CHAPTER 1: *A meta-analysis on the biodiversity in perennial and intermittent rivers*

and

CHAPTER 2: *Macroinvertebrate patterns between perennial and intermittent rivers in reference and non-reference conditions: a comparison between the Mediterranean Basin and Chile.*

AUTHOR: MARIA SORIA EXTREMERA

DEPARTMENT: F.E.M. Research Group. Department of Ecology. University of Barcelona (UB).

DIRECTOR: NÚRIA BONADA

DATA: October 5, 2015

MASTER: Master in Ecology, Management and Restoration of the Natural Environment. Faculty of Biology, University of Barcelona (UB).

COLLABORATION IN CHAPTER 1: IRBAS: Intermittent River Biodiversity and Synthesis Project (www.irbas.fr).

COLLABORATION IN CHAPTER 2: Ricardo Figueroa. EULA center in University of Concepción (Chile).

AUTHOR: MARIA SORIA EXTREMERA

DEPARTMENT: F.E.M. Research Group. Department of Ecology. University of Barcelona (UB).

DIRECTOR: NÚRIA BONADA

DATA: October 5, 2015

MASTER: Master in Ecology, Management and Restoration of the Natural Environment. Faculty of Biology, University of Barcelona (UB).

COLLABORATION IN CHAPTER 1: IRBAS: Intermittent River Biodiversity and Synthesis Project (www.irbas.fr).

COLLABORATION IN CHAPTER 2: EULA center in University of Concepción (Chile).

Maria

Maria Soria Extremera

Núria Bonada

A la Núria Bonada per guiar-me en aquest procés tant frenètic i esbojarrat. Al Ricardo Figueroa per l'acolliment i aprenentatge a Chile. Al projecte IRBAS per l'ajut en el Metanàlisi, en especial a la Catherine Leigh i en Thibalt Datry. Així com als autors/es que ens van cedir les dades per al Metanàlisis. Als companys i companyes del centre EULA de Concepción (Chile) i del grup de recerca F.E.M., per tot el suport i ajut. En resum: a tota aquella persona que m'ha hagut d'aguantar durant aquest treball. Gràcies!

Universitat de Barcelona

F.E.M. Freshwater Ecology and Management Research Group

Intermittent River Biodiversity Analysis & Synthesis
IRBAS

Centro de Ciencias Ambientales
EULA-CHILE

RESUMS

A continuació s'exposen els resums en català dels 2 capítols. Els resums en anglès estan dins dels corresponents capítols.

CAPÍTOL 1

1. Tot i que la investigació en els rius intermitents (IRs) s'ha incrementat durant l'última dècada, no hi ha estudis que ofereixin una visió general de la biodiversitat dels IRs. Per tant, encara hi ha controvèrsia sobre si els IRs presenten més o menys biodiversitat que els rius permanents (PRs). El nostre objectiu va ser determinar si la biodiversitat en els IRs difereix dels PRs, i com la biodiversitat en ambdós tipus de rius es veu influenciada per diversos factors com: el clima, la zonificació, l'estació de mostreig, el grup taxonòmic, l'hàbitat mostrejat, i el nivell de pertorbació antròpica.

2. Es va dur a terme un metanàlisis amb 68 estudis publicats que tractaven de la biodiversitat en els PRs i els IRs. D'aquests, 48 eren amb dades replicades i 20 amb dades no replicades. Es van extreure les riqueses mitjanes i les desviacions estàndard dels PRs i IRs dels estudis replicats, i amb això es va obtenir les mides de l'efecte emprant la g de Hedge. El biaix de publicació en els estudis replicats es va analitzar visualment mitjançant l'aplicació de gràfics en embut. A causa de l'heterogeneïtat dels estudis, es va aplicar un model d'efectes aleatoris per obtenir la mida de l'efecte general i els seus intervals de confiança. Es va utilitzar un *forest plot* per il·lustrar els resultats individuals i globals del model. Finalment, també es van aplicar el biaix de publicació i els models d'efectes aleatoris en els estudis separats per cada factor i totes les categories corresponents.

3. En general, la biodiversitat va ser significativament major en els PRs que en els IRs, tot i que les diferències eren relativament baixes. Pel que fa als factors, en les categories macroinvertebrats, multihàbitat, diverses zones, totes les estacions, les pertorbacions antropogèniques de baix i mig nivell, els climes generals B i C, i els climes específics Csa i Csb, es van observar biodiversitat majors als PRs. Mentre que altres categories com les algues, els ràpids (riffles), els climes generals D i E, i climes específics Cfb, Dfa i ET, no van mostrar diferències significatives.

4. Malgrat que els IRs estan sotmesos a pertorbacions severes que eliminen tota la comunitat aquàtica durant el període de sequera, la seva biodiversitat és relativament alta en comparació amb els PRs, el que suggereix que les espècies dels IRs tenen trets particulars adaptats a aquestes condicions. Malgrat que el canvi global està augmentant la freqüència dels IRs en moltes regions, l'elevada biodiversitat d'aquests ecosistemes que hauria de promoure mesures de conservació urgents.

CAPÍTOL 2

1. Els ecosistemes fluvials estan constantment amenaçats per pertorbacions antropogèniques, a més d'estar sotmesos a pertorbacions naturals. A diferència de les pertorbacions naturals com la sequera, que ha tingut lloc durant el temps suficient com per a seleccionar espècies adaptades a aquesta, les pertorbacions antropogèniques són relativament joves en el temps evolutiu, fet que podria explicar les seves dramàtiques conseqüències sobre els ecosistemes fluvials. El nostre objectiu va ser analitzar quin patrons segueixen els macroinvertebrats pel que fa a la biodiversitat i a la composició taxonòmica i funcional, segons siguin rius permanents (PRs) o intermitents (IRs), i entre els rius de no-referència (NREF) i els referència (REF) de les regions de clima mediterrani de Catalunya i Xile.

2. Per a Xile, es va construir una matriu de trets biològics utilitzant la informació existent publicada, observacions visuals i l'opinió d'experts. Per a Catalunya, els mateixos trets biològics van ser extrets de bases de dades europees que ja estan disponibles. La biodiversitat es va considerar a partir de la riquesa rarificada, l'índex de Shannon i l'índex de Simpson com a estructura taxonòmica, i l'índex de diversitat de Rao per a l'estructura funcional. La composició dels macroinvertebrats es va analitzar mitjançant l'aplicació de l'Anàlisi de Correspondència (CA) per a l'estructura taxonòmica, i l'Anàlisi de Correspondència Fuzzy (FCA) per a la funcionalitat dels trets. El test de Kruskal Wallis es va emprar per a les mètriques de biodiversitat, i el test de Randomització de Monte Carlo per a els anàlisis de composició.

3. Per a la biodiversitat, es van trobar diferències significatives per a la riquesa en PRs_IRs de Xile, per la diversitat de Shannon REF_NREF a Catalunya, i per la diversitat de Simpson en REF_NREF a Xile. Per a la composició taxonòmica, es van trobar diferències significatives en tots els casos a excepció dels RP-RI a Xile, mentre que per la composició dels trets totes les comparacions van ser significatives. Com era d'esperar, no es van trobar diferències entre els PRs i IRs per a qualsevol mètrica de la biodiversitat a les regions de clima mediterrani de Xile i Catalunya. Pel que fa a la comparació REF i NREF en ambdues regions, es va trobar una major biodiversitat taxonòmica a REF que no pas al NREF a Xile, però no a Catalunya. Gairebé no es va trobar una superposició en la composició taxonòmica i dels trets biològics entre PRs i llocs IRs en les dues regions.

INDEX

CHAPTER 1:

A meta-analysis on the biodiversity in perennial and intermittent rivers

ABSTRACT

1. Despite research on intermittent rivers (IRs) has increased during the last decade, no studies have been done so far that provide a general overview of the biodiversity of IRs. Therefore, there is still controversy about whether IRs host more or less biodiversity than permanent rivers (PRs). Our aim was to determine if biodiversity in IRs differs from PRs, and how biodiversity in both river types is influenced by several factors, such as climate, zonation, sampling season, taxonomic group, sampled habitat, and the level of anthropogenic disturbance.

2. A meta-analysis was conducted on 68 published papers that dealt with biodiversity in PRs and IRs, 48 with replicated data and 20 with non-replicated data. Richness means and SDs were extracted from both river types in replicated studies, and effect sizes were obtained using Hedge's g. Publication bias on the replicated studies was visually analysed by applying funnel plots. Because of the heterogeneity of the studies, a random effect model was applied on replicated studies to obtain the overall effect size and its confidence intervals. A forest plot was used to illustrate the individual and overall results of the model. Finally, publication bias and random effect models were also applied splitting studies by each factor and all the corresponding categories.

3. Overall, biodiversity was significantly greater in PRs than IRs, despite the biodiversity difference was relatively low. Categories such as the macroinvertebrates group, multihabitat, multiple zones, all categories of seasons, low and medium anthropogenic disturbance, B and C general climates, and Csa and Csb specific climates, resulted in a greater biodiversity in PRs than in IRs. Whereas others such as the algae group, riffles habitat, D and E general climates, and Cfb, Dfa and ET specific climates did not show significant differences.

4. Although IRs are subjected to drying events that reset aquatic communities, biodiversity appear to be relatively high in comparison to PRs, suggesting that IRs host species with particular traits adapted to these conditions. Despite global change is increasing the occurrence of IRs in many regions, IRs can still host a relatively high biodiversity value, which should promote conservation efforts in these ecosystems.

KEYWORDS: macroinvertebrates, fish, temporary rivers, biodiversity, anthropogenic, flow intermittency, meta-analysis

INTRODUCTION

Despite they have been largely ignored in the past, intermittent rivers (IRs) are the most common fluvial ecosystems occurring between latitudes 84ºN and S (Jacobsen, 2004; Larned et al., 2010). Their high occurrence has increasingly stimulated their study during the last decade (Datry et al., 2011; Sheldon, 2005). A large part of this research has been focused on understanding species biodiversity, especially because global change is increasing flow intermittency in most parts of the world and endangering local biodiversity (Blanchette & Pearson, 2012; Garcia-Roger et al., 2011; Thoms & Sheldon, 2002). In particular, aquatic macroinvertebrates has been the taxonomic group most studied in IRs indicating that these ecosystems harbor high numbers of rare and unique species with particular biological traits (Bonada et al., 2008; Bogan et al., 2013).

There is controversy about whether IRs hosts more or less biodiversity than permanent rivers (PRs). While some studies found that IRs had less richness than PRs (Delucchi & Peckarky, 1989; Del Rosario & Resh, 2000), other studies found the contrary, or similar biodiversity values between both river types (Casas & Langton, 2008; Feminella, 1996; Boulton & Suter, 1986; Prograr & Moldenke, 2002; Grubbs, 2011; Miller & Goday, 1996; Bonada et al., 2008). However, despite this controversy, all studies highlight that the dry period in IRs poses several physicochemical and biological challenges to most species (Fritz & Dodds, 2002). Many species in IRs have thus evolved specific adaptations, making invertebrate assemblages of IRs unique (Del Rosario & Resh, 2000).

Most studies to date have focused on studying biodiversity in IRs by only considering single rivers or catchments (e.g., Bunn & Davies, 1992; Closs & Lake, 1994; Delucchi, 1988; Pires et al., 2000; Bonada et al., 2007). This, together with the controversies explained above, make very difficult to have an overall view of the biodiversity of IRs. In addition, there have been no studies in IRs that empirically provide a general overview of their biodiversity and community patterns (Datry et al., 2013).

Several approaches have been used to study general patterns using different types of published data. Traditional methods, such as narrative reviews or ‘vote counting’ methods, have potential for serious bias, and may yield misleading conclusions (Gates, 2002). More recent methods, such as meta-analyses, are designed to avoid these problems. Meta-analyses are nowadays used in many research areas and offer a general overview of a specific question using published data. The meta-analysis approach determines the significance and magnitude of the global effect size, evaluates the sources of variation among studies, and considers sample sizes of studies (Koricheva et al., 2013). Despite these advantages, meta-analyses have not been without criticism, specially related to statistical details and tests to be applied (Koricheva et al., 2013).

In this study, we compared biodiversity in PRs and IRs rivers using a meta-analysis approach. PRs were considered as those with continuous flow whereas IRs referred to rivers or streams that cease surface flow at some point for some period of time. Our aim was to examine published papers that dealt with biodiversity in PRs and IRs to determine: a) whether IRs biodiversity differs from PRs and, if so, how much and in which direction; (b) whether some variables such as climate, zonation, sampling season, taxonomic group, sampled habitat, and the level of anthropogenic disturbance influences biodiversity between PRs and IRs. Although taxa in both rivers type are supposed to be adapted to the particular flow conditions (Bonada et al., 2007), we should expect that richness differ between them in some cases (see hypotheses in Table 1).

Table 1: Aims and hypotheses addressed in this meta-analysis and the datasets used to test them.

Aims	Hypothesis	Dataset used
AIM 1: Whether IRs biodiversity differs from PRs and, if so, how much and in which direction.	**H1:** Biodiversity should be higher in PRs than IRs, because in the dry season, organisms adapted to flowing conditions will disappear (Garcia-Roger et al., 2011). However, IRs can also have a high annual diversity because flow conditions are more variable, selecting for different species along the year (Bonada et al., 2007). In PRs instead, the community composition is maintained along the year (Delucchi & Peckarsky, 1989). Alternatively, PRs and IRs might have similar biodiversity, because the species that appear in IRs during the dry period can compensate those that disappear in this same period (Grubbs, 2011).	All
AIM 2: Whether some variables such as climate, zonation, sampling season, taxonomic group, sampled habitat, and level of anthropogenic disturbance influences	**H2:** Less or no difference between PRs and IRs should be expected in regions with predictable climates, such in the Mediterranean, because the predictability of the dry season should have selected species adapted to IRs (Lytle & Poff, 2004). In regions with less-predictable climates, a greater biodiversity in PRs than IRs should be expected.	Climate data
	H3: Alteration of flow intermittency may cause changes on floodplain, and thus, alter their biodiversity (Datry et al., 2007). More differences between PRs and IRs should be found in small than medium reaches because medium reaches usually have more shelters (isolated pools) that maintain biodiversity (Datry et al., 2013). So, in small reaches, PRs should have greater biodiversity than PRs, whereas PRs and IRs might have similar biodiversity in medium reaches.	Zonation data
	H4: In spring IRs should have greater biodiversity than PRs because whereas in IRs simultaneous habitats of riffles, connected and isolated	

biodiversity between PRs and IRs.	pools are present, PRs only have riffles and connected pools (Bonada et al., 2006). However, in autumn and winter less or no differences between PRs and IRs should be expected because of their flow intermittence similarity (Delucchi, 1988; Garcia-Roger et al., 2011). Finally, in summer more biodiversity should be found in PRs because habitat can be completely lost in IRs, with only isolated pools at best.	Sampling season data
	H5: Many species of macroinvertebrates have multiple traits adapted to dry conditions that cannot be found in other taxonomic groups such as fish or algae (Bêche et al., 2006; Bonada et al., 2008). Therefore, the difference between PRs and IRs would be less important for macroinvertebrates than for other groups.	Taxonomic group data
	H6: Habitat is a key filter for species (Poff, 1997) and biodiversity should thus differ among microhabitats. Specifically, biodiversity should be greater in PRs than IRs in riffles because this habitat disappear in IRs during drying. Instead, pools should display the contrary pattern because they dominate in IRs, either as connected or disconnected to riffles (Bonada et al., 2006).	Sampled habitat data
	H7: A greater biodiversity in PRs than in IRs should be found under low and medium anthropogenic disturbance (see hypothesis 1), whereas biodiversity should be similar under high anthropogenic disturbances because the homogenization of species that this type of disturbance imposes (see Chapter 2)	Anthropogenic disturbance data

METHODS

Data selection

Published studies of authors from around the world who compared biodiversity PRs and IRs were searched in the ISI web of knowledge (https://www.accesowok.fecyt.es/) considering a time span from the 1900s to the 21st of August 2014. Searches were made, firstly, for the different terms of the “IR research” topic, resulting in 10800 records (Appendix 1). These publications were secondly searched for the research terms of the other four topics in Appendix 1 (i.e., invertebrate ecology, fish ecology, biogeochemistry, and assessment and management), resulting in 3851 records. These records were further pre-selected obtaining 1237 publications. Non-selected publications primarily included those dealing with permanent waters or aquatic environments other than streams and river environments, those that included one or more of the search terms but were not related in any way to limnology, and those not focused on the relevant search topic. Repeated records were excluded (Appendix 1).

The pre-selected publications were carefully investigated and filtered again by considering the following specific criteria: the publication had to discuss or provide direct insight into the ecology and/or management of IRs and PRs, the experimental design had to include PRs and IRs sites located on independent rivers, and the publication had to include mean values and standard deviation (SD) for each river type or enough information to calculate these values. This selection resulted in a total of 68 publications, 48 with replicated data (i.e., studies with several PRs and/or IRs sites from where mean and SD were obtained) and 20 with non-replicated data (see Appendixes 2 and 3 for the full references of these papers). Most publications included studies scattered across North America, Europe, and Australia. Very few studies were placed in Africa and Asia, and none was found in South America (Appendix 4). Means and SDs were extracted from these studies and, in cases where authors only presented a presence/abundance table, mean richness, n, and SD were computed. In few cases, data were extracted from figures using the Plot Digitiser software (plotdigitizer.sourceforge.net/) or obtained directly from authors. When possible, the biodiversity measure used was richness but in few cases Shannon diversity was considered. For each individual publication, information on site or sampling characteristics was obtained. In particular, we considered the following 6 factors with several categories (Appendix 5): climate, zonation, sampling season, taxonomic group, sampled habitat, and level of anthropogenic disturbance.

Statistical analysis

For replicated studies, effect sizes were obtained using Hedge's g, which corresponds to the difference between the means of biodiversity in PRs and IRs divided by the pooled standard deviation and with a correction for small sample bias (Rosenberg et al., 2000). For non-replicated studies, where means and standard deviations were not available, effect sizes were obtained using the response ratio for the log-transformed ratio of means. This measure is equal to log(m1i/m2i), being i a particular study, 1 and 2 the two factors to be compared, and m the observed means, which makes the measure symmetric around 0 and its distribution closer to normal (Hedges et al., 1999). The response ratio was also computed for replicated studies for comparison with the non-replicated studies, but it was not included in the formal meta-analysis.

Publication bias on the replicated studies was visually analysed by applying funnel plots. These plots allow seeing the scatter of effect sizes (plotted on the horizontal axis) against a measure of the study size such as the standard error (plotted on the vertical axis, with a reversed scale that put the most powerful studies on the top) (Sterne et al., 2011). An asymmetrical funnel usually indicates publication bias (i.e., there is a relationship between the effect size and the study size), whereas a symmetrical funnel indicates that there is no publication bias. As an asymmetrical funnel may also indicate a truly difference between studies with large and small sizes, the Begg and the Egger tests were applied. The Begg is a non-parametric test based on a correlation whereas the Egger (Egger et al., 1997) is a parametric test based on a regression. In both cases, significant test values indicate asymmetry and therefore, publication bias. The use of these tests has been very controversial, specially the Begg's one, which has been identified as having a very low power with small number of sites (e.g., less than 25 by Begg & Mazumdar, 1994). Finally, the trim-and-fill method was applied in order to derive a symmetrical funnel plot and to have an estimated number of missing studies, which can help to quantify the publication bias.

Because of the heterogeneity of the studies (i.e., different taxonomical groups, sampling methodologies, or biodiversity measures), a random effect model was applied on replicated studies to obtain the overall effect size and its confidence intervals. In addition, the appropriateness of a random effect model was also checked by computing heterogeneity tests. The model was computed using the original data and the data derived from the trim-and-fill method to have an estimation of the effect of the missing studies on the results. In all cases, the models provided an estimate value, its confidence interval (*ci.lb* and *ci.ub*), and a p-value indicating model's significance.

A forest plot was used to illustrate the individual and overall results of the model. This plot represents the effect size and the confidence interval of each study and the overall effect size (Gates, 2002). The interpretation of the overall effect size comes from the model's results and the visualization of the forest plot. In our case, a significant model or an overall effect size which confidence interval did not include the 0 would indicate that there were significant differences between PRs and IRs biodiversity. The amount of overall effect size indicates the amount of difference between the two stream types. In our case, a positive overall effect size would indicate that biodiversity in PRs was higher than in IRs, whereas a negative overall effect size would indicate the contrary. Finally, publication bias and random effect models were applied splitting studies by each variable and category.

Our meta-analysis was checked against the checklist of the 16 quality criteria provided by Koricheva and Gurevitch (2014). All criteria except 10, 11 and 13 were considered (see Appendix 6). Criteria number 11, although meta-analyses combined studies conducted on different species, the phylogenetic relatedness was not taken into account because we focused on macroinvertebrates group (lack of number of studies in other taxonomic group). All statistics were computed using the R freeware (Ihaka, 1996) and the libraries metaphor (Viechtbauer, 2010) and rmeta (Lumley, 2012).

RESULTS

General differences between PRs and IRs

The funnel plots with and without the trim-and-fill method suggested a visually low publication bias (Figure 1). The Begg test indicated that there was non-significant publication bias (Kendall's tau= 0.184, p= 0.065), whereas the Egger test found a significant publication bias (z= 2.169, p= 0.030). The trim-and-fill method indicated that there were only 7 missing to have a symmetrical graphic (Table 2, Figure 1), suggesting that the publication bias was very low. In addition, the random effect model before and after applying the trim-and-fill method indicated the same result, confirming that publication bias was negligible (Table 2). The random effect model was also justified after computing heterogeneity tests (Appendix 7). The model results considering all replicated studies were significant and positive (estimate value = 0.861, p < 0.0001) indicating a significantly greater biodiversity in PRs than on IRs sites (Appendix 8). Correspondingly, the confidence interval did not include the 0 (*ci.lb* of 0.550 and *ci.ub* of 1.173). Forty studies had a positive effect size, whereas 8 had a negative effect size. The positive effect sizes ranged from 0.01 to 7.95, whereas the negative ones ranged from -1.10 to -0.04. Therefore, despite being significant, an overall effect size between PRs and IRs of 0.861 was very low.

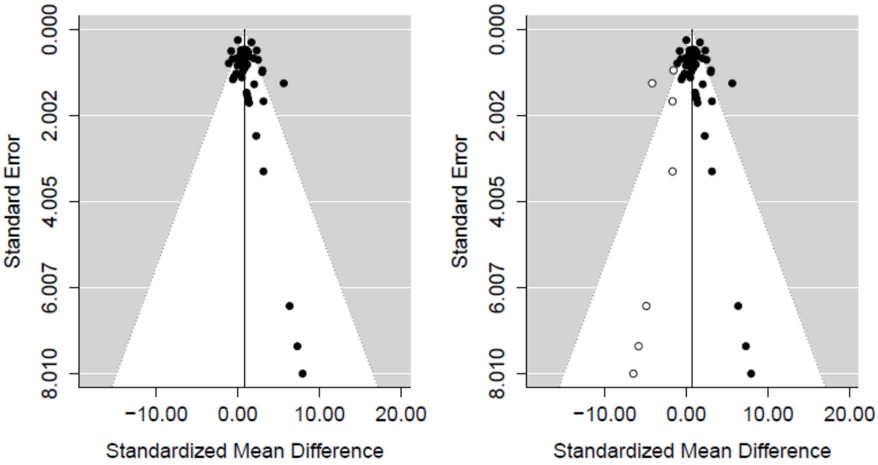


Figure 1. Funnel plots using replicated studies with and without the trim-and-fill method (left and right, respectively). Black circles represent the individual replicated studies, whereas white circles represent the missing studies to have a symmetrical plot.

The comparison between the forest plots with response ratios for replicated and non-replicated studies (Appendix 9) revealed that there was not much difference between the designs. Most non-replicated studies had their effect size located in the positive area, indicating again a greater biodiversity in PRs than in IRs.

Differences between PRs and IRs by factors

Given that some factors were considered in a very low number of studies (see N values in Table 2), the publication bias was assessed in a similar way as for the overall design. For factors with only 1 or 2 studies, publication bias could not be assessed and cannot be interpreted here. Several factors in Table 2 had a relatively low number of studies (i.e., ≤5): algae taxonomic group, riffles samples habitat, and D and E general climates. However, the Begg and Egger tests were non-significant and the model with and without the trim-and-fill method gave similar and non-significant results, suggesting that there was not publication bias.

Among the factors that did not show publication bias after applying the Begg and Egger tests, the taxonomic group of macroinvertebrates had a significant difference and a positive effect size, showing a greater diversity in PRs than IRs (Table 2). A similar result was found for studies that included multihabitat samples, reaches located in multiple zones, all categories of season factor, low and medium anthropogenic disturbance, B and C general climates, and Csa and Csb specific climates (Table 2), which also means a higher biodiversity in PRs than IRs. However, factors such as algae taxonomic group, riffles samples habitat, D and E general climates, and Cfb, Dfa and ET specific climates had no significant results with and without trim-and-fill, indicating no differences between PRs and IRs.

Finally, factors such as small zonation and C_mult specific climate, despite having a relatively high number of studies, had a significant publication bias according to the Begg and Egger tests and could not be interpreted (Table 2). The taxonomic group of fish could not be interpreted either because, despite the Begg and Egger tests were not significant, the model gave different results with and without trim-and-fill (Appendix 10).

Table 2. Model results, Begg and Egger tests, and the application of the trim-and-fill method on the general replicated design and separated by factors. In bold, significant factors after applying random effect models. (**) Significant difference at p < 0.01; (*) Significant difference at p < 0.05; N = number of studies considered in each category; ci.lb and ci.ub = confidence interval.

Design			Model Results				Begg Test		Egger Test			Model Results with Trim-and-fill				Studies missing to have a symmetrical graphic
Factors	**Categories**	**N**	**Estimate**	**p-value**	**ci.lb**	**ci.ub**	**Kendall's tau**	**p-value**	**Z**	**p-value**	**estimate N**	**Estimate**	**p-value**	**ci.lb**	**ci.ub**	
General design		48	0.861	<0.0001 (**)	0.550	1.173	0.184	0.066	2.169	0.030 (*)	55	0.728	<0.0001 (**)	0.397	1.058	7
Group	**Macroinvertebrate**	38	1.097	<0.0001 (**)	0.738	1.456	0.212	0.063	1.876	0.061	43	1.003	<0.0001 (**)	0.619	1.39	5
	Fish	6	0.544	0.068	-0.039	1.127	-0.733	0.056	-1.282	0.200	7	0.624	0.030 (*)	0.059	1.188	1
	Diatoms	1	0.009	0.972	-0.470	0.488	-	-	-	-	-	-	-	-	-	-
	Algae-macrophytes	3	0.066	0.879	-0.788	0.920	-0.333	1	-1.442	0.149	3	0.066	0.879	-0.788	0.920	0
Habitat	**Multihabitat**	37	0.950	<0.0001 (**)	0.588	1.312	0.178	0.131	1.564	0.118	37	0.946	<0.0001 (**)	0.584	1.307	0
	Riffles	4	0.915	0.267	-0.700	2.530	0.667	0.333	1.168	0.243	5	0.517	0.516	-1.045	2.080	1
	Pools	2	0.675	0.431	-1.003	2.353	-	-	-	-	-	-	-	-	-	-
Zonation	Medium	2	0.035	0.971	-1.845	1.915	-	-	-	-	-	-	-	-	-	-
	Multiple	12	1.084	<0.0001 (**)	0.524	1.644	0.061	0.841	0.414	0.679	12	1.084	0.0001 (**)	0.524	1.644	0
	Small	23	0.999	0.0004 (**)	0.448	1.549	0.384	0.008 (**)	2.237	0.025 (*)	32	0.492	0.125	-0.137	1.122	9
Season	**Autumn**	3	4.789	<0.0001 (**)	2.844	6.735	-0.333	1	0.218	0.827	4	4.737	<0.0001 (**)	2.806	6.668	1
	Multiple	27	0.711	0.0005 (**)	0.312	1.110	0.088	0.535	0.773	0.439	28	0.706	0.0005 (**)	0.308	1.103	1
	Spring	11	0.640	0.016 (*)	0.120	1.160	0.127	0.648	0.432	0.666	15	0.262	0.369	-0.309	0.833	4
	Summer	7	1.394	<0.0001 (**)	0.794	1.994	0.333	0.381	0.702	0.483	8	1.383	0.0001 (**)	0.788	1.977	1
Anthropogenic impact	High	1	0.598	0.542	-1.326	2.522	-	-	-	-	-	-	-	-	-	-
	Low	30	0.715	<0.0001 (**)	0.374	1.057	0.182	0.165	1.619	0.106	40	0.363	0.066	-0.024	0.749	10
	Medium	14	1.152	0.002 (**)	0.429	1.874	0.121	0.591	0.999	0.318	16	0.881	0.031 (*)	0.081	1.680	2
General Climate	**B**	6	0.920	0.001 (**)	0.361	1.479	0.333	0.469	0.314	0.753	7	0.862	0.002 (**)	0.317	1.407	1
	C	32	0.742	<0.0001 (**)	0.375	1.110	0.109	0.393	1.643	0.100	34	0.730	<0.0001 (**)	0.366	1.095	2
	D	4	2.209	0.152	-0.813	5.232	0.333	0.750	0.785	0.433	5	1.988	0.175	-0.881	4.857	1
	E	3	1.342	0.221	-0.808	3.492	1	0.333	0.819	0.413	3	1.342	0.221	-0.808	3.492	0
Specific Climate	BSh	2	0.537	0.430	-0.795	1.869	-	-	-	-	-	-	-	-	-	-
	BSk	2	0.813	0.067	-0.058	1.683	-	-	-	-	-	-	-	-	-	-
	BWk	2	1.191	0.007 (**)	0.320	2.061	-	-	-	-	-	-	-	-	-	-
	C_mult	8	1.069	0.009 (**)	0.271	1.866	0.357	0.275	2.490	0.013 (*)	8	1.069	0.009 (**)	0.272	1.866	0
	Cfa	1	0.598	0.542	-1.326	2.522	-	-	-	-	-	-	-	-	-	-
	Cfb	5	0.293	0.682	-1.106	1.691	-0.200	0.817	1.414	0.158	6	0.230	0.744	-1.154	1.615	1
	Csa	9	0.940	0.032 (**)	0.083	1.797	-0.056	0.920	0.063	0.950	10	0.907	0.034 (*)	0.069	1.745	1
	Csb	8	0.562	0.048(*)	0.005	1.119	0.357	0.275	0.902	0.367	8	0.562	0.048(*)	0.005	1.119	0
	Dfa	3	1.996	0.218	-1.178	5.170	0.333	1	1.693	0.091	3	1.996	0.218	-1.178	5.170	0
	Dwa	1	6.357	0.323	-6.256	18.970	-	-	-	-	-	-	-	-	-	-
	ET	3	1.342	0.221	-0.808	3.491	1	0.333	0.819	0.413	3	1.342	0.221	-0.808	3.491	0

DISCUSSION

The publications analysed here included studies scattered across the globe that compared biodiversity in PRs and IRs in a wide range of climates, river zones, seasons, sampled habitats, and anthropogenic disturbances. The significant greater biodiversity in PRs than IRs across these worldwide studies confirmed our first hypothesis. This finding agrees with several individual studies, especially with those that found much higher differences in abundance and biodiversity between PRs and IRs (Delucchi & Peckarky, 1989; Del Rosario & Resh, 2000). Instead, other studies found only subtle differences between PRs and IRS biodiversity or similar values (Casas & Langton, 2008; Feminella, 1996; Progar & Moldenke, 2002; Grubbs, 2011). Similarity in biodiversity between PRs and IRs are expected during the wet period, where PRs and IRs have similar flow regimes. However, during a greater biodiversity in PRs than IRs is usually found during the dry period because flow differs more between them and organisms adapted to flowing conditions in IRs disappear (Delucchi, 1988; Garcia-Roger et al., 2011). However, species that appear in IRs only during the dry period can compensate those that disappear (Grubbs, 2011), reducing the differences in biodiversity between PRs and IRs. So, the time of sampling (dry or wet) could explain this variability of patterns of biodiversity between PRs and IRs.

Biodiversity differences between PRs and IRs change also depending on the factor considered. In agreement with our hypotheses, in climates with less predictible dry and flood periods (e.g., B: arid, C: temperate), biodiversity was greater in PRs than IRs. Unexpected floods or droughts can have severe effects on biological communities because they have not acquired traits to cope with these disturbances and other strategies (e.g., changing temporarily the behaviour) are used (Lytle & Poff, 2004). In contrast, the Mediterranean specific climate (Cfa and Cfb, included in C: temperate) seems to contradict our hypothesis, as PRs was greater biodiversity than IRs. In this case, other factors besides predictability could play a more important role. The duration of the drought period, for example, is also an important characteristic that also influences biodiversity (Lytle & Poof, 2004).

Although not enough data was available for small and medium categories, the multiple zonation factor had a greater PRs biodiversity than IRs. Multiple zonation includes biodiversity information from small and medium reaches, where we expected contrasting patterns. However, headwaters make up a large proportion of all river networks (>80% according to Naiman, 1983 or Benda et al., 2005) and are usually much more sampled than mid-order rivers (Finn et al., 2011). Therefore, studies that include multiple reaches from a single or several catchments, are supposed to consider a greater number of headwater reaches than mid-order reaches. Headwater reaches have less isolated pools to maintain biodiversity than mid-order reaches and drying is supposed to occur earlier (Datry et al., 2013), which can explain the greater biodiversity in PRs than in IRs.

In accordance to our hypotheses, biodiversity was greater in PRs than IRs in autumn and summer. In autumn, with the first rains, flow is restored in IRs and organisms start to colonise these empty habitats (Datry et al., 2013), which would explain the high difference between PRs and IRs. Instead, PRs are only subjected to floods in autumn which can have devastating effects on biological communities, but that also affect IRs. On the other hand, habitat is completely lost in IRs in summer, with only isolated pools at best, also increasing the difference in biodiversity between PRs and IRs. Contrary to our expectations, PRs had also a greater biodiversity in spring, indicating that the higher flow connectivity in PRs than in IRs is an important factor controlling biodiversity, as already mentioned.

The different sample habitat did not support our hypotheses. For riffles, a similar biodiversity was found in PRs and IRs, whereas not enough data was available for pools. The similar biodiversity values in riffles indicate that, although this habitat disappears during drying in IRs, it can fully behave as riffles in PRs when the river is flowing. In contrast, multihabitat category had significant differences, suggesting that pools can have a significant biodiversity value. These aquatic refuges across river landscapes, combined with taxa-specific differences in dispersal abilities, may explain much of the colonization and succession dynamics in IRs (Datry et al., 2013).

Regarding the taxonomic group, macroinvertebrates biodiversity decreases as the dry season is progressing in IRs because most of them are susceptible to desiccation (Datry et al., 2012). This supports our results of a significantly greater biodiversity in PRs than in IRs. However, several authors have shown that IRs have particular taxa in comparison to PRs, with particular biological traits adapted to drying (Blanchette & Pearson, 2012; Bonada et al., 2006). As for the fish group, despite we found publication bias, among the 6 studies included in our analyses, 4 found a greater biodiversity in PRs than IRs (Beugly et al., 2010; Monaghanet et al., 2010; Okur et al., 2008; Roux et al., 2008), which confirm the need of continuous flow for fish survival. In the other 2 studies, a greater biodiversity was found in IRs than in PRs (Alexandre et al., 2013; Lorig et al., 2013) (Appendix 10).

Finally, about the anthropogenic disturbance factor, our results are in agreement with our hypothesis, indicating a greater biodiversity in PRs than IRs under low and medium anthropogenic disturbances. Instead, the single study analysed here that consider IRs under high anthropogenic disturbance did had a non-significant model output, indicating similar biodiversity values between PRs and IRs. In comparison to low or medium anthropogenic disturbances, a high disturbance homogenizes communities and erodes diversity differences between river types (Chapter 2).

Although IRs are subjected to drying events that reset aquatic communities, biodiversity appear to be relatively high in comparison to PRs, suggesting that IRs host species with particular traits adapted to these conditions. Despite global change is increasing the occurrence of IRs in many regions (Datry et al, 2013), IRs can still host a relatively high biodiversity value, which should promote conservation efforts in these systems to halt freshwater biodiversity loss and to preserve the multiple goods and services they provide.

Appendix 1: Literature searches used to investigate the history and maturation IR research within and across topics (conducted on 21st of August 2014 in the Web of Science, for publications produced and catalogued from the 1900s until date of search).

Topic	**Search terms**	**All results**	**Pre-selected results**	**Years of publication**
IR research**†**	"intermittent river(s)", "intermittent stream(s)", "ephemeral river(s)", "ephemeral stream(s)", "temporary river(s)", "temporary stream(s)", "temporal river(s)", "temporal stream(s)", "interrupted river(s)", "interrupted stream(s)", "discontinuous river(s)", "discontinuous stream(s)", "seasonal river(s)", "seasonal stream(s)", "episodic river(s)", "episodic stream(s)", "semi-permanent river(s)", "semi-permanent stream(s)", "non-perennial river(s)", "non-perennial stream(s)", "dry river(s)", "dry stream(s)", wadi(s), "desert river(s)", "desert stream(s)", "dryland river(s)", "dryland stream(s)", "Mediterranean river(s)", "Mediterranean stream(s)", "flow intermittence" or "flow intermittency"	10800	Not applicable	1911-2014
Invertebrate ecology	*invertebrate*, "aquatic insect(s)" or arthropod*	741	381	1967-2014
Fish ecology	fish*	567	275	1964-2014
Biogeochemistry	biogeochem*, nutrient*, carbon, nitrogen, phosphorus, "organic matter" or "organic material(s)"	1063	323	1981-2014
Assessment and management	bioassessment, *monitor*, "stream classification", "river classification", "water quality", contamin*, "land use" or management	1480	539	1971-2014

(†)While the search terms used for the IR research topic do not cover all those used to describe what we refer to here as IRs, they cover the majority of common terms used in the literature through time, and in different regions and research disciplines.

Appendix 2: Codes used in the forest plot to identify each replicated study and their corresponding full references.

Author code	**Full reference**
Alexandre2013	Alexandre C.M., Ferreira T.F. & Almeida P.R. (2013) Fish assemblages in non-regulated and regulated rivers from permanent and temporary Iberian systems. River Research and Applications, 29, 1042-1058.
Artemiadou2008	Artemiadou V., Statiri X., Brouziotis T. & Lazaridou M. (2008) Ecological quality of small mountainous Mediterranean streams (river type R-M4) and performance of the European intercalibration metrics. Hydrobiologia, 605, 75-88.
Bae2014	Bae M.J., Chon T.S. & Park Y.S. (2014) Characterizing differential responses of benthic macroinvertebrate communities to floods and droughts in three different stream types using a Self-Organizing Map. Ecohydrology, 7, 115-126.
Banks2007	Banks J.L., Li J. & Herlihy A.T. (2007) Influence of clearcut logging, flow duration, and season on emergent aquatic insects in headwater streams of the Central Oregon Coast Range. Journal of the North American Benthological Society, 26, 620-632.
Beche2007	Bêche L.A. & Resh V.H. (2007) Short-term climatic trends affect the temporal variability of macroinvertebrates in California 'Mediterranean' streams. Freshwater Biology, 52, 2317-2339.

Belmar2013	Belmar O., Velasco J., Gutierrez-Canovas C., Mellado-Diaz A., Millan A. & Wood P.J. (2013) The influence of natural flow regimes on macroinvertebrate assemblages in a semiarid Mediterranean basin. Ecohydrology, 6, 363-379.
Beugly2010	Beugly J. & Pyron M. (2010) Variation in Fish and Macroinvertebrate Assemblages Among Seasonal and Perennial Headwater Streams. American Midland Naturalist, 163, 2-13.
Blanchette2012	Blanchette M.L. & Pearson R.G. (2012) Macroinvertebrate assemblages in rivers of the Australian dry tropics are highly variable. Freshwater Science, 31, 865-881.
Bogan2013	Bogan M.T., Boersma K.S. & Lytle D.A. (2013) Flow intermittency alters longitudinal patterns of invertebrate diversity and assemblage composition in an arid-land stream network. Freshwater Biology, 58, 1016-1028.
Bonada2006	Bonada N., Rieradevall M., Prat N. & Resh V.H. (2006) Benthic macroinvertebrate assemblages and macrohabitat connectivity in Mediterranean-climate streams of northern California. Journal of the North American Benthological Society, 25, 32-43.
Bonada2007_Multiple	Bonada N., Doledec S. & Statzner B. (2007) Taxonomic and biological trait differences of stream macroinvertebrate communities between mediterranean and temperate regions: implications for future climatic scenarios. Global Change Biology, 13, 1658-1671.
Bonada2008	Bonada N., Rieradevall M., Dallas H., Davis J., Day J., Figueroa R., et al. (2008) Multi-scale assessment of macroinvertebrate richness and composition in Mediterranean-climate rivers. Freshwater Biology, 53, 772–788.
Bonada2007_Spain	Bonada N., Rieradevall M. & Prat N. (2007) Macroinvertebrate community structure and biological traits related to flow permanence in a Mediterranean river network. Hydrobiologia, 589, 91-106.
Chadwick2012	Chadwick M., Thiele J., Huryn A., Benke A. & Dobberfuhl D. (2012) Effects of urbanization on macroinvertebrates in tributaries of the St. Johns River, Florida, USA. Urban Ecosystems, 15, 347-365.
Death2003	Death R.G. (2003) Spatial patterns in lotic invertebrate community composition: is substrate disturbance actually important? Canadian Journal of Fisheries and Aquatic Sciences, 60, 603-611.
DeJong2013	De Jong G.D., Smith E.R. & Conklin D.J. (2013) Riffle beetle communities of perennial and intermittents streams in Nothern Nevada, USA, with a new state record for *Optioservus Castaneipennis* (fall) (COLEOPTERA: ELMIDAE). Coleopterists Bulletin, 67, 293-301.
Donath2001	Donath U. & Robinson C.T. (2001) Ecological characteristics of lake outlets in Alpine environments of the Swiss Alps. Archiv für Hydrobiologie, 150, 207-225.
Garcia2011	García-Roger E., Del Mar Sánchez-Montoya M., Gómez R., Suárez M., Vidal-Abarca M., Latron J., et al. (2011) Do seasonal changes in habitat features influence aquatic macroinvertebrate assemblages in perennial versus temporary Mediterranean streams? Aquatic Sciences, 73, 567-579.
Garcia2013	Garcia-Roger E.M., Sanchez-Montoya M.D., Cid N., Erba S., Karaouzas I., Verkaik I., et al. (2013) Spatial scale effects on taxonomic and biological trait diversity of aquatic macroinvertebrates in Mediterranean streams. Fundamental and Applied Limnology, 183, 89-105.
Graca2004	Graça M.A., Pinto P., Cortes R., Coimbra N., Oliveira S., Morais M., et al. (2004) Factors Affecting Macroinvertebrate Richness and Diversity in Portuguese Streams: a Two-Scale Analysis. International Review of Hydrobiology, 89, 151-164.
Leigh2013	Leigh C. (2013) Dry season changes in macroinvertebrate assemblages of highly seasonal rivers: responses to low flow, no flow and antecedent hydrology. Hydrobiologia, 703, 95-112.
Lorig2013	Lorig R.C., Marchetti M.P. & Kopp G. (2013) Spatial and temporal distribution of native fish larvae in seasonal and perennial tributaries of the Sacramento River, CA, USA. Journal of Freshwater Ecology, 28, 179-197.
Mackie2013	Mackie J.K., Chester E.T., Matthews T.G. & Robson B.J. (2013) Macroinvertebrate response to environmental flows in headwater streams in western Victoria, Australia. Ecological Engineering, 53, 100-105.
MALMQVIST1995	Malmqvist B., Nilsson A.N. & Baez M. (1995) Tenerife's fresh-water macroinvertebrates - status and threats (Canary-Islands, Spain). Aquatic Conservation-Marine and Freshwater Ecosystems, 5, 1-24.
Monaghan2010	Monaghan K.A. & Soares A.M. (2010) The bioassessment of fish and

	macroinvertebrates in a Mediterranean–Atlantic climate: Habitat assessment and concordance between contrasting ecological samples. Ecological Indicators, 10, 184-191.
Munne2011	Munne A. & Prat N. (2011) Effects of Mediterranean climate annual variability on stream biological quality assessment using macroinvertebrate communities. Ecological Indicators, 11, 651-662.
Novais2014	Novais M.H., Morais M.M., Rosado J., Dias L.S., Hoffmann L. & Ector L. (2014) Diatoms of temporary and permanent watercourses in Southern Europe (Portugal). River Research and Applications, 30, 1216–1232.
Okur2008	Okur E. & Yalcin-Oezdilek S. (2008) Preliminary study of fish community structure in Amanos Mountain streams (Hatay-Turkey). Biologia, 63, 427-438.
Perez2011	Pérez-Quintero J.C. (2011) Freshwater mollusc biodiversity and conservation in two stressed Mediterranean basins. Limnologica - Ecology and Management of Inland Waters, 41, 201-212.
Perez2013	Pérez-Quintero J.C. (2013) Mollusc communities along upstream–downstream gradients in small coastal basins of the south-western Iberian Peninsula. Hydrobiologia, 703, 165-175.
Prenda1999	Prenda J. & Gallardo-Mayenco A. (1999) Distribution patterns, species assemblages and habitat selection of the stoneflies (Plecoptera) from two Mediterranean river basins in southern Spain. International Review of Hydrobiology, 84, 595-608.
Price2003	Price K., Suski A., Mcgarvie J., Beasley B. & Richardson J.S. (2003) Communities of aquatic insects of old-growth and clearcut coastal headwater streams of varying flow persistence. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere, 33, 1416-1432.
Progar2002	Progar R.A. & Moldenke A.R. (2002) Insect production from temporary and perennially flowing headwater dtreams in Western Oregon. Journal of Freshwater Ecology, 17, 391-407.
Rabeni1998	Rabeni C.F. & Wallace G.S. (1998) The influence of flow variation on the ability to evaluate the biological health of headwater streams. IAHS PUBL, 411-417.
Robson2005	Robson B.J., Hogan M. & Forrester T. (2005) Hierarchical patterns of invertebrate assemblage structure in stony upland streams change with time and flow permanence. Freshwater Biology, 50, 944-953.
Roux2008	Roux D.J., Nel J.L., Ashton P.J., Deacon A.R., De Moor F.C., Hardwick D., et al. (2008) Designing protected areas to conserve riverine biodiversity: Lessons from a hypothetical redesign of the Kruger National Park. Biological Conservation, 141, 100-117.
Ruegg2004	Ruegg J. & Robinson C.T. (2004) Comparison of macroinvertebrate assemblages of permanent and temporary streams in an Alpine flood plain, Switzerland. Archiv für Hydrobiologie, 161, 489-510.
Ruiz2006	Ruiz García A., Herrera Grao A.F. & Ferreras-Romero M. (2006) Distribution of Trichoptera communities in the Hozgargantacatchment (Los Alcornocales Natural Park, SW Spain). International Review of Hydrobiology, 91, 71-85.
Sanchez2010	Sánchez-Montoya M.M., Vidal-Abarca M.R. & Suárez M.L. (2010) Comparing the sensitivity of diverse macroinvertebrate metrics to a multiple stressor gradient in Mediterranean streams and its influence on the assessment of ecological status. Ecological Indicators, 10, 896-904.
Santos2011	Santos A.N. & Stevenson R.D. (2011) Comparison of Macroinvertebrate Diversity and Community Structure among Perennial and Non-Perennial Headwater Streams. Northeastern Naturalist, 18, 7-26.
Skoulikidis2014	Skoulikidis N., Lampou A., Karaouzas I., Gritzalis K., Lazaridou M. & Zogaris S. (2014) Stream ecological assessment on an Aegean island: insights from an exploratory application on Samothraki (Greece). Fresenius Environmental Bulletin, 23, 1173-1182.
Storey2008	Storey R.G. & Quinn J.M. (2008) Composition and temporal changes in macroinvertebrate communities of intermittent streams in Hawke's Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research, 42, 109-125.
Zbinden2008	Zbinden M., Hieber M., Robinson C.T. & Uehlinger U. (2008) Short-term colonization patterns of macro invertebrates in alpine streams. Fundamental and Applied Limnology, 171, 75-86.

Appendix 3: Codes used in the forest plot to identify each non-replicated study and their corresponding full references.

Author code	Full reference
Boulton_2003	Boulton A.J., Moss G.L. & Smithyman D. (2003) Short-term effects of aerially-applied fire-suppressant foams on water chemistry and macroinvertebrates in streams after natural wild-fire on Kangaroo Island, South Australia. Hydrobiologia, 498, 177-189.
Boulton_1992	Boulton A.J., Valett H.M. & Fisher S.G. (1992) Spatial distribution and taxonomic composition of the hyporheos of several Sonoran Desert streams. Archiv für Hydrobiologie, 125, 37-61.
Bunn_1992	Bunn S.E. & Davies P.M. (1992) Community structure of the macroinvertebrate fauna and water-quality of a saline river system in South-Western Australia. Hydrobiologia, 248, 143-160.
Burk_2013	Burk R.A. & Kennedy J.H. (2013) Invertebrate communities of groundwater-dependent refugia with varying hydrology and riparian cover during a supraseasonal drought. Journal of Freshwater Ecology, 1-20.
Death_1994	Death R.G. & Winterbourn M.J. (1994) Environmental Stability and Community Persistence: A Multivariate Perspective. Journal of the North American Benthological Society, 13, 125-139.
Rosario_2000	Del Rosario R.B. & Resh V.H. (2000) Invertebrates in intermittent and perennial streams: is the hyporheic zone a refuge from drying? Journal of the North American Benthological Society, 19, 680-696.
Delucchi_1988	Delucchi C.M. (1988) Comparison of community structure among streams with different temporal flow regimes. Canadian Journal of Zoology, 66, 579-586.
Earle_2004	Earle J.I. (2004) Stonefly (Plecoptera) species of an acidic intermittent stream in southwestern Pennsylvania, USA, comparison with a circumneutral perennial stream and consideration of survival strategies. Archiv für Hydrobiologie, 159, 97-114.
Fritz_2002	Fritz K.M. & Dodds W.K. (2002) Macroinvertebrate assemblage structure across a tallgrass prairie stream landscape. Archiv für Hydrobiologie, 154, 79-102.
Gallardo_1998	Gallardo-Mayenco A., Prenda J. & Toja J. (1998) Spatio-Temporal Distribution and Ecological Preferences of Coexisting Hydropsychid Species (Trichoptera) in Two Mediterranean River Basins (S Spain). International Review of Hydrobiology, 83, 123-134.
Langton_1998	Langton P.H. & Casas J. (1998) Changes in chironomid assemblage composition in two Mediterranean mountain streams over a period of extreme hydrological conditions. Hydrobiologia, 390, 37-49.
Leigh_2013	Leigh C., Reis T.M. & Sheldon F. (2013) High potential subsidy of dry-season aquatic fauna to consumers in riparian zones of wet–dry tropical rivers. Inland Waters, 3, 411-420.
Leigh_2009	Leigh C. & Sheldon F. (2009) Hydrological connectivity drives patterns of macroinvertebrate biodiversity in floodplain rivers of the Australian wet/dry tropics. Freshwater Biology, 54, 549-571.
Mas_2010	Mas-Marti E., Garcia-Berthou E., Sabater S., Tomanova S. & Munoz I. (2010) Comparing fish assemblages and trophic ecology of permanent and intermittent reaches in a Mediterranean stream. Hydrobiologia, 657, 167-180.
Miller_1996	Miller A.M. & Golladay S.W. (1996) Effects of spates and drying on macroinvertebrate assemblages of an intermittent and a perennial prairie stream. Journal of the North American Benthological Society, 15, 670-689.
Muñoz_2003	Muñoz I. (2003) Macroinvertebrate community structure in an intermittent and a permanent Mediterranean streams (NE Spain). Limnetica, 22, 107-116.
Reznickova_2010	Reznickova P., Soldan T., Paril P. & Zahradkova S. (2010) Comparison of mayfly (Ephemeroptera) taxocenes of permanent and intermittent Central European small streams via species traits. Biologia, 65, 720-729.
Robinson_2004	Robinson C.T., Tockner K. & Burgherr P. (2004) Drift benthos relationships in the seasonal colonization dynamics of alpine streams. Archiv für Hydrobiologie, 160, 447-470.
Stanlake_1997	Stanlake G.J. & Landwer A.J. (1997) Rapid bioassessment of intermittent streams in the Upper Brazos River watershed. In: Global Environmental Biotechnology. (Ed^Eds D. Wise), pp. 559-565. Springer Netherlands.

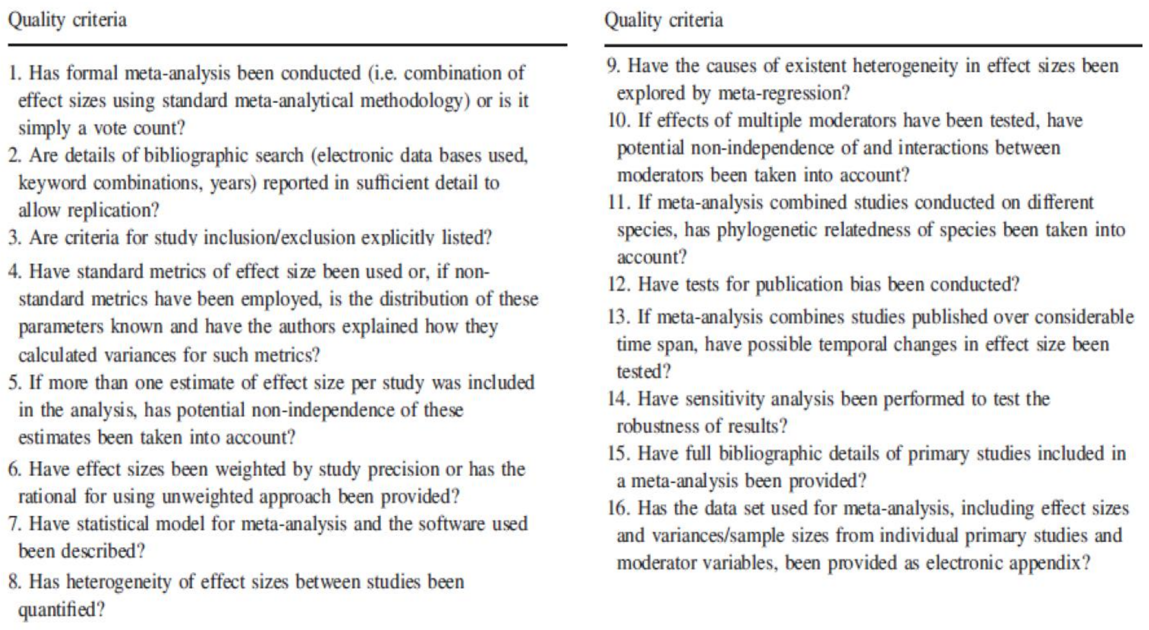
Appendix 4: Distribution of publications, identified from an ISI web of knowledge literature search that examine biodiversity in perennial and intermittent independent rivers (PRs and IRs, respectively). White stars refer to studies with non-replicated data for PRs and/or IRs (n = 20), whereas black stars refer to studies with replicated data for PRs and IRs (n = 48).

Appendix 5: Description of the factors and categories from each individual publication and used in metanalysis with replicated data.

Factors	Categories	Observations
Group	Macroinvertebrate, Fish, Diatoms, Algae-macrophytes	More papers were found about Macroinvertebrates (from general aquatic benthic invertebrates to specific organisms like Chironomidae) than about the other groups. The algae group includes filamentous and encrusted forms that are not diatoms.
Habitat	Riffles, Pools, Multihabitat	Multihabitat includes riffles and pools.
Zonation	Small, Medium, Multiple	Small refers to headwater reaches with a catchment area <100km2, or an stream order equal to or less than 3. Medium refers to reaches with a catchment area between 100 and 1000 km2 or an stream order of 4-6. Multiple includes small and medium.
Season	Spring, Summer, Autumn, Multiple	No studies sampled exclusively the winter season. Multiple refers to studies that sampled different seasons.
Anthropogenic impact	Low, Medium, High	This factor was considered very general without distinguishing among the different anthropogenic impacts.
General Climate	B, C, D, E	Dominant climate of each system was determined according to Peel et al. (2007), which is an updated version of the Koppen classification.
Specific Climate	BSh, BSk, BWk C_mult, Cfa, Cfb, Csa, Csb	These authors consider a total of 30 possible climate types, which are divided into 3 general climates with several specific ones: tropical (A: Af, Am and Aw), 4 arid (B: BWh, BWk, BSh and

Dfa, Dwa ET Multiple	BSk), 9 temperate (C: Csa, Csb, Csc, Cfa, Cfb, Cfc, Cwa, Cwb and Cwc), 12 cold (D: Dsa, Dsb, Dsc, Dsd, Dfa, Dfb, Dfc, Dfd, Dwa, Dwb, Dwc and Dwd) and 2 polar (E: ET and EF). Some of these general and specific climates were not considered in the publications and are not presented here. Also, in specific climate, Multiple refer to a combination of categories (e.g., Csa and BSk), and C_mult a combination of C (e.g., Csa and Csb).

Appendix 6: Checklist of quality criteria for meta-analysis for research synthesis, peer reviewers and editors (Koricheva & Gurevitch, 2014).



Quality criteria
1. Has formal meta-analysis been conducted (i.e. combination of effect sizes using standard meta-analytical methodology) or is it simply a vote count?
2. Are details of bibliographic search (electronic data bases used, keyword combinations, years) reported in sufficient detail to allow replication?
3. Are criteria for study inclusion/exclusion explicitly listed?
4. Have standard metrics of effect size been used or, if non-standard metrics have been employed, is the distribution of these parameters known and have the authors explained how they calculated variances for such metrics?
5. If more than one estimate of effect size per study was included in the analysis, has potential non-independence of these estimates been taken into account?
6. Have effect sizes been weighted by study precision or has the rational for using unweighted approach been provided?
7. Have statistical model for meta-analysis and the software used been described?
8. Has heterogeneity of effect sizes between studies been quantified?

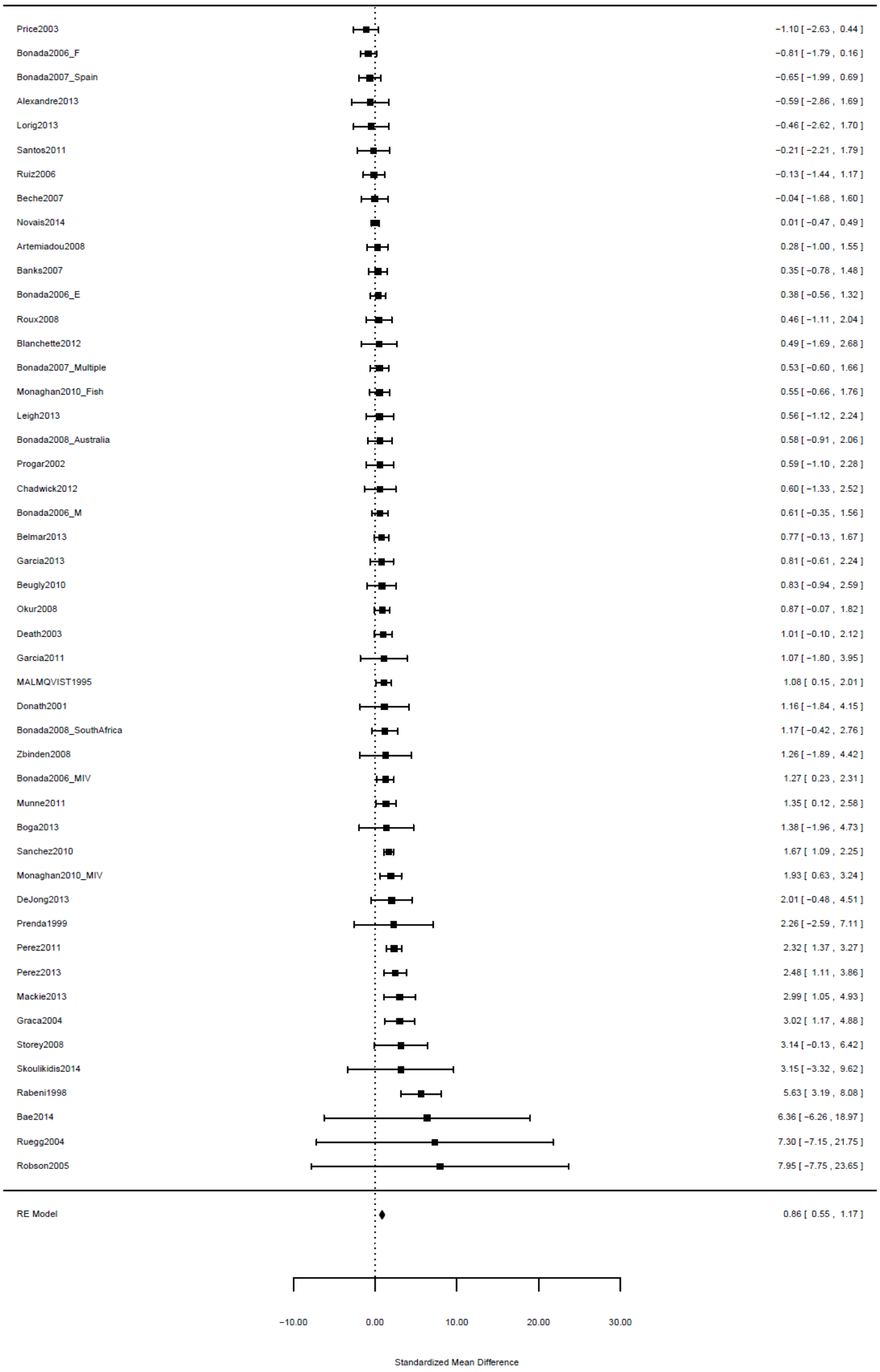
Quality criteria
9. Have the causes of existent heterogeneity in effect sizes been explored by meta-regression?
10. If effects of multiple moderators have been tested, have potential non-independence of and interactions between moderators been taken into account?
11. If meta-analysis combined studies conducted on different species, has phylogenetic relatedness of species been taken into account?
12. Have tests for publication bias been conducted?
13. If meta-analysis combines studies published over considerable time span, have possible temporal changes in effect size been tested?
14. Have sensitivity analysis been performed to test the robustness of results?
15. Have full bibliographic details of primary studies included in a meta-analysis been provided?
16. Has the data set used for meta-analysis, including effect sizes and variances/sample sizes from individual primary studies and moderator variables, been provided as electronic appendix?

Appendix 7: Results of the heterogeneity tests considering replicated publications for the general design and separated by factors. In bold factors were indicated significant results. (**) Significant difference at p < 0.01; (*) Significant difference at p < 0.05; N = number of studies considered in each category.

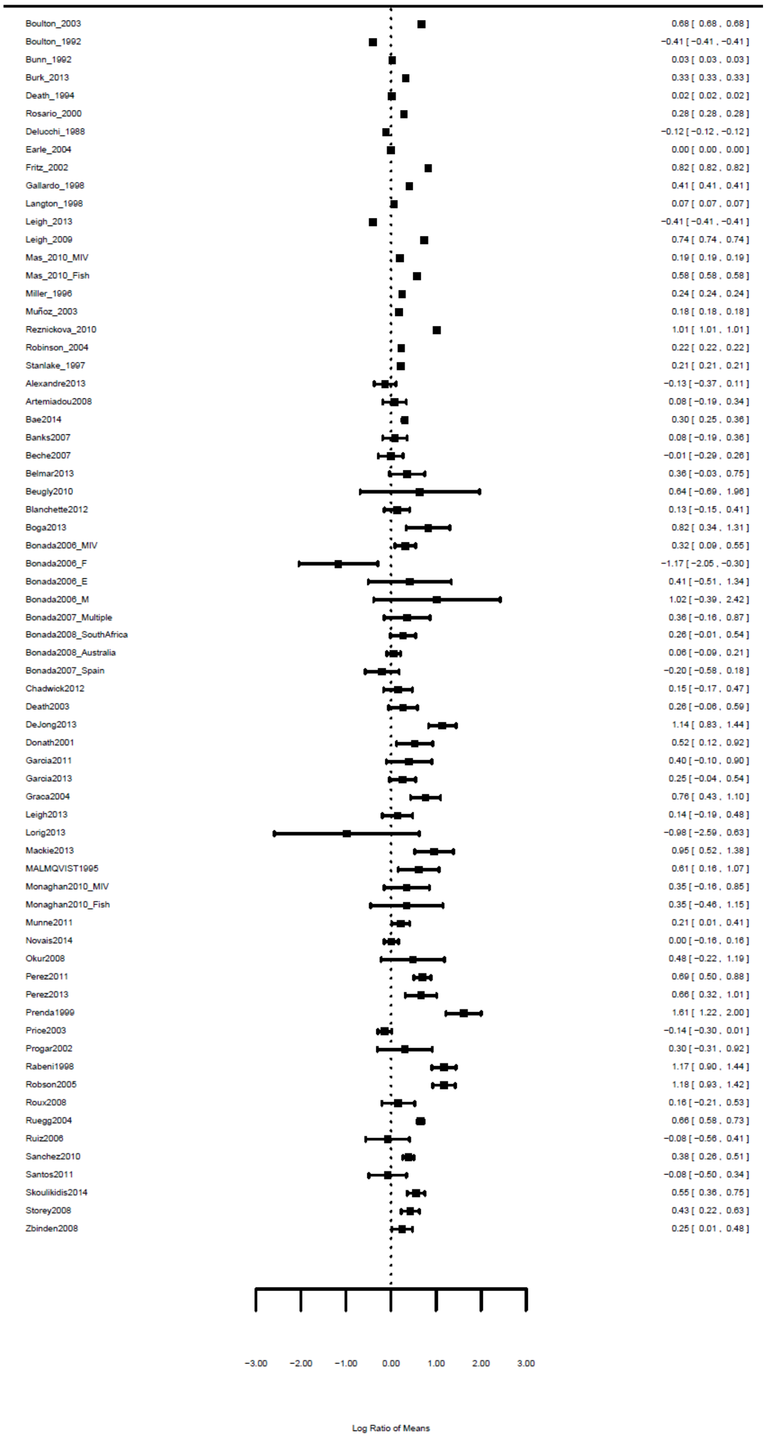
Design			**Heterogeneity test**	
Factors	**Categories**	**N**	**Q**	**p-value**
General design		47	102.023	<0.0001 (**)
Group	**Macroinvertebrate**	37	69.398	<0.001 (**)
	Fish	5	2.368	0.796
	Diatoms	0	0	1
	Algae	2	4.771	0.092
Habitat	Riffles	3	8.761	0.033
	Pools	1	0.834	0.361
	Multihabitat	36	77.000	<0.0001 (**)

Zonation	Medium	1	0.912	0.340
	Multiple	11	37.455	<0.0001 (**)
	Small	22	41.990	0.006 (**)
Season	**Autumn**	2	1.585	0.453
	Multiple	26	42.710	0.021 (*)
	Spring	10	29.577	<0.0001 (**)
	Summer	6	6.061	0.416
Anthropogenic impact	High	0	0	1
	Low	29	53.717	0.004 (**)
	Medium	13	40.127	0.0001 (**)
General Climate	**B**	5	1.346	0.930
	C	31	71.106	<0.0001 (**)
	D	3	14.847	0.002 (**)
	E	2	0.671	0.715
Specific Climate	BSh	1	0.002	0.961
	BSk	1	0.119	0.73
	BWk	1	0.476	0.490
	C_Multiple	7	20.592	0.004 (**)
	Cfa	0	0	1
	Cfb	4	10.366	0.035 (*)
	Csa	8	20.141	0.01 (*)
	Csb	7	13.865	0.054
	Dfa	2	14.297	0.001 (**)
	Dwa	0	0	1
	ET	2	0.671	0.715

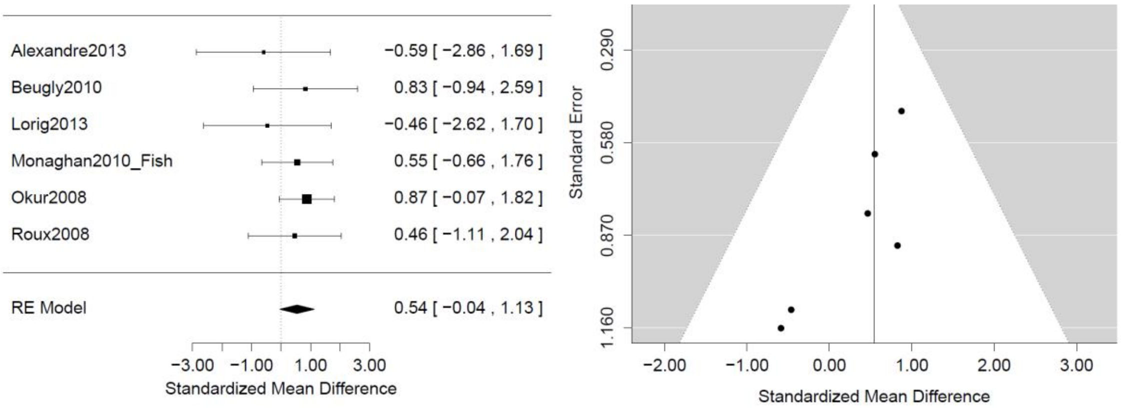
Appendix 8: Forest plot considering the 48 replicated studies ordered by increasing effect size from the top to the bottom. Each study is indicated in the left column with the first author and the year (see Appendix 2 for the complete reference). Effect sizes of each study (using the standardized mean difference) with their corresponding confidence intervals are displayed in the centre of the plot with the exact values in the right. The black diamond at the bottom shows the overall effect size estimated by the model with the edges of the diamond showing the corresponding confidence interval.



Appendix 9: Forest plots with all studies (replicated and non-replicated) using the response ratio as measure of effect size (see Appendix 2 and 3 for the complete reference). With author column (left) and estimates values with confidence interval (right). Black squares indicate standardised mean difference (replicated studies) or the response ratio (non-replicated studies) for each study, and the black diamond at the bottom shows the general effect size.



Appendix 10: Forest plot (left) and Funnel plot (right) considering the 6 fish replicated studies. In Forest plot (left) each study is indicated in the left column with the first author and the year (see Appendix 2 for the complete reference). Effect sizes of each study (using the standardized mean difference) with their corresponding confidence intervals are displayed in the centre of the plot with the exact values in the right. The black diamond at the bottom shows the overall effect size estimated by the model with the edges of the diamond showing the corresponding confidence interval. About Funnel plot (right), it is without the trim-and-fill method. Black circles represent the individual replicated studies.



CHAPTER 2:

Macroinvertebrate patterns between perennial and intermittent rivers in reference and non-reference conditions

ABSTRACT

1. River ecosystems are constantly threatened by many human-driven disturbances and also subjected to natural disturbances. In contrast to natural disturbances, such as drought, which have occurred long enough to select adapted species, anthropogenic disturbances are relatively young in evolutionary time which could explain their dramatic consequences on river ecosystems. Our aim was to analyse patterns of aquatic macroinvertebrate biodiversity, taxonomic and functional trait composition between permanent (PRs) and interminent rivers (IRs) and between non-reference (NREF) and reference (REF) rivers from the Mediterranean-climate regions of Catalonia and Chile.

2. For Chile, biological traits matrix was built up using existing published information, visual observations, and expert opinion. For Catalonia, the same biological traits were extracted from already available European databases. Biodiversity was considered using richness, Shannon, and Simpson diversity indexs for the taxonomic structure, and the Rao diversity index for the functional structure. Macroinvertebrate composition was analysed by applying Correspondence Analysis (CA) for the taxonomic structure and Fuzzy Correspondence Analysis (FCA) for the functional trait structure. Kruskal Wallis for the biodiversity metrics and Monte Carlo Randomisation tests for the composition analyses were applied.

3. For biodiversity, significant differences were found for rarefied richness in PRs_IRs of Chile, for Shannon diversity REF_NREF in Catalonia, and for Simpson diversity in REF_NREF in Chile. For taxonomic composition, significant differences were found in all cases except for PRs-IRs in Chile, whereas for trait composition all comparisons were significant. As expected, no difference between PRs and IRs were found for any biodiversity metric in the Mediterranean climate regions of Chile and Catalonia. Regarding REF and NREF comparison in both regions, a higher taxonomic biodiversity was found in REF than in NREF in Chile but not in Catalonia. Almost no overlap in taxonomic and trait composition was found between PRs and IRs sites in both regions. A weak overlap in taxonomic and trait composition were found between NREF than in REF sites in both regions because anthropogenic disturbances are supposed to homogenize their communities, reduce biodiversity and select for generalist taxa.

KEYWORDS: macroinvertebrates, intermittent, permanent, Mediterranean, biological traits, reference rivers.

INTRODUCTION

River ecosystems are constantly threatened by many human-driven disturbances, such as land use, water abstraction, pollution, or global change (Datry et al., 2011). In addition, river ecosystems are also subjected to natural disturbances, such as fires, floods, and droughts (Lytle & Poff 2004). The effects of floods and droughts on rivers depend on the frequency, predictability, and intensity of both events, which at the same time depend on the climatic characteristics of each particular region (Lytle & Poff, 2004). Mediterranean climate rivers, for example, are really dynamic and are characterised by severe and predictable floods and droughts, whereas drought are almost absent in temperate climate rivers and floods much less predictable (Bonada and Resh, 2013). Thus, despite all river ecosystems are affected by floods, not all are affected by extreme droughts.

Intermittent rivers (IRs), also classified as ephemeral or temporary, cease surface flow during the drought period. In contrast, permanent rivers (PRs) are those with continuous flow. Research in IRs has increased notably during the last two decades (Datry et al., 2013; Sheldon, 2005). Most of this research has been done in reference conditions. In our meta-analysis, for example, 30 of the 48 studies were made in rivers with low anthropogenic disturbances (see Chapter 1). Given that IRs host species with particular traits adapted to drought conditions (Bonada et al., 2008; Bogan et al., 2013), the study of non-reference (NREF) IRs is highly needed to preserve their unique biodiversity. Many studies have compared biodiversity and community composition between REF and NREF rivers sites (Alexandre et al., 2013; Beugly et al., 2010. Bonada et al., 2006; Munné et al., 2011; Sánchez-Montoya et al., 2010; Novais et al., 2014). Anthropogenic disturbances reduce biodiversity, homogenize biological communities, and select for tolerant species with wide distributions ranges (i.e., generalists) (Bonada et al., 2008). In contrast to natural disturbances, such as drought, which have occurred long enough to select adapted species (Lytle & Poff, 2004), anthropogenic disturbances are relatively young in evolutionary time, which could explain their dramatic consequences on river ecosystems.

Despite IRs are subjected to drying events that reset aquatic communities, their biodiversity is relatively high in comparison to PRs (Chapter 1). However, there are indications that macroinvertebrate communities from distant river ecosystems display similar responses to variation in flow intermittency (Darty et al., 2013). For example, richness in IRs of France, New Zealand, and the US, decreased when flow intermittence increased (Darty et al., 2012, Fritz and Dodds, 2004). In Mediterranean climate regions, richness was significantly different between regions but not between PRs and IRs (Bonada et al., 2008). For example, richness was higher in the Mediterranean Basin and in California than in south-western Australia (Bonada et al., 2008). On the other hand, macroinvertebrate communities in PRs and IRs were significantly different in northern Mediterranean climate regions, whereas no differences were found in South Africa and south-western Australia because of a mixture of historical and ecological factors (Bonada et al., 2008). Similarly, other comparative studies about composition between PRs and IRs have found less overlapping composition in Northern Hemisphere IRs than in Australia (Boulton & Suter 1986). However, none of these studies included data from the Mediterranean climate region of Chile.

In recent years, there has been an increased interest in Chile to know and protect river ecosystems, and to study their biodiversity changes over time using benthic macroinvertebrates as biological indicators (Figueroa et al., 2003). These studies are usually done at the taxonomical level of family and only consider taxonomic composition. Other aspects of the macroinvertebrates communities, such as biological traits are commonly neglected despite they might provide functional information on the ecosystem (Bonada & Dolédec, 2011). Information on Chilean freshwater biodiversity has recently been collected in a special issue of the journal Gayana (Concepción) (2006, volume 70), and this information allows detailed analyses of freshwater groups nationwide (Figueroa et al, 2013), including functional trait analyses.

Studies on functional traits are increasing worldwide. Several trait databases already exist, containing biological information from several genera/families in different places (Bonada & Dolédec, 2011). For the Mediterranean climate region of Europe, for example, the extensive Tachet et al. database (Tachet et al., 2002) has been used in several areas (Bonada et al., 2007; García-Roger, 2011). This database includes biological information of 11 biological traits and 63 categories gathered form 473 taxa in Europe (Bonada & Dolédec, 2011). For South America, there have been some attempts to develop trait databases, such as Tomanova and Usseglio-Polatera (2007) or Reynaga and Dos Santos (2012), although they are limited to particular regions outside of Chile. Given that the Chilean fauna is highly endemic (Di Castri, 1991), many genera are missed in these databases and thus they are not applicable.

Our aim was to analyse aquatic macroinvertebrate differences and similarities between non-reference (NREF) and reference (REF) PRs and IRs from the Mediterranean-climate regions of Catalonia and Chile. In particular, we determined (a) whether biodiversity and community composition differs between PRs and IRs in a similar way in both regions, (b) whether biodiversity and community composition differs between REF and NREF rivers in a similar way in both regions, (c) whether higher similarities between regions are found when comparing the effect of the anthropogenic disturbance (REF vs NREF) than the drought disturbance (PRs vs IRs), and (d) to building up a biological traits database for some of the genera found in the Mediterranean region of Chile in order to accomplish the above objectives. As a measure of biodiversity we used different metrics such as richness and diversity indexes, whereas as a measure of community composition we used taxonomic composition and biological traits composition at the genus level.

Table 1: Aims and hypotheses addressed in this study. The aim (d) of creating a Chilean trait matrix is not included.

Aims	Hypotheses
AIM 1: Whether biodiversity and community composition differs between PRs and IRs in a similar way in both regions	**H1. BIODIVERSITY:** Less or no difference between PRs and IRs should be expected in regions with predictable climates, such in the Mediterranean, because the predictability of the dry season should have selected species adapted to IRs (Lytle & Poff, 2004). **H1. COMMUNITY COMPOSITION:** Almost no overlap in taxonomic and traits composition should be found between PRs and IRs sites in both regions because drought conditions have acted long enough in these Mediterranean climate regions to trigged evolutionary adaptations (Bonada and Resh, 2013).
AIM 2: Whether biodiversity and community composition differs between REF and NREF rivers in a similar way in both regions.	**H2. BIODIVERSITY:** A higher macroinvertebrates biodiversity should be expected in REF than in NREF sites in both regions because anthropogenic disturbances reduce biodiversity (Bonada et al., 2008) **H2. COMMUNITY COMPOSITION:** Weak overlap in taxonomic and trait composition should be found between NREF than in REF sites in both regions because anthropogenic disturbances are supposed to reduce biodiversity while keeping generalist taxa (Bonada et al., 2008). Thus, NREF communities should have a subset of REF communities in both, taxonomic and trait structure.
AIM 3: Whether higher similarities are found when comparing the effect of the	**H3. BIODIVERSITY:** When comparing biodiversity in PRs and IRs between Chile and Catalonia, similar values should be obtained because drought is affecting in a similar way in both regions (Bonada and Resh, 2013). Similarly, similar values should be found when comparing REF and NREF between both regions. However, higher similarities should be found for NREF than for REF because

anthropogenic disturbance (REF vs NREF) than the drought disturbance (PRs vs IRs) in both regions	anthropogenic factors reduce biodiversity (Bonada et al., 2008). **H3. COMMUNITY COMPOSITION:** Taxonomic community composition should differ largely in PRs and IRs when comparing Chile and Catalonia because of different historical and environmental factors affecting both regions (Bonada and Resh, 2013). However, functional community composition should be more similar, because traits are less sensible to regional differences (Rodríguez-Capitulo et al. 2009). On the other hand, when comparing REF and NREF, higher similarities (in both, taxonomic and functional composition) should be found for NREF between regions because anthropogenic disturbances are supposed to homogenize communities (Bonada et al. 2008).

METHODS

Study area

Macroinvertebrates were sampled in the Mediterranean climate regions of Catalonia and Chile. Chile is located in south-western South America, in a region with a predominantly temperate climate, with mountains dominating 80% of the country. However, Mediterranean climate conditions, characterised by seasonal precipitation with a dry period from November to February, are present in the Central Zone, between the IV and the VIII administrative regions (Figueroa et al., 2013). Catalonia is located in northeast of the Iberian Peninsula with a Mediterranean climate conditions also characterised by seasonal precipitation, with a dry period from July to September and peaks in early winter and spring (Muñoz et al., 2003).

Sites were located in independent rivers in both regions and included PRs and IRs with REF and NREF conditions. The distinction between PRs and IRs was done considering their flow permanence (i.e., site that regularly dried in summer were considered as IRs), whereas the distinction between REF and NREF was done considering published information that included physico-chemical and biological data, and the expert opinion (Sanchez-Montoya et al., 2010). Specifically, 3 sites were considered as reference PRs (REF_PRs) and reference IRs (REF_IRs) in each Mediterranean region; 2 and 3 as non-reference PRs (NREF_PRs) in Catalonia and Chile, respectively, and 1 and 2 sites as non-reference IRs (NREF_IRs) in Catalonia and Chile, respectively, (see more details in Appendix 1). In Catalonia, sites were located in the Barcelona province (41°22′57″N 2°10′37″E), whereas in Chile were located between the VI O'Higgins Region (34°10′02″S 70°43′37″O, and see Appendix 2) and the VIII

Bio-bío Region (36°50′S 73°03′W). Given that macroinvertebrate composition largely differs between calcareous and siliceous geology (Bonada et al., 2005), all sites were located over a siliceous geology. The number of rivers in Catalonia was lower because of the difficulty of finding silicic rivers with similar characteristics to those of Chile.

In the Mediterranean region of Chile, the main economic activity is based on forest industry, which accounts for about 1 million ha of plantations, and has largely replaced the native forest (Ovalle, 2012). In these plantations, the two most important species are *Pinus radiata* and *Eucalyptus globulus*. Native vegetation consisted of a mixture of perennial and deciduous native forest mainly composed by *Drymis winteri* and *Nothophagus* spp. (Pedreros et al., 2013). In Catalonia, sites were dominated by *Fagus sylvatica, Alnus glutinosa*, *Salix atrocinerea, Fraxinus angustifolia, Corylus avellana, Ulmus minor, Populus nigra, Populus tremula, Vitex agnus-casteus,* and *Populus alba.* The predominant economic activity is the recreational activities related to local and foreigner tourism.

Biological abundance data

In both regions, macroinvertebrates were sampled before and during the drought period (i.e. spring and summer) following the GUADALMED protocol (Jáimez-Cuéllar et al., 2002). Samples were collected in all available microhabitats using a 250-μm-mesh kicknet, preserved in 70% ethanol, and counted and identified to family and genus level in the laboratory (Appendix 3 and 4 for Chile, and Appendix 5 and 6 for Catalonia). Environmental variables, such as pH, temperature, dissolved O2 (DO), and conductivity were measured at each sampling site in both Mediterranean regions (Appendix 7). Habitat diversity was quantified using the fluvial habitat index (IHF) (Pardo et al., 2004) developed for Mediterranean climate rivers (Appendix 8). The QBR index (Munné et al., 2003) was also applied (Appendix 9). Although all sites were visited in summer, some IRs were completely dried: 3 IRs in Chile (RA_10, MA_4, and MA_3, see Appendix 7), and 4 in Catalonia (B08a, B07, Pi01, and T30).

Biological trait data

As indicated in the Appendix 10, to create Chile biological traits matrix for each genera, information was compiled from several existing published databases in the southern hemisphere (Tomanova & Usseglio-Polatera, 2007; Reynaga & Dos Santos, 2012), or coded using biological information from different literature sources (Domínguez & Fernández, 2009; Stark et al., 2006; Domínguez et al., 2006; Ovalle, 2012), visual observations, and expert opinion. Despite the lack of biological information about the biology of most of the collected genera in Chile, 9 biological traits with 52 categories were considered (Appendix 11). These traits included information about the morphology, behaviour, and physiology of each genus. Each category was coded using a fuzzy-coding approach (i.e., giving a weight between 0 to 3, depending on whether the category was present or not in a particular genus and their affinity level). This approach is very convenient because it allows including trait plasticity within genera, or across space, and provides semi-quantitative data (Bonada & Dolédec, 2011). Genera from all aquatic insects except Diptera were used to create this matrix. Diptera, Amphipoda, Decapoda, and Molusca orders were excluded because of the difficulty to find biological information. For Catalonia, the same biological traits from all aquatic insects except Diptera were extracted from the Tachet et al. (2002) database and Bonada & Dolédec (2011) (Appendix 12). However, all macroinvertebrate collected in both regions were identified at the lowest taxonomic level possible (genus except for some Diptera) and used in the taxonomic analyses.

Statistical analysis

In order to compare and describe macroinvertebrate patterns in PRs, IRs, REF, and NREF in each region, biodiversity and community composition were analysed. Biodiversity was considered using richness, Shannon, and Simpson diversity for the taxonomic structure, and the Rao diversity index for the functional structure. Because of the high variability in abundance of samples and the fact that richness depends on the sample size, the rarefaction technique was applied. The Rao’s index is based on the Simpson index, and it uses the trait dissimilarity between genera pairs on the abundance matrix and has a high accuracy in the measurement of functional divergence (Schleuter et al. 2010). Macroinvertebrate composition was analysed by applying Correspondence Analysis (CA) for the taxonomic structure and Fuzzy Correspondence Analysis (FCA) for the functional structure. CA and FCA are multivariate techniques designed to compare taxonomic and traits between sites. For all trait analyses, a traitXsite matrix, with information on the proportion of each category at each sampled site, was obtained by multiplying the abundance genusXsite matrix obtained from the field samples by the traitXgenus matrix generated by us (Appendix 13) (Rodríguez et al., 2009). This procedure was performed with both, the Chilean and the Catalonian matrices. To examine significant differences in structure and functional composition between all categories (i.e., PRs-IRs and REF-NREF), Kruskal Wallis for the biodiversity metrics and Monte Carlo randomisation tests for the composition analyses were applied. All statistical analysis were computed using the R freeware (Ihaka, 1996) and the libraries vegan

(Oksanen et al., 2015) and ade4 (Dray & Dufor, 2007; Dray et al., 2007; Chessel et al., 2004).

RESULTS

Biodiversity patterns

A total of 11 orders, 45 families and 62 genera were found in the 11 rivers from Chile, whereas 12 orders, 89 families and 101 genera in the 9 rivers from Catalonia. Rarefied richness was not significantly higher in PRs than in IRs in both regions (Chile: k-w test= 0.002, p = 0.967; Catalonia: k-w test = 0.112, p= 0.738) (Appendix 14). A similar pattern was found when analysing the Shannon diversity and Simpson diversity, with the same Kruskal Wallis test results for both indexs (Chile: k-w test= 0, p= 1; Catalonia: k-w test = 0.111, p= 0.739) (Appendixs 15 and 16). Similarly, the Rao index showed that there were not significant differences between PRs and IRs in any region either (Chile: k-w test = 1.152, p= 0.283; Catalonia: k-w test = 0.004, p= 0.947) (Appendix 17).

Regarding the comparison between REF and NREF, rarefied richness was significantly higher in REF than in NREF in Chile (k-w test= 9.041, p= 0.003), but non-significant differences were found in Catalonia (k-w test = 0.040, p= 0.841) (Appendix 14). A similar pattern was found for Shannon (Chile: k-w test = 9.257, p= 0.002; Catalonia: k-w test = 0.04, p= 0.842) and Simpson (Chile: k-w test = 6.864, p= 0.009; Catalonia: k-w test = 0.004, p= 0.947) diversities (Appendixs 15 and 16). For the Rao index, there were non-significant differences between REF and NREF in any region (Chile: k-w test = 0.064, p= 0.799; Catalonia: k-w test = 0.538, p= 0.463) (Appendix 17).

Finally, when comparing the regional effects of the natural and the anthropogenic disturbance in both regions, rarefied richness showed that the mean difference between PRs and IRs was very low in each region. In contrast, the mean difference REF and NREF was higher in both regions (Table 2, Appendix 14).

Table 2: Mean and SD of rarefied richness for Catalona and Chile. Kruskal Wallis tests and mean differences when comparing the regional effects of the natural and the anthropogenic disturbance in both regions (Catalonia and Chile). (*) Significant differences at p-value <0.05

CATALONIA

	Mean	SD	K-W test	p-value	Mean difference
PRs	20	7.008	0.112	0.738	-0.4

IRs	20.4	4.879			
REF	21.22	3.962	0.040	0.841	3.022
NREF	18.2	9.783			

CHILE

	Mean	SD	K-W test	p-value	Mean difference
PRs	9.364	3.931	0.002	0.967	-0.011
IRs	9.375	5.012			
REF	11.58	3.825	9.041	0.003 (*)	6.012
NREF	5.571	1.272			

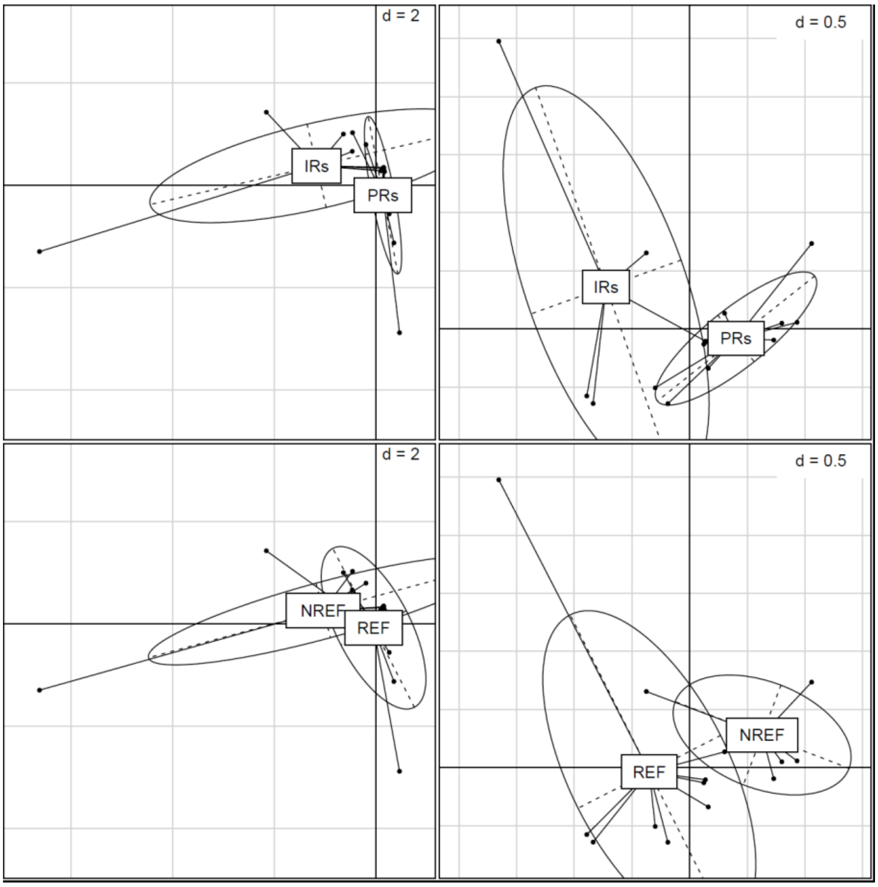
For the Shannon diversity index (Appendix 15), higher values were found in REF-PRs, REF-IRs and NREF_PRs from Catalonia than NREF_PRs and NREF_IRs (REF-PRs: k-w test = 7.5, p= 0.006; REF-IRs: k-w test = 5.5, p= 0.019; NREF-PRs: k-w test = 6, p= 0.014; NREF-IRs: k-w test = 1.5, p= 0.221). For the Simpson diversity index (Appendix 16), there were significant differences in all comparisons except for the NREF_IRs (REF-PRs: k-w test = 7.5, p= 0.006; REF-IRs: k-w test = 6.546, p= 0.011; NREF-PRs: k-w test = 6, p= 0.014; NREF-IRs: k-w test = 1.5, p= 0.221). Finally, for Rao index there were only significant differences in REF_PRs and REF_IRs (REF-PRs: k-w test = 7.5, p= 0.006; REF-IRs: k-w test = 3.682, p= 0.055; NREF-PRs: k-w test = 1.5, p= 0.221; NREF-IRs: k-w test = 1.5, p= 0.221).

Taxonomic and functional trait composition patterns

In Chile, biological traits were coded for 44 genera. Of these genera, 9 belonged to Plecoptera, 6 to Ephemeroptera, 10 to Trichoptera, 13 to Coleoptera (which 5 were larvae and 8 adults), 4 to Heteroptera, 1 to Megaloptera, and 3 belonged to Odonata, (Appendix 3 and 4). A complete trait information for only 29 genera was obtained from literature or coded by us using published information or expect opinion. The rest of genera were coded using the mean of each corresponding family or the closest taxon (Appendix 10). In Catalonia, 7 orders, 67 families, and 74 genera were used. Of these genera, 7 belonged to Plecoptera, 12 to Ephemeroptera, 23 to Trichoptera, 19 to Coleoptera, 6 to Heteroptera, and 8 to Odonata (Appendix 5 and Appendix 6). None Megaloptera was found.

The CA for PRs and IRs comparisons (Figure 1) showed different macroinvertebrate communities in both regions. However, the Randomisation test only showed significant differences for Catalonia (Chile: p= 0.344; Catalonia: p= 0.014).

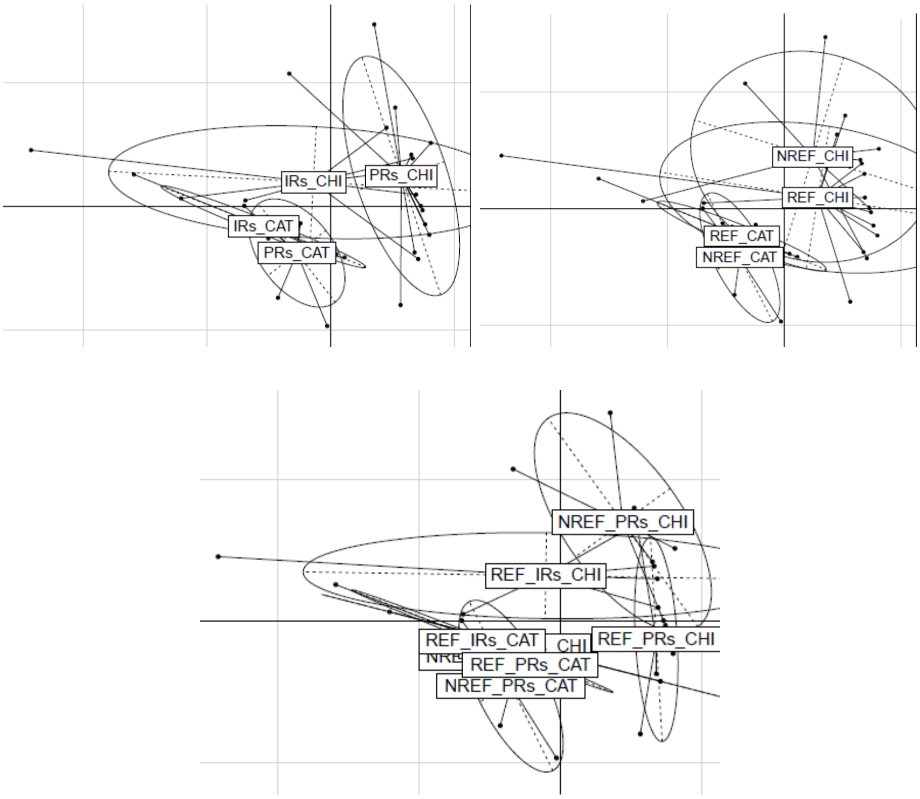
Figure 1: Correspondence Analysis (CA) on the taxonomic composition in PRs-IRs and REF-NREF in Chile (left columns) and in Catalonia (right columns). Each ellipse envelops 70% of samplings of a particular category.



For REF and NREF, significant different communities were found in both regions (Chile: p= 0.004; Catalonia: p= 0.004).

Regarding the biological trait composition, the FCA showed that macroinvertebrates in PRs and IRs comparison between both regions had significantly different trait composition (p= 0.001) (Figure 2). A similar pattern was found when comparing REF and NREF comparison between both regions (p= 0.002).

Figure 2: Fuzzy Correspondence Analysis (FCA) to find the similarities between the biological traits compositions of genres found in Chile and Catalonia. Grouped by PRs and IRs (up and left), by REF and NREF (up and right), and comparing the regional effects of the natural and the anthropogenic disturbance in both regions (down).



Finally, when analyzed separately for each category trait, Kruskal Wallis tests in PRs and IRs comparisons in both regions indicated that there were significant differences in 27 categories in Chile and in Catalonia, but different ones (Table 3). For REF and NREF comparisons, significantly differences were found in 26 categories in Chile and 28 in Catalonia (Table 3). In all comparisons, the most significant traits when Kruskal Wallis was applied were maximal size (a), locomotion (u), food (h), feeding habitats (i), body flexibility (m) and form (n), and specific attachment mechanism (o1: suckers, o3: mineral material-case).

Table 3. Separately analyses for each category of 9 traits which were significantly ($p < 0.05$) when Kruskal Wallis test was applied.

PRs and IRs in Chile	**PRs and IRs in Catalonia**	**REF and NREF in Chile**	**REF and NREF in Catalonia**
a5, a7, j1, j4, u1, u2, u6, u8, h1, h2 h4, h5, h6, h7, h8, h9, i2, i4, i6, i7, m1, m2, n1, n3, n4, o1, o3.	a5, a7, j1, j4, u1, u2, u8, h1, h2, h4, h5, h6, h7, h8, h9, i2, i4, i6, i7, m1, m2, n1, n3, n4, o1, o2, o3.	a4, a5, a7, j2, u1, u2, u3, u6, u8, h1, h2, h3, h4, h5, h8, h9, i2, i4, i7, m2, n1, n2, n3, n4, o1, o3.	a4, a5, a7, j2, u1, u2, u3, u6, u8, h1, h2, h3, h4, h5, h7, h8, h9, i2, i4, i7, m1, m2, n1, n2, n3, n4, o1, o3.

DISCUSSION

Biodiversity differences

As expected, no difference between PRs and IRs were found for any biodiversity metric in the Mediterranean climate regions of Chile and Catalonia. Lytle and Poff (2004) argue that flow predictability results in species adapted to particular flow conditions. The high predictability of the drought period in the Mediterranean climate has triggered many adaptations to drought conditions, such as species with synchronised life cycles to the drought period or with particular resistance strategies (Bonada and Resh, 2013). However, many of the IRs sampled were dried in

Regarding REF and NREF comparison in both regions, and in agreement with our hypothesis, a higher taxonomic biodiversity was found in REF than in NREF in Chile but not in Catalonia, which partially confirm that anthropogenic disturbances affecting NREF rivers are supposed to reduce their biodiversity (Chapter 1; Bonada et al., 2008). When comparing the regional effects of the natural and the anthropogenic disturbance in both regions, biodiversity was more affected by the anthropogenic disturbance than by the drought disturbance. Despite Mediterranean climate regions are subjected to severe human disturbances (Bonada and Resh, 2013), drought in the Mediterranean has a longer history. Actually, Mediterranean climate conditions date back from the Pliocene (Suc, 1984) and have had enough time to select for adaptive biological traits, shorten the differences between PRs and IRs in terms of biodiversity. Instead, higher similarities were found for NREF than for REF between both regions, because anthropogenic factors reduce their biodiversity dramatically (Bonada et al., 2008). In addition, although NREF_IRs in Catalonia has a very high value, generally, higher values were observed in REF_PRs and REF_IRs. This agrees with other studies which have shown that sites with similar hydrological characteristics should share similar biodiversity composition (Belmar et al., 2012). Therefore, as Poff et al. (2010) suggested, ecological responses of flow regimes to a given anthropogenic change (NREF) should be broadly similar in rivers with PRs than with IRs.

Community composition differences

As expected, almost no overlap in taxonomic and trait composition was found between PRs and IRs sites in both regions. Again, drought conditions have acted long enough in these Mediterranean climate regions to trigged evolutionary adaptations in river types (Bonada and Resh, 2013). On the other hand, this differentiation between PRs and IRs, may be also explained because ecological changes during the drying process may be gradual at first, but cessation of flow causes abrupt loss of habitat, alteration of physicochemical conditions in pools, and fragmentation of the watercourse (Bonada et al., 2008), resulting in severe effects to aquatic communities. Thus, composition in IRs shift to include species with strategies to survive the dry period. These strategies, as Delucchi & Peckarsky (1989) and Lytle and Poff (2004) suggested, include taxa that are able to migrate from the IRs to adjacent refuges or to the hyporheic zone, or have adaptations to survive in pool habitats.

As expected too, weak overlap in taxonomic and trait composition were found between NREF than in REF sites in both regions because anthropogenic disturbances are supposed to homogenize their communities, reduce biodiversity and select for generalist taxa (Bonada et al., 2008). In addition, this pattern could be explained because REF have higher habitat heterogeneity and thus host more specialist species than NREF (Bonada et al., 2007).

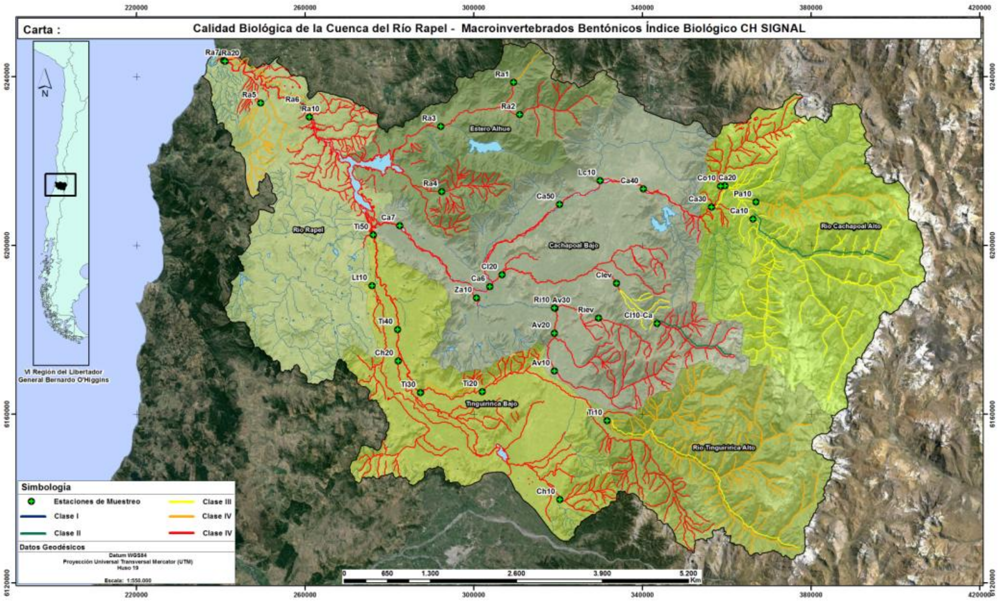
Finally, higher similarities between regions were found for the anthropogenic than for the natural disturbance for both, taxonomic and functional biodiversity and composition. Species in highly disturbed environments (NREF) are likely to have life histories and morphologies adapted to large and rapid shifts in environmental variables (Sheldon, 2005) which usually correspond to widely distributed species (Bonada et al., 2008) eroding any possible regional difference between Chile nad Catalonia. Thus, for example, Caenis is one of the genera present in both regions in NREF sites. Instead, species in natural disturbed environments, such as IRs, are characteristic species with traits adapted to these conditions. Again, as Suc (1984) indicated, in the Mediterranean climate natural disturbances of flood and drought are predictable and have acted long enough to enable species adaptations. Thus, the taxonomic community composition between Chile and Catalonia differs notably when analysing PRs and IRs. Different historical and environmental factors affecting both regions have resulted in particular and different species adapted to PRs and IRs in each region (Bonada and Resh, 2013). However, functional trait composition should be more similar, because traits are less sensible to regional differences (Rodríguez-Capítulo et al. 2009). Despite resistance strategies are recognized in almost all groups of aquatic organisms (Lytle and Poff 2004), specific traits were observed for PRs and IRs in both regions (Table 3), including those that enable endurance to droughts, such as the resistance cysts of macroinvertebrates (Bonada et al. 2007).

This study collected enough information to use this matrix of biological traits in Mediterranean area of Chile (see Appendix 14). However, due to the lack of information at the genus level for some orders, this matrix has focused in to aquatic insects except for Diptera. In addition, our matrix does not contain all Mediteranean genera from Chile, only those taxa collected in 11 rivers (Appendix 1). We encourage our colleagues experts in Chilean macroinvertebrate to provide information on the biological traits of all the genera found in the Mediterranean climate region of Chile to carry studies on functional aspects of macroinvertebrates.

Appendix 1: Reference and non-reference sampling sites in the Mediterranean region of Chile and Catalonia (Spain), separated by permanent (PRs) and intermittent (IRs) rivers. The code used for each sampling site appears in brackets. Non-reference sites include sites with anthropogenic disturbances of urban or/and land use, whereas reference sites include natural perturbations.

	REFERENCE		**NON-REFERENCE**	
	Permanent	**Intermittent**	**Permanent**	**Intermittent**
Catalunya	Tordera (T00)	Pineda (Pi01)	Vallvidrera (VV6)	Fuirosos (T30)
	Vallcàrquera (B35)	Avencó (B29)	Riera Major (Te22)	
	Vallforners (B08a)	Arenes (B07)		
Chile	Claro (CL_10)	Renegado (Re_1)	Cachapoal (CA_30)	Estero Yerba (MA_3)
	Diguillín (Di_1)	Afluente Cachapoal (MA_1)	Tinguiririca (Ti_30)	Nilhaue (MA_4)
	Lía (Lia)	Lonquen (LO)	Rapel (RA_10)	

Appendix 2: Map of the VI O'Higgins Region (34°10′02″S 70°43′37″O), with sampling located punts.



Appendix 3: Macroinvertebrates found in PRs and IRs in reference conditions in Chile. Samples taken in spring and summer.

			REFERENCE											
			PERMANENT						INTERMITTENT					
			CL_10		Di_1		LIA		Re_1		MA_1		LO	
ORDER	**FAMILY**	**GENUS**	**Oct-14**	**march-15**	**oct-14**	**march-15**	**des-14**	**march-15**	**oct-14**	**march-15**	**oct-14**	**march-15**	**des-14**	**march-15**
DIPTERA	Chironomidae	non-identified	157	7	212	84	23	28	773	14	197	7	19	19
	Simulidae	non-identified	3	0	1	5	0	0	67	40	33	0	0	0
	Empididae	non-identified	25	0	0	0	0	0	0	0	0	0	0	0
	Ceratopogonidae	non-identified	3	0	8	0	3	0	3	5	2	3	0	2
	Athericidae	non-identified	44	13	2	10	0	0	5	2	0	6	0	0
	Blephariceridae	non-identified	9	2	0	0	0	0	0	0	0	0	0	0
	Tipulidae	non-identified	0	0	4	0	0	0	108	0	0	0	0	0
	Syrphidae	non-identified	0	0	0	0	0	0	0	0	0	0	0	0
	Limoniidae	non-identified	0	0	7	0	0	1	2	3	0	0	0	0
COLEOPTERA	Elmidae	Austrelmis-larvae	0	16	0	0	5	13	0	0	0	18	0	0
	Psephenidae	Ectropia-larvae	0	0	0	0	0	0	2	0	0	0	0	0
	Elmidae	Hydora-larvae	0	0	8	12	0	0	8	3	0	0	0	0
	Elmidae	Macrelmis-larvae	38	2	0	0	2	4	12	3	8	5	0	0
	Elmidae	Stethelmis-larvae	0	8	3	4	1	5	0	0	0	2	0	0
	Gyrinidae	Andogyrus-adult	0	0	0	0	0	0	0	0	0	0	3	0
	Elmidae	Austrelmis-adult	4	3	1	4	0	0	2	0	1	66	0	0
	Dysticidae	Cybister-adult	0	0	0	0	0	0	0	0	0	0	2	0
	Hydrophilidae	Enochrus-adult	0	0	0	0	0	0	0	0	0	2	6	0
	Hydrophilidae	Hemiosus(Berosini)-adult	0	0	0	0	0	0	0	0	0	0	0	0
	Hydraenidae	Hydraenida-adult	0	0	0	0	0	0	0	0	0	0	0	0
	Noteridae	Notomicrus-adult	0	0	0	0	0	0	0	0	1	0	0	0
	Dysticidae	Rhantus-adult	0	0	0	0	0	0	0	0	0	0	1	1
TRICHOPTERA	Helicophidae	Austrocentrus	0	0	0	0	0	0	0	0	0	0	0	0
	Hydrobiosidae	Cailloma-Parachoerma	0	0	0	2	0	0	0	0	4	0	0	0
	Glossosmatidae	Mastigoptila	0	0	0	0	0	0	2	0	0	0	0	0
	Hydroptilidae	Metrichia-Ochrotrichia	3	0	0	24	0	0	5	1	0	12	0	0
	Leptoceridae	Oecetis(?)	0	0	0	0	0	0	0	0	0	0	0	0
	Glossosmatidae	Protoptila	47	0	0	0	0	0	0	0	0	0	0	0
	Hydropsychidae	Smicridea	7	8	28	61	0	0	58	20	47	51	0	0

	Philopotamidae	Sortosa	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	Triplectides(?)	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	Trianodes	0	0	0	0	0	6	0	0	0	0	0	0
EPHEMEROPTERA	Baetidae	Andesiops	43	16	52	11	0	0	43	32	45	36	7	0
	Caenidae	Caenis	4	0	0	0	0	0	0	0	0	0	10	0
	Leptophlebiidae	Demoulinellus	48	59	17	0	3	5	0	0	0	2	0	0
	Leptophlebiidae	Meridialaris	0	0	11	15	0	0	14	8	5	0	0	0
	Leptophlebiidae	Penaphlebia	4	2	6	0	0	0	14	0	14	0	0	0
	Oniscigastridae	Siphonella	16	0	0	0	3	0	0	0	0	0	0	0
PLECOPTERA	Gripopterygidae	Antarctoperla	0	0	0	0	0	0	0	0	0	0	0	0
	Gripopterygidae	Aubertoperla	0	0	12	0	0	0	17	13	0	0	0	0
	Diamphipnoidae	Diamphipnoa	0	0	0	0	0	0	0	0	0	0	0	0
	Diamphipnoidae	Diamphipnopsis	0	0	0	0	0	0	0	0	0	0	0	0
	Perlidae	Inconeuria	0	0	0	0	0	0	0	0	0	0	0	0
	Gripopterygidae	Limnoperla	11	0	35	0	0	0	5	0	0	0	0	0
	Gripopterygidae	Notoperlopsis	0	0	0	8	0	2	0	0	0	0	0	0
	Gripopterygidae	Pelugoperla	0	0	0	0	0	0	0	0	0	0	0	0
	Austroperlidae	Penturoperla	0	0	0	0	0	0	0	0	0	0	0	0
AMPHIPODA	Hyalellidae	Hyalella	0	0	0	0	0	0	15	2	0	0	20	0
MOLLUSCA	Planorbidae	Antillorbis	0	0	0	0	0	0	0	0	0	0	0	0
	Amnicolidae	Bromphalaria chilensis	0	0	0	0	0	0	0	0	0	0	0	0
	Chilinidae	Chilina dombeyana	0	0	0	0	0	0	16	3	0	0	0	0
	Planorbidae	Gundlachia gayana	0	4	0	0	0	0	0	0	0	0	5	0
	Amnicolidae	Littoridina	0	0	1	1	0	1	9	0	0	2	0	0
	Physidae	Physa Chilensis	0	0	0	0	0	0	0	0	0	8	3	0
HETEROPTERA	Gerridae	Aquarius	0	0	0	0	0	0	0	0	0	1	0	0
	Belostomatidae	Belostoma	0	0	0	0	0	1	0	0	0	0	3	1
	Gerridae	Eurygerris	0	0	0	0	0	0	0	0	0	1	0	0
	Corixidae	Tenagobia	0	0	0	0	0	0	0	0	0	6	0	0
MEGALOPTERA	Corydalidae	Protochauliodes	0	4	1	5	0	0	0	2	0	2	0	0
ODONATA	Aeshnidae	non-identified-Aeshnidae	0	0	0	0	0	0	0	0	0	1	3	0
	Gomphidae	non-identified-Gomphidae	0	0	1	0	0	0	1	0	0	0	0	0
	Libellulidae	Libellulinae	0	0	0	0	0	0	0	0	0	0	0	1
DECAPODA	Brachyura Trichodactylidae	/////	0	0	0	0	0	0	0	0	0	0	0	0
	Aeglidae	Aegla	0	0	1	1	3	2	0	0	0	0	0	0

Appendix 4: Macroinvertebrates found in PRs and IRs in non-reference conditions in Chile. Samples taken in spring and summer.

			NON-REFERENCE									
			PERMANENT						INTERMITTENT			
			CA_30		Ti_30		RA_10		MA_4		MA_3	
ORDER	**FAMILY**	**GENUS**	**october-14**	**march-15**	**october-14**	**march-15**	**october-14**	**march-15**	**october-14**	**march-15 (*)**	**october-14**	**march-15 (*)**
DIPTERA	Chironomidae	non-identified	24	134	1068	12	78	4	374	0	227	0
	Simulidae	non-identified	0	2	154	0	0	0	1	0	0	0
	Empididae	non-identified	0	0	0	0	0	0	0	0	11	0
	Ceratopogonidae	non-identified	1	3	2	0	0	0	4	0	0	0
	Athericidae	non-identified	0	0	0	0	0	0	0	0	0	0
	Blephariceridae	non-identified	0	0	0	0	0	0	0	0	0	0
	Tipulidae	non-identified	0	0	0	0	0	0	1	0	2	0
	Syrphidae	non-identified	0	0	0	0	0	0	0	0	2	0
	Limoniidae	non-identified	0	2	0	0	0	0	0	0	0	0
COLEOPTERA	Elmidae	Austrelmis-larvae	0	0	0	0	0	0	0	0	0	0
	Psephenidae	Ectropia-larvae	0	0	0	0	0	0	0	0	0	0
	Elmidae	Hydora-larvae	0	0	0	0	0	0	0	0	0	0
	Elmidae	Macrelmis-larvae	0	4	13	0	0	0	0	0	0	0
	Elmidae	Stethelmis-larvae	0	0	0	0	0	0	0	0	0	0
	Gyrinidae	Andogyrus-adult	0	0	0	0	0	0	0	0	0	0
	Elmidae	Austrelmis-adult	2	7	0	1	0	0	0	0	0	0
	Dysticidae	Cybister-adult	0	0	0	0	0	0	0	0	1	0
	Hydrophilidae	Enochrus-adult	0	0	0	0	0	0	0	0	0	0
	Hydrophilidae	Hemiosus(Berosini)-adult	0	0	0	2	0	0	0	0	0	0
	Hydraenidae	Hydraenida-adult	0	0	0	0	0	0	1	0	0	0
	Noteridae	Notomicrus-adult	0	0	0	0	0	0	0	0	0	0
	Dysticidae	Rhantus-adult	0	0	0	0	0	0	0	0	1	0
TRICHOPTERA	Helicophidae	Austrocentrus	0	0	0	0	0	0	0	0	0	0
	Hydrobiosidae	Cailloma-Parachoerma	0	0	0	0	0	0	0	0	0	0
	Glossosmatidae	Mastigoptila	0	0	0	0	0	0	0	0	0	0
	Hydroptilidae	Metrichia-Ochrotrichia	0	0	31	0	3	0	0	0	0	0
	Leptoceridae	Oecetis(?)	0	0	0	0	0	0	0	0	0	0
	Glossosmatidae	Protoptila	0	0	0	0	0	0	0	0	0	0

	Hydropsychidae	Smicridea	0	9	1	30	1	0	0	0	0	0
	Philopotamidae	Sortosa	1	0	0	0	0	0	0	0	0	0
	Leptoceridae	Triplectides(?)	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	Trianodes	0	0	0	0	0	0	0	0	0	0
EPHEMEROPTERA	Baetidae	Andesiops	2	6	115	7	0	0	4	0	2	0
	Caenidae	Caenis	0	0	0	0	2	0	0	0	0	0
	Leptophlebiidae	Demoulinellus	0	1	0	0	0	0	0	0	0	0
	Leptophlebiidae	Meridialaris	0	0	2	0	0	0	0	0	0	0
	Leptophlebiidae	Penaphlebia	0	0	0	0	0	0	0	0	0	0
	Oniscigastridae	Siphonella	0	0	0	0	0	0	4	0	0	0
PLECOPTERA	Gripopterygidae	Antarctoperla	0	0	0	0	0	0	0	0	0	0
	Gripopterygidae	Aubertoperla	0	0	0	0	0	0	0	0	0	0
	Diamphipnoidae	Diamphipnoa	0	0	0	0	0	0	0	0	0	0
	Diamphipnoidae	Diamphipnopsis	0	0	0	0	0	0	0	0	0	0
	Perlidae	Inconeuria	0	0	0	0	0	0	0	0	0	0
	Gripopterygidae	Limnoperla	0	0	0	0	0	0	0	0	0	0
	Gripopterygidae	Notoperlopsis	0	4	0	0	0	0	0	0	0	0
	Gripopterygidae	Pelugoperla	0	0	0	0	0	0	0	0	0	0
	Austroperlidae	Penturoperla	0	0	0	0	0	0	0	0	0	0
AMPHIPODA	Hyalellidae	Hyalella	0	0	0	0	1	0	2	0	0	0
MOLLUSCA	Planorbidae	Antillorbis	0	0	0	0	0	0	1	0	0	0
	Amnicolidae	Bromphalaria chilensis	0	0	0	0	0	0	0	0	24	0
	Chilinidae	Chilina dombeyana	0	0	0	0	0	0	0	0	0	0
	Planorbidae	Gundlachia gayana	0	0	0	0	0	0	0	0	0	0
	Amnicolidae	Littoridina	0	0	0	0	6	0	0	0	0	0
	Physidae	Physa Chilensis	0	0	0	63	3	0	13	0	4	0
HETEROPTERA	Gerridae	Aquarius	0	0	0	0	0	0	0	0	0	0
	Belostomatidae	Belostoma	0	0	0	0	0	0	0	0	0	0
	Gerridae	Eurygerris	0	0	0	0	0	0	0	0	0	0
	Corixidae	Tenagobia	0	0	0	23	0	0	0	0	0	0
MEGALOPTERA	Corydalidae	Protochauliodes	0	0	0	0	0	0	0	0	0	0
ODONATA	Aeshnidae	non-identified-Aeshnidae	0	0	0	0	0	0	0	0	0	0
	Gomphidae	non-identified-Gomphidae	0	0	0	0	0	0	0	0	0	0
	Libellulidae	Libellulinae	0	0	0	0	0	0	0	0	0	0

DECAPODA	Brachyura Trichodactylidae	/////	0	0	0	0	0	0	0	0	0	0
	Aeglidae	Aegla	0	0	0	0	0	0	0	0	0	0

Appendix 5: Macroinvertebrates found in PRs and IRs in reference conditions in Catalonia. Samples taken in spring and summer. Rank abundance data (1 from 1 to 3 individuals, 2 from 4 to 10 individuals, 3 from 11 to 100 individuals, 4 for more than 100 individuals).

			REFERENCE											
			PERMANENT						**INTERMITTENT**					
			T00	**T00**	**B35**	**B35**	**B08a**	**B08a**	**B07**	**B07**	**B29**	**B29**	**Pi01**	**Pi01**
Order	**Family**	**Genera**	may-14	july-14	may-14	july-14	may-14	july-14	may-14	july-14	may-14	july-14	may-14	june-14
DIPTERA	Ceratopogonidae	non-identified	3	3	3	0	1	0	2	0	2	3	0	2
	Stratiomyidae	non-identified	0	0	2	0	0	0	0	0	0	0	0	0
	Athericidae	non-identified	1	2	0	0	0	0	0	0	1	1	0	0
	Limoniidae	non-identified	0	0	2	0	0	0	0	0	0	1	0	0
	Dixidae	non-identified	0	1	0	0	0	0	0	0	0	3	0	1
	Tipulidae	non-identified	0	1	0	0	1	0	0	0	0	0	0	0
	Empididae	non-identified	3	2	0	0	1	0	0	0	0	3	0	0
	Dolichopodidae	non-identified	0	0	0	0	0	0	0	0	0	0	0	0
	Anthomyidae	non-identified	0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae	non-identified	0	0	0	0	0	0	0	0	0	0	0	2
	Chironomidae	non-identified	4	4	4	4	4	0	4	0	4	4	0	4
	Psychodidae	non-identified	0	0	0	0	3	0	0	0	1	2	0	2
	Simuliidae	non-identified	0	2	0	0	3	0	0	0	3	3	0	0
	Culicidae	non-identified	0	0	0	0	0	0	2	0	0	2	0	0
COLEOPTERA	Dryopidae	Dryops	0	0	0	0	0	0	1	0	0	1	0	0

	Dytiscidae	Meladema	0	0	0	0	0	0	0	0	0	0	0	0
	Elmidae	Oulimnius	0	0	0	0	0	0	0	0	0	0	0	2
	Dytiscidae	Deronectes	0	0	0	0	0	0	0	0	2	3	0	1
	Elmidae	Esolus	1	0	0	0	0	0	0	0	0	0	0	0
	Hydrophilidae	Hydrobius	0	0	0	0	0	0	0	0	0	0	0	0
	Dytiscidae	Laccophilus	0	0	0	0	0	0	0	0	0	0	0	0
	Dytiscidae	Laccobius	0	0	0	0	0	0	0	0	0	0	0	0
	Dytiscidae	Agabus	0	0	0	0	0	0	1	0	0	0	0	2
	Dytiscidae	Stictonectes	0	0	0	0	0	0	3	0	0	0	0	0
	Dytiscidae	Yola	0	0	0	0	0	0	2	0	2	0	0	0
	Elmidae	Limnius	0	0	3	3	1	0	0	0	0	0	0	0
	Elmidae	Elmis	0	2	3	0	4	0	0	0	0	2	0	2
	Gyrinidae	Gyrinus	0	0	0	0	0	0	2	0	0	0	0	0
	Dytiscidae	Platambus	0	0	0	2	0	0	0	0	0	0	0	0
	Haliplidae	Haliplus	0	0	0	0	0	0	2	0	0	0	0	0
	Helodidae	Elodes	0	0	3	3	0	0	0	0	1	2	0	3
	Helodidae	Hydrocyphon	0	0	0	0	0	0	0	0	2	0	0	0
	Hydraenidae	Hydraena	2	2	2	3	3	0	0	0	2	3	0	2
EPHEMEROPTERA	Baetidae	Baetis	4	2	4	4	4	0	0	0	4	4	0	4
	Baetidae	Centroptilum	0	0	0	0	0	0	0	0	0	0	0	0
	Baetidae	Cloeon	0	0	0	0	0	0	0	0	0	0	0	0
	Caenidae	Caenis	0	0	0	0	0	0	0	0	0	0	0	0
	Ephemerellidae	Serratella	3	0	2	0	3	0	0	0	1	1	0	2
	Heptageniidae	Rhithrogena	0	1	0	0	0	0	0	0	0	0	0	0
	Heptageniidae	Epeorus	3	1	1	0	4	0	0	0	0	0	0	0
	Ephemeridae	Ephemera	1	0	1	0	0	0	0	0	0	0	0	1
	Heptageniidae	Ecdyonurus	3	3	3	4	4	0	0	0	3	3	0	4
	Heptageniidae	Electrogena	0	0	0	0	0	0	0	0	1	2	0	0

	Leptophlebiidae	Habroleptoides	0	4	3	0	0	0	0	0	2	1	0	0
	Leptophlebiidae	Habrophlebia	3	4	3	3	0	0	4	0	0	2	0	0
HETEROPTERA	Hydrometridae	Hydrometra	0	0	0	2	0	0	2	0	0	0	0	0
	Gerridae	Gerris	0	3	0	0	3	0	0	0	0	0	0	0
	Corixidae	Micronecta	0	0	0	2	0	0	0	0	0	0	0	0
	Notonectidae	Hydro	0	0	0	0	0	0	0	0	0	0	0	0
	Notonectidae	Notonecta	0	0	0	2	0	0	0	0	0	0	0	0
	Veliidae	Velia	0	3	0	1	3	0	2	0	3	3	0	2
HIRUDINOIDEA	Erpobdellidae	Erpobdella	0		2	2	0	0	0	0	2	2	0	0
	Erpobdellidae	Dina	0		0	0	0	0	2	0	0	0	0	0
MOLUSCA	Hydrobiidae	Potamopyrgus	0	0	4	4	0	0	0	0	0	0	0	0
	Lymnaeidae	Radix	0	0	0	0	0	0	0	0	0	0	0	0
	Sphaeriidae	Sphaerium	0	0	0	0	0	0	0	0	0	0	0	0
	Sphaeriidae	Pisidium	0	0	0	0	0	0	0	0	0	0	0	0
	Ancylidae	Ancylus	1	2	3	3	3	0	2	0	2	0	0	0
ODONATA	Lestidae	Chalcolestes	0	0	1	0	0	0	3	0	0	0	0	0
	Aeshnidae	Boyeria	1	1	0	0	0	0	0	0	0	0	0	0
	Lestidae	Chalcolestes	0	0	0	0	0	0	0	0	0	0	0	0
	Libellulidae	Sympetrum	0	0	0	0	0	0	1	0	0	0	0	0
	Aeshnidae	Aeshna	0	0	0	3	0	0	0	0	0	0	0	0
	Calopterygidae	Calopteryx	1	2	0	0	2	0	0	0	0	0	0	1
	Cordulegasteridae	Cordulegaster	1	2	0	0	0	0	0	0	0	0	0	1
	Gomphidae	Onychogomphus	0	3	1	0	0	0	0	0	0	0	0	0
PLECOPTERA	Chloroperlidae	Siphonoperla	2	0	0	0	0	0	0	0	2	0	0	0
	Leuctridae	Leuctra	3	4	0	0	2	0	0	0	2	3	0	0
	Nemouridae	Protonemura	0	4	0	0	0	0	0	0	4	3	0	0
	Nemouridae	Amphinemura	2	0	0	0	0	0	0	0	0	0	0	0
	Nemouridae	Nemoura	0	0	0	0	0	0	0	0	0	3	0	0

	Perlidae	Perla	1	4	1	0	0	0	0	0	0	0	0	0
	Perlodidae	Isoperla	0	0	3	0	0	0	0	0	3	3	0	0
TRICHOPTERA	Glossosomatidae	Synagapetus	2	0	3	0	2	0	0	0	3	3	0	0
	Lepidostomatidae	Lepidostoma	3	2	0	0	0	0	0	0	2	3	0	0
	Leptoceridae	Oecetis	1	0	0	0	0	0	0	0	0	0	0	0
	Limnephilidae	Chaetopteryx	0	0	0	2	3	0	0	0	3	3	0	0
	Philopotamidae	Wormaldia	0	0	0	0	0	0	0	0	2	0	0	0
	Sericostomatidae	Sericostoma	2	3	0	3	0	0	0	0	2	2	0	1
	Leptoceridae	Triaenodes	1	0	0	0	0	0	0	0	0	0	0	0
	Limnephilidae	Halesus	3	2	0	2	4	0	0	0	0	0	0	0
	Polycentropodidae	Polycentropus	2	1	0	0	0	0	0	0	0	0	0	0
	Hydroptilidae	Ptilocoletus	0	0	0	0	0	0	0	0	0	3	0	0
	Hydropsychidae	Hydropsyche	1	0	3	0	3	0	0	0	0	0	0	2
	Limnephilidae	Potamophylax	3	2	4	0	3	0	0	0	0	0	0	0
	Odontoceridae	Odontocerum	1	0	3	4	0	0	0	0	0	0	0	3
	Leptoceridae	Adicella	0	2	0	0	0	0	0	0	0	0	0	0
	Psychomyiidae	Tinodes	0	0	2	2	0	0	0	0	0	0	0	1
	Leptoceridae	Mystacides	0	0	0	3	0	0	0	0	0	0	0	0
	Limnephilidae	Limnephilus	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	Philopotamus	0	0	0	2	1	0	0	0	0	0	0	2
	Limnephilidae	Allogamus	0	0	0	0	0	0	0	0	0	1	0	0
	Hydroptilidae	Hydroptila	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	Chimarra	0	0	0	0	0	0	0	0	0	0	0	0
	Psychomyiidae	Psychomyia	0	0	0	0	0	0	0	0	0	0	0	0
	Rhyacophilidae	Rhyacophila	0	0	0	0	0	0	0	0	0	0	0	0
	Rhyacophilidae	Hyporhyacophila	1	0	0	0	0	0	0	0	0	1	0	0
AMPHIDODA	Gammaridae	Echinogammarus	0	0	4	2	4	0	0	0	0	0	0	4
TRICLÀRIDES	Planariidae	non-identified	1	2	0	0	0	0	0	0	0	0	0	0

	Dugesiidae	Dugesia	0	3	0	0	4	0	0	0	0	0	0	0
CNIDARIA	Hydridae	Hydra	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 6: Macroinvertebrates found in PRs and IRs in non-reference conditions in Catalonia. Samples taken in spring and summer. Rank abundance data (1 from 1 to 3 individuals, 2 from 4 to 10 individuals, 3 from 11 to 100 individuals, 4 for more than 100 individuals).

			NON-REFERENCE					
			PERMANENT				**INTERMITTENT**	
			VV6	**VV6**	**Te22**	**Te22**	**T30**	**T30**
Order	**Family**	**Genera**	may-14	july-14	may-14	july-14	may-14	july-14
DIPTERA	Ceratopogonidae	non-identified	0	3	1	3	0	0
	Stratiomyidae	non-identified	0	1	0	0	0	0
	Athericidae	non-identified	0	0	0	0	0	0
	Limoniidae	non-identified	0	0	3	3	3	0
	Dixidae	non-identified	0	0	0	0	3	0
	Tipulidae	non-identified	0	0	3	0	0	0
	Empididae	non-identified	0	0	1	0	0	0
	Dolichopodidae	non-identified	0	0	1	0	0	0
	Anthomyidae	non-identified	0	0	1	1	0	0
	Tabanidae	non-identified	0	0	0	1	0	0
	Chironomidae	non-identified	4	0	4	4	4	0
	Psychodidae	non-identified	0	2	0	3	0	0
	Simuliidae	non-identified	0	2	4	4	3	0
	Culicidae	non-identified	0	0	0	0	0	0
COLEOPTERA	Dryopidae	Dryops	0	0	0	0	0	0
	Dytiscidae	Meladema	0	0	0	3	0	0

	Elmidae	Oulimnius	0	0	0	3	4	0
	Dytiscidae	Deronectes	0	0	0	0	0	0
	Elmidae	Esolus	0	0	0	0	0	0
	Hydrophilidae	Hydrobius	0	0	0	0	1	0
	Dytiscidae	Laccophilus	0	0	0	1	2	0
	Dytiscidae	Laccobius	0	0	3	3	2	0
	Dytiscidae	Agabus	0	0	0	0	0	0
	Dytiscidae	Stictonectes	0	0	0	0	0	0
	Dytiscidae	Yola	0	0	0	0	1	0
	Elmidae	Limnius	0	0	0	3	0	0
	Elmidae	Elmis	2	2	2	3	0	0
	Gyrinidae	Gyrinus	0	0	0	3	0	0
	Dytiscidae	Platambus	0	0	0	0	0	0
	Haliplidae	Haliplus	0	0	0	0	0	0
	Helodidae	Elodes	0	0	1	0	0	0
	Helodidae	Hydrocyphon	0	0	0	0	0	0
	Hydraenidae	Hydraena	0	0	0	0	3	0
EPHEMEROPTERA	Baetidae	Baetis	3	4	4	4	4	0
	Baetidae	Centroptilum	0	0	1	1	0	0
	Baetidae	Cloeon	0	0	0	0	3	0
	Caenidae	Caenis	1	0	3	3	3	0
	Ephemerellidae	Serratella	0	0	2	0	3	0
	Heptageniidae	Rhithrogena	0	0	0	0	0	0
	Heptageniidae	Epeorus	0	0	3	0	0	0
	Ephemeridae	Ephemera	0	0	1	0	0	0
	Heptageniidae	Ecdyonurus	0	0	3	0	3	0
	Heptageniidae	Electrogena	0	0	0	0	1	0
	Leptophlebiidae	Habroleptoides	0	0	0	0	4	0

	Leptophlebiidae	Habrophlebia	0	0	1	0	4	0
HETEROPTERA	Hydrometridae	Hydrometra	0	0	0	1	2	0
	Gerridae	Gerris	0	0	3	3	0	0
	Corixidae	Micronecta	0	0	1	4	0	0
	Notonectidae	Hydro	0	0	0	1	0	0
	Notonectidae	Notonecta	0	0	0	0	1	0
	Veliidae	Velia	0	0	0	0	3	0
HIRUDINOIDEA	Erpobdellidae	Erpobdella	0	0	0	0	0	0
	Erpobdellidae	Dina	0	0	0	0	0	0
MOLUSCA	Hydrobiidae	Potamopyrgus	4	4	1	2	1	0
	Lymnaeidae	Radix	0	4	0	1	0	0
	Sphaeriidae	Sphaerium	0	0	0	1	0	0
	Sphaeriidae	Pisidium	0	0	1	0	0	0
	Ancylidae	Ancylus	1	3	0	3	3	0
ODONATA	Lestidae	Chalcolestes	0	0	0	0	0	0
	Aeshnidae	Boyeria	0	0	0	0	0	0
	Lestidae	Chalcolestes	0	0	0	0	3	0
	Libellulidae	Sympetrum	0	0	0	0	3	0
	Aeshnidae	Aeshna	0	0	0	0	0	0
	Calopterygidae	Calopteryx	2	1	0	0	0	0
	Cordulegasteridae	Cordulegaster	1	0	0	0	0	0
	Gomphidae	Onychogomphus	0	0	1	1	0	0
PLECOPTERA	Chloroperlidae	Siphonoperla	0	0	0	0	0	0
	Leuctridae	Leuctra	0	0	3	3	1	0
	Nemouridae	Protonemura	0	0	0	0	0	0
	Nemouridae	Amphinemura	0	0	0	0	0	0
	Nemouridae	Nemoura	0	0	0	0	0	0
	Perlidae	Perla	0	0	0	0	0	0

	Perlodidae	Isoperla	0	0	0	0	3	0
TRICHOPTERA	Glossosomatidae	Synagapetus	0	0	0	0	0	0
	Lepidostomatidae	Lepidostoma	0	0	0	0	0	0
	Leptoceridae	Oecetis	0	0	0	0	0	0
	Limnephilidae	Chaetopteryx	0	0	0	0	0	0
	Philopotamidae	Wormaldia	0	0	0	0	0	0
	Sericostomatidae	Sericostoma	0	0	0	0	0	0
	Leptoceridae	Triaenodes	0	0	0	0	0	0
	Limnephilidae	Halesus	0	0	3	0	1	0
	Polycentropodidae	Polycentropus	0	0	1	0	0	0
	Hydroptilidae	Ptilocoletus	0	0	0	0	0	0
	Hydropsychidae	Hydropsyche	0	0	3	3	1	0
	Limnephilidae	Potamophylax	0	0	0	0	0	0
	Odontoceridae	Odontocerum	0	0	0	3	0	0
	Leptoceridae	Adicella	0	0	0	0	0	0
	Psychomyiidae	Tinodes	0	0	0	0	0	0
	Leptoceridae	Mystacides	0	0	0	3	0	0
	Limnephilidae	Limnephilus	0	0	0	0	1	0
	Philopotamidae	Philopotamus	0	0	0	0	0	0
	Limnephilidae	Allogamus	0	0	0	0	0	0
	Hydroptilidae	Hydroptila	0	0	3	3	0	0
	Philopotamidae	Chimarra	0	0	1	0	0	0
	Psychomyiidae	Psychomyia	0	0	1	3	0	0
	Rhyacophilidae	Rhyacophila	0	0	3	1	0	0
	Rhyacophilidae	Hyporhyacophila	0	0	3	0	0	0
AMPHIDODA	Gammaridae	Echinogammarus	4	4	0	0	0	0
TRICLÀRIDES	Planariidae	non-identified	0	0	0	0	0	0
	Dugesiidae	Dugesia	0	0	3	1	1	0

CNIDARIA	Hydridae	Hydra	0	0	0	0	3	0

Appendix 7: Phisico-chemical table for Chile sites. Flow item indicates: 1=no, 2=dry 3=disconnected pools.

			OCTOBER 2014						MARCH 2015					
Code	PRs or IRs	REF	Data	Flow	T ºC	Cond µS/cm^2	pH	O_2 mg/l	data	Flow	T ºC	Cond µS/cm^2	pH	O_2 mg/l
CL_10	PRS	No	06/10/2014	1	15.09	70	7.31	9.75	06/03/2015	1	14.21	78	7.57	14.60
CA_30	PRs	Yes	06/10/2014	1	15.6	480	7.25	9.45	05/03/2015	1	15.49	600	7.41	10.79
Ti_30	PRs	Yes	06/10/2014	1	20.4	245	7.45	8.89	06/03/2015	1	22.3	305	7.68	12.88
RA_10	PRs	Yes	07/10/2014	1	14.9	400	7.17	10.78	05/03/2015	1	22.8	490	7.78	10.60
MA_1	Irs	No	06/10/2014	1	11.42	111	7.36	9.2	05/03/2015	3	18.19	380	7.15	11.2
MA_4	IRs	Yes	07/10/2014	1	21	156	7.4	9.61	05/03/2015	2	///	///	///	///
MA_3	IRs	Yes	07/10/2014	1	26.3	180	7.34	7.81	05/03/2015	2	///	///	///	///
Lia	PRs	No	22/12/2014	1	11.3	25	8.32	10.9	12/03/2015	1	14.5	40.1	7.89	10.15
Di_1	IRs	No	17/10/2014	1	13.8 (*)	76 (*)	7.74	85 (*)	10/03/2015	1	///	///	///	///
Re_1	PRs	No	17/10/2014	1	12	187	7.97	44 (*)	10/03/2015	1	///	///	///	///
LO	IRs	No	17/12/2014	3	32.4	210	7.45	/////	30/01/2015	3	23	186	7.64	6.8

Appendix 8: Table with IHF index for Chilean rivers.

Rivers Code	Embeddedness in riffles and runs – sedimentation in pools	Riffle frequency	Substrate composition	Velocity/depth regime	Shading of river bed	Heterogeneity components	Aquatic vegetation cover	Final score
Ti_30	0	2	17	4	3	6	20	52
CL_10	5	10	17	6	3	0	10	51
CA_30	10	4	14	6	3	4	0	41
RA_10	10	2	14	6	3	4	0	39
MA_1	10	10	20	6	3	0	10	59
MA_3	10	2	14	4	3	0	10	43
MA_4	10	2	14	4	3	0	15	48
Di_1	20	10	17	6	3	2	5	63
Re_1	20	10	20	6	5	6	10	77
LIA	5	10	17	6	3	0	10	51
LO	0	4	14	6	3	0	5	32

Appendix 9: Table with QBR index for Chilean rivers.

Rivers Code	Geomorphological type	Total riparian cober	Cover structure	Cover quality	Channel alternation	Final score
Ti_30	3	0	10	0	0	10
CL_10	2	15	10	20	25	60
CA_30	1	10	5	5	15	35
RA_10	1	15	15	20	0	50
MA_1	3	0	5	5	10	20
MA_3	3	0	0	0	10	10
MA _4	3	0	5	0	10	15
Di_1	3	0	5	5	10	20
Re_1	2	15	15	15	10	55
LIA	2	15	10	15	25	65
LO	3	0	5	0	10	15

Appendix 10: Table with the extracted information of genera, which is used to create the matrix of biological traits (see Appendix 3) of Mediterranean area in Chile. Specifically, the extracted information indicated with numbers from 1 to 9, which mean: **1:** Tomanova & Usseglio-Polatera, 2007; **2:** Reynaga & Dos Santos, 2012; **3:** Domínguez & Fernández, 2009; **4:** Stark et al.: South American Stoneflies (Plecoptera); **5:** Dominguez et al., 2006: Ephemeroptera of South America; **6:** Thesis from Ovalle, 2012; **7:** own criteria, from information articles and books cited; **8:** own criterio for "p" trait; **9:** Equador matrix of biological traits.

FAMILY	GENUS	INFORMATION EXTRACTION	TRAIT LEVEL
Elmidae	Austrelmis-larvae	1, 3, 6, 7, 8	Genera
Psephenidae	Ectropia-larvae	1, 3, 6, 7, 8	Family
Elmidae	Hydora-larvae	1, 3, 6, 7, 8	Genera
Elmidae	Macrelmis-larvae	1, 3, 6, 7, 8	Genera
Elmidae	Stethelmis-larvae	1, 3, 6, 7, 8	Genera
Gyrinidae	Andogyrus-adult	3, 8	Family
Elmidae	Austrelmis-adult	1, 3, 8, 9	Genera
Dysticidae	Cybister-adult	3, 7, 8	Family
Hydrophilidae	Enochrus-adult	1, 3, 8	Family
Hydrophilidae	Hemiosus(Berosini)-adult	1, 3, 8	Family
Hydraenidae	Hydraenida-adult	3, 7, 8	Family
Noteridae	Notomicrus-adult	3, 7, 8	Family
Dysticidae	Rhantus-adult	3, 7, 8	Family
Helicophidae	Austrocentrus	3, 6, 8	Family
Hydrobiosidae	Cailloma-Parachoerma	1, 2, 3, 6, 8	Genera
Glossosmatidae	Mastigoptila	1, 3, 8	Family
Hydroptilidae	Metrichia-Ochrotrichia	1, 2, 3, 8	Genera
Leptoceridae	Oecetis(?)	1, 2, 3, 6, 8	Genera
Glossosmatidae	Protoptila	1, 2, 3, 8	Genera
Hydropsychidae	Smicridea	1, 2, 3, 6, 8	Genera
Philopotamidae	Sortosa	1, 3, 8	Family
Leptoceridae	Triplectides(?)	1, 3, 8	Family
Leptoceridae	Trianodes	1, 3, 8	Family
Baetidae	Andesiops	1, 3, 5, 6, 8	Genera
Caenidae	Caenis	2, 3, 5, 8	Genera
Leptophlebiidae	Demoulinellus	3,5, 8	Genera
Leptophlebiidae	Meridialaris	3, 5, 6, 8	Genera
Leptophlebiidae	Penaphlebia	3, 5, 6, 8	Genera
Oniscigastridae	Siphonella	3,5, 7, 8	Genera
Gripopterygidae	Antarctoperla	3, 4, 6, 8	Genera
Gripopterygidae	Aubertoperla	3, 4, 6, 8	Genera
Diamphipnoidae	Diamphipnoa	3, 4, 6, 8	Genera
Diamphipnoidae	Diamphipnopsis	3, 4, 6, 8	Genera
Perlidae	Inconeuria	1, 3, 4, 6, 8	Genera

Gripopterygidae	Limnoperla	3, 4, 6, 8	Genera
Gripopterygidae	Notoperlopsis	3, 4, 8	Genera
Gripopterygidae	Pelugoperla	3, 4, 6, 8	Genera
Austroperlidae	Penturoperla	3, 4, 8	Genera
Gerridae	Aquarius	3, 8	Genera
Belostomatidae	Belostoma	3, 8	Genera
Gerridae	Eurygerris	3, 8	Genera
Corixidae	Tenagobia	1,3, 8	Genera
Corydalidae	Protochauliodes	1, 3, 8	Family
Aeshnidae	non-identified-Aeshnidae	1, 3, 8	Family
Gomphidae	non-identified-Gomphidae	1, 3, 8	Family
Libellulidae	Libellulinae	1, 3, 8	Family

Appendix 11: Traits, categories and codes used to make matrix of biological traits in Mediterranean area of Chile. Consisting of a single formed by 9 traits with 49 categories.

TRAIT	CATEGORY	CODE
Maximal size	≤ 0.25cm	a1
	> 0.25-.5cm	a2
	> 0.5-1cm	a3
	> 1-2cm	a4
	> 2-4cm	a5
	> 4-8cm	a6
	> 8cm	a7
Respiration	Tegument	j1
	Gill	j2
	Plastron	j3
	Spiracle (aerial)	j4
Locomotion	Flier	u1
	Surface swimmer	u2
	Swimmer	u3
	Crawler	u4
	Burrower (epibenthic)	u5
	Interstitial (endobenthic)	u6
	Temporarily attached	u7
	Permanently attached	u8
Food	Fine sediment+microrganisms	h1
	Detritus<1mm	h2
	Plant detritus≥1mm	h3
	Living microphytes	h4
	Living macrophytes	h5
	Dead animal>1mm	h6
	Living microinvertebrates	h7

	Living macroinvertebrates	h8
	Vertebrates	h9
Feeding habits	Deposit feeder	i2
	Shredder	i3
	Scraper	i4
	Filter-feeder	i5
	Piercer (plantoranimal)	i6
	Predator (carver/engulfer/swallower)	i7
Body flexibility(degrees)	None (<10)	m1
	Low (>10-45)	m2
	High (>45)	m3
Body form	Streamlined	n1
	Flattened	n2
	Cylindrical	n3
	Spherical	n4
Body armouring	None (soft-bodied)	p1
	Moderate (sclerotised)	p2
	Strong (case/shell)	p3
Attachment mechanism	Suckers	o1
	Siltgland	o2
	Mineral material-case	o3
	Anal hooks	o4
	Tarsal hooks	o5

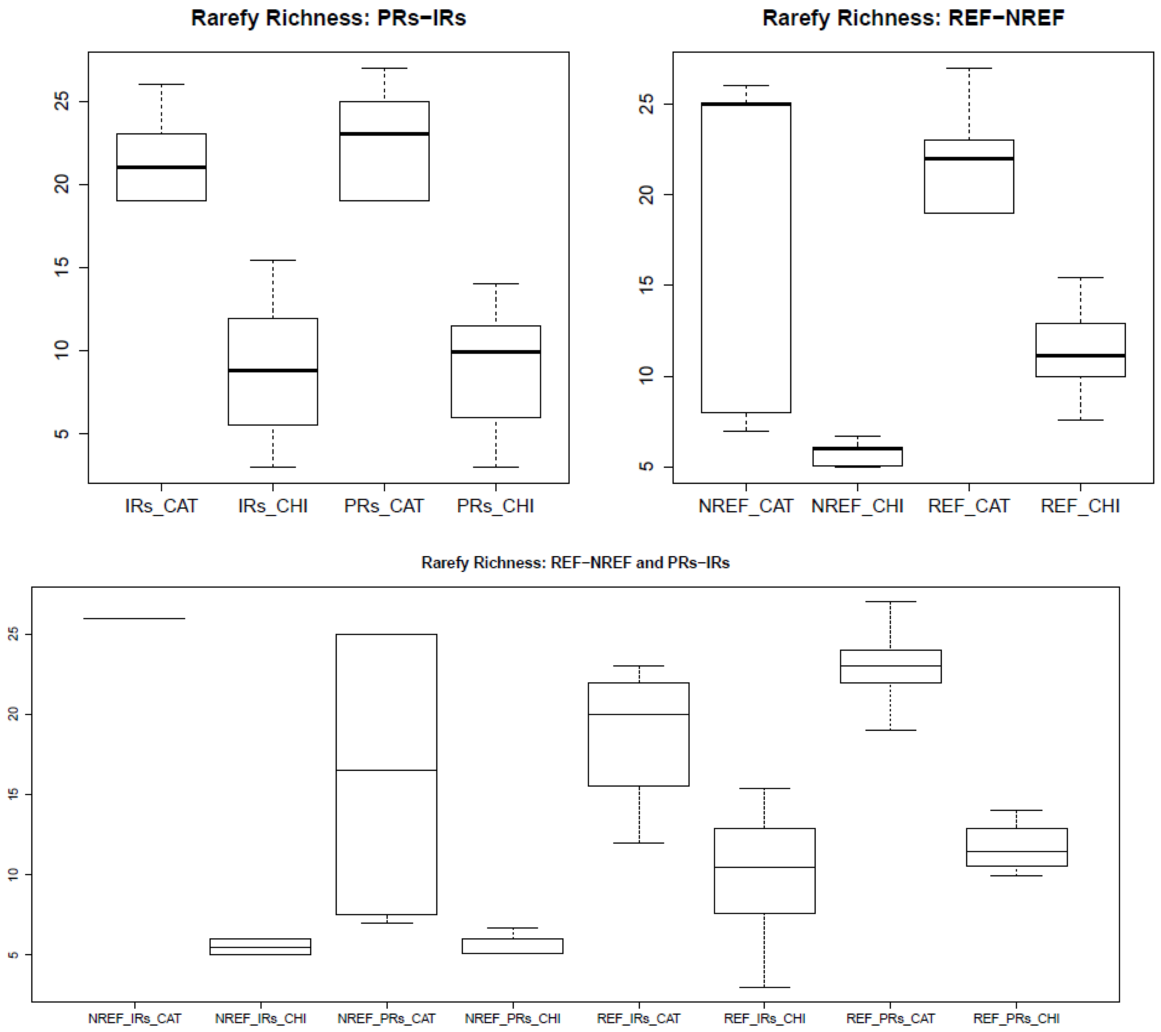
Appendix 12: Matrix of biological traits in the sampled Mediterranean climate region of Catalonia. The matrix include 9 traits with 49 categories.

	a1	a2	a3	a4	a5	a6	a7	j1	j2	j3	j4	u1	u2	u3	u4	u5	u6	u7	u8	h1	h2	h3	h4	h5	h6	h7	h8	h9	i2	i3	i4	i5	i6	i7	m1	m2	m3	n1	n2	n3	n4	p1	p2	p3	o1	o2	o3	o4	o5
Adicella	0	0	3	0	0	0	0	2	2	0	0	0	0	0	5	0	0	0	0	0	0	0	1	4	0	0	0	0	0	3	3	0	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Aeshna	0	0	0	0	2	3	0	1	3	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	1	4	1	0	0	0	0	0	3	3	0	0	1	0	2	0	0	0	2	0	0	0	0	3
Agabus	0	0	3	2	0	0	0	1	0	0	3	1	0	3	3	0	0	0	0	0	0	0	0	0	0	1	3	1	0	3	0	0	3	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Allogamus	0	0	0	1	3	0	0	3	2	0	0	0	0	0	5	0	0	0	0	0	0	3	2	1	0	0	2	0	0	3	1	0	0	1	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Amphinemura	0	1	3	0	0	0	0	3	2	0	0	0	0	0	5	0	0	0	0	0	1	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	3	1	2	1	0	0	3	0	0	0	0	0	3
Baetis	0	0	3	1	0	0	0	1	2	0	0	0	0	3	4	0	1	0	0	0	2	2	5	5	1	0	0	0	1	0	3	0	0	0	0	0	3	3	0	0	0	0	3	0	0	0	0	0	3
Boyeria	0	0	0	0	3	1	0	1	3	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	1	4	1	0	0	0	0	0	3	3	0	0	1	0	2	0	0	0	2	0	0	0	0	3
Caenis_cat	0	2	3	0	0	0	0	1	3	0	0	0	0	0	5	1	1	0	0	1	4	2	1	1	1	0	0	0	3	1	0	0	0	0	0	0	3	2	3	0	0	0	3	0	0	0	0	0	3
Calopteryx	0	0	0	1	3	1	0	1	3	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	3	3	0	0	1	0	2	0	0	0	2	0	0	0	0	3
Centroptilum	0	0	3	0	0	0	0	1	2	0	0	0	0	3	1	1	0	0	0	0	2	0	3	0	0	0	0	0	2	0	3	0	0	0	0	0	3	3	0	0	0	0	3	0	0	0	0	0	3
Chaetopteryx	0	0	0	3	2	0	0	2	2	0	0	0	0	0	5	0	0	0	0	0	0	4	0	4	1	0	1	0	0	3	0	0	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Chalcolestes	0	0	0	0	3	0	0	1	2	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	3	3	0	0	1	0	2	0	0	0	2	0	0	0	0	3
Chimarra	0	0	3	0	0	0	0	3	1	0	0	0	0	0	2	0	0	3	0	0	3	0	3	0	0	0	0	0	0	0	2	3	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Cloeon	0	0	3	0	0	0	0	1	2	0	0	0	0	3	1	0	0	0	0	0	3	1	3	1	0	1	0	0	3	1	3	0	0	0	0	3	0	1	2	1	0	0	3	0	0	0	0	0	3
Cordulegaster	0	0	0	0	2	3	0	1	3	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	3	3	0	0	1	0	2	0	0	0	2	0	0	0	0	3
Deronectes	0	3	1	0	0	0	0	1	0	0	3	1	0	3	3	0	0	0	0	0	0	0	0	0	0	2	3	0	0	3	0	0	3	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Dryops	0	3	0	0	0	0	0	3	0	3	3	2	0	0	3	3	0	0	0	0	0	3	3	0	0	0	0	0	0	3	3	0	0	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Ecdyonurus	0	0	0	3	0	0	0	1	3	0	0	0	0	1	5	0	0	0	0	1	2	3	2	0	0	0	0	0	0	2	3	0	0	0	0	0	3	0	3	0	0	0	3	0	2	0	0	0	3
Electrogena	0	0	0	3	0	0	0	1	3	0	0	0	0	1	5	0	0	0	0	0	3	1	3	0	0	0	0	0	0	0	3	0	0	0	0	3	0	1	2	1	0	0	3	0	0	0	0	0	3
Elmis	0	3	0	0	0	0	0	1	3	3	0	1	0	0	4	0	1	0	0	0	1	0	3	0	0	0	0	0	0	1	3	0	0	0	0	2	2	2	1	0	1	0	3	0	0	0	0	0	3
Elodes	0	3	0	0	0	0	0	1	3	0	0	0	0	0	5	0	0	0	0	0	1	0	3	0	0	0	0	0	0	1	3	0	0	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Epeorus	0	0	0	3	0	0	0	1	3	0	0	0	0	0	5	0	0	0	0	0	1	0	3	1	0	0	0	0	1	0	3	0	0	0	0	0	3	0	3	0	0	0	3	0	2	0	0	0	3
Ephemera	0	0	0	0	3	0	0	1	3	0	0	0	0	0	1	4	0	0	0	0	3	2	1	0	0	2	0	0	1	3	0	3	0	1	0	0	3	1	0	3	0	0	3	0	0	0	0	0	3
Esolus	0	3	0	0	0	0	0	1	3	3	0	1	0	0	4	0	1	0	0	0	1	0	3	0	0	0	0	0	0	1	3	0	0	0	0	2	2	2	1	0	1	0	3	0	0	0	0	0	3

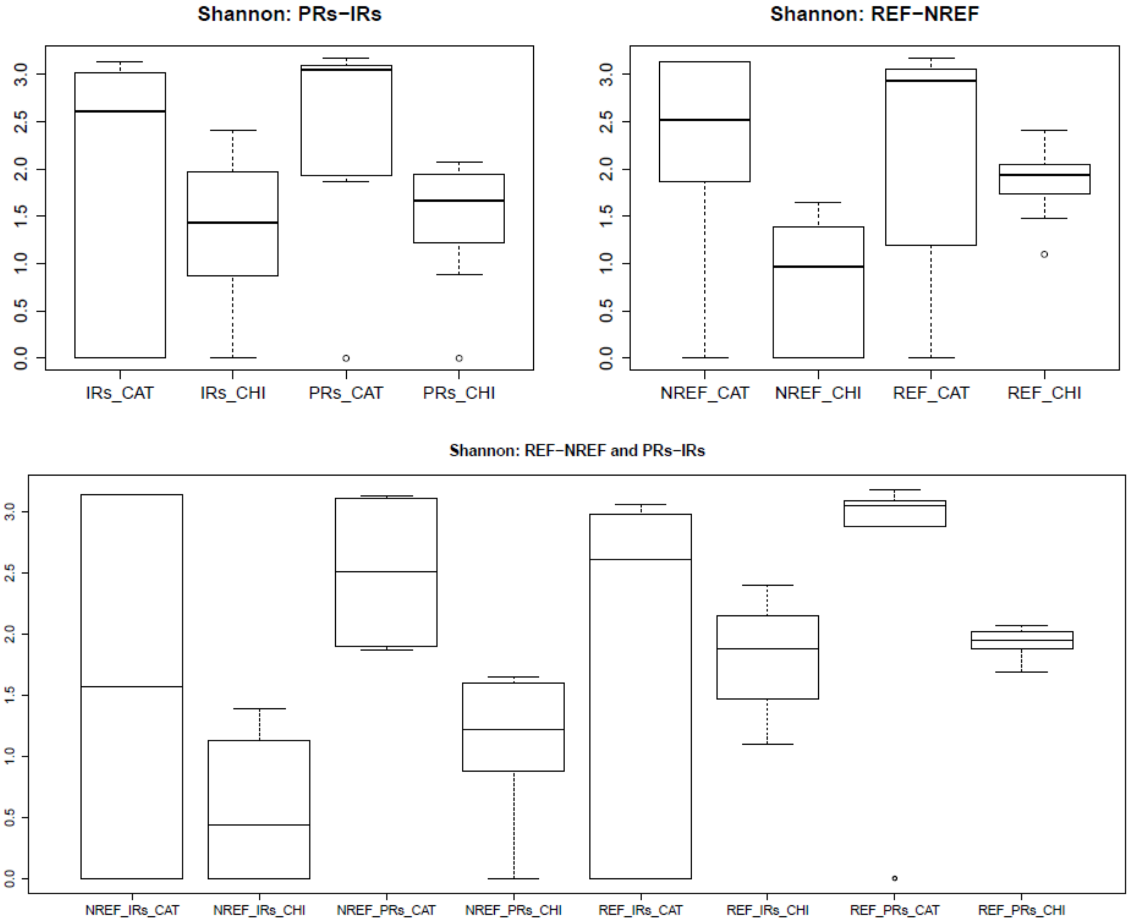
Gerris	0	0	1	3	0	0	0	0	0	0	3	3	4	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	3	1	3	0	0	1	0	2	0	0	0	3	0	0	0	0	3
Gyrinus	0	2	3	0	0	0	0	1	3	0	3	1	3	3	3	0	0	0	0	0	0	0	0	0	0	1	3	0	0	3	0	0	3	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Habroleptoides	0	0	1	3	0	0	0	1	3	0	0	0	0	0	3	1	0	0	0	1	3	1	3	0	0	0	0	0	0	2	3	0	0	0	0	0	3	2	3	0	0	0	3	0	0	0	0	0	3
Habrophlebia	0	0	3	0	0	0	0	1	3	0	0	0	0	1	3	0	0	0	0	0	1	3	3	0	0	0	0	0	1	3	0	0	0	0	0	3	0	1	2	1	0	0	3	0	0	0	0	0	3
Halesus	0	0	0	0	3	0	0	3	2	0	0	0	0	0	5	0	0	0	0	0	0	3	0	3	0	0	1	2	0	3	0	0	0	0	3	0	0	0	0	3	0	0	0	3	0	0	0	0	3
Haliplus	0	3	0	0	0	0	0	3	0	0	3	1	0	3	3	0	0	0	0	0	0	0	3	3	0	0	0	0	0	3	0	0	3	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Hydraena	0	3	0	0	0	0	0	0	0	3	2	1	0	3	3	0	0	0	0	0	1	0	3	0	0	0	0	0	0	1	3	0	0	0	0	2	2	2	1	0	1	0	3	0	0	0	0	0	3
Hydrobius	0	0	3	1	0	0	0	1	0	1	3	1	0	3	3	0	0	0	0	0	0	0	3	0	0	3	1	0	0	3	0	0	0	1	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Hydrocyphon	2	2	0	0	0	0	0	1	3	0	0	0	0	0	5	0	0	0	0	0	1	0	3	0	0	0	0	0	0	1	3	0	0	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Hydrometra	0	0	1	3	0	0	0	0	0	0	3	1	4	0	2	0	0	0	0	0	0	0	0	0	3	3	1	0	0	0	0	0	3	0	3	0	0	1	0	2	0	0	0	3	0	0	0	0	3
Hydropsyche	0	0	1	3	1	0	0	2	3	0	0	0	0	0	2	0	0	3	0	0	2	1	3	0	0	3	1	0	0	0	0	3	0	1	0	0	3	0	0	3	0	0	3	0	0	3	0	3	3
Hydroptila	0	3	1	0	0	0	0	3	1	0	0	0	0	0	3	0	0	1	0	0	2	0	1	4	0	0	0	0	1	1	1	0	3	0	3	0	0	0	0	3	0	0	0	3	0	0	3	0	3
Hyporhyacophila	0	0	2	2	0	0	0	3	0	0	0	0	0	2	3	0	0	1	0	0	0	1	1	0	1	0	5	0	0	2	0	0	0	1	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Isoperla	0	0	1	3	0	0	0	3	0	0	0	0	0	0	4	0	1	0	0	0	0	0	2	0	0	1	4	0	0	3	1	0	0	1	0	0	3	1	2	1	0	0	3	0	0	0	0	0	3
Laccobius	0	3	0	0	0	0	0	1	0	1	3	1	0	3	3	0	0	0	0	0	0	0	3	0	0	3	1	0	0	3	0	0	0	1	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Laccophilus	0	3	0	0	0	0	0	1	0	0	3	1	0	3	3	0	0	0	0	0	0	0	0	0	0	2	3	0	0	3	0	0	3	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Lepidostoma	0	0	3	1	0	0	0	2	2	0	0	0	0	0	5	0	0	0	0	0	0	4	1	0	0	0	0	0	0	3	1	0	0	0	3	0	0	0	0	3	0	0	0	3	0	0	3	0	3
Leuctra	0	0	3	1	0	0	0	3	0	0	0	0	0	0	5	2	1	0	0	0	1	1	2	2	1	0	0	0	1	3	1	0	0	0	0	0	3	1	2	1	0	0	3	0	0	0	0	0	3
Limnephilus	0	0	0	3	2	0	0	2	2	0	0	0	0	0	5	0	0	0	0	0	1	5	0	2	1	0	0	0	0	3	0	0	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Limnius	0	3	0	0	0	0	0	1	3	3	0	1	0	0	4	0	1	0	0	0	1	0	3	0	0	0	0	0	0	1	3	0	0	0	0	2	2	2	1	0	1	0	3	0	0	0	0	0	3
Meladema	0	0	0	0	3	0	0	1	0	0	3	1	0	3	3	0	0	0	0	0	0	0	0	0	0	1	3	1	0	3	0	0	3	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Micronecta	3	1	0	0	0	0	0	1	0	1	1	0	0	3	2	0	0	0	0	0	0	0	2	2	0	3	0	0	0	3	2	0	3	0	3	0	0	1	0	2	0	0	0	3	0	0	0	0	3
Mystacides	0	0	3	1	0	0	0	3	1	0	0	0	0	1	4	0	0	0	0	0	2	0	2	4	0	0	1	0	1	3	2	0	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Nemoura	0	1	3	0	0	0	0	3	0	0	0	0	0	0	5	0	0	0	0	0	1	2	1	0	0	0	0	0	0	3	0	0	0	0	0	0	3	1	2	1	0	0	3	0	0	0	0	0	3
Notonecta	0	0	0	3	0	0	0	1	0	1	3	2	2	4	0	0	0	0	0	0	0	0	0	0	3	3	1	0	0	0	0	3	1	3	0	0	1	0	2	0	0	0	3	0	0	0	0	3
Odontocerum	0	0	0	3	1	0	0	2	3	0	0	0	0	0	3	2	0	0	0	0	0	0	1	3	0	3	2	0	0	3	0	0	0	3	3	0	0	0	0	3	0	0	3	0	0	0	3	0	3
Oecetis	0	0	3	1	0	0	0	2	3	0	0	0	0	1	4	0	0	0	0	0	1	1	2	3	0	2	0	0	1	3	1	0	0	1	3	0	0	0	0	3	0	0	3	0	0	0	3	0	3
Onychogomphus	0	0	0	0	3	0	0	1	3	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	3	3	0	0	1	0	2	0	0	0	2	0	0	0	0	3
Oulimnius	0	3	0	0	0	0	0	1	3	3	0	1	0	0	4	0	1	0	0	0	1	0	3	0	0	0	0	0	0	1	3	0	0	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3

Perla	0	0	0	0	3	0	0	0	3	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	1	4	0	0	3	0	0	0	1	0	0	3	1	2	1	0	0	3	0	0	0	0	0	3
Philopotamus	0	0	1	3	0	0	0	3	0	0	0	0	0	0	2	0	0	3	0	0	2	0	3	1	0	0	1	0	0	0	2	3	0	1	0	0	3	0	0	3	0	2	3	0	0	1	0	3	3
Platambus	0	0	3	0	0	0	0	1	0	0	3	1	0	3	3	0	0	0	0	0	0	0	0	0	0	1	3	1	0	3	0	0	3	0	3	0	0	2	0	0	3	0	0	3	0	0	0	0	3
Polycentropus	0	0	1	3	0	0	0	3	0	0	0	0	0	1	1	0	0	3	0	0	1	1	3	1	0	3	4	0	0	1	0	1	0	3	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Potamophylax	0	0	0	3	2	0	0	2	2	0	0	0	0	0	5	0	0	0	0	0	0	4	0	4	1	0	1	0	0	3	0	0	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Protonemura	0	0	3	1	0	0	0	3	2	0	0	0	0	0	5	0	0	0	0	0	1	2	1	0	0	0	0	0	0	3	0	0	0	0	0	0	3	1	2	1	0	0	3	0	0	0	0	0	3
Psychomyia	0	1	3	0	0	0	0	3	0	0	0	0	0	0	2	0	0	3	1	0	1	0	5	1	0	1	0	0	1	0	3	2	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Ptilocoletus	0	1	3	0	0	0	0	3	0	0	0	0	0	0	5	0	0	0	0	0	1	0	2	3	0	0	0	0	0	1	1	0	1	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Rhithrogena	0	0	1	3	0	0	0	1	3	0	0	0	0	1	5	0	1	0	0	0	1	0	3	1	0	0	0	0	1	0	3	0	0	0	0	0	3	0	3	0	0	0	3	0	0	0	0	0	3
Rhyacophila	0	0	1	2	2	0	0	2	1	0	0	0	0	2	3	0	0	1	0	0	1	1	1	0	0	1	5	0	0	0	0	0	0	3	0	0	3	0	1	3	0	0	3	0	0	0	0	3	3
Sericostoma	0	0	0	3	0	0	0	2	2	0	0	0	0	0	4	1	1	0	0	0	0	3	1	2	0	1	1	0	0	3	1	0	0	0	3	0	0	0	0	3	0	0	3	0	0	0	3	0	3
Serratella	0	0	3	0	0	0	0	1	3	0	0	0	0	1	5	0	0	0	0	0	1	3	4	3	0	1	0	0	1	2	2	0	0	1	0	3	0	1	0	1	0	0	3	0	0	0	0	0	3
Siphonoperla	0	0	3	2	0	0	0	3	0	0	0	0	0	0	4	1	1	0	0	1	1	2	1	0	0	1	5	0	1	3	1	0	0	1	0	0	3	1	2	1	0	0	3	0	0	0	0	0	3
Stictonectes	0	3	0	0	0	0	0	1	0	0	3	1	0	3	3	0	0	0	0	0	0	0	0	0	0	2	3	0	0	3	0	0	3	0	3	0	0	2	2	0	3	0	0	3	0	0	0	0	3
Sympetrum	0	0	0	3	0	0	0	1	3	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	3	3	0	0	1	0	2	0	0	0	2	0	0	0	0	3
Synagapetus	0	0	3	0	0	0	0	3	0	0	0	0	0	0	3	0	0	2	0	0	2	0	5	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Tinodes	0	1	3	1	0	0	0	3	0	0	0	0	0	0	2	0	0	3	1	0	2	0	3	1	0	2	1	0	1	0	3	2	0	1	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Triaenodes	0	0	3	2	0	0	0	2	3	0	0	0	0	2	4	0	0	0	0	0	2	0	1	2	0	0	0	0	0	3	1	0	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Velia	0	0	3	0	0	0	0	0	0	0	3	1	4	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	3	1	3	0	0	1	0	2	0	0	0	3	0	0	0	0	3
Wormaldia	0	0	3	0	0	0	0	3	1	0	0	0	0	0	2	0	0	3	0	0	3	0	3	0	0	0	0	0	0	0	2	3	0	0	0	0	3	0	0	3	0	0	2	0	0	0	1	1	3
Yola	0	3	0	0	0	0	0	1	0	0	3	1	0	3	3	0	1	0	0	0	0	0	0	0	0	2	3	0	0	3	0	0	3	0	0	3	0	2	0	0	3	0	3	0	0	0	0	0	3

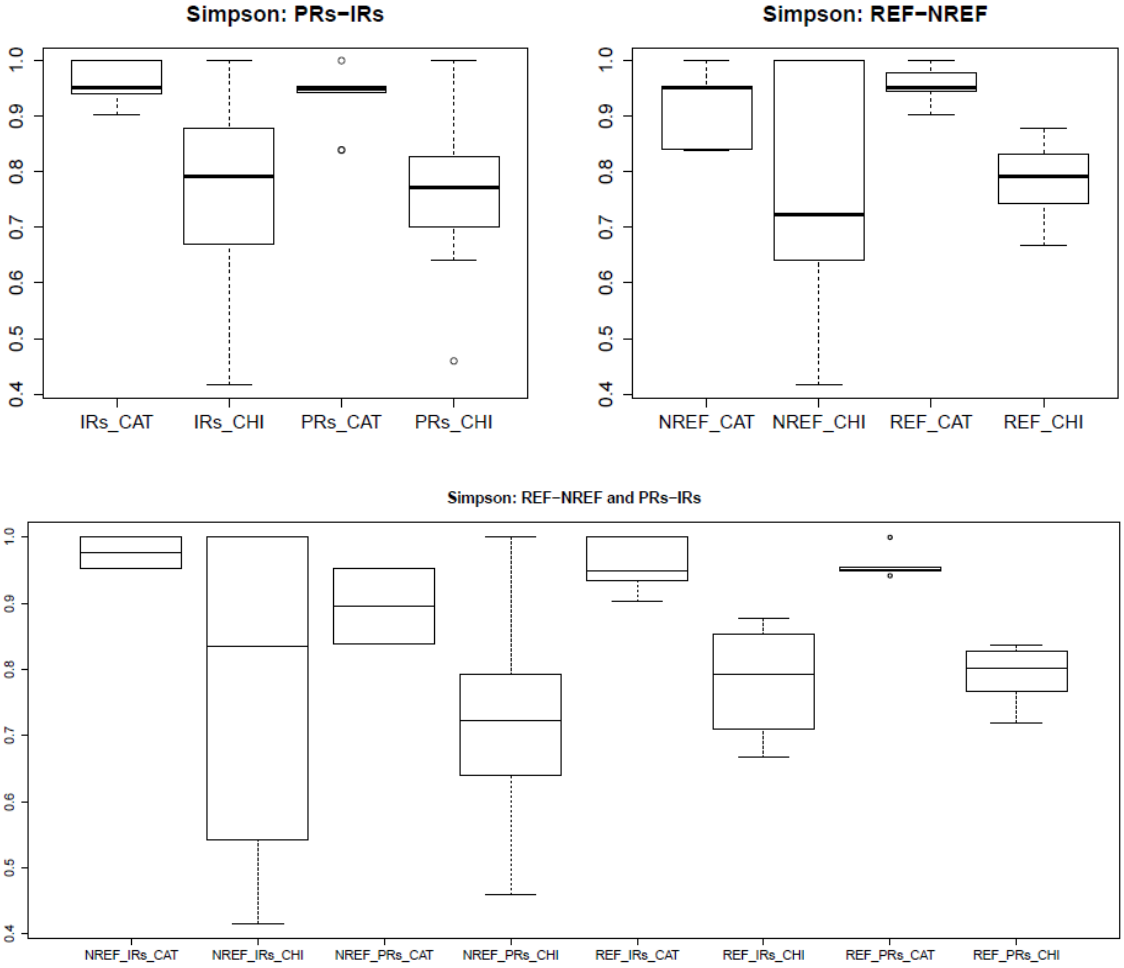
Appendix 14: Boxplots of rarefied richness from Chile and Catalonia. Grouped by permanent (PRs) and intermittent (IRs) rivers (up and left), reference (REF) and non-reference (NREF) rivers (up and right), and comparing the regional effects of the natural and the anthropogenic disturbance in both regions (down). The boxes indicate envelop data between the 25 (lower limit) and the 75 (upper limit) percentile, and line inside of the box refers to the median



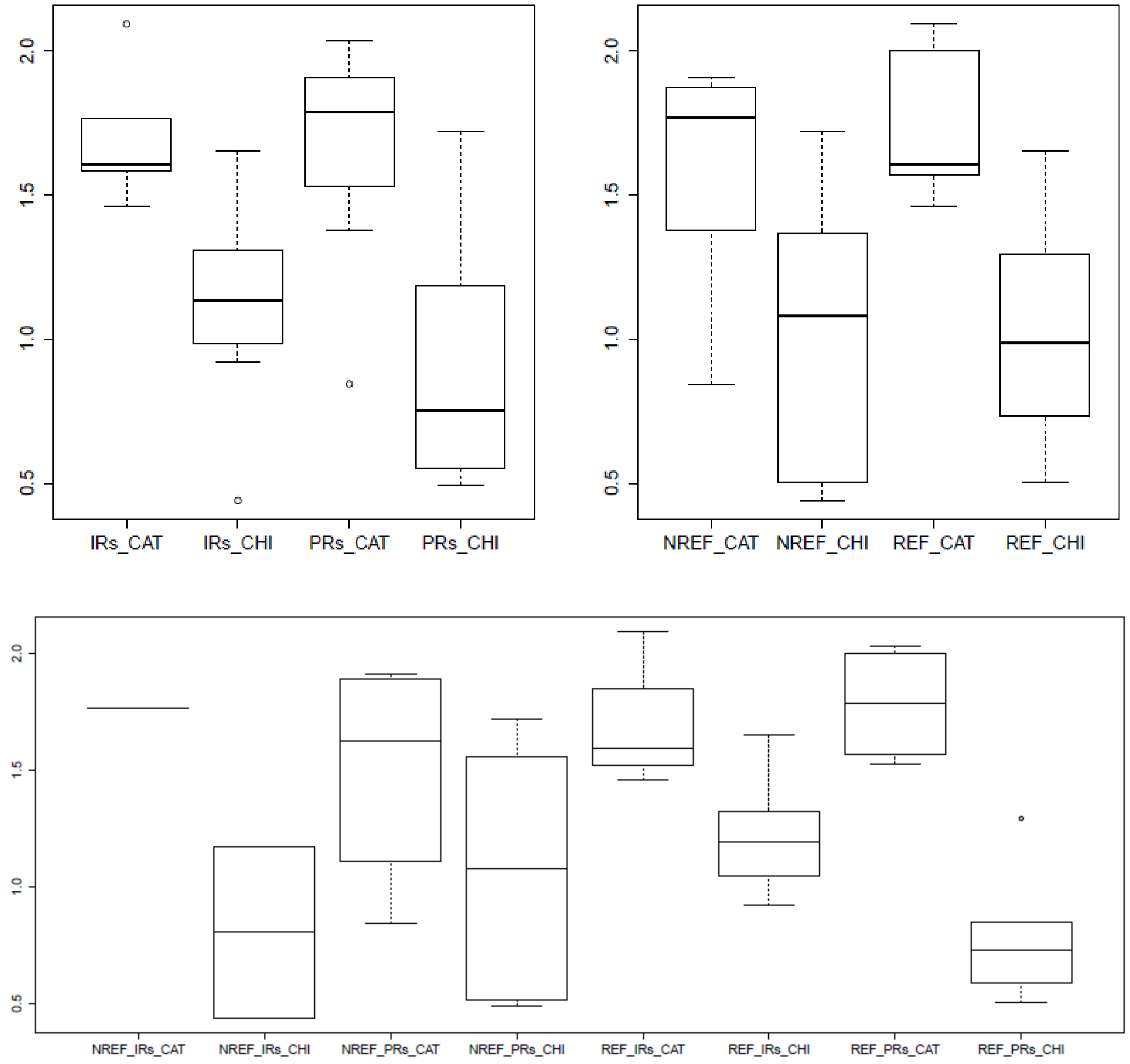
Appendix 15: Boxplots of Shannon (H') biodiversity index from Chile and Catalonia. Grouped by permanent (PRs) and intermittent (IRs) rivers (up and left), reference (REF) and non-reference (NREF) rivers (up and right), and comparing the regional effects of the natural and the anthropogenic disturbance in both regions (down). The boxes indicate envelop data between the 25 (lower limit) and the 75 (upper limit) percentile, and line inside of the box refers to the median.



Appendix 16: Boxplots of Simpson biodiversity index from Chile and Catalonia. Grouped by permanent (PRs) and intermittent (IRs) rivers (up and left), reference (REF) and non-reference (NREF) rivers (up and right), and comparing the regional effects of the natural and the anthropogenic disturbance in both regions (down). The boxes indicate envelop data between the 25 (lower limit) and the 75 (upper limit) percentile, and line inside of the box refers to the median.



Appendix 17: Boxplots of Rao index from Chile and Catalonia. Grouped by permanent (PRs) and intermittent (IRs) rivers (up and left), reference (REF) and non-reference (NREF) rivers (up and right), and comparing the regional effects of the natural and the anthropogenic disturbance in both regions (down). The boxes indicate envelop data between the 25 (lower limit) and the 75 (upper limit) percentile, and line inside of the box refers to the median.



REFERENCES

Papers:

Acuña, V.; Muñoz, I.; Giorgi, A.; Omelia, M.; Sabater, F. & Sabater, S. (2005). Drought and postdrought recovery cycles in an intermittent Mediterranean stream: structural and functional aspects. J. N. Am. Benthol. Soc. 24: 919-933.

Alexandre, C.M.; Ferreira, T.F. & Almeida, P.R. (2013) Fish assemblages in non-regulated and regulated rivers from permanent and temporary Iberian systems. River Research and Applications 29: 1042-1058.

Bêche, L.A.; McElravy, E.P. & Resh, V.H. (2006). Long-term seasonal variation in the biological traits of benthic-macroinvertebrates in two Mediterraneanclimate streams in California, U.S.A. Freshwater Biology 51: 56-75.

Begg, C.B. & Mazumdar, M. (1994). Operating characteristics of a rank correlation test for publication bias. Biometrics 50: 1088-1101.

Benda, L.E.; Hassan, M.A.; Church, M. & May, C.L. (2005). Geo- morphology of Steepland Headwaters: The Transition From Hillslopes to Channels. Journal of the American Water Resources Association 41: 835-851.

Beugly, J. & Pyron, M. (2010). Variation in Fish and Macroinvertebrate Assemblages Among Seasonal and Perennial Headwater Streams. American Midland Naturalist 163: 2-13.

Blanchette, M.L. & Pearson, R.G. (2012). Macroinvertebrate assemblages in rivers of the Australian dry tropics are highly variable. Freshwater Science 31: 865-881.

Bogan, M.T.; Boersma, K.S. & Lytle, D.A. (2013). Flow intermittency alters longitudinal patterns of invertebrate diversity and assemblage composition in an arid-land stream network. Freshwater Biology 58: 1016-1028.

Bonada, N.; Zamora-Muñoz, C.; Rieradevall, M. & Prat, N. (2005). Ecological and historical filters constraining spatial caddisfly distribution in Mediterranean rivers. Freshwater Biology, 50: 781-797

Bonada, N.; Rieradevall, M.; Prat, N. & Resh, V.H. (2006). Benthic macroinvertebrate assemblages and macrohabitat connectivity in Mediterranean-climate streams of northern California. Journal of the North American Benthological Society 25: 32-43.

Bonada, N.; Doledec, S. & Statzner, B. (2007). Taxonomic and biological trait differences of stream macroinvertebrate communities between mediterranean and temperate regions: implications for future climatic scenarios. Global Change Biology 13: 1658-1671.

Bonada, N.; Rieradevall, M.; Dallas, H.; Davis, J.; Day, J.; Figueroa R., et al. (2008). Multi-scale assessment of macroinvertebrate richness and composition in Mediterranean-climate rivers. Freshwater Biology 53: 772–788.

Bonada, N. & Dolédec, S. (2011). Do Mediterranean genera not included in Tachet et al. 2002 have Mediterranean trait characteristics? Limnetica 30: 129-142.

Bonada, N. & Resh, V.H. (2013). Mediterranean-climate streams and rivers: geographically separated but ecological comparable freshwater systems. Hydrobiologia, 719: 1-29.

Begg, C.B. & Mazumdar, M. (1994). Operating characteristics of a rank correlation test for publication bias. Biometrics 50: 1088-1101.

Boulton, A.J. & Suter, P.J. (1986). Ecology of temporary streams - an Australian perspective. Limnology in Australia: 313-327.

Bunn, S.E. & Davies, P.M. (1992). Community structure of the macroinvertebrate fauna and water-quality of a saline river system in South-Western Australia. Hydrobiologia 248: 143-160.

Casas. J.J & Langton, P.H. (2008). Chironomid species richness of a permanent and a temporary Mediterranean stream: a long-term comparative study. Journal of the North American Benthological Society 27: 746-759.

Chessel, D.; Dufour, A.B. & Thioulouse, J. (2004). The ade4 package-I- One-table methods. R News. 4: 5-10.

Closs, G.P. & Lake, P.S. (1994). Spatial and Temporal Variation in the Structure of an Intermittent-Stream Food Web. Ecological Monographs 64:1–21

Datry, T.; et al (2007). Responses of hyporheic invertebrate assemblages to large-scale variation in flow permanence and surface-subsurface exchange. Freshwater Biology 52: 1452-1462.

Datry, T.; et al (2011). Recent perspectives on temporary river ecology. Aquatic Science 73: 453-457.

Datry, T.; et al. (2012). Spatial and temporary aquatic-terrestrial transitions in the temporary Albarine River, France: responses of invertebrates to experimental rewetting. Freshwater Biology 57: 716-727.

Datry, T.; Larned, S.T; Fritz, K.M; Bogan, M.T; Wood, P.J.; Meyer, E.I. & Santos, A.N. (2013). Broad-scale patterns of invertebrate richness and community composition in temporary rivers: effects of flow intermittence. Ecography 36: 001-011.

Del Rosario, R.B. & Resh, V.H. (2000). Invertebrates in intermittent and perennial streams: is the hyporheic zone a refuge from drying? Journal of the North American Benthological Society 19: 680-696.

Delucchi, C.M. (1988). Comparison of community structure among streams with different temporal flow regimes. Canadian Journal of Zoology 66: 579-586.

Delucchi, C.M & Peckarsky, B.L. (1989). Life History Patterns of Insects in an Intermittent and a Permanent Stream. Journal of the North American Benthological Society 8: 308-321.

Dray, S. & Dufour, A.B. (2007). The ade4 package: implementing the duality diagram for ecologists. Journal of Statistical Software. 22: 1-20.

Dray, S.; Dufour, A.B. & Chessel, D. (2007). The ade4 package-II: Two-table and K-table methods. R News. 7: 47-52.

Egger, M.; Smith, G.D.; Schneider, M. & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. British Medical Journal 315: 629-634.

Feminella, J. W. (1996). Comparison of benthic macroinvertebrate assemblages in small streams along a gradient of flow permanence. Journal of the North American Benthological Society 15: 651–669.

Figueroa, F.; Valdovinos, C.; Araya, E. & Parra, O. (2003). Macroinvertebrados bentónicos como indicadores de calidad de agua de ríos del sur de Chile Benthic macroinvertebrates as indicators of water quality of southern Chile rivers. Revista Chilena de Historia Natural 76: 275-285.

Figueroa, R.; Bonada, N.; Guevara, M.; Pedreros, P.; Correa-Araneda, F.; Díaz, M.E. & Ruiz, V.H. (2013). Freshwater biodiversity and conservation in mediterranean climate streams of Chile. Hydrobiologia, 719: 269-289

Finn, D.S.; Bonada, N.; Múrria, C. & Hughes, J. (2011). Small but mighty: headwaters are vital to stream network biodiversity at two levels of organization. Journal of the North American Benthological Society 30: 963-980.

Fritz, K.M. & Dodds, W.K. (2002). Macroinvertebrate assemblage structure across a tallgrass prairie stream landscape. Archiv für Hydrobiologie 154: 79-102.

Fritz, K.M. & Dodds, W.K. (2004). Resistence and resilence of macroinvertebrate assemblages to drying and flooding in a tallgrass prairie stream. Hydrobiologia 527: 99-112.

García-Roger, E.; Del Mar Sánchez-Montoya, M.; Gómez, R.; Suárez, M.; Vidal-Abarca, M.; Latron, J.; et al. (2011). Do seasonal changes in habitat features influence aquatic macroinvertebrate assemblages in perennial versus temporary Mediterranean streams? Aquatic Sciences 73: 567-579.

Gates, S. (2002). Review of methodology of quantitative reviews using meta-analysis in ecology. Journal of Animal Ecology 71: 547–557.

Grubbs, S.A. (2011). Influence of flow permanence on headwater macroinvertebrate communities in a Cumberland Plateau watershed, USA. Aquatic Ecology 45:185-195.

Hedges, L. V., Gurevitch, J., & Curtis, P. S. (1999). The meta-analysis of response ratios in experimental ecology. *Ecology* 80: 1150–1156.

Ihaka, R. (1996). R: A Language for Data Analysis and Graphics. Journal of Computational and Graphical Statistics 5: 299–314.

Jacobsen, D. (2004). Contrasting patterns in local and zonal family richness of stream invertebrates along an Andean altitudinal gradient. Freshwater Biology 49: 1293-1305.

Jáimez-cuéllar, P.; Vivas, S.; Bonada, N.; Robles, S.; Mellado, A.; Álvarez, M.; Avilés, J. et al. (2002). protocolo guadalmed (prece). Limnetica, 21(3-4): 187-204.

Larned, S.T.; et al. (2010). Emerging concepts in temporary-river ecology. Freshwater Biology 55: 717-738.

Leigh, C. (2013). Dry season changes in macroinvertebrate assemblages of highly seasonal rivers: responses to low flow, no flow and antecedent hydrology. Hydrobiologia 703: 95-112.

Leigh, C. & Sheldon, F. (2009). Hydrological connectivity drives patterns of macroinvertebrate biodiversity in floodplain rivers of the Australian wet/dry tropics. Freshwater Biology 54: 549-571.

Lorig, R.C.; Marchetti, M.P. & Kopp G. (2013). Spatial and temporal distribution of native fish larvae in seasonal and perennial tributaries of the Sacramento River, CA, USA. Journal of Freshwater Ecology 28: 179-197.

Lytle, D.A. & Poff, N.L. (2004). Adaptation to natural flow regimes. Trends in Ecology and Evolution 19: 94-100.

Lumley, T. (2012). Rmeta: Meta-analysis. Journal of Computational and Graphical Statistics.

Miller, A.M. & Golladay S.W. (1996). Effects of spates and drying on macroinvertebrate assemblages of an intermittent and a perennial prairie stream. Journal of the North American Benthological Society 15: 670-689.

Monaghan, K.A. & Soares, A.M. (2010). The bioassessment of fish and macroinvertebrates in a Mediterranean–Atlantic climate: Habitat assessment and concordance between contrasting ecological samples. Ecological Indicators 10: 184-191.

Munné, A.; Prat, N.; Solà, C.; Bonada, N. & Rieradevall, M. (2003). A simple field method for assessing the ecological quality of riparian habitat in rivers and streams: QBR index. Aquatic Conservation: Marine and Freshwater Ecosystems 13: 147-163.

Muñoz I. (2003) Macroinvertebrate community structure in an intermittent and a permanent Mediterranean streams (NE Spain). Limnetica, 22, 107-116.

Naiman, R.J. (1983). The Annual Pattern and Spatial Distribution of Aquatic Oxygen Metabolism in Boreal Forest Watersheds. Ecological Monographs 53: 73-94.

Novais M.H., Morais M.M., Rosado J., Dias L.S., Hoffmann L. & Ector L. (2014) Diatoms of temporary and permanent watercourses in Southern Europe (Portugal). River Research and Applications, 30, 1216–1232.

Ovalle, K.P. THESIS (2012). Degradación de hojarasca y Estudio de Organismos Macroinvertebrados Bentónicos mediante análisis del tracto intestinal, zona alta del Estero Nonguén, Región del Biobío, Chile. Universidad de Concepción (Chile)

Oksanen, J.; Blanchet, F.G.; Kindt, R.; Legendre, P.; Minchin, P.R.; O'Hara, R.B.; Simpson, G.L.; Solymos, P.; Stevens, M.H. & Wagner, H. (2015). Vegan: Community Ecology Package. R package version 2.2-1.

Okur, E. & Yalcin-Oezdilek, S. (2008). Preliminary study of fish community structure in Amanos Mountain streams (Hatay-Turkey). Biologia 63: 427-438.

Pardo, I.; Álvarez, M.; Casas, J.; Moreno, J.L.; Vivas, S.; Bonada, N.; Alba-Tercedor, J.; Jáimez-Cuéllar, P.; Moyà, G.; Prat, N.; Robles,S.; Suárez, M.L; Toro, M. & Vidal-Abarca, M.R. (2004). El hábitat de los ríos mediterráneos. Diseño de un índice de diversidad de hábitat. Limnetica 21: 2002.

Peel, M.C.; Finlayson, B.L. & Mcmahon, T.A. (2007). Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences Discussions 4 :439-473.

Pedreros, P.; Guevara, M.; Figueroa, R.; Araneda, A.; Stehr, A; Link, O. & Urrutia,R. (2013). Comportamiento térmico en ríos mediterráneos andinos de la zona centro-sur de Chile. Limnetica 32: 87-96

Pires, A.M.; Cowx, I.G. & Coelho, M.M. (2000). Benthic macroinvertebrate communities of intermittent streams in the middle reaches of the Guadiana Basin (Portugal). Hydrobiologia 435: 167-175.

Poff, N.L. et al. (1997). The natural flow regime. BioScience 47: 769-784.

Progar, R.A. & Moldenke, A.R. (2002). Insect production from temporary and perennially flowing headwater dtreams in Western Oregon. Journal of Freshwater Ecology 17: 391-407.

Reynaga, M.C. & Dos Santos, D.A. (2012). Rasgos biológicos de macroinvertebrados de ríos subtropicales:patrones de varación a lo largo de gradients ambientales espacio-temporales. Ecología Austral 22: 112-120.

Rosenberg, M. S.; Adams, D.C. & Gurevitch, J. (2000). MetaWin statistical software for meta-analysis version 2. Sinauer Associates, Sunderland, Massachusetts, USA.

Roux, D.J.; Nel, J.L.; Ashton, P.J.; Deacon, A.R.; et al. (2008). Designing protected areas to conserve riverine biodiversity: Lessons from a hypothetical redesign of the Kruger National Park. Biological Conservation 141:100-117.

Sánchez-Montoya M.M., Vidal-Abarca M.R. & Suárez M.L. (2010) Comparing the sensitivity of diverse macroinvertebrate metrics to a multiple stressor gradient in Mediterranean streams and its influence on the assessment of ecological status. Ecological Indicators, 10, 896-904.

Schleuter D, Daufresne M, Massol F, Argillier C (2010) A user’s guide to functional diversity indices. Ecol Monogr 80:469–484

Sheldon, F. (2005). Incorporating natural variability into the assessment of ecological health in Australian dryland rivers. Hydrobiologia 552: 45–56.

Sterne, J.A.; Sutton, A.J.; Ioannidis, J.P; et al., (2011). Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials, BMJ 342.

Tomanova , S. & Usseglio-Polatera, P. (2007). Patterns of benthic community traits in neotropical streams: relationship to mesoscale spatial variability. Fundamental and Applied Limnology 170: 243-255.

Thoms, M.C. & Sheldon, F. (2002). An ecosystem approach for determining environmental water allocations in Australian dryland river systems: the role of geomorphology. Geomorphology 47: 153-168.

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metaphor package. Journal of Statistical Software 36: 1-48.

Books:

Di Castri, F. (1991). An ecological overview of the five regions of the world with a Mediterranean climate. Biogeography of Mediterranean Invasions: 3-16.

Domínguez, E. & Fernández, H.R. (2009). Macroinvertebrados bentónicos sudamericanos. Sistemática y biología. Fundación Miguel Lillo. Tucumán-Argentina.

Domínguez, E.; Molineri, C.; Pescador, M.L. Hubbard, M.D. & Nieto, C. (2006). Ephemeroptera of South America. Volume 2. Aquatic Biodiversity in Latin America.

Koricheva, J.; Gurevitch, J. & Mengersen, K. (2013). Handbook of meta-analysis in ecology and evolution.

Rodrígues-Capítulo, A.; Muñoz, I.; Bonada, N.; Gaudes, A.; Tomanova, S. La biota de los ríos: los invertebrados. Elosegi, A.; Sabater, S. <<Conceptos y técnicas en ecologia fluvial>>. Fundación BBVA, 2009, cap. 14, pàg. 253-270.

Tachet, H.; Richoux, P.; Bournaud, M. & Usseglio-Polatera, P. (2002) Invertébrés d'Eau Douce (2nd corrected impression). CNRS editions. Paris. 588pp.

Stark, B.P.; Froehlich, C. & Zúñiga, M.C. South America Stoneflies (Plecoptera). Volume 5. Aquatic Biodiversity in Latin America.

Suc, J. P. (1984). Origin and evolution of the Mediterranean vegetation and climate in Europe. Nature, 307: 429-432.