Folia Zool. – 55(3): 315–322 (2006)

Effect of multiple electro-fishing on determining the structure of fish communities in small streams

Martin HUMPL and Stanislav LUSK

Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, Květná 8, 603 65 Brno, Czech Republic; e-mail: humpl@email.cz; lusk@ivb.cz

Received 15 May 2006; Accepted 15 August 2006

A b s t r a c t . Altogether 71 samples collected in 1968–2004 from the Rokytná and Loučka rivers were used to estimate proportional fish species richness from single-pass electro-fishing and probabilities of detection for individual fish species. Mean estimated species richness from single-pass sampling (p'_{s1}) was 95.4% and 96.2% of estimated total species richness for Rokytná and Loučka rivers, respectively. However, p'_{s1} values for individual sites ranged from 71.4% to 100% of estimated total species richness. Additional species unique to the second pass were collected in 38% (Rokytná) and 22% (Loučka) of the samples. When assessing the fish assemblage structure by a multivariate technique (PCA), considerable inaccuracy between the single-pass and two-pass electro-fishing data was also observed. Decisions regarding standardized sampling effort and whether to conduct one or more electro-fishing passes must be based on study objectives. For more accurate evaluations of fish assemblage structure two-pass electro-fishing is recommended. Three-pass electro-fishing did not produce significant increase of species richness.

Key words: electro-fishing efficacy, repeated sampling, probability of detection, species richness

Introduction

In connection with increased efforts to conserve the native biodiversity on all levels, the importance of so-called faunal investigations is re-emphasized. Since the Czech Republic has become a member of the EU, it is our duty to introduce a succession of measures and activities that must be based on a thorough knowledge and monitoring of the species composition of fish communities in streams (Directive 92/43/EEC, Directive 2000/60/EC). In the EU, various efforts were initialized recently to help implement the European Water Framework Directive by developing, evaluating and implementing a fish-based assessment method for the ecological status of rivers (e.g. FAME project). Efficient data collection efforts that provide the opportunity to examine fish community structure at both local and regional geographic scales are desirable. Standardized sampling protocols are inherent tools used for the data collection.

In a few years time, it will be necessary to establish the species composition and status of fish communities in a number of localities and stream profiles in the Czech Republic. Electro-fishing appears to be the most effective method of sampling fish communities, particularly in small streams. In general, the use of single-pass (i.e. not repeated) sampling is most effective in terms of time and organization but may provide considerably inaccurate data. Multiple electro-fishing requires more time (duration of the sampling, necessary intervals between successive passes), leading to decreased numbers of localities that can be investigated within a limited time, and even to increased financial costs.

Although considerable effort has been given to problems associated with electro-fishing data, no study has examined the effects of multi-pass electro-fishing on interpretations of fish community structure (for the purposes of status and bioassessment) from Czech

Republic streams. Among the earlier studies, let us mention Junge & Libosvárský (1965), Lelek (1965), and Libosvárský (1966, 1967) who examined the problems of efficacy of multiple electro-fishing with regard to fish size, water temperature, and effects of successive fishing passes. The effects of fish catchability on data obtained on the species richness of fish communities have been evaluated by Angermeier & Smogor (1995), Meador et al. (2003) and Reynolds et al. (2003).

In the present paper, we analyzed information obtained from a single-pass vs. multiple-pass electro-fishing in the stream sections examined over a 36 years. The aim was determine the effectiveness of these data to describe species richness and relative abundance of individual species. Specifically we investigated (1) the relative proportions of species richness collected in first pass sampling and (2) probabilities of detection based on abundance of individual species. Moreover we evaluated the effects of seasonal aspects, e.g. variability between the successive seasons of the year.

Material and Methods

This paper is based on data on fish stocks (occurrence of species and their abundance), obtained within a long-term monitoring of two sections of the rivers Rokytná and Loučka. The Rokytná is a 6th order stream (Strahler 1957), 89.3 km in total length, with 1.23 m^3s^{-1} mean water discharge at its mouth into the Jihlava River. The monitored section, 220 m in length and 7.6 m in mean width, lies in river km 5.6 (83.7 km away from the spring), 49°04'19.8" N, 16°21'42.8" E. It harbours a cyprinid *(Barbus-Chondrostoma)* type community. The Loučka is a 5th order stream, 60.1 km in total length, with 2.11 m^3s^{-1} mean water discharge at its mouth into the Svratka River. The investigated section, 180 m in length and 9.0 in mean width, lies in river km 14.0 (46.1 km away from the spring), 49°23'57.7" N, 16°17'94.1" E. The section harbours a salmonid *(Salmo-Thymallus)* type community. Each section under study was closed at both ends with 10 mm mesh size nets. Each fishing pass was carried out in an upstream direction. The time interval between the first and second pass was at least 60 minutes, that between the 2nd and 3rd pass was 90 minutes. In both streams, the fishing was done in the same way throughout the study. (4) In all cases, the electro-fishing was performed by one and the same person and the stunned fish were collected by two persons. The quantitative sampling and evaluation involved fish 30 mm and over in standard length. Invariably two, and in 13 cases three successive sampling passes were performed, using an electrical gear (type ZB6, Czech make) that produced pulsating direct EC 220 V and 1.1– 2.3 A, depending on water conductivity. During the successive excursions, the water conductivity varied between 515 and 690µS.cm. The pulsating electric current showed 40 pulses per second.

The data from the Rokytná River were collected in 1968–1977; in most cases, there were four samplings annually (in spring, early summer, late summer, and autumn). The fish inhabiting the Loučka River were sampled only once a year in September) in 1968–2004. The available records on the species composition, abundance and biomass numbered 34 from the Rokytná River and 37 from the Loučka River.

Data analysis

The probability that all individual fish were represented in a given sampling (probability of detection – p') was computed from the simple relationship according to Seber & Le Cren (1967):

$$p' = (n_1 - n_2)/n_1,$$

where n_1 is the number of individuals from the 1st capture event, and n_2 is the number of individuals from the 2nd capture event. The assumptions of the model are (1) the population is closed, (2) the probability of detection is constant among all individuals in the population, and (3) the probability of detection is constant between samples (fishing passes). The model was used in a similar way to estimate the probability that all individuals of any given species were detected (p'_j).

For each sample, species richness from the first pass was determined and the second (or third) pass was evaluated to determine if additional species were collected. The probability of detecting all species by single pass fishing was computed from the relationship:

$$p'_{(S)} = (s_1 - s_2)/s_1,$$

where s_1 is the number of species detected by the 1st capture event, and s_2 is the number of species detected by the 2nd capture event. Percent species richness of the 1st pass (percent of estimated total species richness) was determined using the formula $p'_{s1} = (s_1/S)100$. The variation in $p'_{(s1)}$ between the successive seasons of the year (in the case of the Rokytná River) was assessed using the analysis of variance (ANOVA). The statistical significance of the differences between the numbers of species detected by single, two, and three pass fishing was evaluated by Student's t-test for dependent samples. Multivariate statistics (Principal component analysis, PCA) was used in comparing data on the species composition of communities obtained by single and two-pass sampling. For this purpose, only the data on the presence/absence of species were used. In all statistical analyses, statistical significance on the $\alpha = 0.05$ level was declared.

Results

Three-pass electro-fishing

The analysis is based on 13 records of three-pass electro-fishing (Rokytná R., 9 records; Loučka R., 4 records). A statistically significant difference in the number of species detected by single and two pass sampling was revealed by the t-test: t = -3.6055 ($P < 0.0036$). On the other hand, comparing the numbers of species detected by two and three-pass fishing, the value of the t-test was below the significance level: t = -1.8058 ($P < 0.0961$). Hence,

Table. 1. Rokytná R.: between-season probability of detecting all species ($p'_{(S)}$) by the 1st pass (in per cent).

year	spring	early summer	late summer	autumn
1968	100	-	100	-
1969	78	80	100	89
1970	89	100	100	100
1971	70	-	-	100
1972	91	90	89	100
1973	100	89	100	100
1974	91	100	-	100
1975	100	100	100	100
1976	-	80	92	100
1977	100	100	92	100

a two-pass fishing appears sufficient from this point of view, the third pass not yielding any significant increase in the number of species detected. Additional species were detected by the third pass in 3 out of the 13 records (23 %). There were four infrequent and accidentally occurring species (*Cyprinus carpio, Rhodeus sericeus, Scardinius erythrophthalmus* and *Anguilla anguilla*) that were not detected by the first and second pass sampling. In subsequent analyses we concentrated on evaluation of data obtained by two vs. single-pass sampling (the evaluation included records of three-pass samplings but only the data obtained by the first and second pass were used).

Two vs. single-pass electro-fishing

Rokytná River

The probability of detecting all individual fish by a single pass (p') varied in the individual records between 45.5 and 88.3 %, and for individual species (p'_j) between 17.5 and 100 %. In 7.4 % of samples was $n_2 \geq n_1$ and, hence, the value of p'_j could not be determined. In the individual records, the probability of detecting all species by a single-pass fishing ($p'_{(S)}$) varied between 70 and 100 %. The values of $p'_{(S)}$ showed a slightly increasing trend in dependence on time (Fig. 1a). The differences between the values of $p'_{(S)}$ in successive seasons of the year are given in Table 1. Comparing these values by the ANOVA show that the differences between them are non-significant ($P < 0.1430$).

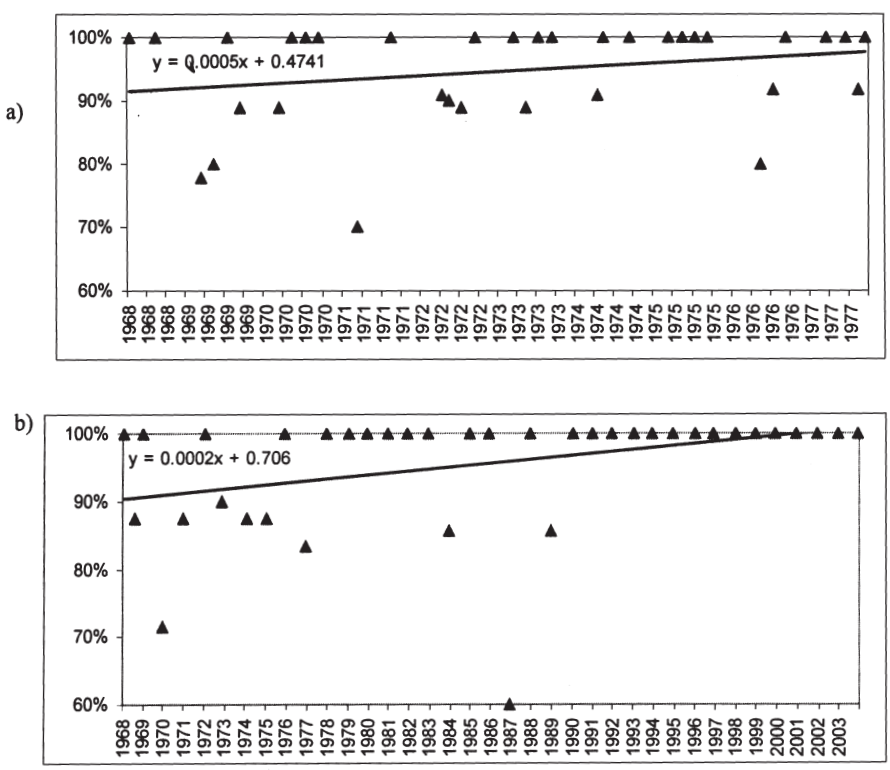

Fig. 1. Probability of detecting all species by the 1st pass fishing ($p'_{(S)}$): a) Rokytná R., b) Loučka R.

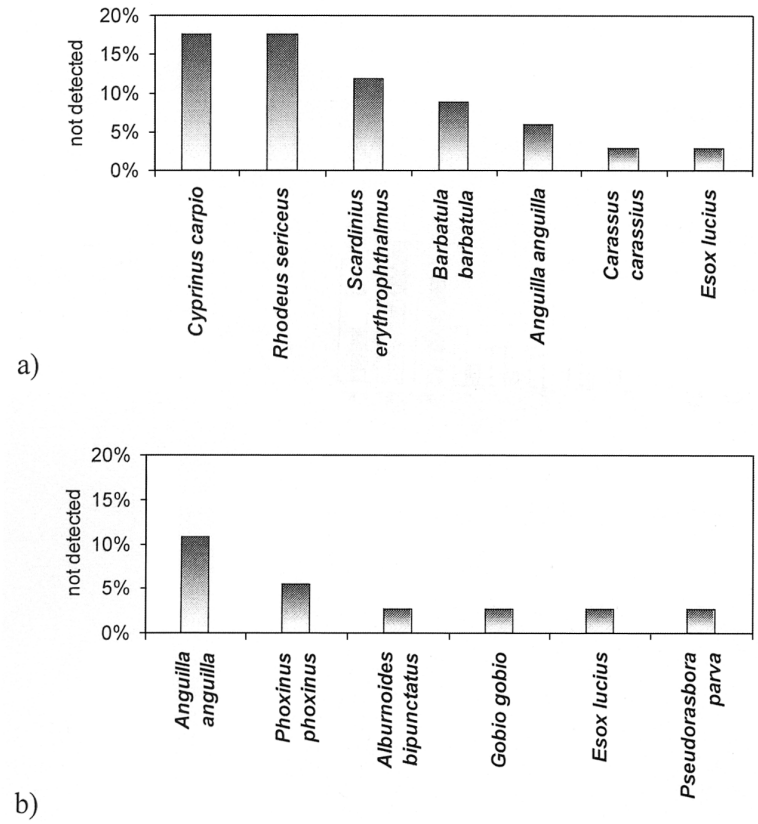

Fig. 2. Frequencies of species not detected by the 1st pass fishing: a) Rokytná R., b) Loučka R.

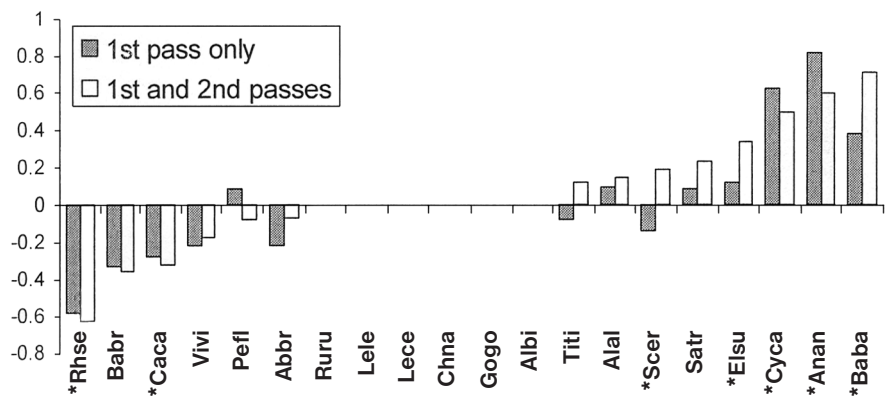

Fig. 3. Rokytná R.: PCA species loadings comparison between the 1st pass only and 1st and 2nd passes. Species not detected in some cases during the 1st pass are indicated with asterisk (*). *NOTE:* Species abbreviations: Abbr – *Abramis brama*, Alal – *Alburnus alburnus*, Albi – *Alburnoides bipunctatus*, Anan – *Anguilla anguilla*, Baba – *Barbatula barbatula*, Babr – *Barbus barbus*, Caca – *Carassius carassius*, Cogo – *Cottus gobio*, Chna – *Chondrostoma nasus*, Cyca – *Cyprinus carpio*, Eslu – *Esox lucius*, Gogo – *Gobio gobio*, Lece – *Leuciscus cephalus*, Lele – *Leuciscus leuciscus*, Pefl – *Perca fluviatilis*, Phph – *Phoxinus phoxinus*, Rhse – *Rhodeus sericeus*, Ruru – *Rutilus rutilus*, Satr – *Salmo trutta* m. *fario*, Scer – *Scardinius erythrophthalmus*, Thth – *Thymallus thymallus*, Titi – *Tinca tinca*, Vivi – *Vimba vimba*.

In the course of the study period, 20 fish species were recorded, of which 9 to 14 always occurred together. The percentage of species detected by the first pass (p'_{s1}) varied between 76.9 and 100 %. By the second pass, additional species were detected in 13 of the 34 records (38 %). Most frequently, *Cyprinus carpio, Rhodeus sericeus,* and *Scardinius erythrophthalmus* were not detected by the single-pass fishing (Fig. 2a). These species did not produce stable populations in the given sections and their quantitative occurrence was negligible, only a single specimen (or at most five) having been detected in the sections examined.

Our comparison of data obtained from single and two-pass sampling by PCA is based on the presumption that, by employing the data from two-pass sampling, the structure of fish communities can be detected more precisely. Comparing only the data obtained from the single pass has indicated that the greatest discrepancies in the analyses are posed by the species that, in some cases, evaded attention in the first pass sampling. The loadings of these undetected species differ to the greatest extent (Fig. 3).

Loučka River

The probability of detecting all individual fish by a single pass (p') varied in the individual records between 48.3 and 83.4 %, and for individual species (p'_j) between 12.1 and 100 %. In 3.5 % of cases was $n_2 \geq n_1$ and, hence, the value of p'_j could not be determined. In the individual records, the probability of detecting all species by a single-pass fishing ($p'_{(S)}$) varied between 60 and 100 %. Fig. 1 shows a distinct increase in the values of $p'_{(S)}$ in dependence on time. During the past 15 (1990–2004) years of investigations no fish species evaded detection in the first pass fishing.

In the course of the study period, 14 fish species were detected in the locality under study, of which 6 to 10 always occurred together. The percentage of species detected by the first pass (p'_{s1}) varied between 71.4 and 100 %. Additional species were detected by the second pass in 8 out of the 37 records (22 %). Most frequently, such infrequent and accidentally occurring species as *Anguilla anguilla* and *Phoxinus phoxinus* were not detected by the first pass sampling (Fig. 2b).

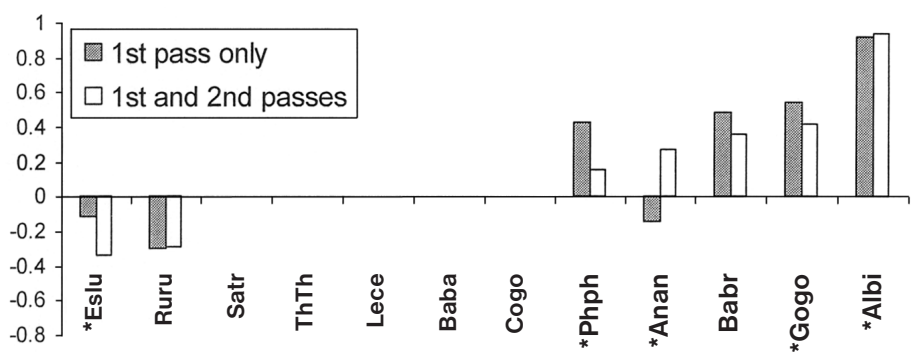

Fig. 4. Loučka R.**:** PCA species loadings comparison between the 1st pass only and 1st and 2nd passes. Species not detected in some cases during the 1st pass are indicated with asterisk (*).
NOTE: Species abbreviations – see Fig. 3.

The evaluation of the species composition by PCA (Fig. 4) can be interpreted similarly as in the preceding case of fish communities found in the Rokytná River.

Discussion

The probability of detecting all individual fish by a single-pass sampling varied considerably. In individual records from the two localities under study, the values of p' varied between 45 and 88 %, those for individual species (p'_j) between 12 and 100 %. As regards species, the mean probability values of detecting them by a single pass increased in time. They were slightly higher in the records obtained from the Loučka River (91–100 %) than those obtained from the Rokytná River (92–98 %). This fact is mainly due to the character of fish communities living in the two rivers (salmonid type in the Loučka R., cyprinid type in the Rokytná R.), and thus also to the possible overall number of species that are common in the two fish community types (P i v n i č k a & H u m p l 2004). The overall number of fish is higher in the Rokytná River. Besides, it has been demonstrated in this study that the first pass electro-fishing most frequently failed to detect species showing low frequencies of occurrence. In the case of the Rokytná R., it was the infrequent cyprinid species that evaded detection; in the Loučka R., it was *A. anguilla*. Furthermore, the percentage of cases in which additional species have been detected by the second pass, is correlated with the degree of difficulties with which a given stream section can be thoroughly fished. In the Rokytná R., the percentage of species that evaded the first pass was 38 %, whereas in the Loučka R. this percentage was 22 % only. Furthermore, this may be connected with the more rugged bed of the Rokytná River section examined, in which case the single-pass sampling can less readily detect all species present (L u s k et al. 1998).

Although the values of $p'_{(S)}$ could be expected to depend even on stream size (i.e. the width of its bed), no such correlation has been confirmed in 9 out of the 10 drainage areas in the United States (183 records from 80 localities) (M e a d o r et al. 2003). In conditions identical with those of the present investigations, J u n g e & L i b o s v á r s k ý (1965) arrived at the same conclusion. Furthermore, these authors confirmed the increasing probability of capture with increasing body length in three common fish species *(Leuciscus cephalus, Gobio gobio,* and *Salmo trutta* m. *fario)*.

Our further assumption was that the probability of detecting particular fish species would depend on season. This assumption was not confirmed (ANOVA, $P < 0.1430$), fish species were caught with the same probability in spring, summer or autumn. This could be an important conclusion for fish managers that are preparing the species' composition monitoring.

The mean percentage of species detected by the first pass (p'_{s1}) was 95.4 % in the Rokytná R. and 96.2 % in the Loučka R. In a study of ten drainage areas in the U.S.A., the mean percentage ($p'_{s1)}$) was 89.9 % (M e a d o r et al. 2003). Their evaluation involved bigger streams 11.4 m in mean bed width (in our study this was 7.5–9 m). In two streams in Australia, P u s e y et al. (1998) recorded the mean percentages of species detected by the single pass fishing to be 89 % (mean streambed width 8.9 m) and 82 % (mean streambed width 8.1 m).

Standardized sampling protocols for data collection as a part of regional and national monitoring programs vary. For example, in the U.S.A., the "Environmental Monitoring and Assessment Program" of the U.S. Environmental Protection Agency (USEPA) uses a standard single-pass electro-fishing within a reach blocked off with nets placed at both ends of the reach. In contrast, the "National Water Quality Assessment Program" (NAWQA) of the U.S. Geological Survey (USGS) uses two-pass electro-fishing without block nets. Decision pertaining standardized sampling effort and whether to conduct one or more electro-fishing

passes should be subject to the priorities and goals of any particular study. In this study it has appeared that a third-pass fishing does not result in any statistically significant increase in the number of species detected, moreover requiring greater labour and time investment. Two consecutive electro-fishing passes appear suitable for a more precise assessment of fish species diversity in streams.

A c k n o w l e d g e m e n t

We extend our warm thanks to Professor Richard M a n n for constructive comments and emendation of the English text. We gratefully acknowledge the help in fieldwork provided by a number of our colleagues. We thank two anonymous opponents for critical notes on our paper. This study was implemented within the research project VaV-SM/6/3/05 supported by the Ministry of Environment of the Czech Republic.

L I T E R A T U R E

Angermeier P.L. & Smogor R.A. 1995: Estimating number of species and relative abundances in stream-fish communities: effects of sampling effort and discontinuous spatial distributions. *Canadian Journal of Fisheries and Aquatic Sciences 52: 936–949*.

Junge C.O. & Libosvárský J. 1965: Effects of size selectivity on population estimates based on successive removals with electrical fishing gear. *Zool.listy 14(2):171–178*.

Lelek A. 1965: Vnímavost jelce tlouště *Leuciscus cephalus* (L.) k opakovanému působení stejnosměrného pulsujícího proudu v terénním pokusu (Field experiment on the receptivity of the chub, *Leuciscus cephalus* to the repeated efferts of pulsating direct current). *Zool. listy 15(1): 69–78 (in Czech with English summary)*.

Libosvárský J. 1966: Successive removals with electrical fishing gear – a suitable method for making populations estimates in small streams. *Verh. Internat. Verein. Limnol. 16: 1212–1216*.

Libosvárský J. 1967: The effect of fish irritation by electrofishing on the population estimate. *Ekologia Polska, Seria A 15 (4): 91–106*.

Lusk S., Lusková V., Halačka K., Šlechta V. & Šlechtová V. 1998: Trends and production of fish communities of the barbel zone in a stream of the Czech Republic. *Folia Zool. 47(Suppl. 1): 67–72*.

Meador M.R., McIntyre J.P. & Pollock K.H. 2003: Assessing the efficacy of single-pass backpack electrofishing to characterize fish community structure. *Transactions of the American Fisheries Society 132: 39–46*.

Pusey B.J., Kennard M.J., Arthur J.M. & Arthington A.H. 1998: Quantitative sampling of stream fish assemblages: single- vs. multiple-pass electro-fishing. *Australian Journal of Ecology 23:365–374*.

Pivnička K. & Humpl M. 2004: Fish assemblages in the Elbe River watershed – species richness, frequency, and clusters. *Acta Universitatis Carolinae Environmentalica 18: 107–116*.

Reynolds L., Herlihy A.T., Kaufmann P.R., Gregory S.V. & Hughes R.M. 2003: Electrofishing effort requirements for assessing species richness and biotic integrity in western Oregon streams. *North American Journal of Fisheries Management 23:450–461*.

Seber G.A. & Le Cren E.D. 1967: Estimating population parameters from catches large relative to the population. *J. Anim. Ecol. 36: 631–643*.

Strahler A.N. 1957: Quantitative analysis of watershed geomorphology. *Transactions of American Geophysical Union 38: 913–920*.