - Inter-basins water transfer
  - Damming
- Land-use changes /landscape changes
- Geomorphological disturbances
  - Channel simplification and straightening
  - Flow derivation
  - Geomorphological effects of reservoirs

Biogeochemical and biological-driven

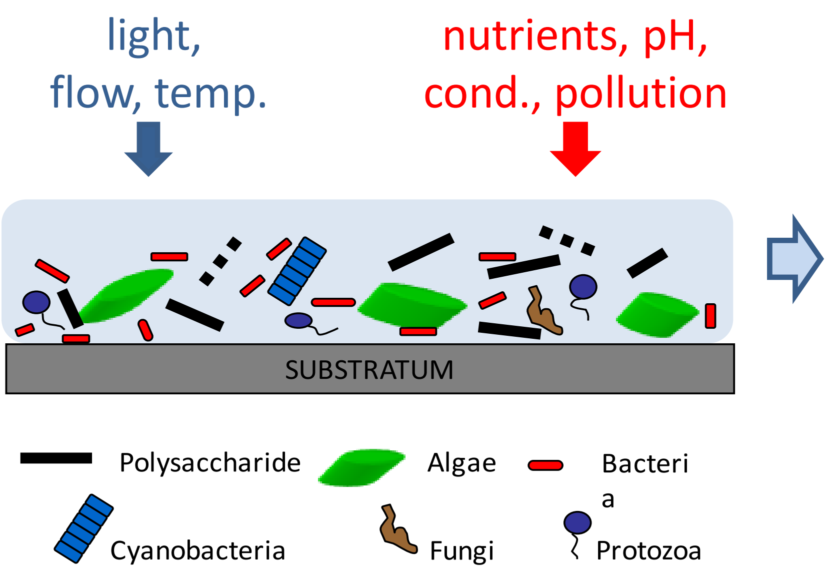
- Species invasions
- Pollutant inputs
- Nutrient enrichment

Least intense and irreversible effects

Fluvial biofilms: biological indicators of multiple stress

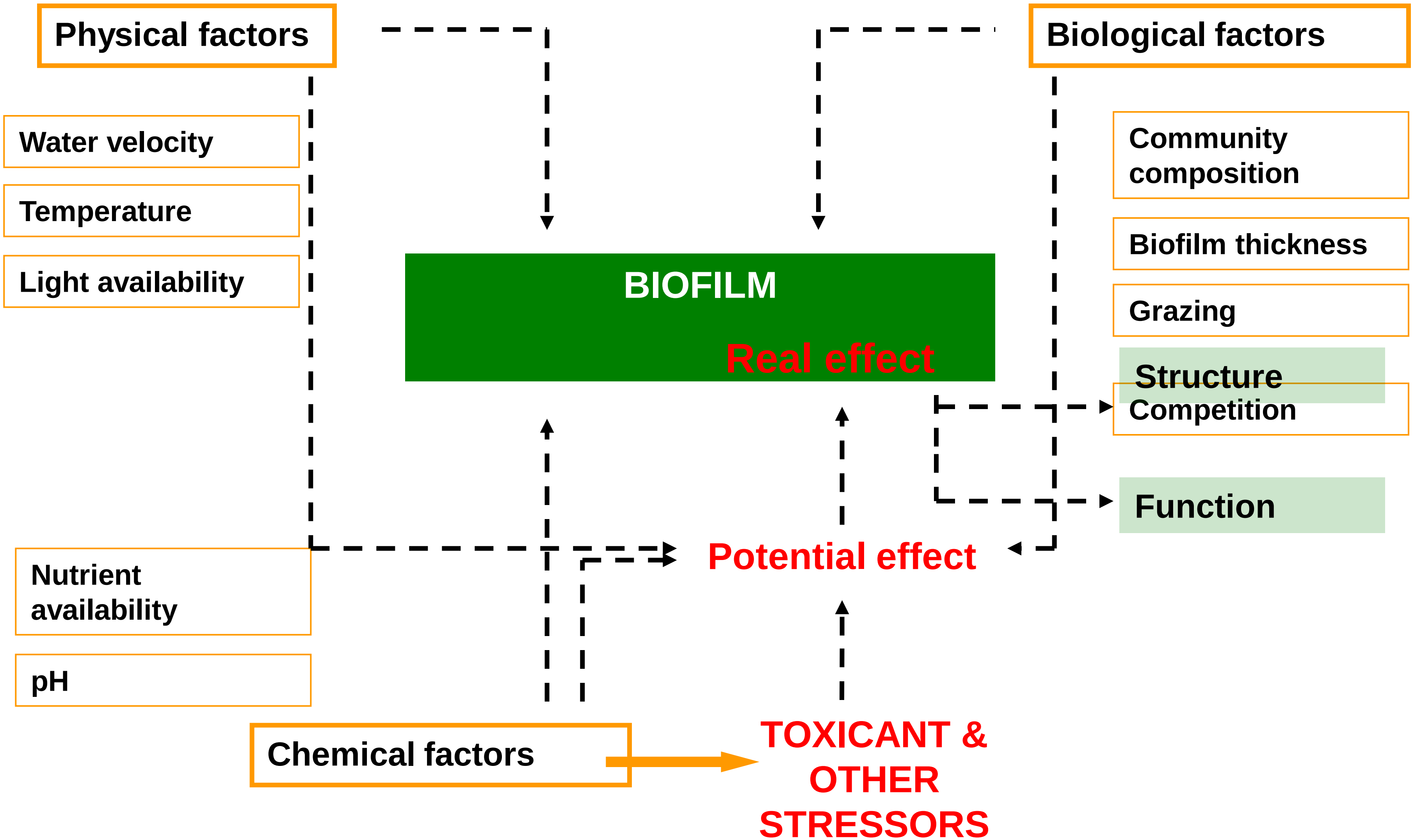


- Ubiquitous in streams and rivers
- The (generally) most relevant primary producers
- Heterotrophs and users of DOC
- Nutrient and organic matter recyclers



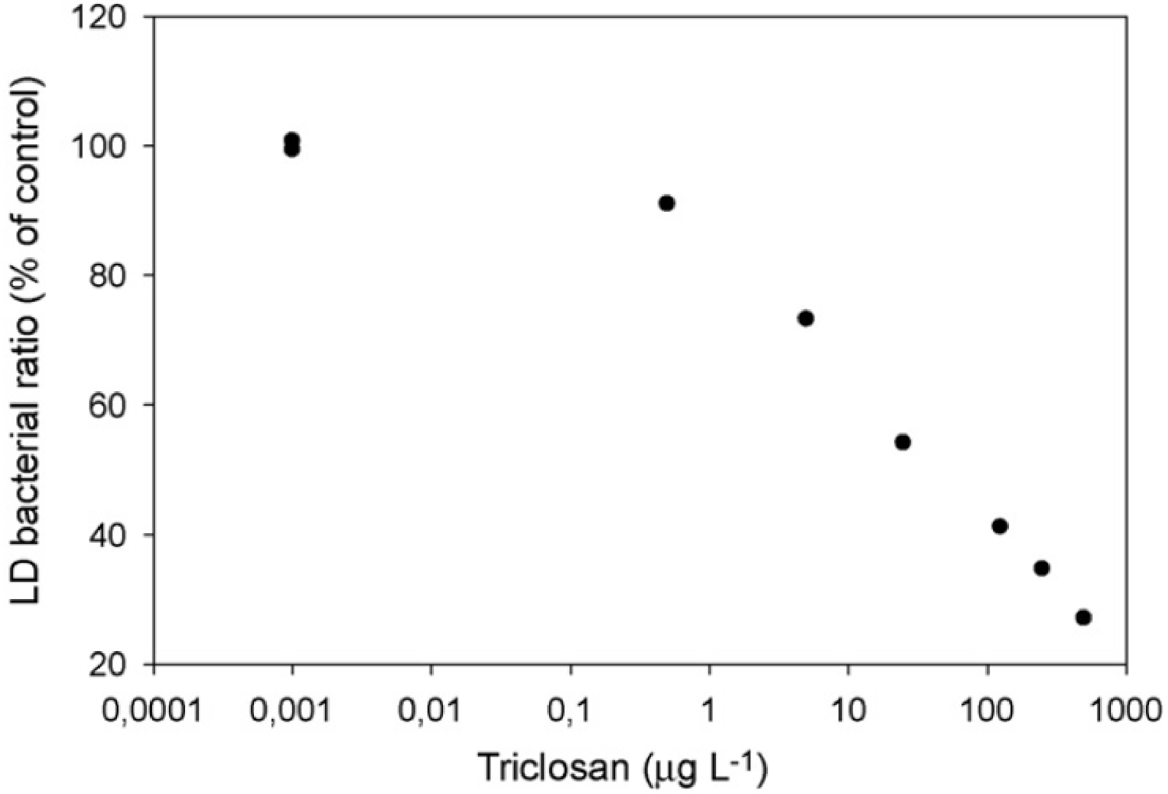
Allow to detect acute and long-term effects of environmental changes

Fluvial biofilms: biological indicators of multiple stress



Non-target effects of CECs in biofilms: the implications of the biological community

Effects of Triclosan on biofilms- Bacteria



Ricart et al. 2010. Aquatic Toxicology 100: 346-53

Effects of Triclosan on biofilms- Algae

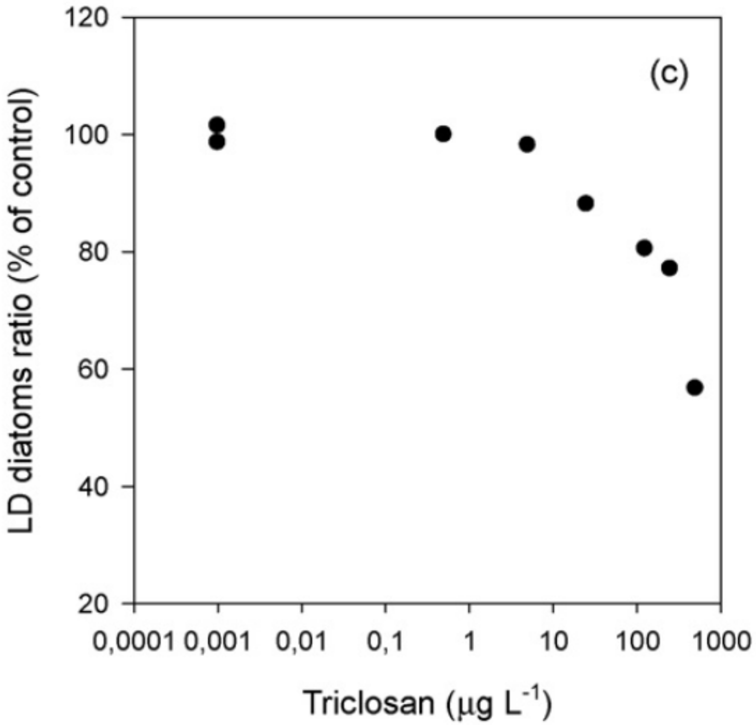


Table 4
Non-effect concentrations (NEC) and effect concentrations (EC_{10} and EC_{50}) and the corresponding range (in brackets, for the NEC) and standard error (for the EC_{10} and EC_{50}), obtained by each endpoint. The best-fit model and the estimated model parameters (φ_1, φ_2 and φ_3) of the each concentration–response function are given for concentrations expressed in $\mu g\, L^{-1}$.

Endpoints	NEC ($\mu g\, L^{-1}$)	EC_{10} ($\mu g\, L^{-1}$)	EC_{50} ($\mu g\, L^{-1}$)	Best-fit model	Model parameters		
					φ_1	φ_2	φ_3
Photosynthetic efficiency (Y_{eff})	0.42 [9.1×10^{-8}–84.3]	3.37 ± 4.74	–	Five-parameter log-logistic	–0.13	0.01	5.74
Non-photochemical quenching (NPQ)	n.s.	1.31 ± 5.53	110.97 ± 29.42	Two-parameter log-logistic	–0.49	4.77	
Live–dead diatom ratio	1.49 [0.006–26.5]	3.70 ± 0.64	–	Two-parameter log-logistic	–0.71	6.82	
Live–dead bacterial ratio	0.21 [0.077–0.47]	0.56 ± 0.15	43.76 ± 4.75	Five-parameter log-logistic	–0.32	0.18	4.37

Ricart et al. 2010. Aquatic Toxicology 100: 346-53

The effect of emerging compounds on biofilms differ with different hydrological conditions

High water flow vs low-water flow periods, summer-autumn **2011- 2012**

Five sites per basin selected for simultaneous chemical and biological analyses

Data set used in the analysis

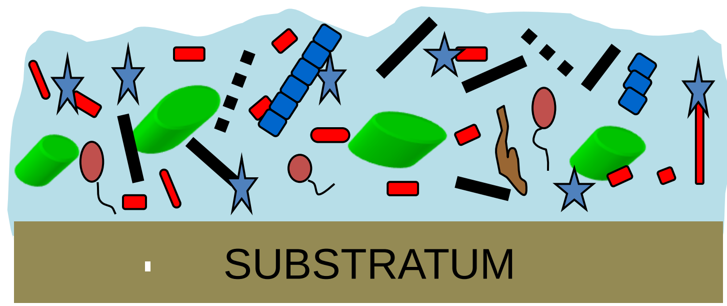
- **Physical and Chemical parameters**: flow (Q), water nutrient content (PT, DIN), DOC, Temperature, Oxygen, pH and conductivity.

- **Pollutants in water**

Identified toxicants	nº of compunds	nº of families
Non essential metals (MN)	4	1
Essential metals (ME)	2	1
Pesticides (Pest)	49	11
Perfluorinated compounds (PFC's)	23	3
Endocrine disruptors (ED)	26	7
Pharmaceutical products (Pharm)	88	14
TOTAL	**192**	**37**

Data set used in the analysis

- **Biofilm analysis**



Algal parameters

Bacterial parameters

- Algal biomass (Chl-a)
- Diatom composition (diversity, % abundance)
- Photosynthetic efficiency (Yeff)

- Bacterial density
- Alkaline phosphatase (AP)

- **Statistical analysis**

Influence of physical and chemical parameters and pollutants on biofilm parameters → Redundancy Analysis -Variance partitioning technique

Natural conditions

- **Seasonality:**

Droughts

Floods

High hydrologic variability

Global change

- **Climate change:**

More frequent extreme hydrological situations

- **Human activity:**

irregular hydrodynamics

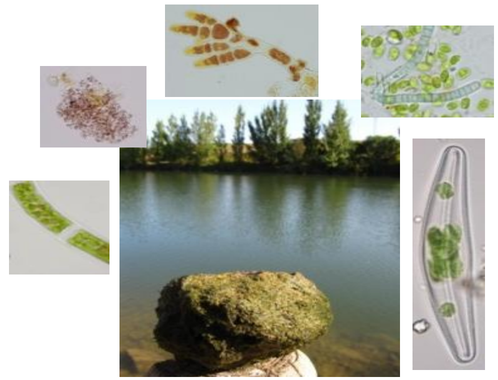
water pollution

- **↑Conductivity**
- **↑ Nutrients**
- **↑ Toxicants**

(i.e. biofilms)

Epilithic biofilms are subjected to stress conditions

Water quantity and quality is altered due to global change

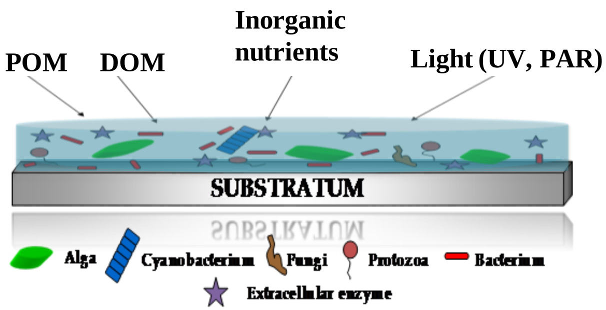


High flow – Thin biofilms

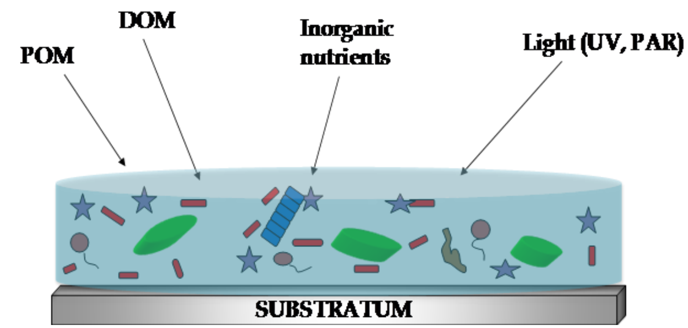
- High shear stress
- First stages of colonization process
- High species turnover
- High diffusion

Base flow – Thick biofilms

- High biofilm maturity
- Large extracellular matrix
- Lower diffusion
- High retention capacity



POLLUTION

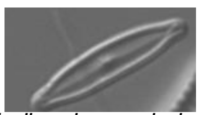


Chemical stressors (nutrients, toxicants, ...) respective relevance is altered by water flow patterns

High flow

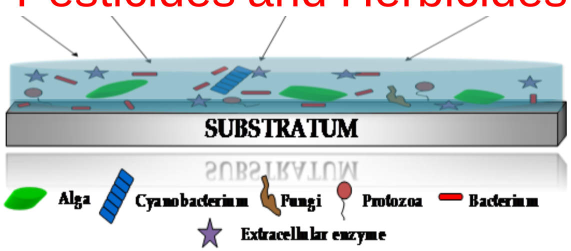
- ↓ **algal biomass (chl-a)**
- ↑ **bacterial densities**
- **Active metabolism**
- ↓ **bioaccumulation**
- **Diatom species characteristic of early successional stages**

Achnanthes biassolettiana



Cymbella microcephala

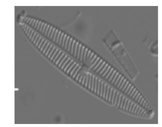
Pollutants from runoff:
Pesticides and Herbicides



Hydrological-driven responses

Base flow

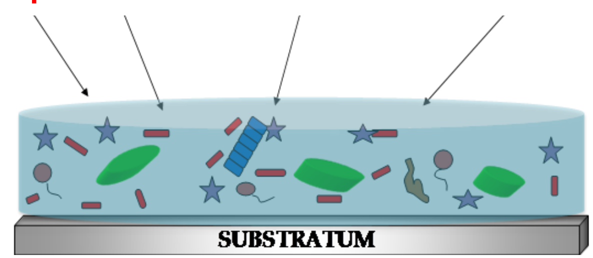
- ↑ **algal biomass (chl-a)**
- **Metabolism less active**
- ↑ **bioaccumulation**
- **Diatoms tolerant to pollution**



Navicula tripunctata

Nitzchia dissipata

Pollutants from point sources:
Industrial and pharmaceuticals compounds



Higher relevance of water pollution

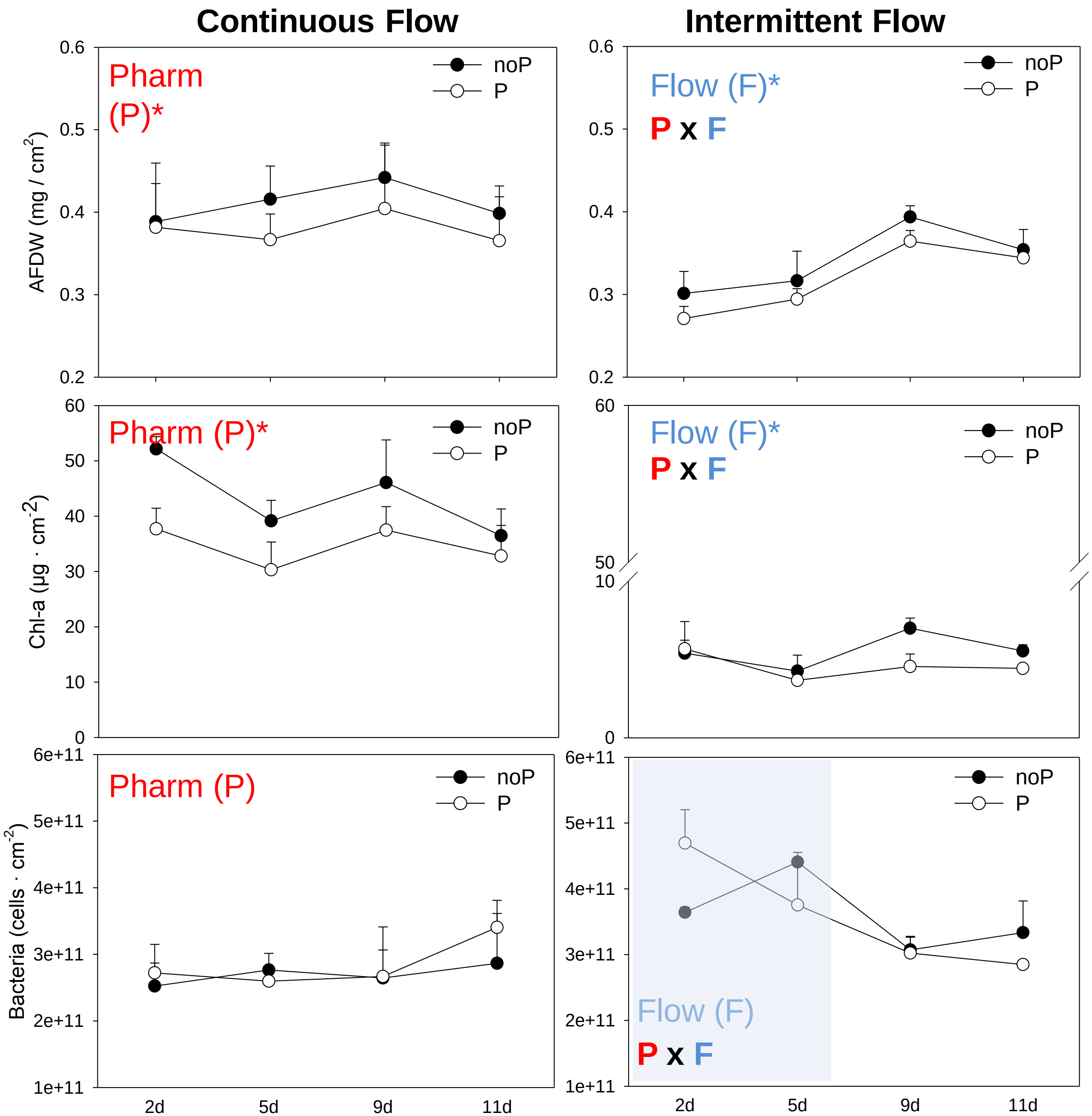
Response of biofilms to pharmaceuticals and flow interruption- primacy vs interaction

➢Flow intermittency

- ↓↓ **Algal biomass** / changes in species composition
- ↓ **Bacterial density** / changes in structure composition
- Overall effects on **metabolism (primary production & respiration)**

Corcoll et al. 2014. STOTEN in press

Results: Biomass



● noP: no pharmaceuticals
○ P: pharmaceuticals exposure

Pharmaceuticals:
- total biomass reduction≈ 8%
- algal biomass reduction ≈ 20%
- non-effect on bacterial density

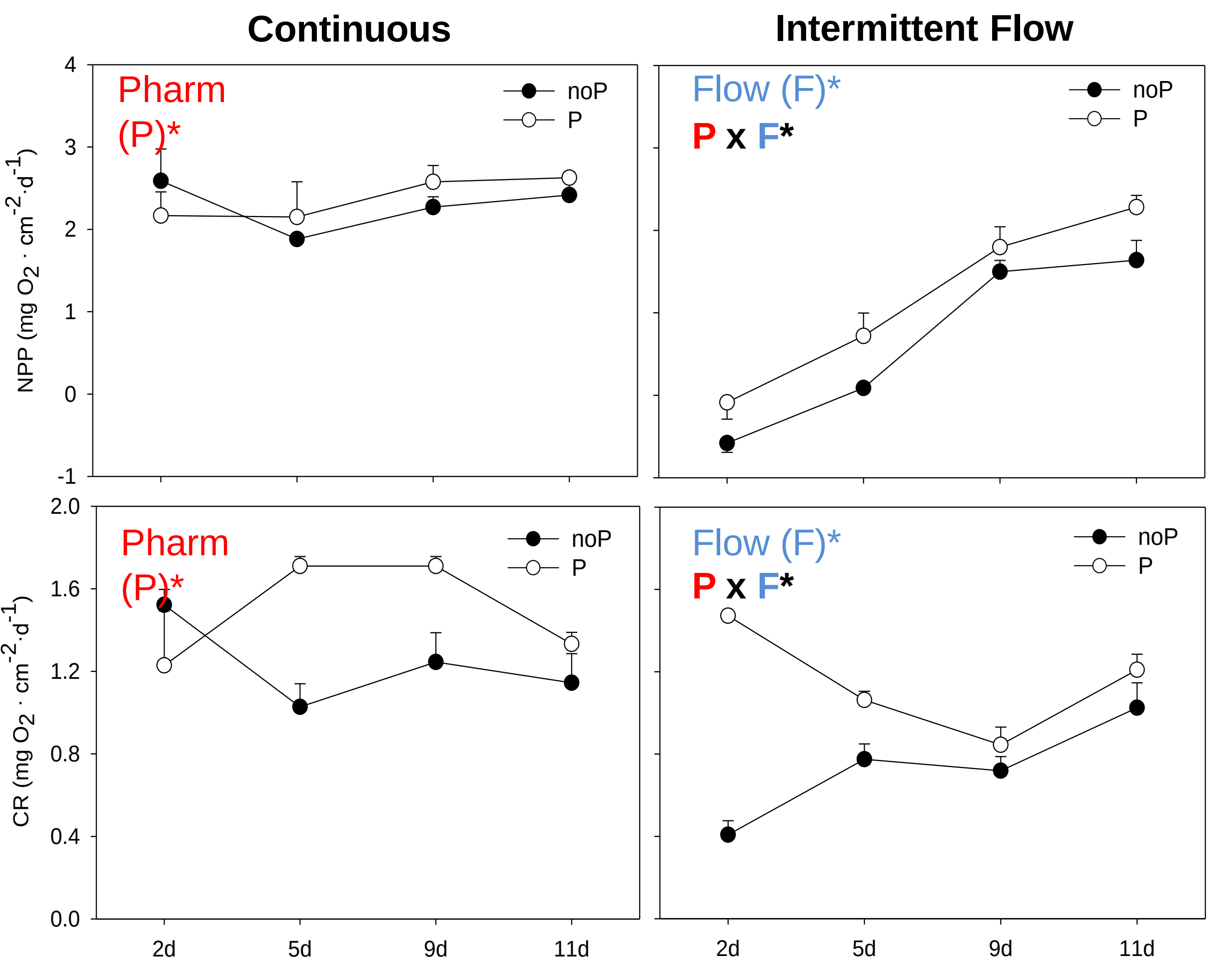
Intermittent Flow
- total biomass reduction≈ 17%
- algal biomass reduction≈ 87%
- increase in bacterial density at 2d-5d

P x F (multi stress)
- no significant effects

* $p<0.05$ (ANOVA 2 ways of repeated measures)

Results: Metabolism

● noP: no pharmaceuticals
○ P: pharmaceuticals exposure



Pharmaceuticals:
- ↑ **NPP** ≈ 8%→ ↑ unicel green-algae
- ↑ **CR** ≈ 20%→↑ heterotrophic contr.

Intermittent Flow
- **NPP**→ ↓ algal biomass
- **CR** → ↓total biomass

P x F
- ↑↑ **NPP**→ ↑ unicel. green-algae
- ↑ **CR** → ↑ heterotrophic contr.

* $p<0.05$ (ANOVA 2 ways of repeated measures)

Acute effects are mixed to those long-term: Pharmaceutical bioaccumulation in biofilms-

ng / gDW	Cont_P		Int_P	
	2d	11d	2d	11d
Carbamazepine	**2.72 (0.44)**	**0.9 (1.55)**	**0.94 (1.63)**	**1.31 (2.03)**
Sulfamethoxazole	**9.03 (3.73)**	**13.79 (8.40)**	**11.28 (0.98)**	**16.48 (8.59)**
Erythromycin	nd	nd	nd	nd
Metoprolol	**47.87 (9.98)**	**83.08 (9.98)***	**35.09 (6.22)**	**90.57 (9.15)***
Atenolol	nd	nd	nd	nd
Ibuprofen	nd	nd	nd	nd
Diclofenac	**13.45 (4.15)**	**nd***	**17.76 (8.92)**	**<LOQ***
Gemfibrozil	nd	nd	nd	nd
Hidrochlorothiazide	**28.43 (7.76)**	**25.82 (7.94)**	**29.95 (13.45)**	**39.86 (29.86)**

* $p<0.05$

- Bioaccumulation: Metropolol **>** Hydrochlorothiazide **>** Sulfamethoxazole ≈Diclofenac **>** Carbamazepine

- Bioaccumulation similar when exposed to Continuous and Intermittent flow

- Metroprolol bioaccumulation ↑ over time (↑40-60%)

- Diclofenac bioaccumulation ↓ over time → acclimated biofilm?

Potential implications

• The receptor as a whole (the biological community) needs to be included in the effect-based decisions of prioritisation

•Complexity includes the variety of stressors, their co-occurrence, the geographical-specificities, and the biological complexity (community-based)

•Long-term effects (bioaccumulation) may have unknown consequences

Potential implications

•Uncertainty is part of the real environment; adding uncertainty estimates into the process to include community-based, nature-based responses

•Moving from effect-based values to management options requires including estimates of uncertainty

THANKS TO

Natàlia Corcoll, Maria Casellas, Belinda Huerta, Helena Guasch, Vicenç Acuña, Sara Rodríguez-Mozaz, Albert Serra-Compte, Damià Barceló, Mira Petrovic, Lydia Ponsati, Albert Ruhi, Dani von Schiller, Marta Terrado, Elisabet Tornés

Scarce Consolider-Ingenio 2010 (CSD2009-00065). “Assessing and Predicting Effects On Water Quantity and Quality In Iberian Rivers Caused By Global Change (2009-2014)” and Spanish Ministry of Economy and Competitiveness.