

The relative influence of watershed, riparian zone and local anthropogenic pressures on fish and macro-invertebrate communities in French rivers

Influences des pressions humaines à différentes échelles spatiales sur les peuplements piscicoles et macro-invertébrés dans les rivières françaises

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RÉSUMÉ

Cette étude vise à comparer l'influence relative des pressions humaines sur les peuplements des rivières à différentes échelles (bassin, zone riparienne, site) tout en différenciant l'effet de l'environnement "naturel" et des pressions humaines. De 2005 à 2008, des données concernant la biologie, l'environnement ainsi que les pressions humaines ont été compilées pour 301 sites français. Les résultats sont cohérents avec de nombreuses études ayant démontré le rôle fondamental des pressions humaines dans la détermination des communautés biologiques des rivières. Les communautés de poissons et de macroinvertébrées présentent des distributions similaires le long des gradients de pressions. Une large part de la variabilité expliquée de la composition des communautés est liée aux interactions entre plusieurs facteurs (~40%) et aux variables "naturelles" (~30%). De plus, les occupations du sol ainsi que les pressions humaines locales expliquent significativement la composition des communautés piscicoles et macroinvertébrées. Nous recommandons l'utilisation des occupations du sol en suppléments des pressions locales et que les facteurs non-liés aux pressions humaines soient pris en compte *a priori* afin d'analyser les effets des activités humaines sur les peuplements des rivières. Enfin, cette étude confirme la complexité des effets des pressions humaines sur les peuplements ainsi que la difficulté à déterminer les pressions principales affectant les rivières.

ABSTRACT

The present study aim at comparing the relative influence of anthropogenic pressures on river biological assemblages at different scales (watershed, riparian zone, site) while differentiating influence of "natural" environmental factors and anthropogenic stressors. Environmental data, land uses, reach scale anthropogenic modifications and biological data were compiled for 301 French sites from 2005 to 2008. Common distribution patterns in agreement with taxa bio-ecological knowledge were observed along pressure gradients for the two biological communities. A large part of the explained variability in community composition was related to complex interaction among factors (around 40%) and to "natural" variables (about 30%). In addition, land uses and local anthropogenic pressures both significantly explained river fish and macroinvertebrate community compositions. These findings are consistent with numerous studies demonstrating the important role played by human-induced pressures on the species composition of riverine assemblages. We advocate that land uses should be combined with information on local scale pressures and the "natural" environmental factors be considered beforehand when describing effects of human activities. Finally, this study supports the idea that pressure effects on river communities are usually complex and that the main pressure affecting a river is hard to determine.

KEYWORDS

Anthropogenic stressors, fish, macroinvertebrate, redundancy analysis, river.

1 BACKGROUND

The idea that rivers should be managed at the catchment scale has become widespread. Managers are more and more prone to use money saving and easy to acquire proxies of river ecological status such as land uses/covers instead of fastidious direct measures of the local pressures and samplings of the biological communities. Indeed, it is commonly accepted that river reach scale communities are structured by local abiotic factors (e.g. water physical and chemical parameters) that are in turn constrained at larger scales such as buffer or catchment factors (land uses and covers). Impacts of anthropogenic factors on river communities have been largely documented at the local scale and are now well documented at large scales too (segment and catchment). Nevertheless, to our knowledge, only few studies have attended to compare the ability to explain the variability in biological assemblages at these different spatial scales and results are not always consistent among studies. In addition, most of the studies did not distinguished environmental factors defining the system conditions and that are quasi-independent of human activity (here named "natural" environment factors) from those directly influenced by human activity (commonly named "human pressure factors"). As other authors, we advocate that for river management purposes, the latter are of prime interest as they represent meaningful triggers for stakeholders to restore or maintain ecological quality of water bodies.

2 OBJECTIVES AND APPROACH

The objective of this study was to compare the relative influence of anthropogenic pressures on river biological assemblages at different scales (watershed, riparian zone, site) while differentiating influence of "natural" environmental factors and anthropogenic stressors. Three questions were addressed: (i) What are the links among watershed and riparian zone land uses and reach scale pressures? (ii) What are the links among anthropogenic pressures variables and river biological community composition in French rivers? (iii) What is the part of the variation in French freshwater communities (fish and macroinvertebrates) explained by system condition variability, human-induced pressures at the reach scale, riparian land uses and catchment land uses?

Based on the results of previous studies, we expected to observe strong links between land uses and local pressure variables, links between pressure variables and biological community compositions and that biological composition variability would be more affected by natural environmental factors and reach scale pressures than larger scale stressors. Finally, we suspected that complex interaction effects exist among these spatially different pressures.

Our predictions were examined using French national data on 301 river sites. In order to describe land uses relationship with local habitat modifications, correlations were calculated among land cover types at the two scales (buffer, catchment) and local stressors. Partial redundancy analyses were conducted at three spatial scales (local, buffer, catchment) for each biological group to define the relationship among anthropogenic pressures and river communities removing beforehand the effect of the "natural" environment. Finally, partition of the variation of the biological communities were analysed in order to compare unique and shared influences of natural environment and of the 3-scales anthropogenic variables.

3 RESULTS

3.1 Land uses as proxies of local anthropogenic pressure variables

Water quality parameters were generally better correlated to land covers than hydro-morphological parameters implying that when considering land uses as proxies for river local degradations, water quality problems will be better represented than local habitat and hydro-morphological problems. Upstream catchment land covers were better correlated to water quality reach scale parameters and buffer land covers to hydro-morphological degradations. These results are in accordance to those of previous studies (e.g. Moerke and Lamberti, 2006) suggesting that catchment land covers are possible proxies of local water quality parameters and buffer land covers predictors of local habitat and hydro-morphological parameters.

3.2 Linked among human pressures and biological community composition

In this part, we have focused on the influence of human-induced pressure variables at different scales after having removed the variability related to "natural" environment factors. The part of the total inertia of communities' compositions explained by the analyses was lower for macroinvertebrate than for fish. However, common patterns were observed for the response of fish and macroinvertebrate communities to pressures at the different scales and biological community distributions along the pressure gradients were coherent with bio-ecological knowledge on fish and macroinvertebrate taxa. The presence of an impoundment emerged as the main human pressure factor shaping the communities at the local scale, followed by water quality and morphological pressure gradients. At broader scales (buffer and catchment), fish and macroinvertebrate communities appears to be greatly influenced by a common gradient from forested covers to agricultural land uses. Increase in buffer artificial and wetland covers appears to be another important gradients influencing macroinvertebrate assemblage composition. These findings are consistent with numerous previous studies demonstrating the important role played by human-induced pressures on the species composition of riverine assemblages.

3.3 Ability of catchment, buffer or local variables to explain biological assemblage variation

As expected, variables not directly influenced by human activities, as geology or altitude, account for a large part of the among-sites explained differences in community composition (about 30%). These findings strengthen the idea that "natural" variability in environment is a key parameter explaining river community composition diversity and should be always considered and taken into account beforehand when looking at the effect of human-induced pressures on river ecological quality in order to attempt to distinguish the two effects.

A large part of the explained variability in community composition was related to factor shared effects (around 40% of the explained variability). Such complex effects illustrate why it is so delicate to establish simple pressure-impact relationship for fish and macroinvertebrates in river as pressure effects are generally difficult to separate. Consequently, in the common case of multi-impacted sites, it will very hard to answer the water managers about the main pressure disturbing the river ecological status.

In addition, results concerning relative influences of anthropogenic pressures were different for macroinvertebrate and fish communities. Land use variables seem more important for macroinvertebrate community composition while fish community composition appears to be more sensitive to local anthropogenic pressures. These results are not surprising given previous finding supporting that land use variables mainly reflect water quality degradations of reach and upstream area. Indeed, previous works have already shown that macroinvertebrate communities are generally more sensitive to water quality degradation than fish communities.

4 CONCLUSIONS

Given these results, it appears likely that land uses and local pressures both significantly explain river fish and macroinvertebrate community compositions. Although land uses appear to be useful approximations of the global water quality degradation of the upstream river, they should be combined with information on local scale pressures and the "natural" environmental factors be considered beforehand to describe effect of human activities. Finally, this study supports the idea that pressure effects on river communities are usually complex and that it is often hard to determine the main pressure affecting a river.

LIST OF REFERENCES

Moerke, A.H. and Lamberti, G.A. (2006). *Scale-dependent influences on water quality, habitat, and fish communities in streams of the Kalamazoo River Basin, Michigan (USA)*. *Aquatic Sciences*, 68(2), 193-205.