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Assessing environmental degradation of montane riparian zones in Greece

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Abstract: *A survey of 218 woody vegetation plots at 109 streamside sites was undertaken to describe anthropogenic degradation of riparian zone woodlands in the mountains of mainland Greece. Two assessment indices and specific anthropogenic pressure variables were employed and they showed good correlations at both the site and river segment scales. It was demonstrated through the Spanish Riparian Forest Quality Index (Qualitat de Bosc de Riber: QBR) that most riparian zones were in moderate or good condition, although extremely few sites were of high ecological status. Most riparian sites were affected by several anthropogenic pressures, some pressures produce notable degradation beyond the site-scale (i.e. at the river segment scale). This work provides a summary of the first wide-ranging vegetation-based assessment of montane riparian zones in Greece; the results support the use of site-based rapid assessment protocols along-side aquatic ecological status surveys.*

Key words: *Riparian zone, Woodlands, Ecological assessment, Degradation, Indicators*
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Introduction

Streamside riparian zones are one of the most dynamic and heterogeneous habitats, and in many parts of the world they are still poorly researched (Hupp and Rinaldi, 2007). Even the definition of the riparian zone often varies among researchers (Verry *et al.*, 2004; Naiman *et al.*, 2005). Naiman and Decamps (1997) provide a much-cited delineation: "the riparian zone encompasses the stream channel between the low and high water marks towards the uplands where vegetation may be influenced by elevated water tables or flooding and by the ability of soils to hold water". The natural riparian vegetation, widely used to indicate riparian ecological quality, has often been extensively degraded by human activities. In fact, riparian floodplains are considered one of the most transformed and endangered habitats in the Northern Hemisphere (Tockner and Stanford, 2002; NRC, 2002). In cultural landscapes, such as in the Mediterranean countries, it is often difficult to discriminate between human or natural disturbances; only in the mountains do substantial semi-natural riparian habitats survive (Ferreira *et al.,* 2002). Furthermore, in regions such as the Mediterranean there is a dearth of information on natural riparian vegetation structure and the specific effects of anthropogenic pressures (Aguiar, 2004).

Since riparian vegetation directly affects the structure and functioning of in-stream conditions, it is important not to ignore riparian zones when assessing the environmental state of rivers and streams (Gonzalez del Tanago and Garcia de Jalon, 2006). Unfortunately, riparian zone assessments are often not included in surveys of aquatic ecological status. Especially in the Eastern Mediterranean countries, riparian zones have only rarely been assessed in relation to the ecological integrity of surface waters. A reason for this neglect may be their remarkable biocomplexity and a poor appreciation of riparian area's interrelations with in-stream ecological conditions (Naiman *et al.,* 2005).

An example of a poorly researched riparian resource involves upland riparian woodlands in Greece. Upland areas above 200 m cover 65.4% of Greek territory and since this country has a diverse geology, varied bioclimates, and different biogeographic influences a naturally varied assemblage of riparian features exist (Catsadorakis, 2003). Much of the perennial water flow has been poorly mapped and state forest maps also do not adequately show riparian vegetation. Finally little is known of the state of riparian forests especially after large-scale abandonment of many upland village settlements and the recent influence of various development projects and modern road access in previously unroaded areas.

Researching the conservation state of thin linear networks of riparian zones in small mountain stream corridors usually does need attention to details often requiring on-site assessments. Many anthropogenic pressures such as surface water abstraction, invasive alien plants, overgrazing, dumping and rubbish are usually not effectively documented through remote sensing desk studies; site-based field protocols have therefore been developed for riparian assessments in other parts of the world (NRC, 2002; Winward, 2000). A field-based site-specific knowledge of anthropogenic pressures is important for a robust assessment. This is especially true where the habitat feature to be assessed has high levels of natural variability, as do upland riparian zones.

We developed and applied a rapid assessment scheme to collect stream-side vegetation data and record anthropogenic pressures in riparian zones, in order to complement aquatic ecological status assessments. In this paper, we present results outlining riparian

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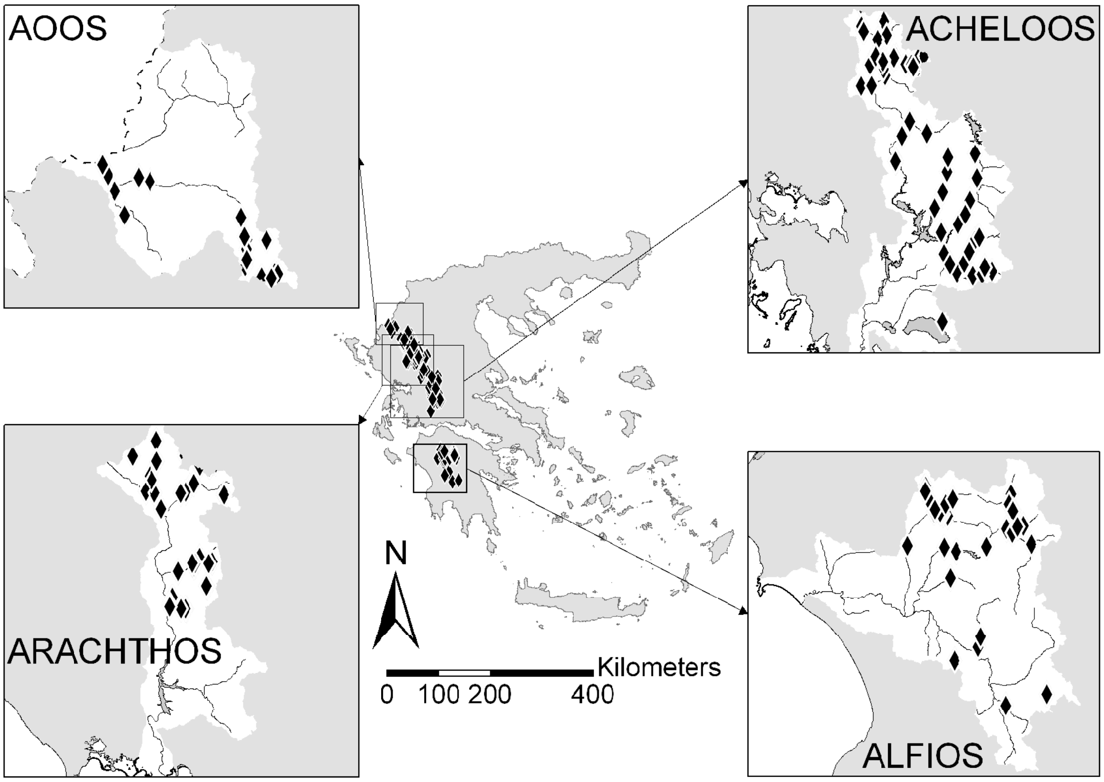

Fig. 1: Sites surveyed in the four major river basins in the Hellenic ranges of mainland Greece

vegetation features and the identification of anthropogenic pressures and degradation in montane riparian zones of mainland Greece.

Materials and Methods

Site selection and survey assessment: Chiefly montane riparian zones (238 to 1325 m elevation) were surveyed on perennial streams of the Hellenid mountain ranges, within four major (Fig.1) river basins (Alfios, Acheloos, Arachthos and Aoos). Representative river reaches were selected, and sites of varying degrees of apparent anthropogenic degradation on the river's main stem and its tributaries were chosen. The survey was undertaken on an expedition from 21 July to 21 September 2005 resulting in a total of 109 surveyed river sites; since both left and right banks of each site were surveyed the total vegetation study consisted of 218 riparian woodland plots. All vegetation surveys were compiled by a single assessor and the riparian condition assessment was collected by the same two assessors, in order to limit bias.

Riparian woodland zone and ecotone: We simultaneously conducted two different survey procedures at each site: a) collection of 'riparian woodland' woody species floristic data separately from each streamside bank and, b) assessment of anthropogenic pressures and degradation on the wider riparian ecotone of each river site.

For the riparian vegetation survey we focused our attention specifically on the stream-side wooded area within the wider riparian corridor, called here the 'riparian woodland zone' (Fig.2). This stream-side strip of woody vegetation is often recognizable and distinctive since it forms the first rooted line of perennial woody vegetation immediately adjacent to the stream's active channel. This woody vegetational edge on this upland end of the active channel can be called the "greenline";/ an analogous term is described in Winward (2000). The riparian woodland's upland lateral limits are usually defined by recognizable vegetational and topographic changes usually associated with a lack of high floodwater interaction, reduced soil wetness and/or minimal groundwater influence. The upland limit of the riparian woodland is therefore often distinguished by a marked decline of hygrophilous or mesophytic vegetation, creating a so-called "brownline", which is especially prominent in semi-arid climatic areas (Fig. 3).

The assessed riparian length was standardized at 100 m since this length has proven adequate in characterizing floristic richness and is widely used in river assessments in Mediterranean rivers (Ferreira and Moreira, 1999). The width of the assessed vegetation plots necessarily varied (2-50 meters), being related to the extent of the riparian woodland on each river bank (Fig. 3). Within the rectangular transect-like woodland plots the percent cover of all woody plants was visually estimated; taxa were identified to species level or operation taxonomic units on-site.

Assessing degradation of riparian zones was based on anthropogenic pressure identification. A laterally wider area of the river corridor, the so-called riparian ecotone (Verry *et al.*, 2004)

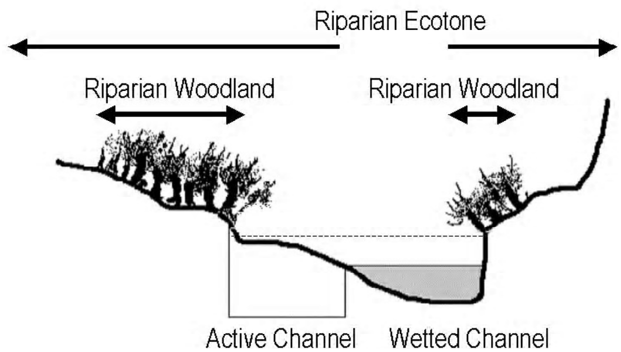

Fig. 2: Schematic cross-section of a generic river corridor in Greece depicting the relative extent of the 'riparian ecotone' and the 'riparian woodland'. The riparian woodland does not usually include the active channel (defined by the dotted horizontal line denoting the annual high-water mark). Within the active channel vegetation is usually restricted to non-woody species able to survive extended periods of inundation and fluvial flood stress

was considered; this often goes beyond the limited plot of the riparian woodland zone (Fig. 2). The field protocols used were: the Riparian Forest Quality Index -Qualitat de Bosc de Riber: QBR (Munne *et al.,* 2003) and a specially-adapted Stream Visual Assessment Protocol - SVAP (Bjorkland *et al.,* 2001; 2006). Additionally, environmental pressure variables from the FAME in-stream assessment protocol (FAME, 2005) were also utilized (Table 1). Several different variables of anthropogenic pressures and degradation were utilized and compared; most of these assess the specific 100 m site, while five variables assess the longitudinally broader "river segment" (*i.e.* FAME variables: land-use, urbanization, connectivity, riparian pressure and floodplain lateral movements). Selected variables for each basin are presented in Table 3. QBR metric scores range from 0 (bad quality) to 25 (excellent); and 0 (bad quality) to 100 (excellent) for the QBR total score. SVAP riparian and land-use metrics range from 1 (heavy pressure) to 10 (no pressure) and riverbed and floodplain dynamics pressure value 0 is for unmodified sites. FAME pressure values range from 1 (no pressure) to 5 (heavy pressure) (Bjorkland *et al.,* 2006).

Results and Discussion

Vegetational attributes: Montane riparian woodland covered very narrow strips (Fig. 4); only in exceptional cases did woodlands have widths over 100 m (n=4), and only 18 river banks had riparian woods that were wider than 30 m. 111 woody species were recorded; maximum species richness per plot was 31, and the mean species richness was 11.6 species (SD=5.9). Table 2 shows the frequency of occurrence of the 30 most abundant tree and shrub species, and presents the total species-richness per basin with richness per plot in each basin also. Generally species-richness per plot and per basin is higher than other surveys in Mediterranean riparian zones (Ferreira and Moreira, 1999; Salinas *et al.*, 2000; Aguiar, 2004; Hupp and Rinaldi, 2007). The remarkable prevalence of *Platanus orientalis* is a distinctive feature of Greek riparian zones. This obligate phreatophyte represents a long-lived keystone species creating unique linear groves, often co-dominated by other

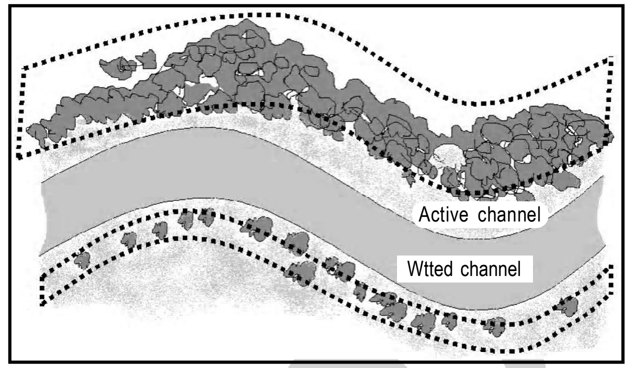

Fig. 3: Schematic plan-view of riparian woodland zone plots delineated in this study (dotted lines). Each plot's longitudinal length is standardized at 100 m but the width varies with the extent of the riparian woodland (shown in dark grey patches)

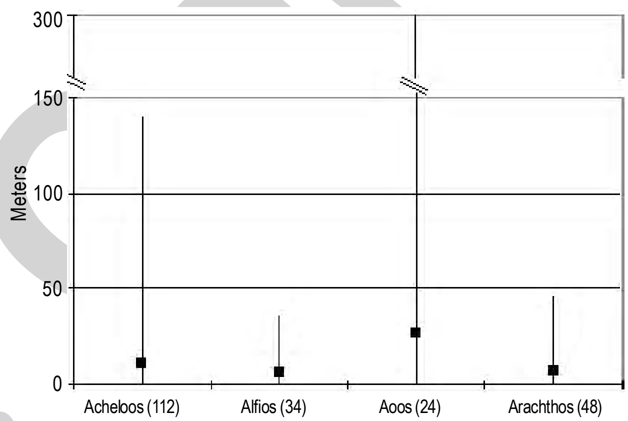

Fig. 4: The riparian woodland width range. The maximum riparian width is shown as the upper part of the line-bar, the average value of the mean width as the black rectangle and the minimum width as the lowest part of the line-bar for the four river basins. Values in parentheses denotes the number of plots surveyed (one for each bank)

hygrophilous trees. Widespread hygrophilous trees and shrubs that also dominate riparian formations are: *Salix eleagnus*, *Alnus glutinosa, Salix alba* and more locally *Salix purpurea* and *Salix amplexicaulis.* Varied forest and cliff-dwelling trees are also important aspects of the riparian flora, often including characteristic mesic forest species such as *Ostrya carpinifolia, Fraxinus ornus* and some distinctive rare species (*Laurus nobilis* and *Aesculus hippocastanum).* Vines are especially abundant – particularly *Hedera helix* and *Clematis* spp.*;* moreover species of the bramble complex *(Rubus* spp.*)* are common and widespread. As observed in other Mediterranean riparian studies (Aguiar *et al*., 2004), several typically terrestrial Mediterranean trees and shrubs frequently colonize the humid stream banks (Table 2).

Alien species: Six non-native species were recorded and only four of these were woody phanerophyte species (only 3,6% of all species). *Robinia pseudoacacia* was the most widespread alien (recorded at 14 site plots) but in no cases did this species dominate river banks. All other non-natives had a marginal presence: *Populus x canescens* (11 site plots), *Cupressus sempervirens* (2 site plots),

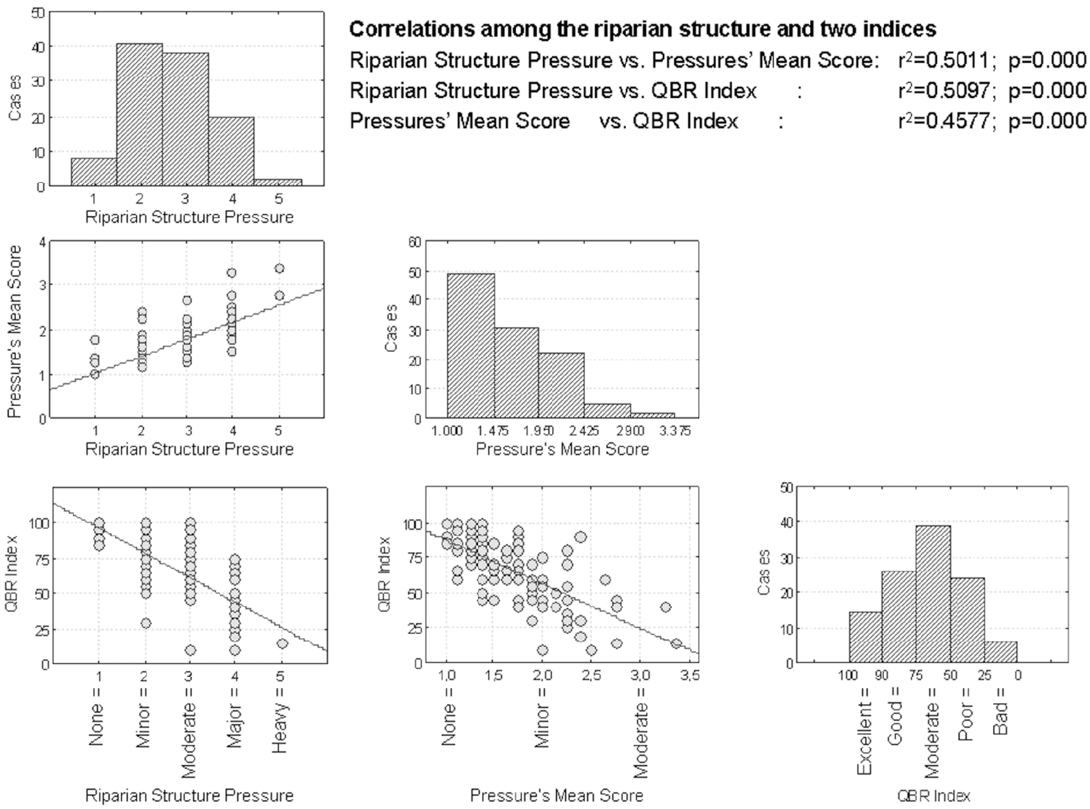

Fig. 5: Correlations among FAME's riparian structure pressure metric, FAME's pressure mean score index (compilation of five metrics) and the riparian forest quality index -QBR in the 109 sites

Table - 1: Data elements collected with different protocols with respect to site (100 m) or segment (1 or 10 km lengths depending on river catchment size) (FAME, 2005)

	Protocol / index name	Reference	Collected information categories	Range of scores (min. to max. impact)
Data from riparian and in-stream protocols	Riparian macrophyte field form	Modified from M.T. Ferreira (unpublished)	% cover of species cover in the woodland riparian area on each bank; 5 Site modifications (% cover), 8 anthropogenic alterations for left and right bank reaches (% cover of alteration)	% cover of species and pressures
	FAME anthropogenic pressures	Modified from E.U. FAME project (FAME, 2005)	8 pressures affecting riparian ecotone: Land use per segment; Urbanization per segment; Connectivity per segment; Floodplain Lateral movement per segment; Riparian zone segment; Hydrological regime per site; Morphological condition per site; Overgrazing per site	1 – 5
	Artificiality characteristics, modifications (SVAP)	Bjorkland *et al*. (2006)	Water abstraction, water impoundment structures, bridges, flood-protection works, gravel/sand extraction, channel alterations, construction works	0 - 200
Indices	Riparian forest quality index (Qualitat de Bosc de Riber: QBR)	Munne *et al*. (2003)	Four metrics: Total riparian cover; Cover structure; Cover quality; Channel alteration; Channel typology	100 – 0
	Stream visual assessment protocol (SVAP)	Bjorkland *et al*. (2001)	15 metrics referring to in-stream and riparian corridor; including riparian vegetation integrity	10 – 0

Table - 2: Frequency of occurrence of the thirty most prevalent species in the four river basins, in 218 surveyed plots

Taxa	Acheloos (112)	Alfios (34)	Aoos (24)	Arachthos (48)
Abies x borisii-regis	++		+	+
Aesculus hippocastanum	+			+
Alnus glutinosa (H)	++	+	+++	+++
Buxus sempervirens (s)			++	
Carpinus orientalis	++	+	++	++
Clematis spp. (s)	++	++	++	++
Cornus spp. (s)	+			+
Cotinus coggygria (s)	+		++	+
Crataegus sp.	+	+	+	+
Fagus sylvatica	+		++	++
Fraxinus ornus	++	++	++	++
Hedera helix (s)	++	++	++	++
Juniperus oxycedrus	++		++	++
Laurus nobilis		++		
Ostrya carpinifolia	++	+	++	++
Phillyrea latifolia (s)	+		+	
Pinus nigra	+		+++	++
Platanus orientalis (H)	+++	++++	+++	+++
Populus nigra (H)			++	
Quercus coccifera	+	++	+	+
Quercus frainetto	+		+	+
Rubus idaeus (s)			++	+
Rubus sp. (s)	++	+++	+++	++
Salix amplexicaulis (sH)	+	++	++	++
Salix alba (H)	++	++	++	++
Salix elaeagnos (sH)	+++	++	++	+++
Salix purpurea (sH)	+	++	+	++
Sambucus nigra (s)	+		+	
Quercus ilex	+	++		
Ulmus minor	+		++	+
Total number of prevalent species [total species] per basin	26 [90]	16 [45]	26 [67]	24 [63]
Average number of total species [standard deviation] per plot	10.7 [5.1]	8.3 [3.8]	15.2 [7.7]	13.8 [5.9]

The total number of the thirty prevalent species recorded in each basin is given, as is the total documented species-richness for each basin (in brackets). Hygrophilous species are shown with (H); species normally encountered as shrubs are denoted with (s). Frequency of occurrence is shown with respect to relative percent cover of each species in each basin: + = 0-1%, ++ = 1.01- 10%, +++ = 10.01 - 50%, ++++ = 50.01-100%

Ailanthus altissima (1 site plot), *Arundo donax* (2 site plots) and *Datura stramonium* (1 site plot). It is clear that the intrusion of non-native plants in the riparian zones of the mountains of Greece is not yet a widespread anthropogenic pressure. The occurrence of aliens is substantially lower than has been recorded in other areas of Mediterranean and western Europe (Aguiar *et al.,* 2000; Weber, 2003). However, the localized spread of *Robinia pseudoacacia* in the Arachthos river basin should raise concern. This alien's distribution seems to be related to erosion-control afforestation projects (begun in the late 1960s) and we confirm invasive colonization since many specimens and small stands are now widely established along the Arachthos' main stem. Although our samples with non-native species are relatively few, there are indications that anthropogenic pressures and disturbances in the riparian zone are often associated with the presence of non-native trees. More samples are needed particularly in areas that are affected by alien species, in order to explore relationships among species presence and other forms of anthropogenic degradation.

Correlations among metrics and pressures: The effectiveness of the QBR index is confirmed since it correlates positively with SVAP's riparian cover quality and land-use naturalness; and negatively with the floodplain dynamics pressure (Table 4). The SVAP recordings of artificial characteristics in the riparian zone and especially those that interfere in the lateral connectivity (bank resection, embankment, realignment) were highly correlated with the relevant FAME and QBR parameters (Table 4). The FAME pressures metric "riparian structure pressure" (relating to riparian forest integrity at the river corridor segment scale) was found to correlate well with both the FAME's pressure's mean score index and the QBR index (Fig. 5). In this way, the wider segment-scale assessment of riparian forest integrity seems to be a good indicator of both the cumulative pressures means score and the riparian forest habitat condition at the site-scale, as detected by the QBR index. Therefore,

Table - 3: Descriptive statistics for selected attributes and degradation variables per river basin. FAME pressure values range from 1 (no pressure) to 5 (heavy pressure). QBR metrics from 0 (bad quality) to 25 (excellent); and 0 (bad quality) to 100 (excellent) for the QBR total score. SVAP riparian and land-use metrics range from 1 (heavy pressure) to 10 (none) and riverbed and floodplain dynamics pressure value 0 is for unmodified sites. * Variables related to segment scale; all others to site scale

River	Acheloos N = 52				Alfios N = 13				Aoos N = 12				Aracthos N = 18			
	Mean	Min.	Max	S.D.	Mean	Min	Max	S.D.	Mean	Min	Max	S.D.	Mean	Min.	Max	S.D.
Site attributes																
Elevation (m)	745	277	1197	258.2	449	270	735	120	786	338	1325	413	606	238	1036	202.42
Gradient (%)	2.14	0.39	7.5	1.70	0.95	0.2	2	0.57	1.22	0.36	3.08	0.80	2.62	0.11	10	2.87
Watershed (km^2)	189	7.7	1390	275	333	21	834	295	326	6	1166	351	97	13.7	322	84.69
FAME pressures																
Urbanisation pressure*	1.15	1	3	0.41	1.23	1	2	0.44	1.08	1	2	0.29	1.11	1	2	0.32
Connectivity pressure*	1.40	1	4	0.77	1.92	1	5	1.26	1.25	1	3	0.62	1.67	1	4	0.97
Riparian structure pressure*	2.65	1	5	1.10	3.08	2	4	0.86	2.50	1	4	0.80	2.72	2	4	0.75
Hydrological pressure	1.65	1	4	0.90	2.77	1	5	1.24	2.50	1	4	1.00	1.72	1	4	1.02
Overgrazing pressure	1.81	1	4	1.03	1.69	1	4	0.85	1.08	1	2	0.29	1.22	1	2	0.43
QBR																
Cover structure	18.17	0	25	7.92	18.85	10	25	6.50	18.75	10	25	7.72	17.22	10	25	6.69
Channel alteration	18.17	0	25	8.52	18.08	10	25	7.78	19.17	0	25	9.00	20.00	10	25	7.28
QBR score	69.62	10	100	22.98	61.54	25	90	19.8	68.75	25	95	22.6	69.44	30	100	23.26
SVAP																
Riparian cover quality	5.35	2	10	2.42	4.92	2	10	2.63	6.58	1	9	2.35	5.56	3	10	2.38
Land use naturalness	7.02	1	10	2.08	5.00	2	8	1.96	7.58	2	10	2.81	7.06	3	10	2.51
Riverbed dynamics pressure	2.63	0	15	3.72	2.77	0	19	5.42	5.33	0	13	5.69	5.72	0	22	5.74
Floodplain dynamics pressure	3.17	0	27	4.69	6.15	0	22	7.07	6.17	0	16	6.34	5.83	0	22	6.27

Table - 4: Spearman's rho correlations among the different pressure/degradation variables and indices recorded at the surveyed sites. ** Significant at the 0.01 level and * at the 0.05 level (2-tailed)

	Elevation	Gradient	Urbanisation pressure	Riparian pressure	Overgrazing pressure	Cover structure	QBR score	Riparian cover quality	Land-use naturalness	Floodplain dynamics pressure
Elevation	-									
Gradient	0.337**	-								
Urbanisation pressure	-0.069	0.010	-							
Riparian structure pressure	-0.217*	-0.269**	0.371**	-						
Overgrazing pressure	0.007	0.132	0.072	0.195*	-					
Cover structure	0.014	0.031	-0.210	-0.513**	-0.338**	-				
QBR score	0.046	0.165	-0.451**	-0.752**	-0.359**	0.760**	-			
Riparian cover quality	0.226	0.196	-0.308*	-0.703**	-0.189	0.491**	0.715**	-		
Land-use naturalness	0.281*	0.155	-0.468**	-0.545**	0.042	0.309*	0.626**	0.619**	-	
Floodplain dynamics pressure	-0.024	0.025	0.178	0.257	-0.074	-0.292	-0.469**	-0.193	-0.194	-

there is evidence that if riparian conditions are degraded over a wider area, specific conditions at the site scale should also usually be similarly recorded as degraded. In this sense, degradation of longitudinal riparian connectivity and structure usually affects multiple scales, it was easily detected both at the site and segment scale in this study.

Generalizations on the state of the montane riparian zones: Specifically, at the site scale, QBR index results show that a large proportion of sites are in good or moderate condition, but only 13 sites had a score of above 90 (*i.e.* high ecological status or near-natural conditions) (Fig 5). Small incremental anthropogenic modifications were prevalent in most riparian woodland zones as assessed in the riparian vegetation protocol. It is important to note that most montane rivers show relatively limited channel alterations (only 15 river banks had evidence of canalization, 9 had gabion). The most widespread recorded anthropogenic modifications within the vegetation plots were: tree cutting (128 sites), rubbish (125 sites), livestock grazing/trampling (97 sites), roads (79 sites) and mineral extraction (39 sites). Many of these impacts affect riparian zones in multiple ways. Our incidental observations show that roads are one of the most destructive pressures since they may facilitate other anthropogenic pressures (*e.g.* artificial erosion, river siltation) and indirectly assist other forms of human exploitation of riparian zones (overgrazing, tree-cutting, in-filling, *etc.*).

Of the four river basins, the Alfios river has the heaviest pressure in terms of urbanization and land-use (Table 3). In contrast, the Aoos and upper Acheloos rivers, receive the least of the land-use pressures. Recently, hydrological pressures have become important elements of degradation as new hydroelectric dams, river diversion projects and water abstraction schemes are being developed, affecting all four basins (Table 3). The Acheloos sites currently maintain the lowest hydrological pressure (FAME) and the lowest floodplain dynamics pressure (SVAP) yet several sites on this river are threatened by recent developments connected with the Acheloos river diversion mega-project and associated hydroelectric dams.

This study also provides indications that anthropogenic pressures may also be responsible for observed vegetation structure, and these may be apparent at broad scales. For example, the more pristine Aoos basin had the widest riparian woodland zones, very high species richness (N=67), highest species richness per plot (15,2) and hosted several forest species not found in the other basins (Table 2, Fig. 4). In contrast, the most anthropogenically-degraded study area, the Alfios, had the narrowest woodland widths, the lowest species richness (N=45), the lowest species richness per plot (8,3) and was lacking several species of otherwise widely-distributed forest shrubs and trees (Table 2, Fig.4). The Alfios' degradation may not be as apparent today but the area had many large mountain villages that necessarily imposed intense anthropogenic exploitation on riparian zones in the recent past. In contrast, the Aoos and the upper Acheloos have always had small and isolated permanent settlements separated by large wilderness valleys. Today many mountain villages are abandoned in all four of the studied basins, but the centuries-old effects of long-term exploitation (*i.e.* wood-cutting, overgrazing, occupational burning) are probably still prevalent on the riparian woodland structure. It goes without saying that it is important to attempt to interpret anthropogenic pressures in riparian zones at varying scales of space and time, as has been explored in other European case-studies (Decamps *et al.,* 1988; Bernez *et al.,* 2002).

In order to apply both a rapid floristic description and site-based assessment, an innovative distinction has been promoted here to define a strictly stream-side "riparian woodland zone" and a wider geomorphologically-driven "riparian ecotone". The use of riparian assessment metrics from three protocols provide important input into testing the usefulness of particular indicators of riparian degradation. Despite sampling design constraints (i.e. limited by site inaccessibility), we believe that the recorded conditions/assessments present a fairly representative snapshot of typical anthropogenic degradation over a fairly large portion of mainland Greece. This survey provides support for the further development of site-based rapid assessment schemes of the riparian zone along-side aquatic ecological status assessments.

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