Are PCB ‘bouillabaisse’ soluble? A case study of PCBs in the Rhone river

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Project team

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https://tsip-pcb.cemagref.fr/

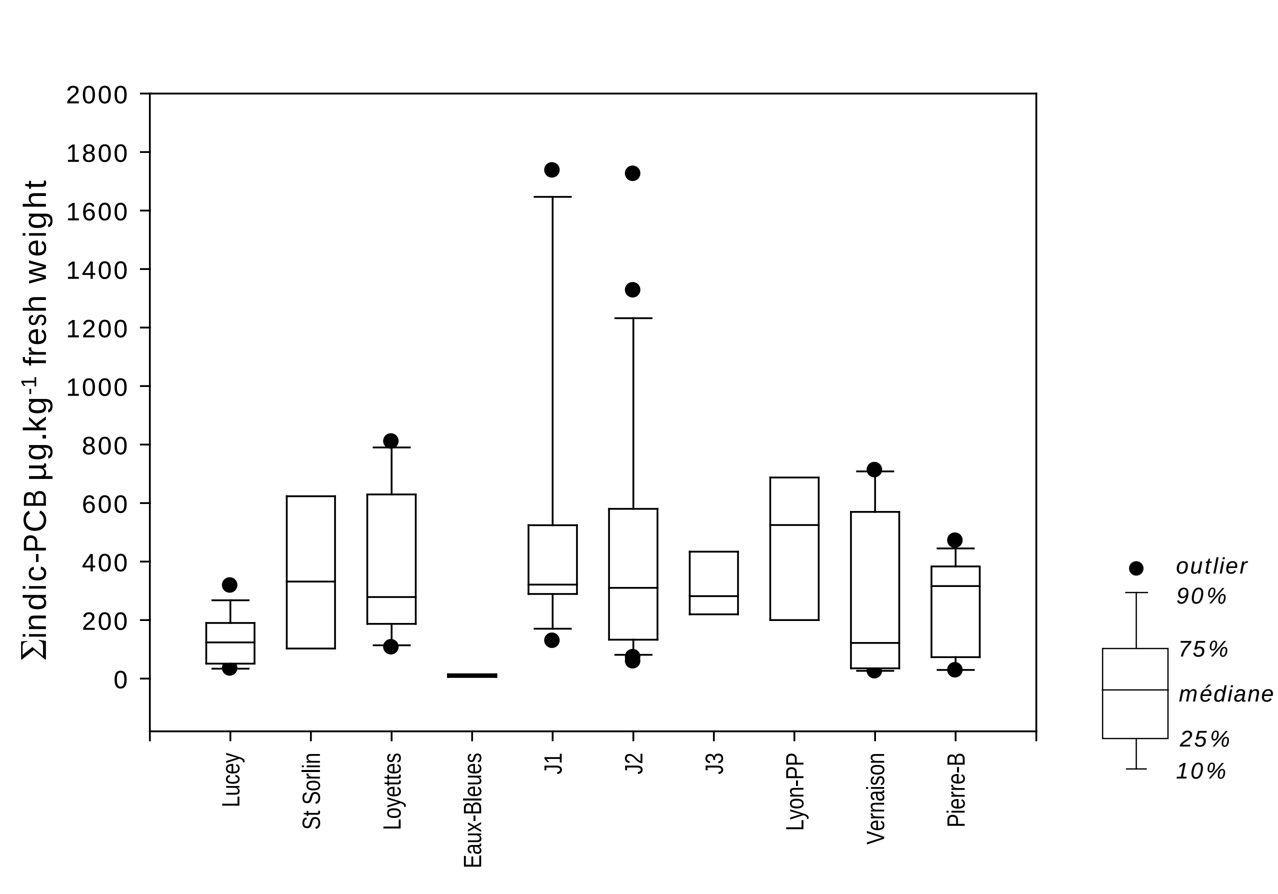
ZABR

ZONE ATELIER BASSIN DU RHONE
RHONE BASIN LONG TERM ENVIRONMENTAL RESEARCH

A long story

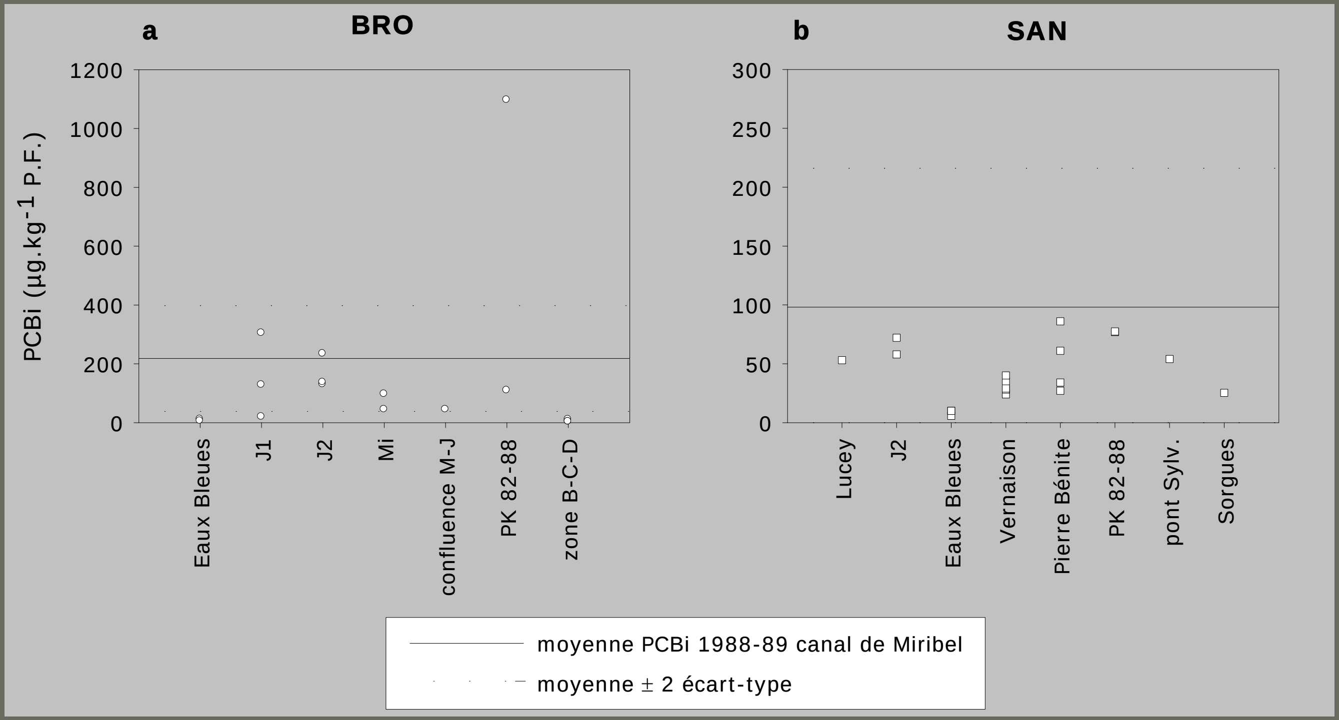
- … which begins in the 80's … around a facility for special industrial wastes elimination
- From 1986 to 1999,
  - source control (1988, 1995)
  - extensive surveys of fish contamination
- In 2005, fortuitous observation - 2 breams / professional fishery - AFSSA points out a risk to consumers
- 2005-06: first studies ⇨ fish, sediments around Lyon
- 2007 :
  - Studies extended to the whole river course
  - Crisis rising
  - Risk management: action plan – working groups with stakeholders
- 2008 :
  - Cases in other watersheds, national action plan …

Overview of fish contamination



2006, Lyon area

Are 2006 fishes more contaminated than 1988-89 ones?



+ 2SD

mean

Pike *Esox lucius*

Pikeperch *Sander lucioperca*

Management issues

- Fish advisories adjustments?
- Relationships with sediment contamination?

http://www.rhone-mediterranee.eaufrance.fr/usages-et-pressions/pollution_PCB/pcb-arretes-interdiction.php

‘TSIP’ objectives

1. Identify, for key fish species, the main exposure routes and factors controlling the contamination
2. Describe the transfer of PCB along the trophic network of these species (food-web bioaccumulation model)
3. Determine impacted areas and trends
4. Determine a range of PCB concentrations in sediments consistent with fish consumption threshold ($TEQ_{tot} < 8$ pg.g^{-1} fw)

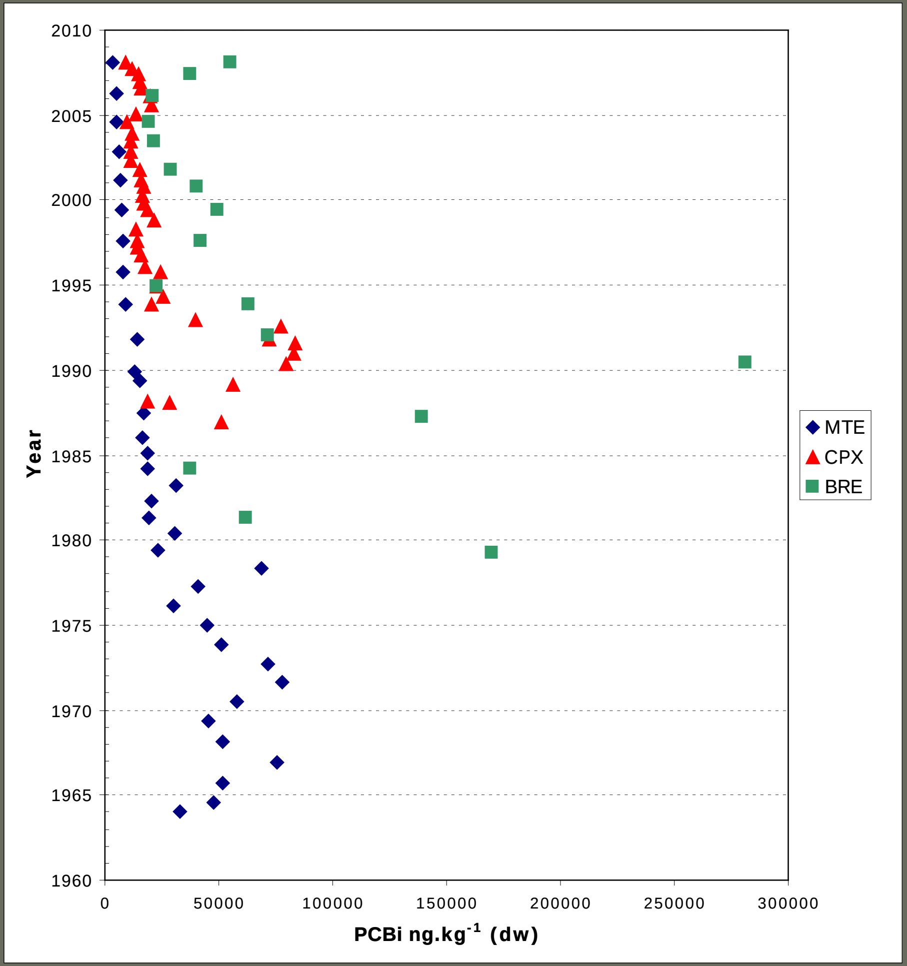
TSIP approach and challenges

- Sediment cores (isotopes, grain size, OC, PCB)
  - contamination history
  - contamination patterns
- Sampling / analysis of biota
- Modeling
- Challenges
  - Core sampling (river system)
  - Food-web description (river)
  - Uncertainty

Study area

Sediment contamination - ΣPCBi

- Σ[18] congeners
- MTE: decrease since end 80s
- CPX: site dug ~ 1980; decrease since ~ 1992-95
- BRE: influenced by Saône, Lyon, Gier; strong variations, increase in top cm



Pattern analysis

Samples: N=158

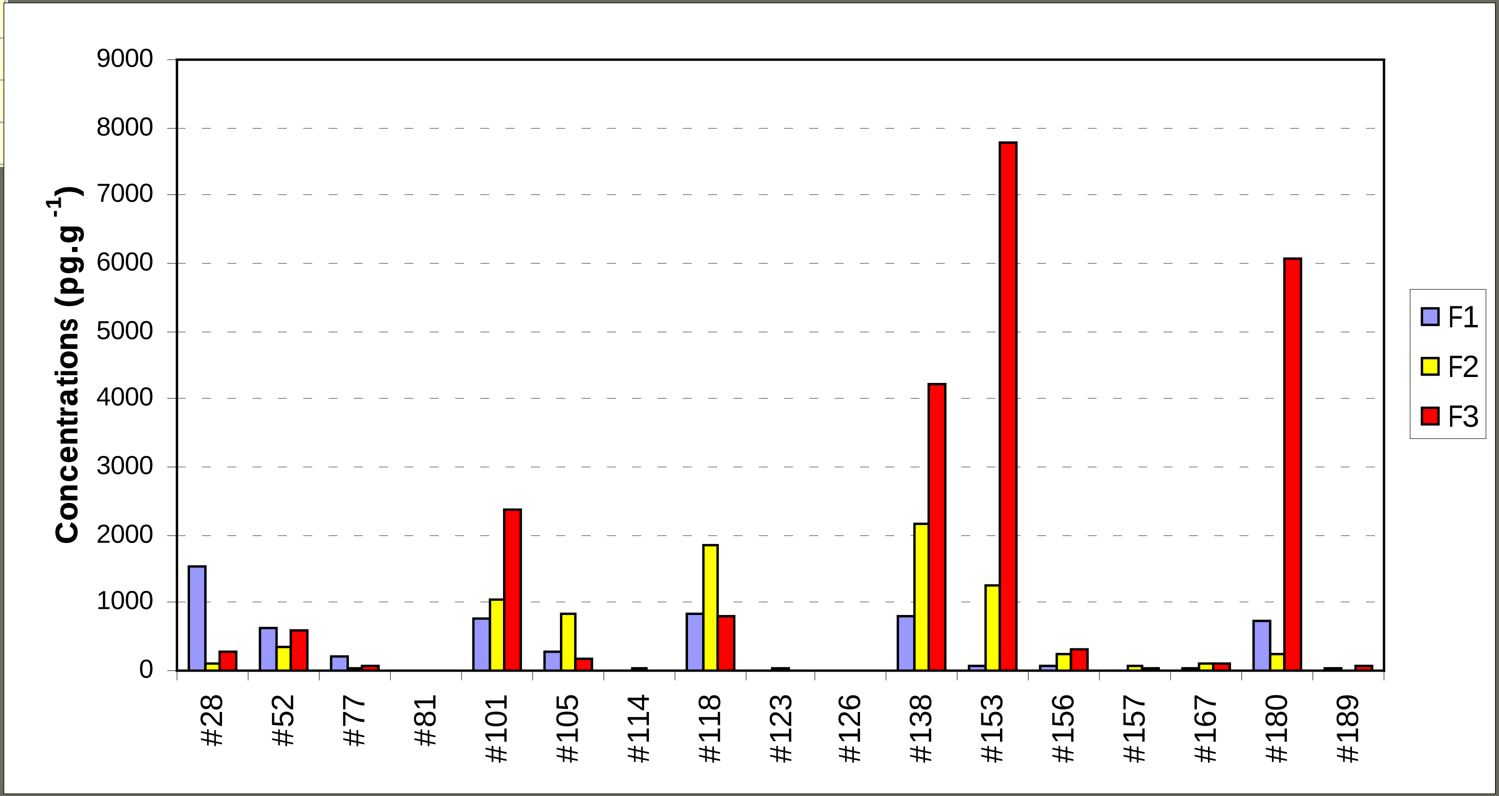
- SNRS – DIREN Cores, 2006 (N = 22 from 7 cores)
- Min. Transp. – Surface, 2006 (N = 6)
- SNRS – DIREN Sites from a longitudinal profile, 2007, (N = 4, Rhône & Saône)
- TREDI – surface, 2006 - 2008, Lucey & Loyettes (N= 6)
- This project, cores, 2008 (N = 102 from 3 cores)
- This project, surface, 2008 (N= 18, fluvial lake "Grand Large ")

18 PCB congeners: # 28, 52, 77, 81, 101, 105, 114, 118, 123, 126, 138, 153, 156, 157, 167, 169, 180 & 189

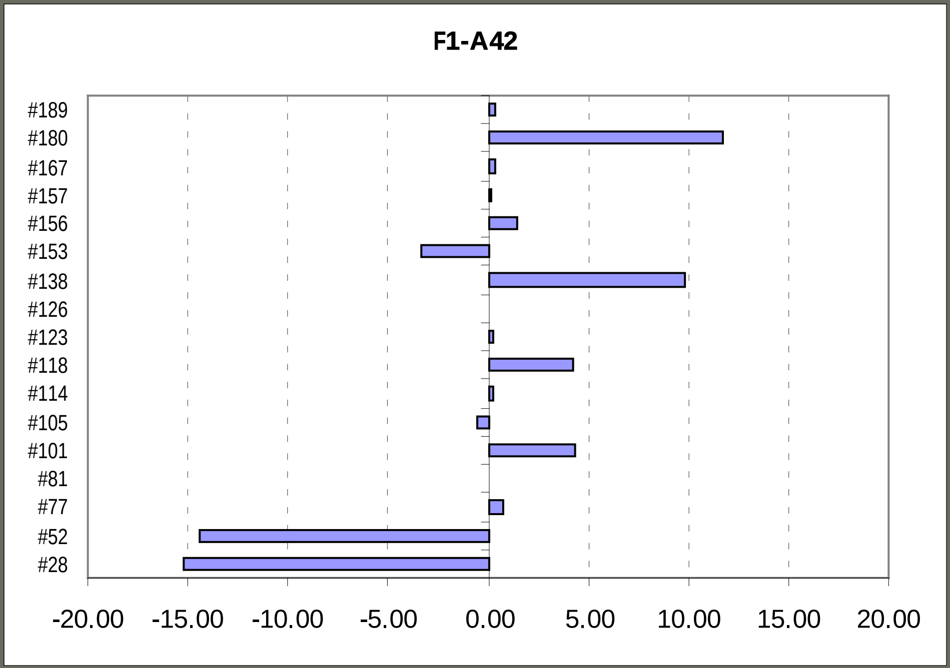
Tools: PMF, Unmix (http://www.epa.gov/heasd/products/products.htm)

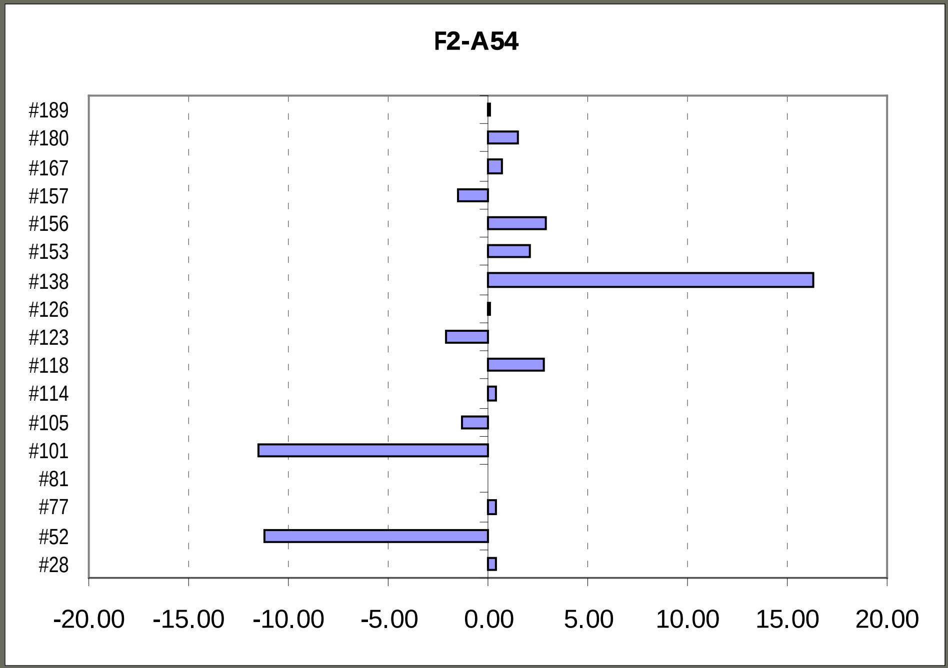
PMF – best solution = 3 factors

	Q Robust	Q True
max	1580.7	1592.2
min	1580.6	1592.2
run 9	1580.6	1592.2



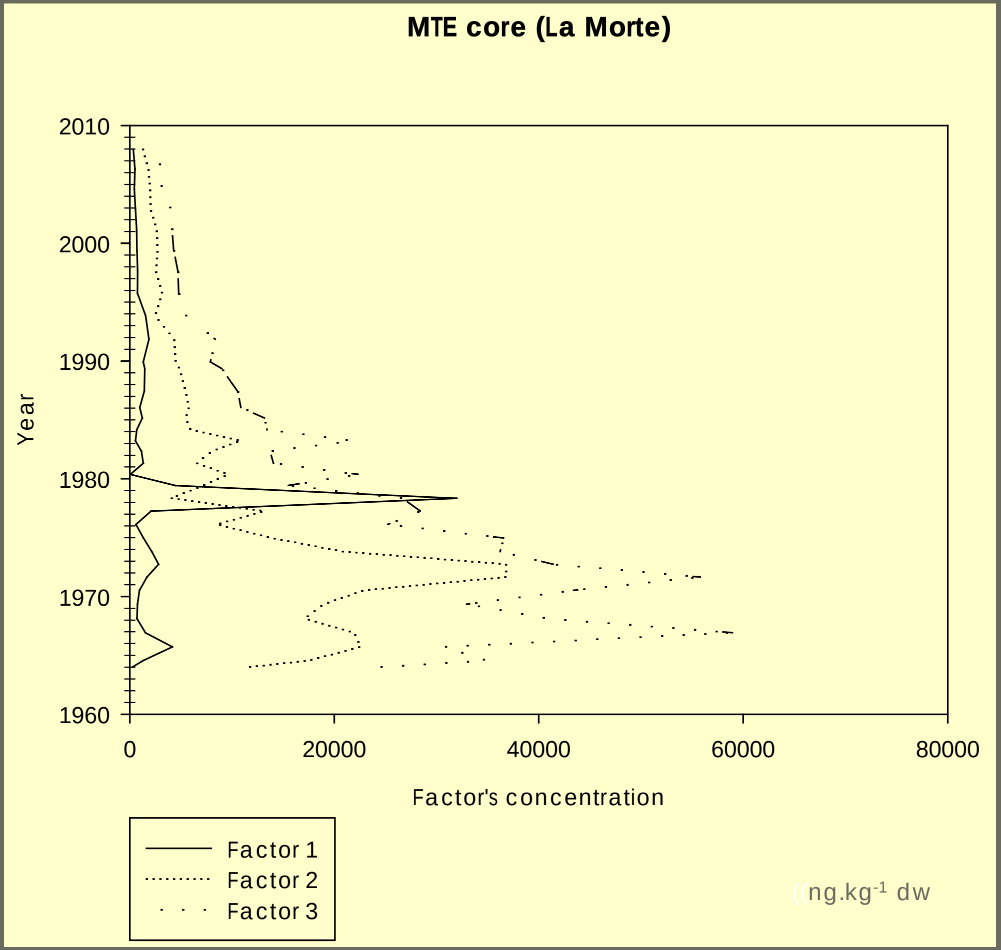
Comparison with technical mixtures





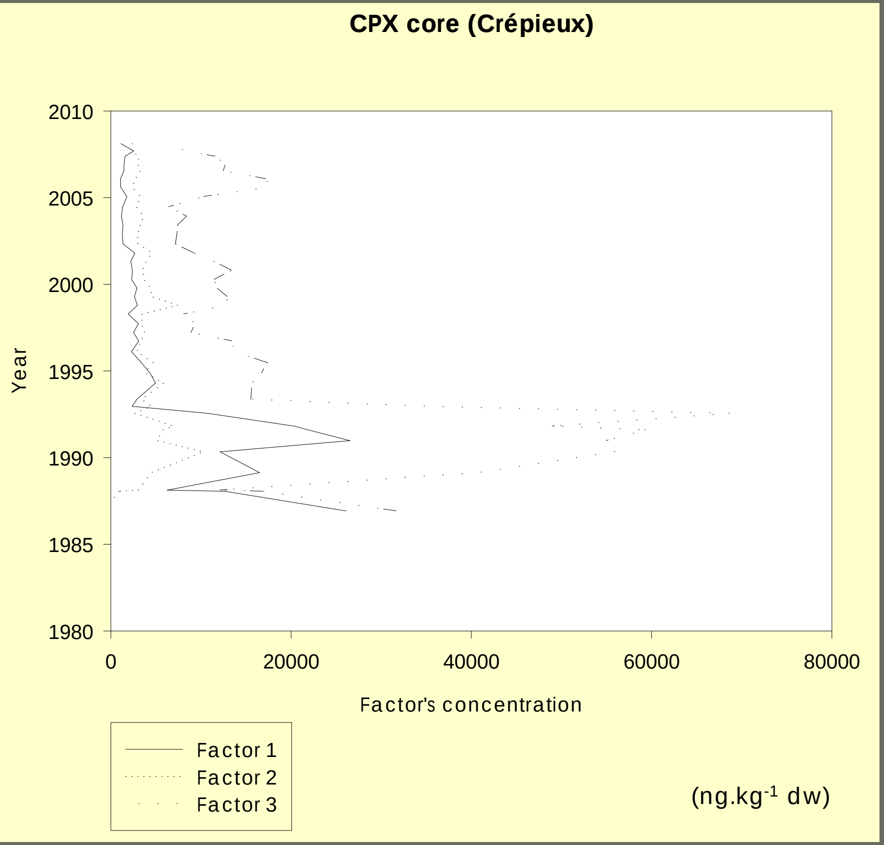
Factors concentrations in MTE core

- Factor 1 nearly absent except 1 peak
- F2 – F3 correlated ($R=0.89$, $p<0.0001$)
  - Suggests a common origin
- F1 peak:
  - Could be explained by a voluntary sediment flush



Factors concentrations in CPX core

- Limited contribution of F2
- 90's peaks due to F1 and F3
- Recent variations of ΣPCBi solely due to F3
- Weak correlation F1-F3 between 1987-1993
- Main peaks may correspond to a major flooding (1990) and subsequent re-adjustments
- Main industrial discharge (< 1988) mostly missing



Summary (sediment)

- PCB decrease since 80’s (MTE, upstream) consistent with remote lake studies
- Decrease also observed in CPX (intermediary site), variations presumably related to floods
- No decrease downstream? but strong variations, also related to flows
- Pattern analysis shows an increasing proportion of highly chlorinated – less degradable congeners

Biota – sampling and analyses (1)

- Fish

Sites	Common bream	Chub	Barbel
La Morte (MTE)	7 (3♀ + 4♂)	20 (13♀ + 7♂)	11 (11♀ + 0♂)
Grand-Large (GDL)	15 (9♀ + 6♂)	15 (6♀ + 9♂)	15 (8♀ + 7♂)
Île du Beurre (BRE)	17 (10♀ + 7♂)	17 (12♀ + 5♂)	5 (3♀ + 2♂)

Abramis brama

Squalius cephalus

Barbus barbus

- Measures, analyses
  - Size, weight, sex, age (scale rings)
  - Stomach content
  - $\delta^{13}C$ and $\delta^{15}N$
  - Lipid content, indicator-PCB

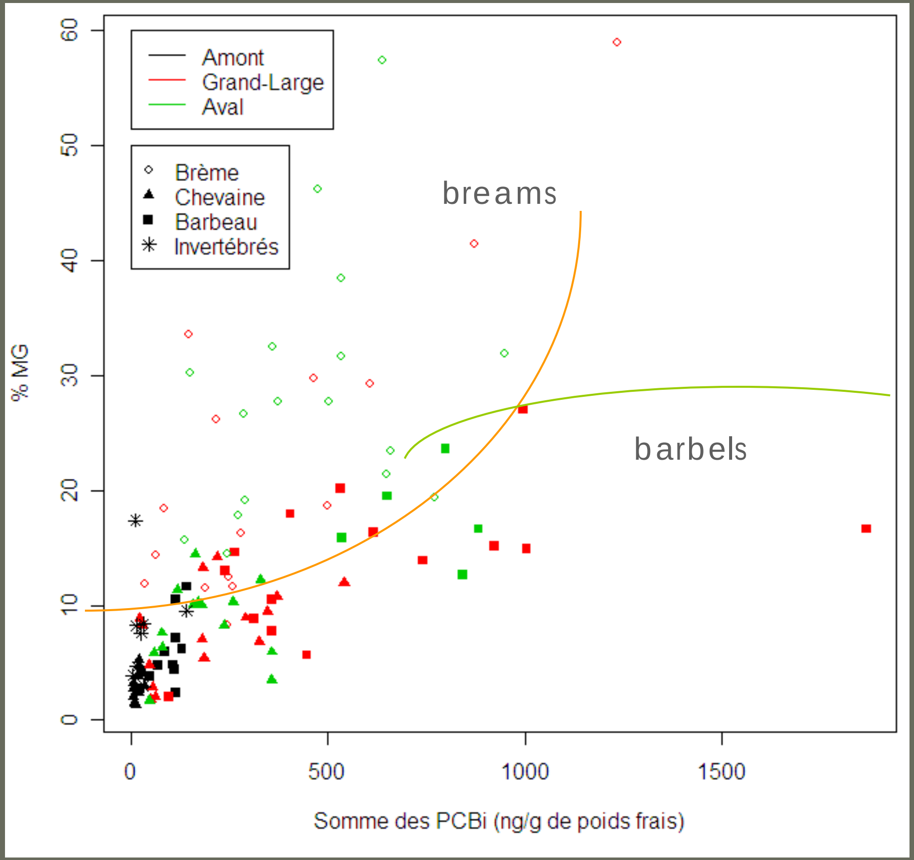
Biota – sampling and analyses(2)

- Invertebrates

Sites	Chironomids	Shrimps *D. villosus *Gammarus	Ephemera	Corbicules (3 cm)	Corbicules (1cm) - Pisidium
MTE	25	60* – 200*	94	15	15 – 140
GDL	200	53* – 120*	21	13	50 – 160
BRE	400	130*	_	18 – 18 – 24	85 – 130

- Measures, analyses
  - Macro-invertebrates inventories
  - $\delta^{13}C$ and $\delta^{15}N$ analyses
  - Lipid contents, indicators PCB, DL-PCBs

Contamination vs lipid content



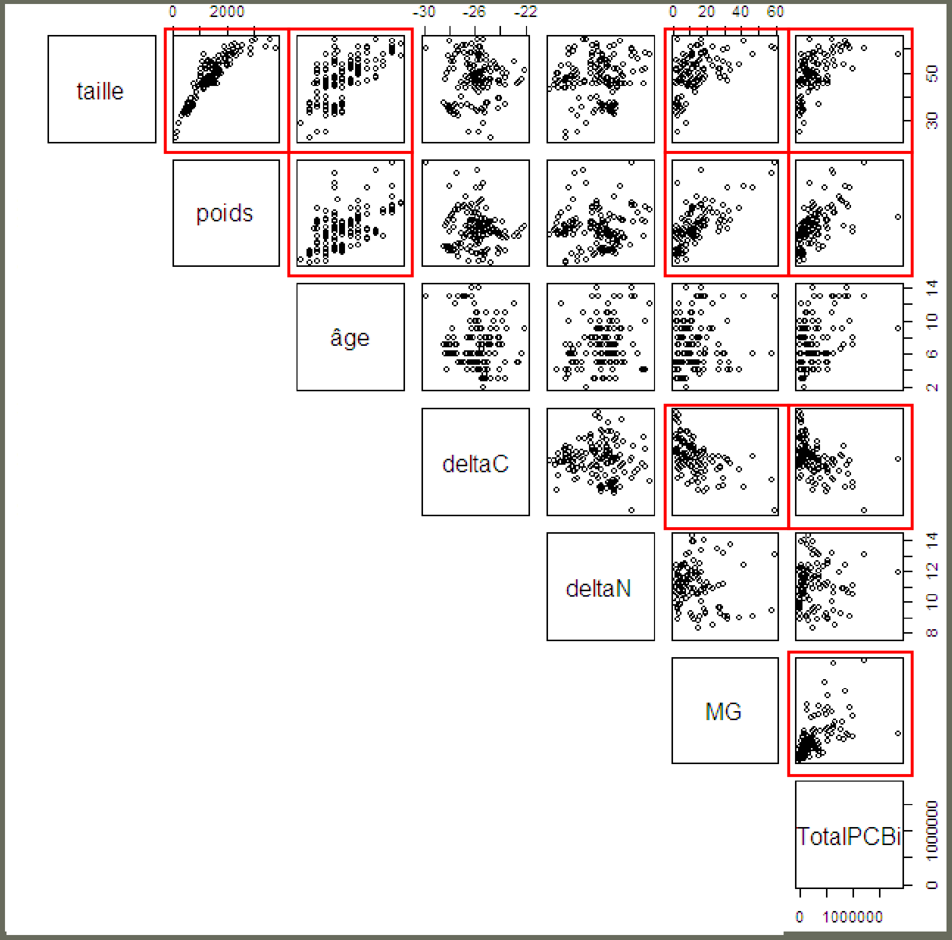
Overall, significant relationship, but:

- not significant within each species group
- not significant at site scale

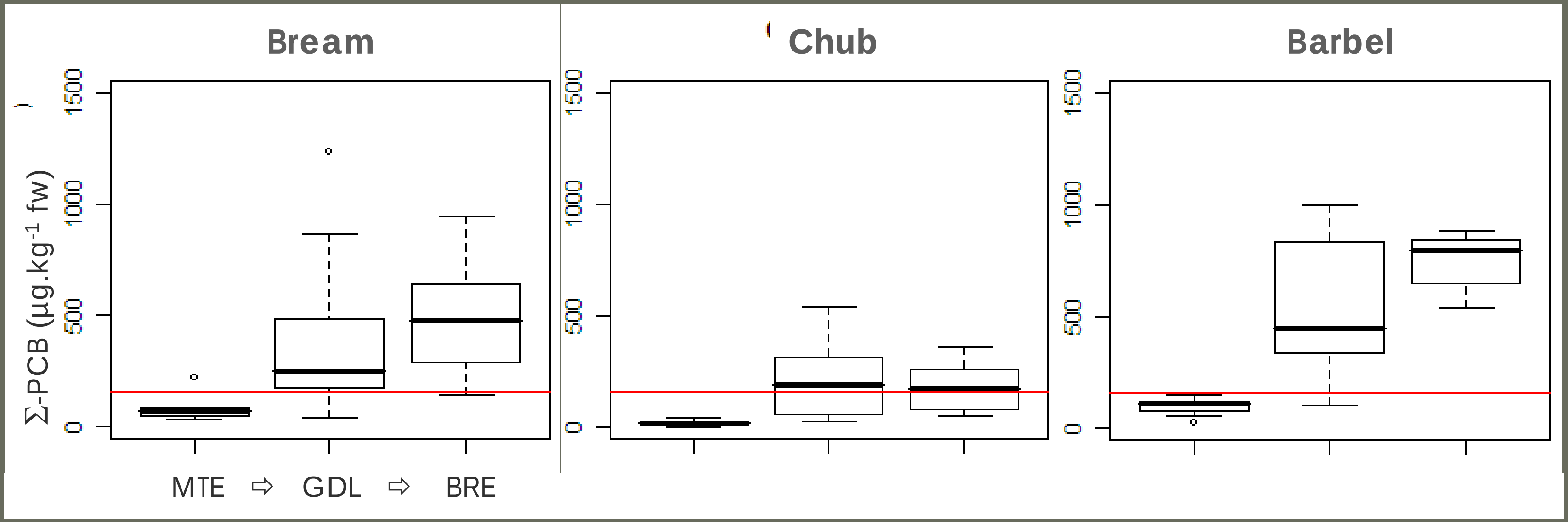
No need to standardize according to lipid content

Fish contamination (∑PCBi)

- Significant :
  - species
  - size/weight/age
  - $\delta^{13}C$
  - %MG
- Not significant:
  - $\delta^{15}N$
  - sex



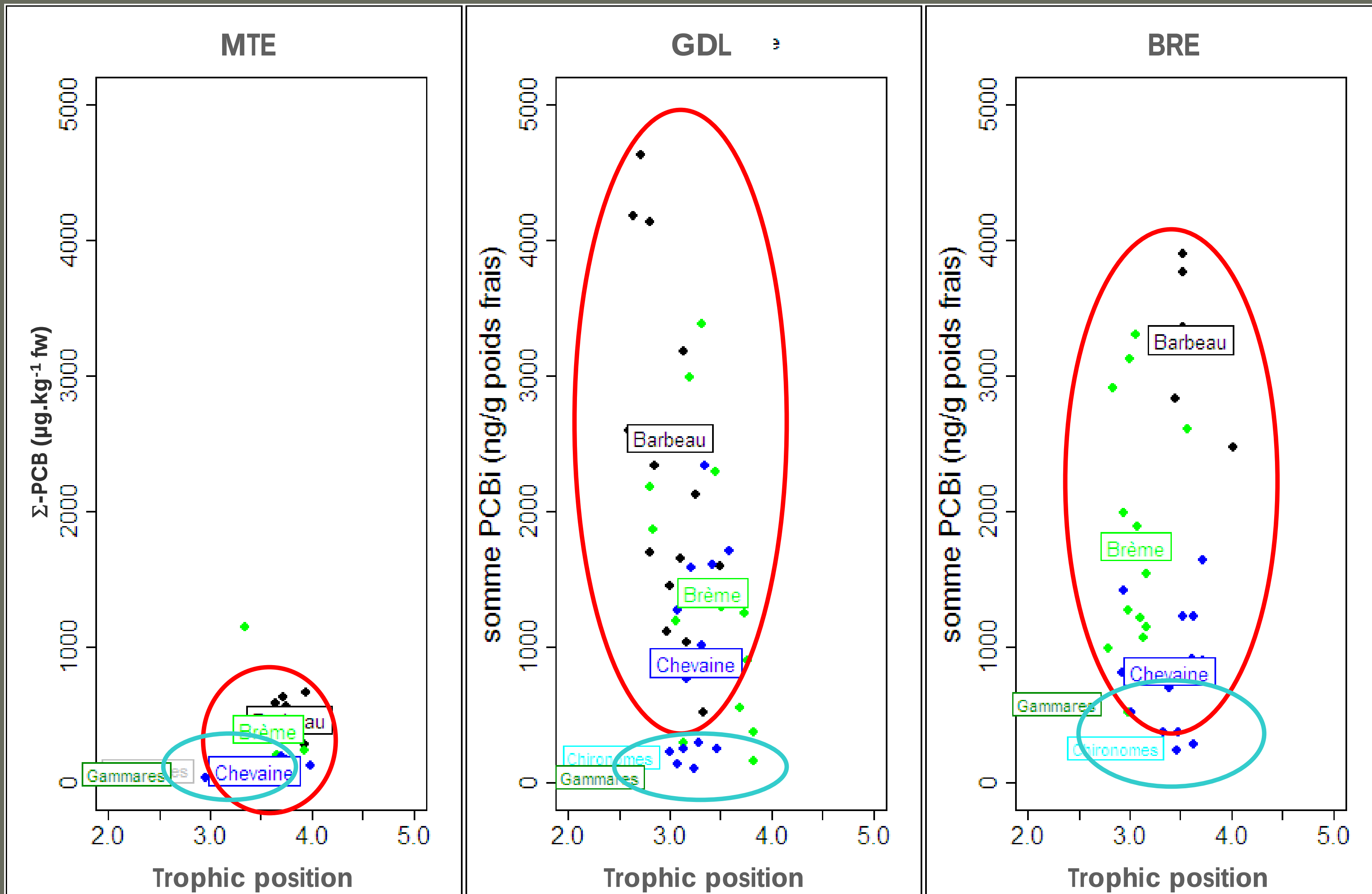
Trends in biota



Invertebrates display (much) lower concentrations

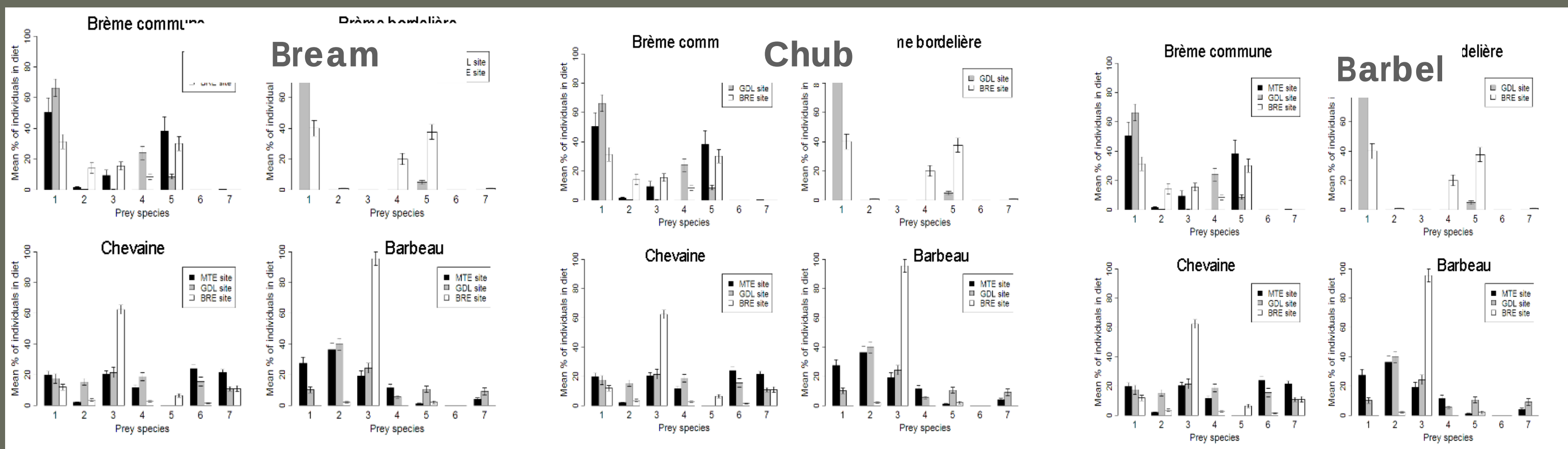
- Chironomids more contaminated than Ephemera
- Shrimps more contaminated downstream

Trophic position and contamination



Trophic network description (a)

- Based on stomach contents (snapshot of food resources)

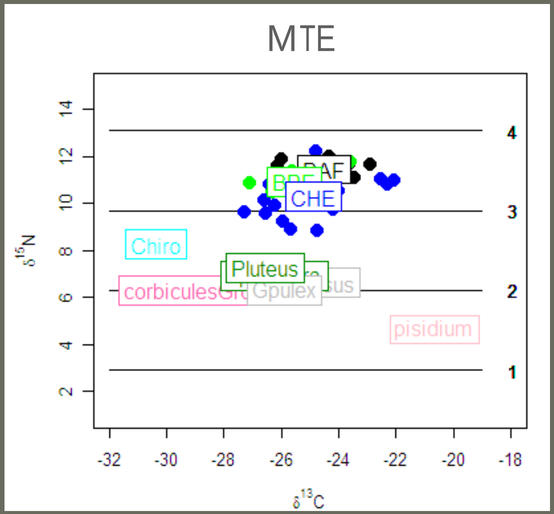


1- Dipterans; 2- other aquatic insects; 3- Crustaceans; 4- Gastropods; 5- Bivalves; 6- Macrophytes; 7- Other (algae, worms…)

- Overall, low individual variability
- Food preferences differ between species and sites
- Chub and barbel have more diverse regimes

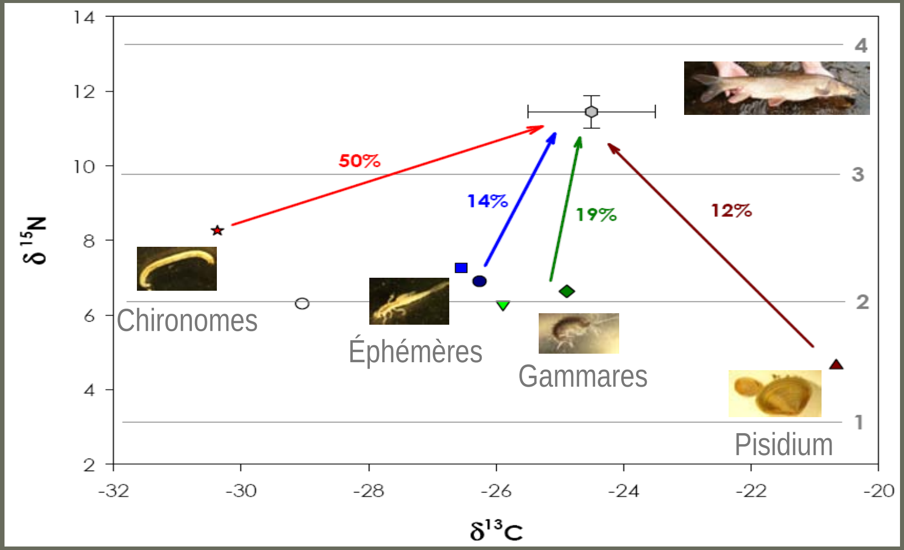
Trophic network description (b)

- Stable isotopes analysis = mean food sources



- For each species, similar resources on each site, but differences among sites
- Among species, similar food sources but different proportions

- Combination with stomach content



Barbel at MTE

Summary (biota)

- Up-stream – downstream gradient
- Fish
  - Species gradient
  - Size – weight – age - $\delta^{13}C$
  - Same congeners profiles
- Invertebrates ~ 1/10 fish contamination

Model development

- Kinetic physiology-based bioaccumulation model
  - More complete but needs to document more variables

fish

$$\frac{dC_i}{dt} = U_p \, \alpha_{p,w} \, C_w + \sum_j \beta_p \, Q_{p,j} \, F_p \, C_j - \left(E_p + G_p\right) C_p - R_p \, C_p$$

invertebrates

$$\frac{dC_i}{dt} = U_i \, \alpha_{i,w} \, C_w + \sum_j \beta_i \, Q_{i,j} \, F_i \, C_j - E_i \, C_i$$

- Output of the fish bioaccumulation model could be coupled with a model population dynamics model (accounting for the variation of fish biomass in an age class)

TSIP – ongoing

- Analysis of 3 new cores (GDL + 2 new sites)
- SM sampling campaign during a planned sediment flush
- Model development

The bouillabaisse recipe

- Lessons from the past
  - 1988-99 survey – poor understanding of the impacted area
  - Fishes deemed safe in 1999, risky in 2005
- A SQG can/will be derived, but
  - Management options?
  - Ecosystem restoration (‘plan Rhône’)
- Changing paradigm on risk management: inventing the framework