Determination of BSAFs for freshwater fish and derivation of a sediment standard for PCBs: a case study of the Rhone basin

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Context, study objectives

- Inventories of fish contamination by PCBs and dioxins since 2005-2006 in the Rhone basin
  - Bed sediments considered as the main source
- European policy on dioxin-related compounds – Directive 2006/13/EC
  - 8 pg TEQ.g^{-1}(fresh weight) except eels, 12 pg TEQ.g^{-1}
- Water Framework Directive (WFD) implementation:
  - A sediment standard for PCBs (or dioxins) would not be very relevant if only based on toxicity to benthic invertebrates
  - Trophic transfer from sediment to higher trophic level organisms not covered by the draft guidance on environmental quality standard (EQS) derivation
- Objectives
  - Develop robust biota to sediment accumulation factors (BSAFs) for freshwater fish species (basin-wide)
  - Derive a “trigger value” for sediment (SQG: sediment quality guideline)

Background

- Most current definition
- Uncertainties, limitations
  - "connection" sediment – fish (spatially and temporally)
  - knowledge of distributions generally missing
- Availability of 2 large databases in the Rhone basin:
  - Fish contamination inventory (2005-2009, ca. 2000 samples)
  - Sediment contamination (monitoring since 1993)

$$BSAF = \frac{C_l}{C_{soc}} = \frac{C_{org} / f_l}{C_{sed} / f_{soc}}$$

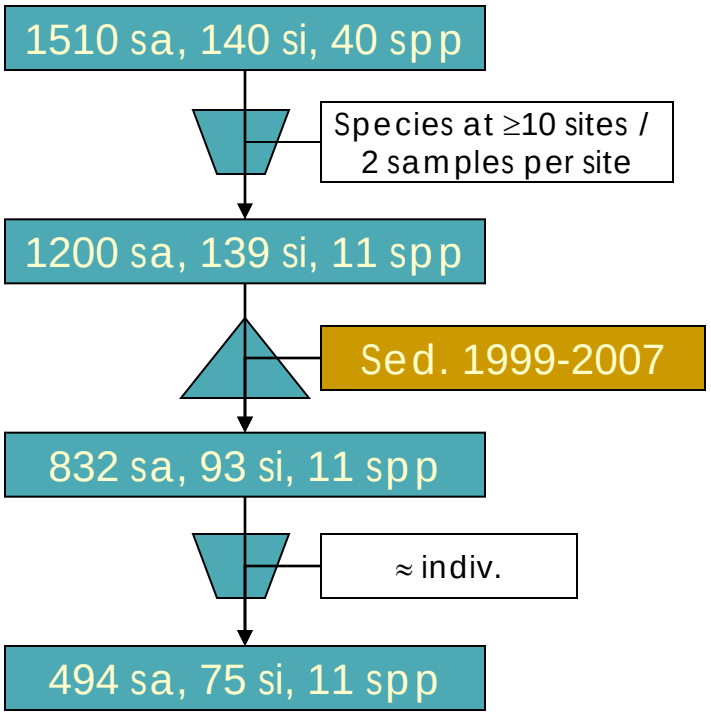
- C_{org} concentration in organism (µg.kg^{-1} wet weight),
- C_{sed} concentration in sediment (µg.kg^{-1} dry weight),
- f_l lipid fraction (g lipids / g ww),
- f_{soc} organic fraction (g OC / g dw)

Approach

- Dataset: matching the 2 databases
- Data selection
  - Fish: sampling protocol, number of samples
  - Sediment ↔ fish exposure
- BSAF determination
  - Bootstrap method ⇨ BSAF variability
  - Site by site, 3 sets (fish, sediment – PCB and TOC)
- Threshold derivation: indirect approach
  - Regulatory threshold (RT) refers to dioxins and related compounds
  - Most sediment data cope with indicator congeners (ΣiPCB)
  - BSAF more appropriate when referring to a single compound

Data selection

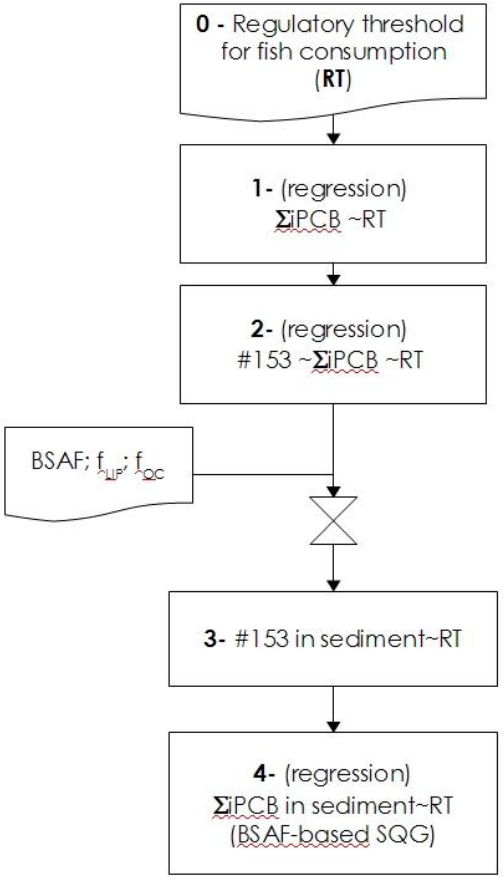
- Online fish database
  - Sites for which sediment data are available
  - Fish sampled 2007-2009
    - Spp present at ≥ 10 sites
    - ≥ 2 samples / site
    - Individuals or pools (restricted to 2 individuals same size)
- Online sediment database
  - Sites for which fish data are available
  - 1999 – 2007 (according to fish size-age)



http://www.rhone-mediterranee.eaufrance.fr/usages-et-pressions/pollution_PCB/basepcb

Sediment threshold derivation

- TEQ correlated to ΣiPCB
  - unless local dioxin sources
- More chlorinated congeners (e.g. #153) correlated to ΣiPCB in fish and sediment
- Uncertainty on the SQG
  - Confidence intervals for each parameter (slope and intercepts) of successive regressions



Overview of fish data

- Consistent relationship size / weight
- Few non-detects (less chlorinated #)
- Concentration ranges
- Almost no relationship
  - weight / lipid content
  - weight / PCB
  - lipid content / PCB
- Distributions normal (gaussian) or log-normal
- ⇨ rather consistent dataset
- #153 correlated to ΣiPCB (whole set, each species)

Pearson similarity matrix

	Lip. Cont.	# 28	# 52	# 101	# 118	# 138	# 153	# 180
# 28	0.47							
# 52	0.56	**0.83**						
# 101	0.36	0.59	**0.84**					
# 118	0.45	0.54	**0.84**	**0.97**				
# 138	0.33	0.49	0.70	**0.89**	**0.87**			
# 153	0.31	0.43	0.65	**0.84**	**0.83**	**0.94**		
# 180	0.18	0.35	0.46	0.61	0.58	**0.87**	**0.83**	
ΣiPCBs	0.33	0.49	0.71	**0.89**	**0.87**	**0.99**	**0.97**	**0.89**

N = 457 samples – all # ≥ LQ

Overview of sediment data

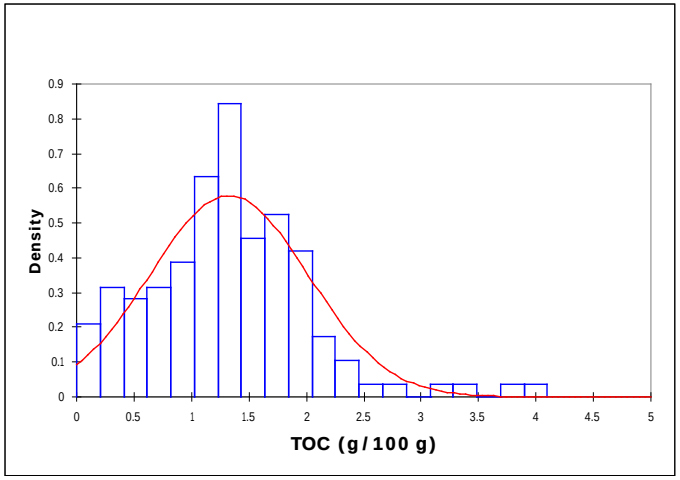
- 459 sets(75 sites)
  - … 111 ≥ LQ
- Reliability?
- #153 correlated to ΣiPCB
- Some other congeners correlated to #153
- BSAF ⇨ #153
- Organic Carbon (TOC)
  - 157 samples (Rhône river)
  - 1st quartile 0.013 g.g^{-1} (dw); 3rd quartile 0.019 g.g^{-1} (dw)

Each # ⇨Σ

	N	adj R^2	p
# 101	54	0.73	< 0.0001
# 118	49	0.15	0.003
# 138	88	**0.94**	< 0.0001
# 153	90	**0.95**	< 0.0001
# 180	68	**0.90**	< 0.0001

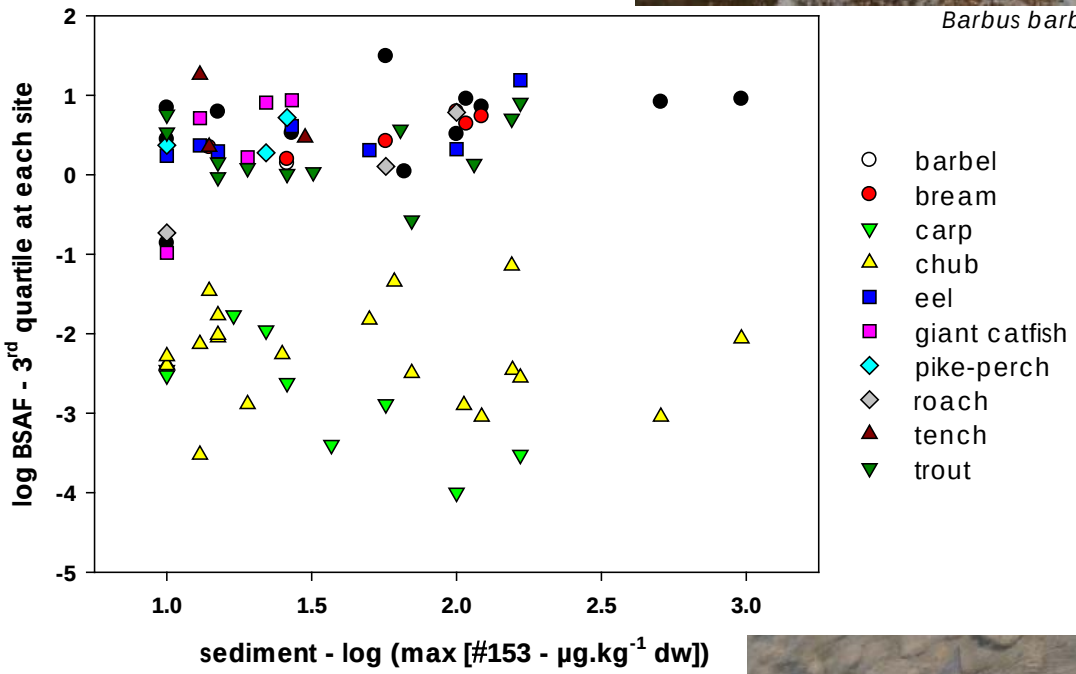
#i ⇨#153

	N	adj R^2	p
# 101	54	0.62	< 0.0001
# 138	83	**0.89**	< 0.0001
# 180	68	**0.95**	< 0.0001



BSAFs distribution

Barbus barbus



Squalius cephalus

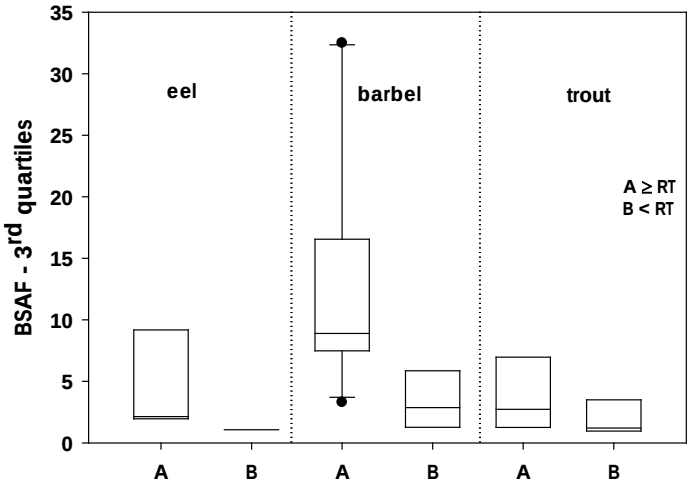
- No direct relationship with sediment concentrations
- Roughly 2 groups
  - carp, chub
  - giant catfish, roach, bream, pike-perch, tench, trout, eel, barbel
- Low BSAFs in chub related to food regime
- Low BSAFs in carps may be related to physiology and habitat
- Highest BSAFs (3rd quartile)
  - eel 1.7 – 15.5
  - barbel 0.14 - 31

Refined approach

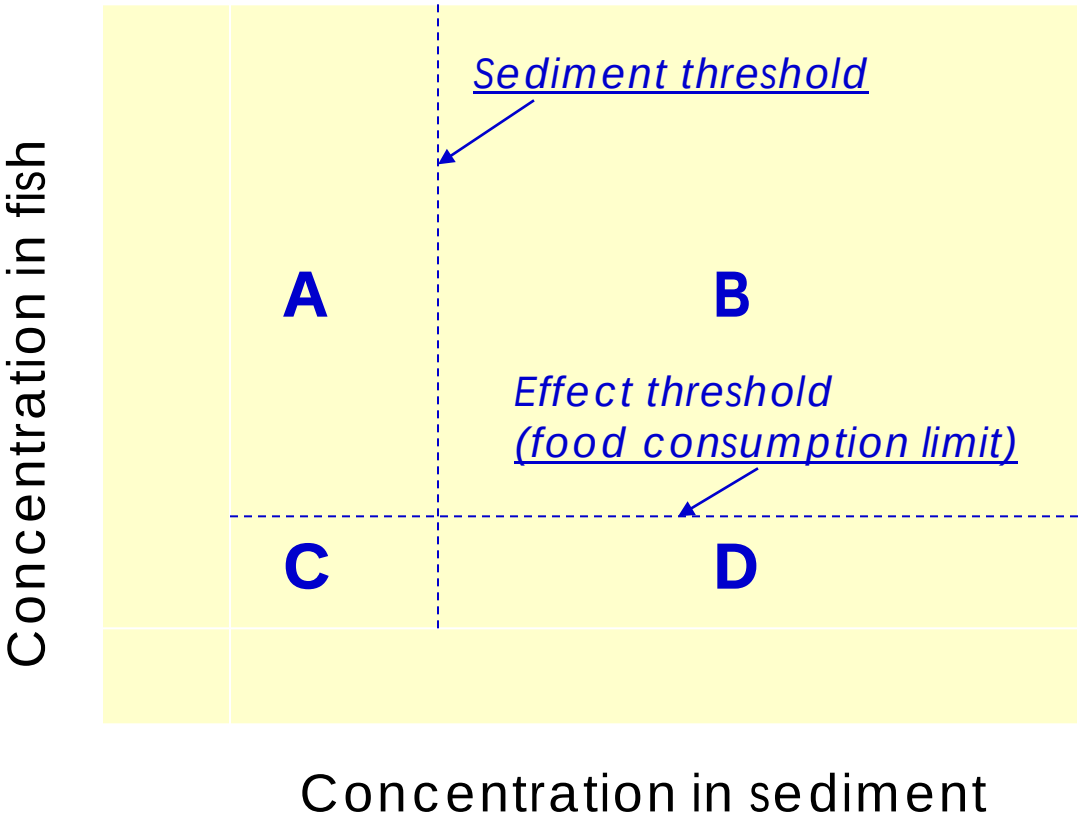
- 2 groups according to RT exceedence
  - G1 = fish ≥ RT (A)
  - G2 = fish < RT (B)
  - Some sites belong to both groups
- Statistics = Kaplan-Meier for left-censored data for calculating quartiles in sediment
- Refined bootstrap - BSAFs higher in G1 (A) than in G2 (B)

Sediments
(µg.kg^{-1} dw)

	G1	G2
N sites	33	69
N sites > LQ / N sites	64%	48%
1st quartile	10	10
median	15	10
mean	80.1	29.7
std deviation	32.4	8.2
3rd quartile	66	22
max	963	507



How efficient is the threshold?

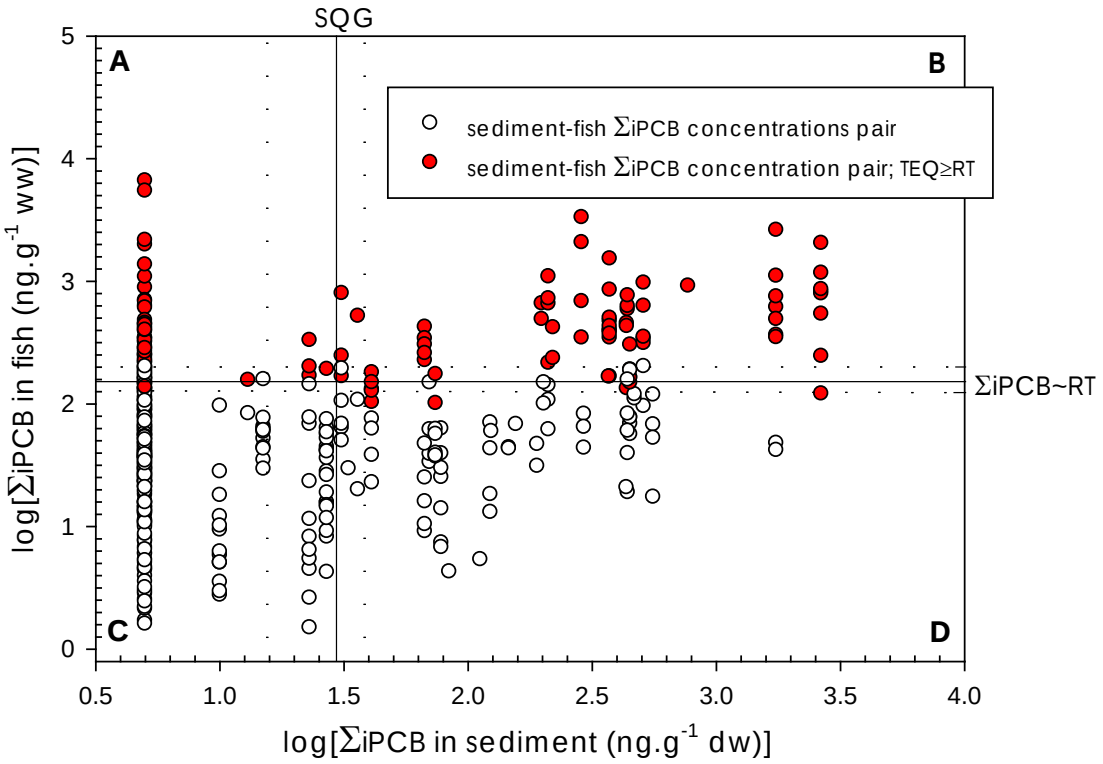


- Sensitivity = B/(A+B)
- Specificity = C/(C+D)
- Type I % = (D/(D+B))*100
- Type II % = (A/(A+C))*100
- Overall efficiency = (B+C)/(A+B+C+D)

Adapted from Shine J.P. & al. (2003) *Envir. Toxicol. Chem.* 22/7 1642-1648

Calculation results / efficiency

- 26.6 ng. g^{-1} dw [15.8 – 38.6]
  - based on 3rd quart. of barbels BSAF
- 62 % fishes correctly classified according to RT
- Sensitivity (B/A+B)
  - 0.50
- specificity (C/C+D)
  - 0.71
- overall efficiency (B+C/A+B+C+D)
  - 0.65



Discussion

- Method consistency
  - Fish exposure “window”
- BSAF consistent with literature
  - Except for the carp
- Why BSAFs are different in G1 and G2?
  - Fatter fish specimens in G1
  - More contaminated sediments in G1
  - BSAF higher, but not correlated to sediment contamination
    - Bioavailability (among others?)
- Sediment threshold
  - Comparable to some extent to “co-occurrence” SQGs
  - ± comparable to Great Lakes *fca-SQT* (Bhavsar et al., 2010), but more robust / adaptable to varying local conditions

Bhavsar S.P., Gewurtz S.B. et al. (2010) *Integ. Environ. Assess. Manag.* 6/4 641-652

Conclusions & perspectives

- SQG applicability?
  - Not an environmental quality standard (EQS)!
  - SQG (screening): is the efficiency high enough?
    - Test on another dataset (nationwide)
- Compliance monitoring: towards a tiered approach?
  - Sediments at the first step (if possible)
  - Biota if sediment screening level exceeded
- Management guideline?

Thank you for attention

- study supported by a grant from DREAL Rhône-Alpes