RESEARCH ARTICLE

Microhabitat preference of sympatric *Hydraena* Kugelann, 1794 species (Coleoptera: Hydraenidae) in a low order forest stream

Bo Tiziano[a], Piano Elena[b], Doretto Alberto[b], Bona Francesca[b] and Fenoglio Stefano[a]*

[a] DISIT, Università del Piemonte Orientale, Viale T. Michel 11, I-15121, Alessandria, Italy;

[b] DBIOS, Università degli Studi di Torino, Via Accademia Albertina 13, I-10123 Torino, Italy.

*Corresponding author e-mail: stefano.fenoglio@uniupo.it (ORCID: orcid.org/0000-0001-6931-652x) Tel +39 0131 360201

ABSTRACT

Aim of this study was to investigate the presence and distribution of Hydraenidae in relation to selected abiotic parameters in a single, uniform riffle of the Caramagna Stream (northwestern Italy). Six species belonging to the genus of *Hydraena* Kugelann, 1794 were found (*H. andreinii* D'Orchymont, 1934, *H. subimpressa* Rey, 1885, *H. assimilis* Rey, 1885, *H. heterogyna* Bedel, 1898, *H. truncata* Rey, 1884 and *H. devillei* Ganglbauer, 1901), with evident niche preferences. Our study provided interesting information about ecological requirements of minute moss beetles at small-scale and evidenced that maintaining elevate habitat diversity is essential to preserve high species abundance at local scale.

Introduction

Lotic insects are generally thought to be distributed according to environmental factors, aside from historical constrains, that operate at different scales (Heino, Muotka, and Paavola 2003; Lancaster and Downes 2013). Most studies have considered distribution patterns along geographical and environmental gradients (Pearson and Boyero 2009), while there are far fewer works investigating small scale distribution models. This is especially true for non-EPT (Ephemeroptera, Plecoptera and Trichoptera) groups such as Hydraenidae and other small lotic Coleoptera, for which a good taxonomic knowledge is often not associated with comparable ecological information (Audisio et al. 2010; Sánchez-Fernández, Lobo, Abellan, and Millan 2011).

Generally, physical factors have often been used to explain distribution of benthic organisms (Sheldon and Walker 1998) and, in particular, flow conditions and substratum characteristics are considered key factors operating at within-site scale in shaping species distribution (Minshall 1984; Malmqvist and Maki 1994). Small scale differences in physical conditions created by a combination of velocity, depth and substratum characteristics have a major role in the spatial distribution of macroinvertebrate communities in riffle environments (Brooks, Haeusler, Reinfelds, and Williams 2005). These factors are especially considered important in defining the ecological niche of individual species (Resh et al. 1988). It is well known that many species of Hydraenidae can coexist in the same low-order stream reach, but information about their fine distribution and ecological requirements at small scale are practically absent for these environments. Aim of this short study was to explore the micro-distribution of Hydraenidae in a forest stream of northwestern Italy, analyzing the relationship between species occurrence and simple physical variables.

Methods

This study was carried out in the Caramagna Stream, Piemonte, northwestern Italy (44°36'00"N, 8°32'00"E; 280 m a.s.l.), a forest and pristine small order stream with moderate slope, narrow and sinuous channel, and riverbed width approximately equals to 2.0–2.5 m. In a single, large and homogeneous riffle (50 m length), we realized 109 Surber samples ($0.06 \ m^2$, 250 µm mesh), collecting and sorting aquatic insect assemblages. Each Surber sampled a patch, in which we measured flow velocity, water depth and substratum characteristics (% of boulders, % of cobbles, % of gravel and % of sand). Samplings were performed from January to December 2005. Data were analyzed by means of the Outlier Mean Index (OMI) analysis, a two-table ordination technique that positions the sampling units in a multidimensional space as a function

of environmental parameters (Doledec, Chessel, and Gimaret-Carpentier 2000). The distribution of species in this space represents their realized niches and considers two aspects: marginality and tolerance. The marginality measures the distance between the mean habitat conditions used by a species and the mean habitat conditions across the study area. Species with high values of OMI have marginal niches (occur in atypical habitats in a study site), and those that get low values have non-marginal niches (occur in typical habitats in a study site). The tolerance measures the niche breadth, which means the amplitude in the distribution of each species along the sampled environmental gradients. Low values mean that a species is distributed across a limited range of conditions (specialist species), while high values imply that a species is distributed across habitats with widely varying environmental conditions (generalist species). Another value reported is the percentage of residual tolerance (%Rtol), which measures the unexplained variance, accounting for variability not related to environmental factors here considered.

The advantage of this method over other two-table ordination methods (i.e., CCA and RDA) is that it does not assume any shape for the response curves to the environmental gradients (CCA assumes a unimodal response, while RDA assumes a linear one) (Doledec et al. 2000).

The statistical significance of the marginality of each species was tested by a Monte Carlo (MC) permutation test with 9999 random permutations. The frequency of random permutations with values greater than the observed marginality was used as an estimated probability of rejecting the null hypothesis that the environmental gradient does not constrain species distribution. The OMI analysis and MC permutations were performed via the function 'niche' and 'rtest' respectively in the package *ade4* (Dray and Dufour 2007) for the R software (R Core Team 2015).

Results

Adult Hydraenidae were found in 46 Surber samples out of 109. We identified adults of six species belonging to the genus *Hydraena* Kugelann, 1794. *Hydraena andreinii* D'Orchymont, 1934 resulted the most abundant and widely distributed species, with 92 individuals recorded in 33 samples, followed by *H. subimpressa* Rey, 1885 with 40 individuals recorded in 15 samples. The other four species, *H. assimilis* Rey, 1885, *H. heterogyna* Bedel, 1898, *H. truncata* Rey, 1884 and *H. devillei* Ganglbauer, 1901 showed lower number of individuals and were less frequent. In the greatest part of samples, only one species was recorded, even if in 14 samples co-occurrence among different species was observed, indicating a possible overlap of ecological niches. In particular, the less frequent species in most cases co-occurred with *H.*

andreinii or *H. subimpressa.* Conversely, *H. subimpressa* co-existed with *H. andreinii* in only five out of the 15 samples in which was recorded, despite they were the most abundant and frequent species. These observations were statistically confirmed by the niche analysis. The OMI analysis results are reported in Table 1 and 2. The first three axes of the OMI analysis were selected, which accounted for 96.38% (55.52% for the first, 33.47% for the second and 7.38% for the third axis) of the total explained variability. All the environmental variables here considered were highly correlated with at least one of these axes. The first axis is positively correlated with % of gravel and it is negatively correlated with water depth, flow velocity and % of boulders. The second axis is positively correlated with % of sand and water depth while it is negatively correlated with the flow velocity. The third axis is positively correlated with % of boulders and negatively correlated with water depth (Table 2a). The OMI analysis revealed different levels of niche overlap/differentiation among the six species, even if the mean habitat requirements did significantly differ from the mean habitat values of the investigated microhabitats (Table 2a and 2b). The amount of unexplained variance ranges between 45.80 for *H. heterogyna* to 75.50 for *H. devillei*, similarly to other works in which the OMI analysis was performed (Merigoux and Doledec 2004; Falasco et al. 2015). Figure 1 shows that *H. andreinii* has the widest niche and it overlaps with the niche of all the other species. It can be considered a generalist species, even if it showed a slight preference for boulders. A similar pattern can be observed for *H. devillei*, which can also be considered a generalist species, even if it resulted much less abundant and frequent than *H. andreinii.* Conversely, ecological niches of *H. assimilis* and *H. subimpressa,* despite being quite wide, displayed little overlap. *Hydraena assimilis* seems to prefer deep microhabitats, with substrates dominated by boulders, while *H. subimpressa* showed a preference for shallow microhabitats with gravel substrates. *Hydraena heterogyna* and *H. truncata* can be considered two specialist species since their ecological niches resulted much smaller than the ones of the other species. While *H. truncata* seems to prefer gravel-dominated substrates, the niche of *H. heterogyna* is shifted towards microhabitats characterized by high flow velocities and prevalence of boulders and cobbles in the substrate.

Discussion

At present, knowledge about Palaearctic and European Hydraenidae is quite consolidated at both taxonomic and zoogeographical level (Audisio and De Biase 2005; Trizzino, Carnevali, De Felici, and Audisio 2013). Unfortunately, our knowledge still has many gaps in other

contexts, especially regarding the ecological requirements that regulate the small-scale distribution of the different species. Mediterranean area, and, in particular, the Italian, Iberian and Balkan Peninsulas, represents one of the richest areas in the whole Palearctic for many freshwater groups, and this also applies to Hydraenidae (Tierno de Figueroa, López-Rodríguez, Fenoglio, Sánchez-Castillo, and Fochetti 2013): approximately 380 species are currently listed in the Mediterranean Basin, of which 57% are endemics (Jäch and Skale 2015). This taxonomic richness is also confirmed by our data, with six species found in a small riffle. *Hydraena subimpressa*, *H. assimilis* and *H. truncata* are diffused in Western Europe, *H. heterogyna* and *H. devillei* are present in small streams throughout Italy, while *H. andreinii* is an endemic species of Northern Apennines. Because our sampling plots were located inside a single stream, we could characterize the ecological preferences of Hydraenidae species at microhabitat level, without confounding effects related to the presence of different water courses. We noticed that the two most abundant species rarely coexist while sometimes they were found in association with the others. It is remarkable that, despite the relatively simple approach, our study highlights a clear separation of niches among the six species found, underlining that physical elements of the benthic habitat here considered are all extremely important in shaping the micro-distribution of lotic species. Indeed, according to our results, species distribution was related to both substratum grain size as well as to hydraulic conditions. Furthermore, despite their different ecological requirements, the results of the Monte Carlo permutations showed that all the species occur in microhabitats typical of the investigated site. This suggests that the high heterogeneity of the stream reach is determinant for hosting species with different ecological requirements (Bereczki, Szivák, Móra, and Csabai 2012).

These results may have a certain interest to assess conservation priorities for Hydraenidae. In fact, anthropogenic disturbance and climate change are rapidly deteriorating physical conditions of small order lotic environments: hydrological alterations, clogging, channeling, and straightening increasingly banalize substrata and alter flow conditions (Doretto et al. 2015). In this context, our study highlights that some species may disappear or decline as a result of small changes in flow, riverbed granulometry or other environmental factors. Our results, therefore, stresses the importance of maintaining a high environmental heterogeneity in lotic ecosystems, because complex habitats sustain greater taxonomic richness and then functional integrity. It should, however, be noticed that this study is based solely on abiotic parameters. For a future implementation of this investigation topic, also biotic environmental factors, like organic sediment availability, algal and macrophyte presence should be taken in consideration.

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Table 1. Niche parameters of Hydraenidae species. Inertia = variance or weighted sum of squared distances to the origin of the environmental axes; %OMI = percentage of variability of outlying mean index (marginality); %Tol = percentage of variability of tolerance index; %Rtol = residual tolerance (%); p–value = significance of the Monte Carlo permutation test.

Species	Inertia	%OMI	%Tol	%Rtol	p-value
Hydraena andreinii	5.83	5.00	36.00	59.00	0.2624
Hydraena assimilis	7.41	13.20	18.80	68.00	0.3900
Hydraena subimpressa	4.53	21.10	16.70	62.10	0.2427
Hydraena devillei	5.39	9.80	14.70	75.50	0.8626
Hydraena heterogyna	9.37	51.90	2.30	45.80	0.0872
Hydraena truncata	1.49	45.90	4.90	49.20	0.4530

Table 2. Environmental variables normed scores on (a) the three axes of OMI analysis (CS1 = first axis; CS2 second axis; CS3 third axis) and (b) on Hydraenidae species.

(a) Axis	Water depth	Flow velocity	%boulders	%cobbles	%gravel	%sand
CS1	-0.5129	-0.4855	-0.4507	-0.1195	0.5326	0.0033
CS2	0.5303	-0.4375	-0.3282	-0.1810	-0.2101	0.5855
CS3	-0.5014	-0.3304	0.5539	-0.3218	-0.3892	0.2785
(b) Species						
Hydraena andreinii	-0.1303	0.2713	0.3303	0.1071	-0.0946	-0.2623
Hydraena assimilis	0.6883	0.2257	0.5580	-0.0016	-0.3643	-0.0841
Hydraena subimpressa	-0.7142	-0.0854	-0.1058	-0.0122	0.5482	-0.3582
Hydraena devillei	-0.0308	-0.2010	0.4105	-0.5192	0.0757	0.2098
Hydraena heterogyna	0.6354	1.6479	0.8530	0.4285	-0.8362	-0.3599
Hydraena truncata	0.1841	0.1842	-0.3271	0.2074	0.5316	-0.4269

Figure caption:

Figure 1. Projection of environmental variables on the axis of OMI analysis and representation of ecological niches of the six analysed species.