Acta Zoologica Academiae Scientiarum Hungaricae 50 (3), pp. 195–210, 2004

A NEW MEASURE OF CONSERVATION VALUE COMBINING RARITY AND ECOLOGICAL DIVERSITY: A CASE STUDY WITH LIGHT TRAP COLLECTED CADDISFLIES (INSECTA: TRICHOPTERA)

SCHMERA, D.[1] and KISS, O.[2]

[1]*Plant Protection Institute, Hungarian Academy of Sciences*
H-1525 Budapest, POB 102, Hungary, e-mail: schmera@julia-nki.hu
[2]*Eszterházy Károly College of Education, Department of Zoology*
H-3300 Eger, Leányka u. 6, Hungary

The objective of the present study was to analyse the conservation importance of streams, rivers and lakes for maintaining caddisfly assemblages of Hungarian localities. Light traps ensured comparable catches of caddisflies from different aquatic habitats. A total of 245,363 individuals belonging to 152 species collected from 23 localities over the flight period were included in the analysis. Conservation value of caddisfly assemblages was evaluated on the basis of a newly developed Rarity and Ecological Diversity (*RED*)-index expressing ecological diversity and the average rarity of caddisflies in Hungarian localities. The results showed that streams were the most suitable habitats for maintaining rare caddisfly species in diverse assemblages, while rivers had the lowest conservation importance.

Key words: conservation value, ecological diversity, rarity, Trichoptera, light trap

INTRODUCTION

The extent of human alteration of the environment has caused several changes in the global distribution of organisms (CHAPIN *et al.* 2000). To detect these changes along a scale of natural to impaired states, several attempts have been made to quantify the conservation value of areas. Different measurements can be applied to express our perception of conservation value.

Some of these measures focus on the conservation of biodiversity and express the conservation value of an area by an ecological diversity index (but see IZSÁK & PAPP 2002) or more directly by the (species) richness of the selected organisms (FRENCH & CUMMINS 2001, GÖTMARK *et al.* 1986, LEFEVRE & SHARPE 2002, OERTLI *et al.* 2002, PÄRT & SÖDERSTRÖM 1999, SPACKMAN & HUGHES 1995, TRAVAINI *et al.* 1997, TSCHARNTKE *et al.* 2002). The reason for regarding ecological diversity as a sign of high conservation status is that a species rich community shows higher stability than a poorer one (PIMM 1984), and high species diversity enhances ecosystem functioning through interspecific facilitation (CARDINALE *et al.* 2001). A disadvantage of using diversity of organisms in area priori-

tisation is that different habitats maintain different diversity levels of the same taxon. For instance, species richness of caddisflies shows a strong dependence upon stream order (VINSON & HAWKINS 1998, WIBERG-LARSEN *et al*. 2000), thus, contrasts between diversity patterns do not necessarily reflect differences in conservation values.

Other approaches focus chiefly on the conservation of a single or several prioritised species (BÁLDI *et al.* 2001, SUTHERLAND 2000). In this case, the evaluation of the conservation value can be based on rarity (COATES & ATKINS 2001, EYRE & RUSHTON 1989, SCHMERA 2003, SEYMOUR *et al*. 2001, TURPIE *et al.* 2000), endangered status (BROOKS *et al.* 1999, COATES & ATKINS 2001, SCHMERA 2001), typicalness (EYRE & RUSHTON 1989) or endemism (BROOKS *et al.* 1999, SEYMOUR *et al.* 2001, TURPIE *et al*. 2000) of the collected species and conservation value expresses the uniqueness of the fauna. These indices based on a species prioritisation, however, are not necessarily sensitive to a finer change of the community along a scale of natural to impaired states. For instance, if the occurrence of the prioritised species is extremely low, diversity of the community could be a more adequate measure of the conservation value.

In this study, a new method (Rarity and Ecological Diversity index or *RED*-index) is proposed on the basis of the actual frequencies of each caddisfly species in Hungary and on the basis of their ecological diversity in order to assess the conservation status of the caddisfly assemblages of Hungarian localities. The new score intends to combine the advantages of using ecological diversity and rarity indices (coming from the frequencies) in a standardised form. The usefulness of the new method is demonstrated by comparing the conservation value of light-trap collected caddisfly assemblages of streams, rivers and lakes.

MATERIAL AND METHODS

Source of data

Light traps were used to sample caddisfly assemblages because they ensured comparable catches of caddisflies from different water bodies (BOURNAUD *et al.* 1983). Altogether 30 catches (assemblages) collected during the flight period (from May to October) from 23 localities were considered from our own and from literature-derived data (Table 1). To ensure the independence of the assemblages, samples used in the analyses differed in the collection year, or the distance between any two sampling localities was kept at a minimum of 5 kilometres. The light traps were situated on the banks of streams (1st to 4th order), rivers (over 4th order), and lakes in different regions of Hungary (Fig. 1). Unpublished caddisfly data were identified based on the work of MALICKY (1983). The identification of *Hydropsyche* females was not possible to species level during the identification (MALICKY 1983, but see NEU & TOBIAS 2003), so they were presented on the species list as *Hydropsyche* spp. indeterminate female. They were included in the analysis, following other studies (COLLIER

Table 1. Source of data

Place	Year	Water type	Name of the water body	Source
Bakonynána	1984	stream	Gaja	NÓGRÁDI & UHERKOVICH 1985
Bakonynána	1985	stream	Gaja	NÓGRÁDI & UHERKOVICH 1985
Balatonmagyaród	1988	lake	Balaton	NÓGRÁDI & UHERKOVICH 1994
Balatonudvari	1990	lake	Balaton	NÓGRÁDI & UHERKOVICH 1994
Bernecebaráti	1996	stream	Bernecei	KISS & SCHMERA 1999
Bernecebaráti	1998	stream	Bernecei	SCHMERA, unpubl.
Csongrád	2001	river	Tisza	SCHMERA, unpubl.
Eged	1980	stream	no name	KISS & MIKUS 1983
Eged	1981	stream	no name	KISS & MIKUS 1983
Göd	2001	river	Danube	ANDRIKOVICS *et al.* 2001
Gyepükaján	1987	stream	Meleg-víz	NÓGRÁDI & UHERKOVICH 1999
Hercegszántó-Karapancsa	1989	river	Danube	NÓGRÁDI & UHERKOVICH 1992
Kárász	1984	stream	no name	NÓGRÁDI 1987
Királyrét	1999	stream	Morgó	SCHMERA, unpubl
Kölked-Boki	1989	river	Danube	NÓGRÁDI & UHERKOVICH 1992
Magyarszombatfa	1983	stream	Szentgyörgyvölgy	UHERKOVICH & NÓGRÁDI 1992
Magyarszombatfa	1984	stream	Szentgyörgyvölgy	UHERKOVICH & NÓGRÁDI 1992
Magyarszombatfa	1985	stream	Szentgyörgyvölgy	UHERKOVICH & NÓGRÁDI 1992
Mezőtúr-Perecs	1988	river	Körös	UHERKOVICH & NÓGRÁDI 1990
Nagyvisnyó	1984	stream	Nagy völgyi	KISS 1987
Szilvásvárad	1980	stream	Szalajka	KISS 1983
Szilvásvárad	1981	stream	Szalajka	KISS 1983

Table 1 (continued)

Place	Year	Water type	Name of the water body	Source
Tihany	1983	lake	Balaton	NÓGRÁDI & UHERKOVICH 1985
Tihany-Sajkod	1990	lake	Balaton	NÓGRÁDI & UHERKOVICH 1994
Tiszaroff	2001	river	Tisza	SCHMERA, unpubl.
Tiszaszőlős	2001	river	Tisza	SCHMERA, unpubl.
Uppony	1993	stream	Csernely	KISS & SCHMERA 1997
Verőce	1980	river	Danube	CHANTARAMONGKOL 1983
Vörösk ő	1981	stream	no name	KISS 1984
Vörösk ő	1982	stream	no name	KISS 1984

& SMITH 1995, GREENWOOD *et al.* 2001) where taxa not specified to species-level were also included in the analysis.

Developing Rarity and Ecological Diversity (RED)-index

Ecological diversity indices measure the distribution of entities in a sample (MAGURRAN 1988). Several diversity indices have been developed to characterise ecological diversity of a sample (MAGURRAN 1988). In this study the Gini-Simpson index (*D*) was used (SIMPSON 1949, COOD 1982), as it varies between 0 to 1:

$$D_j = 1 - \sum_{i=1}^{S_j} y_{ij}^2 ,$$

where D_j is the Gini-Simpson index of the *j*-th assemblage, y_{ij} is relative abundance of the *i*-th species in assemblage *j*, and S_j is the total number of species of the *j*-th assemblage. In order to ensure that the proposed Rarity and Ecological Diversity (*RED*) index be sensitive to the rare species in the sample, a constant weighting factor (*w*) was inserted into the formula:

$$RED_j = 1 - \sum_{i=1}^{S_j} w_i \; y_{ij}^2 ,$$

where RED_j is the Rarity and Ecological Diversity Index of the *j*-th assemblage and w_i is the weighting factor of the *i*-th species (see elaboration of meaning of *w* below).

The rarity value of each caddisfly species in Hungary was calculated based on the work of NÓGRÁDI and UHERKOVICH (1995). Their database contains 534,689 individual records collected by using UV lamps, light traps and by individual netting in 650 localities. These data are regarded as the basic data set as the use of several sampling methods may solve the biases of single methods and ensures the accurate calibration of countrywide rarity of caddisflies. Let *i* be a member (species) of the Hungarian Trichoptera fauna (*i* = 1 to *T*, where *T* is the total number of species in the Hungarian Trichoptera fauna, NÓGRÁDI & UHERKOVICH 1995). Let A_i be the frequency (abundance) of the *i*-th caddisfly species based on the work of NÓGRÁDI and UHERKOVICH (1995). Some species, however, are

not present in the basic data set because of their extreme rarity ($A_i = 0$). As the weighting factor (w) in the *RED*-index is a part of a subtraction, therefore a rare species should decrease the product, while a common one should increase it. In addition, to ensure that w_i vary between 0 to 1 ($w_i = 0$ if the species is extremely rare, $w_i = 1$, if the species is extremely abundant in Hungary), the weighting factor of the i-th species was expressed as a ratio of A_i to the maximum value of $A_{i = 1 \text{ to } T}$. Unfortunately, the distribution of the members of the Hungarian Trichoptera fauna showed an uneven distribution (95.6% of species fall into a frequency range from 0 to 0.1), therefore A_i and $max(A_i)$ were $log_{10}(x + 1)$ transformed before the division. Accordingly, the following formula was used to calculate weighting factor:

$$w_i = \frac{\log_{10}(A_i + 1)}{\max(\log_{10}(A_i + 1))}$$

where, A_i is the abundance (number of individuals) of the i-th species in NÓGRÁDI and UHERKOVICH (1995), and i is the member of the Hungarian Trichoptera fauna ($i = 1$ to T, where T is the total number of species in Hungary).

In conclusion, *RED*-index could vary between 0 to 1. If *RED* = 0, then only a single species is present in the sample ($y = 1$), which is extremely abundant ($w = 1$). In contrast, if *RED* = 1, then there are only a single or several species in the sample, however, each of them should be extremely rare ($w = 0$).

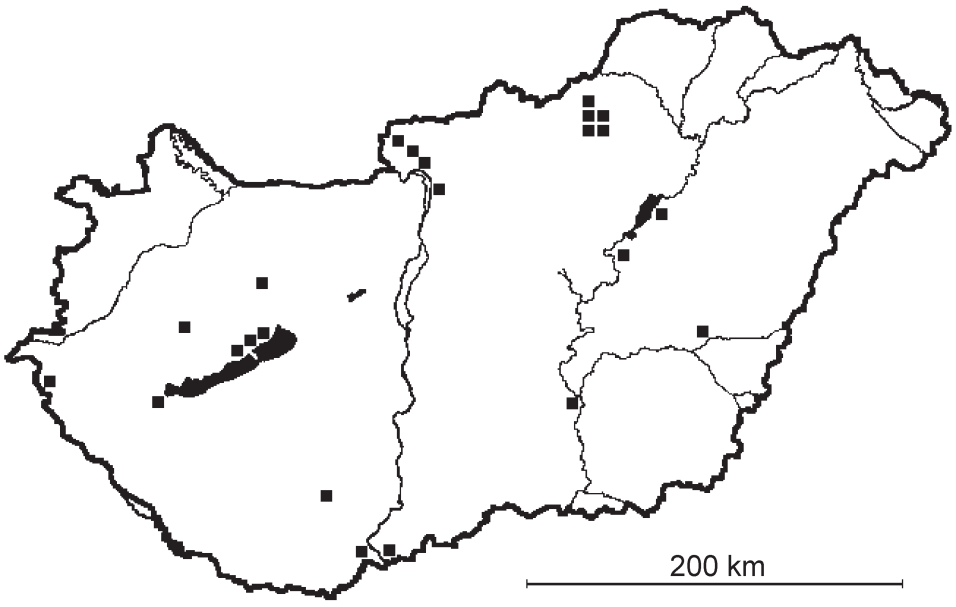

Fig. 1. The map of Hungary with the position of the sampling sites (filled squares show light traps)

Statistics and data visualisation

The conservation value of different aquatic habitats (streams, rivers and lakes) evaluated on the basis of the newly developed *RED*-index was compared by the Kruskal-Wallis ANOVA and non-parametric Tukey-test for unequal sample size (ZAR 1999). As *RED*-index combines the Gini-Simpson diversity (*D*) with the rarity of each species (expressed by *w*) in a sample, therefore it could be divided into two components: diversity and rarity. As *w* represents a rarity value for each species, therefore a *RAR*-index was developed to characterise the total assemblage. The *RAR*-index was calculated by the following formula:

$$RAR_j = \sum_{i=1}^{S_j} w_i \; y_{ij} \; ,$$

If $RAR = 1$, then only the most common species is in the sample and if $RAR = 0$, then the rarest species in Hungary are in the sample. For each sample, the Gini-Simpson index (*D*) and the *RAR*-index were calculated.

If the rarity component of the *RED*-index is responsible for the differences between the conservation values (*RED*) of the aquatic habitats, then the species-composition of the studied habitats should be different. Multi-Response Permutation Procedures (MRPP, MCCUNE & GRACE 2002), the non-parametric form of discriminating analysis, was used to test whether the species composition of streams, rivers and lakes were different. If there are differences between the species composition of the habitats, then there should be some species which are represented in higher abundances in one of the habitats. The number of these specific species should reflect the differentiation of the given habitat from the others. Indicator species analysis (DUFRENE & LEGENDRE 1997) was used to identify species being specific to each aquatic habitat. Tests of significance were made using Monte Carlo randomisation (1000 runs were used). The probability of Type I error (*p*) is the proportion of times that the randomised statistic (*Indicator Value* or *IV*) equals or exceeds the observed one. The observed indicator species for the given habitat was compared with literature data (MOOG 1995) to check its validity.

Non-parametric tests were used because of small sample sizes for some aquatic habitat categories and the uneven distribution of some metrics. The Kruskal-Wallis ANOVA and Spearman Rank Order Correlations were performed by the STATISTICA computer program (STATSOFT 2000), while Multi-Response Permutation Procedures and Indicator Species Analysis by the PC-ORD computer program (MCCUNE & MEFFORD 1997). The Gini-Simpson index was calculated by the DIVERSI computer program (IZSÁK 1998) and the non-parametric Tukey-test by using Microsoft Excel. For the latter, statistical tables (ZAR 1999) were used to find critical/significant values of the analysis.

Results

Species assemblage structure

Altogether 245,363 individuals belonging to 152 caddisfly species were analysed. The Multi-Response Permutation Procedures (MRPP) showed that streams, rivers and lakes are different in their species composition ($T = -4.777$, $R = 0.057$, $p = 0.0003$). In addition, the *R*-value of the MRPP showed that the heterogeneity

within groups (aquatic habitats) is close to a value expected by chance ($R = 0$). In other words, the species composition similarity within a habitat type is very variable, however, the similarity among habitats is significantly different. Indicator species analysis was used to find species being specific to one of the three habitats.

Table 2. List of species in alphabetic order being significant ($p < 0.05$) indicators of the given aquatic habitat (*IV*: Indicator Value, *p*: Type I error), the frequency of these species in Hungary (A_i) according to NÓGRÁDI and UHERKOVICH (1995), and the calculated weighting factors (w_i)

Species	Habitat	*IV*	*p*	A_i	w_i
Agrypnia pagetana CURTIS, 1835	lake	37.5	0.050	18	0.2473
Agrypnia varia (FABRICIUS, 1793)	lake	99.2	0.000	1257	0.5994
Anabolia furcata BRAUER, 1857	stream	65.9	0.011	668	0.5464
Athripsodes cinereus (CURTIS, 1834)	lake	48.6	0.031	5409	0.7219
Ceraclea alboguttata (HAGEN, 1860)	lake	83.6	0.002	1715	0.6255
Ceraclea fulva (RAMBUR, 1842)	lake	47.9	0.013	184	0.4384
Ceraclea senilis (BURMEISTER, 1839)	lake	41.6	0.037	284	0.4747
Chaetopteryx fusca BRAUER, 1857	stream	61.1	0.017	966	0.5776
Goera pilosa (FABRICIUS, 1775)	stream	44.3	0.043	2268	0.6489
Halesus digitatus (SCHRANK, 1781)	stream	66.5	0.018	1289	0.6015
Halesus tesselatus (RAMBUR, 1842)	stream	77.2	0.005	2491	0.6568
Holocentropus picicornis (STEPHENS, 1836)	lake	63.5	0.006	231	0.4574
Hydropsyche bulgaromanorum MALICKY, 1977	river	96.2	0.001	7374	0.7480
Hydropsyche instabilis CURTIS, 1834	stream	82.5	0.011	958	0.5766
Hydropsyche saxonica MCLACHLAN, 1884	stream	66.7	0.013	2913	0.6700
Hydroptila dampfi ULMER, 1929	lake	49.0	0.017	604	0.5379
Ironoquia dubia (STEPHENS, 1837)	stream	50	0.043	316	0.4836
Limnephilus extricatus MCLACHLAN, 1865	stream	59.6	0.014	320	0.4847
Limnephilus ignavus MCLACHLAN, 1865	stream	75.0	0.008	1153	0.5922
Limnephilus rhombicus (LINNAEUS, 1758)	stream	71.9	0.025	1267	0.6001
Micropterna lateralis (STEHPENS, 1837)	stream	44.4	0.044	60	0.3452
Micropterna nycterobia MCLACHLAN, 1875	stream	60.3	0.022	343	0.4905
Mystacides longicornis (LINNAEUS, 1758)	lake	88.0	0.001	1949	0.6362
Oecetis lacustris (PICTET, 1834)	lake	82.6	0.012	3523	0.6858
Plectrocnemia conspersa (CURTIS, 1834)	stream	77.8	0.001	913	0.5726
Potamophylax nigricornis (PICTET, 1834)	stream	70.3	0.002	1011	0.5811
Potamophylax rotundipennis (BRAUER, 1857)	stream	61.1	0.010	1477	0.6129
Rhyacophila fasciata HAGEN, 1859	stream	77.8	0.002	2448	0.6554
Stenophylax permistus MCLACHLAN, 1895	stream	74.2	0.002	2973	0.6717

Twenty-nine species out of 152 (total number of species) were found being indicator for one of the habitats (Table 2). Eleven point eight percent of the species (18) are indicators of streams, 6.6 (10) of lakes and 0.7 (1) of rivers.

Evaluation of conservation status

The conservation status of light trap-collected caddisfly assemblages from streams, rivers and lakes were different (Kruskal-Wallis ANOVA, $H = 7.043$, $p = 0.029$) measured by the newly developed *RED*-index (Fig. 2). Streams show the highest median value followed by lakes and rivers. On the basis of the *RED*-index, streams are the most valuable habitats for caddisflies, while rivers are the worst ones. Although the conservation value of caddisfly assemblages shows a wide range in streams and only a narrow one in lakes, the Tukey-test showed significant difference ($SE = 3.741$, $Q = 3.275$, $p < 0.005$). As *RED*-index is an additive score, therefore it makes it possible to identify which components are responsible for the differences. The diversity component (D) of the *RED*-index was not different among the aquatic habitats (Kruskal-Wallis ANOVA, $H = 4.109$, $p = 0.128$, Fig. 3A), while the rarity component (*RAR*) showed significant difference among

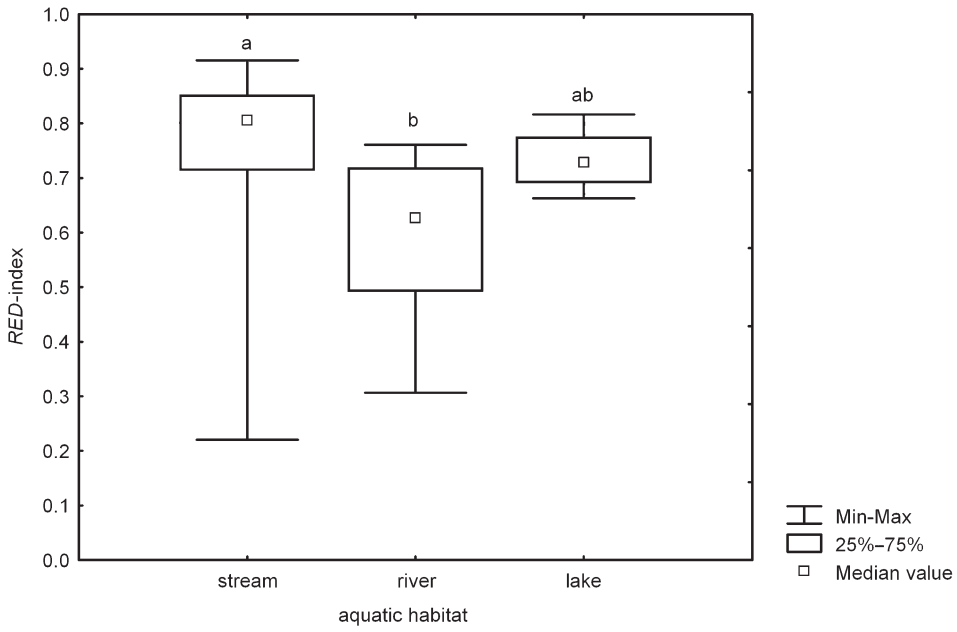

Fig. 2. The Rarity and Ecological Diversity (*RED*)-index of the different aquatic habitats (aquatic habitats with the same letter are not significantly different at $p = 0.05$ by non-parametric Tukey-test)

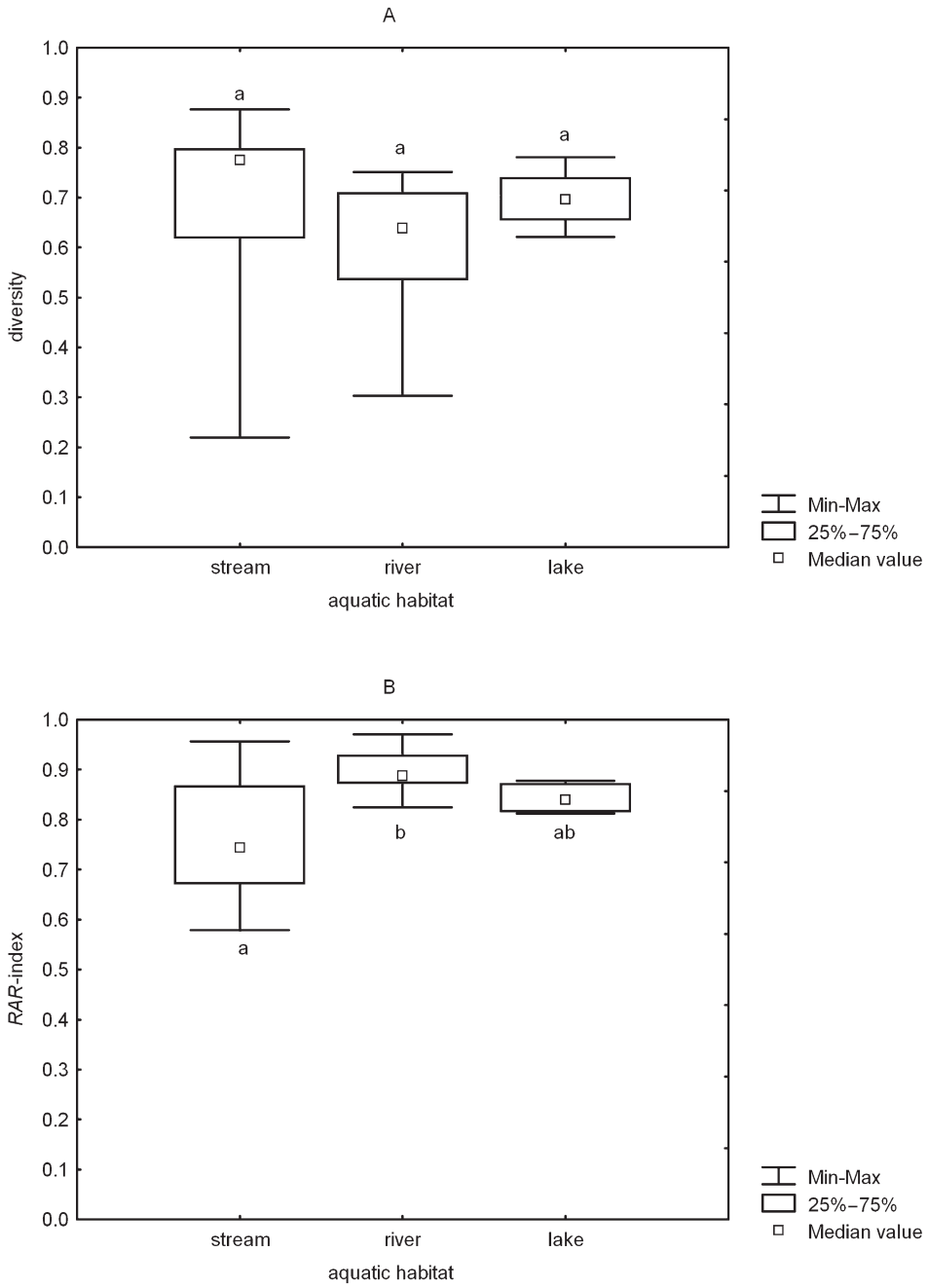

Fig. 3. The diversity (A) and *RAR*-index (B) of the different aquatic habitats (aquatic habitats with the same letter are not significantly different at $p = 0.05$ by non-parametric Tukey-test)

the habitats (Kruskal-Wallis ANOVA, $H = 9.638$, $p = 0.008$, Fig. 3B) and the Tukey-test showed significant difference between the rarity component of the assemblages of streams and rivers ($SE = 3.741$, $Q = 3.128$, $p < 0.01$). The Spearman Rank Order Correlation ($R = –0.6947$, $t = –5.1497$, $p < 0.001$) showed a negative relationship between the Gini-Simpson index (D) and the *RAR*-index; consequently diverse assemblages contain rare species, while less diverse assemblages contain common species. According to Fig. 4, streams generally maintain rare (low *RAR*-index) and diverse caddisfly assemblages, however, in some cases, it is not true. Rivers maintain common (high *RAR*-index) species in assemblages with intermediate or low diversity, and lakes are represented by moderate-common species in upper-intermediate diverse assemblages.

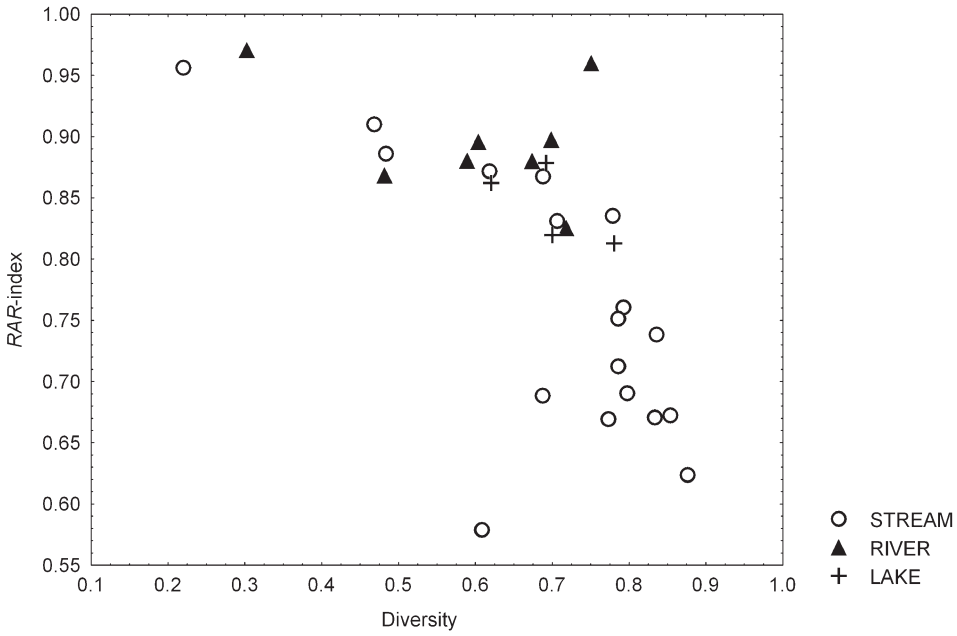

Fig. 4. The relationship between diversity (D) and rarity (*RAR*-index) of the samples

DISCUSSION

Usefulness of light trap catches for conservation biological purposes

The present study focused on the comparison of the conservation status of caddisfly assemblages from different aquatic habitats. Streams, rivers and lakes provide great variability of habitats for the larvae of aquatic insects, therefore several sampling methods have been developed to collect them (ELLIOTT *et al.* 1993, CARTER & RESH 2001). Some of these methods are suitable in habitats characterised by special features. To gain comparable samples, in this study, light traps were used to collect caddisflies. Although light traps are selective (CRICHTON 1976) and their captures are influenced by meteorological parameters (WARINGER 1991), light traps are widely used and capture data are available in the literature (SZENTKIRÁLYI 2002). Several studies demonstrated that adult caddisflies stay close to the aquatic habitats, and the probability of their occurrence gets lower, as the distance from the water increases (SVENSON 1972, 1974, SODE & WIBERG-LARSEN 1993, PETERSEN *et al.* 1999). Overall, literature data suggest that adult caddisflies, as other aquatic insects, stay close to egg-laying sites.

On the basis of the larval habitat preference of each caddisfly species (MOOG 1995) and on the basis of the sensitivity of the light traps to the local populations, it could be hypothesised that the species caught in traps will be different on the bank of streams, rivers and lakes. In this study, Multi-Response Permutation Procedures distinguished the assemblages from different aquatic habitats, supporting the usefulness of light trap catches in nature conservation.

Evaluation of conservation status

Wildlife conservation requires methods to express the conservation status of areas in order to identify those of national importance. Different measures should be applied to express our perception of conservation value. Two basic types could be found in the literature, the first one focuses on diversity, while the second one on the conservation of some prioritised species (for instance, rare species). In fact, there are advantages using both the diversity and the species prioritisation indices (SUTHERLAND 2000). In the literature, several efforts were made to link ecological diversity with phylogenetic diversity (IZSÁK & PAPP 2000, RICOTTA 2002) or to combine other measures (CURIO 2002). In this study, an attempt was made to develop a new conservation index, which could combine the ecological diversity and rarity measures. To avoid the weighting problem of the different values (CURIO 2002), both ecological diversity and rarity measures were standardised into a range

varying from 0 to 1. Thus, the newly developed *RED*-index varies between 0 to 1. A further advantage of the *RED*-index is that it not only sums the rarity and the diversity of the same assemblage. Instead, it amalgamates the rarity and diversity aspects of each species in the assemblage into a number, and then sums these numbers into a *RED*-index. Consequently, the *RED*-index is sensitive to a possible correlation between the countrywide rarity of a species and the contribution of the same species to the diversity of the assemblage.

The conservation values of caddisfly assemblages from streams, rivers and lakes were different using the new formula. This result highlights the different conservation importance of streams, rivers and lakes for maintaining caddisflies in Hungarian localities. Obviously, the distinct physical habitat between streams, rivers and lakes should firstly be responsible for the differences between those conservation values. Moreover, we assume that streams are probably less affected by human activity, while rivers and lakes are widely used for industrial purposes and are polluted by industrial and agricultural waste as well as sewage (BRÖNMARK & HANSSON 1998, GILLER & MALMQVIST 1998). When the two aspects of the *RED*-index were separately analysed, comparison showed that the contrast in the countrywide rarity of caddisfly species was responsible for the differences between the conservation values of stream and river assemblages: streams maintained rare species, while rivers common ones. Indicator Species Analysis found only a single unique species for rivers. In other words, rivers, as the most endangered aquatic habitats in Hungary, seem to lose their individual species even though they are still different from other aquatic habitats in their species composition (as shown by MRPP analysis).

The negative correlation between the *RAR*-index (that increases when the rarity of the species decrease) and the Gini-Simpson index showed a concordance between rarity and diversity hotspots of caddisflies in Hungary. In contrast, a previous study focusing only on stream habitats could not support it (SCHMERA 2003). The obvious difference between this study and the previous one (SCHMERA 2003) was the spatial extension of the studied habitats. Including lake and river habitats in the present analyses, we obtained a clearer picture on the conservation importance of stream, river and lake habitats in maintaining caddisfly assemblages in Hungary. In the light of the conservation value evaluation in the present study it can be stated that streams have the greatest importance in maintaining rare caddisfly species in diverse assemblages of the studied Hungarian localities.

*

Acknowledgements – We thank Dr. ÁRPÁD SZENTESI, Dr. IAN WALLACE, and an anonymous reviewer for their comments on the manuscript.

REFERENCES

ANDIKOVICS, S., KISS, O., NOSEK, J. & OERTEL, N. (2001) Bioindication by macroinvertebrates in the Danube. 7. Possibility of light-trapping for the study of aquatic invertebrates. *Hidrológiai Közlöny* **81**: 314–315. [In Hungarian]

BÁLDI, A., CSORBA, G. & KORSÓS , Z. (2001) Setting priorities for the conservation of terrestrical vertebrates in Hungary. *Biodiversity and Conservation* **10**: 1283–1296.

BOURNAUD, M., ARENS, M. F., TACHET, H. & USSEGLIO-POLATERA, P. (1983) The problem of sampling Trichoptera in a large river. *Aquatic Insects* **5**: 167–172.

BROOKS, T. H., PIMM, S. L., KAPOS, V. & RAVILIOUS, C. (1999) Threat from deforestation to montane and lowland birds and mammals in insular South-East Asia. *J. Anim. Ecol.* **68**: 1061–1078.

BRÖNMARK, C. & HANSSON, L. A. (1998) *The biology of lakes and ponds.* Oxford University Press, Oxford, 216 pp.

CARDINALE, B. J., PALMER, M. A. & COLLINS, S. L. (2001) Species diversity enhances ecosystem functioning through interspecific facilitation. *Nature* **415**: 426–429.

CARTER, J. L. & RESH, V. H. (2001) After site selection and before data analysis: sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies. *J. North Am. Benthological Soc.* **20**: 658–682.

CHANTARAMONGKOL, P. (1983) Light trapped caddisflies (Trichoptera) as water quality indicators in large rivers: results from the Danube at Verőce, Hungary. *Aquatic Insects* **5**: 33–37.

CHAPIN III, F. S., ZAVALETA, E. S., EVINER, V. T., NAYLOR, R. L., VITOUSEK, P. M., REYNOLDS, H. L., HOOPER, D. U., LAVOREL, S., SALA, O. E., HOBBIE, S. E., MACK, M. C. & DIAZ, S. (2000) Consequence of changing biodiversity. *Nature* **405**: 234–242.

CRICHTON, M. I. (1976) The interpretation of light trap catches of Trichoptera from the Rothamsted Insect Survey. *Proc. First Intern. Symp. Trichoptera. 1974.* Junk Publishers, The Hague. The Netherlands, pp. 147–158.

COATES, D. J. & ATKINS, K. A. (2001) Priority setting and the conservation of Western Australia's diverse and highly endemic flora. *Biol. Conserv.* **97**: 251–263.

COLLIER, K. J. & SMITH, B. J. (1995) Sticky trapping of adult mayflies, stoneflies and caddisflies alongside three constrasting streams near Hamilton, New Zealand. *New Zealand Nat. Sci.* **22**, 1–9.

CONNELL, J. H. (1978) Diversity in tropical rain forests and coral reefs. *Science* **199**: 1302–1310.

COOD, I. J. (1982) Comment on diversity as a concept. *J. Am. Stat. Assoc.* **77**: 561–563.

CURIO, E. (2002) Prioritisation of Philippine Island avifaunas for conservation: a new combinatorial measure. *Biol. Conserv.* **106**: 373–380.

DUFRENE, M. & LEGENDRE, P. (1997) Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecol. Monogr.* **67**: 345–366.

ELLIOTT, J. M., TULLETT, P. A. & ELLIOTT, J. A. (1993) *A new bibliography of samplers for freshwater benthic invertebrates*. Occasional publication of the Freshwater Biological Association No. 30.

EYRE, M. D. & RUSHTON, S. P. (1989) Qualification of conservation criteria using invertebrates. *J. Applied Ecol.* **26**: 159–171.

FRENCH, D. D. & CUMMINS, R. P. (2001) Classification, composition, richness and diversity of British hedgerows. *Applied Veget. Sci.* **4**: 213–228.

GILLER, P. S. & MALMQVIST, B. (1998) *The biology of streams and rivers*. Oxford University Press, Oxford. 296 pp.

GÖTMARK, F., AHLUND, M. & ERIKSSON, M. O. G. (1986) Are indices reliable for assessing conservation value of natural areas? An avian case study. *Biol. Conserv.* **38**: 55–73.

GREENWOOD, M. T., BICKERTON, M. A. & PETTS, G. E. (2001) Assessing adult Trichoptera communities of small streams: a case study from Charnwood Forest, Leicestershire, UK. *Aquatic Conservation: Marine and Freshwater Ecosystems* **11**: 93–107.

IZSÁK, J. (1998) DIVERSI 1.1: A program for diversity calculations. *Abstracta Botanica* **22**: 157–160.

IZSÁK, J. & PAPP, L. (2000) A link between ecological diversity and measures of biodiversity. *Ecol. Modelling* **130**: 151–156.

IZSÁK, J. & PAPP, L. (2002) Sensitivity of diversity indices: a study of dipterous assemblages. *Community Ecol.* **3**: 79–86.

KISS, O. (1983) A study of the Trichoptera of the Szalajka Valley near Szilvásvárad as indicated by light trap material. *Folia hist. nat. Musei Matraensis* **8**: 97–106.

KISS, O. (1984) Trichoptera collected by light-trap from Vöröskő-Valley in the Bükk Mountains. *Acta Acad. Agriensis* **17**: 709–718.

KISS, O. (1987) Trichoptera collected by light-trap from Nagy-Valley (Nagyvisnyó) in the Bükk Mountains. *Acta Acad. Agriensis* **18**: 3–8. [In Hungarian]

KISS, O. & MIKUS, L. (1983) Data on the Trichoptera in the environs of Nagy-Eged at Eger. *Folia ent. hung.* **44**: 327–328. [In Hungarian]

KISS, O. & SCHMERA, D. (1997) The caddisflies of a refugium area in North Hungary. Pp. 221–225. *In* HOLZENTHAL, R. W. & FLINT, O. S. (eds): *Proc. 8th Intern. Symp. Trichoptera.* Ohio Biological Survey, USA.

KISS, O. & SCHMERA, D. (1999) Trichoptera from a light trap in the Börzsöny Mountains, northern Hungary, 1996. Pp. 171–174. *In*: MALICKY, H. & CHANTARAMOGKOL, P. (eds): *Proc. 9th Intern. Symp. Trichoptera*. Chiang Mai University, Thailand.

LEFEVRE, S. R. & SHARPE, W. E. (2002) Acid stream water remediation using limestone sand on Bear Run in Southwestern Pennsylvania. *Restoration Ecol.* **10**: 223–236.

MAGURRAN, E. (1988) *Ecological diversity and its measurement*. Croom Helm, London. 192 pp.

MALICKY, H. (1983) *Atlas of European Trichoptera*. Junk, The Hague. 310 pp.

MCCUNE, B. & GRACE, J. B. (2002) *Analysis of ecological communities*. MjM Software Design, Glenden Beach, Oregon, USA. 304 pp.

MCCUNE, B. & MEFFORD, M. J. (1997) *PC-ORD for Windows. Multivariate analysis for ecological data*. MjM Software, Gleneden Beach, Oregon, USA.

MOOG, O. (1995) *Fauna Aquatic Austriaca.* Lieferung Mai/95. Wasserwirtschaftkataster, Bundesministerium für Land- und Forstwirtschaft, Wien.

NEU, P. J. & TOBIAS, W. (2003) *Digitale Schlussel zur Bestimmung der in Deutschland vortkommenden Hydrosychidae (Insecta: Trichoptera).* CD Version 200703a. Quelle: //w.tobias@vff.uni-frankfurt.de.

NÓGRÁDI, S. U. (1987) Caddisflies of the Eastern Mecsek Mountains, Hungary (Trichoptera). I. *A Janus Pannonius Múzeum Évkönyve* **30–31**: 11–22.

NÓGRÁDI, S. & UHERKOVICH, Á. (1985) The caddisfly fauna of the Bakony Mountains and environs, I. *Folia Musei Historico Naturalis Bakonyiensis* **4**: 107–127. [In Hungarian]

NÓGRÁDI, S. & UHERKOVICH, Á. (1992) The Trichoptera of Béda-Karapancsa nature protection area, South Hungary. *Dunántúli Dolgozatok Természettudományi Sorozat* **6**: 155–164. [In Hungarian]

NÓGRÁDI, S. & UHERKOVICH, Á. (1994) The Trichoptera fauna of the lake Balaton and its catchment area (Hungary). *A Janus Pannonius Múzeum Évkönyve* **38**: 27–45.

NÓGRÁDI, S. & UHERKOVICH, Á. (1995) Distribution and abundance of caddisflies (Trichoptera) in Hungary during the past decades based on computer data processing. *A Janus Pannonius Múzeum Évkönyve* **39**: 49–67. [In Hungarian]

OERTLI, B., JOYE, D. A., CASTELLA, E., JUGE, R., CAMBIN, D. & LACHAVANNE, J. B. (2002) Does size matter? The relationship between pond area and biodiversity. *Biol. Conserv.* **104**: 59–70.

PÄRT, T. & SÖDERSTRÖM, B. (1999) Conservation value of semi-natural pastures in Sweden: contrasting botanical and avian measures. *Conserv. Biol.* **13**: 755–765.

PETERSEN, I., WINTERBOTTOM, J. H., ORTON, S., FRIBERG, N., HILDREW, A. G., SPIERS, D. C. & GURNEY, W. S. C. (1999) Emergence and lateral dispersal of adult Plecoptera and Trichoptera from Broadstone Stream, U.K. *Freshwater Biol.* **42**: 401–416.

PIMM, S. L. (1984) Complexity and stability of ecosystems. *Nature* **307**: 321–324.

RICOTTA, C. (2002) Bridging the gap between ecological diversity indices and measures of biodiversity with Shannon's entropy: comment to Izsák and Papp. *Ecol. Modelling* **152**: 1–3.

SCHMERA, D. (2001) A method for quantitative evaluation of the endangerment status of Trichoptera assemblages in Hungary. *Lauterbornia* **40**: 101–107.

SCHMERA, D. (2003) Assessing stream dwelling caddisfly assemblages (Insecta: Trichoptera) collected by light traps in Hungary. *Biodiv. & Conserv.* **12**: 1175–1191.

SEYMOUR, C. L., DE KLERK, H. M., CHANNING, A. & CROWE, T. M. (2001) The biogeography of the Anura of sub-equatorial Africa and the prioritisation of areas for their conservation. *Biodiv. & Conserv.* **10**: 2045–2076.

SIMPSON, E. H. (1949) Measurement of diversity. *Nature* **163**: 688.

SODE, A. & WIBERG-LARSEN, P. (1993) Dispersal of adult Trichoptera at a Danish forest brook. *Freshwater Biol.* **30**: 439–446.

SPACKMAN, S. C. & HUGHES, J. W. (1995) Assessment of minimum stream corridor width for biological conservation: species richness and distribution along mid-ordered streams in Vermont, USA. *Biol. Conserv.* **71**: 325–332.

STATSOFT, INC. (2000) *STATISTICA for Windows.* Computer program manual. Tulsa, OK, USA.

SUTHERLAND, W. J. (2000) *The conservation handbook: research, management and policy*. Blackwell Science, Oxford. 278 pp.

SVENSSON, B. W. (1972) Flight periods, ovarian maturation, and mating in Trichoptera at a South Swedish stream. *Oikos* **23**: 370–383.

SVENSSON, B. W. (1974) Population movements of adult Trichoptera at a South Swedish stream. *Oikos* **25**: 157–175.

SZENTKIRÁLYI, F. (2002) Fifty-year-long insect survey in Hungary: T. Jermy's contributions to light-trapping. *Acta zool. Hung.* **48** (Suppl. 1): 85–105.

TRAVAINI, A., DELIBES, M., FERRERAS, P. & PALOMARES, F. (1997) Diversity, abundance or rare species as a target for conservation of mammalian carnivores: a case study in Southern Spain. *Biodiv. & Conserv.* **6**: 529–535.

TSCHARNTKE, T., STEFFAN-DEWENTER, I., KRUESS, A. & THIES, C. (2002) Contribution of small habitat fragments to conservation of insect communities of grassland-cropland landscapes. *Ecol. Applications* **12**: 354–363.

TURPIE, J. K., BECKLEY, L. E. & KATUA, S. M. (2000) Biogeography and the selection of priority areas for conservation of South African coastal fishes. *Biol. Conserv.* **92**: 59–72.

UHERKOVICH, Á. & NÓGRÁDI, S. (1990) The Trichoptera fauna of the Great Hungarian Plain, Hungary. *Folia hist. nat. Musei Matraensis* **15**: 43–75.

UHERKOVICH, Á. & NÓGRÁDI, S. (1992) The Trichoptera fauna of Magyarszombatfa, West Hungary. *A Janus Pannonius Múzeum Évkönyve* **36**: 13–30.

UHERKOVICH, Á. & NÓGRÁDI, S. (1999) Caddisflies (Trichoptera) of artificial water courses in the Bakony Mountains, Central Hungary. *Braueria* **26**: 21–23.

VINSON, M. R. & HAWKINS, C. P. (1998) Biodiversity of stream insects: variation at local, basin and regional scale. *Ann. Rev. Entom.* **43**: 271–293.

WARINGER, J. A. (1991) Phenology and the influence of meteorological parameters on the catching of light-trapping for Trichoptera. *Freshwater Biol.* **25**: 307–319.

WIBERG-LARSEN, P., BRODERSEN, K. P., BRICKHOLM, S., GRON, P. N. & SKRIVER, J. (2000) Species richness and assemblage structure of Trichoptera in Danish streams. *Freshwater Biol.* **43**: 633–647.

ZAR, J. H. (1999) *Biostatistical analysis*. 4th ed. Prentice Hall, New Jersey. 663 pp.

Revised version received November 15, 2004, accepted November 19, 2004, published December 6, 2004