Detecting patterns and relationships of human pressures in European Rivers

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ABSTRACT

Most European rivers are affected by different types of human pressures that may impair fish populations. We analysed 15 pressure variables of 4 different pressure groups, i.e. hydrology, morphology, water quality and connectivity to detect spatial patterns, relationships and interactions between pressures and natural environment at the European scale. Based on literature, national databases and expert knowledge important pressures were identified and collected within the EU-project EFI+ in 14 countries at about 10 000 fish-sampling sites in Europe. In 90% of the catchments analysed fish migration was interrupted by barriers. We used PCA and correlation analysis to identify key pressures and to eliminate redundant pressures at local and river segment scale. Thirteen variables were found to describe the majority of human degradation at a specific site. To aggregate into pressure type specific indices we first harmonized the variables along a gradient from 1-5, i.e. from nearly undisturbed to strongly impacted sites. Further, we calculated the mean of values > class 2 only, to avoid that values <=2 compensate values >2, i.e. to better indicate degradation. Pressure analysis showed that 24% of sites are affected by single, 22% by double 19% by triple and 12% by four pressure groups. Only 23% of sites are less affected, i.e. class <=2. In terms of pressure types, analysed sites showed alterations in 55% for water quality pressures, 40% for hydrology, 37% for morphology and 34% for connectivity (river segment). In 45% of the cases water quality problems are also associated with other pressures. The results clearly show that European rivers are multi-impacted. Therefore, only restoration strategies simultaneously considering all important types of pressures will guarantee the achievement of the good ecological status or potential sensu EU Water Framework Directive.

Key words: multi-impacted rivers, European scale, ecological status, pressure index

1 INTRODUCTION

A number of human alterations - herein after referred to as pressures - directly affecting the physico-chemical conditions of running waters, have a strong influence on fish communities. In European rivers, the most important pressure signifi-

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cantly affecting fish is water pollution (FAME 2004, Degerman et al. 2007). Hydrological alterations as impoundment (Reid 2004), water abstraction (Pyrce 2004) and hydropeaking (Flodmark et al. 2004) are known to degrade fish communities. Morphological alterations such as channelisation (Aarts et al. 2004) and river bed degradation (Raat 2001) also have deleterious effects. Finally, disruption of both longitudinal (Rieman & Dunham 2000) and lateral (Hughes & Rood 2003) connectivity significantly impairs fish communities.

Recently, studies in Europe and worldwide emphasize the influence of different human pressures on rivers and it clearly has been demonstrated that a better understanding of the distinct effects of single pressures, multiple pressures and their interactions is a pre-condition for effective river restoration (Schmutz et al. 2007). But due to the traditional focus on single case studies, basins, watersheds or ecoregions, there is a lack of common understanding of pressures across Europe, though the European Water Framework Directive (WFD, EU 2000) requires a consistent and comparable "identification of significant anthropogenic pressures and the assessment of their impacts on water bodies" (ANNEX II, WFD).

In the IES report (European Commission 2006, Institute for Environment and Sustainability) it's indicated that pressures act simultaneously in most cases and that managers must define a hierarchy amongst these to identify priority actions. The few existing studies, examining relationships between pressures are suggesting strong influences and interactions between two or more kinds of pressures. According to Vinebrooke et al. 2004, pressures rather often have comparative, additive and multiplicative effects. Despite this, only a few studies have focused on the importance of that topic, especially in context of the WFD, dealing with pressure combinations, large datasets or multiple pressures and taking interactions of pressures into consideration.

In this paper we analyse different types of pressures from 15 European countries and 16 ecoregions. Our primary objectives are (1) to identify various pressure groups, (2) to detect dominating pressures (chemical–physical pressures vs. hydromorphological pressures), (3) to analyse multiple pressures and prevailing pressure combinations and (4) to detect spatial patterns of pressures across Europe.

2 METHODS

Dataset

A database prepared and maintained by the consortium of the EU project EFI+ (**http://efi-plus.boku.ac.at/**) was used to quantify human pressures for our study. The EFI+ database is a pan-European database and contains data on fish assemblages, environmental characteristics and human pressures in 15 European countries.

Related to the compulsive "Characterisation of river basins", (Article 5, WFD), a lot of different pressure information has been gathered by EU-member countries since 2004, which was used for this pressure analysis. In addition, regional and national monitoring programmes and profound protocol data from field mappings were available. Qualified pressures for our analysis must be scientifically proven, must have potentially large negative effects on fish and must be relevant on a continental scale. We are aware that land use also has strong indirect influences on rivers, but due to our focus on direct effects of pressures on the river, we only considered instream variables for pressure analysis. In total, 15 pressure variables out of the EFI+ database were qualified for our analyses.

Pressure variables

In total, pressure data at 10208 sites in about 4800 rivers and 16 ecoregions (Table 1) were available for our study. As more than 90% of sites showed continuum disruption at the catchment level, this variable was not used for further analyses.

Table 1: Number of analysed sites per country and ecoregion (NoData represents sites where ecoregion classification was not available/possible).

		Country abbreviation															
		AT	CH	DE	ES	FI	FR	HU	IT	LT	NL	PL	PT	RO	SE	UK	Total
Ecoregions	Alps	371	163				52		88								**674**
	Borealic uplands					12									61		**73**
	Central highlands	439	2	289			14					23					**767**
	Central plains			440							76	414			326		**1256**
	Eastern plains											176		72			**248**
	England															1228	**1228**
	Fenno-scandian shield					251									207		**458**
	Hungarian lowlands	63						163									**226**
	Ibero-Macaronesian region				2077								922				**2999**
	Italy and Corsica		9				5		338								**352**
	NoData		106	30		15	66	28	72	94	38	235	1	15	11		**711**
	Pontic province													19			**19**
	Pyrenees				20		18										**38**
	The Carpathiens							2				59		157			**218**
	Western highlands		220				219										**439**
	Western plains			22	1		411				68						**502**
	Total	**873**	**500**	**781**	**2098**	**278**	**785**	**193**	**498**	**94**	**182**	**907**	**923**	**263**	**605**	**1228**	**10208**

First, we summarized the selected pressure variables in 4 groups, i.e. connectivity (2 variables), hydrology (5), morphology (5) and water quality (3). Information on pressure intensity was available in verbal ordinal form, ranging from 2 to 5 modalities (Table 2). To overcome this inequity, we defined an ordinal ranking scheme and harmonized all pressure variables along a gradient from 1-5, i.e. from nearly undisturbed to strongly impacted sites. In the next step, Principle Component Analysis (PCA) was used to identify key and redundant pressures. PCA was done for all pressure variables in one step and then for each pressure group. Finally, 13 variables remained for further analyses (see Table 2).

Table 2: Human pressure variables selected for pressure analyses, separated in the groups hydrology (H), morhphology (M), water quality (W) and connectivity (C).

Pressure variable	Group	Code	Explanation; short description of classes
Impoundment	H	H_imp	Natural flow velocity reduction on site due to impoundment; 1 = no (no impoundment), 3 = weak, 5 = strong
Hydropeaking	H	H_hydrop	Site affected by hydropeaking; 1 = no (no hydropeaking), 3 = partial, 3 = yes
Water abstraction	H	H_waterabstr	Site affected by water flow alteration/minimum flow; 1 = no (no water abstraction), 3 = weak to medium (less than half of the mean annual flow), 5 = strong (more than half of mean annual flow)
Reservoir flushing	H	H_resflush	Fish fauna affected by flushing of reservoirs upstream of site; 1 = no, 3 = yes
Hydrograph modification	H	H_hydromod	Seasonal hydrograph modification due to hydrological alteration (water storage for irrigation, hydropower etc.); 1 = no, 3 = yes
Channelisation*	M	M_channel	Alteration of natural morphological channel plan form; 1= no, 3 = intermediate, 5 = straightened
Cross section*	M	M_crosssec	Alteration of cross section; 1 = no, 3 = intermediate, 5 = technical crossec./U-profile
Instream habitat*	M	M_instrhab	Alteration of instream habitat conditions; 1= no, 3 = intermediate, 5 = high
Embankment	M	M_embankm	Artificial embankment; 1 = no (natural shoreline), 2 = slight (local presence of artificial material for embankment), 3 = intermediate (continuous embankment but permeable), 5 = high (continuous, no permeability)
Flood protection	M	M_floodpr	Presence of dykes for flood protection; 1 = no, 3 = yes
Barriers segment upstream	C	C_B_s_up	Barriers on segment level upstream; 1 = no, 3 = partial, 3 = yes
Barriers segment downstream	C	C_B_s_do	Barriers on segment level downstream; 1 = no, 4 = partial, 4 = yes
Acidification	W	W_acid	Acifidication; 1 = no, 3 = yes
Eutrophication	W	W_eutroph	Artificial eutrophication; 1 = no, 3 = low, 4 = intermediate (occurrence of green algae), 5 = extreme (oxygen depletion)
Organic pollution	W	W_opoll	Is organic pollution observed; 1 = no, 3 = weak, 5 = strong
* Variables summed up into M_morhph_instr (Mean of M_channel, M_instrhab, and M_crossec)			

To evaluate the status of European rivers in terms of pressure type, 4 pressure type specific indices (hydrological, morphological, water quality and connectivity) were aggregated. They were calculated by averaging values > class 2 only, to avoid that values <=2 compensate values >2, i.e. to better indicate degradation.

Combination of pressures

To focus on the degradation of European rivers related to different types of single/ multiple pressures, we analysed typical combinations of pressures across Europe:

Water quality pressures only, hydromorphological pressures only and a combination of the two types (W, HMC, W + HMC). For this analysis, the pressure type specific indices have been used.

3 RESULTS

Pressure type specific indices

Water quality pressures were detected in 55.9 % of sites (Figure 1), with worst conditions for sites in the Netherlands and Germany (90% of sites affected by water quality pressures). For hydrological pressures, impacts were classified in 40% of sites with worst conditions for sites in the Netherlands, Germany, France, Italy, Portugal and UK (about 50% of sites are impacted by hydrological pressures).

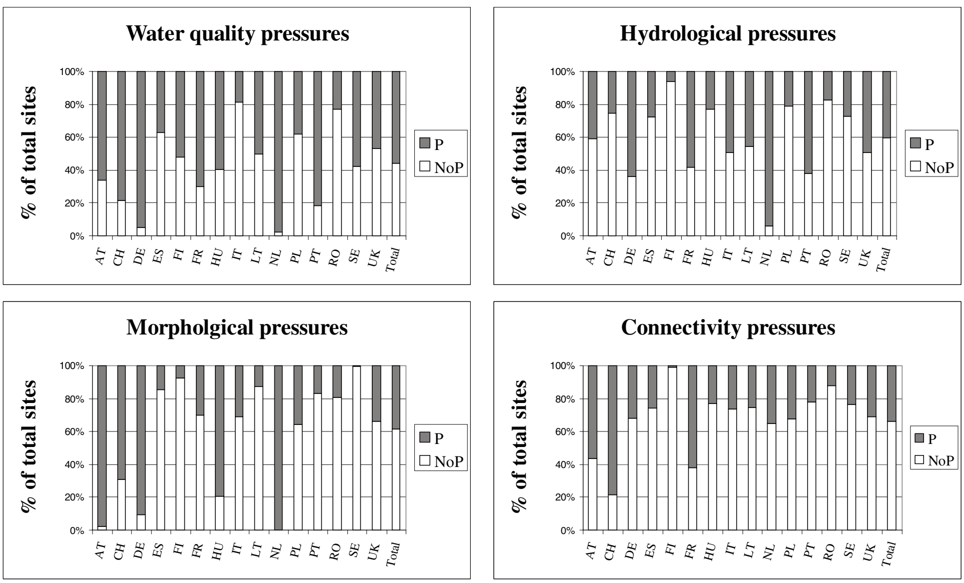

Figure 1: Results of pressure type specific indices in % of sites per country, P = impacted by pressure, NoP = no pressure (class <=2).

Morphological habitat degradation was frequent, as unsatisfactory conditions were noted at 38% of sites with worst conditions for sites in the Netherlands, Austria, Germany, Switzerland and Hungary (more than 50% of sites are related to impact class 3-5 for morphological pressures). Connectivity pressures were reported for only 34% of sites with worst conditions for sites in Austria, Switzerland and France (more than 50% of sites are impacted by connectivity pressures, Figure 1).

Combination of pressures

In 45% of the cases water quality problems are also associated with other pressures and only 11 % of sites are affected by water quality problems only (Figure 2).

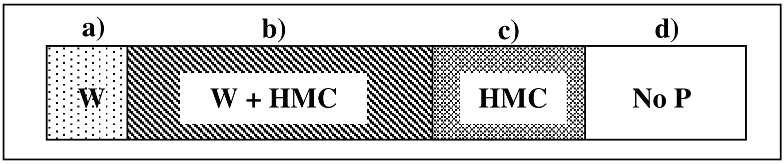

Figure 2: Proportion of sites affected by (a) water quality pressures only (11 %), (b) by water quality and hydromorphological pressures (about 45%), (c) by hydromorphological pressures only (21%) and (d) nearly undisturbed sites (about 23%).

Combined pressure analysis showed that patterns and relationships vary throughout Europe. Combined pressures (W+HMC) are frequent at sites in Austria, Switzerland, Germany, France, Netherlands and Portugal (more than 50% of sites). Hydromorphological pressures without significant water quality pressures can be detected at 47% of Italian sites, only water quality pressures at about 40% of Swedish sites. All other countries do not show specific patterns of pressure combinations (Figure 3).

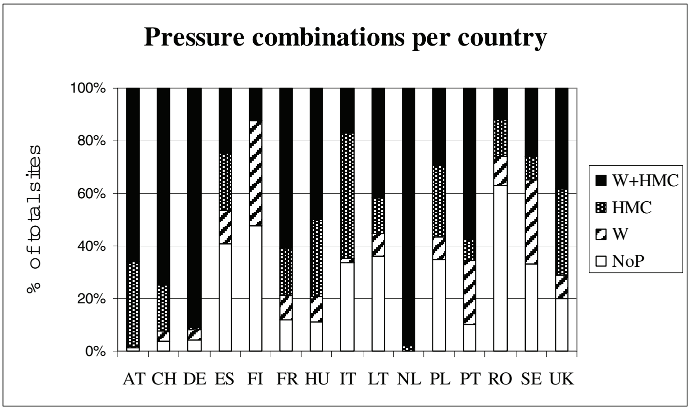

Figure 3: Pressure combinations per country

For the analysis of pressure combinations in different European ecoregions, the output was that particular the Alps are affected by hydrological impacts in combination with morphological degradation. In the Central highlands, almost all sites are affected by hydro-morphological as well as water quality pressures.

Combined pressure analysis also showed that 24% of sites are affected by only one, 22% by two, 19% by three and 12% by four pressure groups. Only 23% of sites are not affected, i.e. class <=2. Especially German, Swiss and Dutch sites are affected by three or four pressure groups (around 40% of sites and more).

4 DISCUSSION

Our intent in analysing pressure variables was to classify river sites by pressure type specific indices, able to separate highly disturbed sites from slightly disturbed sites. This exercise worked well and the pressure type specific indices were able to detect high frequent combination types as hydro-morphological pressures.

Clear limitations in our study were differences in data quality between countries and data sources. Especially the level of detail and the categorization of pressures vary among countries. We tried to overcome this problem by harmonising pressure information into an ordinal ranking scheme, but nevertheless some uncertainty remains. Another problem is that data are not always representative for all countries and ecoregions because of their spatial unequal distribution (e.g. Romania and Spain, Figure 1).

Finally, it appears from our analysis that degradation of European streams is widespread. More than 76% of sites were in moderate to poor pressure condition, mainly as a result of water quality pressures in combination with other pressures.

5 CONCLUSIONS

This study has demonstrated that the different indices allow comparison of pressure status across a large spatial range of countries and river types. Further, the pressure type specific indices have shown that they can distinguish between impacted and unimpacted sites. However, further efforts must be put in the accuracy of pressure data and the compilation of common databases. In-depth examination of relationships among different types of pressures and the linkages to biotic classifications may help reveal a better understanding of restoration and mitigation requirements.

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