Chapter 8

OPTIMUMS AND ECOLOGICAL PROFILES OF CADDISFLIES FROM MEDITERRANEAN STREAMS

INTRODUCTION

The study of relationships between organisms and environmental variables has been the major goal to be achieved by applied freshwater ecologists to predict and determine water quality (e.g., see Cairns & Pratt, 1993). Very often in applied hydrology, organisms are qualified as tolerant or sensitive without detailed studies about its sensitivity to pollution and is not easily to found a specific quantification of their tolerance to different environmental variables (Verdonschot & Higler, 1992; Lenat & Resh, 2001). Several statistical procedures, based in the idea that the abundances of organisms along an environmental gradient follow a unimodal distribution (Whittaker, 1967), have been developed to estimate taxa optimums and tolerances in front of several environmental variables (e.g., Ter Braak & Looman, 1986; Ter Braak & Van Dam, 1989; Juggins, 1997). These methods have been extensively used in Paleolimnology to infer past environmental conditions (e.g., Ter Braak & Van Dam, 1989; Birks *et al.*, 1990; Bigler & Hall, 2002). However, although recent multivariate models (e.g., RIVPACS, AusRivAS) designed to assess water quality include this idea of quantifying ecological requirements of macroinvertebrate communities (Wright *et al.*, 1989; Wright, 1995; Smith *et al.*, 1999), few studies report specific optimums and tolerances of macroinvertebrate taxa (but see Verdonschot

& Higler, 1992). Ecological profiles for macroinvertebrate taxa are required to test effectiveness of biological indexes and to determine indicator species and autoecological information from environmental conditions (Moretti & Mearelli, 1981). Indicator species have specific requirements to several variables (Johnson *et al.*, 1993) that can vary in a higher taxonomic resolution (Resh & Unzicker, 1975; Cranston, 1990), and for this reason, several authors suggest to take caution in the use of higher taxonomic levels in bioassessment methods (as families) (e.g., Moog & Chovarec, 2000). Today, numerous controversies exist in literature in the taxonomic sufficiency to be used because ecological patterns showed by species and families may be similar using all the community (Furse *et al.*, 1984; Marchant, 1990; Rutt *et al.*, 1993; Hewlett, 2000).

At family, species and individuals level, Trichoptera have been considered as an appropriated group to assess water quality using larvae (e.g., see Resh, 1992; De Moor, 1999; Stuijfzand *et al.*, 1999; Bonada *et al.*, Chapter 9) or adults (Malicky, 1981; Usseglio-Polatera & Bournaud, 1989). In a study in Luxembourg Rivers, Dohet (2002) found that Trichoptera were more appropriated for bioassessment than Ephemeroptera, Coleoptera or Plecoptera. Factors as their ubiquity, diversity, biological and ecological characteristics and the simplicity of their sampling may explain this (Mackay & Wiggins, 1979; de Moor, 1999; Waringer & Graf, 2002). At family and species levels, caddisfly have been related to several environmental variables displaying some specific trends in ecological requirements (e.g., Dohet, 2002; Bonada *et al.*, Chapter 7) without establishing optimums and tolerance ranges. Caddisfly ecological profiles can be obtained from literature from several ways. From one hand, studies performed in deformities (Décamps *et al.*, 1973; Petersen & Petersen, 1983; Camargo, 1991; Vuori, 1995; Vuori & Kukkonen, 2002), asymmetries (Bonada & Williams, 2002) or toxicity tests (Greve *et al.*, 1998) may allow us to infer optimums and tolerances for a single species. On the other hand, studies performed using large sets of field data including several species can also be useful (e.g., Gordon & Wallace, 1975; Moretti & Mearelli, 1981; Herranz & García de Jalón, 1984; Verdonschot & Higler, 1992; Stuijfzand *et al.*, 1999; Kay *et al.*, 2001). However, most of these studies usually are done in small areas, with insufficient data, or without taking into account the abundance of organisms, and thereby some cautions should be taken in extrapolating these results to other areas or taxonomical levels.

In this study, caddisflies ecological profiles have been studied from field data obtained in streams of the Iberian Mediterranean coast. Four factors make the caddisflies in this area an ideal group to study their ecological profiles to water quality variables. Firstly, the high diversity and endemicity of caddisfly in the Iberian Peninsula because interactions between ecological and historical factors, (González *et al.*, 1987) with 331 species (Vieira-Lanero, 2000 plus González & Ruiz, 2001 and Zamora-Muñoz *et al.*, 2002 —see Bonada *et al.*, Chapter 6). Secondly, the harsh natural abiotic conditions in these mediterranean ecosystems (see Bonada *et al.*, Chapter 3) that may yield to a high diversification of ecological profiles of trichopterans. Third, the lack of information about autoecology studies of caddisflies in Mediterranean areas, except the obtained from taxonomical papers (Bonada *et al.*, Chapter 6). Finally, the significant river alteration in the Mediterranean area by human impact (Prat, 1993) implies the presence of a variety of reaches subjected to different water quality where optimums and tolerances of caddisflies can be studied.

The objectives of the present chapter are: (1) to determine optimums and tolerances of caddisfly taxa for several ecological variables at different taxonomical resolution and (2) to calculate ecological profiles for each taxon and to evaluate their sensitivity.

METHODOLOGY

Sampling area

Ten basins from the Mediterranean coast in east Spain were sampled (Figure 1): Besòs, Llobregat, Mijares, Turia, Júcar, Segura, Almanzora, Aguas, Adra and Guadalfeo (an extensive description of sampled basins can be found in Robles *et al.*, in prep). The area is subjected to mediterranean climate (Köppen, 1923), with a significant spring and autumn rainfall. Limestone and sedimentary materials mainly compose geology, although some siliceous areas are also present as Sierra Nevada, Pyrenees and Montseny ranges (Figure 1). Sclerophyllous and evergreen trees and shrubs mainly compose basin vegetation, although in some medium and high altitude areas deciduous and coniferous forests are present.

Because of the seasonality of the climatic patterns and the variability in landscape, topography and geomorphology, rivers in the sampled basins are highly variable in space and time. Overall, sampled rivers are subjected to high annual discharge variability, more or less important depending on the local conditions, with frequent floods and droughts (Molina *et al.*, 1994; Gasith & Resh, 1999). In space, a high variability of rivers have been sampled (Bonada *et al.*, in press-a): alpine, siliceous and short rivers from Sierra Nevada, longer and calcareous rivers from Pyrenees and Iberian Ranges; small rivers and tributaries with a temporary condition to karstic streams and saline ramblas in the south-east.

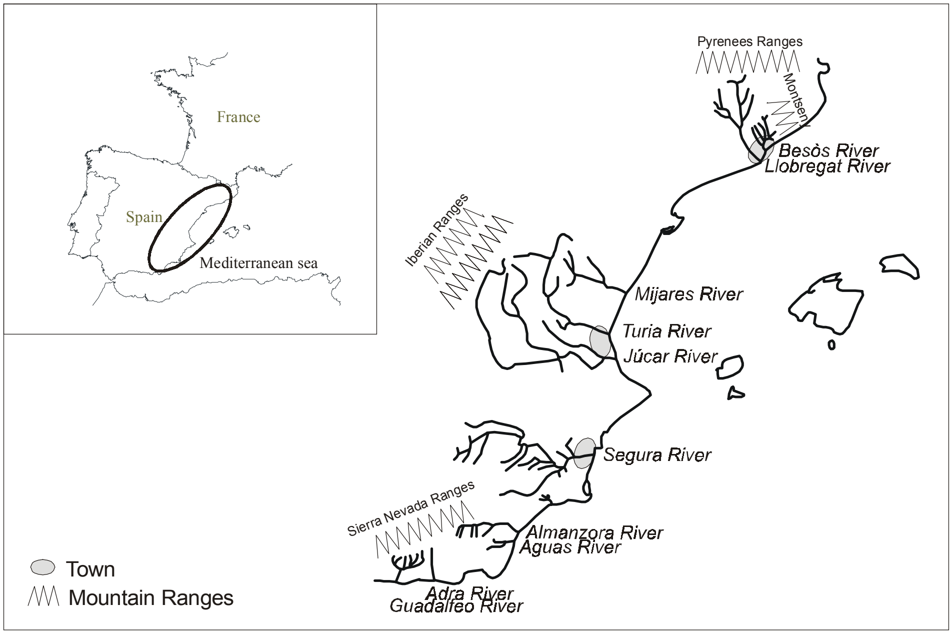

Figure 1. Basins sampled along Spanish Mediterranean coast.

As in other mediterranean regions, sampled basins have been largely affected by human activities (Trabaud, 1981) as agriculture, cattle, urbanization, salinization, water abstraction and regulation... (Conacher & Sala, 1998). All these factors have contributed to the river alteration in a direct or indirect way (Prat, 1993).

Sampling sites

A total of 157 sampling sites have been surveyed along Iberian Mediterranean coast four times in 1999 (spring, summer, autumn and winter) and three times in 2000 (spring, summer and autumn). They are part of the GUADALMED Project to assess the ecological status of the Spanish mediterranean rivers according to the Water Frame Directive (European Parliament and Council, 2000). Sites are more or less equally distributed among all basins, and they include reference and non-reference sites (see Bonada *et al.*, in press-b). The variety of sampled river types and reaches subjected to different local climates and landscape characteristics, implies the presence of different riparian communities with reaches without a structured riparian vegetation by natural conditions (i.e., ramblas and ephemeral rivers) to well preserved riparian forests in the headwaters of main rivers or tributaries (Suárez *et al.*, in press). However, the high human activities present in the sampled basins imply an extreme human alteration of riparian areas (Prat *et al.*, 1999) with numerous species introductions as *Platanus hispanica, Populus* *deltoides*, *Robinia pseudoacacia* and *Nicotiana sp.*. However, in some reference and permanent headwaters, communities of *Salix alba*, *Corylus avellana, Populus nigra and Populus alba* are dominant. Sampling sites present a high variability in substrate types that enable the presence of abundant instream vegetation (e.g., mosses, diatoms, zygnematales and *Cladophora* sp.) and macrophytes (e.g., *Apium nodiflorum*, *Veronica* sp., *Rorippa* sp. and *Chara* sp.).

Sampling procedure

Sites were sampled following GUADALMED Protocol (Jáimez-Cuéllar, in press; Bonada *et al.*, Chapter 1) designed as a bioassessment method, but the fine mesh size used and the absence of sampling restrictions comparing with other procedures, allow us the use of this Rapid Bioassessment Protocol in macroinvertebrate community studies (Bonada *et al.*, Chapter 2).

The environmental variables considered in this study are oxygen and conductivity (directly measured in the field) and ammonium, N-nitrites, P-phosphates, suspended solids, sulphates and chloride, that were analyzed in the lab using the methods exposed in Toro *et al.* (in press). Also, the riparian quality was measured using QBR index (Munné *et al.*, 1998; in press; Suárez & Vidal-Abarca, 2000). The sinecological value of the entire macroinvertebrate community was introduced by the IBMWP index, which also informs about the water quality.

Macroinvertebrate samples were collected in riffles and pools with a kick-net of 250 µm mesh size. Samples were firstly examined in the field, and successive samples in both habitats were taken until no more families were found, to collect the maximum sample representativeness of taxa richness. Several invertebrates seen in the field but not taken in the sample were also recorded, as the large Heteroptera and Coleoptera. Samples were preserved in alcohol 70% and sorted in the lab. The biological index IBMWP (Alba-Tercedor & Sánchez-Ortega, 1988; Alba-Tercedor, 1996; Alba-Tercedor & Pujante, 2000) was recorded for each site and season. Caddisfly taxa were identified at the maximum level possible, and rank of abundances was recorded for each taxon: 1 from 1-3 individuals, 2 from 4-10, 3 from 11-100 and 4 for more than 100 individuals. Because the large amount of undescribed larvae in the Iberian Peninsula (Vieira-Lanero, 2000) we were not able to identify all taxa at species level with certainty. When it was possible pupae and adults were collected in the field to ensure larvae identifications. Moreover, in some cases mature larvae were reared in the lab using a system inspired in Vieira-Lanero (1996). Identified caddisfly data obtained from all sampling seasons were selected to check for optimums and tolerances under different environmental variables. In total, 3423 records were used, corresponding to 13 different families and 41 taxa at genus or species level depending on their degree of confidence in the identification and their frequency (see Annex 1). Taxa used were present in 10 or more records.

Data analysis

A Weighted Average Regression was performed with the CALIBRATE vs0.7 program (Juggins, 1997) to calculate the optimums and tolerances for all caddisflies (13 families and 41 genus/species) using environmental data obtained (Table 1). This analysis estimates the optimum of an environmental variable of each species using the average of the values of the variable where taxa are present, weighted by the species' relative abundance (Birks *et al.*, 1990). Consequently, the optimum of a species is referred to the environmental conditions with its highest relative abundance and tolerance is equivalent to the standard deviation from the optimum. Weighted regression (to estimate the taxon's optima) and calibration (to infer the environmental data using the optima of all taxa present in the sample) have been widely applied in paleolimnology to infer environmental conditions using optimums and tolerances of diatoms species (e.g., Birks *et al.*, 1990; Bigler & Hall, 2002).

To interpret the optimums and tolerances of each taxon for each environmental variables, the reference values for biotic and riparian indexes and several chemical characteristics from Prat *et al.* (2000 and 2001) have been used and are presented in Annex 2.

Table 1. Variables measured and used in the analysis.

Variable	Considerations
NH_4^+	Concetration in mg/l of NH4+
$N\text{-}NO_2^-$	Concetration in mg/l of N-NO2-
$P\text{-}PO_4^{3-}$	Concentration in mg/l of P-PO43-
SO_4^{2-}	Concetration of sulfates in mg/l
Cl^-	Concentration of chloride in mg/l
SS	Suspended solids in mg/l
O2	Oxygen in mg/l
QBR	Index of Riparian Vegetation Quality (Munné et al., 1998)
IBMWP	Biological index for water quality (Alba-Tercedor & Sánchez-Ortega, 1988)
IASPT	Relationship between IBMWP and number of families

RESULTS

Optimums and tolerances of caddisflies families

A general pattern can be observed when caddisflies families are arranged according to their optimum values (Figure 2). Brachycentridae, Sericostomatidae, Lepidostomatidae and Odontoceridae are exclusive from high water quality and good ecological conditions. In contrast, Glossosomatidae, Hydropsychidae and Hydroptilidae have the optimum in lower values of biologic and riparian indices and higher chemical parameters concentration.

Overall, caddisflies families present IBMWP optimums over than 100, indicating that they tend to be present in reaches with very good biological quality. Hydropsychidae, Hydroptilidae and Lepidostomatidae are more frequent at lower biological indexes whereas, families as Brachycentridae or Sericostomatidae present the maximum of their abundance at higher values of biological quality index. A similar pattern is observed in the QBR index, with Lepidostomatidae preferring higher values of riparian quality index respect Hydropsychidae and Hydroptilidae. In contrast, Glossosomatidae that have the maximum of abundance at intermediate IBMWP prefers a fair riparian quality. No caddisflies have the optimum in QBR values corresponding to a poor or very poor riparian quality. Oxygen concentration optimums and tolerances for caddisflies are similar between families, with values around 10 mg/l and tolerances between 7 and 13 mg/l.

Optimums and tolerances for chemical parameters may follow different patterns for different families. Overall, families with higher optimums values for a variable can tolerate a wider range of chemical concentrations than taxa with lower optimums values. For ammonium, Brachycentridae, Lepidostomatidae, Leptoceridae and Philopotamidae present optimums typical from clean waters with less than 0.1 mg/l, whereas the rest of families are more frequent at concentrations between 0.1 and 0.25 mg/l. Hydropsychidae and Hydroptilidae although having the optimum lower than 0.4 mg/l, can be present until almost 0.9 mg/l, tolerating waters subjected to an important chemical stress. A similar pattern is observed in N-nitrites concentration with all families presenting the optimum at less than 0.3 mg/l, and Hydropsychidae, Glossosomatidae, Hydroptilidae, Rhyacophilidae, Brachycentridae and Odontoceridae tolerating concentrations, until 0.58 mg/l in Hydropsychidae.

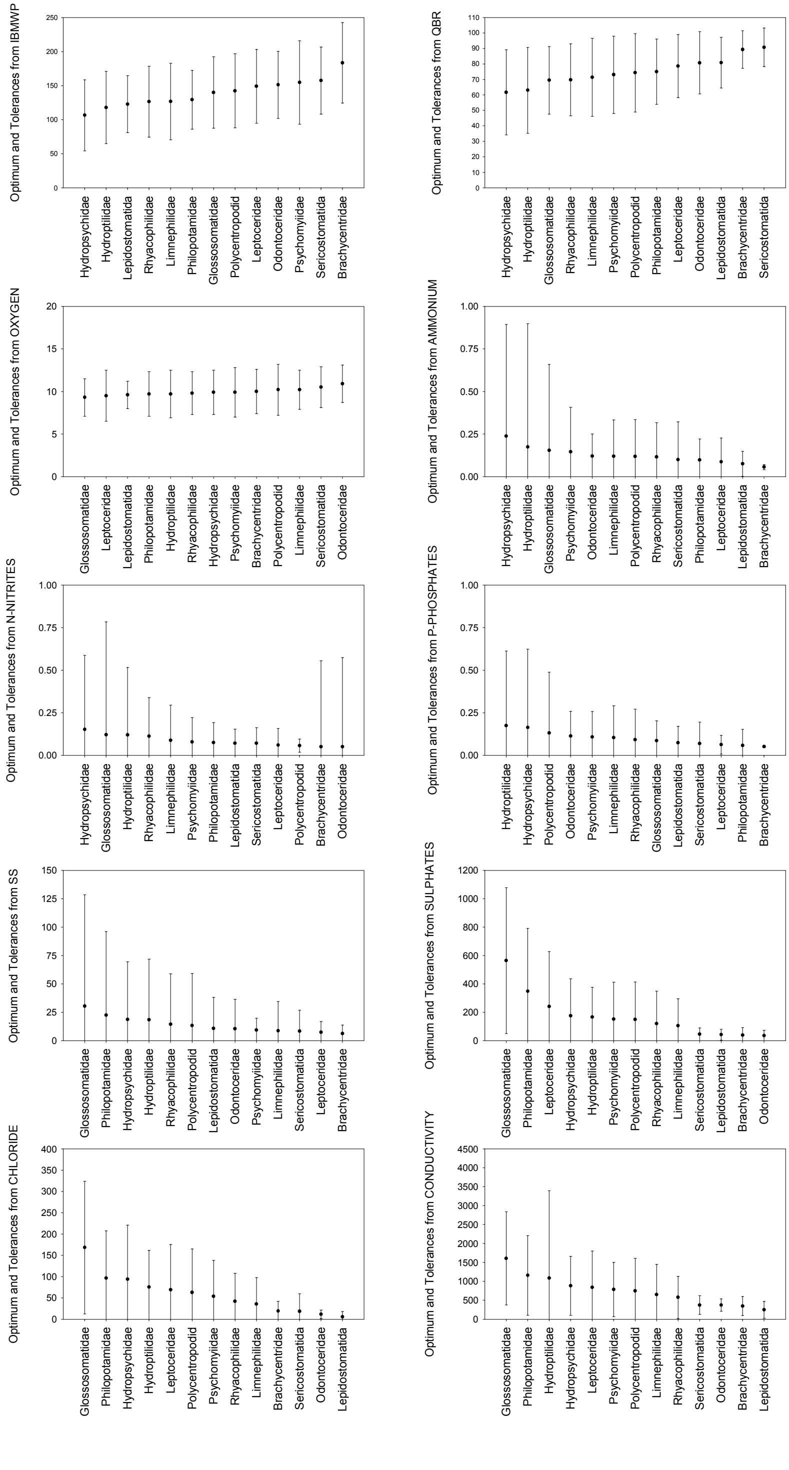

Figure 2. Scatter plots of optimums with error bars indicating the standard deviation (equivalent to the tolerance) of caddisfly families. X axes are arranged according to increasing optimum in IBMWP, QBR and oxygen and decreasing in ammonium, N-nitrites, P-phosphates, suspended solids, sulphates, chloride and conductivity.

All caddisflies have maximum abundances at levels under 0.03 mg/l of P-phosphates indicating that they prefer clean water without eutrophy. Only, Hydroptilidae, Hydropsychidae and Polycentropodidae appear more tolerant with maximum values of tolerance around 0.5 mg/l. Glossosomatidae present a low optimum in P-phosphates but high in ammonium and N-nitrites, indicating a high sensitivity to eutrophy. Optimums on high suspended solids concentrations correspond to families with species characteristics from midstreams and lowland rivers as Glossosomatidae, Philopotamidae and the filter-feeder Hydropsychidae (see Bonada *et al.*, Chapter 7). In contrast, some headwater families as Brachycentridae and Sericostomatidae have maximum abundances at low suspended solid concentrations with a narrow range of tolerance.

All chemical measurements related to salinity conditions present a similar pattern, indicating a strong relationship between chloride, sulphates and conductivity with basin geology (Toro *et al.*, in press). Philopotamidae, that for the other parameters occupied an intermediate position is more abundant at higher values of sulphates, suspended solids, chloride and conductivity than other families. Leptoceridae also appear very abundant in high chloride concentrations and conductivity, although is unable to tolerate high concentrations of suspended solids, P-phosphates, N-nitrites and ammonium. Concentrations of sulphates over than 250 mg/l may be related to pollution or to the presence of gypsum in the basin. Glossosomatidae and Philopotamidae have the optimum in these conditions followed by some leptocerids. Other families have the optimum under 250 mg/l but can tolerate up to 400 mg/l, as Hydropsychidae, Psychomyiidae, Polycentropodidae and Rhyacophilidae. Similarly, high chloride concentrations may be present by pollution or be natural, and Glossosomatidae, Philopotamidae, Hydropsychidae, Hydroptilidae and Leptoceridae have the maximum abundances between 69 and 168 mg/l. The high values of conductivity achieved by some families that are abundant in high IBMWP score, as Glossosomatidae or Philopotamidae, indicate the presence in our set of dates of reaches with natural salinity (e.g., sedimentary marls). Thus, Glossosomatidae is very abundant at 1606μS/cm and tolerates until 2800 μS/cm. Hydroptilidae appears as the most tolerant family because it can be present until values up to 3300 μS/cm. In contrast, Lepidostomatidae, Brachycentridae, Odontoceridae and Sericostomatidae have the optimum around 300 μS/cm and a narrow range of tolerance.

Optimums and tolerances of caddisflies genus/species

Looking at the species or genus within families, some different patterns may be observed (Figure 3, 4 and 5). IBMWP index present the optimum over 100 in all species except for *H. exocellata* with 65.6 value and a tolerance going from 31.7 to 99.5. Many species have their maximum of abundance over 100 but can tolerate moderately polluted waters as *L. guadarramicus*, *C. marginata, Stenophylax* sp., *H. infernalis*. Instead, *H. dinarica, Micrasema* sp., *Rh.* gr. *tristis, P. cingulatus, P. kingi* and *Allogamus* sp., only tolerate a very good water quality. A similar species arrangement is observed for QBR index (Figure 3). *H. exocellata* and *M. aspersus* have the maximum of abundance in reaches with a poor riparian quality, whereas other species prefer well preserved riparian forest as *Allogamus* sp., *Potamophylax* sp., *Micrasema* sp. and *P. montanus*. As in families, oxygen optimums and tolerances are similar between species (Figure 3), with many caddisflies having optimums over 10mg/l (e.g., *P. flavomaculatus*, *H. dinarica, H. siltalai, M. azurea*).

Except few species, caddisflies are very sensitive to toxicity by ammonium (Figure 4). *H. exocellata* is the more tolerant species having the optimum at 0.59 mg/l and able to tolerate until 2 mg/l. Other species as *H. radiatus*, *Sericostoma* sp., *H. sp1* and *Hydroptila* sp. present the maximum of abundance in water with some stress and even may tolerate concentrations over 0.4 mg/l. *Agapetus* sp., a very abundant Glossosomatidae, present a wide range of tolerance to ammonium, whereas *A. chauviniana, Ithytrichia* sp., *Micrasema* sp. and *H. tesselatus* are very sensitive to this toxic. *Hydropsyche* gr. *pellucidula*, that have the optimum at low values of riparian vegetation is very intolerant to ammonium but can be present at concentrations of N-nitrites over than 0.3 mg/l. A similar pattern is observed with *Chaetopteryx* sp. which appears as the species more tolerant to N-nitrites, having the optimum at 0.32 mg/l, but intolerant to ammonium. The rest of species present optimums of N-nitrites between 0.03-0.3mg/l, although, surprisingly, most of them are able to survive in a wide range of N-nitrites concentration. Looking at the P-phosphates (Figure 4), *H. exocellata* is the most tolerant species with the optimum in reaches with high eutrophy, and able to tolerate very high concentrations. Instead, many species have the maximum of abundance between 0.03 and 0.09 mg/l and few can tolerate eutrophy. *C. lepida, H. dinarica, M. longulum* and *Rh. meridionalis* although having the optimum at very low P-phosphates concentrations can tolerate a wide range of concentrations, appearing independently of eutrophy. Optimums and tolerances for suspended solids and salinity measurements are plotted in Figure 5. At species level, some differences can be observed from the patterns showed by families in Figure 2. The predator *Rh. munda* is the caddisfly more tolerant to solids with it maximum of abundance in 38.4 mg/l, followed by some filter-feeding Hydropsychids, *P. kingi* and *C. marginata*. Most of the species have the optimum in quite clear waters with levels of suspended solids under 25 mg/l, and the headwater caddisfly *H. dinarica* appears as the less tolerant to suspended particles. Caddisfly species arrangement in salinity parameters is similar. *Agapetus* sp. is the species with the higher optimum in sulphates, chloride and conductivity, followed by *S. argentipunctellus, C. marginata* and some

Hydropsychids (e.g., *H. exocellata, H. brevis, H. infernalis, H.* gr. *pellucidula*). Most of the caddisflies have the optimums at sulphates concentrations under 250 mg/l, indicating their preferences for basins without gypsum geology, as *Micrasema* sp., *Sericostoma* sp. or *Halesus* sp. The glossosomatid *Agapetus* sp. is very frequent in chloride concentrations over than 200 mg/l and conductivities of 1802 μS/cm. However, *Hydroptila* sp. although having the optimum of sulphates and chloride under 250 mg/l and 99 mg/l respectively, presents the widest tolerance to conductivity, beeing able to survive at more than 4000 μS/cm.

Ecological profiles for caddisfly taxa

Ecological profiles for each genus/species and family levels have been figured out using tolerances for six measured environmental variables (oxygen, suspended solids, P-phosphates, ammonium, sulphates and chloride) (Figures 6, 7, 8, 9 and 10). N-nitrites have been omitted because the high tolerance values in some species with low optimums, what could be an error in chemical analysis. Profiles have been drawn as a polyhedral figure (Figure 6). Each axis represents the tolerance range constrained between 1 and 0. The extremes of each axis indicate the intolerance of taxa to high values of chemical parameters (i.e., suspended solids, P-phosphates, ammonium, sulphates and chloride) or to low values of oxygen. When combining the tolerance ranges for all axes a shaded figure appears indicating the degree of tolerance for each taxon, whereas the non-shaded area displays the degree of intolerance to pollution. Thereby, caddisfly very sensitive to all environmental variables will have narrow shade and large empty areas, in contrast to very tolerant taxa. The degree of intolerance score (DIS) has been measured using the following formula:

$$\mathrm{DIS}=\sum_{i=1}^{5}(1-\max_i)+\min_j$$

for i=chemical variables and j=oxygen concentration

This score varies between 0 to 6 and give us an idea of the sensitivity of each species to pollution (higher the value, more intolerant).

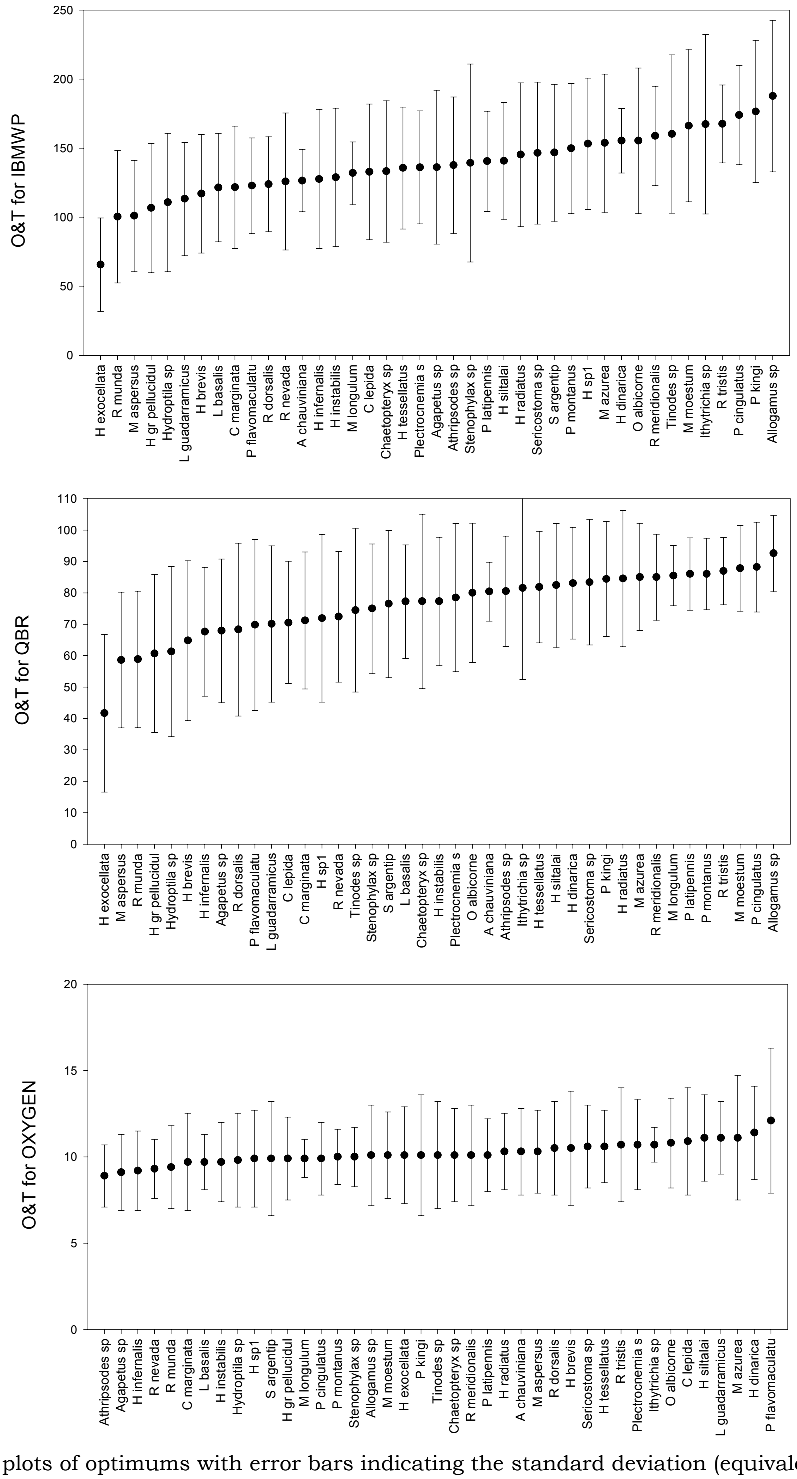

Figure 3. Scatter plots of optimums with error bars indicating the standard deviation (equivalent to tolerance) (O&T) of caddisfly genus/species and IBMWP, QBR and oxygen. X axes are arranged according to increasing optimum. Codes are in Annex 1.

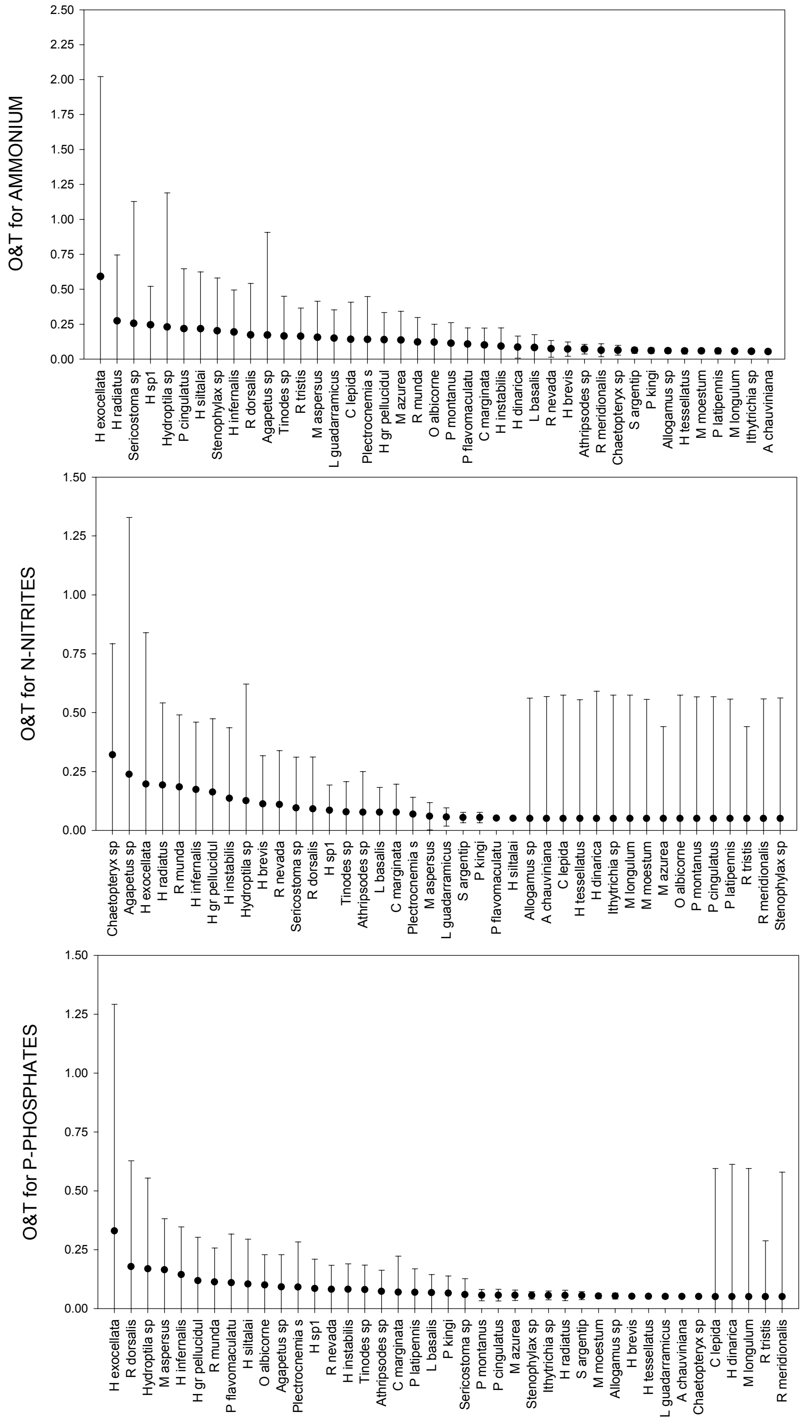

Figure 4. Scatter plots of optimums with error bars indicating the standard deviation (equivalent to tolerance) (O&T) of caddisfly genus/species and ammonium, N-nitrites and P-phosphates. X axes are arranged according to decreasing optimum. Codes are in Annex 1.

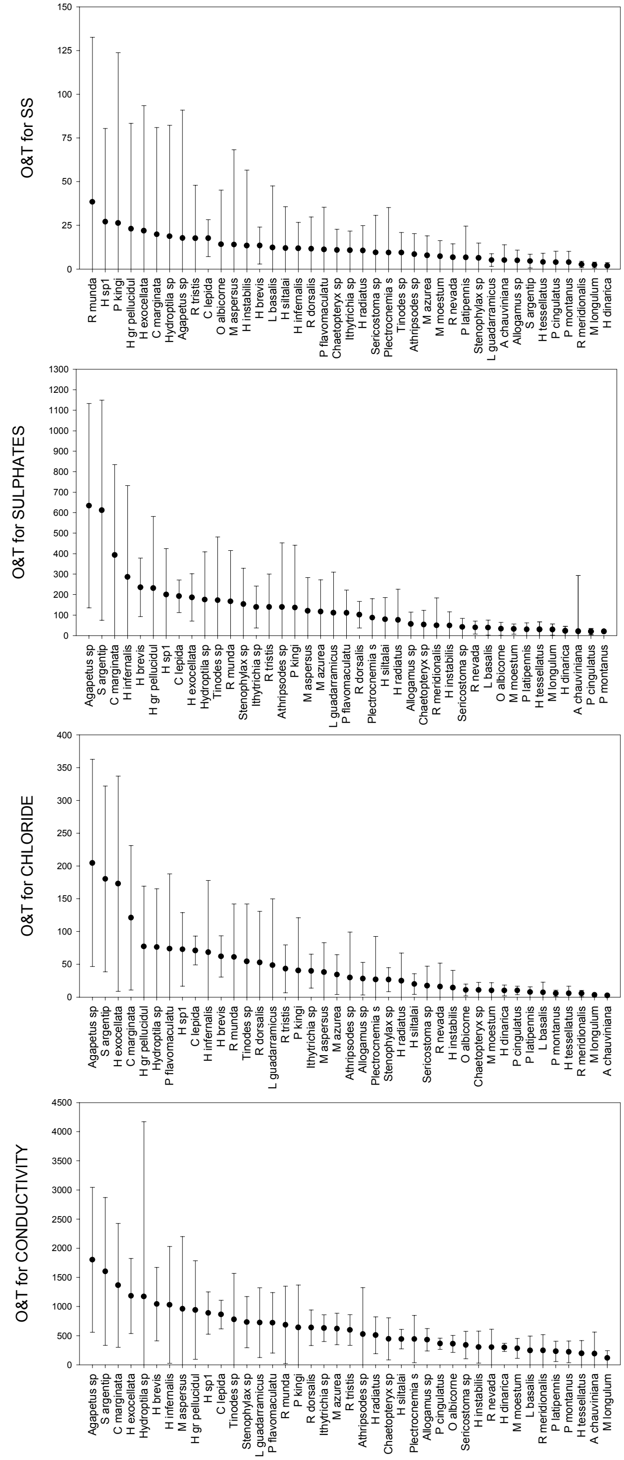

Figure 5. Scatter plots of optimums with error bars indicating the standard deviation (equivalent to tolerance) (O&T) of caddisfly genus/species and suspended solids, sulphates, chloride and conductivity. X axes are arranged according to decreasing optimum. Codes are in Annex 1.

Brachycentridae, Lepidostomatidae, Odontoceridae and Sericostomatidae are the families more sensitive to pollution, with DIS from 4.47 to 5.07 (Figure 7, Table 2). Brachycentridae does not tolerate any of the chemical parameters measured although it can be present in a wide range of oxygen concentration. Lepidostomatidae, Sericostomatidae and Odontoceridae can tolerate minor values of ammonium, P-phosphates and suspended solids. Leptoceridae can tolerate high sulphates and chloride concentrations and even low ammonium, but not other chemical parameters. Instead, Limnephilidae, Psychomyiidae and Rhyacophilidae appear as quite tolerant families for all variables, but more sensitive to salinity by sulphates or chloride. Philopotamidae is able to tolerate high concentration of suspended solids and sulphates but it is very sensitive to eutrophy and toxicity. The most tolerant families are Glossosomatidae, Hydropsychidae and Hydroptilidae, and, with DIS values from 1.61 to 2.14 (Table 2). Glossosomatidae can be present in almost all environmental conditions except to very high P-phosphates concentrations, whereas Hydropsychidae cannot tolerate a very high sulphates or suspended solids. Hydroptilidae present a similar profile with Hydropsychidae. When DIS for families is compared with IBMWP score, a positive relationship is observed between both indexes with some exceptions. Glossosomatidae appears more tolerant to environmental variables than should be expected from a score of 8, and Limnephilidae is slightly more sensitive than Leptoceridae but have a lower IBMWP score.

Figures 8, 9 and 10 present the ecological profiles for caddisfly genus/species. High variability in tolerances is showed by Hydropsychidae species. *Hydropsyche exocellata* is the most tolerant species although quite sensitive to sulphates but very tolerant to chloride. Profiles for *H.* gr. *pellucidula* and *H. sp1* display similar patterns beeing sensitive to P-phosphates and ammonium but tolerant to suspended solids. Contrarily, *H. infernalis* prefers higher sulphates but lower solids, and *C. lepida* prefer low concentrations of solids and sulphates but can be present in a wide range of P-phosphates concentration. The rest of hydropsychids appear to be highly sensitive to environmental variables, with *H. dinarica* beeing very restricted to low sulphates, chloride and solids but tolerating some eutrophy, in contrast to *H. brevis*. Looking at Philopotamidae and Hydroptilidae, *C. marginata* and *Hydroptila* sp. may survive in a wider range of environmental variables while *P. montanus* and *Ithytrichia* sp. are more restricted to clean waters. As we have been seen in previous figures, *Agapetus* sp. appears to be very tolerant to suspended solids, ammonium, sulphates and chloride, but intolerant to eutrophy. As in Hydropsychidae, Limnephilidae also display a high variability in ecological profiles (Figure 9). The abundant *M. aspersus* is the most tolerant species, beeing able to survive at high solids and relatively high P-phosphates and salinity. On the other hand, *H. tesselatus, Potamophylax* sp., *A. chauviniana*, *Allogamus* sp. and *Chaetopteryx* sp. and are restricted to high water quality.

The two species of *Potamophylax* have similar pattern, but *P. cingulatus* appear slightly more tolerant to ammonium. *Stenophylax* sp. is able to tolerate some ammonium and sulphates concentrations. Except for *Rh. munda*, than is able to survive to higher sulphates, chloride and suspended solids, or *Rh. dorsalis* that tolerates some P-phosphates, ammonium and chloride concentrations, rhyacophilids displays profiles quite sensitive to water quality. Except for *M. azurea* quite sensitive to all chemical parameters, the rest of Leptoceridae appear tolerant to high sulphates and chloride concentrations (Figure 10). Similar pattern is observed with Polycentropodidae, with *P. kingi* more tolerant to sulphates, chloride and solids than other genus and species. Finally, *Micrasema* sp. is a very sensitive genus, beeing *M. longulum* more tolerant to P-phosphates than *M. moestum*.

Overall, *H. tessellatus* is the most sensitive taxon with a DIS of 5.27, whereas *H. exocellata* is the most tolerant species (Table 2). Except for some species, hydropsychids present a low DIS value, what agree with patterns observed at family level. Philopotamidae present a low DIS value although one the analyzed species (*P. montanus*) is very sensitive to pollution (DIS=5.2) whereas the other is not (*C. marginata*). Similar pattern is observed in Hydroptilidae, with *Ithytrichia* sp. presenting a DIS of 4.95 and *Hydroptila* sp. of 2.99, or Rhyacophilidae.

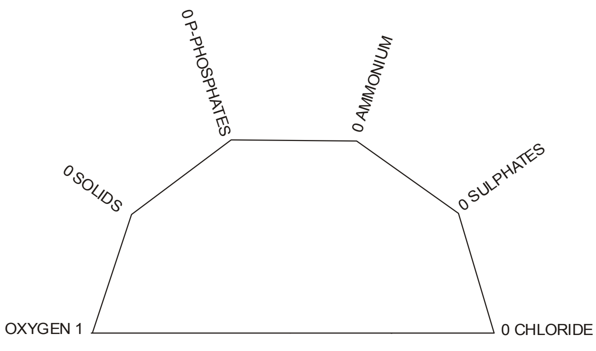

Figure 6. Graph to interpret ecological profiles from Figures 7, 8, 9 and 10.

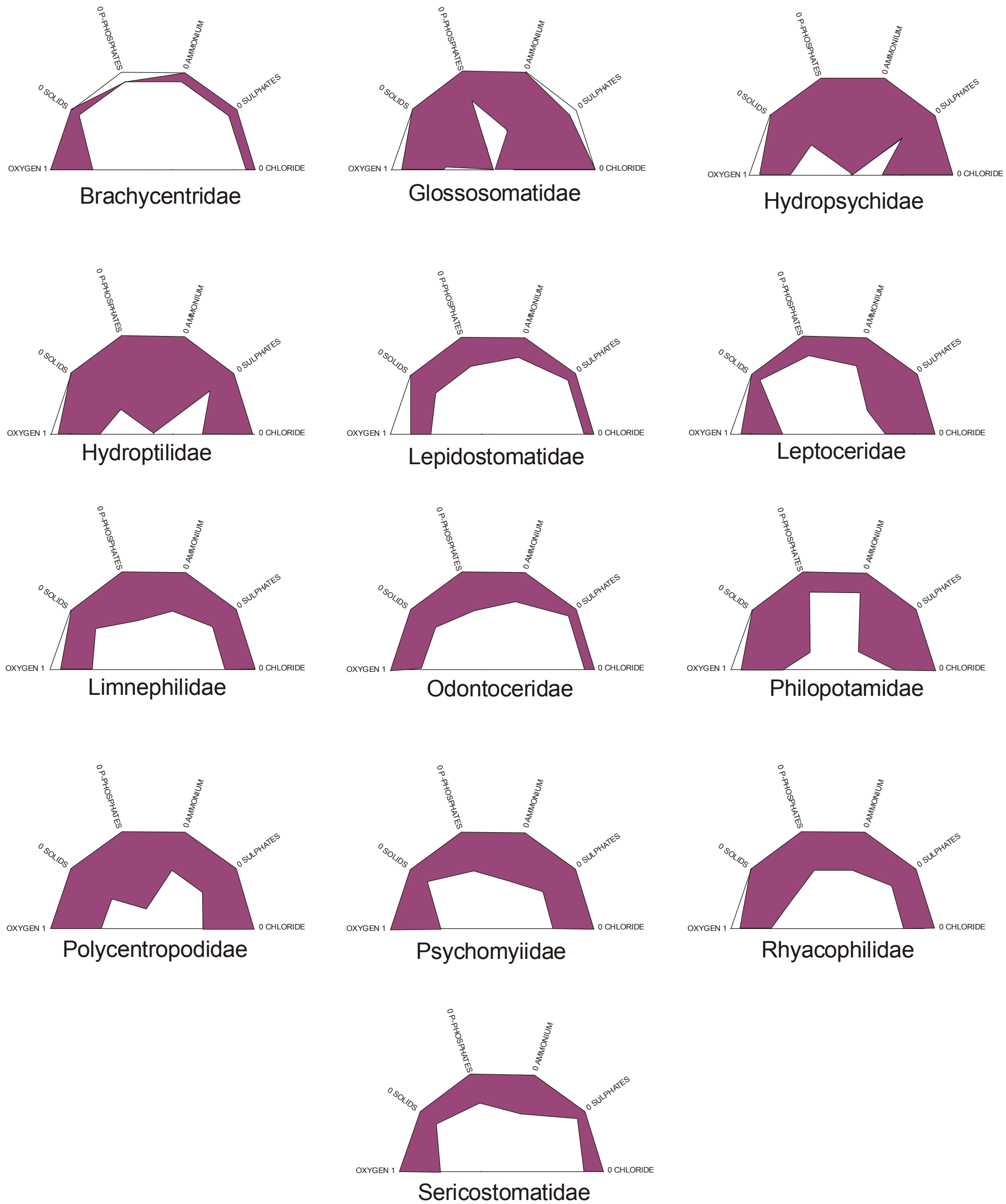

Figure 7. Ecological profiles for caddisfly families. Only oxygen, suspended solids (solids), P-phosphates, ammonium, sulphates and chloride are plotted.

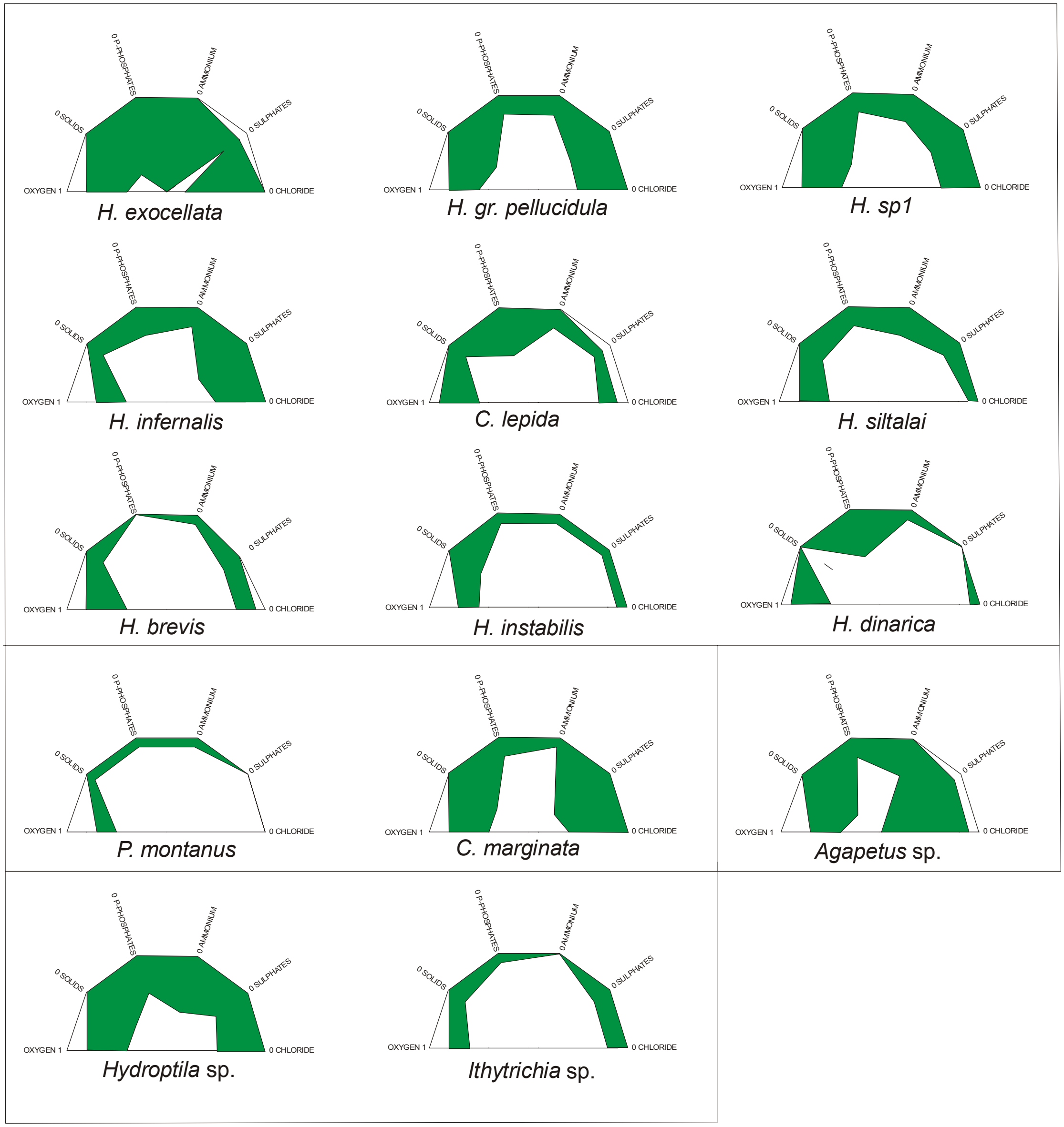

Figure 8. Ecological profiles for caddisfly genus/species grouped by families. Only oxygen, suspended solids (solids), P-phosphates, ammonium, sulphates and chloride are plotted.

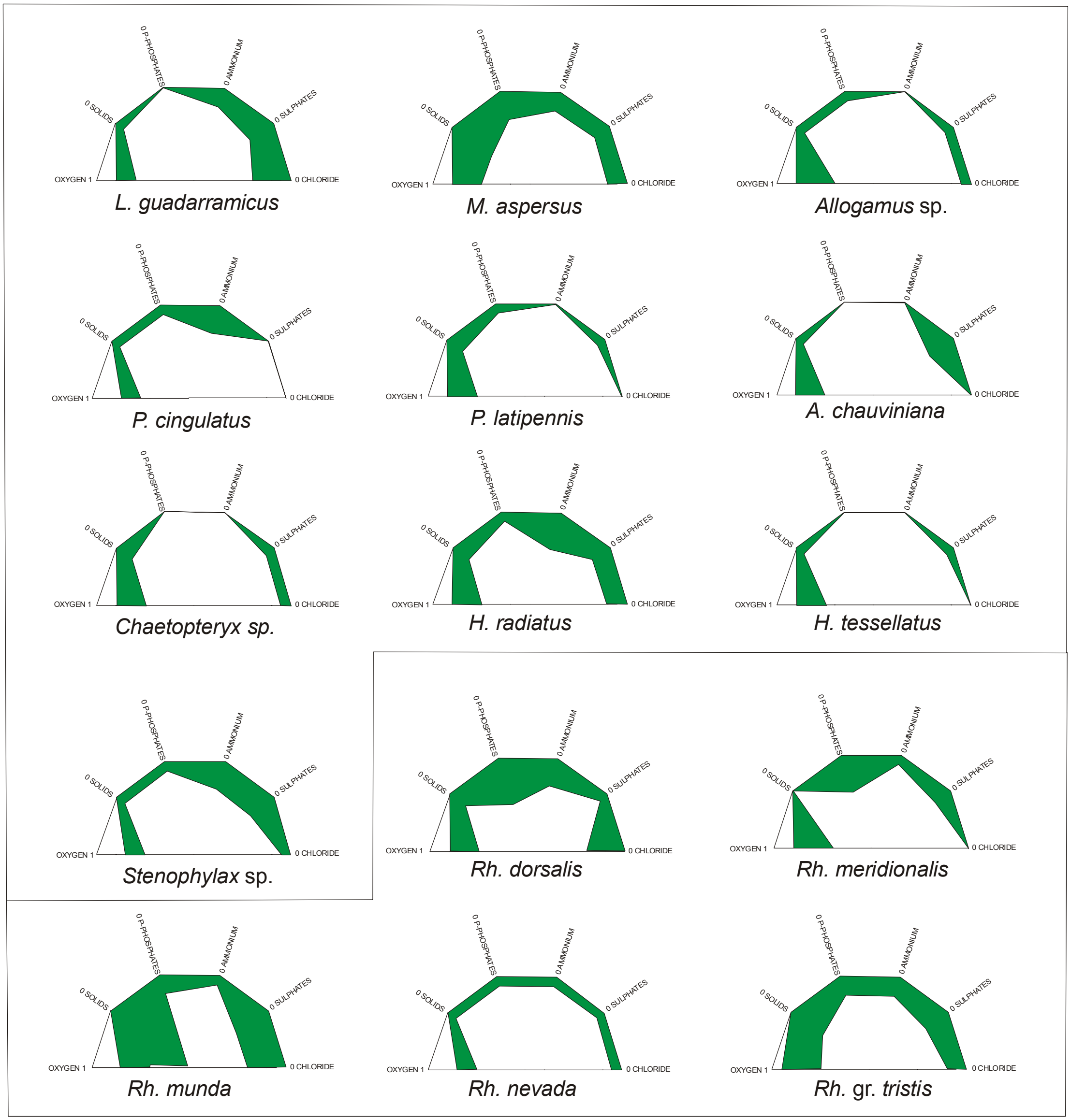

Figure 9. Ecological profiles for caddisfly genus/species grouped by families. Only oxygen, suspended solids (solids), P-phosphates, ammonium, sulphates and chloride are plotted.

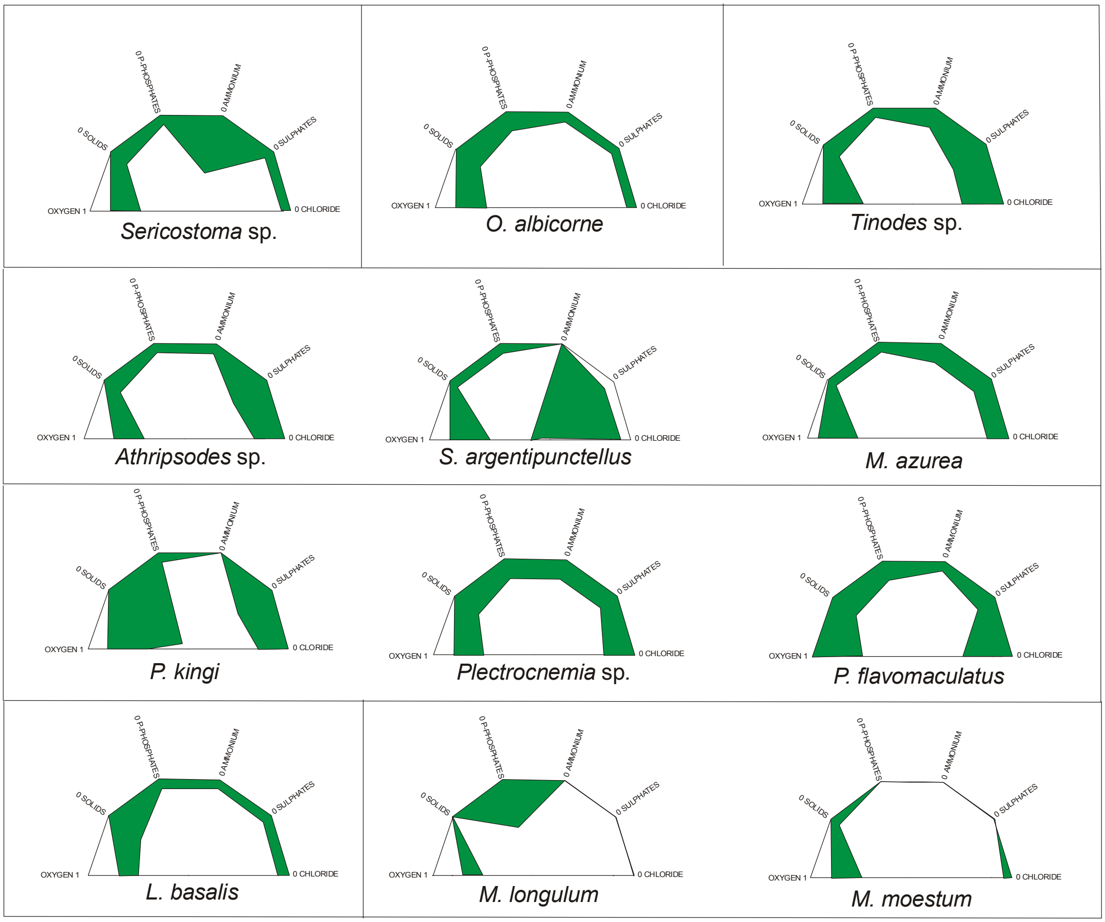

Figure 10. Ecological profiles for caddisfly genus/species grouped by families. Only oxygen, suspended solids (solids), P-phosphates, ammonium, sulphates and chloride are plotted.

Table 2. DIS value from ecological profiles for families and genus/species. Taxa are arranged by decreasing DIS. High DIS indicate a very sensitive taxa whereas low values are typical from the most tolerant caddisfly. The score used in IBMWP is also presented.

	DIS	IBMWP Score
Brachycentridae	5.07	10
Lepidostomatidae	4.75	10
Odontoceridae	4.55	10
Sericostomatidae	4.47	10
Limnephilidae	3.92	7
Leptoceridae	3.79	10
Psychomyiidae	3.71	8
Rhyacophilidae	3.65	7
Polycentropodidae	3.04	8
Philopotamidae	2.93	8
Hydroptilidae	2.14	6
Hydropsychidae	1.93	5
Glossosomatidae	1.61	8

	DIS
H. tessellatus	5.27
P. montanus	5.20
M. moestum	5.15
P. latipennis	5.04
A. chauviniana	5.04
Allogamus sp	5.02
Chaetopteryx sp.	5.02
M. longulum	4.96
Ithytrichia sp.	4.95
Rh. nevada	4.95
P. cingulatus	4.95
H. dinarica	4.86
L. basalis	4.81
O. albicorne	4.75
Rh. meridionalis	4.72
M. azurea	4.68
Stenophylax sp.	4.65
L. guadarramicus	4.58
H. brevis	4.57
H. instabilis	4.56
H. radiatus	4.50
H. siltalai	4.47
Athripsodes sp.	4.44
Sericostoma sp.	4.41
Plectrocnemia sp.	4.38
Rh. gr. *tristis*	4.21
P. flavomaculatus	4.15
C. lepida	4.12
Tinodes sp.	4.09
M. aspersus	4.00
Rh. dorsalis	4.00
H. sp1	3.68
P. kingi	3.60
H. infernalis	3.58
H. gr. *pellucidula*	3.46
S. argentipunctellus	3.36
Rh. munda	3.33
C. marginata	3.17
Hydroptila sp.	2.99
Agapetus sp.	2.13
H. exocellata	1.56

DISCUSSION

The wide range of ecological profiles showed by caddisfly families and species in the Mediterranean area confirm the idea expressed by several authors that Trichoptera is an ideal group to assess water quality (e.g., Resh, 1992; Berlin & Thiele, 2002; Waringer & Graf, 2002; Dohet, 2002). In this study, a gradient of caddisfly families and species have been provided using several chemical and other ecosystem properties as riparian vegetation and the macroinvertebrate community. Consequently, caddisflies appear to be good indicators of water quality, and a good tool to protect aquatic ecosystems where they exist, especially for the most sensitive species (de Moor, 1999). However, some overlooked variables because unavailable, would refine final ecological profiles and tolerances to water quality variables. For example, heavy metals (Besch *et al.*, 1979; Darlington *et al.*, 1987), hydrocarbons (Simpson, 1980) or pesticides (Décamps *et al.*, 1973) have been proved to have a significant effect on caddisflies taxa. Several mechanisms have been identified as the responsible to allow the presence of some species in poor water conditions and avoid others (see Wiederholm, 1984): morphological adaptations, behavior, metabolic processes, osmoregulation, or detoxification.

In general, our results agree with the ones obtained from ecological studies in literature. Looking at the ecological profiles of several species of *Rhyacophila* sp., Moretti & Mearelli (1981) found that *Rh. dorsalis* had a wider ecological profile than *Rh.* gr. *tristis*, what can be also observed in our results. *Rh. dorsalis* has been found in headwater and midstream rivers with different biological quality (Bonada *et al.*, Chapter 8). Species with a quite restricted ecological profile as *H. siltalai*, *M. azurea* or *O. albicorne* were proved to be species with high indicator values of sites with low organic pollution (Dohet *et al.*, 2002). However, our study suggests that some caddisflies families and species in the Iberian rivers are sensitive to some variables but more tolerant to others, indicating a higher ecological diversification in the sampled mediterranean rivers. This phenomena is rarely noticed in literature because most of the studies have been performed using few species or with species from a single family. Moreover, most of the published studies looking at the effects of specific chemical parameters in caddisflies in behaviour, life history or metabolic processes only include one or two chemical variables (see Resh, 1992). Both aspects make difficult interpretations of results obtained using numerous chemical variables (Stuijfzand, 1999), as in the present study.

Overall, except for some species, caddisflies can be present in a wide range of riparian and biological conditions. Riparian vegetation is an important element to the macroinvertebrate community organization (e.g., Molles, 1982; Aguiar *et al.*, 2002) that indirectly may affect caddisfly composition (Molles, 1982; Bonada *et al.*, Chapter 7). Similarly, biological adjacent community can be more or less divers because water quality characteristics, by substrate availability or temporality (Bonada *et al.*, Chapter 5). Thereby, caddisfly composition is indirectly affected by both factors but directly exposed to chemical features. For example, different species of the net-spinning Hydropsychidae are segregated to different suspended solids concentrations probably because their feeding and net morphological requirements (e.g., Gordon & Wallace, 1975; Wiggins & Mackay, 1978; Alstad, 1987). Hydropsychidae have been found as a very tolerant family over the world (e.g., Mackay, 1979; Vuori, 1995) with some species able to tolerate anaerobic conditions during several hours (Becker, 1987). Hydropsychid species appear segregated at different water qualities along the river (Décamps *et al.*, 1973; Gordon & Wallace, 1975; Ross & Wallace, 1982; Gallardo-Mayenco *et al.*, 1998), with *H. exocellata* considered a very tolerant species by several authors (e.g., Higler & Tolkamp, 1983; Gallardo-Mayenco *et al.*, 1998; Usseglio-Polatera & Bournaud, 1989). Although in our results this is true for species, at family level Glossosomatidae is more tolerant than Hydropsychidae, especially to salinity.

Numerous controversies are found in literature about the appropriate taxonomical level to be used in water monitoring, especially to know if environmental requirements for lower taxonomical levels may be extrapolated to family or orders (Resh & Unzicker, 1975; Cranston, 1990; Lenat & Resh, 2001). According to our results, similar ecological profiles are shown by all taxonomical levels when a family has few species (e.g., Odontoceridae) or when family displays a restricted profile (e.g., Brachycentridae, Lepidostomatidae). In other cases, as in the abundant Hydropsychidae or Hydroptilidae, ecological patterns from family level are very different from the ones obtained from some species. Resh & Unzicker (1975) looking at tolerances of *Ceraclea* sp. (*Athripsodes* sp.) observed different pollution tolerances at genus and species level, what would agree with some of our results. Therefore, the use of family level might underestimate higher water qualities, specially in that situation when habitat structure or temporality yield a poor macroinvertebrate diversity (e.g., Bonada *et al.*, Chapter 5), because scores at family level usually use intermediate species tolerance values (Lenat & Resh, 2001). In the same sense, in a very poor water quality conditions, indexes at family levels may overestimate water quality more than those based in species. Biological indexes at species level have been used in some countries (e.g., the saprobic system in Austria) providing good results (Moog & Chovarec, 2000). In that sense, because the DIS values obtained here are a representation of the sensitivity (or tolerance) of taxa, it could be used to obtain a biological index using caddisflies at genus/species level, similarly, for example, to the saprobic method used in Austria. However, caddisfly larvae identification is not easy especially in areas where larvae are poorly known as in the Iberian Peninsula (see Vieira-Lanero, 2000; Bonada *et al.*, Chapter 6). Though some error is incorporated, indexes at family level although may be more adequate in terms of cost-efficiency, especially when few taxonomic experts are available (Lenat & Resh, 2001).

The biological index IBMWP has been extensively applied in the Iberian Peninsula beeing highly sensitive to water quality (Camargo, 1993; Zamora-Muñoz *et al.*, 1995; Alba-Tercedor, 1996; Zamora-Muñoz & Alba-Tercedor, 1996; García-Criado *et al.*, 1999; Prat *et al.*, 1999, 2001; Alba-Tercedor & Pujante, 2000). Overall, scores assigned to caddisflies families in the IBMWP agree with the tolerance to pollution for each family in the mediterranean sampled area, and only in some cases minor modifications may be applied, especially in Glossosomatidae. For this last family, and especially in *Agapetus* genus, some larvae were found very abundant in semiarid areas with lower water qualities than should be expected from a score of 8 in the IBMWP. Although conductivity (mainly by sulphates) present in that areas may have a geological origin (see Toro *et al.*, in press), larvae appear tolerant to some ammonium and chloride concentrations, what might suggest a reassignment of its IBMWP score. These divergences observed in Glossosomatidae between its DIS and IBMWP scores may be related to the specific sensitivities displayed by several species present in some areas but absent in others. In that sense, for example *A. fuscipes* has been considered as a very sensitive species (González del Tánago & García de Jalón, 1984; Wallace *et al.*, 1990), whereas *A. incertulus* have been found in slightly polluted streams with high salinity (see Bonada *et al.*, Chapter 6).

Ecological profiles are dynamic structures that can change in space and time, and therefore, studies performed in small areas or integrating short periods may be incomplete (Moretti & Mearelli, 1981). Moreover, environmental variables may also change widely in time and space what difficult the establishment of organisms tolerances to pollution (Resh & Unzicker, 1975). Consequently, when ecological profiles are obtained from field data instead of experimental studies, large sets of data integrated in time and space are required to determine species' autoecology with certainty. However, several considerations have to be done when optimum and tolerances are calculated assuming a unimodal distribution of organisms. In some cases, it has been demonstrated that organisms can fit a bimodal, multimodal or skewed distribution (Hengeveld, 1990). Several factors have been considered as the responsible to that deviation as biotic interactions (Westman, 1991), life cycle stage (Verdonschot & Higler, 1992), or because the environmental variable does not show a gradient (Wiens, 1989). However, in most of the cases and maybe because incomplete data, is not possible to know if organisms display an unimodal distribution with certainty (Verdonschot & Higler, 1992), and these considerations must be assumed and results interpreted with caution.

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Annex 1. List of caddisfly families and genus/family used in the analysis with the number of records (N).

Family	**N**	***Genus/Species***	**N**	**Code**
Brachycentridae	37	*Micrasema longulum*	10	M longulum
		Micrasema moestum	23	M moestum
Glossosomatidae	61	*Agapetus* sp.	38	Agapetus sp
Hydropsychidae	449	*Cheumatopsyche lepida*	10	C lepida
		Hydropsyche brevis	23	H brevis
		Hydropsyche dinarica	10	H dinarica
		Hydropsyche exocellata	136	H exocellata
		Hydropsyche gr. *pellucidula*	159	H gr pellucidul
		Hydropsyche infernalis	31	H infernalis
		Hydropsyche instabilis	115	H instabilis
		Hydropsyche siltalai	30	H siltalai
		Hydropsyche sp1	13	H sp1
Hydroptilidae	254	*Hydroptila* sp.	222	Hydroptila sp
		Ithytrichia sp.	10	Ithytrichia sp
Lepidostomatidae	62	*Lasiocephala basalis*	59	L basalis
Leptoceridae	95	*Athripsodes* sp.	38	Athripsodes sp
		Mystacides azurea	21	M azurea
		Setodes argentipunctellus	21	S argentip
Limnephilidae	222	*Allogamus* sp.	15	Allogamus sp
		Anomalopterygella chauviniana	12	A chauviniana
		Chaetopteryx sp.	11	Chaetopteryx sp
		Halesus radiatus	18	H radiatus
		Halesus tessellatus	30	H tessellatus
		Limnephilus guadarramicus	29	L guadarramicus
		Mesophylax aspersus	60	M aspersus
		Potamophylax cingulatus	13	P cingulatus
		Potamophylax latipennis	29	P latipennis
		Stenophylax sp.	13	Stenophylax sp
Odontoceridae	12	*Odontocerum albicorne*	10	O albicorne
Philopotamidae	83	*Chimarra marginata*	55	C marginata
		Philopotamus montanus	14	P montanus
Polycentropodidae	139	*Plectrocnemia* sp.	23	Plectrocnemia s
		Polycentropus kingi	27	P kingi
		Polycentropus flavomaculatus	19	P flavomaculatu
Psychomyiidae	64	*Tinodes* sp.	44	Tinodes sp
Rhyacophilidae	224	*Rhyacophila* gr. *tristis*	13	R tristis
		Rhyacophila dorsalis	35	R dorsalis
		Rhyacophila meridionalis	23	R meridionalis
		Rhyacophila munda	63	R munda
		Rhyacophila nevada	61	R nevada
Sericostomatidae	74	*Sericostoma* sp.	61	Sericostoma sp

Annex 2. Chemical ranges from several variables from Prat *et al.* (2001).

IBMWP	
<15	Extremely poor community
16-35	Very polluted waters
36-60	Polluted waters
61-100	Moderately polluted waters
>100	Very good water quality

QBR	
?25	Extreme dregadation, very poor quality
30-50	Strong alteration, poor quality
55-70	Considerable disturbance, fair quality
75-90	Some disturbance, good quality
?95	Riparian habitat in natural condition

AMMONIUM	(mg/l)
<0.1	Clean waters, without stress
0.1-0.4	Waters with some stress depending on the pH
0.5-0.9	Fair water quality
1-4	Poor water quality
>4	Very poor water quality, with high toxicity

N-NITRITES (mg/l)	
<0.03	Clean waters, without stress
0.03-0.3	Fair water quality
>0.3	Very Poor water quality, with high toxicity

P-PHOSPHATES (mg/l)	
<0.03	Clean waters, without stress and eutrophy
0.03-0.09	Waters with some eutrophy
0.1-0.29	Fair water quality and eutrophy
0.3-0.5	Poor water quality and high eutrophy
>0.5	Very poor water quality and very high eutrophy

SULPHATES (mg/l)	
<250	Clean waters, without stress
250-1000	Fair water quality by pollution of gypsum basin geology
>1000	Very Poor water quality

CHLORIDE (mg/l)	
<25	Clean waters, without stress
25-99	Waters with some stress
100-199	Fair water quality
200-1000	Poor water quality
>1000	Very poor water quality, saline