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WATER BEETLE DISTRIBUTION ALONG A PERENNIAL DISTANCE GRADIENT IN AN INTERMITTENT STREAM FROM THE MEDITERRANEAN PART OF MONTENEGRO

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Abstract - In this study, we examined the impact of an unstable hydrological regime (floods and seasonal drying) on water beetle fauna after a drought period, in an intermittent stream in the Mediterranean part of Montenegro. Aquatic beetles were collected between November 2009 and May 2010 from three intermittent sites along the Rimanić stream at different distances from the perennial part (DP), using quantitative sampling methods. We predicted that water beetle assemblages would vary in structure and composition along DP gradients. Total abundance, taxa richness, main faunal groups and proportion of adults and larvae were assessed in order to describe the changes in the water beetle assemblages. The water beetle fauna in the studied sites recovered slowly from the drought periods in terms of both total abundance and taxa richness. Analysis of similarity (ANOSIM) showed no significant changes in community structure between the sites, but revealed changes in terms of date (Rho = 0.403).

Key words: Aquatic Coleoptera, ecology, drought, intermittent stream, Montenegro

INTRODUTION

Intermittent and ephemeral rivers comprise a large proportion of the total number, length and discharge of the world's rivers (Tooth, 2000).The Mediterranean basin is characterized by an extensive range of physical conditions, including severe flooding and droughts (Pires et al., 1999). Intermittent streams, such as those found in Montenegro, present a particularly severe physical environment. Stream flow permanence has been identified as a major factor affecting other abiotic and biotic factors that regulate lotic macrozoobenthic processes and patterns (Wood et al., 2005; Stubbington et al., 2009; Datry et al., 2010).

Water beetles are common in virtually all aquatic systems, including temporary rivers (Larson, 1985, Collinson et al., 1995). The permanence of a water body affects species composition and fewer species are adapted to temporary habitats than to permanent ones (Collinson et al., 1995, Valladares et al., 2002). Amongst the macroinvertebrate taxa that inhabit temporary and fluctuating streams, aquatic Coleoptera are particularly well suited, to both assess habitat quality and explore ecological patterns, since this group is relatively diverse and occurs across a wide spectrum of stream types. Patterns in their biology and distribution have been used as an indication of the general characteristics of the system and of its biological and conservation quality (see e.g. Foster, 1991).

In this study, we examined the response and recovery of water beetle assemblages to hydrologic extremes (floods and seasonal drying) at three sites along one undisturbed intermittent Mediterranean stream. Two types of habitats within the stream were distinguished according to the natural periodicity of their discharge conditions. The upper stretch of

the Rimanić stream has temporal flow but the lower stretch is perennial. The primary focus was to compare seasonal differences in structural parameters (density, richness of main faunal groups and proportion of adults and larvae) in three sites at different distances from the perennial order stream, considering that the sites closer to the perennial part will present a higher diversity in community structure in response to flow regime.

MATERIALS AND METHODS

Study area

This study was carried out in the Rimanić stream which is situated in the central part of Montenegro, flowing through the city Spuž to the Zeta River (Fig. 1). This region is one of the driest regions of Montenegro and the upper part of the brook dries up every summer due to climatic, geological and geomorphological conditions.

The alluvial portion of the Rimanić main stream has two abutting sections. The upper part is an intermittent reach; all surface flow is lost for at least part of each year (from the end of May to the end of October in the study year). After accumulating groundwater, the stream becomes perennial again ≈ 1.5 km from the Zeta iver.

Three sampling sites along the intermittent reach were selected for this study. Site 1 is situated near the border with the perennial reach; sites 2 and 3 are situated at ca. 0.85 and 1.7 km from the perennial reach, respectively. The upper site of stream (site 3) is devoid of human impact, and the remaining two sites lie close to human settlements.

Sampling and evaluation methods

Immediately after the re-establishment of the water flow in November, the macroinvertebrate community was sampled using a Surber net (0.35 m^2 area, 200 μm mesh; three random samples covering an area of 1.05 m^2 were taken at each site) at three selected sites, and transported to the laboratory. Samples were taken at monthly intervals from November 2009 to May 2010.

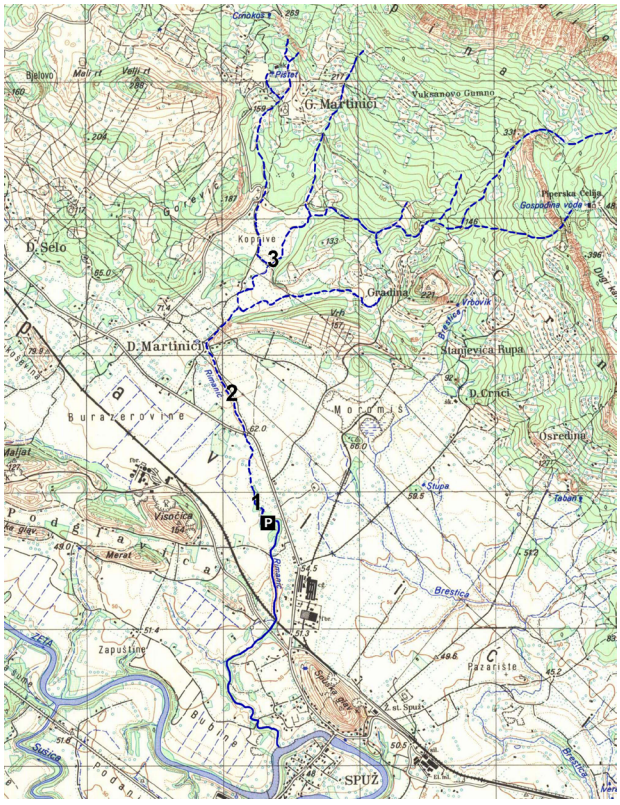


Fig. 1. Topographic map (at scales 1: 25000) showing location of the study sites (numbers) along intermittent part of Rimanić stream. The interrupted lines represent intermittent reach of Rimanić stream. P - show location where stream become perennial.

Material from each sampling site was sorted in the laboratory and specimens of water beetles were removed from the organic matter and stored in 70% ethanol. Larvae of aquatic Coleoptera were identified to the family level, adults to the species level. Material examined was deposited in the collections of the authors, in the collection of the Department of Biology in Podgorica.

The absolute abundances of specimens from quantitative samples were converted to a unit area of 1 m^2. Shannon-Weaver's index of diversity was calculated and all subsequent quantitative comparisons were made based on these data.

Table 1. The list of the water beetle taxa from the studied sampling sites (Loc I-III) with their density (ind./m2) per each sampling date.

TAXA	*16.11.2009.*			*13.12. 2009.*			*16.01.2010.*			*22.02.2009.*			*20.03.2010.*			*30.04.2010.*			*30.05. 2010.*		
	Loc I	Loc II	Loc III	Loc I	Loc II	Loc III	Loc I	Loc II	Loc III	Loc I	Loc II	Loc III	Loc I	Lok II	Loc III	Loc I	Loc II	Loc III	Loc I	Loc II	Loc III
Dytiscidae																					
Hydroporus pubescens																		2			4
Deronectes moestus inconspectus																		1		1	1
Scarodytes halensis					1	1															
Agabus guttatus								1							1			3			4
Ilybius chalconatus															1			4	2		1
Helophoridae																					
Helophorus brevipalpis levantinus														1					35	25	7
H.montenegrinus																	8	4	1	76	42
H. obscurus obscurus																	1		3		
Hydrophilidae																					
Anacaena limbata																			5		1
Laccobius obscuratus																				1	
Hydraenidae																					
Hydraena nigrita	1	1	1	1			15	2	7	16	1	1	32	54		23	5	3	97	25	25
Hydraena palustris																			1		
Hydraena paganettii	1	1	1	1										1					1		
Limnebius truncatellus																				2	
TOTAL	**2**	**2**	**2**	**2**	**1**	**1**	**15**	**3**	**7**	**16**	**1**	**1**	**32**	**56**	**2**	**23**	**14**	**17**	**145**	**130**	**85**
COLEOPTERA LARVAE																					
Dytiscidae larvae					2	2			2		2							18			10
Hydrophilidae larvae																				1	1
Elmidae larvae							1													1	4
TOTAL					**2**	**2**	**1**		**2**		**2**							**18**		**2**	**15**

Statistical analyses were conducted to examine spatial trends in beetle species composition between the sampling sites. This approach required the use of multivariate (ANOSIM and nMDS) techniques. Multivariate analyses were conducted using the PRIMER statistical package (PRIMERE, 2000). Nonmetric multidimensional scaling (nMDS) (Clarke, 1993) was used to examine spatial patterns. Analysis of similarity (ANOSIM) (Clarke and Warwick, 1994) was used to test the difference between the sampling site groups (across all sampling data groups), and between sampling data groups (across all sampling site groups), respectively, in nMDS ordinations.

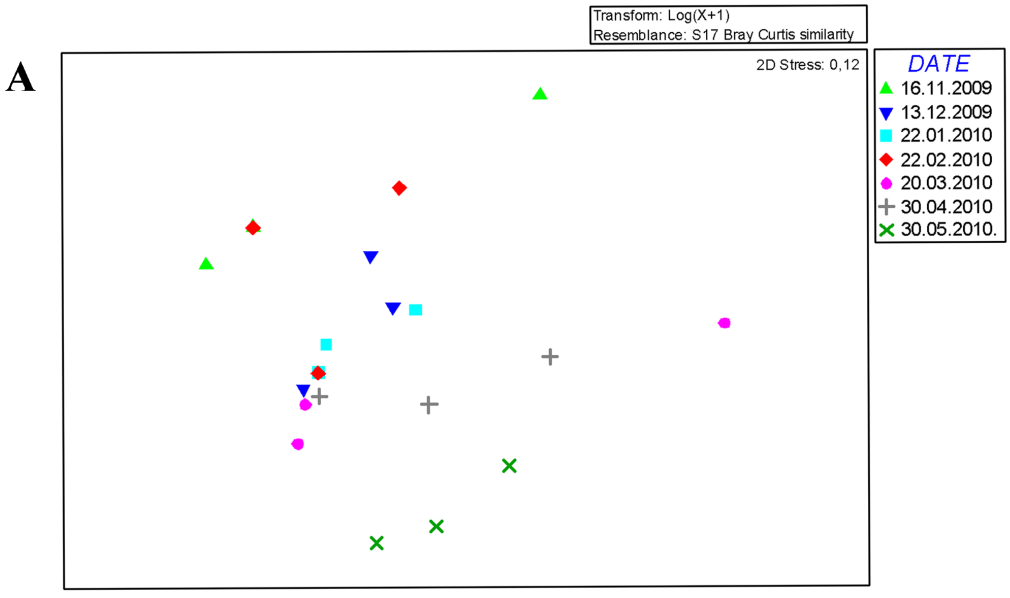
RESULTS

Assemblages of water beetles

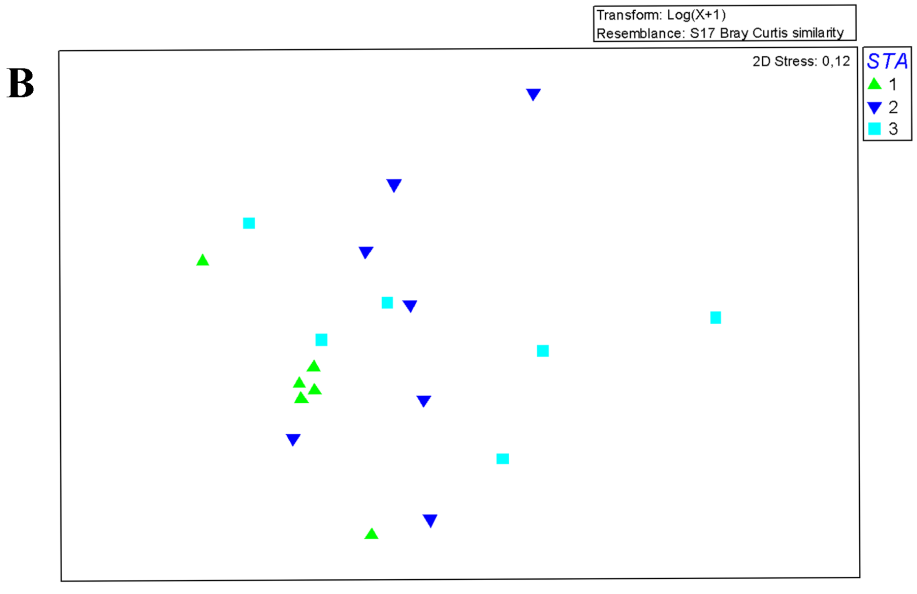
From quantitative samplings, adults and larvae of aquatic beetles were available. In total, 582 specimens of adults and 47 of larvae were collected during our investigation. Fourteen taxa of four families were identified to species level. Among these, four species in the survey were new records for Montenegro. These were *Hydraena palustris* Erichson, 1837, *Limnebius truncatellus* (Thunberg, 1794), *Helophorus brevipalpis levantinus* Angus, 1981 and *Helophorus obscurus* Mulsant, 1844. The list of all recorded taxa, including data on their density (ind./m^2) per each date is given in Table 1.

The total abundance of water beetle adults increased with decreasing DP, and reached maximum values at the near perennial site (site 1) with 238.05 ind./m^2. In contrast, the lowest abundances were reached at the upper sampling site of the stream (site 3) with 148.54 ind./m^2. Density increased at all sites from late autumn to spring.

The Shannon-Wiener diversity index was not significantly different between the sites. The highest species richness was noted at site 2 (9 species, H=1.732). In contrast, a slightly lower number of



Sample statistic (Rho): 0.403
Significance level of sample statistic: 0.8%
Number of permutations: 999 (Random sample)
Number of permuted statistics greater than or equal to Rho: 7



Sample statistic (Rho): 0.16
Significance level of sample statistic: 99%
Number of permutations: 999 (Random sample)
Number of permuted statistics greater than or equal to Rho: 989

Fig. 2A-B. nMDS ordinations of water beetle assemblage from the three studied sites by date (A) and by sampling sites (B).

taxa were recorded at sites I (8 species, H=1.507) and III (8 species, H=1.430), respectively.

Richness in all sites was greatest in late spring due to the presence of several species that mainly appear in that season (*Hydroporus pubescens, Deronectes moestus inconspectus, Ilybius chalconatus, Helophorus brevipalpis levantinus, H. montenegrinus, H. obscurus, Anacaena limbata, Laccobius obscuratus*).

Faunistic notes

Representatives of four families, Dytiscidae, Hydraenidae, Helophoridae and Hydrophilidae, were recorded. The majority of the recognized species belong to the families Dytiscidae and Hydraenidae.

While Hydraenidae and Helophoridae represented 59.27% and 34.87%, respectively, of all obtained specimens at all sites, the remaining families accounted for less than 10%. The suborder of predaceous aquatic beetles (Adephaga, Dytiscidae) was represented by five rheophilic – rheobiontic species (*Hydroporus pubescens, Deronectes moestus inconspectus, Scarodytes halensis, Agabus guttatus and Ilybius chalconatus*). They occurred occasionally in low numbers and mainly at site 3 in April and May (Table 1).

The only recorded species of the family Hydrophilidae were *Anacaena limbata and Laccobius obscuratus,* which were found infrequently at the sampling sites and occur only in late spring. Hydraenidae were represented by two genera: *Hydraena* Kugelann, 1794 (3 species) and *Limnebius* Leach, 1815 (1 species). *Hydraena nigrita* was dominant, occurring at all sampling sites in the whole period of sampling (almost every month) in the highest numbers. Other species were found in distinctly lower numbers compared with *Hydraena nigrita*. The proportion of hydraenid taxa decreased with increasing DP, from 58.84% at near perennial sites (203 specimens from 4 species) and 12.75% at the most intermittent site (44 specimens from 2 species). The highest number of specimens was collected in late spring (43.8% of the total number of collected adult specimens).

The bulk of the obtained material was composed of different larval instars, mainly dytiscids (80.85% of the total number of collected larvae). Larvae were collected at sampling sites 2 and 3, but were absent at site 1. The highest number of larvae was collected in late spring (38.3% of the total number of collected larvae). The proportion of larvae increased with increasing DP, with 0.4% at the near perennial site and 23% at the most intermittent site.

Multivariate analyses

Quantitative samples for water beetle composition from the three studied sites did not appear to separate in nMDS ordinations when all sites were considered. Analysis of similarity (ANOSIM) showed no significant changes in community structure between sites (Rho = 0.16), but revealed changes in terms of date (Rho = 0.403).

DISCUSSION

Mediterranean streams are characterized by an extensive range of physical conditions, including severe flooding and droughts (Pires et al., 1999). The intermittent stream type dries up periodically and is characterized by greater frequency and variability of disturbances. However, the droughts in these seasonal streams can be considered as a predictable disturbance (Boulton and Lake, 1992) and consequently the development of water beetle assemblages in such a "stream type" is seasonal and predictable.

Delucchi (1987) considered that the duration and intensity of the dry periods might be an important factor in determining whether a species regularly found in a perennial habitat can survive in an ephemeral habitat. Four potential mechanisms of re-colonization in the ephemeral reaches of an intermittent stream are proposed (Williams and Hynes, 1976): oviposition, downstream drift, upstream migration, and migration from within the substrate. In our case, the process of recolonization in the ephem-

eral stream reaches following rewetting appears to be dominated by taxa that drift or crawl from downstream perennial reaches.

Despite the mode of recolonization, the water beetle fauna in the studied sites along the ephemeral part of the Rimanić stream recovered slowly from the drought periods in terms of both total abundance and taxa richness. This is possibly because the ephemeral conditions during drought cause a decline in species richness, as has been described in other studies for the whole macroinvertebrate assemblage in intermittent streams (see e.g., Williams and Hynes, 1976; Dieterich and Anderson, 2000). In our study, we predicted that water beetle assemblages vary in response to distance from the perennial part (DP) along the Rimanić stream, suggesting that this can be an important factor determining the structure assemblages after a drought period. However, analysis of similarity (ANOSIM) showed no significant changes in water beetle assemblages between the studied sites, but revealed changes in terms of date (Rho = 0.403).

In conclusion, the beetle fauna of this intermittent stream are sensitive to the severe environmental conditions experienced and can therefore be used as a valuable monitoring tool in assessing freshwater aquatic environments. Aquatic beetle are sensitive to drought conditions and have developed efficient recolonization mechanisms, however, the process of recovery from a drought period is slow, both in terms of total abundance and taxa richness.

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