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Comparison of species richness of light trap-collected caddisfly assemblages (Insecta: Trichoptera) using rarefaction

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Abstract. Conservation value of light trap-collected caddisfly assemblages (Insecta: Trichoptera) was evaluated on the basis of their species richness. The assemblage coming from an artificial stream showed a higher conservation value based on species richness than the natural ones. In contrast, using rarefaction, the conservation value of the assemblage in the artificial stream was lower in comparison with assemblages in natural habitats. Further examples are given to demonstrate the importance of rarefaction in comparing species richness of assemblages.

Human environmental disturbance and its effect on biota are one of the most important phenomena for community ecologists (Pianka, 1970; Southwood, 1977). Falling biodiversity (Juhász-Nagy, 1993) has been the first and most significant sign calling our attention to changes in structure in the biosphere. This process is of global scale, however, could also be demonstrated by local studies. For instance, butterfly communities at the foot of Fuji Mountains (Japan) show sensitivity (reduction in species richness) to human disturbance (Kitahara & Fujii, 1994; Kitahara & Sei, 2001). Nowadays, it is generally accepted that degradation processes could be measured through various community structural characteristics. Among others, species richness is the simplest measurement to indicate degradation. Generally, a wide array of species represents a "well being" state of community (high conservation value), while low species richness does not (low conservation value) (Magurran, 1988). This conception is strongly supported in aquatic ecology, where biotic indices (for instance Ephemeroptera-Plecoptera-Trichoptera index) are chiefly based on species richness (Stone & Wallace, 1998). Accordingly, numerous studies have been conducted using species richness as a measure of environmental conditions (Ivol & al., 1997; DeWalt & al., 1999; Ruse & Herrmann, 2000; Lomond & Colbo, 2000). In addition, species richness is also commonly used in measuring seasonality of phytoplankton (Padisák, 1993) or in comparing macroinvertberate assemblages in streams (Schmera, 1999; Andrikovics & Kiss, 2000; Csörgits, 2000; Kiss & al., 2001) or carabid communities (Magura & Tóthmérész, 1996). The number of species in a sample would be a proper measure of the species richness of a studied community, however, we scarcely are in the position to collect all the organisms (species and individuals) in the given community. Based on field observations (Gotelli & Graves, 1996), the more individuals are sampled, the species richness rises until an asymptote is reached. Several hypothesises have been proposed to explain the phenomenon. The most commonly known hypothesis include a passive sampling model, where richness is larger because of the statistically greater probably of sampling new species in a large sample (Giller & Malmqvist, 1998). Consequently, species richness yielding from samples significantly differing in sizes (number of specimens) could not be compared.

Therefore, the general purpose of this study was to demonstrate the advantages using rarefaction in community comparisons based on species richness. Rarefaction is a mathematical method, thereby the species richness of communities could be compared, as if their number of individuals where the same. This method has been used in comparing carabid communities (Magura & Tóthmérész, 1996) or macroinvertebrate assemblages (McCabe & Gotelli, 2000). As species richness of stream dwelling caddisflies is strongly de-

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Table 1. *Comparison of sampling circumstances*

Code	Place	Sampling year	Name of the water	Habitat type	Note	Reference
A	Bernecebaráti	1998	Bernecei	stream	natural	Schmera, 2001
B	Gyepükaján	1987	Meleg-víz	stream	artificial	Uherkovich & Nógrádi, 1999
C	Királyrét	1999	Morgó	stream	natural	Schmera, 2001
D	Göd	1999	Danube	river	natural	Andrikovics & al., 2001
E	Tiszaszőlős	2001	Tisza	river	natural	unpublished
F	Verőce	1980	Danube	river	natural	Chantaramongkol, 1983

pendent on the stream order (Wiberg-Larsen & al., 2000) and size (Vilson & Hawkins, 1998), therefore assemblages representing streams and rivers were separately studied. Specifically, caddisfly (Insecta: Trichoptera) assemblages collected by light traps on the bank of streams and rivers were separately compared using the collected by light traps on the bank of streams and rivers were separately compared using the collected number of species and the rarefaction of each caddisfly assemblages from own and a literature data set.

MATERIAL AND METHODS

Origin of the data

Six caddisfly assemblages of streams and rivers were collected by light traps installed at the bank of the waters (Table 1). Assemblages *A* and *C* were collected at an undisturbed, nature reaches of the streams, while assemblage *B* sprang from an artificial stream ("Meleg-víz"; Uherkovich & Nógrádi, 1999). "Meleg-víz" carries the warm karstic water of a bauxite mine. Thus, in February, its temperature does not fall below 17°C even approximately 15 km away from the pumping station (Uherkovich & Nógrádi, 1999). Rivers were represented by assemblages *D*, *E* and *F*. Assemblages *D* and *F* came from the River Danube, while assemblage *E* from the River Tisza. Danube, as other large rivers in Europe, is heavily affected by domestic and industrial sewage, therefore its water quality can be classified as 2-3 (betamesosaprobic to alpha-mesosaprobic, Chantaramongkol, 1983).

The identification of *Hydropsyche* females is currently not possible to species level (Malicky, 1983), so they are used as a new „species" in the analysis. Consequently, species richness could be increased (*S*+1) comparing with one in the published data.

The rarefaction solution

The number of species shows increasing function as the number of collected individuals growth. To solve this phenomenon, rarefaction intends to evaluate the number of species of a theoretical assemblage defined by its number of individuals. Consequently, assemblages differing in number of individuals can be compared in a way, as if their number of individuals were the same. The rarefaction could be calculated on the basis of a probably calculation or randomisation. The expected number of species of a theoretical community could be evaluated on the basis of the theoretical number of individuals and on the basis of the relative abundance vectors of the realistic community (Hulbert, 1971; Tóthmérész, 1995):

$$ES(m) = ST - \sum_{i=1}^{ST} (1 - p_i)^m$$

where *ES* is the expected number of species at *m* theoretical number of individuals, while p_i is the relative abundance of the *i*-th species in the realistic community characterised by *ST* species.

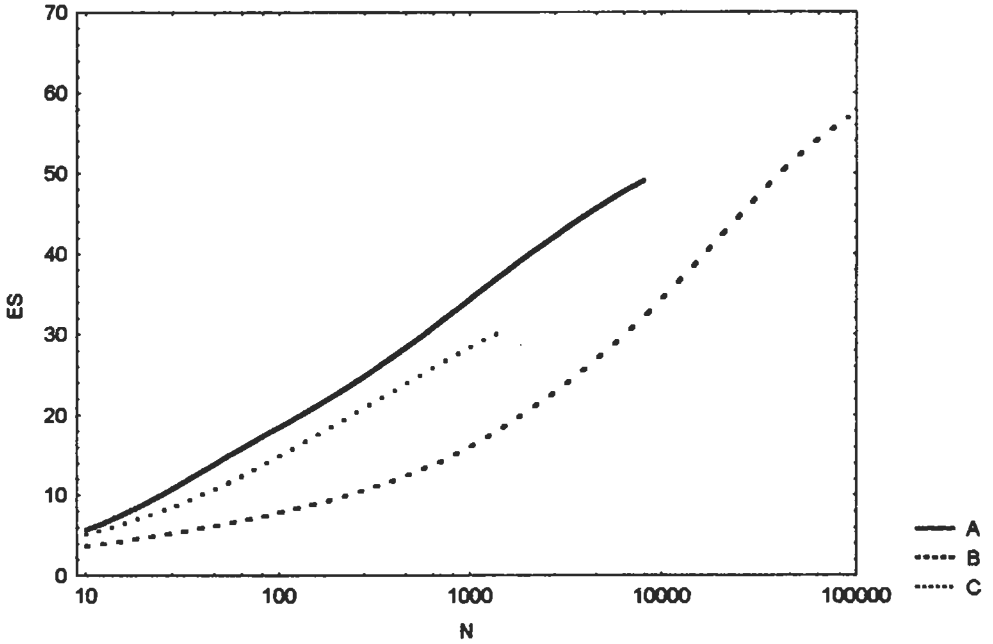

Figure 1. The comparison of species richness of stream assemblages (A, B and C) using rarefaction

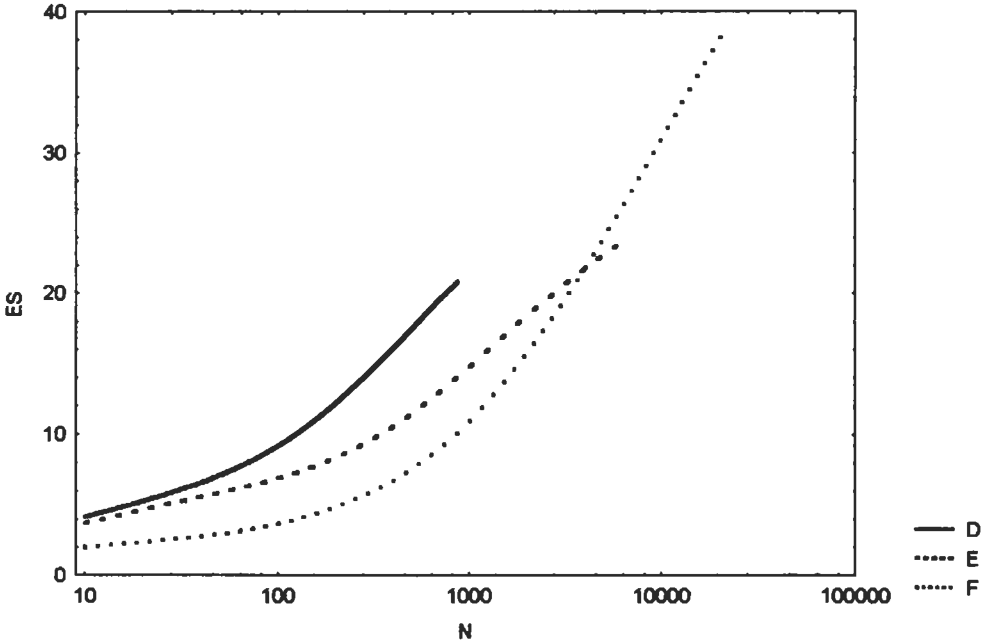

Figure 2. The comparison of species richness of river assemblages (D, E and F) using rarefaction

***Table* 2.** *Species richness and number of individuals of the studied assemblages*

Assemblage	Species richness	Number of individuals
A	53	8065
B	62	90506
C	34	1395
D	26	831
E	27	6164
F	48	22882

At each comparison, *ES* was calculated between $m = 10$ to $min(N_j)$, where N_j represents the number of individuals of *j* assemblage (Table 1). *ES(m)* was calculated using the DIVORD computer program (Tóthmérész, 1993, 1994).

Unfortunately, such a kind of evaluation of species richness makes it impossible the statistical comparison of different assemblages, as only the expected number of species with the highest probably is given. By comparison of two assemblages using randomisation, the assemblage (*x*) represented by higher number of individuals was rarefied to the abundance level (number of individuals, *a*) of the smallest assemblage (*y*) 1000 times in the following way: *a* individuals were randomly sampled from the assemblage *x* (Gotelli & Graves, 1996). In each case, the number of species will also be obtained. Thereby, mean and variance of the expected number of species of assemblage *x* could be obtained at the abundance level of the assemblage *y*. The difference between the two values could be calculated on the basis of the normal distribution (Gotelli & Entsminger, 2001). Randomisation and the mean and variance of the expected number of species were calculated using the ECOSIM computer program (Gotelli & Entsminger, 2001). The differences between the two values were calculated on the basis of the probably distribution calculator of STATISTICA computer program (StatSoft 2000).

RESULTS

Species richness of stream dwelling caddisfly assemblages

Among the stream assemblages, the species richness of assemblage *B* is the highest followed by *A* and *C* (Table 2). Based on the measurement of species richness, the assemblage of an artificial stream represents a high conservation status, while the nature ones do not. Stream dwelling caddisfly assemblages showed the following rank of species richness obtained on the basis of rarefaction measured through probably: assemblage *A* had the highest estimated species richness followed by *C* and *B* (Fig. 1). Using rarefaction with randomisation, significant difference was found in stream assemblages between species richness of assemblage *A* and assemblage *B* and between assemblage *B* and *C*, respectively (Table 3). No significant difference was found between the species richness of assemblage *A* and *C* (Table 3).

Species richness of river dwelling caddisfly assemblages

Comparing species richness of assemblages came of the rivers, assemblage *F* is the most valuable one followed by *E* and *D*, respectively (Table 2). However, caddisfly assemblages coming from the rivers show the following rank after rare-

Table 3. *Expected number of species of stream assemblages (observed value is given as mean ± variance, NS denote non significant difference, *** means highly significant (p<0.001) difference)*

Assemblage	Rarefied to the abundance level of assemblage *A*		Rarefied to the abundance level of assemblage *C*	
	observed value	significance	observed value	significance
A	---	---	37.6 ± 5.1	NS
B	32.8 ± 7.8	***	18.4 ± 4.9	***

Table 4. *Expected number of species of river assemblages (observed value is given as mean ± variance, NS denote non-significant difference, *** means highly significant (p<0.001) difference)*

Assemblage	Rarefied to the abundance level of assemblage *D*		Rarefied to the abundance level of assemblage *E*	
	observed value	significance	observed value	significance
E	14.3 ± 3.4	***	---	---
F	9.9 ± 4.1	***	27.5 ± 7.3	NS

faction: assemblage *D* has the highest estimated species richness at all *m* values followed by *E* and *F* (Fig. 2). The curve of *E* and *F* cross each other, therefore the rank of the estimated species richness depends upon the abundance level (number of individuals), at which the comparison would made. In river assemblages (Table 4), significant difference was found between assemblages *D* and *E* and between *D* and *F*. No significant difference was found between assemblages *E* and *F*.

DISCUSSION

Species richness is the simplest way to describe community or regional diversity (Magurran, 1988). Species richness shows sensitivity to human activity (Kitahara & Fujii, 1994; Kitahara & Sei, 2001), therefore, it can be used as a measure of conservation value.

The comparison of species richness in stream assemblages showed the *B>A>C* rank, while on the basis of rarefaction using probably calculations *A>C>B*. However, rarefaction based on randomisations could not confirm the obtained rank as no significant difference was found between the species richness of assemblage *A* and *C*. By comparing assemblages representing rivers, species richness indicated the reversed order than on the basis of rarefaction (*F>E>D* vs. *D>E~F*). Consequently, if conservation value would be measured through the number of species or number of expected species, different solutions could be obtained. For instance, even though species richness indicated the highest conservation value of an assemblage coming from an artificial stream, rarefaction rejected this assumption indicating another rank of conservation value.

Obviously, the differences between the two approaches (species richness and rarefaction solutions) came chiefly from the differences in number of individuals (sampling effort, Table 2) and from the distribution of individuals among species (abundance). For instance, while assemblage *B* was represented by 90,506 individuals, assemblage *C* by only 1,395. While at a small assemblage size, the presence of a rare species was small, in a big one it was higher. Therefore, a specific species–individual curve could be obtained: number of species grows as the number of collected species increases (Magurran, 1988). The concept of rarefaction was efficiently used in comparison of species richness of stream macroinvertebrates (McCabe & Gotelli, 2000) or in comparison of number of passerine bird species at different territorial pairs (Gjerde & Saetersdal, 1997). In addition, Gjerde & Saetersdal (1997) noted that diversity indices, like Shannon (*H'*) or Simpson's index (*D*), could not always be used in comparison of diversity of communities.

In spite of its importance, ecologists do not always consider the effects of abundance and sampling effort on species richness measures and comparisons. Overall, rarefaction solution allows for meaningful standardisation and comparison of datasets (Gotelli & Colwell, 2001). This study demonstrated that using rarefaction in comparison of assemblages with great differences in number of individuals was recommended.

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