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Dragonflies (Insecta: Odonata) as indicators of habitat quality in Mediterranean streams and rivers in the province of Barcelona (Catalonia, Iberian Peninsula)

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In a field study carried out in 2011 and 2014 adult dragonflies were identified as a rapid and easy-to-use means of assessing habitat quality and biological integrity of Mediterranean streams and rivers in the province of Barcelona (Region Catalonia, Iberian Peninsula). The study included sampling sites from five different river catchments: Besòs, Foix, Llobregat, Ter and Tordera. Multivariate statistical procedures and indicator species analysis were used to investigate the relationship between river ecological status, study sites and dragonfly species or species assemblages' occurrence. The dragonfly association identified with western Mediterranean permanent streams, i.e. *Cordulegaster boltonii*, *Boyeria irene*, *Onychogomphus uncatus* and *Calopteryx virgo meridionalis*, was found only at the sites with the highest status. All these taxa were identified as indicator species of sites with the best scores for the macroinvertebrate based IBMWP index and for the combined IASPT index, which reflects the sensitivity of the macroinvertebrate families present to environmental changes; besides, *B. irene* and *C. virgo meridionalis* also proved to be indicator species of the riparian forest quality index and *C. boltonii* of the more inclusive ECOSTRIMED, which assesses the overall conservation status of the riverine habitats. The information obtained on habitat preferences and indicator value showed that adults of these taxa may constitute a valuable tool for preliminary or complementary cost-effective monitoring of river status and restoration practices as part of a broader set of indices reflecting biodiversity and ecosystem integrity.

Keywords: riverine habitats; ecological status; dragonflies; species assemblages; multivariate analysis; biondicators; province of Barcelona; Catalonia

Introduction

The ecological status of Mediterranean rivers can be strongly influenced by seasonality, which has a significant impact on water flow and thus on the physical, chemical and biological characteristics of the water and on the riparian area in general. At the same time, environmental and climatic factors such as fires and global warming have adverse effects on their conservation and, additionally, they are subjected to a strong anthropic pressure. The drying and exploitation of water resources for agriculture, industry, tourism and urban growth, along with the construction of water infrastructures (e.g. damming and canalization) is causing the regression or degradation of many riverine habitats (Riservato et al., 2009).

The Water Framework Directive (EU Water Framework Directive 2000/60/EC, 2000) establishes the conditions necessary for the protection of inland waters and provides the metrics that

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should be used to assess their ecological status. Some of them rely on selected bioindicator groups like plants, fish, birds, macroinvertebrates or several together. However, most of these methods are relatively expensive and their application is restricted to specialists. Using faster, simpler and more economical ones would allow the creation of qualified technicians' networks that could participate in conservation and divulgation programs. Among these methods are those using dragonflies (see review in Oertli, 2008).

In general, dragonflies meet the requirements to be considered quality bioindicator insects (Noss, 1990; Oertli, 2008). They have few generations per year, show high sensitivity to early changes in their environment, respond quickly to them and provide continuous information about the damage caused by the alterations, both in the larval (Ferreras-Romero, Márquez-Rodríguez, & Ruíz-García, 2009; Gómez-Anaya, 2008; Watson, Arthington, & Conrick, 1982) and the adult stage (Müller et al., 2003; Samways & Steytler, 1996; Torralba Burrial, 2009).

However, some authors indicate that using larvae is not as practical as using adults since they may be cryptic and have different microhabitat preferences depending on the species (Watson et al., 1982), thus requiring a variety of methods for sampling them (Hawking & New, 1999) and making data comparison difficult. Besides, it is not always easy to identify early instars. Instead, adults can be surveyed at a low cost and can therefore be conveniently used for rapid assessment or preliminary screening (Oertli, 2008).

According to the catalogue provided by Martín (2004) and later updated by Luque and Serra (2006), Lockwood, Soler, and Müller (2007), Escolà, Müller, and Batlle (2011) and Herrera-Grao, Bonada, Gavira, and Blanco-Garrido (2012), the Catalonian dragonfly fauna comprises 67 species including 25 zygopterans (four families) and 42 anisopterans (five families). This is without considering *Coenagrion pulchellum* Vander Linden, 1825 and *Brachytron pratense* (Müller, 1763), which are believed to have become extinct in this region in recent times and *Leucorrhinia pectoralis* Charpentier, 1825, considered to be a vagrant (Martín & Maynou, 2015).

Among these species, some are reported to be running water specialists, mainly those belonging to the genera *Calopteryx*, *Cordulegaster*, *Boyeria* and *Onychogomphus*. These taxa are restricted to lotic habitats both during larval and adult life and are highly sensitive to factors that influence the ecosystem status such as water flow, sediment type, aquatic macrophytes, riparian vegetation structure, amount of sunlight, dissolved oxygen and pollution (Ferreras-Romero, 1988; Ferreras-Romero & García-Rojas, 1995; González del Tanago & García-Jalón, 1984; Torralba Burrial, 2009).

The aim of this study was to find out whether there is a good correlation between presence of certain dragonfly species or species assemblages and high scores for quality status of rivers and streams in the province of Barcelona and assess their suitability for inclusion in biological assessment and monitoring programs as indicator species.

Materials and methods

Study sites

The province of Barcelona (7728 km^2) includes the catchments, or part of them, of the rivers Besòs, Foix, Llobregat, Ter and Tordera. These rivers range from a length of 208 km (Ter) and an average flow of 19 m^3 s^{-1} (Llobregat) to 17.7 km (Besòs) and 0.28 m^3 s^{-1} (Foix).

A series of 32 study sites selected from the 115 included in a monitoring scheme being carried out by the Department of Ecology at the University of Barcelona was checked for species composition and abundance of adult Odonata. These sites belong to upper, mid and lower reaches (from 560 m to 46 m asl) of the above-mentioned rivers and their tributaries.

Table 1. List of study sites with their codes, UTM coordinates and river basin to which they belong.

Study site	UB code	River basin	UTM X	UTM Y	Altitude (m)
Torrent d'Estenalles stream	L45	Llobregat	415763	4616609	540
Gavarresa stream	L64a		411680	4628315	320
Anoia river	L77		381279	4604917	310
Anoia river	L82		375998	4612090	465
Anoia river	L86		393453	4594636	175
Llobregat river	L102		406084	4617909	180
Besòs river	B03	Besòs	435104	4598267	52
Mogent river	B04		440817	4601101	82
Sant Pere de Vilamajor stream	B07a		448978	4616098	315
Vallfornés stream	B08a		445761	4617799	410
Cànoves stream	B08b		446273	4607422	140
Congost river	B10		440013	4614470	220
Ripoll river	B20		426441	4601143	138
Ripoll river	B22		421440	4611242	375
Gallifa stream	B24		425053	4616481	560
Avençó stream	B32		439085	4624365	340
Congost river	B33		439120	4621079	330
Vallcàrquera stream	B35		440308	4619921	361
Vall d'Horta stream	R9b		419296	4614621	510
Torrent del Castelló stream	R13		4422604	4611909	454
Tordera river	T00	Tordera	449269	4625061	520
Tordera river	T01		450950	4621088	310
Tordera river	T12		469745	4620388	57
Vallgorguina stream	T22		456976	4612929	160
Gualba stream	T24		460542	4618585	110
Breda stream	T26		463438	4621133	115
Arbúcies stream	T27		467254	4623031	85
Santa Coloma stream	T28		473112	4621426	46
Tordera river	T29		467141	4619787	66
Fuirosos stream	T30		465316	4617518	105
Foix river	F52	Foix	385643	4569410	100
Major stream	Teb2	Ter	449364	4631900	800

Notes: UB code = University of Barcelona sampling site code; UTM X and UTM Y coordinates are 31N/ETRS89.

They were chosen in order to provide broad geographical coverage, i.e. pre-coastal depression, coastal range, central depression and Montseny and St Llorenç del Munt massifs, the latter two belonging to the pre-coastal range. They also covered a wide range of habitat types, from the high reaches of cold siliceous streams with high levels of dissolved oxygen, absence of hydrophytes and well-developed riparian cover to the middle and lower reaches of watercourses with a more extensive hydrophyte cover and absence of riparian vegetation. The sites were also heterogeneous regarding flow regimes (variable versus permanent) and biotic and chemical status (low, medium and high).

The list of selected study sites is shown in Table 1 and their locations in the map are represented in Figure 1.

Data collection

The 32 sites were sampled twice during the summer between June and September with a spacing of at least one month between visits. Most (24) were sampled in 2011 and the rest in 2014. At each site a transect of 50 m × 5 m was established along the bank of the river and it was walked at a slow pace between 11:00 and 18:00 h (CEST) on warm, sunny and windless days with air temperature ≥ 17°C and at least 50% sunshine (Brooks, 1993). All adult individuals perched or

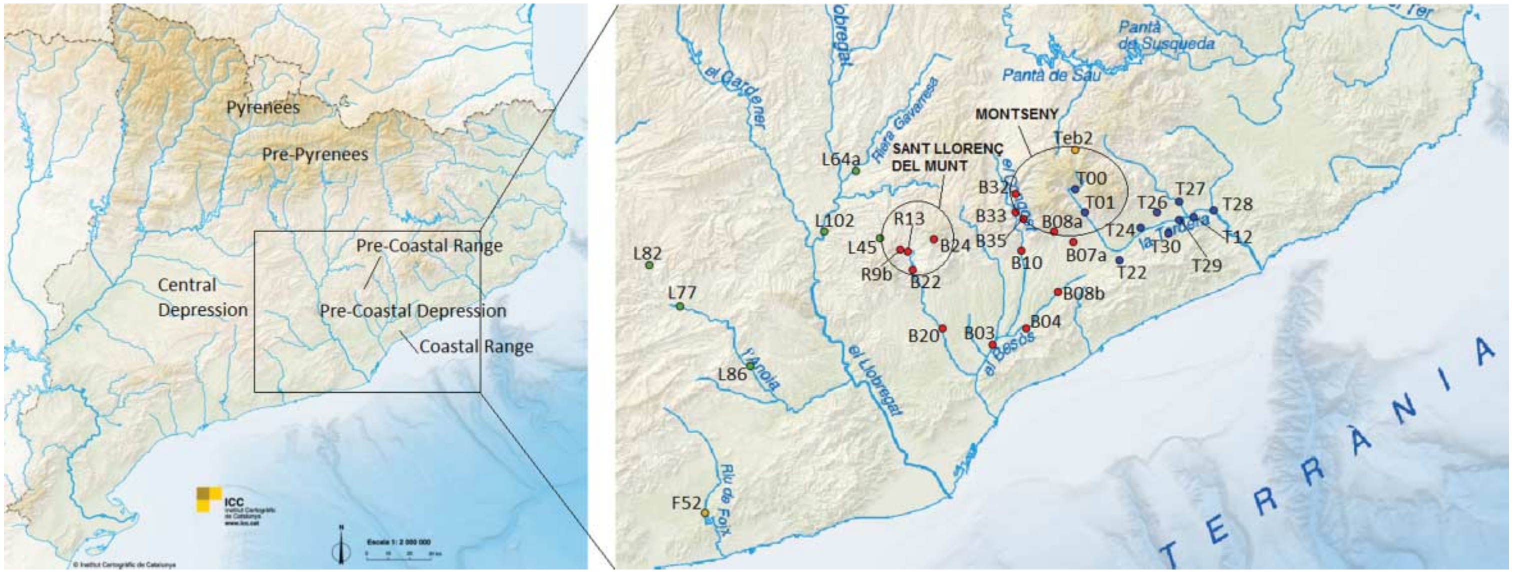

Figure 1. Investigated area and study site locations. Site codes as in Table 1. Map obtained from Institut Cartogràfic i Geològic de Catalunya (ICGC) http://www.icc.cat/vissir3/.

flying in front and on either side were counted (Moore & Corbet, 1990). Some individuals could only be identified after being caught with a hand net but were released after correct identification. The identification keys used were those of Dijkstra and Lewington (2006).

Ecological quality index scores and water quality measurements were obtained from a monitoring scheme that is being carried out in the province of Barcelona by the Department of Ecology at the University of Barcelona, with the collaboration of the Department of Environment of the Barcelona Provincial Council, the "Observatori de la Tordera" (Tordera River Observatory) and the Catalan Water Agency (ACA). As a result, a value for the ECOSTRIMED (Prat, Munné, Rieradevall, Solà, & Bonada, 2000) index is determined in order to provide an integrated quality assessment of the riverine ecosystems in the province of Barcelona. ECOSTRIMED combines a water quality index based on macroinvertebrates (Iberian Bio-Monitoring Working Party [IBMWP] – Alba-Tercedor & Sánchez-Ortega, 1988; or Family Biotic Index for Foix, Besòs and Llobregat rivers [FBILL] – Prat et al., 1999) and a riparian forest quality index (QBR; Munné, Prat, Solà, Bonada, & Rieradevall, 2003); (see http://geographyfieldwork.com/ECOSTRIMED%20Protocol%20Procedure.htm). Other quality indices being monitored are IHF (Fluvial habitat Index; Pardo et al., 2002), S (number of macroinvertebrate families) and IASPT (average score per taxon, i.e. the ratio of IBMWP to S), together with some water quality parameters like dissolved oxygen, ammonium, nitrites, nitrates, phosphates, sulphates, chlorides and conductivity (see Appendix).

The monitoring is performed on a yearly base and the results are published in the series of monographs "Estudis de la Qualitat Ecològica dels rius" (Studies of the Ecological Quality of Rivers). The samplings that provided the river quality data for the present study were done in the spring of 2011 (Barcelona Provincial Council database, http://ecobill.diba.cat/index.php?page=access) and 2014 (Prat et al., 2015). In general, they were made earlier in the season than the surveys made by the authors, in some cases even with a time difference of two months. However, since the biotic and environmental conditions reflected by the quality indices obtained some weeks earlier ensured larval survival, they were assumed to explain the assemblages of adult individuals of autochthonous species recorded later by the authors.

Data analysis

Although odonate abundance estimates were obtained in the field, only species occurrence (presence/absence) was used in the statistical analyses in order to remove the effect of uneven sampling effort.

Principal components analysis (PCA) (Pearson, 1901) was used as an indirect gradient method to relate the study sites to the quality indices and water chemistry measurements. The purpose was to sort the sites along axes, arranging together those that had similar quality indices and water chemistry scores. In the PCA graphs these variables are represented by arrows and their value increases in the direction of the arrow. Its length indicates how much a variable contributes to the segregation of sites. The smaller the angle between arrows, the closer the correlation between variables.

The analysis was performed using the FactoMineR package (Lê, Josse, & Husson, 2008). The quality indices values were standardized to unit variance before being used in the calculations. Some of the water chemistry measurements were missing for three of the sampling sites (B04, B10, L64a). In order to include these sites in the analysis the median of the scores of the previous years was assigned to them. Additionally, the 32 study sites were classified on the basis of their quality scores by means of a cluster analysis employing the Ward method and euclidean distances and a dendrogram was produced as a graphical output.

The indicator value method was performed by means of the program IndVal 2.0 (indicator value method, Dufrêne, 1998) and the software package Indicspecies 1.6.7 (de Cáceres & Legendre, 2009) and it was applied to the structure of the cluster analysis to find the representative taxa for each group of sites and then to the quality indices and water chemistry results to find the species indicative of the sites with the best scores. Prior to analysis the scores were categorized into five classes, from very good to bad, except in the case of IHF (river channel habitat quality), nitrites, nitrates and conductivity, which were ranked within a three-class system (Prat, Rieradevall, & Fortuño, 2012; Sellarès, Jiménez Saldaña, & Ordeix i Rigo, 2014; see Appendix). Taxa occurring in less than 20% of the sites were discarded.

IndVal defined indicator species as the most characteristic of sites assigned to a particular variable quality class, found mostly in those sites and present in the majority of them (*sensu* Dufrêne & Legendre, 1997).

All the statistical techniques were provided by R software (R Development Core Team, 2015).

Results

Species abundances and diversity

The survey yielded a total count of 1539 individuals belonging to 30 dragonfly species (13 Zygoptera and 17 Anisoptera).

According to the classification proposed by Torralba Burrial and Ocharan (2007), among the 30 species there was a remarkable majority of Mediterranean taxa (22 species; 73.3% of the total), the rest being Pontic-oriental (four; 13.3%), Ethiopian (three; 10.0%) and Eurosiberian (one; 3.3%).

Their absolute abundance (sum of results of both sampling occasions) at each study site is given in Supplementary Table S1.

The most abundant was by far *Calopteryx haemorrhoidalis* (49.2% of the records), followed by *Platycnemis latipes* (9.4%) and *Ischnura graellsii* (7.9%). Together with *Calopteryx virgo meridionalis* (4.8%), *Orthetrum coerulescens* (3.4%), *Chalcolestes viridis* (3.4%), *Calopteryx xanthostoma* (3.2%) and *Erythromma lindenii* (2.7%) they made up 84% of the total abundance. At a family level, Calopterygidae (57.2%) was the most abundant followed by Coenagrionidae (14.4%) and Platycnemididae (10.4%).

Regarding the distribution of taxa in the study area, the most widespread were also *C. haemorrhoidalis* (found in 71.9% of the sites) and *P. latipes* (50%), followed by *Cordulegaster boltonii* (43.8%), *C. viridis* (37.5%), *O. coerulescens* (34.4%) and *I. graellsii* and *Onychogomphus forcipatus unguiculatus* (31.3%).

Site T12 (La Tordera river) had the highest number of individuals recorded (154) and T29 (La Tordera river) followed closely with 145. Sites B33 (El Congost river) and L45 (Torrent d'Estenalles stream), with 133 and 106 individuals respectively, also showed remarkable abundances. Conversely, the sites with the lowest abundances were L64A (3) and Teb2 (1).

Species richness was highest at L45 with 14 species, B24 (Gallifa stream) came second with 10 and B22 (Ripoll river), B32 (Avençó stream), R9b (Vall d'Horta stream) and R13 (Castelló stream) third with 9. The lowest values were recorded in L82, L102 and Teb2 (1).

Ordination of quality indices and sites

The application of PCA analysis to the matrix of study sites and variables scores (Table 2) resulted in the first four axes (components) explaining 80.65% of the total variance of the dataset.

Table 2. Biotic quality indices scores and water chemistry measurements obtained by the Department of Ecology, University of Barcelona (2011, 2014). When sites were sampled twice or more times in the same year the results of the first sampling (spring) were taken.

Study site	IBMWP	S	FBILL	ECOSTRIMED	IASPT	QBR	IHF	Ammonium (mg l^{-1})	Nitrites (mg l^{-1})	Nitrates (mg l^{-1})	Phosphates (mg l^{-1})	Conductivity (μS cm^{-1})	Oxygen (mg l^{-1})	pH	Sulphates (mg l^{-1})	Chlorides (mg l^{-1})
L45	126	24	9	5	5.2	100	57	0.008	0.003	0.056	0.003	545	8.95	8.57	14.10	16.43
L64a	35	9	5	1	3.9	10	62	0.165	0.034	3.040	0.091	1617	7.57	8.20	375.00	190.40
L77	57	13	7	2	4.4	75	58	0.041	0.003	3.567	0.072	2280	8.70	8.20	856.00	247.30
L82	95	20	10	3	4.8	75	71	0.041	0.003	3.567	0.072	2280	7.58	8.57	856.00	247.30
L86	52	15	6	2	3.5	45	58	0.247	0.277	3.883	0.098	153	8.80	8.10	480.00	82.60
L102	49	13	6	1	3.8	5	46	0.041	0.034	8.064	0.029	625	9.56	8.20	169.00	203.10
B03	34	10	5	1	3.4	10	70	1.977	0.159	1.806	0.415	704	7.10	7.70	57.00	91.40
B04	56	14	6	2	4.0	25	62	4.000	0.370	4.244	0.326	2102	7.85	6.50	94.45	174.70
B07A	143	25	10	5	5.7	85	84	0.041	0.008	3.431	0.268	271	9.63	7.93	37.00	26.80
B08a	119	20	10	4	6.0	85	77	0.082	0.006	0.564	0.033	159	8.96	8.15	34.00	32.70
B08b	185	36	10	3	5.1	10	80	0.041	0.034	1.445	0.121	283	8.50	7.90	24.00	18.50
B10	67	16	6	2	4.2	60	59	0.155	0.050	2.166	0.413	874	6.75	8.14	102.00	95.85
B20	51	14	6	1	3.6	10	69	0.577	0.317	4.244	0.536	1043	8.20	8.20	76.00	142.30
B22	165	32	10	4	5.2	75	69	0.001	0.049	0.438	0.036	759	10.04	8.21	27.21	25.46
B24	198	40	10	5	5.0	95	63	0.016	0.003	0.056	0.000	669	8.95	8.45	33.29	15.37
B32	250	40	10	4	6.2	75	72	0.041	0.003	0.282	0.011	254	7.40	7.70	19.00	2.50
B33	102	24	10	2	4.3	20	70	0.041	0.116	27.946	0.072	872	12.31	8.52	223.00	89.40
B35	164	30	10	5	5.5	85	70	0.082	0.006	0.564	0.033	443	7.93	8.30	18.00	5.00
R9b	147	31	9	4	4.7	70	40	0.100	0.008	0.056	0.016	568	5.22	7.82	12.40	14.10
R13	157	32	9	5	4.9	100	57	0.040	0.008	0.056	0.016	602	5.12	7.90	14.20	13.20
T00	199	30	10	5	6.6	85	75	0.082	0.002	0.068	0.020	112	9.19	8.06	2.50	5.00
T01	177	29	10	5	6.1	85	66	0.033	0.002	0.158	0.023	138	8.46	7.97	8.00	5.00
T12	29	8	5	1	3.6	65	52	0.041	0.034	1.625	0.011	377	7.80	7.60	31.00	34.50
T22	92	20	7	3	4.6	45	60	0.041	0.095	2.144	0.219	561	8.90	8.00	47.00	47.90
T24	104	18	9	3	5.8	75	78	0.041	0.034	0.282	0.011	146	9.90	7.70	9.00	12.50
T26	148	25	10	4	5.9	50	86	0.041	0.018	0.282	0.011	108	10.20	7.90	8.00	2.50
T27	101	20	9	2	5.0	30	74	0.041	0.003	1.242	0.072	202	10.10	8.10	16.00	15.10
T28	78	17	8	2	4.6	30	54	0.041	0.015	0.282	0.011	390	7.40	8.00	16.00	22.00
T29	70	17	8	1	4.1	40	67	0.247	0.076	0.282	0.098	284	7.90	7.60	27.00	29.10
T30	150	29	10	5	5.2	95	70	0.040	0.008	0.056	0.016	245	9.39	7.80	11.30	21.70
F52	36	11	6	1	3.3	40	66	0.340	0.247	9.284	0.127	1748	10.48	8.50	175.40	303.20
Teb2	209	33	10	5	6.3	100	88	0.040	0.008	0.056	0.016	144	10.17	8.10	5.90	4.10

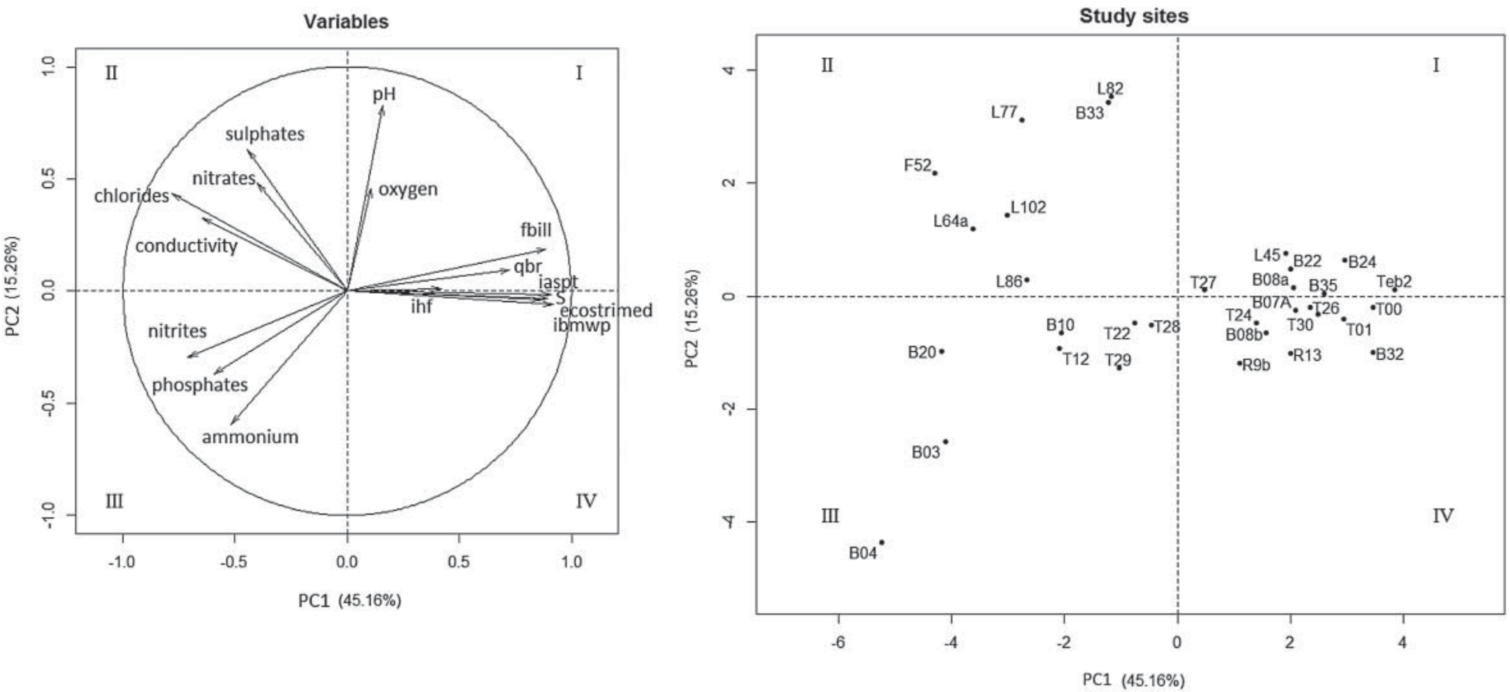

Figure 2. PCA first two principal components of variables (left) and study sites (right). Site codes as in Table 1.

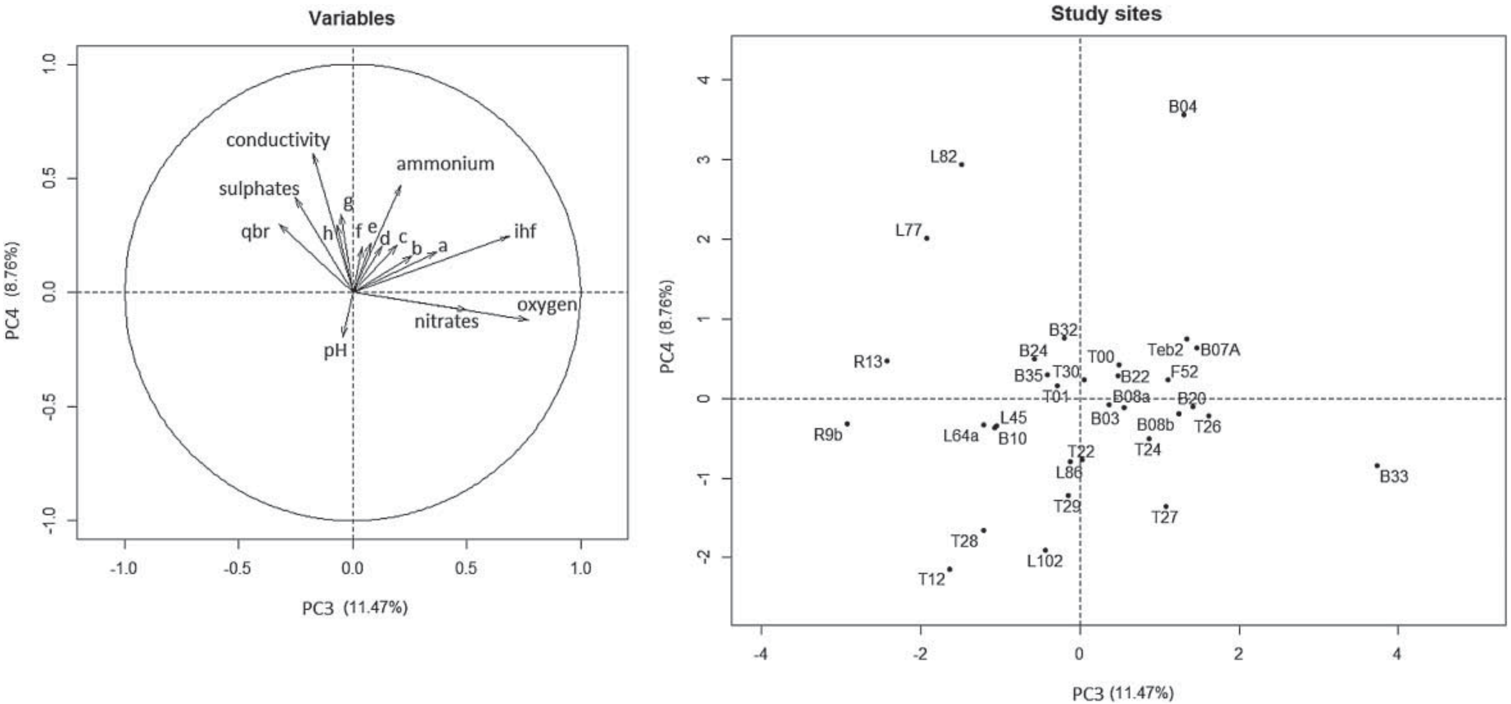

Figure 3. PCA third and fourth principal components of variables (left) and study sites (right). Site codes as in Table 1. (a) phosphates; (b) nitrites; (c) FBILL; (d) IASPT; (e) S; (f) IBMWP; (g) chlorides; (h) ECOSTRIMED.

Table 3. Values of the correlation coefficients measuring the strength of the relationship between the variables and the first four components of the PCA analysis.

Variable	PC1	PC2	PC3	PC4
IBMWP	0.917	–0.059	0.079	0.215
S	0.858	–0.04	0.042	0.198
FBILL	0.884	0.186	0.194	0.206
ECOSTRIMED	0.892	–0.034	–0.067	0.297
IASPT	0.908	–0.016	0.127	0.203
QBR	0.724	0.093	–0.324	0.301
IHF	0.419	0.011	0.688	0.247
Ammonium	–0.517	–0.595	0.209	0.468
Nitrites	–0.711	–0.297	0.37	0.178
Nitrates	–0.399	0.482	0.503	–0.078
Phosphates	–0.594	–0.369	0.261	0.16
Conductivity	–0.647	0.327	–0.171	0.609
Oxygen	0.108	0.457	0.77	–0.12
pH	0.158	0.826	–0.043	–0.193
Sulphates	–0.443	0.629	–0.25	0.415
Chlorides	–0.78	0.433	–0.052	0.341

The quality indices, with the exception of IHF, showed a strong correlation with the first component (which explained 45.16% of the variance) (Figure 2). Those sites located rightmost in the graph were the best ones in terms of ecological status and those leftmost the worst. A similar pattern was observed for the water chemistry variables: those sites on the left had worse scores for water quality, especially regarding chlorides and nitrates, while those on the right had better ones. However, the correlation of the chemical variables to this component was weaker. They correlated better with the second one (which explained 15.26% of the total variance). In relation to these variables, except for dissolved oxygen, sites located closer to the tips of the arrows were those that featured the worst scores. pH, ammonium and sulphates were the major factors influencing the arrangement of sites (Figure 2). Quality indices were poorly correlated to this axis. IHF and oxygen were mainly correlated to the third component (11.47% of the total variance) and conductivity to the fourth (8.76% of total variance) (Figure 3).

In summary, those sites placed rightmost and closer to the first axis in the first two principal components graphs (Figure 2) were the ones that showed better ecological status and chemical variables scores, i.e. sites located in quadrants I and IV. Sites within quadrants II and III were those that showed a poorer ecological condition and physicochemical quality.

According to the correlation coefficients of the quality indices, IBMWP was the main contributor to the differentiation of the study sites. It had a correlation coefficient value with the first axis of 0.917 and was followed by IASPT (0.908), ECOSTRIMED (0.892) and QBR (0.724). In all cases, the correlations of the variables with the first four principal axes (Table 3) were statistically significant.

Classification of sampling sites

Nine groups of study sites were produced by the cluster analysis based on the variables scores (Figure 4).

Site groups belonging to the left branch of the dendrogram are those that had good/very good ecological conditions and water quality. Sites to the right of the graph are those that had medium or low quality scores. Group C comprises the sites with the highest values for all the ecological quality variables and at the same time, the best results for water chemistry measurements, e.g. high levels of oxygen and weak mineralization. Group B sites were characterized by fairly good

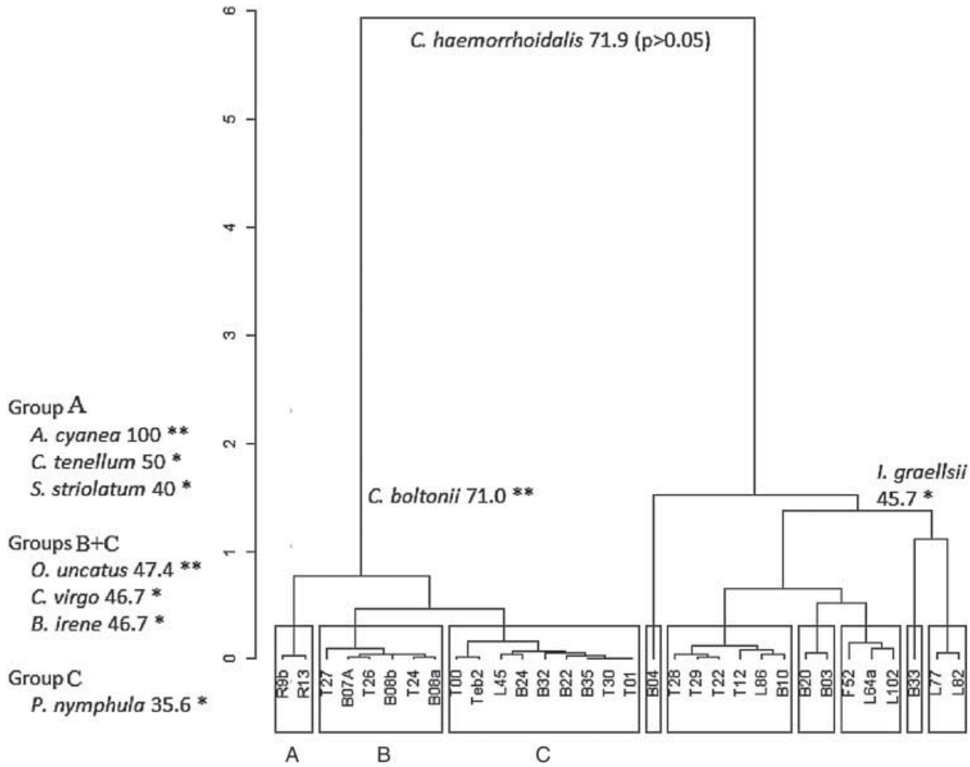

Figure 4. Classification of the 32 sampling sites based on the ecological quality indices and physicochemical variable scores. Indicator species are highlighted for the main dendrogram branches including those corresponding to the best quality site groups A, B + C and C. Site codes as in Table 1. $*p < 0.05$, $**p < 0.01$.

quality scores although not as good as those for group C. In the case of ECOSTRIMED and QBR they featured intermediate values even when the water chemistry results were good. Group A included two sites, R13 and R09b, which also had good quality values but low levels of dissolved oxygen and more mineralized water. The other groups featured low or intermediate values for most ecological variables and poor results for the water chemical parameters.

Indicator value analysis

In order to find the species indicative of each site group the IndVal routine was applied to the dendrogram hierarchy.

Cordulegaster boltonii was identified as an indicator of the groups of sites A, B and C, which had good or very good ecological quality conditions and physicochemical scores. *Aeshna cyanea*, *Ceriagrion tenellum* and *Sympetrum striolatum* appeared as indicators of the sites of group A. *Onychogomphus uncatus*, *Boyeria irene* and *C. virgo meridionalis* as indicators of sites included in groups B + C and *Pyrrhosoma nymphula* of group C sites. *C. haemorrhoidalis* was recognized as an indicator of all sites combined but the relationship was not statistically significant. *I. graellsii* appeared as indicator of most of the sites with the worst conditions.

The previous analysis limits the search for bioindicator odonates to the species representative of the left branch of the dendrogram.

Table 4. IndVal analysis. Summary of results for significant indicator species of quality indices (left) and water chemistry variables (right).

Variable	Species	IV	Class	Variable	Species	IV	Class
ECOSTRIMED	*C. boltonii*	64.29**	5	Ammonium	*C. boltonii*	52.48*	5
FBILL	*B. irene*	33.33*	5	Ammonium	*O. uncatus*	39.13*	5
FBILL	*C. virgo*	33.33*	5	Chlorides	*B. irene*	46.67**	5
FBILL	*C. haemorrhoidalis*	67.08*	5	Chlorides	*C. boltonii*	57.62**	5
FBILL	*C. boltonii*	57.48**	5	Chlorides	*I. graellsii*	49.00**	4
IASPT	*B. irene*	53.85**	5	Chlorides	*O. uncatus*	47.41**	5
IASPT	*C. virgo*	53.85**	5	Conductivity	*C. boltonii*	53.85*	2
IASPT	*C. boltonii*	54.95**	5	Nitrates	*B. irene*	43.75*	3
IASPT	*O. uncatus*	41.88**	5	Nitrates	*C. boltonii*	64.29**	3
IBMWP	*B. irene*	36.73*	5	Nitrates	*O. uncatus*	44.44*	3
IBMWP	*C. virgo*	36.73*	5	Nitrites	*C. boltonii*	44.51*	3
IBMWP	*C. boltonii*	61.73**	5	Oxygen	*C. boltonii*	41.33*	5
IBMWP	*O. uncatus*	38.89*	5	Phosphates	*B. irene*	36.73*	5
QBR	*B. irene*	35.71*	4	Phosphates	*C. boltonii*	51.02**	5
S	*B. irene*	44.64*	3	Phosphates	*O. uncatus*	50.79**	5
S	*C. virgo*	44.64**	3				
S	*C. boltonii*	43.75*	3				

*$p < 0.05$, **$p < 0.01$.

Accordingly, the IndVal analysis was applied to the categorized biotic quality indices scores and the representative taxa of the groups in the left branch of the dendrogram that occurred in at least 20% of the study sites.

Regarding macroinvertebrate diversity, *C. virgo meridionalis*, *C. haemhorroidalis*, *B. irene* and *C. boltonii* proved to be indicator species of the best quality category of FBILL (class 5). *Cordulegaster boltonii*, *O. uncatus*, *B. irene* and *C. virgo meridionalis* were equally identified as indicators of the top quality class (5) for IBMWP and IASPT. At the same time, *C.v. meridionalis* and *B. irene* stood out as bioindicators of riparian forest quality (QBR, class 4) and *C. boltonii* of overall ecological quality (ECOSTRIMED, class 5). In addition, *C. boltonii*, *O. uncatus* and *B. irene* were also recognized as indicators of good physicochemical quality of water (Table 4).

Discussion

The contribution of the quality indices based on aquatic macroinvertebrate families to the assessment of fluvial ecosystem health is supported by a large amount of scientific evidence and a number of monitoring methods are used in different regions of the world. However, some authors point out that this type of assessment has some limitations: their application is relatively expensive and restricted to specialists and does not provide information at the species level. Besides, aquatic macroinvertebrates are rather more responsive to water quality than to changes in the general structure of the riparian habitat (Smith, Samways, & Taylor, 2006) and on that account they may not completely reflect the latter's overall conservation status (Ferreras-Romero et al., 2009; Simaika & Samways, 2011).

Consequently, they recommend using additional metrics based on particular indicator groups like, for example, dragonflies, at the species level, in order to obtain more accurate information about the ecological state of the river environment. Stenotopic dragonflies constitute a valuable tool for quick and economical assessments based on larval and adult stages since they are highly influenced by riparian vegetation structure, habitat heterogeneity, seasonality and other environmental variables (Ferreras Romero et al., 2009). Their monitoring helps in the early detection of changes (Smith et al., 2006) and they are increasingly used as indicators of ecosystem integrity and disturbance. Thus, Simaika and Samways (2011) introduced DBI (Dragonfly Biotic Index) as a riverine habitat monitoring tool while Ferreras-Romero (2013) proposed ISOI (Iberian Stream Odonatological Index) as a measure of ecological integrity of Mediterranean rivers.

The results of the PCA analysis and the IndVal test obtained in the present study clearly indicate that there is a group of species formed by *C. virgo meridionalis*, *B. irene*, *O. uncatus* and *C. boltonii* that can be associated with sites having the highest quality indices scores. These results point in the same direction as others obtained in other areas of the Iberian Peninsula. For example, González del Tanago and García Jalón (1984), working on larvae in the Duero river basin, found that *B. irene* and *C. boltonii* were intolerant to pollution. Ferreras-Romero (1988), also using larvae, distinguished between tolerant and stenotopic species. He found that *O. uncatus* and *C. boltonii* were very good quality indicators and so were *B. irene* and *O. forcipatus unguiculatus*, although to a lesser degree. Torralba Burrial (2009), in a study of the Odonata of the region of Aragón river network, found that adults of *B. irene*, *O. uncatus* and *C. boltonii* were excellent indicators of ecological quality. Ferreras-Romero et al. (2009) suggested that the absence of *Calopteryx* and *Oxygastra* along the river Guadiamar indicated environmental degradation. The conclusions drawn from the present study are in line with those presented by the above-mentioned authors and also introduce *C. virgo meridionalis* as a potential bioindicator. Although *C. haemhorroidalis* was also identified as an indicator of macroinvertebrate diversity (FBILL class 5), the fact that it was associated with sites featuring both good and bad results for the quality variables (Figure 4) makes it unsuitable for this purpose.

The stenotopic species were found mainly in the upper stretches of the Tordera river basin, in the Montseny massif area. The watercourses in this area are characterized by a well-developed riparian forest cover, shadier and cooler waters, coarse sediment and absence of hydrophytes. These features correspond to the high and middle reaches of siliceous mountain rivers, an environment to which few odonate species are adapted. These exigent taxa also occur in the Besòs and Llobregat basins, especially in the Sant Llorenç del Munt mountain range, with the exception of *C. virgo meridionalis*. Here the riparian forest is sparser, allowing sunnier conditions, the hydrophyte cover is more extensive, the sediment is finer grained and the species assemblage is enriched with other interesting taxa like *Coenagrion caerulescens* and *Coenagrion mercuriale*.

Evidence was obtained, by means of exuviae collection, to prove that the proposed bioindicator species reproduce in the study sites where adults were found and can thus be considered autochthonous.

The implementation of species monitoring programs making use of these bioindicator odonate taxa as a straightforward approach preliminary or complementary to more comprehensive assessment methods could contribute to effective monitoring of the ecological status of rivers and streams in the Montseny and St Llorenç del Munt nature reserves. The ease with which adults can be observed and identified in the field could allow trained park technicians and wardens to join fluvial ecosystems conservation programs (Torralba Burrial, 2009).

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Supplemental data

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References

Alba-Tercedor, J., & Sánchez-Ortega, A. (1988). Un método rápido y simple para evaluar la calidad biológica de las aguas corrientes basado en el de Hellawell (1978). *Limnetica*, *4*, 51–56. Retrieved from http://www.limnetica.com/Limnetica/Limne04/L04u051_Metodo_calidad_basado_BMWP.pdf

Brooks, S. J. (1993). Review of a method to monitor adult dragonfly populations. *Journal of the British Dragonfly Society*, *9*, 1–4.

de Cáceres, M., & Legendre, P. (2009). Associations between specie and groups of sites: Indices and statistical inference. *Ecology*, *90*(12), 3566–3574. Retrieved from http://adn.biol.umontreal.ca/ ∼ numericalecology/Reprints/De_Caceres_&_Legendre_Ecology_2009.pdf

Dijkstra, K. D. B., & Lewington, R. (2006). *Field guide to the dragonflies of Britain and Europe*. Gillingham: British Wildlife Publishing.

Dufrêne, M. (1998). IndVal 2.0. Program freely available at: http://old.biodiversite.wallonie.be/outils/indval/home.html

Dufrêne, M., & Legendre, P. (1997). Species assemblages and indicator species: The need for a flexible asymmetrical approach. *Ecological Monographs*, *67*(3), 345–366. Retrieved from http://adn.biol.umontreal.ca/ ∼ numericalecology/Reprints/Ecol%20Monogr%2067,%201997.pdf

Escolà, J., Müller, P., & Batlle, R. M. (2011). Odonatofauna del nuevo "Estany d'Ivars i Vila-sana" (Pla d'Urgell, Lleida NE Península Ibérica) (Odonata). *Boletín de la Sociedad Entomológica Aragonesa*, *48*, 329–334. Retrieved from http://www.estanyivarsvilasana.cat/engine/files/files/estudis-de-seguiment/odonats-05-09.pdf

EU Water Framework Directive 2000/60/EC. (2000). *Official Journal (OJ) of the European Union* 327, 22 December 2000, pp. 1–73. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri = celex%3A32000L0060

Ferreras Romero, M. (1988). New data on the ecological tolerance of some rheophilous Odonata in Mediterranean Europe (Sierra Morena, Southern Spain). *Odonatologica*, *17*(2), 121–126. Retrieved from https://www.sciencebase.gov/catalog/item/50538521e4b097cd4fce1786

Ferreras-Romero, M. (2013). Comparative analysis of the conservation state of southern Iberian streams using Odonata as indicators of environmental quality. *Métodos en Ecología y Sistemática*, *7*(3), 20–36. Retrieved from https://www.researchgate.net/publication/258220882_Comparative_analysis_of_the_conservation_state_of_southern_Iberian_streams_using_Odonata_as_indicators_of_environmental_quality

Ferreras-Romero, M., & García-Rojas, A. M. (1995). Life-history patterns and spatial separation exhibited by the odonates from a Mediterranean inland catchment in southern Spain. *Vie et Milieu*, *45*(2), 157–166.

Ferreras Romero, M., Márquez-Rodríguez, J., & Ruíz-García, A. (2009). Implications of anthropogenic disturbance factors on the Odonata assemblage in a Mediterranean fluvial system. *International Journal of Odonatology*, *12*(2), 413–428. doi:10.1080/13887890.2009.9748354

Gómez-Anaya, J. A. (2008). *Ecología de los ensamblajes de larvas de odonatos (insecta) y su uso potencial como indicadores de la calidad ecológica en la Sierra de Coalcomán, Michoacán, México* (PhD thesis). Universidad Autónoma del estado de Hidalgo. Retrieved from http://dgsa.uaeh.edu.mx:8080/bibliotecadigital/handle/231104/60

González del Tanago, M., & García-Jalón, D. (1984). Desarrollo de un índice biológico para estimar la calidad de las aguas de la cuenca del Duero. *Limnetica*, *1*, 263–272. Retrieved from http://www.limnetica.com/Limnetica/Limne01/L01u263_Indice_biologico_cuenca_Duero.pdf

Hawking, J. H., & New, T. R. (1999). The distribution patterns of dragonflies (Insecta: Odonata) along the Kiewa River, Australia, and their relevance in conservation assessment. *Hydrobiologia*, *392*, 249–260. doi:10.1023/A:1003510514937

Herrera-Grao, T., Bonada, N., Gavira, O., & Blanco-Garrido, F. (2012). First record of Trithemis kirbyi Sélys, 1891 in Catalonia (Odonata, Libellulidae). *Boletín de la Asociación Española de Entomología*, *36*(3–4), 457–459. Retrieved from http://www.entomologica.es/cont/publis/boletines/1510.pdf

Lê, S., Josse, J., & Husson, F. (2008). FactoMineR: An R Package for multivariate analysis. *Journal of Statistical Software*, *25*, 1–18. Retrieved from http://www.jstatsoft.org/article/view/v025i01

Lockwood, M., Soler, E., & Müller, P. (2007). Primera cita de Cordulia aenea Leach 1815 (Odonata: Corduliidae) para España. *Boletín de la Sociedad Entomológica Aragonesa*, *41*, 471–472. Retrieved from http://www.sea-entomologia.org/Publicaciones/PDF/BOLN41/471_472_NB_BSEA_41_Cordulia_aenea.pdf

Luque, P., & Serra, A. (2006). *Macromia splendens* i *Gomphus graslinii*, dues noves espècies d'odonats per a Catalunya. *Butlletí de la Institució Catalana d'Història Natural*, *74*, 113–116. Retrieved from http://publicacions.iec.cat/repository/pdf/00000051%5C00000070.pdf

Martín, R. (2004). Odonatos de Cataluña: catálogo y análisis geográfico. *Boletín de la Asociación Española de Entomología*, *28*(1–2), 55–69. Corrigendum in *Boletín de la Asociación española de Entomología*, 30(1–2). Retrieved from http://www.entomologica.es/cont/publis/boletines/735.pdf

Martín, R., & Maynou, X. (2015). Evaluación del estado de amenaza de los odonatos (Insecta: Odonata) de Cataluña. *Boletín de la Sociedad Entomológica Aragonesa*, *56*, 161–172. Retrieved from https://www.researchgate.net/publication/279538605_EVALUACION_DEL_ESTADO_DE_AMENAZA_DE_LOS_ODONATOS_INSECTA_ODONATA_DE_CATALUNA_ESPANA

Moore, N. W., & Corbet, P. S. (1990). Guidelines for monitoring dragonfly populations. *Journal of the British Dragonfly Society*, *6*, 21–23.

Müller, Z., Jakab, T., Toth, A., Devai, G., Szallassy, N., Kiss, B., & Horvath, R. (2003). Effect of sports fisherman activities on dragonflies assemblages on a Hungarian river floodplain. *Biodiversity and Conservation*, *12*, 167–179.

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. doi:10.1002/aqc.529

Noss, R. (1990). Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology*, *4*(4), 355–364. Retrieved from http://noss.cos.ucf.edu/papers/Noss1990.pdf

Oertli, B. (2008). The use of dragonflies in the assessment and monitoring of aquatic habitats. In A. Córdoba-Aguilar (Ed.), *Dragonflies and damselflies: Model organisms for ecological and evolutionary research* (pp. 79–95). Oxford: Oxford University Press. doi:10.1093/acprof:oso/9780199230693.003.0007

Pardo, I., Álvarez, M., Casas, J., Moreno, J. L., Vivas, S., Bonada, N., … Vidal-Abarca, M. R. (2002). El hábitat de los ríos mediterráneos. Diseño de un índice de diversidad de hábitat. *Limnetica*, *21*(3–4), 115–133. Retrieved from http://limnetica.com/Limnetica/limne21b/L21b115.indice.habitat.fluvial.rios.mediterraneos.proyecto.Guadalmed.pdf

Pearson, K. (1901). On lines and planes of closest fit to systems of points in space. *Philosophical Magazine*, *2*, 559–572. Retrieved from http://pbil.univ-lyon1.fr/R/pearson1901.pdf

Prat, N., Fortuño, P., Rieradevall, M., Acosta, R., Bonada, N., Pace, G., … Tarrats, P. (2015). *Efectes del Canvi Ambiental en les comunitats d'organismes dels RIus MEDiterranis (CARIMED). Informe 2014*. Diputació de Barcelona. Àrea d'Espais Naturals. Estudis de la Qualitat Ecològica dels Rius, 23. 67 p. Retrieved from http://www.ub.edu/riosandes/docs/CARIMED2014/INFORME%20CARIMED%202014_definitiu.pdf

Prat, N., Munné, A., Rieradevall, M., Solà, C., & Bonada, M. (2000). *ECOSTRIMED. Protocol per determinar l'estat ecològic dels rius mediterranis*. Diputació de Barcelona Àrea de Medi Ambient. Estudis de la Qualitat Ecològica dels Rius, 8. 94 pp.

Prat, N., Munné, A., Solà, C., Rieradevall, M., Bonada, M., & Chacón, G. (1999). *La qualitat ecològica del Besòs i el Llobregat. Informe 1997*. Diputació de Barcelona. Àrea de Medi Ambient. Estudis de la Qualitat Ecològica dels rius, 6. 154 pp.

Prat, N., Rieradevall, M., & Fortuño, P. (2012). Metodología F.E.M. para la evaluación del ESTADO ECOLÓGICO de los ríos Mediterráneos. Retrieved from http://www.ub.edu/fem/docs/protocols/fem_%20prot_cast_2012.pdf

R Development Core Team. (2015). *R: A language and environment for statistical computing*. Vienna, Austria: The R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Riservato, E., Boudot, J.-P., Ferreira, S., Jovic, M., Kalkman, V. J., Schneider, W., … Cuttelod, A. (2009). *The status and distribution of dragonflies of the Mediterranean Basin*. Gland: IUCN. vii + 33pp. doi:10.2305/IUCN.CH.2009.18.en

Samways, M. J., & Steytler, N. S. (1996). Dragonfly (Odonata) distribution patterns in urban and forest landscapes, and recommendations for riparian management. *Biological Conservation*, *78*, 279–288. doi:10.1016/S0006-3207(96)00032-8

Sellarès i Oró, N., Jiménez Saldaña, L., & Ordeix i Rigo, M. (2014). Seguiment de l'estat ecològic dels cursos fluvials d'Osona. Any 2014. Centre d'Estudis dels Rius Mediterranis – Museu del Ter. Retrieved from http://transparencia.manlleu.cat/files/doc22198/ee-osona-2014-def.pdf

Simaika, J. P., & Samways, M. J. (2011). Comparative assessment of indices of freshwater habitat conditions using different invertebrate taxon sets. *Ecological Indicators*, *11*(2), 370–378.

Smith, J., Samways, M., & Taylor, S. (2006). Assessing riparian quality using two complementary sets of bioindicators. *Biodiversity and Conservation*, *16*(9), 2695–2713. doi:10.1007/s10531-006-9081-2

Torralba Burrial, A. (2009). *Estado ecológico, comunidades de macroinvertebrados y de odonatos de la red fluvial de Aragón*. Zaragoza: Consejo Económico y Social de Aragón; 224 pp. Retrieved from https://www.researchgate.net/publication/235932610_Composicion_biogeografica_de_la_fauna_de_libelulas_Odonata_de_la_Peninsula_Iberica_con_especial_referencia_a_la_aragonesa

Torralba Burrial, A., & Ocharan, F. J. (2007). Composición biogeográfica de la fauna de libélulas (Odonata) de la Península Ibérica, con especial referencia a la aragonesa. *Boletín de la Sociedad Entomológica Aragonesa*, *41*, 179–188. Retrieved from https://www.researchgate.net/publication/235932610_Composicion_biogeografica_de_la_fauna_de_libelulas_Odonata_de_la_Peninsula_Iberica_con_especial_referencia_a_la_aragonesa

Watson, J. A. L., Arthington, A. H., & Conrick, D. L. (1982). Effect of sewage effluent on dragonflies (Odonata) of Bulimba Creek, Brisbane. *Australian Journal of Marine & Freshwater Research*, *33*, 517–528. doi:10.1071/MF9820517

Appendix. Categorization of the quality indices

IHF (fluvial habitat index for Mediterranean streams)

General range: 9–100
This index is a measure of the heterogeneity of the fluvial ecosystem in a particular stretch.

It takes into account seven components:

(a) Embeddedness in riffles and runs – sedimentation in pools (0, 5 or 10)
(b) Riffle frequency (2, 4, 6, 8 or 10)
(c) Substrate composition (0, 2 or 5)
(d) Velocity/depth regime (4, 6, 8 or 10)
(e) Shading of river bed (3, 5, 7 or 10)
(f) Heterogeneity components (0, 2 or 4)
(g) Aquatic vegetation cover (0, 5 or 10)

Categorization:

Category	IHF	
1	< 40	Poor habitat. Possibility of obtaining low values for biological indices due to habitat status rather than water quality.
2	40–60	Habitat that can support a large community of macroinvertebrates but in which, due to natural (e.g. floods) or anthropogenic causes, some elements are not well represented. Biological indices should not be low, but some effect on them cannot be excluded.
3	> 60	Mature habitat. Excellent for development of macroinvertebrate communities. Biological indices can be applied without restrictions.

QBR (index of riparian quality)

General range: 0–100.

This index takes into account four components:

(a) Total riparian cover of both river banks (0–25)
(b) Cover structure as a measure of complexity (0–25)
(c) Cover quality as a measure of autochthony (0–25)
(d) River channel naturalness (0–25)

Categorization:

Category	QBR	
1	< 25	Extreme degradation, very bad quality
2	30–50	Strong alteration, bad quality
3	55–70	Important disturbance, fair quality
4	75–90	Some disturbance, good quality
5	> 95	Riparian habitat in natural condition

FBILL (acronym for Foix, Besòs and Llobregat rivers)

Range: 0–10.

This index takes into account the presence of sensitive taxa and richness of macroinvertebrate families at a sampling point. It focuses on the rapids area.

Categorization:

Category	FBILL	
1	0–1	Extremely polluted waters
2	2–3	Highly polluted waters
3	4–5	Obvious signs of water pollution
4	6–7	Moderately polluted water
5	8–10	Water of very good quality

S (macroinvertebrate families richness)

Range: > 0

This is not a quality index but provides valuable information to determine the ecological status of a fluvial ecosystem. In general, S achieves high values where water quality is good but it is important to consider the river type.

Categorization:

Category	S	
1	< 10	Very bad
2	10–20	Bad
3	21–30	Moderate
4	31–40	Good
5	> 40	Very good

IBMWP (Iberian Biological Monitoring Working Party)

Range: > 0

This index is based on aquatic macroinvertebrate diversity at a family level, taking into account the river type and the different sensitivity of each family.

Categorization:

	1 (Very bad)	2 (Bad)	3 (Moderate)	4 (Good)	5 (Very good)
Main channels	< 15	15–35	36–60	61–100	> 101
Mediterranean main channels	< 15	15–35	36–60	61–100	> 101
Large rivers with low mineralization	< 15	15–35	36–60	61–100	> 101
Humid mountain calcareous rivers	< 20	20–50	51–85	86–140	> 141
Humid mountain siliceous rivers	< 20	20–50	51–85	86–140	> 141
Siliceous Mediterranean mountain rivers	< 20	20–50	51–85	86–140	> 141
Siliceous Mediterranean rivers	< 20	20–50	51–85	86–140	> 141
Calcareous mountain rivers	< 20	20–40	41–70	71–120	> 121
Mediterranean large flow rate rivers	< 20	20–40	41–70	71–120	> 121
Mediterranean variable flow rivers	< 20	20–40	41–70	71–120	> 121
Coastal streams	< 20	20–40	41–70	71–120	> 121
Rivers with karst influences	< 20	20–40	41–70	71–120	> 121

IASPT (Iberian average score per taxon)

Range: > 0

This index results from dividing the total IBMWP value into the total number of macroinvertebrate families (S). It complements the IBMWP index, providing additional information on the sensitivity of the families present to water pollution.

Categorization:

Category	IASPT	
1	0.0–2.0	Very bad
2	2.1–3.0	Bad
3	3.1–4.0	Moderate
4	4.1–5.0	Good
5	> 5.0	Very good

ECOSTRIMED (ecological status river Mediterranean)

Range: 1–5

This includes IBMWP (or FBILL) and QBR. The macroinvertebrate indices contribute more to the final result, although the status of the banks is also important.
Categorization:

		QBR		
FBILL	IBMWP	> 75	45–75	< 45
8–10	Very good	Very good	Good	Moderate
6–7	Good	Good	Moderate	Bad
4–5	Moderate	Moderate	Bad	Very bad
0–3	Bad or very bad	Bad	Very bad	Very bad

The information presented in this Appendix has been taken from Prat et al. (2012) and Sellarès et al. (2014).