TRANSFER OF PCB FROM THE SEDIMENT TO THE BIOTA IN THE RHÔNE RIVER: EFFECTS OF FORAGING BEHAVIOURS

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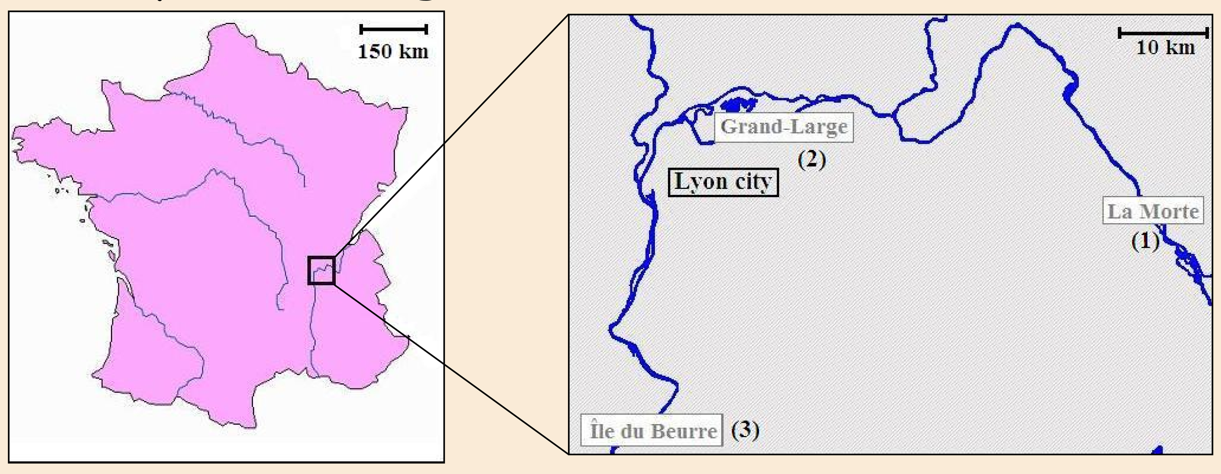
Introduction

- Many factors known to influence PCB bioaccumulation processes and trophic transfers: chemical factors (properties of PCB congeners), physiological factors (organisms lipid content, body size, sex) and trophic factors (diet preferences, habitat use, trophic position) ⟶ essential to understand primary factors and their relative contributions to assess and predict risks to upper-trophic levels consumers including humans.
- Stable isotope analyses (SIA) largely used to study trophic factors, and more recently development of multiple stable isotope mixing models with incorporation of uncertainty and individual variability through Bayesian Inference (SIAR package in the R software: Parnell et al., 2010).
- Goal: Identifying PCB contamination pathways by distinguishing physiological and trophic factors explaining individual and specific variability in PCB concentrations.
- Case study: The Rhône river in the vicinity of Lyon (France), where fish consumption is prohibited because of exceeding European sanitary level of 8 pg TEQ/g wet weight. Three freshwater river fish species studied (all large and long-living species prone to accumulate PCB over many years but having different diets and exploiting different habitats): the barbell *Barbus barbus*, the European chub *Squalius cephalus* and the bream *Abramis brama*. In the three sites explored, sediment cores also removed and analysed.

Materials and methods

Study sites (Fig. 1):



(1) relative reference upstream Lyon (MTE)

(2) fluvial lake in contaminated area (GDL)

(3) site downstream Lyon (BRE)

Figure 1: View of the study sites along the Rhône river near Lyon

Sampling (Tab. 1) and data:

- Fish data: length, weight, sex, age, stomach content, $\delta^{13}C$, $\delta^{15}N$, lipid content (%) and PCB_i concentrations.
- Invertebrate data (used as food-web baselines): weight, $\delta^{13}C$ and $\delta^{15}N$.
Corbicula → detrital carbon
Pisidium → autochtonous carbon
- Sediment cores: datation, PCB levels

Sites	Bream	Chub	Barbell	Pisidium	Corbicula
La Morte	7 (3♀+4♂)	20 (13♀+7♂)	11 (11♀+0♂)	140	15
Grand-Large	15 (9♀+6♂)	15 (6♀+9♂)	15 (8♀+7♂)	160	13
Île du Beurre	17 (10♀+7♂)	17 (12♀+5♂)	5 (3♀+2♂)	130	60

Table 1: Number of fishes and invertebrates sampled in each site

Data analyses

- Classical statitics to compare data between fish species and between sites
- Fish trophic position (TP) estimated by Bayesian Inference from the equation of Post (2002) with 2 baselines (Eq. 1) → data variability and uncertainties around parameters
- Stable isotope mixing models (SIAR package) at the population and individual levels to determine the proportion of detrital and autochtonous carbon and thus diet habitat
- Backward stepwise log-linear and generalized linear models to predict PCB_i levels in fishes and the probability to exceed the sanitary treshold of 8 pg TEQ/g wet weight (≈ 153 ng/g ww for ΣPCB_i), according to size, sex, $\delta^{13}C$ or % of detrital carbon in the fish isotope profile (Cd) estimated above, $\delta^{15}N$ (or TP estimated above), lipid content (%) and maximal ΣPCB_i in the sediment at which fihes were exposed during their life (PCB_{sed})

$$TP = \lambda + \frac{\delta^{15}N - \left(\alpha\,\delta^{15}N_{base1} + (1-\alpha)\,\delta^{15}N_{base2}\right)}{\Delta n}$$

$$\text{with } \alpha = \frac{\delta^{13}C_c - \delta^{13}C_{base2}}{\delta^{13}C_{base1} - \delta^{13}C_{base2}}$$

where λ is the trophic position of the baselines, $\delta^{15}N_{base}$ and $\delta^{13}C_{base}$ are the Nitrogen and Carbon ratios of the baselines, α is the contribution of the first baseline to the N consumer signature and Δn is the enrichment in $\delta^{15}N$ per trophic

Equation 1: Estimation of trophic position according to Post (2002) with two baselines

$$\log_{10}(PCB_{fish}) = -0.569(\pm 0.167) + 0.036(\pm 0.003)*\text{size} - 0.779(\pm 0.188)*Cd + 0.591(\pm 0.065)*\log_{10}(PCB_{sed})$$

Equation 2: linear model explaining 78% of the total variability in fish PCB concentrations.

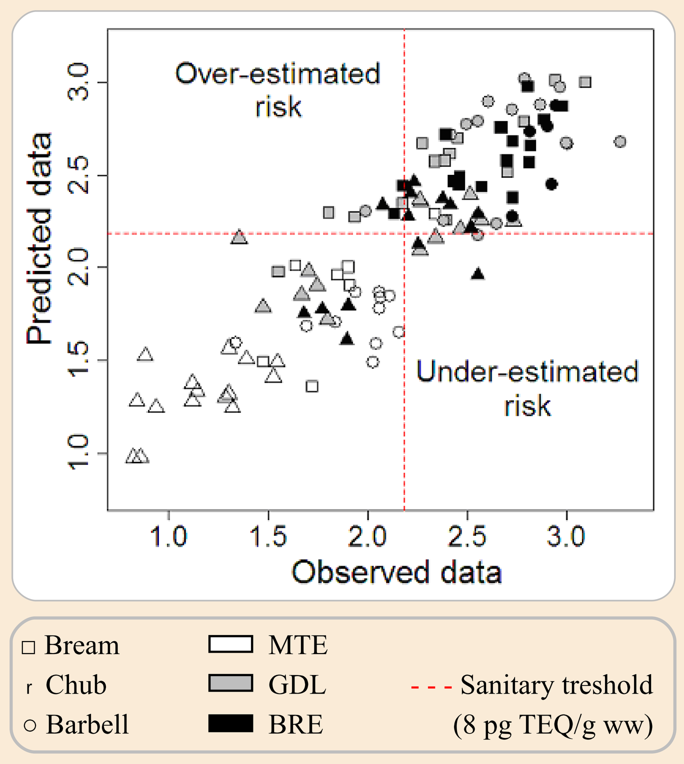


Figure 5: Relationship between predicted (Eq. 2) and observed PCB_i concentrations (in $\log_{10}$)

Results and discussion

Contamination data (Fig. 2):

- Contamination gradient from upstream to downstream Lyon for each species
- Chub less contaminated than bream and barbell
- High individual variability at GDL

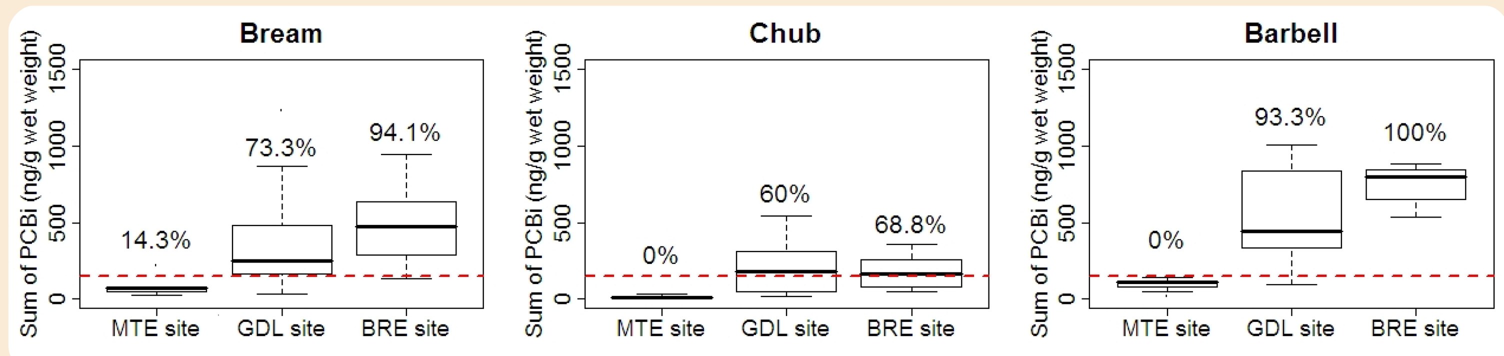


Figure 2: PCB_i concentrations per species and per site and percentage of individuals above the sanitary treshold.

Stable isotope analysis

- Bayesian inference on $\delta^{13}C$ and $\delta^{15}N$ data to infer trophic position (Eq. 1) for each species in each site: good estimation of each parameter and TP. Baselines as primary consumers (λ mean=2); Δn higher than the usually used 3.4 ‰ at MTE and BRE and lower at GDL; lower trophic position for the chub
- No difference in $\delta^{13}C$ between species at MTE but differences at GDL and MTE (Fig. 3)
- Contamination gradient from high to low $\delta^{13}C$ values representing detrital carbon (Fig. 3)

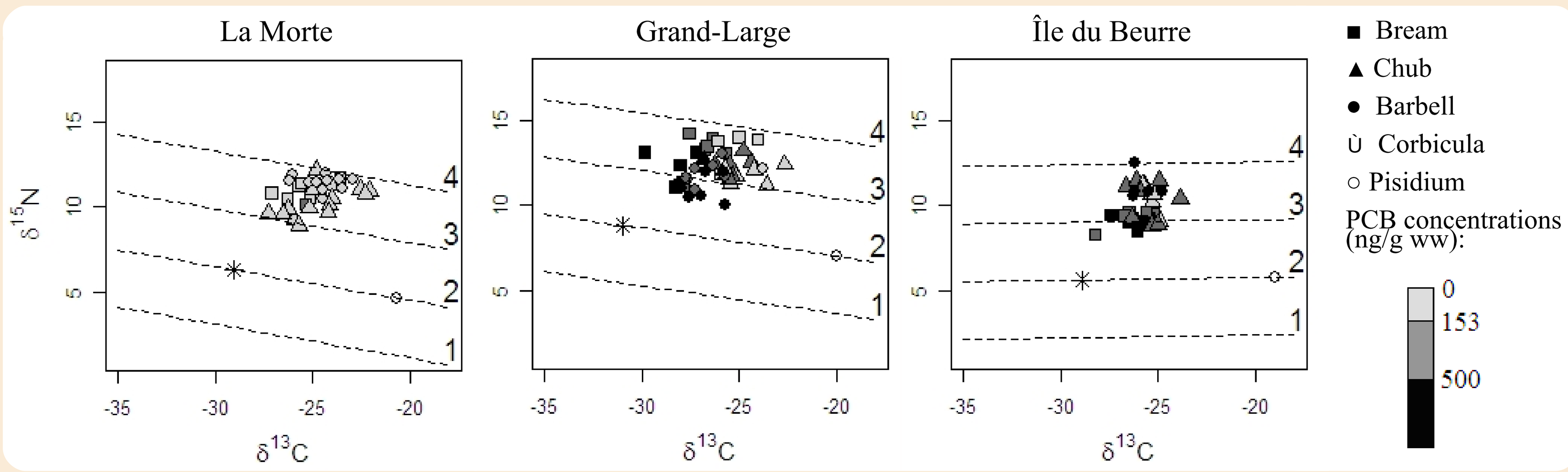


Figure 3: Dual isotope plots in each site with TP estimated by Bayesian Inference (right y-axis) and fish contamination

Stable isotope mixing models

- At the population level, 2 patterns obtained (Fig. 4): (A) the 2 carbon sources similarly exploited by the bream and barbell at MTE and BRE; (B) autochtonous carbon used preferentially by bream and barbell at GDL and chub everywhere
- At the individual level, increase of PCB concentrations with the proportion of detrital carbon in isotope profile

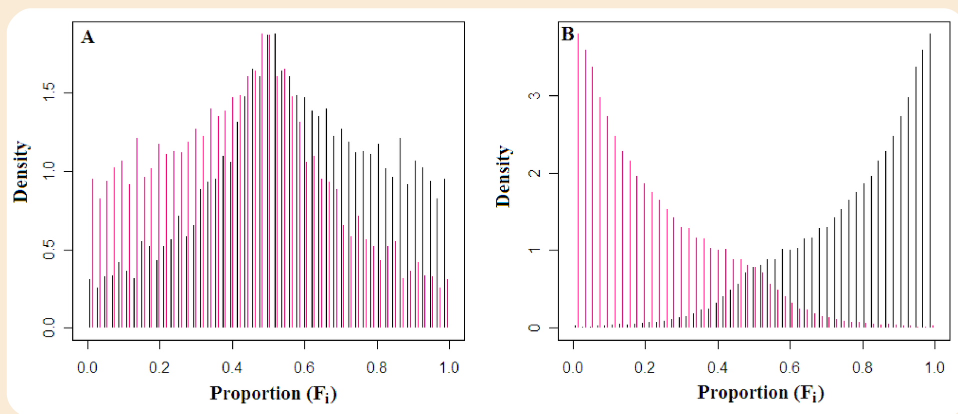


Figure 4: Proportion of autochthonous (black) and detrital (red) carbon in fish isotopic profiles obtained with mixing models.

Predictive statistical models

- No significant difference in fish age between sites (mean=7.3 years) → According to sedimentation rate: PCB_{sed} at MTE and GDL (section 0-7cm) = 6.26 and 69.7 ng/g dry weight and at BRE (section 0-5cm) = 55.1 ng/g dry weight
- 78% of contamination levels and 70% of probability to be contaminated explained by only 3 significant explanatory variables: size (related to weight and age), % of detrital carbon and maximal PCB concentration in the sediment (Eq. 2 and Fig. 5).
- Robust predictions in a risk assessment perspective (Fig. 5)

Conclusion and perspectives

- Central role of sediment compartment in food-web contamination
- Main factor in fish PCB contamination: not what fishes eat, but rather where they eat!
- Perspectives: (1) validation of the log-linear model for other species data set and (2) development of a bioaccumulation food-web model to descrive PCB transfer whithin the network and to help sediment management guidelines.

References

Parnell A., Inger R., Bearhop S. and Jackson A.L. (2010). Source partitioning Using Stable Isotopes: Coping with Too Much Variation. PLoS ONE 5(3): e9672

Post D.M. (2002). Using stable isotopes to estimate trophic position: Models, methods, and assumptions. Ecology 83(3): 703