

The effect of artificial increases in water conductivity on the efficiency of electric fishing in tropical streams (Paraná, Brazil)

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Abstract

Four sites in three small tropical streams each were sampled with three successive electrofishings per constant unit effort, starting at the site with lowest natural water conductivity. Each second-fourth site was sampled at double water conductivity (up to 300 $\mu\text{S cm}^{-1}$ only) by dissolving salt in the water. Electric fishing efficiency estimated by three efficiency indexes was not significantly correlated with increasing conductivity. The reasons for this result are discussed.

Introduction

The efficiency of electric fishing in tropical streams is often low (Cordiviola de Yuan, 1992; Lasso & Castroviejo, 1992; Menni et al., 1992; Agostinho & Penczak, 1995), because of low water conductivity (Welcomme, 1985; Zalewski & Cowx, 1990). Limitations in using this method may occur at 100 $\mu\text{S cm}^{-1}$ (Reynolds, 1983) or below 60 $\mu\text{S cm}^{-1}$ (Fisher & Brown, 1993).

Consequently, the aims of our paper were: (1) to find streams with different morphological structure; (2) to make three successive samplings at constant unit effort starting at sites with low natural conductivity, followed by sites with higher conductivity.

Study area, material and methods

Three streams of Paraná State (Figure 1) that could be accessed with equipment in four continuous sites each were studied. The banks were covered by high grasses, overhanging into the water. Submerged macrophytes, *Mysiophyllum* sp and *Cyperaceae*, occurred only in the Ourico and Agua de Valencia Rivers, not in the Caracu River.

Physical and chemical characteristics of the sites are presented in Table 1. For morphometry, we used bathymetric maps, the other measurements were taken at both ends and in the middle of each site and averaged. During dissolving salt, water conductivity was measured continuously with a YSI 3800 Water Quality Logging System (USA). The required water conductivity level was sustained for the period of three successive samplings by sinking plastic sacks filled up with salt at the upstream end of a site.

In 12 sites, 1150 fish specimens belonging to 31 taxa (Appendix) were captured; 3 of them were identified only to genus. Benthic species dominated over pelago-benthic ones; this is significant as pelagic ones escape from sites against noise, while benthic ones hide in the closest hiding places, which does not necessarily prevent them from being captured by electrofishing.

Samples were taken on 7–8 and 16 December 1995. A stop net (5 mm diameter mesh) was placed at the downstream limit of each site. The catch per unit of effort (CPUE) method was applied, i.e. two people waded upstream and electrofished with anode-dipnets for a constant time at each site, amounting to 15, 9 and 6 min. for the Ourico, Agua de Valencia & Caracu Rivers, respectively (Penczak, 1981; Penczak & Molinski, 1984). Full-wave rectified, pulsed current

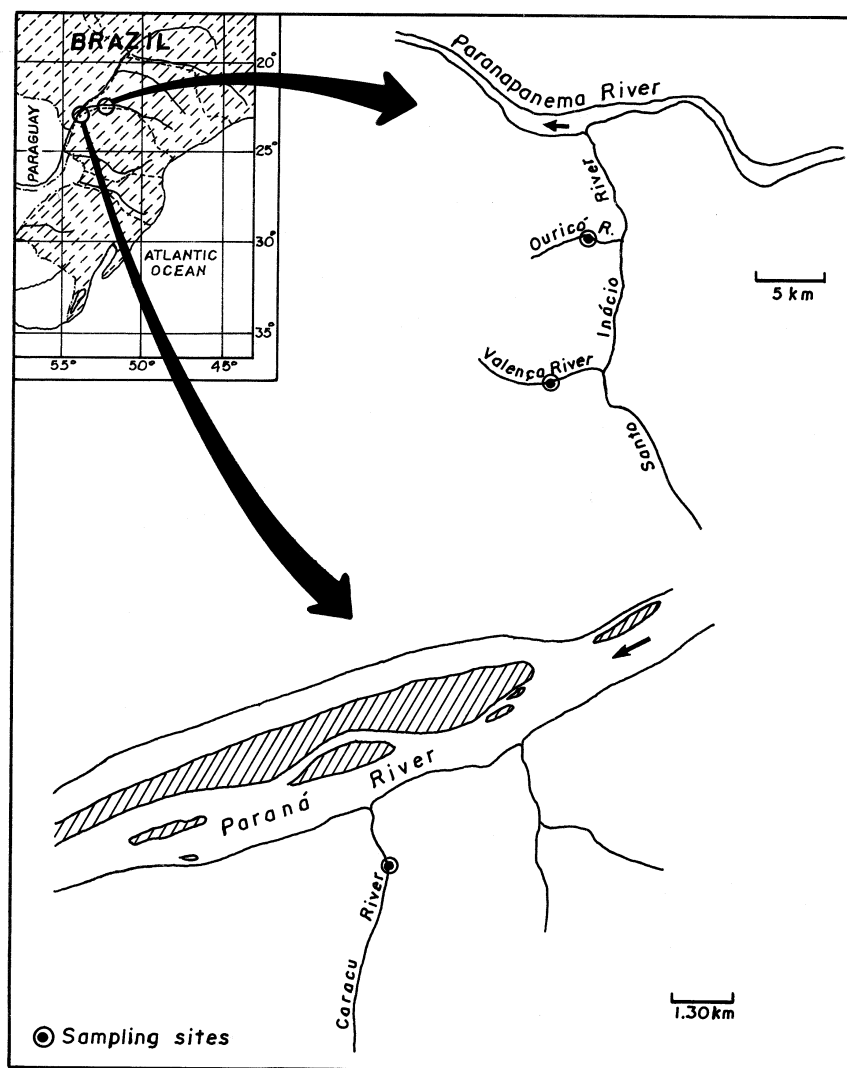


Figure 1. Map of the Ourico, Agua de Valencia and Caracu Rivers showing location of sites.

from a 3 kW generator with an output of 220 V, and 2.5–3.0 Amp was used.

Fish from each catch were anaesthetised and fixed in 4% formalin. In the laboratory, they were identified, weighed and measured.

The Zippin maximum-likelihood method for three catches (Zippin, 1956, 1958) was used for estimating population density (\hat{N}). The procedure of calculating \hat{N} when the Zippin method was not applicable is explained in examples in former studies (Penczak et al., 1994; Agostinho & Penczak, 1995).

Estimated standing crop (\hat{B}) was calculated from the equation: $\hat{B} = e^{+n} B \hat{N} / e^{+n} N$; symbols are explained below and in Table 2.

The following indexes were used to estimate the impact of increasing conductivity on electrofishing:

1. efficiency per sampling run (SE), as the percentage of the total number of specimens of a fish species captured by electrofishing and stopnetting in three sampling runs ($e^{+n} N_t$) in the total estimated number of specimens of this species in the site (\hat{N}) (Alabaster & Hartley, 1962), i.e. $SE = (e^{+n} N_t \times 100) / \hat{N}$,
2. \hat{p} = catch efficiency from the Zippin model, and

Table 1. Sites characters. Explanations: ^{a)} s - sand, r - rocks; ^{b)} - natural conductivity

| River | Site | Mean width (m) | Mean depth (m) | Site length (m) | Area (m ²) | Substratum ^{a)} | Macrophyte cover (%) | Water temperature (°C) | Water velocity (m s ⁻¹) | Conductivity $\mu\text{S cm}^{-1}$ (20°C) | pH | O ₂ (ml l ⁻¹) |
|------------------|------|----------------|----------------|-----------------|------------------------|--------------------------|----------------------|------------------------|-------------------------------------|---|------|--------------------------------------|
| Ourico | A | 2.0 | 0.25 | 50 | 100 | s | 10 | 31.0 | 0.61 | 39 ^{b)} | 6.93 | 7.06 |
| | B | 1.8 | 0.25 | 50 | 90 | s | 12 | 31.0 | 0.68 | 50 | 6.81 | 6.59 |
| | C | 2.1 | 0.18 | 50 | 105 | s | 20 | 32.0 | 0.32 | 100 | 7.08 | 6.51 |
| | D | 1.8 | 0.23 | 50 | 90 | s | 10 | 31.0 | 0.81 | 150 | 6.97 | 6.61 |
| Agua de Valencia | E | 1.9 | 0.36 | 30 | 57 | s | 50 | 22.5 | 0.41 | 62 ^{b)} | 7.22 | 8.58 |
| | F | 1.9 | 0.31 | 30 | 57 | s | 85 | 22.5 | 0.78 | 100 | 7.34 | 8.45 |
| | G | 3.1 | 0.30 | 30 | 93 | s,r | 85 | 23.0 | 0.46 | 200 | 7.34 | 8.45 |
| | H | 2.6 | 0.41 | 30 | 78 | s,r | 80 | 23.0 | 0.38 | 300 | 7.45 | 8.38 |
| Caracu | I | 2.0 | 0.12 | 30 | 59 | s | 0 | 26.0 | 0.67 | 49 ^{b)} | 6.80 | 7.12 |
| | J | 2.1 | 0.17 | 30 | 64 | s | 0 | 26.0 | 0.58 | 100 | 6.80 | 7.67 |
| | K | 1.3 | 0.18 | 30 | 40 | s | 0 | 26.0 | 0.62 | 200 | 6.78 | 7.14 |
| | L | 1.7 | 0.12 | 30 | 50 | s | 0 | 26.0 | 0.59 | 300 | 6.79 | 7.35 |

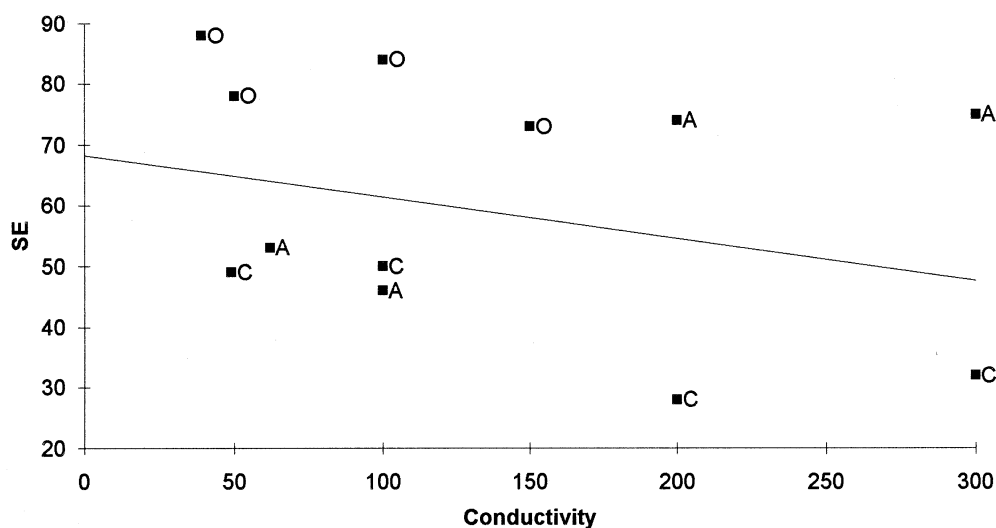


Figure 2. Water conductivity ($\mu\text{S cm}^{-1}$) and sampling efficiency (SE) in O - Ourico, A - Agua de Valencia, C - Caracu Rivers.

3. $e\%$ = catch efficiency index by Penczak & Romero (1990), i.e. $e\% = (95\%CL \times 100) / \hat{N}$; explanations of symbols are in Table 2. The efficiency was assessed on a 4-point scale: $e\% \leq 10\%$ is a very good estimate, 11–25% is a good estimate, 26–50% is an adequate estimate and $\geq 50\%$ is a poor estimate.

Also, fish stopped by the stop net (${}^n N_t$) were calculated as the percentage of fish caught by electrofishing (${}^e N_t$).

Efficiency indices \hat{p} and $e\%$ are included in Table 2, because both were calculated for separate populations.

Matrix correlation analysis was used to determine which site character (Table 1) influences fishing efficiency (reflected in the above listed three fishing efficiency indices), using Amstrad CPC (Coleman & Coleman, 1986).

Results

Results of catches at sites, density estimates and standing crops per 100 m², and also catch efficiencies both from the Zippin model and from Penczak & Romero (1990), $e\%$, are included in Table 2. The totals of these

indexes for given sites and the values of the third efficiency index, SE, calculated from 'total catch', are included in Table 3, along with percentages of fish stopped by the stop net, number of species per site and 'total' number and biomass of fish caught by electrofishing, stop net, and both gear together.

In the Ourico, all indexes decreased proportionally with increase in conductivity. In contrast, the investigated populational parameters and species number (Table 3), including \hat{N} and \hat{B} , were lowest at the lowest natural conductivity.

In the Agua de Valencia, all five indices were independent of conductivity, while populational parameters ${}^{e+n}N_t$, ${}^{e+n}B_t$ and eN_t , and also \hat{N} and \hat{B} were also lowest in site E, with natural, low water conductivity. Note that in all the sites in that river there was extensive submerged macrophyte cover (50–85%), in two of them there were rocks besides sand in the bottom, and the river was deepest of all three rivers.

In the Caracu, index e% was lowest (adequate estimate) at the lowest natural conductivity, but it did not change proportionally with conductivity, while at site I the lowest values of ${}^{e+n}N_t$, eN_t , \hat{N} and \hat{B} were recorded. Here also, similarly as in the Agua de Valencia no relation between fishing efficiency and conductivity was noted, although river bottom was homogenous, sandy and free of submerged macrophytes.

Only four species, *B. stramineus*, *A. bimaculatus*, *G. carapo* and *H. derbyi*, occurred at sufficiently high numbers at 6–9 sites to make calculating of their density possible. As these data were scattered over 4 to 7 various conductivity categories, correlations (r) between conductivity and fishing efficiency estimated with the Zippin model (\hat{p}) were calculated. The correlation values were not statistically significant for all these species ($\hat{p} > 0.28$ – 0.62). Nevertheless, the highest values of \hat{p} and the best estimates with e% for *G. carapo* and *H. derbyi* were recorded at the highest conductivity ($300 \mu\text{S cm}^{-1}$), and for *A. bimaculatus* for $200 \mu\text{S cm}^{-1}$. For *B. stramineus* the highest \hat{p} occurred at 49 – $50 \mu\text{S cm}^{-1}$, while a very good estimate of e% for $150 \mu\text{S cm}^{-1}$, despite this species having the highest number of data ($n = 9$). Of the four species *A. bimaculatus* was pelago-benthic, and the other three benthic, but the impact of mobility on the fishing efficiency of these taxa could not be determined.

The function of the net in stopping stunned fish did not display any dependence on water conductivity in any river, although, logically, the highest percent of stunned fish should have been stopped by the net at the highest salinity, when electric shock is strongest.

The results of applying correlation matrix to variables from Tables 1, 3 and \hat{p} and e% from Table 2 were not surprising. Conductivity and water velocity variables were correlated with no other variable even at the lowest significance level ($p = 0.05$), despite 10 d.f., which was also expected.

Discussion

When comparing the scattergrams (water conductivity/sampling efficiency) of the Alabaster & Hartley (1962) study with ours (Figure 2) we see that linear regressions display opposite tendencies. In our case correlation between these variables was negative ($r = -0.23$, $p = 0.62$) and not statistically significant, and in their study positive and significant. The conductivity ranges in their study and ours were similar: 70–270 and 39–300 $\mu\text{S cm}^{-1}$, respectively. In their study mean sampling efficiency (SE) was 34.2 ± 19.2 ($x \pm \text{S.D.}$) (range 6–68%) and in ours 60.8 ± 20.3 (range 28–88%). In their study only one result disturbed the order of the respective scattergram, in ours most, particularly in the Caracu River (Figure 2).

In one respect the results of Alabaster & Hartley (1962) were the same as ours. Multiple regression analysis (taking water velocity, depth and width) used by them also did not show that 'any factors contributed significantly to fishing efficiency'. We also confirmed a lack of correlation with SE (and all variables of Table 3) with the same factors and besides them with site length, area of sampling, substratum, macrophyte cover, water temperature, pH and O_2 .

Although the results in Figure 2 are confusing, particularly those for the Caracu River, yet together with increase in water conductivity in the Ourico proportionally more and more fish were captured (their biomass continuously increased as well). Also, the number of fish captured by stopnetting increased with conductivity, while the sites adjoined one another, and differed to a small degree as regards their investigated characters. It seems that all this can be attributed to increasing conductivity. Note that at site C the presence of almost twice more submerged macrophytes (which obstruct dipnetting stunned fish out of water) than in the other three did not disturb the above noted regularity.

In Agua de Valencia, despite some disturbances, an increase in conductivity caused increase in sampling efficiency (Figure 2). Also the lowest values of population parameters were recorded at the lowest con-

Table 2. Results of three successive catches (C₁₋₃) in the Ourico (localities A-D), the Agua de Valencia (E-H), and the Caracu River (I-L). *N* - number of specimens, *B* - biomass of specimens in grams, \hat{N} - estimated density per 100 m², \hat{B} - estimated standing crop per 100 m² in grams, \hat{p} - catch efficiency from the Zippin model and its mean, e% - catch efficiency estimate proposed by the present authors and its mean. e_1^n , e_2^n , e_3^n - values obtained by electrofishing and stopnetting, respectively, * - Zippin method not applicable, e_1^α is an absolute estimate (number of fish caught ≤ 3 or all fish captured in C₁)(see text for explanation).

| Species | $\frac{C_1}{e_1^n e B}$ | $\frac{C_2}{e_2^n e B}$ | $\frac{C_3}{e_3^n e B}$ | Total $\frac{e_1^n e B}{e_2^n e B}$ | $\frac{n_1 N^n B}{n_2 N^n B}$ | $\frac{n_1 N^n B}{e_1^n e B}$ | $\frac{n_2 N^n B}{e_2^n e B}$ | $\frac{n_1 N^n e^{1+n} B}{e_1^n e B}$ | \hat{N} | \hat{B} | \hat{p} | e% |
|----------------------|-------------------------|-------------------------|-------------------------|--|-------------------------------|-------------------------------|-------------------------------|---------------------------------------|------------------|-----------|-----------|----|
| Site A | | | | | | | | | | | | |
| B. stramineus | | 3/6.4 | 1/0.2 | 1 | 3 | 4/6.6 | | 7.3 | 4.4 | 0.57 | 47.7 | |
| C. aeneus | | 1/1.8 | 1/3.5 | 2 | | 2/5.3 | | 5.3 | 2.0 ^a | | | |
| C. britskii | | 2/0.5 | | 2 | | 2/0.5 | | 0.5 | 2.0 ^a | | | |
| C. notomelas | | 1/0.9 | | 1 | | 1/0.9 | | 0.9 | 1.0 ^a | | | |
| G. carapo | 1/0.2 | 5/1.2 | 1/0.2 | 7 | | 7/1.6 | | 1.9 | 8.3* | 0.46 | 39.0 | |
| H. derbyi | 8/2.5 | 9/3.2 | 1/0.1 | 18 | | 18/5.8 | | 6.9 | 2 1.3 | | | |
| H. malabaricus | 1/3.5 | | | 1 | | 1/3.5 | | 3.5 | 1.0 ^a | | | |
| M. sanctae-filomenae | | 1/21.9 | | 1 | | 1/2.5 | | 2.5 | 1.0 ^a | | | |
| R. hilarii | | 1/21.9 | | 1 | | 1/21.9 | | 21.9 | 1.0 ^a | | | |
| Total | 10/6.2 | 4/7.3 | 4/4.0 | 32 | 5 | 37/48.6 | | 50.7 | 42.0 | 0.52 | 43.4 | |
| Site B | | | | | | | | | | | | |
| A. albifrons | 1/19.3 | | | 1 | | 1/19.3 | | 21.4 | 1.1 ^a | | | |
| A. bimaculatus | 6/71.5 | 1/6.8 | 2/11.0 | 9 | | 9/89.3 | | 112.1 | 11.3 | 0.51 | 41.6 | |
| B. stramineus | 10/11.6 | 2/1.8 | | 12 | | 12/13.4 | | 15.0 | 13.4 | 0.85 | 3.7 | |
| C. aeneus | 3/6.8 | 3/5.7 | | 6 | 1 | 7/16.2 | | 24.5 | 10.6 | 0.36 | 110.4 | |
| C. britskii | 9/16.6 | | 1/14.0 | 9 | 1 | 10/30.6 | | 34.0 | 11.1 | 0.91 | 1.8 | |
| C. notomelas | 2/1.0 | | | 2 | | 2/1.0 | | 1.1 | 2.2 ^a | | | |
| C. paranaense | 3/9.7 | 1/4.9 | 1/10.0 | 1 | | 1/10.0 | | 11.1 | 1.1* | | | |
| E. trilineata | 7/90.7 | 6/69.2 | 1/4.3 | 5 | 2 | 7/42.4 | | 64.2 | 10.6 | 0.36 | 110.4 | |
| G. carapo | 2/0.1 | 7/58.7 | 1/14.3 | 14 | 1 | 15/183.3 | | 238.3 | 19.5 | 0.47 | 40.5 | |
| H. derbyi | 2/0.1 | | | 9 | | 9/58.8 | | 102.6 | 15.7 | 0.29 | 145.9 | |
| Imparfinis sp | 2/1.0 | | 1/0.5 | 3 | | 3/1.5 | | 1.7 | 3.3 ^a | | | |
| M. sanctae-filomenae | 1/2.7 | 1/4.8 | 1/6.2 | 1 | | 1/2.7 | | 3.0 | 1.1 ^a | 0.82 | 5.4 | |
| R. hilarii | 8/104.0 | 2/17.3 | | 9 | 1 | 10/115.0 | | 128.8 | 11.2 | | | |
| S. macrurus | 1/3.0 | 1/51.2 | | 2 | | 2/17.3 | | 19.2 | 2.2* | | | |
| S. marmoratus | | | | 2 | | 2/54.2 | | 60.2 | 2.2 ^a | | | |
| Total | 55/338.0 | 24/220.4 | 5/52.8 | 85 | 6 | 91/655.0 | | 837.2 | 116.6 | 0.57 | 57.5 | |

Table 2. Continued

| Species | C ₁ | | C ₂ | | C ₃ | | Total | | \hat{N} | \hat{B} | \hat{p} | e% |
|----------------------|----------------|----------|----------------|----------|----------------|----------|-------|-------|------------|-----------|-----------|-------|
| | e/N^eB | n/N^mB | e/N^eB | n/N^mB | e/N^eB | n/N^mB | e/N | n/N | | | | |
| Site C | | | | | | | | | | | | |
| A. bimaculatus | 8/60.7 | 1/7.6 | 3/25.3 | 1/7.7 | | | 11 | 2 | 13/101.3 | 98.2 | 0.73 | 9.5 |
| B. stramineus | 17/18.3 | 1/0.9 | 8/6.5 | | 7/2.9 | 2/2.1 | 32 | 3 | 35/30.7 | 42.1 | 0.33 | 58.8 |
| C. aeneus | 15/40.1 | 4/13.6 | 5/7.6 | 1/1.9 | 4/6.1 | 2/6.2 | 24 | 7 | 31/75.5 | 82.8 | 0.49 | 25.3 |
| C. britskii | 10/2.1 | | 4/11.9 | 1/16.2 | 4/1.3 | | 18 | 1 | 19/31.5 | 39.0 | 0.39 | 56.2 |
| C. zebra | | | 1/2.1 | | 1/2.1 | | 1 | | 1/2.1 | 2.0 | | |
| C. notomelas | 2/1.4 | | 3/2.6 | | 2/1.6 | | 7 | | 7/5.6 | 7.9 | | |
| E. trilineata | 1/6.2 | | | | | | 1 | | 1/6.2 | 5.9 | | |
| G. carapo | 7/46.4 | 1/15.4 | 3/39.6 | | 2/17.3 | | 12 | 1 | 13/118.7 | 126.0 | 0.53 | 31.9 |
| H. derbyi | | | 2/0.1 | | 1/20.8 | | 3 | | 3/20.9 | 19.9 | | |
| H. malabaricus | | | | 2/152.2 | 2/243.7 | | 2 | 2 | 4/395.9 | 556.1 | | |
| Imparfinis sp | | | | 1/1.3 | | | 0 | 1 | 1/1.3 | 1.2 | | |
| R. hilarii | 2/32.3 | | 1/24.5 | | | 1/8.7 | 3 | 1 | 4/65.5 | 91.7 | 0.32 | 182.1 |
| S. macrurus | 1/0.0 | | 2/65.5 | | 1/44.1 | | 1 | | 1/0.0 | 0.0 | | |
| S. marmoratus | | | | | | | 3 | | 3/109.6 | 104.4 | | |
| Total | 63/207.5 | 7/37.5 | 31/183.6 | 6/179.3 | 24/339.9 | 5/17.0 | 118 | 18 | 136/964.8 | 1177.2 | 0.48 | 61.5 |
| Site D | | | | | | | | | | | | |
| A. albifrons | 2/55.9 | | 1/42.7 | | 1/33.9 | | 4 | | 4/132.5 | 215.3 | 0.32 | 181.5 |
| A. bimaculatus | 13/160.5 | 2/25.2 | 3/50.3 | 2/18.4 | 2/27.6 | | 18 | 4 | 22/282.0 | 328.1 | 0.65 | 12.9 |
| B. stramineus | 18/22.9 | 32/35.6 | 6/10.5 | 5/4.9 | 1/1.1 | 2/2.5 | 25 | 39 | 64/77.5 | 87.5 | 0.77 | 3.3 |
| C. aeneus | 2/4.6 | | 1/2.6 | | 2/3.9 | | 5 | | 5/11.1 | 18.2 | | |
| C. britskii | 4/60.0 | | | | | | 4 | | 4/60.0 | 66.7 | | |
| E. trilineata | 1/3.4 | | 1/4.4 | | | | 2 | | 2/7.8 | 8.7 | | |
| G. carapo | 13/179.8 | 1/6.2 | 11/94.9 | | 6/91.7 | | 30 | 1 | 31/372.6 | 595.0 | 0.33 | 62.0 |
| H. derbyi | 2/16.0 | | 4/44.5 | | 2/4.7 | | 8 | | 8/65.2 | 106.9 | | |
| H. malabaricus | 1/59.9 | | | 1/32.7 | | | 1 | 1 | 2/92.6 | 102.9 | | |
| Imparfinis sp | 2/3.3 | | 1/5.4 | | 1/1.7 | | 4 | | 4/10.4 | 16.9 | 0.32 | 181.5 |
| M. sanctae-filomenae | | | | | 1/3.9 | | 1 | | 1/3.9 | 4.3 | | |
| N. paranensis | 1/0.5 | | | | | | 1 | 1 | 1/0.5 | 0.6 | | |
| R. hilarii | 4/54.2 | 1/13.6 | 8/77.6 | 1/12.4 | 6/70.7 | | 18 | 2 | 20/228.5 | 374.5 | | |
| S. marmoratus | 8/155.0 | | 4/25.3 | | 4/33.6 | | 16 | | 16/213.9 | 347.6 | 0.32 | 91.2 |
| Total | 71/776.0 | 36/80.6 | 40/358.2 | 9/68.4 | 26/272.8 | 2/2.5 | 137 | 47 | 184/1558.5 | 2272.9 | 0.49 | 77.3 |

Table 2. Continued

| Species | C_1 $\frac{e^N e^B}{n^N n^B}$ | C_2 $\frac{e^N e^B}{n^N n^B}$ | C_3 $\frac{e^N e^B}{n^N n^B}$ | Total $\frac{e^N}{e^N}$ | n^N | $e^{+N} e^{+B}$ | \hat{N} | \hat{B} | \hat{p} | e% | |
|----------------------|------------------------------------|------------------------------------|------------------------------------|----------------------------|-------|-----------------|-------------------|-----------|-----------|-------|--|
| Site E | | | | | | | | | | | |
| A. bimaculatus | | 2/6.8 | 1/8.8 | 2 | 1 | 3/15.6 | 5.3 ^a | 27.4 | | | |
| A. eigenmanniorum | 1/10.1 | | 1/6.4 | 1 | 1 | 2/16.5 | 3.5 ^a | 28.9 | | | |
| A. scabripinnis | 1/5.7 | | | 1 | 1 | 1/5.7 | 1.8 ^a | 10.0 | | | |
| B. stramineus | 2/3.4 | 3/2.0 | 1/2.1 | 6 | 2 | 8/9.1 | 16.9 | 19.2 | 0.45 | 62.7 | |
| Bryconamericus sp | | 4/3.9 | 1/4.6 | 1 | 4 | 5/8.5 | 10.5 [*] | 17.9 | | | |
| C. aeneus | 1/2.2 | 1/2.8 | | 1 | 1 | 2/5.0 | 3.5 ^a | 8.8 | | | |
| C. britskii | 1/16.2 | | | 1 | 1 | 1/16.2 | 1.8 ^a | 28.4 | | | |
| G. carapo | 3/35.3 | | | 3 | 3 | 3/35.3 | 5.3 ^a | 61.9 | | | |
| H. derbyi | 1/0.8 | | | 1 | 1 | 1/0.8 | 1.4 | 1.4 | | | |
| M. sanctae-filomenae | 1/4.7 | | 1/7.4 | 2 | 2 | 2/12.1 | 1.8 ^a | 21.2 | | | |
| N. paranensis | 2/2.1 | | 1/1.1 | 3 | 3 | 3/3.2 | 5.3 ^a | 5.6 | | | |
| P. tortuosus | | 1/21.0 | | 1 | 1 | 1/21.0 | 36.8 | 36.8 | | | |
| S. marmoratus | 1/14.5 | | | 1 | 1 | 1/14.5 | 1.8 ^a | 25.4 | | | |
| Total | 14/95.0 | 4/25.4 | 4/15.2 | 23 | 10 | 33/163.5 | 62.8 | 292.9 | 0.45 | 62.7 | |
| Site F | | | | | | | | | | | |
| A. eigenmanniorum | 1/6.9 | | 2/14.7 | 1 | 2 | 3/21.6 | 5.3 ^a | 37.9 | | | |
| A. scabripinnis | | 3/11.3 | | 3 | 1 | 4/20.2 | 10.3 | 52.0 | 0.32 | 181.6 | |
| B. stramineus | 1/2.2 | | | 1 | 1 | 1/2.2 | 1.8 ^a | 3.9 | | | |
| Bryconamericus sp | 1/3.9 | | | 1 | 1 | 2/7.5 | 3.5 ^a | 13.2 | | | |
| C. aeneus | 1/2.6 | | 1/3.5 | 2 | 2 | 2/6.1 | 3.5 ^a | 10.7 | | | |
| E. trilineata | 3/29.2 | | | 4 | 4 | 4/44.3 | 7.1 | 78.6 | 0.78 | 11.3 | |
| G. carapo | 1/13.6 | 6/95.6 | 5/63.0 | 12 | 12 | 12/172.2 | 31.1 [*] | 445.6 | | | |
| H. derbyi | 4/18.0 | | | 4 | 1 | 5/27.3 | 8.8 ^a | 47.9 | | | |
| Imparfinis sp | 1/5.0 | | | 1 | 1 | 1/5.0 | 1.8 ^a | 8.8 | | | |
| M. sanctae-filomenae | 1/4.0 | | | 1 | 1 | 1/4.0 | 1.8 ^a | 7.0 | | | |
| P. tortuosus | 1/26.3 | 1/23.4 | 1/33.9 | 2 | 1 | 3/83.6 | 5.3 ^a | 146.7 | | | |
| R. hilarii | | 2/21.2 | 2/39.5 | 3 | 2 | 5/68.7 | 12.9 [*] | 177.8 | | | |
| S. marmoratus | 1/16.1 | | | 1 | 1 | 1/16.1 | 1.8 ^a | 28.2 | | | |
| Total | 15/125.6 | 4/24.0 | 7/74.5 | 35 | 9 | 44/478.8 | 95.0 | 1058.3 | 0.55 | 96.5 | |

Table 2. Continued

| Species | C ₁ | | C ₂ | | C ₃ | | Total | | \hat{N} | \hat{B} | \hat{p} | e% |
|----------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-----------|-----------|-----------|-------|
| | $\frac{e^{+n}N^n}{e^{-n}N^n}$ | $\frac{e^{+n}N^n}{e^{-n}N^n}$ | $\frac{e^{+n}N^n}{e^{-n}N^n}$ | $\frac{e^{+n}N^n}{e^{-n}N^n}$ | $\frac{e^{+n}N^n}{e^{-n}N^n}$ | $\frac{e^{+n}N^n}{e^{-n}N^n}$ | $\frac{e^{+n}N^n}{e^{-n}N^n}$ | $\frac{e^{+n}N^n}{e^{-n}N^n}$ | | | | |
| Site G | | | | | | | | | | | | |
| A. bimaculatus | 1/23.4 | | | 1/11.3 | | | 2 | | 2/34.7 | 37.3 | | |
| A. eigenmanniorum | | 1/7.3 | | | | 1 | | 1/7.3 | 7.8 | | | |
| A. scabripinnis | 1/5.5 | 1/6.2 | | | | 1 | | 2/11.7 | 12.6 | | | |
| B. stramineus | 3/8.7 | 4/6.6 | 1/1.5 | 4/6.9 | | 5 | | 12/23.7 | 37.3 | 0.32 | | 105.3 |
| Bryconamericus sp | 2/5.4 | 3/15.5 | | | | 2 | | 5/20.9 | 22.5 | | | |
| C. aeneus | 3/5.8 | 1/2.0 | 2/4.6 | 1/2.8 | | 2 | | 8/17.0 | 21.9 | 0.45 | | 63.1 |
| C. britskii | 4/42.0 | 1/16.8 | | | | 5 | | 5/58.8 | 63.5 | 0.82 | | 7.4 |
| E. trilineata | 1/13.2 | | | 2/21.9 | | 3 | | 3/35.1 | 37.7 | | | |
| G. carapo | 4/49.0 | 4/37.4 | | 2/22.9 | | 10 | | 10/109.3 | 196.7 | 0.26 | | 161.1 |
| H. derbyi | 1/0.4 | 1/21.9 | | 1/21.9 | | 2 | | 2/22.3 | 24.0 | | | |
| M. sanctae-filomenae | 2/6.2 | 1/1.0 | | | | 2 | | 2/6.2 | 6.7 | | | |
| R. hilarii | | 1/25.3 | | | | 1 | | 1/1.0 | 1.1 | | | |
| S. macrurus | | 1/25.3 | | | | 1 | | 1/25.3 | 27.2 | | | |
| Total | 22/159.6 | 9/30.3 | 10/92.4 | 2/4.3 | 11/87.7 | 43 | 11 | 54/373.3 | 496.3 | 0.46 | | 84.2 |
| Site H | | | | | | | | | | | | |
| A. bimaculatus | 4/65.6 | | 2/33.0 | | | 6 | | 6/98.6 | 129.8 | 0.71 | | 16.5 |
| A. eigenmanniorum | 1/6.9 | 1/0.4 | | | | 2 | | 2/7.3 | 9.4 | | | |
| B. stramineus | 3/4.6 | 1/0.3 | 2/6.4 | 1/5.1 | | 5 | 2 | 7/16.4 | 22.3 | 0.63 | | 25.3 |
| Bryconamericus sp | | 1/5.5 | | | | 1 | | 1/5.5 | 7.1 | | | |
| C. aeneus | 2/3.7 | | 2/4.8 | | | 4 | | 4/8.5 | 11.9 | 0.57 | | 46.4 |
| C. britskii | 1/0.8 | | 4/41.9 | | | 5 | | 5/42.7 | 91.4 | 0.26 | | 229.0 |
| E. trilineata | 3/25.9 | | | | | 3 | | 3/25.9 | 33.2 | | | |
| G. carapo | 8/181.0 | | | | | 14 | | 14/241.2 | 325.6 | 0.63 | | 17.5 |
| H. derbyi | 1/30.4 | | 6/60.2 | | | 1 | | 1/30.4 | 39.0 | | | |
| H. malabaricus | 1/151.5 | | | | | 1 | | 1/151.5 | 194.2 | | | |
| M. sanctae-filomenae | | | | | | 1 | | 1/2.3 | 2.9 | | | |
| P. gracilis | | 1/2.3 | | | | 1 | | 1/0.3 | 0.4 | | | |
| R. hilarii | 1/20.7 | 1/0.3 | | | | 2 | | 2/21.1 | 27.1 | | | |
| S. macrurus | 2/22.2 | 1/0.4 | | | | 3 | | 3/28.0 | 35.9 | | | |
| S. marmoratus | 1/15.5 | 1/5.8 | | | | 1 | | 1/15.5 | 19.9 | | | |
| Total | 28/528.1 | 2/5.8 | 21/156.5 | 1/5.1 | | 49 | 3 | 52/695.2 | 950.1 | 0.64 | | 66.4 |
| | | | | | | | | | 73.2 | | | |

Table 2. Continued

| Species | C ₁ | | C ₂ | | C ₃ | | Total | | \hat{N} | \hat{B} | \hat{p} | e% |
|-------------------|----------------|----------|----------------|----------|----------------|----------|-------|-------|-----------|-----------|-----------|-------|
| | $e/N/eB$ | $n/N/nB$ | $e/N/eB$ | $n/N/nB$ | $e/N/eB$ | $n/N/nB$ | e/N | n/N | | | | |
| Site I | | | | | | | | | | | | |
| A. bimaculatus | 10/53.8 | 2/11.5 | 5/38.8 | | 5/17.2 | | 20 | 2 | 22/121.3 | 263.6 | 0.39 | 51.5 |
| B. stramineus | 6/3.0 | | 11/3.7 | | 5/1.9 | 8/3.1 | 22 | 8 | 30/11.7 | 25.4 | | |
| C. britskii | | | 1/13.0 | | | | 1 | | 1/13.0 | 21.9 | | |
| C. zebra | 3/2.9 | | | | 4/4.1 | | 7 | | 7/7.0 | 15.2 | | |
| C. paranaense | 2/24.1 | | 1/7.5 | 1/12.3 | 2/26.6 | | 5 | 1 | 6/70.5 | 153.2 | | |
| G. carapo | 4/50.5 | | | 1/15.8 | 1/13.3 | | 5 | 1 | 6/79.6 | 145.9 | 0.57 | 38.2 |
| H. derbyi | 15/96.5 | | 4/8.2 | | 3/9.7 | 1/10.9 | 22 | 1 | 23/125.3 | 232.6 | 0.55 | 22.0 |
| H. littorale | 2/80.4 | | | | 1/21.1 | | 3 | | 3/101.5 | 170.9 | | |
| H. malabaricus | 2/98.7 | | | | | | 2 | | 2/98.7 | 166.2 | | |
| Imparfnis sp | 3/7.7 | | 1/2.0 | | | | 4 | | 4/9.7 | 16.5 | 0.78 | 11.8 |
| Total | 47/417.6 | 2/11.5 | 23/73.2 | 2/28.1 | 21/94.9 | 9/14.0 | 91 | 13 | 104/638.3 | 1211.4 | 0.57 | 30.9 |
| Site J | | | | | | | | | | | | |
| A. bimaculatus | 23/70.2 | 12/17.4 | 9/23.4 | 7/5.7 | 6/19.8 | | 38 | 19 | 57/136.6 | 232.9 | 0.57 | 11.9 |
| B. stramineus | 21/9.7 | 11/3.9 | 3/1.1 | 9/4.1 | 4/1.6 | | 28 | 20 | 48/20.3 | 33.5 | 0.64 | 9.0 |
| C. zebra | 2/2.9 | 1/1.6 | 2/3.5 | | 1/1.5 | | 5 | 1 | 6/9.5 | 18.8 | 0.41 | 90.8 |
| C. paranaense | 3/63.3 | | 2/19.2 | 2/29.8 | 2/28.0 | | 7 | 2 | 9/140.3 | 559.6 | 0.15 | 374.4 |
| G. carapo | 1/9.2 | | 3/32.8 | | 1/11.5 | | 5 | | 5/53.5 | 213.1 | | |
| H. derbyi | 10/58.4 | 1/3.2 | 7/30.2 | 1/2.9 | 2/3.1 | | 19 | 2 | 21/97.8 | 176.0 | 0.50 | 29.6 |
| H. littorale | 2/48.5 | | | | | | 2 | | 2/48.5 | 76.3 | | |
| H. unitaeniatus | | | 1/17.0 | | | | 1 | | 1/17.0 | 26.7 | | |
| Hypostomus sp b | 5/86.7 | | 4/129.2 | | 3/22.1 | | 12 | | 12/238.0 | 704.1 | 0.22 | 190.7 |
| P. caudimaculatus | 2/0.4 | | | 1/0.5 | | | 2 | 1 | 3/0.8 | 1.3 | | |
| P. maculatus | 1/22.3 | 1/15.1 | | | | | 1 | 1 | 2/37.4 | 58.8 | | |
| R. hilarii | 1/24.2 | | | | | | 1 | | 1/24.2 | 38.1 | | |
| S. insculpta | | | | | 1/33.9 | | 1 | | 1/33.9 | 53.3 | | |
| Total | 71/395.8 | 26/41.2 | 31/356.4 | 20/43.0 | 20/121.5 | | 122 | 46 | 168/857.8 | 2192.5 | 0.42 | 117.7 |

Table 2. Continued

| Species | C_1 | | C_2 | | C_3 | | Total | | \hat{B} | \hat{p} | e% |
|-------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|-----------|-----------|-------|
| | $\frac{e^+N^eB}{n^+N^eB}$ | $\frac{n^+N^eB}{n^+N^eB}$ | $\frac{e^+N^eB}{n^+N^eB}$ | $\frac{n^+N^eB}{n^+N^eB}$ | $\frac{e^+N^eB}{n^+N^eB}$ | $\frac{n^+N^eB}{n^+N^eB}$ | $\frac{e^+N^eB}{n^+N^eB}$ | $\frac{n^+N^eB}{n^+N^eB}$ | | | |
| Site K | | | | | | | | | | | |
| A. bimaculatus | 19/134.9 | 1/5.6 | 3/27.1 | 1/6.2 | 24/173.8 | 1 | 23 | 1 | 441.7 | 0.81 | 3.6 |
| B. stramineus | 2/2.2 | 3/1.3 | 2/2.7 | 2/2.7 | 8/6.7 | 1 | 7 | 1 | 32.3 | | |
| C. zebra | 15/17.2 | 2/2.0 | 2/3.4 | 2/3.4 | 19/22.6 | | 19 | | 58.3 | 0.72 | 8.2 |
| C. paranaense | 2/21.4 | | | | 2/21.4 | | 2 | | 54.0 | | |
| G. carapo | 6/43.3 | 3/20.0 | 2/7.6 | 2/7.6 | 11/70.9 | | 11 | | 217.9 | 0.44 | 56.8 |
| H. derbyi | 22/140.3 | 11/63.4 | 2/8.3 | 14/88.4 | 49/299.4 | 2 | 47 | 2 | 1443.8 | 0.22 | 97.0 |
| H. malabaricus | | | | 1/71.4 | 1/71.3 | 1 | | 1 | 180.1 | | |
| H. unitaeniatus | 1/30.4 | | | | 1/30.4 | | 1 | | 76.8 | | |
| Hypostomus sp b | 3/51.1 | | | | 3/51.1 | | 3 | | 129.0 | | |
| Imparfinis sp | 1/2.0 | | | | 1/2.0 | | 1 | | 5.1 | | |
| P. caudimaculatus | 1/0.1 | | | | 1/0.1 | | 1 | | 0.3 | | |
| R. hilarii | | | | 1/13.3 | 1/13.3 | | 1 | | 33.6 | | |
| S. borelli | 1/16.5 | | | | 1/16.5 | | 1 | | 41.7 | | |
| S. marmoratus | 1/1.9 | | | 2/7.0 | 3/8.9 | | 3 | | 22.5 | | |
| Total | 74/461.4 | 1/5.6 | 22/112.8 | 24/128.6 | 125/788.4 | 5 | 120 | 5 | 2737.1 | 0.55 | 41.4 |
| Site L | | | | | | | | | | | |
| A. bimaculatus | 22/131.4 | 1/10.1 | 8/41.7 | 3/16.8 | 36/212.6 | 3 | 33 | 3 | 450.0 | 0.61 | 11.9 |
| B. stramineus | 4/3.6 | 2/1.0 | 8/9.5 | 1/0.5 | 17/16.1 | 4 | 13 | 4 | 48.7 | 0.30 | 96.9 |
| C. zebra | 14/15.2 | 4/4.1 | 4/4.1 | 10/10.5 | 29/30.6 | 1 | 28 | 1 | 163.9 | 0.14 | 228.1 |
| C. paranaense | 2/30.8 | | | | 2/30.8 | | 2 | | 61.5 | | |
| G. carapo | 1/10.6 | | 1/5.6 | 3/9.6 | 5/25.8 | | 5 | | 138.2 | | |
| H. derbyi | 19/104.2 | 1/11.1 | 5/25.6 | 2/9.0 | 27/149.9 | 1 | 26 | 1 | 306.5 | 0.71 | 7.6 |
| H. malabaricus | 1/53.4 | | | | 1/53.4 | | 1 | | 106.6 | | |
| H. unitaeniatus | 1/17.5 | | 1/21.8 | | 2/39.3 | | 2 | | 78.4 | | |
| Imparfinis sp | | | | 1/2.5 | 1/2.5 | | 2 | | 5.0 | | |
| P. caudimaculatus | | | | 1/0.1 | 1/0.1 | | 1 | | 0.2 | | |
| R. hilarii | | | | 1/20.2 | 1/20.2 | | 1 | | 40.3 | | |
| Total | 64/366.7 | 4/22.2 | 27/108.3 | 20/66.6 | 122/581.3 | 11 | 111 | 11 | 1399.3 | 0.44 | 86.1 |

Table 3. Species number, populational parameters (explanations of symbols in Table 2a) and indices of sampling efficiency (explanations in the text) in the investigated sites. t is the total value. The lowest values are in bold.

| River | Site | Species number | $e^{+n}N_t$ | $e^{+n}B_t$ | eN_t | nN_t | SE | \hat{p} | e% | Caught by nets (%) |
|------------------|------|----------------|-------------|-------------|-----------|-----------|-----------|-------------|-------------|--------------------|
| Ourico | A | 9 | 37 | 49 | 32 | 5 | 88 | 0.52 | 43.4 | 16 |
| | B | 15 | 91 | 655 | 85 | 6 | 78 | 0.57 | 57.5 | 7 |
| | C | 15 | 136 | 965 | 118 | 18 | 84 | 0.48 | 61.5 | 15 |
| | D | 15 | 184 | 1559 | 137 | 47 | 73 | 0.49 | 77.3 | 34 |
| Agua de Valencia | E | 13 | 33 | 164 | 23 | 10 | 53 | 0.45 | 62.7 | 44 |
| | F | 13 | 44 | 459 | 35 | 9 | 46 | 0.55 | 96.5 | 26 |
| | G | 13 | 54 | 373 | 43 | 11 | 74 | 0.46 | 84.2 | 26 |
| | H | 16 | 52 | 695 | 49 | 3 | 75 | 0.64 | 66.4 | 6 |
| Caracu | I | 10 | 104 | 638 | 91 | 13 | 49 | 0.57 | 30.9 | 14 |
| | J | 13 | 168 | 858 | 122 | 46 | 50 | 0.42 | 117.7 | 38 |
| | K | 14 | 125 | 788 | 120 | 5 | 28 | 0.55 | 41.4 | 4 |
| | L | 11 | 122 | 581 | 111 | 11 | 32 | 0.44 | 86.1 | 10 |

ductivity, except for a number of fish captured in the stop net. It was here where an abundance of submerged macrophytes, obstructing stunned fish dipnetting, was recorded.

Results of sampling in the Caracu River are the reverse of those expected and cannot be explained by anything specific, certainly not site characters.

An anonymous reviewer pointed our attention to the fact that much information included in Table 2 is not commented and at least some reference to given fish species should be done. This remark is correct, because it is known that species mobility, for example, affects fishing efficiency (Zalewski & Penczak, 1981; Mann & Penczak, 1984; Penczak & Romero, 1990); hence, benthic species are more efficiently captured with electricity than pelagic ones, particularly in slowly flowing streams and rivers (Vibert, 1967; Mahon, 1980).

Detecting taxonomy-related differences turned out to be impossible for our data, however. Of thirty one species present in the investigated rivers, only *E. tri-lineata* occurred at 2 sites in numbers making dependence estimates between density and fishing efficiency estimates possible. For a conductivity of $50 \mu\text{S cm}^{-1}$ calculated $\hat{p} = 0.36$, and for $100 \mu\text{S cm}^{-1}$ $\hat{p} = 0.78$, but these two values of fishing efficiency were within the limits of \hat{p} calculated for pelago-benthic and benthic species, hence we could not determine any differences related to fish species.

We are of the opinion that artificial increasing of water conductivity during electrofishing in tropical rivers is required, because a higher number of

fish is captured, but this procedure may only apply to streams and small rivers. To raise water conductivity in the investigated rivers for the minimal period of 3 samplings several dozen minutes each 10 to 20 kg of salt (discharge $< 0.2 \text{ m}^3\text{s}^{-1}$) were necessary; in larger rivers, with discharge up to $1 \text{ m}^3\text{s}^{-1}$, this would require hundreds of kilograms.

Lasso & Castroviejo (1992) managed to fish with electricity even at a conductivity of $19.4\text{--}21.9 \mu\text{S cm}^{-1}$. In our investigations without salting, we worked at $39\text{--}62 \mu\text{S cm}^{-1}$ and sampling efficiency measured with \hat{p} , e%, SE in most cases did not diverge from sampling efficiency in temperate zone rivers (Mann & Penczak, 1984; Penczak & Romero, 1990; Penczak & Jakubowski, 1990). This, however, does not solve the general problem and further investigations are necessary.

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Appendix

(b - benthic, pb -pelago-benthic, p - pelagic)

Family ANOSTOMIDAE

Schizodon borelli (Boulenger, 1895), p

Family APTERONOTIDAE

Apteronotus albifrons (Linnaeus, 1766), pb

Family CALLICHTHYIDAE

Corydoras aeneus (Gill, 1864), b

Hoplosternum littorale (Hancock, , 1828), b

Family CHARACIDAE

Sub-family CHARACIDIINAE

Characidium aff. *zebra* (Eigenmann, 1909), b

Characidium fasciatum Reinhardt, b

Sub-family CHEIRODONTINAE

Cheirodon notomelas (Eigenmann, 1915), pb

Sub-family TETRAGONOPTERINAE

Astyanax bimaculatus (Linnaeus, 1758), pb

Astyanax eigenmanniorum (Cope, 1894), pb

Astyanax scabripinnis (Eigenmann, 1927), pb

Bryconamericus sp

Bryconamericus stramineus (Eigenmann, 1908), b

Moenkhausia sanctae-filomenae (Steindachner, 1907), pb

Family CICHLIDAE

Cichlasoma paranaense Kullander, 1983, b

Crenicichla britskii Kullander, 1982, b

Family CURIMATIDAE

Steindachnerina insculpta (Fernández-Yépez, 1948), b

Family ERYTHRINIDAE

Hoplias aff. *malabaricus* (Bloch, 1794), b

Hoplerethrinus unitaeniatus (Spix, 1829), pb

Family GYMNOTIDAE

Gymnotus carapo Linnaeus, 1758, b

Family LORICARIIDAE

Sub-family NEOPLECOSTOMINAE

Neoplecostomus paranensis Langeani, 1990, b

Sub-family PLECOSTOMINAE

Hypostomus aff. *derbyi* (Hasemam, 1911), b

Hypostomus sp b, b

Family PARODONTIDAE

Parodon tortuosus Eigenmann & Norris, 1900, b

Family PIMELODIDAE

Sub-family PIMELODINAE

Imparfinis sp, b

Pimelodella gracilis (Valenciennes, 1840), b

Pimelodus maculatus Lacépède, 1803, pb

Rhamdia cf *hilarii* (Valenciennes, 1840), pb

Family POECILIIDAE

Phallocerus caudimaculatus (Hensel, 1868), pb

Family STERNOPYGIDAE

Eigenmannia trilineata (Lopez & Castello, 1966),

p

Sternopygus macrurus (Bloch & Schneider,
1801), pb

Family SYNBRANCHIDAE

Synbranchus marmoratus (Bloch, 1795), b