Diagnosing stream ecosystem integrity in the Ordesa-Viñamala Biosphere Reserve

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Summary

This work studied the ecological integrity of river ecosystems inside the Ordesa-Viñamala Biosphere Reserve, in the central Spanish Pyrenees. Despite its protected status, the Ordesa-Viñamala Biosphere Reserve endures a considerable number of human stresses, so we aimed to evaluate the conservation status of the two river basins inside the protected area: The Gállego River Basin, located inside the transition zone of the protected area, allowing a wide range of human activities; and the Ara River Basin, inside the buffer zone, where only sound ecological practices are authorised. The environmental status of river ecosystems was analysed by studying fish and macroinvertebrate communities, hydrochemical and habitat characteristics and by calculating environmental quality indices. From August to September 2011 a total of 14 sites were sampled. Fish sampling was conducted using an electrofishing gear and macroinvertebrate was sampling by applying the IBMWP and IASPT procedures. Our results showed that, while the Ara River Basin keeps a good ecological integrity, the Gállego River Basin endures important habitat alteration. Trout, the dominant and exclusive species in the Ara River, were absent and replaced by translocated native cyprinids in the Gállego River Basin. This colonisation was explained by the alteration of the stream ecosystems and their homogenisation. The study of macroinvertebrate communities and the diagnosis obtained with the environmental quality indices also enhanced the deficient ecological integrity of some sites in the Gállego River. Our results suggest that the figure of the Biosphere Reserve is not providing an adequate protection to streams inside its boundaries leading to a major degradation of their biological integrity.

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Introduction

Protected areas are a mainstay of biodiversity conservation throughout the world (Gaston et al., 2008; Chessman, 2013), but uncertainty relative to their effectiveness is particularly high in the cases were biodiversity indicators are used in freshwaters (Herbert et al., 2010). Protected status per se may not adequately conserve freshwater biodiversity especially where the principal threats are habitat destruction and interferences caused by arriving alien species (Maceda-Veiga, 2012).

Biosphere Reserves (BR) are internationally recognized protected areas within the framework of the "UNESCO Programme on Man and the Biosphere (MaB)" (UNESCO, 1996) created for reconciling conservation and sustainable use of the resources. They comprise three different protection zones: (a) core area, securely protected; (b) buffer zones, allowing low-impact activities; (c) transition areas, used for managing and developing resources that can be utilized by man in a sustainable manner.

At a time when the region is facing increasing development pressures it is necessary to detect existing environmental issues, make steps forward for solving them and prevent future threats. As rivers integrate all that happens in their landscapes, their biological condition tells much about the side effects of human actions detecting the causes and consequences of change, especially those that alter living systems (Karr, 1998). Therefore streams and biological communities are sensitive indicators of the relative health of the aquatic ecosystems and their surrounding catchment (Fausch et al., 2002; Hering et al., 2006).

The aims of this paper were 1) to carry out an integral evaluation of the environmental status of freshwater systems inside the Ordesa-Viñamala BR, in the central Spanish Pyrenees, emphasizing the fish communities 2) to detect environmental impacts and to study their origin, processes and consequences, and 3) to evaluate the effectiveness of the protected area for the conservation of the river ecosystems within the reserve.

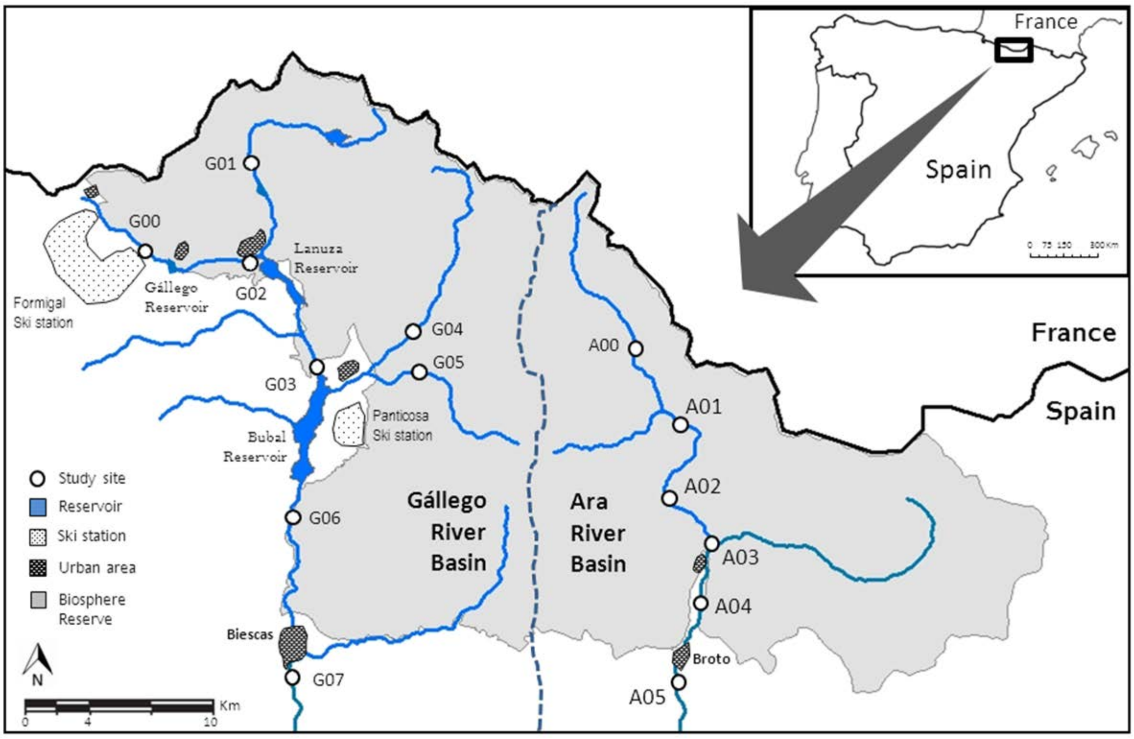

Figure 1. Location of study sites in the Ara and Gállego River Basins, in the Ordesa-Viñamala Biosphere Reserve. Dark-dotted areas represent urban surfaces. The coding of samples sites is used in all figures and tables.

Materials and methods

Study area

The Ordesa-Viñamala BR is located within the central Spanish Pyrenees with the headwater area of the Gállego and the Ara River systems (Fig. 1). Both rivers belong to the Ebro River Basin and flow in parallel through two adjacent valleys.

The climate in the area is quite heterogeneous due to the extreme geomorphology and ranges from mountainous territories with oceanic influence, rainfalls totalling 2000 mm year^{-1} and a mean annual temperature of 5ºC, to dryer mountainous areas with a marked continentality. The Reserve is dominated by mixed mountain and highland systems, with extensive areas of rocky habitats. Forested areas have mixed woodlands of beech (*Fagus sylvatica* L.) and conifers such as *Pinus sylvestris* L. Higher reaches are occupied by black mountain pine (*Pinus uncinata* Ram. ex A.DC.) and widespread pasturelands (Pérez and Alonso, 1994).

The upper Gállego River (drainage area 300 km^2) runs 26 km from its source at 2200 meters above sea level (m a.s.l.) to the village of Biescas (840 m a.s.l.), and encompasses three tributaries, the Aguas Limpias (G01), Caldares (G04) and Bolatica Rivers (G05). Three reservoirs collect the water of the Gállego River (Fig. 1). A large skiing area is also within the basin. The average multi-annual water flow downstream Bubal Reservoir is 28.1 $m^3 s^{-1}$. Several towns are in the area (about 4000 inhabitants). The Gállego River draws the western boundary of the BR, and only the eastern side of its basin is located inside the reserve, in the transition zone.

The headwater area of the Ara River Basin is the contiguous watershed (Fig. 1) covering about 350 km^2 and runs 26 km from its source at 2 930 m a.s.l. to the village of Broto at 867 m a.s.l. There are few towns in the area (about 900 inhabitants). The Ara River is the last "free running" river in the Pyrenees, without any dams. The average multi-annual water flow is 18.2 $m^3 s^{-1}$. The watershed is located in the core and the buffer area of the BR.

Data collection

From August to September 2011 a total of 14 sites were sampled along the Gállego River Basin (five sites for the Gállego River and three sites for its tributaries) and the Ara River (six sites) (Fig. 1).

At each sampling site, temperature (precision 0.1 °C), dissolved oxygen (precision 0.01 mg l^{-1}), pH, and electrical conductivity (precision 1 µS cm^{-1}) were measured with a multi-parameter water quality monitoring system (WTW Multi 340i).The instruments were calibrated daily during sampling period. Besides water samples were collected. These samples were stored in ice and processed in the laboratory one day later. Anions were analysed using ion chromatography (Dionex ICS-2000) and cations were measured using an inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7500a). The analysed parameters were chloride (Cl^{-1}) (mg l^{-1}), sulphate (SO_4^{2-}) (mg l^{-1}), nitrate (NO_{-2}) (mg l^{-1}) and nitrite (NO_{-3}) (mg l^{-1}) as indicators of trophic status of the area (Table 1) (Pesce and Wunderlin, 2000). Habitat structures were characterised by factors such as depth (m), water velocity (m s^{-1}), tree canopy shading percentage and dominant substrate, categorised as fines (<2 mm), gravels (2-64 mm), cobbles (64-256 mm), boulders (>256 mm) and bedrock (Table 1) (Armantrout, 1998).

Four environmental quality indices were applied: the Qualitative Habitat Evaluation Index, QHEI (Rankin, 1989), the Fluvial Habitat Index, IHF (Pardo et al., 2004), the Riparian Forest Quality Index, QBR (Munné et al., 2003) and the Riparian Quality Index, RQI (González del Tánago et al., 2006).

Fish sampling was conducted using a backpack electrofishing unit (Hans Grassl model IG200/2D, 300-600 V, 0.2-2 A). Semi-quantitative surveys with a constant unit of effort were carried out, giving fish densities by catch per unit of effort (CPUE, number of specimens captured per hour) (Meador et al., 2003). This single-pass approach effectively sampled fish communities in the studied rivers (Sály et al., 2009). Whit the aim to obtain a representative sampling, one hour of electrofishing were carried out in all the sampling points (Pierce et al., 1985). Collected fish were anesthetized and subsequently counted, measured, weighed and released after the survey.

Macroinvertebrate sampling was conducted by applying the IBMWP and IASPT procedures (Iberian Biological Monitoring Working Party and Iberian Average Score Per Taxon, respectively) (Alba-Tercedor et al., 2002). Invertebrates were collected using a hand-net (25 cm x 25 cm aperture, 100-mm-mesh size) by kicking and sweeping in all microhabitats in accordance with the protocol for the biotic index estimations (Armitage et al., 1983). Samples were fixed in 5% buffered formaldehyde. Specimens were later identified to the family level and the IBMWP and IASPT scores were obtained.

Data analysis

For analysing and comparing the attributes of the study sites two Principal Components Analysis (PCA) were executed. The first PCA for habitat characterisation was applied using a combined matrix including hydro-chemical parameters (temperature, dissolved oxygen, pH, and conductivity) and habitat structure features (mean depth, water velocity, substrate type, and shade percentage) (Table 1), with the purpose of analysing the natural features of the streams and classifying them attending to their habitat traits. The second PCA was applied to analyse environmental quality, including concentrations of potential water pollutants (nitrite, nitrate, sulphate and chloride), hydro-chemical parameters susceptible to alteration and indicators of human impact (temperature, conductivity, pH and dissolved oxygen) (Pesce and Wunderlin, 2000) and environmental and habitat quality indices (IHF, QBR, QHEI, RQI and IBMWP) (Table 1). These selected parameters may show up the anthropogenic influence that study sites endure and enable their classification attending to their conservation status. The use of these two paired PCAs enabled the separated interpretation of natural and human induced aspects of the study sites.

In order to identify fish and macroinvertebrate assemblages Bray-Curtis similarity analyses were executed. A matrix of abundances was used for studying fish community clustering using PAST statistical software (Hammer et al., 2001). For macroinvertebrates the matrix included the presence/absence of the families.

For PCA calculations, environmental data and mean depth were log (x) transformed. Remaining habitat structure data (with a bimodal distribution) were Arcsen (√x) transformed, and the relative abundances of species were square root transformed. For verifying the robustness of the general model of the PCAs significance tests based on permutation tests (1000 permutations) were carried out. PAST software was used to conduct the PCA statistical analysis and plots (Hammer et al., 2001).

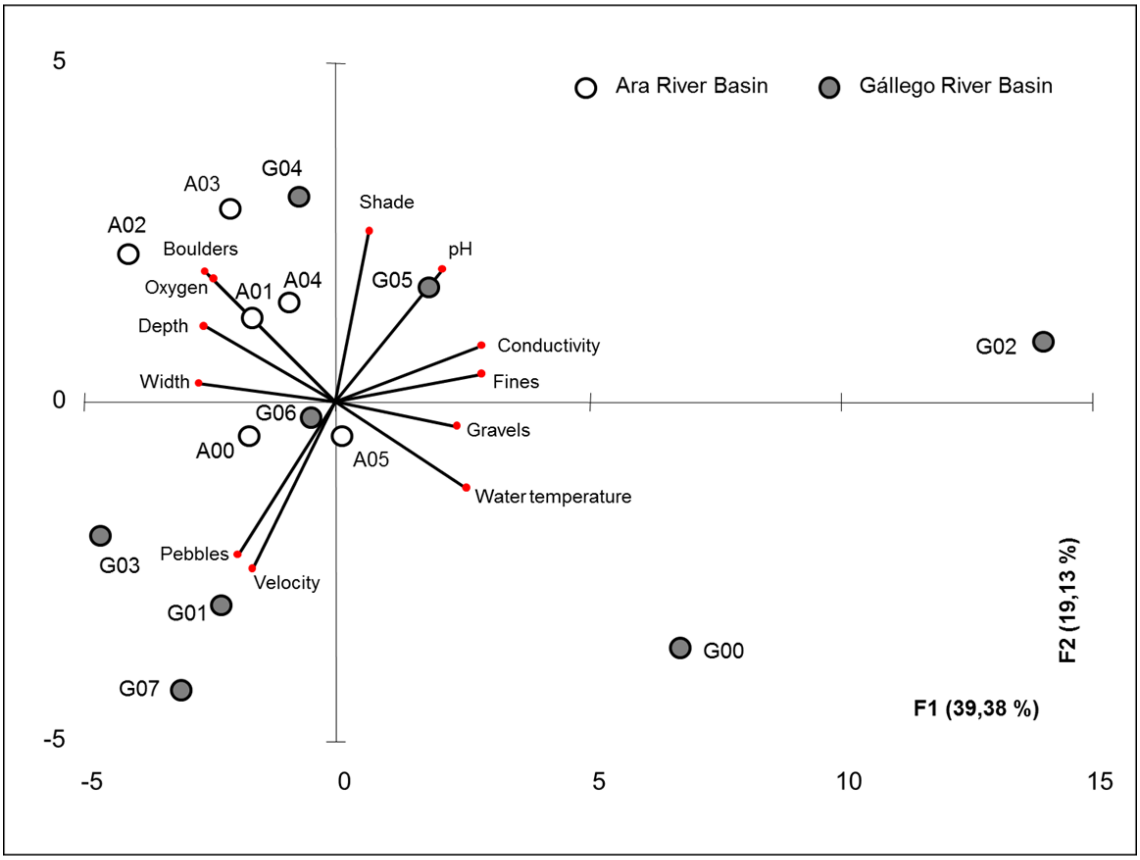

Figure 2. PCA biplot of study for habitat characterisation: Water physicochemical parameters (temperature, oxygen concentration, pH and conductivity) and physical habitat parameters (substrate type, mean width, mean depth, mean water velocity and shaded percentage of the river channel).

Results

Habitat characterisation

The PCA analysis for habitat characterisation (Fig. 2) accounted for 58.82% of the variance on its first two axes. Localities on the Ara River were grouped together on the middle-left section of the graph showing marked habitat homogeneity. Although A00 and A05 (the highest and the lowest site) appeared to be slightly different, for the rest of the sites high dissolved oxygen concentrations, low conductivities, cold water temperatures and the presence of boulders were their main features. Sites on the Gállego River Basin were outspread all over the diagram due to their marked habitat heterogeneity. Sites G02 and G00 were differentiated by high conductivities, high water temperatures and fines and gravels as predominant substrates, and appeared displaced on the right of the graph, markedly different from the rest of sites. G04, G05 and G06 were grouped close to sites on the Ara River Basin, sharing habitat aspects. The remaining sites, G01, G03 and G07 formed another cluster on the left bottom area of the diagram, distinguished by high water velocities and pebbles as dominating substrate.

Environmental quality

The PCA biplot for environmental quality accounted on its two first axes for 66.30% of the variance (Fig. 3). The first axis explained 42.69% of the variability, separating sites with good environmental quality on the left, influenced by high values of the environmental quality indices, opposed to high concentrations of water nutrients. All the sites on the Ara River except A05 were located on this area of the plot among sites G01, G04, G05 and G06 showing good ecological integrity. Site G02 appeared notoriously displaced on the right upper area of the plot, showing the highest anthropogenic alteration.

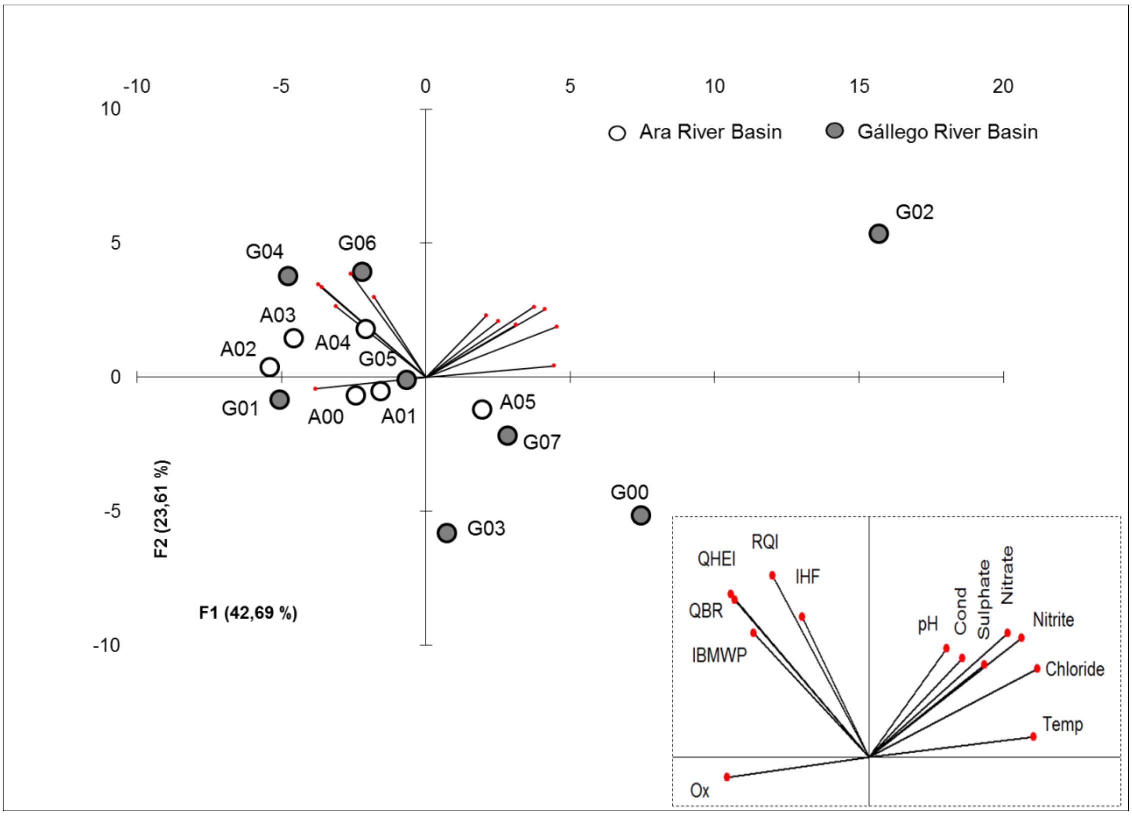

Figure 3. PCA biplot of study sites for ecological integrity: Environmental quality indices (QHEI, QBR, RQI, IHF and IBMWP), nutrients (nitrite, nitrate, chloride and sulphate concentration) and hydrochemical parameters (temperature, oxygen concentration, pH and conductivity).

The second axis accounted for the remaining 23.61% of variability and discriminated sites showing greater physical habitat degradation but with lesser water pollution, distributing them on the right bottom area of the graph. The lowest sites on both basins, A05 and G07 were grouped here suffering similar alteration due to the presence of urban areas, canalisation and sewage. Site G03, on the central bottom area of the plot, presented low concentrations of water pollutants but important physical habitat degradation, explained by the almost artificial morphology of the river channel that flows excavating the tail sediments area of the Bubal Reservoir. Finally, site G00 appeared on the right bottom area of the graph, presenting remarkable water and habitat alterations.

Fish and macroinvertebrate species composition

A total of 1,978 specimens (four species of two families) was collected (Table 2). All species were native: one autochthonous salmonid (brown trout *Salmo trutta* Linnaeus 1758) and three endemic cyprinids (Ebro nase *Parachondrostoma miegii* Steindachner 1866, Pyrenean gudgeon *Gobio lozanoi* Doadrio & Madeira 2004 and Pyrenean minnows *Phoxinus bigerri* Kottelat 2007). The cluster analysis for fish separated sites in three groups (Fig. 4). The majority of them were grouped together showing great similarity as they were exclusively dominated by brown trout. Another cluster, gathered the lower study sites in the Gállego River, G06 and G07, because, in addition to trout, the Pyrenean minnows were found. Finally, sites G02 and G03 formed a remarkably different cluster, distinguished by the absence of brown trout, with great abundances of Pyrenean minnow and presence of the Pyrenean. Nevertheless, these two study sites showed some dissimilarity because the Ebro nase was exclusively found on site G03.

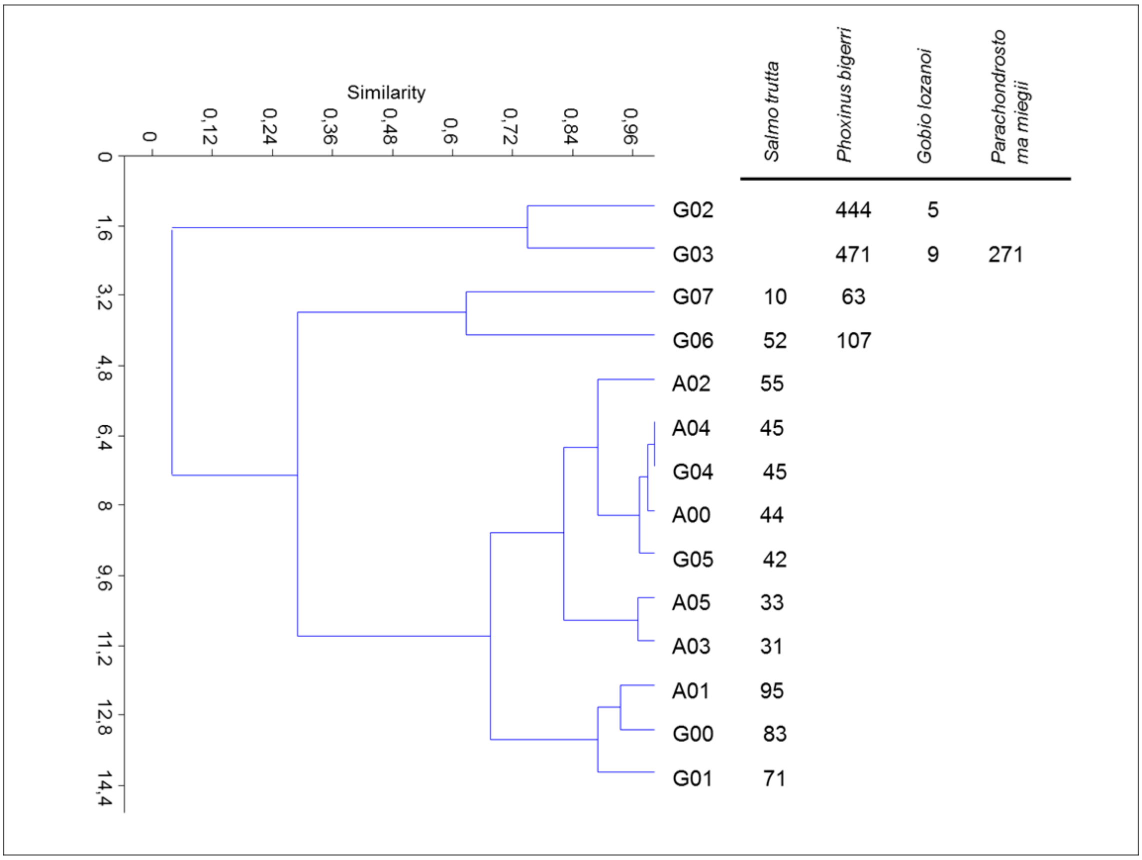

Figure 4. Cluster analysis of study sites based on fish abundances using the Bray-Curtis index of similarity. Fish densities by catch per unit of effort (CPUE, number of specimens captured per hour).

Forty nine taxa of benthic macroinvertebrates were identified for the estimation of biotic indices (Table 2). The cluster analysis for macroinvertebrates (Fig. 5) grouped the G02 and G03 sites together, remarkably differentiated from the rest. Both localities got low IBMWP and IASPT scores and consequently were classified, attending to the categories defined for the application of the IBMWP index, with a “Moderate” ecological status. In the big cluster containing the remaining sites, only A05 was classified with a “Moderate” ecological status, clustered together with G07, classified with “Good” ecological status. Site G00 with only 103 points for the IBMWP index was tightly classified with “Good” ecological status, exhibiting signs of disturbance. The remaining sites were classified inside “Good” and “Very Good” categories.

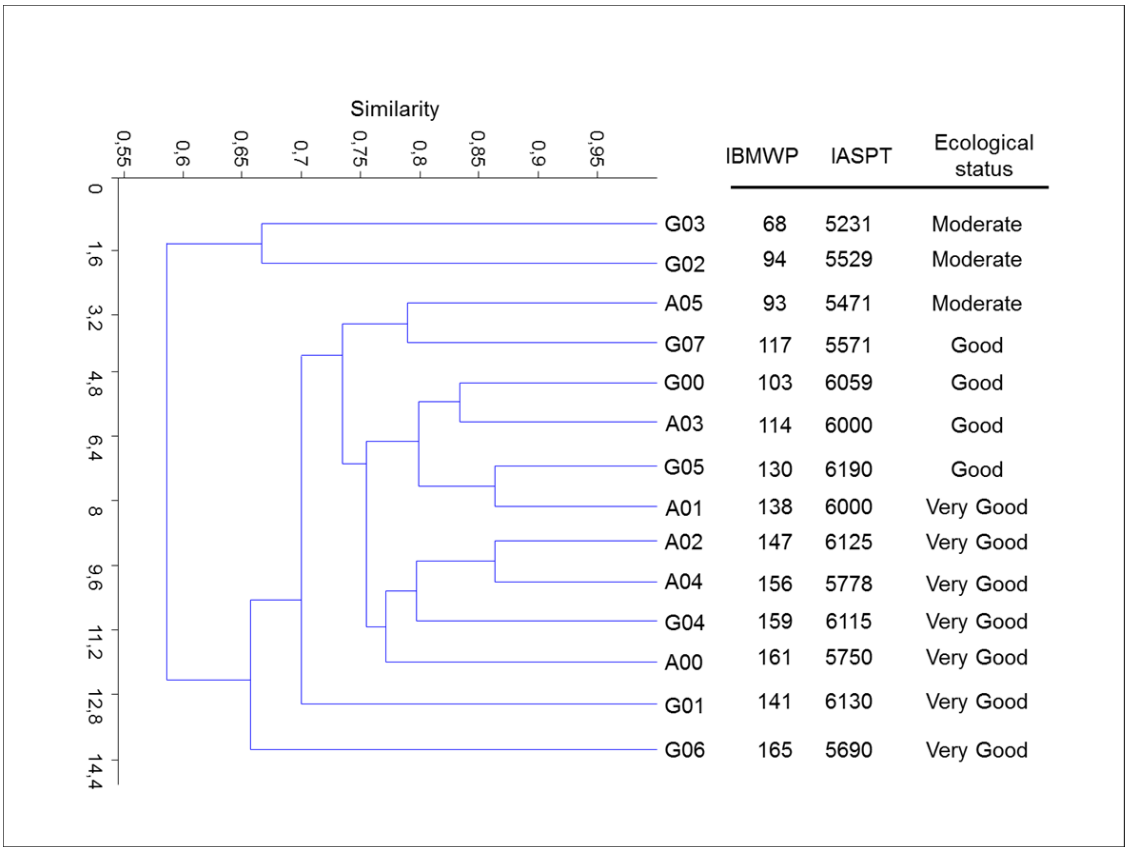

Figure 5. Cluster analysis of study sites based on presence/absence of macroinvertebrate families using the Bray-Curtis index of similarity. Scores for IBMWP/IASPT indices and the classification of their ecological status.

Discussion

This research has been carried out in the study area at one time. So, the entire study is no more than a static picture, ignoring seasonal and inter-annual variability – which is natural and actually need to be known to allow for a trend assessment. Therefore, this study can only be the first step of monitoring and ecosystem integrity assessment. Consequently, further research should be undertaken to establish a true baseline which must include seasonal and inter-annual variability.

Analysing the results of the PCA analyses for habitat characteristics (Fig. 2) and environmental quality (Fig. 3), it comes to light that the Ara River Basin presents a remarkably good conservation status and endures mild human impact. The results obtained for the macroinvertebrate fauna (Fig. 5, Table 2) reinforced that statement. Concerning fish fauna, streams were exclusively dominated by brown trout (Fig. 4) as expected for this sort of rivers.

On the other hand, the results obtained for the Gállego River Basin highlighted a remarkable human impact. The PCA analysis for environmental quality brought out the degraded sites that combined with the PCA for habitat characterisation and cluster analyses for macroinvertebrates and fish helped identify the most damaged river stretches.

Site G00 was identified as an altered locality by both PCA analyses, although it was not stressed as impacted by the invertebrate and fish analyses. The fish community was exclusively composed by brown trout, showing one of the most abundant populations (Table 2). The majority of the trout individuals were fry with +0 or +1 age. That fact, along with the features of the habitat, distinguished by the abundance of gravels and shallow waters, pointed out the site as a trout spawning area (Shirvell and Dungey, 1983). Comparing it with the G01 site in the Aguas Limpias River (another trout spawning area found in the adjacent valley at same elevation and sharing similar natural features) or even with A01 (also an analogous locality in the Ara River), the difference between them was notorious. While G01 and A01 localities demonstrated a remarkable high environmental quality for the river and for the surrounding landscape, G00 showed several traces of habitat degradation. The PCA for habitat characterisation (Fig. 2) addressed the outstanding high water temperatures, the lack of shade and the presence of fine substrates, while the environmental quality PCA analysis also addressed the physical habitat and water quality degradation. This river stretch is totally isolated from the rest of the basin due the presence downstream of the Gállego Reservoir. In addition to the impact of the dam, urban areas, sewage and ripraps affect its ecological integrity. However the greatest menaces upon this river stretch are the increase of water temperature due to the total exposure of the river channel lacking riparian vegetation and the remarkable siltation process caused by major soil erosion, as a consequence of the extensive deforestation of the hillsides occupied by the Formigal ski slopes (David et al., 2009). Both impacts, accentuated by the presence of physical barriers that impede migration, can lead to the siltation and disappearance of suitable spawning areas (Acornley and Sear, 1999) and together with the thermal habitat alteration (Elliott, 1976) finally can cause the extinction of trout populations in this area.

The faunal composition of streams is thought to reflect ambient conditions and integrate the influences of water quality and habitat degradation (Allan, 2004). Therefore the unexpected reophilic cyprinids communities on G02 and G03 sites pointed out an outstanding change in the river ecosystem (García de Jalón, 1996). The abundance of these fish out of their expected distribution range could be considered as a native fish invasion (Scott and Helfman, 2001; Leunda, 2010) and an indicator of the habitat alteration (Courtenay and Moyle, 1996).

The process of invasion necessarily involves habitat destruction (Moyle and Leidy, 1992) prior to human introduction of those new fish species, usually by the hand of anglers utilising them as bait or forage (Maceda-Veiga et al., 2010). Unique and limiting elements like the flood occurrence and clean cold waters are displaced and eventually replaced by common, widespread elements (Scott and Helfman, 2001). Water temperatures and sediment loads increase due to the lack of riparian vegetation (Acuña et al.. 2013), flood occurrence disappears controlled by dams (García de Jalón et al., 1988), reservoirs provide suitable lentic habitats (Clavero et al. 2004) resulting in invasions of the streams that flow into them (García de Jalón, 1996) and nutrient enrichment enhances phytobenthic biomass and favours phytophagous omnivorous species like the Ebro nase (Maceda-Veiga, 2012). In consequence, highland stream conditions change sufficiently to facilitate the establishment of widespread native fish like the Ebro nase and the Pyrenean Minnow (Jones et al., 1999). At the same time, these new habitat conditions may turn out to be adverse for upland endemics like the trout (Elliot, 1976) and the presence of new fish species like the Pyrenean minnow, that may result in trophic competition for resources at the larval and juvenile stages (Oscoz et al., 2008), could end up with the disappearance of trout from these streams.

The replacement of trout from these headwater streams is usually overlooked because these native invasions first lead to no change in diversity and perhaps even an increase in diversity (Courtenay and Moyle 1996), a fact that has been found in a variety of aquatic systems subject to invasions (Rahel, 2000). As stated by Pusey et al. (2006) there is no reason to believe that the consequences derived from the introduction of non-native indigenous species would be any different to those arising from the introduction of fishes from other countries (del Carpio et al., 2010). This is the case of the studied streams, being the Ebro nase, the Pyrenean minnow and the Pyrenean gudgeon the translocated fish species (Leunda, 2010). Therefore, such invasions should be recognized as an early warning sign of the homogenization process of the river ecosystem (Scott and Helfman, 2001) and considered as a wake-up-call of major environmental alteration.

The early detection of environmental threats is becoming essential for developing efficient strategies and to prevent major and irreversible alterations (Allan, 2004). The present work proved the reliability of the study of the ecological integrity of the streams for detecting impacts in the surrounding landscape (Karr, 1998). Even for idyllic sceneries like the central Pyrenees, where everything looks pristine and uncorrupted, rivers, as impact collectors, highlight the anthropogenic pressure endured by the territory.

The studied area possesses a remarkable number of protected zones with a wide range of protection levels (National Park designed by the Spanish Government and Biosphere Reserve by UNESCO, among others). There is no doubt about the effectiveness of the designation of a National Park and core area of a BR, but concerning the protection given by the buffer and transition zones, it was remarkable the different ecological integrity shown by the sites located on the buffer zone and the ones on the transition zone. As seen before, the Ara River Basin located mostly inside the buffer zone demonstrated a very good conservation status. In contrast, the Gállego River Basin located on the transition zone, with the Gállego River drawing the limits of the reserve, presented a remarkable alteration at some localities. This is due to the wider range of land uses that the transition area endures and because only the left margin of the basin is found inside the reserve, leaving the right margin unprotected. Terrestrial protected areas often include only part of a river's catchment or use rivers as boundaries rather than fully including them (Nel et al., 2007). Consequently, rivers within protected areas are often vulnerable to transmission of impacts from land and water use beyond their boundaries (Pringle 2001). Furthermore, some stretches of the Gállego River are not even included inside the BR, even as a boundary. These areas were excluded from the designation of the territories inside the reserve because they were already urbanized or occupied by reservoirs. This fact enhances the inconsideration of the Gállego River as complex, interdependent and unitary ecosystem worthy of being protection target, demoting it to merely drawing the limits of the protected area. Therefore, if we aspire to effectively preserve these freshwater ecosystems, we should respect their entireness, we should take into account all the ecological processes involved in their configuration, we should reckon their tight interconnection with the territories of their watershed and we should develop specific conservation efforts for guaranteeing their safeguard.

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Table 1. Locality and sampling data, habitat characterisation parameters, environmental quality indices and water nutrients values at study sites along the Ara and the Gállego River Basins. Sampling codes correspond to shown in Figure 1. IHF: Fluvial Habitat Index, QBR: Riparian Forest Quality Index, QHEI: Qualitative Habitat Evaluation Index, RQI: Riparian Quality Index, IBMWP: Iberian Biological Monitoring Working Party, IASPT: Iberian Average Score Per Taxon.

Sampling code	**G00**	**G01**	**G02**	**G03**	**G04**	**G05**	**G06**	**G07**	**A00**	**A01**	**A02**	**A03**	**A04**	**A05**
Altitude (m)	1503	1418	1271	1077	1238	1146	963	837	1627	1361	1293	1100	908	867
Latitude	N42º46.551'	N42º47.866'	N42º46.142'	N42º43.255'	N42º43.799'	N42º43.283'	N42º39.763'	N42º36.967'	N42º43.325'	N42º41.935'	N42º40.540'	N42º38.985'	N42º37.063'	N42º35.786'
Longitude	W00º22.593'	W00º19.989'	W00º19.971'	W00º18.248'	W00º16.093'	W00º16.806'	W00º19.368'	W00º19.447'	W00º08.309'	W00º06.896'	W00º07.447'	W00º06.253'	W00º06.866'	W00º07.395'
Date	27/08/11	30/08/11	29/08/11	27/08/11	30/08/11	27/08/11	29/08/11	28/08/11	21/08/11	20/08/11	20/08/11	20/08/11	21/08/11	21/08/11
Water temperature (ºC)	17.8	13.3	19.6	14.6	14.3	14.5	16.1	17.6	12.7	14.5	12.7	13.5	16.2	17.1
Conductivity (µS·cm^{-1})	450	88	550	66	149	233	216	161	95	159	194	270	289	290
Dissolved Oxygen (mg·l^{-1})	8.12	8.55	7.7	9.63	8.91	9.23	9.02	8.13	8.7	9.04	10.3	9.7	8.91	8.78
Dissolved Oxygen (%)	102.4	94.7	97.8	107	101.5	102.3	102.3	95.1	100.1	105.1	109.8	106.1	101.5	101.4
pH	8.04	7.77	8.44	8.08	8.06	8.32	8.09	7.94	8.04	8.04	8.13	8.12	8.27	8.32
Width mean (m)	5.5	9.7	5.0	13.6	5.0	7.7	11.0	15.6	9.9	13.8	19.0	18.7	16.4	9.7
With range (m)	(4.4-6.12)	(8-11.4)	(3.9-6.5)	(11.47-17.6)	(3.73-6)	(4.8-9.5)	(7.8-14.4)	(0-24.2)	(6.3-13.52)	(12-16.5)	(8.8-25.9)	(14.73-21.96)	(12.6-23)	(0-14.4)
Shade (%)	0	0	17	0	67	17	17	0	0	8	17	0	17	25
Depth														
Depth mean (cm)	17.9	22.2	14.5	42.3	28.3	42.7	43.6	56.2	31.3	45.1	45.9	83.3	61.3	51.0
Depth range (cm)	(8-31)	(10-39)	(3-32)	(18-100)	(0-74)	(3-107)	(13-76)	(32-110)	(6-81)	(17-64.5)	(5-98)	(38-155)	(18-150)	(21-93)
Low depth (%, <30 cm)	92	92	92	42	67	42	33	0	58	33	50	0	8	42
Moderate depth (%30-60 cm)	8	8	8	33	33	42	42	56	33	42	25	33	67	25
High depth (%, >60 cm)	0	0	0	25	8	17	25	44	8	25	25	67	25	33
Water velocity														
Mean water velocity	0.56	0.58	0.26	0.72	0.41	0.44	0.37	0.81	0.46	0.26	0.42	0.45	0.58	0.50
Low velocity (%, <0.3 m·s^{-1})	16.67	16.67	50.00	0.00	41.67	58.33	33.33	0.00	33.33	58.33	25.00	66.67	25.00	25.00
Moderate velocity (%, 0.3-0.75 m·s^{-1})	50	58	50	50	42	17	58	33	42	42	67	8	42	50
High velocity (%, 0.75-1.2 m·s^{-1})	33	17	0	50	17	17	8	67	17	0	8	25	25	25
Very High velocity (%, >1.2 m·s^{-1})	0	8	0	0	0	8	0	0	8	0	0	0	8	0
Substrate type														
Fines (%, <2 mm)	3	3	51	0	0	0	0	0	3	3	0	8	0	0
Gravels (%, 2-64 mm)	43	14	36	17	3	25	8	7	19	13	18	22	19	15
Pebbles (%, 64-256 mm)	40	49	11	57	19	25	67	70	38	53	54	11	31	58
Boulders (%, >256 mm)	0	17	0	17	58	6	3	10	33	30	25	49	38	28
Bedrock and concrete (%)	0	0	0	0	0	29	0	0	0	0	0	0	0	0
Environmental quality indices														
IHF	63	64	63	59	78	69	76	60	62	67	64	66	60	58
QBR	5	90	40	30	100	40	90	30	60	60	90	95	90	65
QHEI	48	68	58	53.5	84	63	75	61.5	69.5	65.5	74	80	76.5	62
RQI	18	87	62	33	94	62	82	52	46	51	71	97	95	72
IBMWP	103	141	94	68	159	130	165	117	161	138	147	114	156	93
IASPT	6059	6130	5529	5231	6115	6190	5690	5571	5750	6000	6125	6000	5778	5471
Stream class	**II**	**I**	**III**	**I**	**I**	**II**	**I**	**II**	**I**	**I**	**I**	**II**	**I**	**II**
Ecological status	**Good**	**Very good**	**Moderate**	**Moderate**	**Very good**	**Good**	**Very good**	**Good**	**Very good**	**Very good**	**Very good**	**Good**	**Very good**	**Moderate**

Table 2. Number of fish caught (time surveyed 60 minutes), size range (total length in millimeters), total biomass measured (in grams) and occurrence of taxa of benthic macroinvertebrates (dark circles) collected at study sites along the Ara and the Gállego River Basins.

Sampling code	**G00**	**G01**	**G02**	**G03**	**G04**	**G05**	**G06**	**G07**	**A00**	**A01**	**A02**	**A03**	**A04**	**A05**
Date	27/08/11	30/08/11	29/08/11	27/08/11	30/08/11	27/08/11	29/08/11	28/08/11	21/08/11	20/08/11	20/08/11	20/08/11	21/08/11	21/08/11
Number of collected fish														
Gobio lozanoi			5	9										
Parachondrostoma miegii				271			1							
Phoxinus bigerri			444	471			107	63						
Salmo trutta	83	71			45	43	52	10	44	95	55	31	45	33
Size range (mm)														
Gobio lozanoi			(80-125)	(93-129)										
Parachondrostoma miegii				(84-192)			(93-93)							
Phoxinus bigerri			(25-91)	(48-98)			(29-99)	(39-90)						
Salmo trutta	(49-269)	(37-196)			(58-250)	(57-245)	(64-345)	(71-384)	(41-259)	(43-249)	(48-222)	(50-232)	(54-261)	(58-309)
Biomass (g)														
Gobio lozanoi			63	131										
Parachondrostoma miegii				4236			8							
Phoxinus bigerri			834	1081			303	209						
Salmo trutta	1709	739			1477	1609	3707	571	1990	3945	1524	947	2283	2031
Macroinvertebrates														
Coleoptera														
Dryopidae		•												
Dytiscidae					•		•		•	•	•	•	•	
Elmidae	•	•			•	•	•	•	•	•	•	•	•	•
Gyrinidae							•							
Haliplidae		•					•							
Hydraenidae	•	•			•	•	•		•	•	•	•	•	•
Hydrophilidae		•												
Scirtidae (Helodidae)							•							
Diptera														
Anthomyiidae			•						•				•	•
Athericidae	•	•			•	•		•	•	•	•	•	•	•
Blephariceridae							•		•			•		
Ceratopogonidae									•					
Chironomidae	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Dixidae		•				•			•		•			
Empididae	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Limoniidae	•			•	•		•	•	•	•	•	•	•	•
Psychodidae			•					•	•					
Rhagionidae					•								•	
Simuliidae	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Tabanidae			•											
Tipulidae			•	•	•				•					
Ephemeroptera														
Baetidae	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Caenidae	•			•	•	•	•	•		•		•		
Ephemerellidae	•	•		•	•	•	•	•	•	•	•	•	•	•
Ephemeridae							•							
Heptageniidae	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Leptophlebiidae					•				•					
Heteroptera														
Gerridae							•							
Veliidae		•												
Hirudinea														
Erpobdellidae													•	
Mollusca														
Ancylidae			•		•		•	•		•			•	•
Lymnaeidae							•	•						

Acari														
Hidracarina	•	•				•		•	•	•	•	•	•	•
Oligochaeta														
Oligochaeta			•	•	•	•	•	•	•	•	•		•	•
Plecoptera														
Chloroperlidae		•				•				•				
Leuctridae	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Nemouridae		•			•	•			•	•	•	•	•	
Perlidae	•	•	•		•	•	•		•	•	•	•	•	
Turbellaria														
Dugesiidae									•					
Planariidae		•			•		•	•	•	•	•	•	•	•
Trichoptera														
Glossosomatidae		•			•						•		•	
Hydropsychidae	•	•	•	•	•	•	•	•	•	•	•	•	•	
Hydroptilidae			•			•							•	
Lepidostomatidae											•		•	
Limnephilidae	•	•	•			•	•	•	•	•	•		•	•
Philopotamidae					•		•							
Polycentropodidae							•							
Rhyacophilidae	•	•	•	•	•		•	•	•		•		•	
Sericostomatidae					•	•	•	•		•	•			