Between- and within-tributary variation in fish assemblages: the role of macrophytes and water transparency

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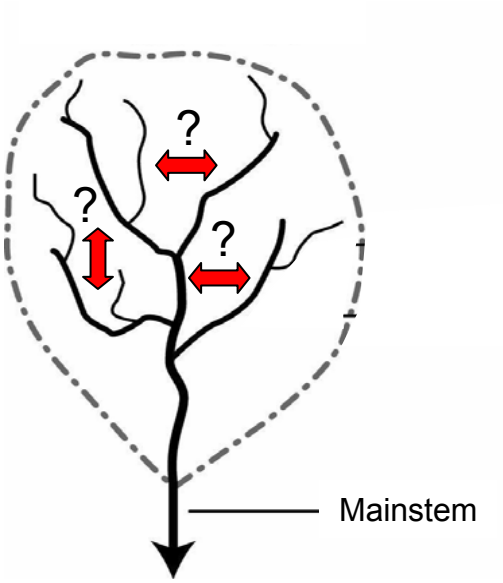
Framework



Within individual tributaries, fish assemblages change along environmental gradients (e.g. temperature, water depth and velocity, chemical features) (Schlosser 1982, 1991, Oberdorff et al. 1993, Reyjol *et al.* 2001, Magalhaes *et al.* 2002, Li & Gelwick 2005).

To our knowledge, no study has specifically investigated the between- *vs.* within-tributary variation in fish assemblages within a watershed.

How are fish assemblages organized at the watershed scale?

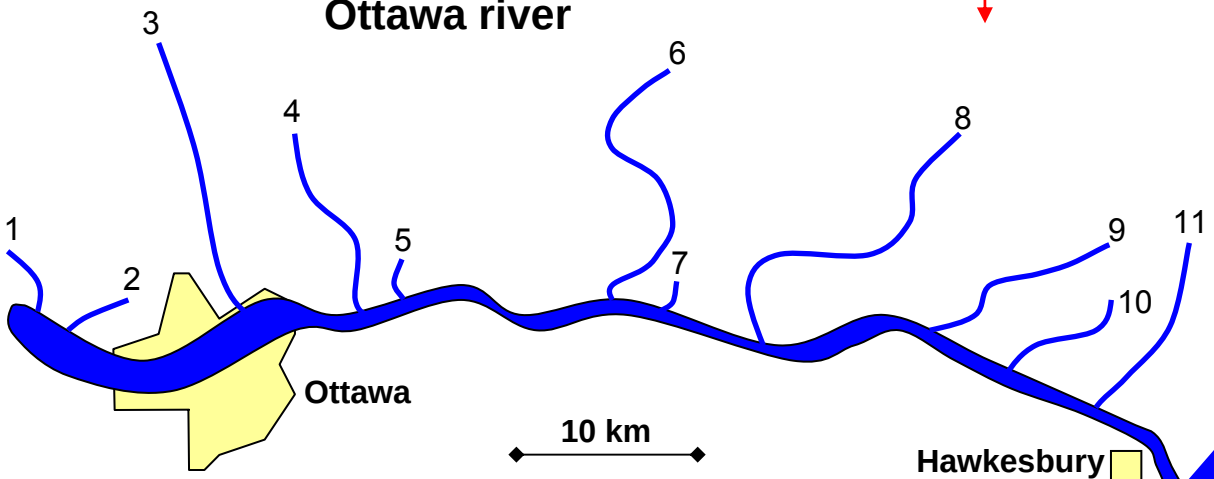
Study area

Canada

Ottawa River watershed

1 – Bélisle
2 – Breckenridge
3 – Gatineau
4 – Blanche à Gatineau
5 – Petite Blanche à Gatineau
6 – Blanche à Thurso
7 – Petite Blanche à Thurso
8 – Petite Nation
9 – Kinonge
10 – Petite Kinonge
11 – Rouge

Ottawa river

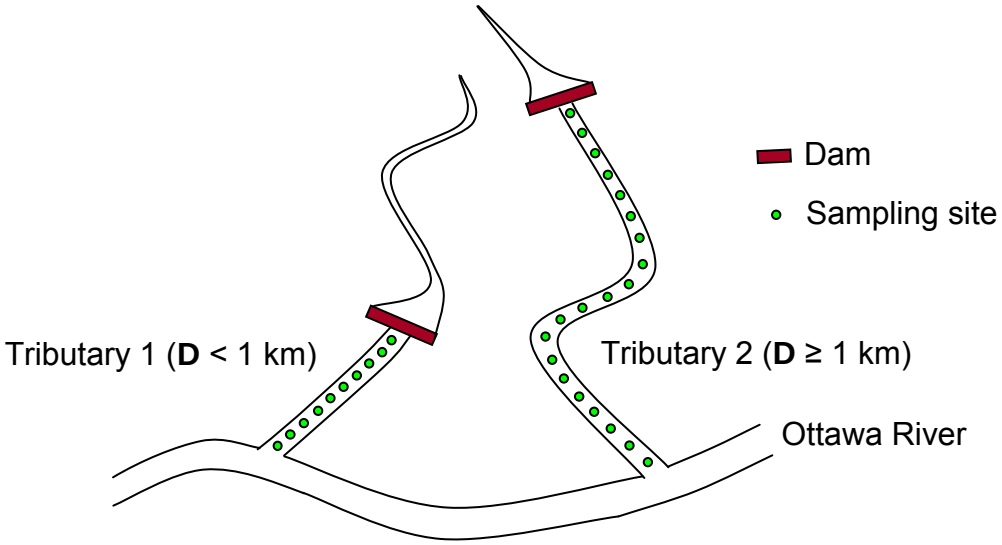


Methods – Sampling design

D: distance between the confluence with the Ottawa River and the first dam on the tributary.

If **D** < 1 km, 10 equidistant sampling sites.

If **D** ≥ 1 km, 20 equidistant sampling sites.



Five tributaries with 10 sampling sites, 6 with 20 sampling sites ➡ **170 sampling sites**

Methods – Sampling protocol

Beach seining along the most suitable bank in each site (gentle slope, no obstacles), during summer 1995 and summer 1996.

Nine environmental variables:

- River width (m)
- Bank slope ($m \cdot 100^{-1} m^{-1}$)
- Water transparency (m)
- Water velocity ($m \cdot s^{-1}$)
- Dissolved oxygen concentration (ppm)
- pH
- Width of the macrophyte beds (m)
- Macrophyte taxonomic richness
- Dominant substrate

Counting and identification (field and laboratory)

Methods – Statistical treatment

Redundancy analysis (RDA)

Linear ordination technique – Extension of multiple linear regression

Simplest case:

Y_{ij} ⟸ X_{ij}

Fish data

Environmental data

With covariates:

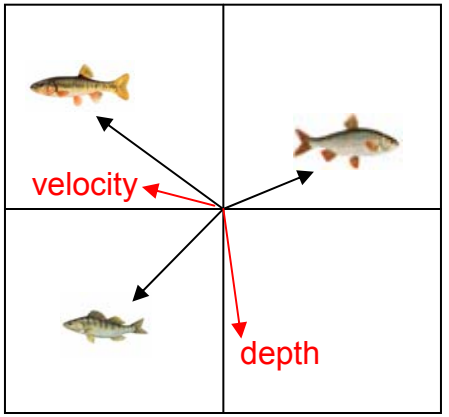
- *Partial* RDA -

Y_{ij} ⟸ X_{ij} & Z_{ij}

Fish data

Environmental data

Covariates (dummy variables)



Methods – Statistical treatment

Three matrices of covariates:

T: Tributaries (1 to 11)
S: Sampling sites (1 to 10 or 1 to 20)
T x S: interaction covariates

Two analyses:

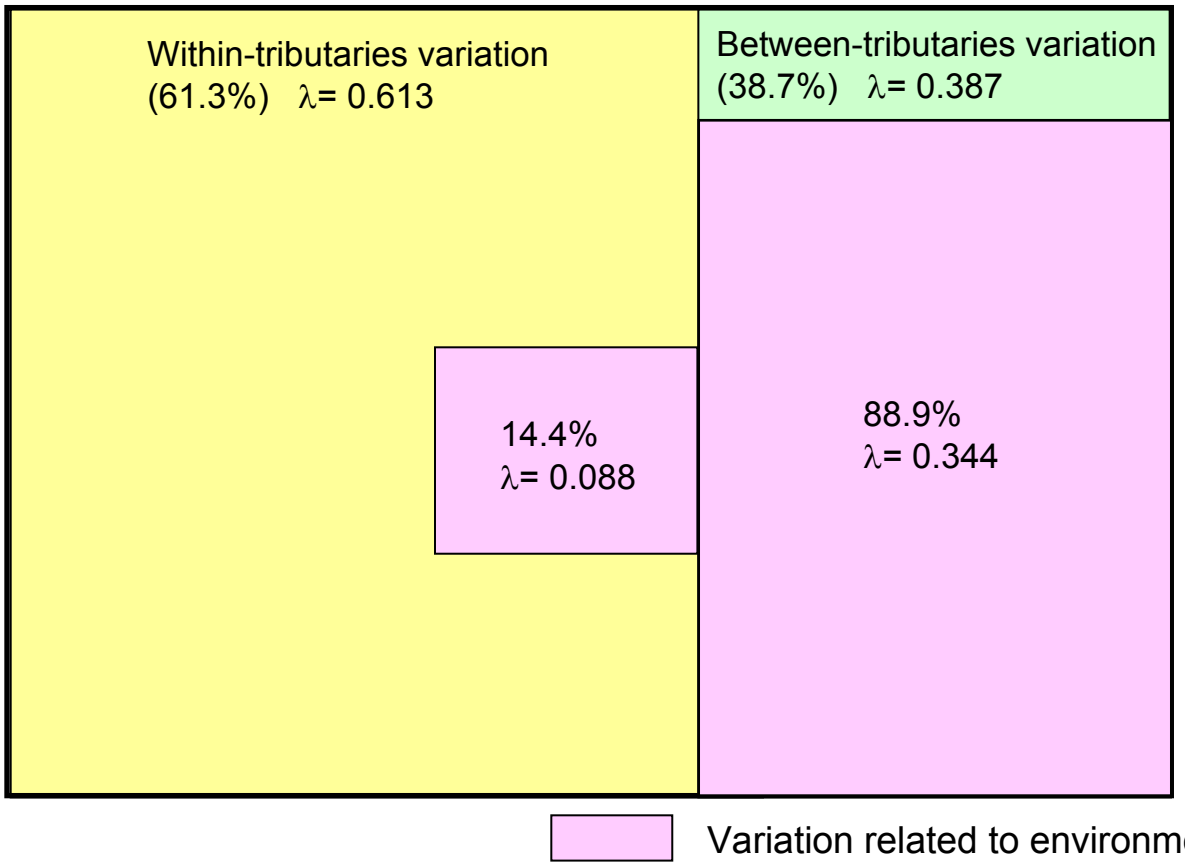
RDA 1: tributaries **T** as covariates ⟺ ***Within-tributaries variation***

RDA 2: sampling sites **S** and interaction matrix **T x S** as covariates ⟺ ***Between-tributary variation***

- **Stepwise selection** of environmental variables ($p < 0.05$)
- **Restricted permutation tests** (999 permutations)
- **Transformation** of environmental variables when necessary (logarithm or squared root)

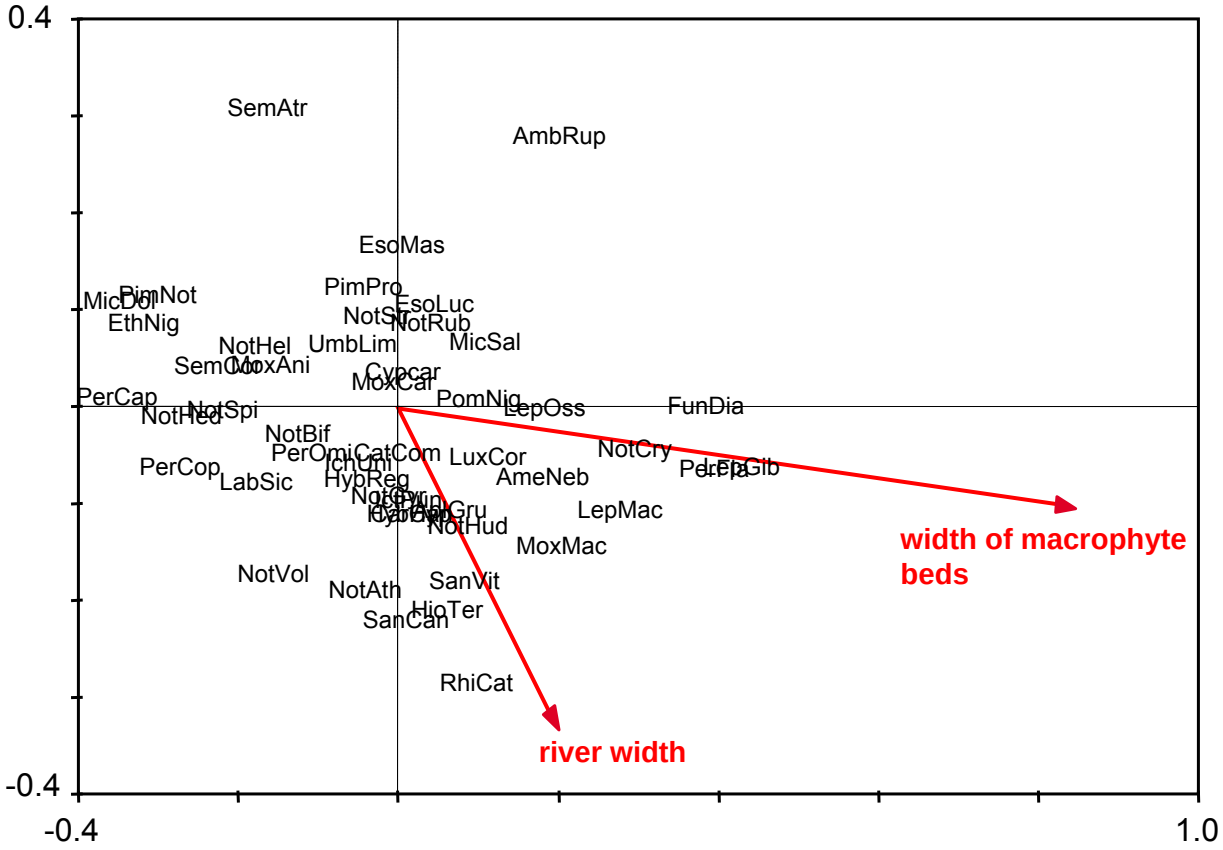
Variation partitioning between **T** and **{S + S x T}, which are orthogonal**

Results – Variation partitioning



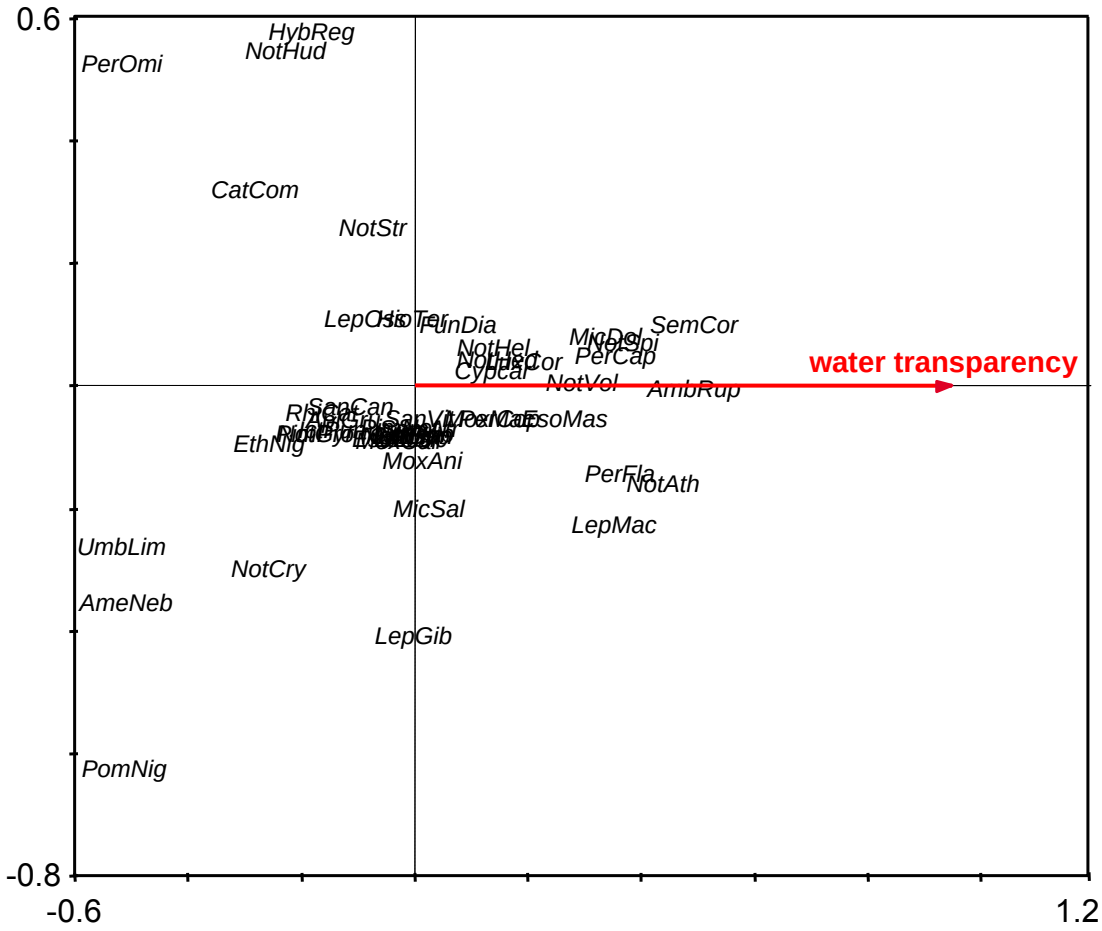
- **Assemblages are more variable within tributaries (common longitudinal pattern) than between tributaries**
- **Environmental variables explained more the between-tributaries variation than the within-tributary variation**

Results – RDA 1 (common longitudinal pattern)



Only two environmental variables were retained by the stepwise selection procedure: **width of macrophyte beds** and **river width**

Results – RDA 2 (between-tributary variation)



Only one environmental variable was retained by the stepwise selection procedure: **water transparency**

Discussion

Macrophytes

⟺

Refuge against predators (Rozas & Odum 1988, Jacobsen & Berg 1998, Saas *et al.* 2006) and food reservoir (Rozas & Odum 1988, Grenouillet & Pont 2001, Grenouillet *et al.* 2002)

Water transparency/turbidity

⟺

Refuge for prey against visual piscivorous species (Rodriguez & Lewis 1997, Ostrand & Wilde 2002) or increase prey catchability for planktivorous or invertivorous species (Lueke *et al.* 1990).

Summary

1 – Restricted permutation tests ⇨ Selection of limited sets of significant environmental variables (2 and 1)

2 – Variation partitioning ⇨ Quantification of the between and within-tributaries variation in fish assemblages (61.3 *vs.* 38.7%; 14.4 *vs.* 88.9% explained by environmental variables after fitting covariates)

3 – Partial RDAs ⇨ Selection of environmental variables which best explained the common longitudinal pattern in fish assemblages (macrophyte cover and river width)

⇨ Selection of environmental variables which best explained the differences among tributaries which were not related to specific longitudinal patterns (water transparency)

These results provide specific insights concerning the between- *vs.* within tributary organization of fish assemblages. It suggested that environmental variables influencing biotic processes (*i.e.* feeding behaviour and predator avoidance) may play an important role in fish assemblages organization at the watershed scale.

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Université du Québec à Trois-Rivières

GRIL

GROUPE DE RECHERCHE SUR LES ÉCOSYSTÈMES AQUATIQUES