PCB transfer from sediment to biota: design and implementation of models in a management perspective

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Ce projet est financé dans le cadre du PLAN RHÔNE 2007-2013

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ZABR

ZONE ATELIER BASSIN DU RHONE

RHONE BASIN LONG TERM ENVIRONMENTAL RESEARCH

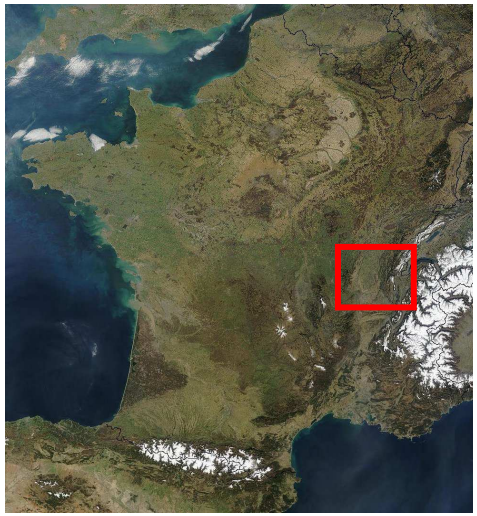
ONEMA Office national de l'eau et des milieux aquatiques

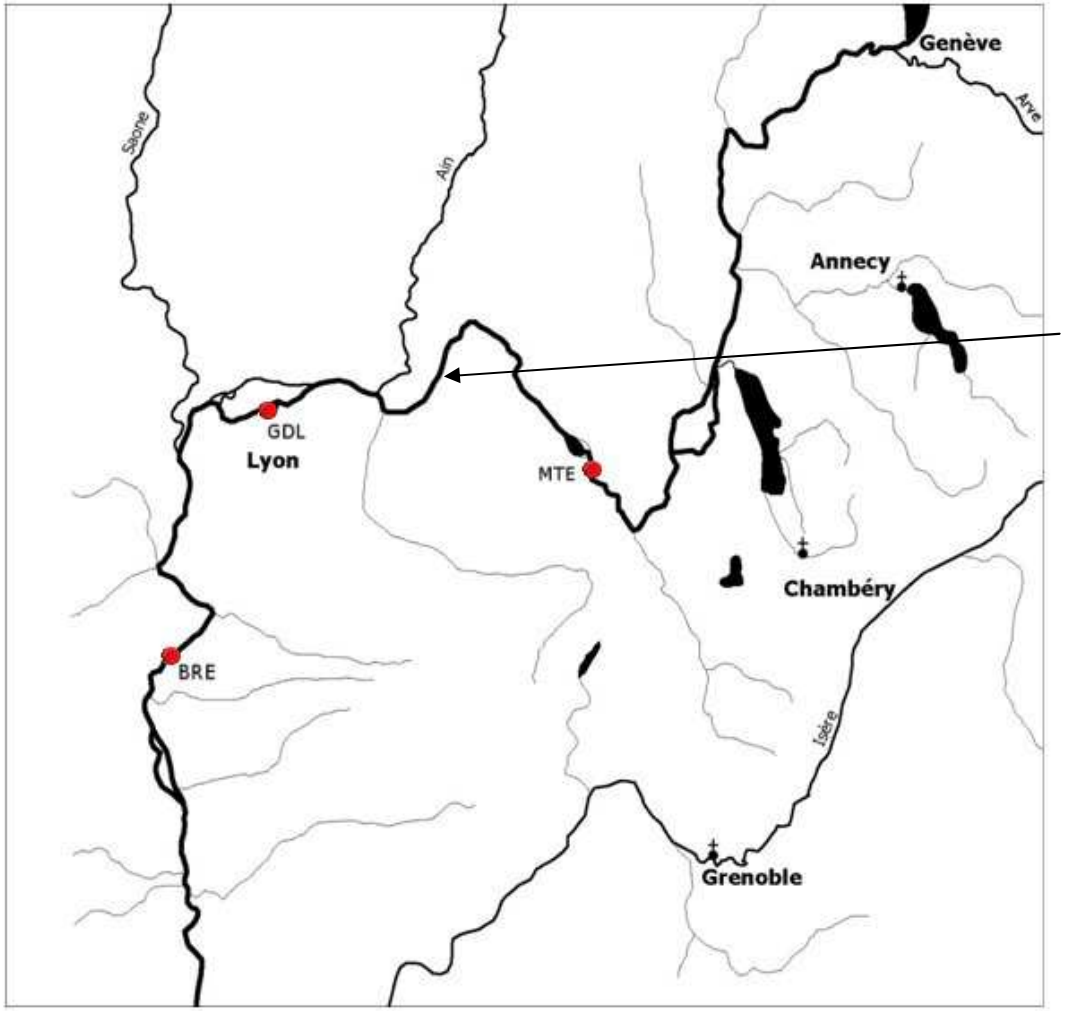
Context, study objectives

- Since 2005, fish consumption partially prohibited along the Rhône River
- Questions raised by authorities and stakeholders about
  - The duration of the problem
  - Its origins, either historical sediment contamination or active releases from electric equipments or so
  - Assuming sediments being a major source/vector, which [ΣPCB] could be deemed acceptable according to the regulatory threshold (fish consumption)?

- Understand the transfer processes from sediment to biota (fish):
  - Exposure pathways and influencing factors
  - Description (numerical model) of PCB transfer in trophic networks
  - Determine a range of PCB sediment concentrations allowing fish consumption
- Characterize spatial-temporal trends

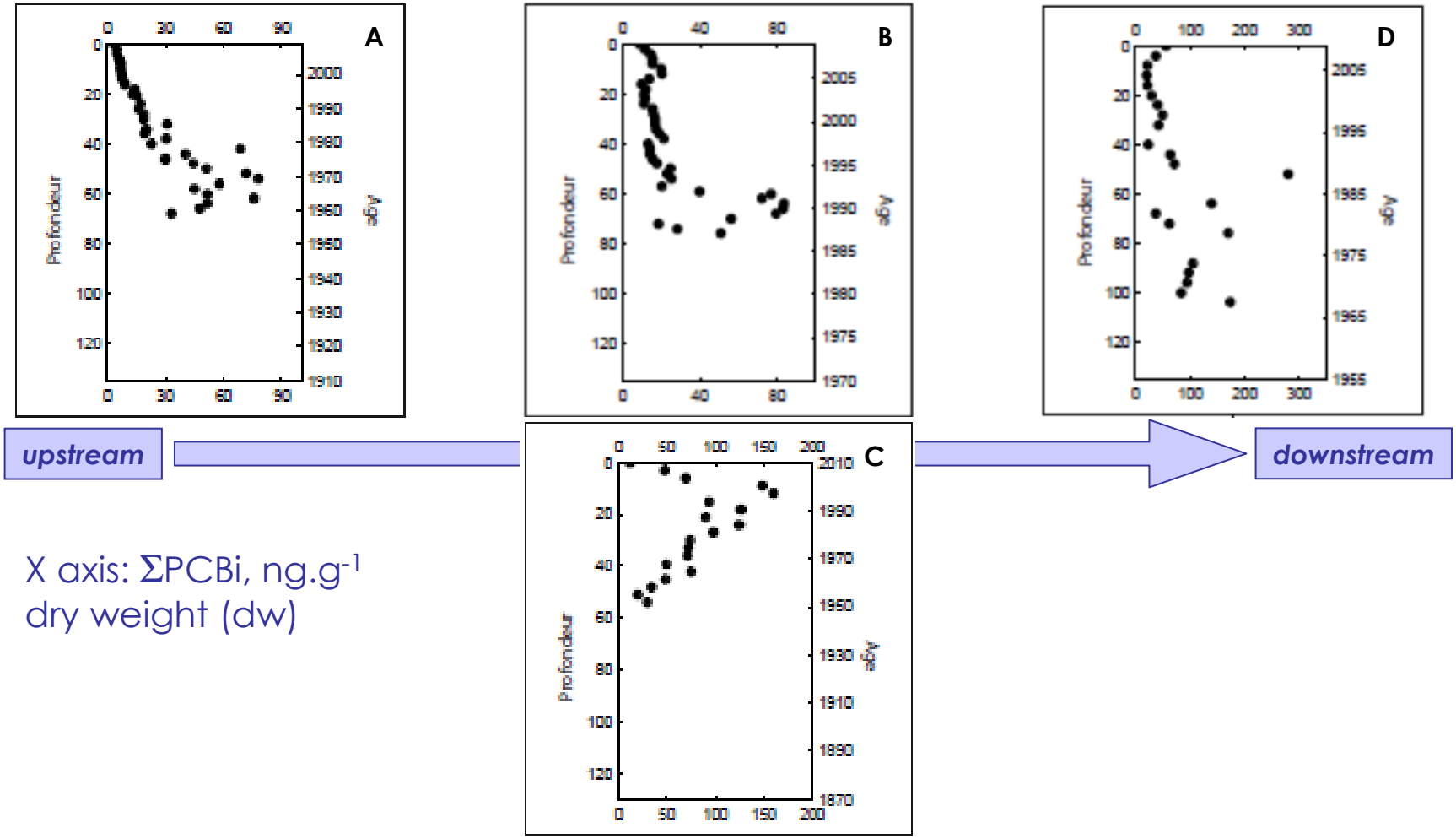
Study sites





Upstream limit of fish consumption advisory

Spatial – temporal gradient in sediments



X axis: ΣPCBi, $ng.g^{-1}$ dry weight (dw)

[1] Desmet M. & al. (acc.). *PCB historical trends as recorded by Rhone river sediments*, Sci. Total Environ.

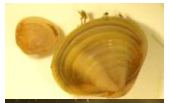
Model design and implementation

- Experimental design
  - Fish sampling and analysis
    - Biometry (size, weight, sex, age, lipids)
    - Stomach contents, δ13C et δ15N
    - Indicator PCBs (PCBi)
  - Invertebrate sampling and analysis (PCB (DL, i), δ13C and δ15N …)
- Statistical model
- Physiology-based bioaccumulation model

Abramis brama

Squalius cephalus

Barbus barbus



Pisidium and corbicula

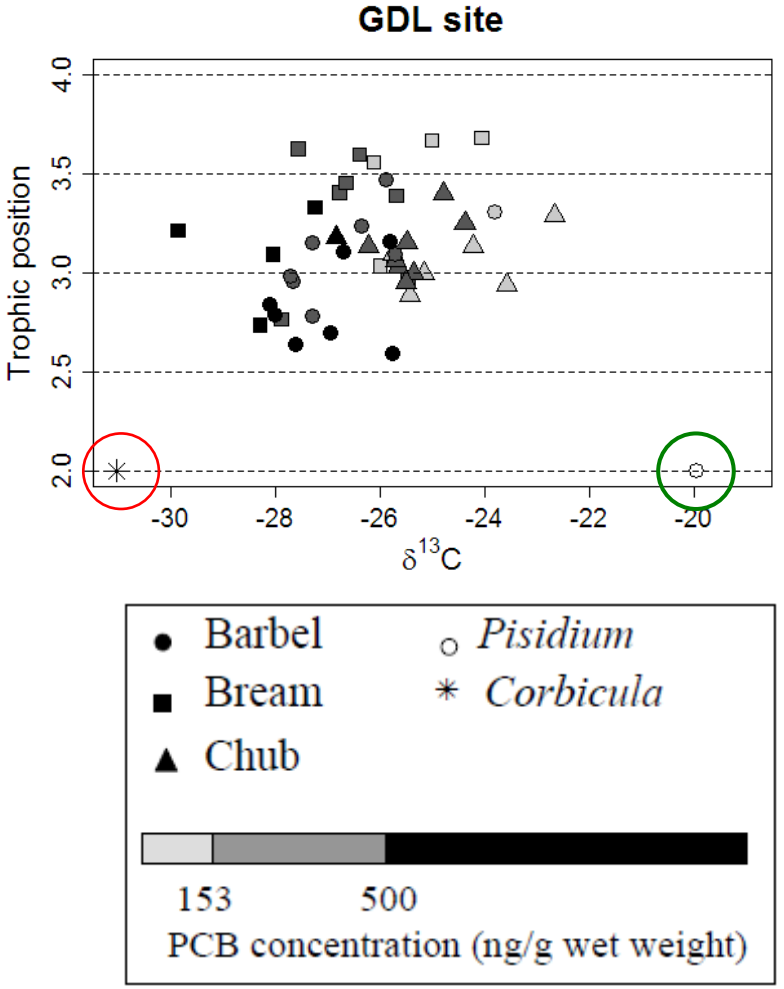
Chironomids

Gammarids

Ephemera

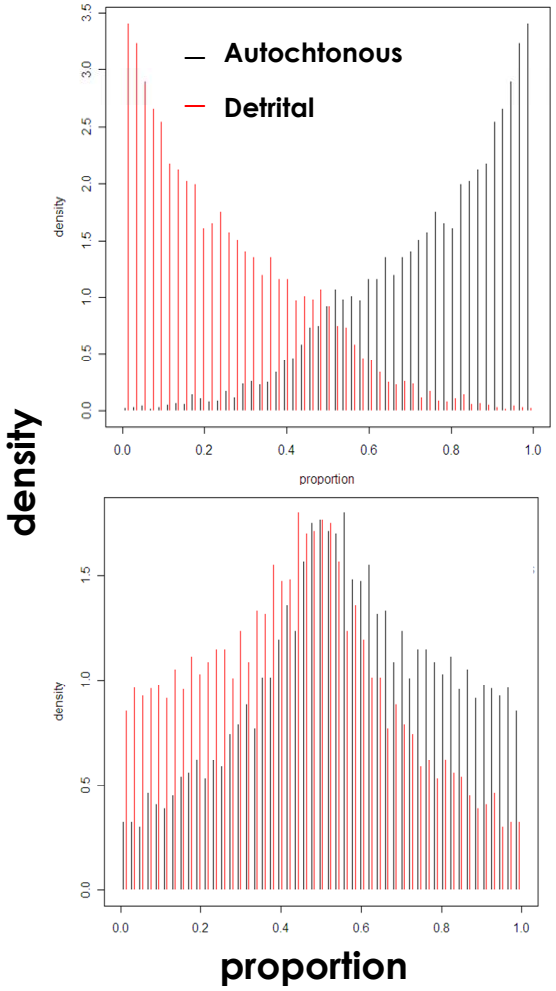
Fish exposure routes

- Possible pathways
  - Respiratory (deemed minor)
  - Trophic
- Information on diet
  - Stomach contents: snapshot
  - Stable isotopes: mean diet and tropic position
- Relationship between PCB contamination and C source



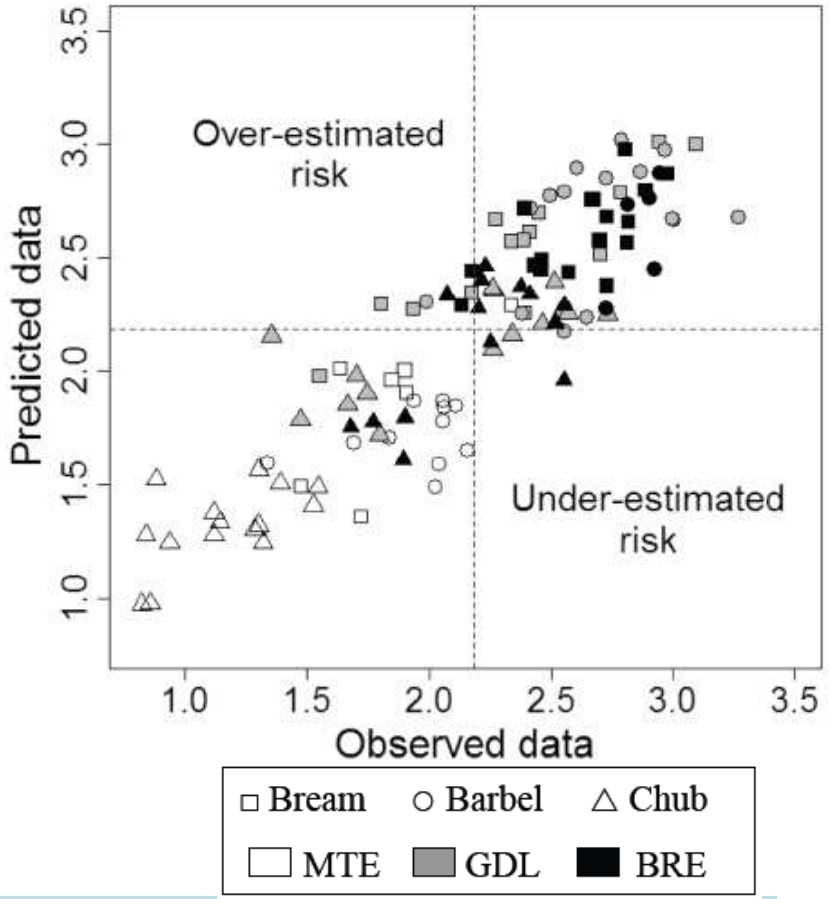
Stable isotope mixing models

- Each baseline, either *Pisidium* or *Corbicula*, represents a carbon source:
  - *Pisidium*: autochtonous / pelagic
  - *Corbicula*: detrital / sediment
- Fish species level: type of habitat foraged
- Individual level: within species variability in habitat foraging behaviour



Statistical model

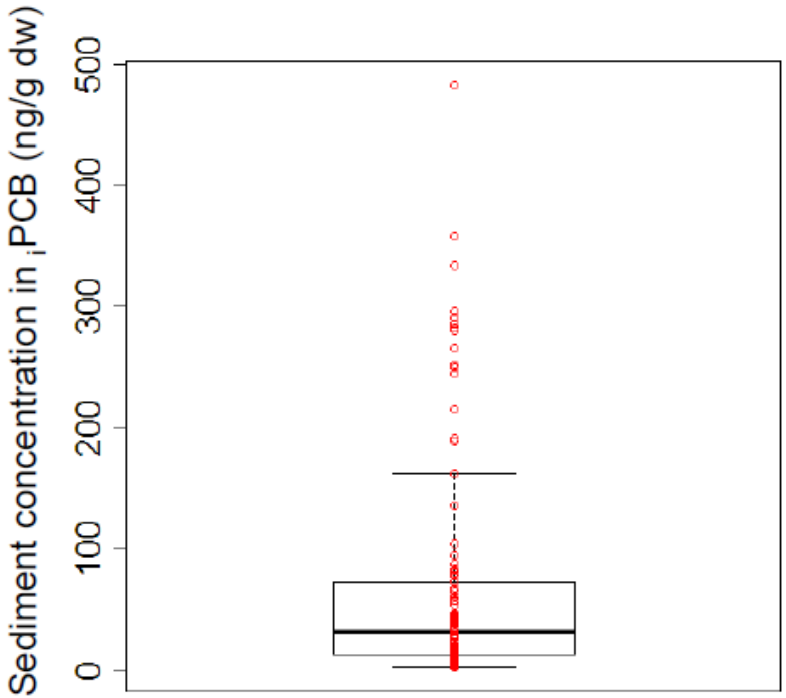
- Backward stepwise regression – log linear model
- Dependant variable: ΣPCBi in fish
- Explanatory variables: size (L), weight, age, TP, % detrital C in the diet (% *detr*-C), % lipid, sex, max. ΣPCBi concentration in sediment ($C_{SED\text{-}max}$)
- 78% of the total variability explained by L, % *detr*-C, $C_{SED\text{-}max}$



[2] Lopes C, Perga ME, Peretti A, Roger M-C, Persat H, Babut M (2011). *Chemosphere*, **85**: 502-508

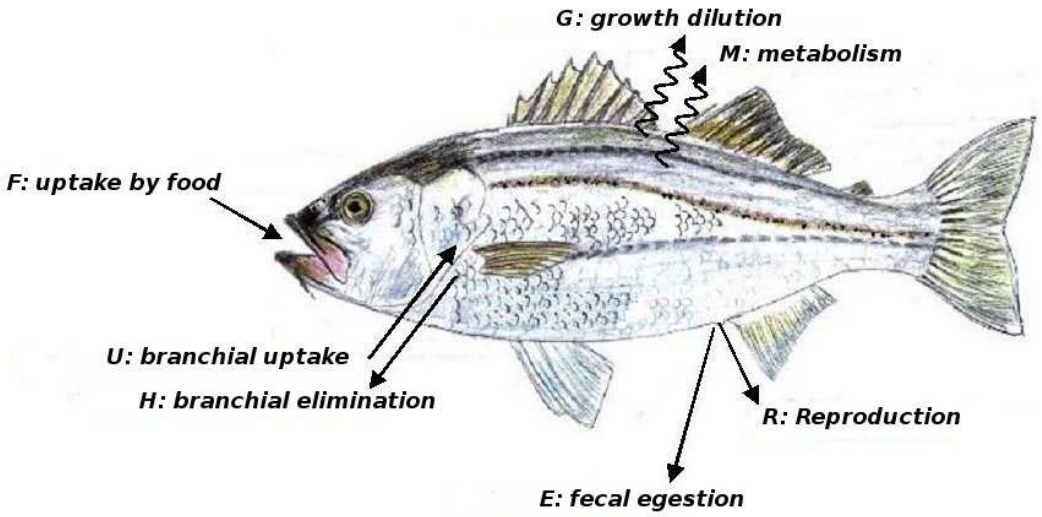
From fish consumption to sediment quality

- Use of the statistical model for estimating a ΣPCBi level in sediment allowing fish consumption
- Performed for each fish of the dataset
  - Distribution of ΣPCBi (for 3 fish species and 3 sites altogether
  - Median at 31.8 $ng.g^{-1}$ (dw);
  - 90th centile at **5.9 $ng.g^{-1}$ (dw)**



Numerical bioaccumulation model

- Goal: to describe fish contamination kinetics
  - Firstly by 1 PCB congener (PCB 153)
  - 3 fish species - 3 experimental sites
- Approach: mathematical description of fish exposure (respiration, diet) and elimination (growth dilution, excretion …) pathways through time:
  - Daily steps for 10-15 years
  - Comparison to the experimental data



Model(s) construction

- Kinetic bioaccumulation model derived from previous works (Connoly 1991, Thomann et al. 1992, etc.)
- Daily water temperature available at 1 site ⇨ U, H, F
- Weight and size fit to our experimental data ⇨ U, H, F, E, G
- Diet preferences from our data (stomach contents)
- R and M neglected for PCB 153

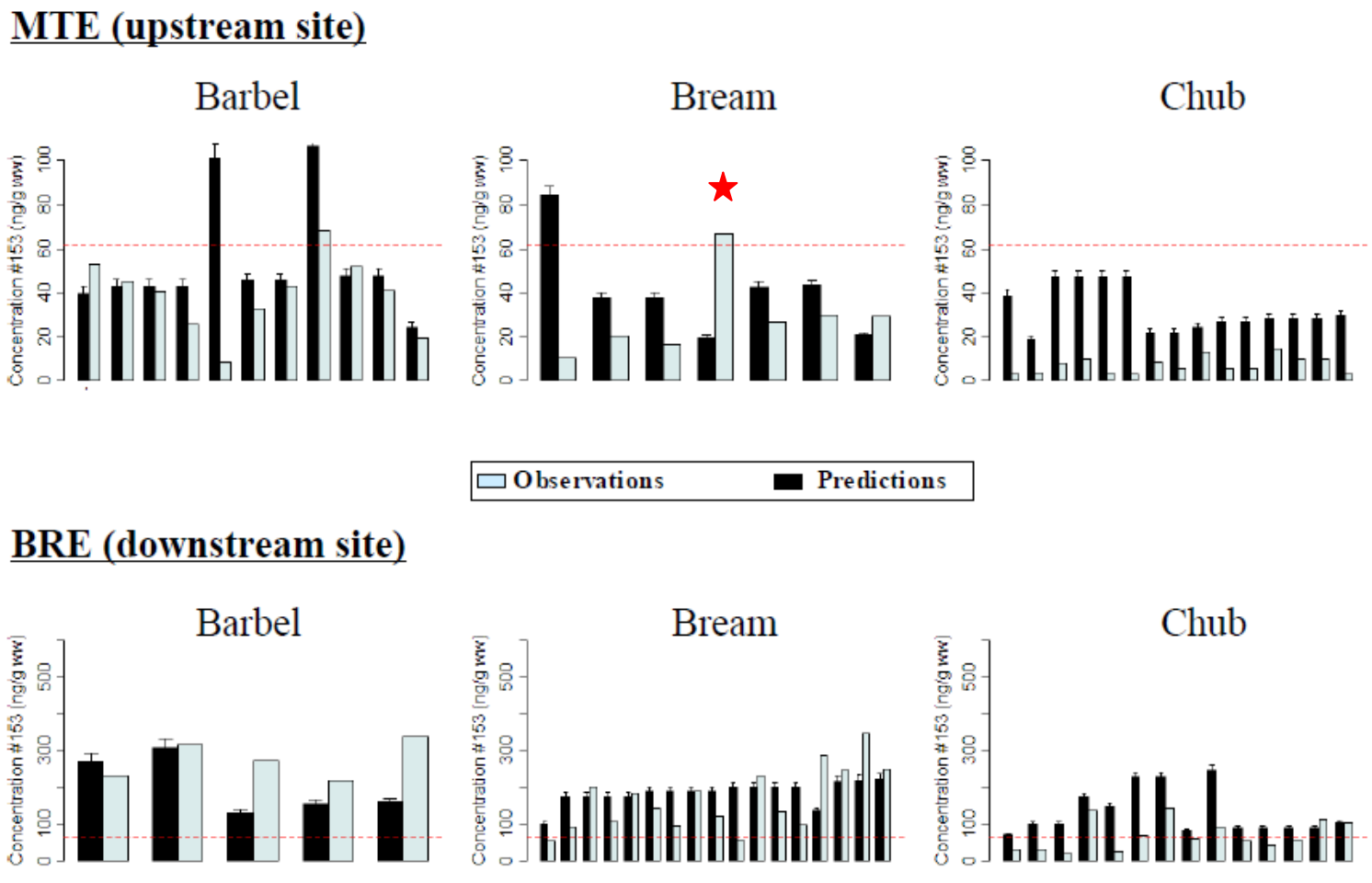
- PCB concentration in water: estimation from a local study, deemed constant
- PCB concentrations in sediments: data from cores
- PCB concentrations in preys: kinetic (steady state) model

$$C_{j,c}(t) = k_{u_{j,c}}(t) C_w(t) + k_{s_{j,c}}(t) C_s(t)$$

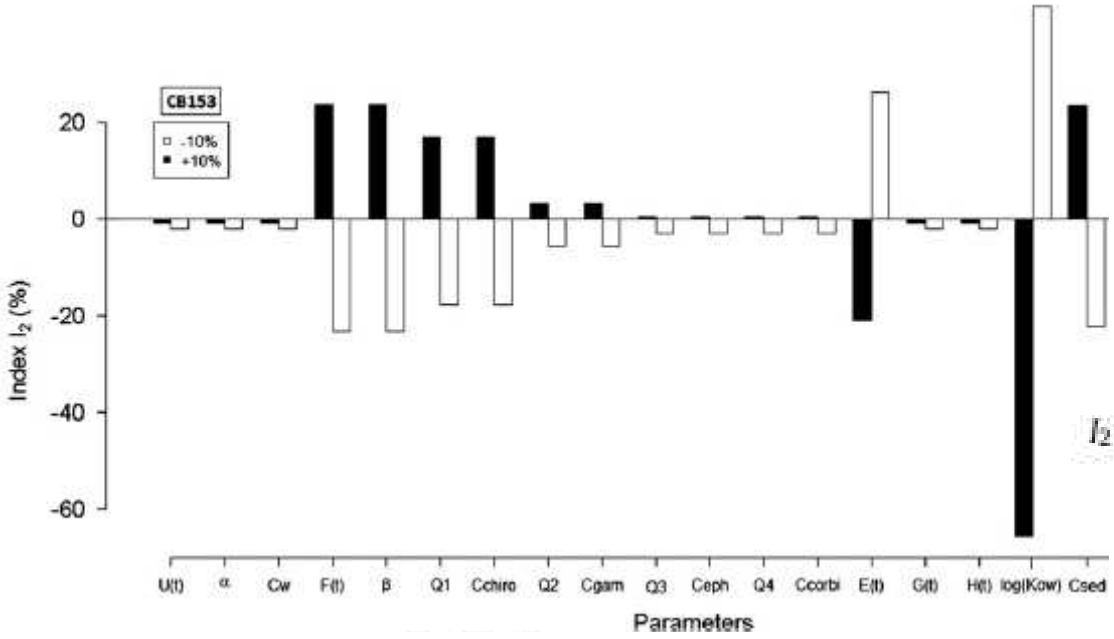
k_U: water filtration rate
k_S: sediment filtration rate

[3] Lopes C, Persat H, Babut M (in press) *Ecotoxicology and Envvironmental Safety*

Results: predictions vs observations



Sensitivity analysis



$$I_2 = 100 * \left(\frac{\sum_{i=1}^{n} (Cmodif_i - Cobs_i)^2}{\sum_{i=1}^{n} (Cmean_i - Cobs_i)^2} - 1 \right)$$

- Main influence of
  - Variables related to diet
  - Sediment concentrations
  - Excretion rate
  - K_{ow}
- Almost no influence of gill uptake, concentration in water …

Sediment concentrations allowing fish consumption

- Based on the model and the relationships between PCB153 and ΣPCBi
- Assumptions
  - No exceedence during the lifetime
  - Exceedence allowed for X% of time (e.g. 20%)
- Outputs depend of the site and the species
- Is it acceptable to allow exceedence time-slots … ?

	Barbel	Bream	Chub
MTE	1	1	2
GDL	0.7	0.5	1
BRE	0.7	1.5	1.2
MTE-20	2.3	1.7	3.3
GDL-20	1.7	1	2
BRE-20	2	3	3

Conclusions

- Successful approach combining field data (high resolution sediment cores, isotopes, contamination) and modelisation
- Critical role of sediment in PCB food-web contamination
- Statistical (log-linear) model efficient,
  - Needs further validation with independent datasets
  - Based on isotope data and SIAR modelling
- Bioaccumulation model nicely predictive,
  - Needs improvements: variations of fish diet with fish age, invertebrate contamination kinetics, excretion …
  - Needs further tests on other sites / species
  - Heavy to implement

After-sales services

- Study website: https://tsip-pcb.cemagref.fr/ (mostly in French)
- Experimental data:
  - fish contamination data recorded in the Rhone-Mediterranee basin database (http://www.rhone-mediterranee.eaufrance.fr/usages-et-pressions/pollution_PCB/basepcb/index.php)
  - Sediment contamination data recorded by the Rhone Sediment Observatory (http://www.graie.org/osr/spip.php?rubrique39)
- Publications
  - Desmet M, Mourier B, Mahler B, van Metre P, Roux G, Persat H, Lefèvre I, Peretti A, Chapron E, Simonneau A, Miège C, Babut M (accepted) PCB historical trends as recorded by Rhone river sediments. *Sci. Total Environ.*
  - Lopes C, Perga ME, Peretti A, Roger M-C, Persat H, Babut M (2011) Is PCBs concentration variability between and within freshwater fish species explained by their contamination pathways? *Chemosphere* **85** (3):502-508
  - Lopes C, Persat H, Babut M (in press) Transfer of PCBs from bottom sediment to freshwater river fish species: a food-web modelling approach in the Rhône River (France) in support of sediment management. *Ecotoxicology and Environmental Safety*. **doi**:10.1016/j.ecoenv.2012.04.007