Review of Hydrobiology
1, 17-25 (2008)

Redelineation of European inland water ecoregions in Slovenia

GORAZD URBANIC[1,2]

[1]Institute for Water of the Republic of Slovenia. Hajdrihova 28c, 1000 Ljubljana, Slovenia
[2]University of Ljubljana, Biotechnical Faculty, Department of Biology, Vecna pot 111, 1000 Ljubljana, Slovenia
e-mail: Gorazd.Urbanic@bf.uni-lj.si

ABSTRACT

A redelineation of European inland water ecoregions (Illies 1978) in the area of Slovenia was performed. A three step approach was used. At first, as a pre-delineation of the area a zoogeographical division of Slovenia based on caddisflies (Urbanic 2004) was selected. Further on a top down approach was used and delineation was prepared based on geology, climate, river regimes and geomorphology. In the last step a bottom-up approach was used, where delineated ecoregions were checked with data on benthic invertebrates. In addition, in case of large rivers historical biological data were used and maximum water temperature analyses were performed. A redelineation of ecoregions was based only on inland water organisms, therefore instead of ecoregion a terminus inland water ecoregion is used. Slovenia shares four European inland water ecoregions, whereas new criteria were set for delineation of the inland water ecoregion 3 - Italy, Corsica and Malta in the north-eastern part. For the inland water ecoregion 11 instead of the name Hungarian lowlands a name Pannonian lowland is proposed.

KEY WORDS: ecoregions, Europe, inland water, redelineation, Slovenia

Review of Hydrobiology
1, 17-25 (2008)

Slovenya sınırları içinde kalan Avrupa iç su ekolojik bölgelerinin yeniden tanımlanması

GORAZD URBANIC[1,2]

[1]Slovenya Cumhuriyeti Su Enstitüsü. Hajdrihova 28c, 1000 Ljubljana, Slovenya
[2]Ljubljana Üniversitesi, Biyoteknoloji Fakültesi, Biyoloji Bölümü, Vecna pot 111, 1000 Ljubljana, Slovenya
e-mail: Gorazd.Urbanic@bf.uni-lj.si

ÖZET

Bu çalışmada Slovenya bölgesindeki Avrupa iç su ekolojik bölgelerinin (Illies 1978) yeniden tanımlaması gerçekleştirildi. Bölgenin bir ön tanımlaması olarak Slovenya'nın Trichoptera'ya dayalı zoocoğrafik bölgeleri (Urbanic 2004) seçildi. Daha sonra, yukarıdan aşağıya doğru bir uygulama kullanılarak jeoloji, iklim, akarsu rejimleri ve jeomorfolojiye dayalı tanımlama yapıldı. Son olarak aşağıdan yukarıya doğru bir uygulama kullanıldı, tanımlanan ekolojik bölgeler bentik omurgasız verileri ile kontrol edildi. Ekolojik bölgelerin yeniden tanımlanması sadece iç su organizmalarına dayalı olarak yapıldı. Bu nedenle, ekolojik bölge yerine iç su ekolojik bölgesi terimi kullanıldı. Slovenya, 4 Avrupa iç su ekolojik bölgesini paylaşmaktadır. Oysa yeni kriter iç su ekolojik bölgesi 3'ün kuzeydoğu bölümündeki İtalya, Korsika ve Malta tanımlanması için oluşturulmuştur. İç su ekolojik bölgesi 11 için Macaristan ovaları yerine Pannonya ovası ismi önerilmiştir.

ANAHTAR KELİMELER: Avrupa, ekolojik bölge, iç su, Slovenya

INTRODUCTION

Ecoregional approach is widely accepted in environmental management. It was adapted for use on aquatic ecosystems by Omernik (1987) in order to define regional goals for water quality and management (Hughes and Larsen 1988). In the European Water Framework Directive (Directive 2000/60/EC) ecoregions are a possible parameter for defining types of waters – the so called national typologies. As a framework for national inland water typologies 25 European ecoregions defined by Illies (1978) were selected. However, Illies (1978) defined the ecoregions on a large European scale and did not regard all local characteristics. Therefore in some European countries e.g. in Austria (Moog et al. 2001) redelineation of ecoregions was performed on the national scale.

Slovenia shares two of Illies' ecoregions. Northern part of Slovenia shares Alps (ecoregion 4), whereas southern part shares Dinaric Western Balkans (ecoregion 5). However, parts of western national border were set also as an ecoregional border to Italy (ecoregion 3), wheras parts of eastern national border as an ecoregional border to Hungarian lowland (ecoregion 11). Moreover, in Slovenia the border between ecoregions Alps and Dinaric western Balkan was set as the line connecting towns Nova Gorica, Ljubljana and Maribor. However, geographical (Gabrovec et al. 1998) and biogeographical (Wraber 1969; Sket 2003; Urbanic 2004) divisions of Slovenia indicated that beside Alpine and Dinaric regions, at least lowland (sub) Pannonian region can be found as well, but Urbanic (2004) also defined a Po region, whereas most others defined a (sub) Mediterranean region as well. These are the main reasons why a new delineation of ecoregions of Slovenia at local scale was necessary. A redelineation of the ecoregions of Slovenia is the main objective of this work.

METODS

A redelineation of inland water ecoregions was performed in three steps. At first, as a pre-delineation of the area a zoogeographical division of Slovenia based on caddisflies (Urbanic 2004) was selected. As a first step four main regions were a priori determined, based on the tectonic map of Slovenia and neighbouring regions (Urbanic 2004). These regions are Alps on the north, Dinarids on the south, Pannonian lowland on the east and Po lowland on the west of Slovenia. This is somewhat similar to the delineation of ecoregions by Illies (1978), although Illies defined Ecoregion 3 (Italy) to the elevation of 1000 m in the Alps, whereas Urbanic (2004) included in the Po region only lowland area not higher than 200 m. In addition, division of Urbanic (2004) is based exclusively on freshwater species and is supported by statistical analyses. However, derived zoogeographic regions are not appropriate per se as ecoregions because only one group of water animals was regarded and the zoogeographic division is prepared based on data of the present situation. For the implementation of WFD (Directive 2000/60/EC) typology has to base on reference conditions, which means a situation without human impact or only with a small one. Therefore in the second step a "top-down" approach was selected. In this approach, previous knowledge or human presumptions are used to develop candidate parameters for delineation of ecoregions. For an "a priori" delineation of ecoregions the following parameters were selected: geological map of Slovenia (1:250,000), geographical maps of Slovenia (1: 25,000), map of karstified area of Slovenia (1:250,000) (Geological Survey of Slovenia, 2004), map of terrain slope (1:250,000), Landscape

regions of Slovenia (Gabrovec et al., 1998) and river regimes (Kolbenzen and Pristov, 1998).

Selected maps were covered with each other and with map of zoogeographic regions of Slovenia (Urbanic 2004). In the third step a "bottom up" approach followed. A priori delineated ecoregions were compared to biological data. Data of benthic invertebrates collected at approximately 150 river sampling sites across Slovenia were used. Only sites that correspond to criteria of reference sites selection (Urbanic and Smolar-Zvanut 2005) and sites which were pre-classified as good according to expert opinion were selected. Each site was allocated into one of the four "a priori" defined ecoregions. Suitability of such a priori classification of sites was tested using nonlinear multidimensional scaling (NMS) analyses. Before analyses a taxonomical adjustment was made and only taxa determined to the species and genus level were used. In addition, for rivers where only impaired sites were available or sampled additional analyses were performed. Following the findings of Urbanic (2004) stating that maximum water temperature is one of the most important parameters defining caddisfly communities in Slovenia, analyses of maximum water temperature at measured sampling sites were also required. National monitoring temperature data were used in cases of large Slovenian rivers (sensu Urbanic 2005b) and rivers of the Sava plain and the Savinja plain. In some cases historical biological data were also used for ecoregion delineation.

RESULTS

Inland water ecoregions
Four inland water ecoregions were delineated in Slovenia (Fig.1):
Ecoregion 3: Italy, Corsica, Malta
Ecoregion 4: Alps
Ecoregion 5: Dinaric western Balkan
Ecoregion 11: Pannonian lowland (Hungarian lowland (sensu Illies 1978))

Ecoregion 3 (Italy, Corsica, Malta) represents less than 1 % of the area of Slovenia. It includes only lower Vipava Valley and Goriska brda hills maximum up to 200 m a.s.l.

Ecoregion 4 (Alps) represents the northern and north-western part of Slovenia. However, most of the Sava plain in the central Slovenia belongs to ecoregion 5, but not most of the medium rivers with most of the catchment area in the Alps e.g. Trziska Bistrica, Kokra, Kamniska Bistrica and the Sava River to the confluence with Ljubljanica, which are part of the Ecoregion 4. In the central Slovenia the border between ecoregions 4 and 5 is a natural border between mountains and the Sava plain but on the north-west not higher than to the elevation of 400 m. On the south-west the Ecoregion 4 extends to the karst area without permanent surface rivers with catchment area > 10 km^2. However, the stream Hubelj to the confluence with Lokavscek also belongs to Ecoregion 4. On the east the ecoregion Alps includes Pohorje and Kozjak and borders on the ecoregion 11 (Pannonian lowland). The border is set at the elevation of ca. 400 m. The whole hilly and plain north-eastern part of Slovenia and plains of Savinja River and Krsko-Breziska kotlina plain are part of the Ecoregin 11. In the Krsko-Breziska kotlina plain the border between ecoregions 5 and 11 is at elevation of 200 m, but all streams with karst spring belong to Ecoregion 5. Ecoregion 11 also includes the

Drava River, which in the upper part of Slovenia flows through the ecoregion Alps, and Sava River after the confluence with Savinja River. Section of the Sava River which flows through the Posavsko hribovje (Ecoregion 4) belongs to the Ecoregion 5. Southern Slovenia also belongs to Ecoregion 5, which is the largest ecoregion in Slovenia and it comprises more than 40 % of the national territory.

Statistical analyses

Results of the NMS analyses (Fig.2) confirmed the correct a priori allocation of the sampling sites to four ecoregions (3, 4, 5, and 11). An overlap that occurred between some sites of ecoregions Alps and Dinaric western Balkan is mainly because sites of the mountainous part of the Ecoregion 5 (the upper Kolpa River catchment area) have similar benthic invertebrate assemblages as mountainous Alpine sites. On the other hand some sites of the Ecoregion 5, especially those of the intermittent streams and slow flowing rivers, have similar benthic invertebrate assemblages as sites of the lowland ecoregions 11 and 3. Moreover, it was very hard to find unimpaired sites in both latter mentioned ecoregions. In the smallest Ecoregion 3 only one unimpaired site was found.

DISCUSSION

Since the delineated ecoregions are applicable only for inland water organisms we believe the name inland water ecoregions more appropriate as ecoregion and use it throughout the paper. Smolar-Zvanut et al. (2004) proposed the name hydroecoregions. However, beside inland water ecoregions also marine ecoregions exists. Therefore we proposed the name inland water ecoregions instead of ecoregions or hydroecoregions only.

Despite only one unimpaired site sampled in the Ecoregion 3, some typical Italian elements occur in this area e.g. caddisfly *Tinodes antonioi* (Urbanic 2004) and a bivalve *Microcondylaea compressa* (Velkavrh 2003). However, no typical Italian species can be found in Slovenia up to 1000 m in the Alps which was the boundary that Illies (1978) defined as the boundary between ecoregions 3 and 4. Moreover, in some cases alpine elements (e.g. caddisflies *Ecclisopteryx asterix*, *Allogamus auricollis*) can be found below 200 m (Urbanic et al. 2003, Urbanic 2004) and therefore these sections are a part of the Ecoregion 4 and not Ecoregion 3. On the other hand Moog et al. (2001) defined a crayfish *Astropotamobius pallipes* as a species indicative of the Ecoregion 3. Therefore, rivers Gail, Gailitz and upper section of the Drava River in Austria belong to the ecoregion 3. *A. pallipes* occurs also in Slovenia in the Adriatic River basin, but rivers of Adriatic river basin belong to three different ecoregions (Urbanic 2005a, this work). Therefore we defined as th Ecoregion 3 only the lowland part of the Vipava valley and Goriska brda hills to the elevation of 200 m. That typical mountainous elements (Alpine, Dinaric) can occur also in the rivers of plains was observed already by Urbanic (2004), which resulted in many zoogeographical gaps in plains. According to Urbanic (2004) the main reason is the maximum water temperature, which is one of the most important ecological factors that impact the occurrence of caddisfly species. Our analyses confirmed that maximum water temperature is important for entire benthic invertebrate assemblage as well. Very similar impact of maximum water temperature was observed also for rivers with karst springs, which was already reported for caddisflies (Urbanic et al. 2003, Urbanic 2004, Urbanic and Toman 2006). This was observed on the whole benthic com-

munity as well (e.g. stream Hubelj). On the other hand, ecoregional gaps were determined also where large rivers flow through a valley in a mountainous region, but upstream they belong to another ecoregion. This provides evidence that maximum water temperature is more important than hydrological conditions of the river for benthic invertebrate distribution. In our case this was evident for the section of the Drava River which flows among Pohorje and Kozjak and the sections of the Sava and Savinja Rivers in Posavsko hribovje mountains. An interesting situation also occurs in the central Slovenia in the lower Sava River plain, where medium and large rivers with headwaters in the Alps belong to the Ecoregion 4, whereas rivers with headwaters in the Sava River plain belong to the Ecoregion 5 (Dinaric western Balkan). Typical dinaric faunistic elements in the Sava River plain are caddisflies *Rhyacophila schmidinarica* and *R. palmeni*. On the other hand at the beginning of the 20th century in the Sava River alpine element *Allogamus auricollis* was collected near Ljubljana as well. Today this species can be found in the Sava River, but not bellow the confluence with Kokra River, more than 15 km upstream. That alpine elements should be found in the reference status in the Sava River much further downstream than today is also evident from the maximum water temperature, which at Ljubljana is ca. 18°C. Therefore the whole section of the Sava River to the confluence with Ljubljanica belongs to the Ecoregion 4. The nort-eastern part of Slovenia belongs to the ecoregion 11. However, Moog et al. (2001) defined the area north of north-east Slovenian-Austrian border as the Ecoregion 5 (Dinaric western Balkans). They regarded as typical indicative faunistical elements of the Ecoregion 5 a snail *Hollandriana (Amphimellania) holandrii*, a leech *Trocheta riparia* and a bivalve *Unio crassus decurvatus*. However, according to the distribution of Hollandriana hollandrii this species can be regarded as south-east European and occurs in Hungary and Slovak Republic (Bank 2005) beside its presence in the Ecoregion 11. Moreover, *Trocheta riparia* is today restricted to a small area of the Danube River in Austria and Hungary (Nesemann 1997) and to the pliocene catchment area of the freshwater lakes of the Slavonia (Nesemann 1993), but Slavonia belongs to the Ecoregion 11 (Illies 1978). In addition, *Unio crassus decurvatus* was found in Hungary as well (Araujo 2005), and Hungary does not share the Ecoregion 5, but the Ecoregion 11. On the other hand, in north-eastern Slovenia many typical lowland species which do not occur in the Dinarids were recorded e.g. caddisflies *Neureclipsis bimaculata*, *Brachycentrus maculatus*, *Triaenodes bicolor* and *Ceraclea riparia*. There are many species that occur in lowland streams and rivers of the Dinaric western Balkan ecoregion (e.g. rivers of Bela krajina), but not in the area that is in our case delineated to th Ecoregion 11. Such species are caddisflies *Rhyacophila palmeni*, *R. schmidinarica*, *Wormaldia subnigra* (Urbanic 2004) and the snail *Sadleriana sadleriana* (Bole 1972). There are many more species that occur in Slovenia only in the Dinaric western Balkan ecoregion. Urbanic (2004) found 27 caddisfly species typical of the Dinaric zoogeographic region.

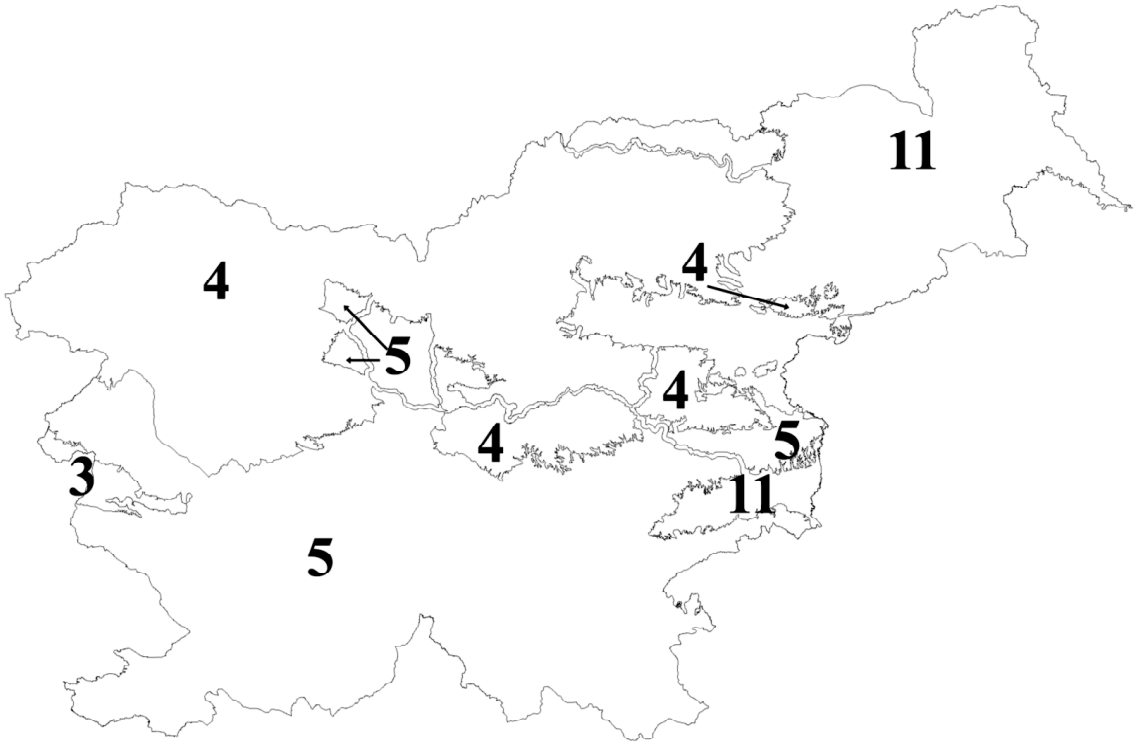

Figure 1. Inland water ecoregions of Slovenia (3 - Italy, Corsica, Malta, 4- Alps, 5 - Dinaric western Balkans, 11 - Pannonian (Hungarian) lowland).

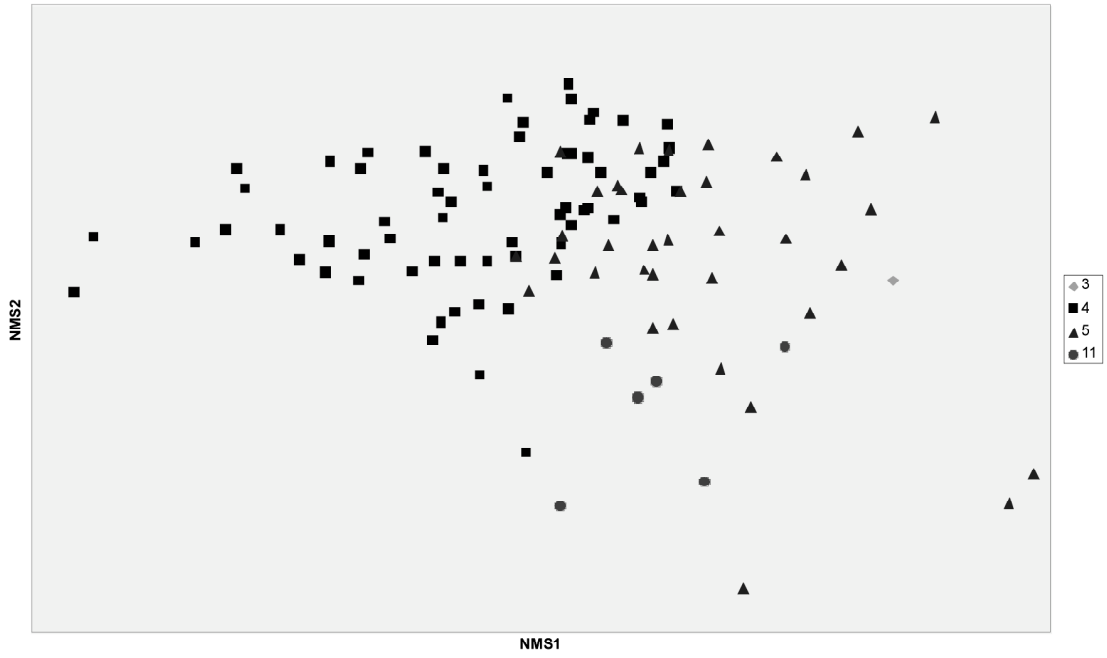

Figure 2. Nonmetric multidimensional scaling ordination diagram of sampling sites, the overlay indicates the ecoregions: 3 - Italy, Corsica, Malta, 4 - Alps, 5 - Dinaric western Balkans, 11 - Pannonian (Hungarian) lowland. Stress = 0,14

ACKNOWLEDGEMENT

The author would like to thank all colleagues who prepared the maps and information used for delineation of the ecoregions and mag. Gregor Sluga for his help with cartography.

REFERENCES

Araujo, R., 2005. Fauna Europaea: Unio crassus cytherea. Fauna Europaea, version 1.2, http://www.faunaeur.org

Bank, R.A., 2005. Fauna Europaea: Amphimelania hollandrii. Fauna Europaea, version 1.2, http://www.faunaeur.org

Bole, J., 1972. Taksonomija in zoogeografija rodu Sadleriana Clessin, 1890 (Gastropoda, Prosobranchia). Razprave XV/3: 51-74.

Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy. Brussels, 72p.

Hughes, R.H., Larsen DP. 1988. Ecoregions: An approach to surface water protection. J. Wat. Pollut. Cont. Fed. 60: 486-493.

Illies, J., 1978. Limnofauna Europaea. 2. Auflage., Gustav Fischer Verlag: Stuttgart, New York, 532p.

Kolbezen, M.and Pristov, J., 1998. Povrsinski vodotoki in vodna bilanca Slovenije. Pages 98, in J. Pristov (Ed.), Ministrstvo za okolje in prostor, Hidrometeoroloski zavod Slovenije: Ljubljana.

Moog, O., Nesemann, H. and Ofenböck, T., 2001. Österreichische Anteil an der europäischen aquatischen Ökoregionen - eine „a priori“ Gliederung auf der Basis landschaftsprägender Milieufaktoren. Sterr. Wasser- und Abfallwirtschaft 52,7/8: 204-209.

Nesemann, H., 1993. Identification key to the Hungarian leeches of the subfamily Trochetinae Pawlowski, 1956, with notes on systematics of the subfamily Erpobdellinae Blanchard, 1894 (Hirudinea). Annls. Hist. Nat. Mus. Nat. Hung 85: 19-35.

Nesemann, H., 1997. Egel und Krebsegel Österreich. Sonderheft der ersten Vorarlberger Malakologischen Gesellschaft. Rankweil, 1-104p.

Omernik, J.M., 1987. Ecoregions of the conterminous United States. Ann. Assoc. Am. Geographers 77,1:118-125.

Perko, D. and Orozen-Adamic, M., 1998. Slovenija - Pokrajine in ljudje. Mladinska knjiga: Ljubljana, 735 str.

Sket, B., 2003. Oblikuje se danasnje zivalstvo, Pages 41-55, in Zivalstvo Slovenije. B. Sket, M. Gogala, V. Kustor, (Eds.), Tehniska zalozba Slovenije: Ljubljana.

Smolar-Zvanut, N., Urbanic, G., Kosi, G. and Povz, M., 2004. Predlog dolocitve hidroekoregij v Sloveniji. Misicev vodarski dan 15: 74-80.

Urbanic. G., 2004. Ekologija in razsirjenost mladoletnic (Insecta: Trichoptera) v nekaterih vodotokih v Sloveniji. Doktorska disertacija, Univerza v Ljubljani, Biotehniska fakulteta: Ljubljana,189p.

Urbanic, G., 2005a. Hidroekoregije Slovenije, Pages 6-10, in G. Urbanic (Ed), Ekolosko stanje za reke in jezera. Institut za vode Republike Slovenije: Ljubljana.

Urbanic, G., 2005b. Tipske regije tekocih voda Slovenije, Pages 11-14, in G. Urbanic (Ed), Ekolosko stanje za reke in jezera. Institut za vode Republike Slovenije: Ljubljana.

Urbanic, G., 2006. Dopolnitve v razmejitvi hidroekoregij in bioregije celinskih voda Slovenije. Pages 12-19, in G. Urbanic, (Ed.), Dodelava tipizacije za reke in jezera. Porocilo o delu v letu 2006. Institut za vode RS: Ljubljana.

Urbanic, G. and Smolar-Zvanut, N., 2005. Kriteriji za izbor referencnih mest, Pages 19-25, in G. Urbanic (Ed.), Ekolosko stanje za reke in jezera. Institut za vode Republike Slovenije: Ljubljana.

Urbanic, G. and Toman, M.J., 2006. Caddisflies in watercourses of the northern part of a Dinaric western Balkans ecoregion in relation to environmental factors. Verh. Internat. Verein. Limnol. 29: 2172-2176.

Urbanic, G., Waringer, J. and Graf, W., 2003. The larva of Ecclisopteryx asterix Malicky, 1979 (Trichoptera: Limnephilidae: Drusinae). Lauterbornia 46:125-134.

Velkovrh, F., 2003. Mehkuzci - Mollusca, Pages 109-132, in B. Sket, M. Gogala, V. Kustor (Eds.), Tehniska zalozba Slovenije: Ljubljana.

Wraber, M., 1969. Pflanzengeographische Stellung und Gliederung Sloweniens. Vegetatio 17,1-6: 176-199.