New Zealand Journal of Marine and Freshwater Research, 2003, Vol. 37: 777–792
0028–8330/03/3704–0777 $7.00

Development of a biotic index using the correlation of protozoan communities with chemical water quality

JIAN-GUO JIANG
College of Food and Bioengineering
South China University of Technology
Guangzhou 510640
People's Republic of China
email: johnjg@scut.edu.cn

YUN-FEN SHEN
Institute of Hydrobiology
Chinese Academy of Sciences
Wuhan, 430072
People's Republic of China

Abstract A method of comparing data on protozoan communities with chemical parameters is presented. Using data from an extensive survey of the River Hanjiang in China, each species of protozoa has been given a species pollution value (SPV) related to its occurrence in waters with different degrees of pollution. A comprehensive chemical index is calculated for each site based on water quality standards for eight chemical parameters. The index is calculated from the relationship between the observed levels of each chemical at a site compared with the limits of the drinking water quality standards of the People's Republic of China. From the distribution of each species at sites with differing chemical index values, a SPV is calculated. The SPV for each species is obtained by summing the logarithmic value of 10 times the chemical pollution divided by the number of chemical parameters, then divided by the stations where the species occurs. The community pollution value (CPV), which is the average SPVs of all protozoa at a site, is used to evaluate water quality. The CPV has been shown to have a close correlation with the degree of water pollution. It is not necessary for all the protozoa in a sample to have SPVs listed in this paper, provided at least 56% of the protozoa in a sample have an SPV value, the CPV will be applicable.

M02027; Online publication date 31 October 2003
Received 11 April 2002; accepted 25 March 2003

Keywords biotic index; water pollution; correlation analysis; SPV; CPV

INTRODUCTION

Over a number of years various biotic indices have been devised by different researchers (Kolkowitz & Marsson 1909; Patrick 1950; Beck 1955; Panlte & Buck 1955; Woodiwiss 1960, 1980; Beak 1965; Graham 1965; Chandler 1970; Chutter 1972; Hilsenhoff 1977; Madoni 1994) in an attempt to classify aquatic biological conditions, and biotic indices up to 1990 were reviewed by Washington (1984) and Samiullah (1990). Although these might have been suitable for the area for which they were devised, their application to other areas has sometimes been restricted by the presence of water conditions not found in the original area and therefore not considered in the formulation of that particular biological index.

As discussed by Washington (1984) and Samiullah (1990), each biotic index has weaknesses that limit its application in a wider area. In general, all the biotic indices have common weaknesses. Each system is more or less a subjective one, mainly depending on the feeling and empiricism of investigators. For example, the indicator organism technique of Beck's (1955) biotic index was considered very subjective by Myslinski & Ginsburg (1977). In Beak's (1965) index, the sensitivity of animals to pollution is a matter of the opinion and the experience of the investigators and the assessment of density is also subjective (Chutter 1972). In the saprobien system (Sladecek 1973), the disregard for species <10% and the distribution of saprobic valency of each species in different saprobic zones are decided only by the experience of the investigators. In the Trent biotic index (Woodiwiss 1960), the division of the total number of groups present and the method of Chutter's (1972) index are also subjective or empirical, etc. Even the Chandler's score system, the best system considered by some authors (Balloch 1976; Hellawell 1978; Washington

1984), is also subjective in the selection of indicator organisms, the determination of the positions of species, and the assessment of levels of abundance. Subjectivity makes these biotic indices dubious and debatable. We find that all these indices are not directly based on physical and chemical characteristics, although some indices had a significant correlation with chemical parameters such as biochemical oxygen demand (BOD) in application (Chutter 1972; Sladecek & Tucek 1975; Hilsenhoff 1977). This may explain why the evaluation results with these indices often do not coincide with the actual situation. For this reason several papers presented objective methods for assigning pollution sensitivity values (Lawrence & Harris 1979; Walley & Hawkes 1996; Chessman 1997).

We present a method of comparing biotic data with a range of chemical parameters in which these problems may be minimised, if not eliminated entirely.

METHODS

The biological and chemical background for the present paper was published elsewhere (Shen et al. 1995). However, it is pertinent to give a brief review of their studies.

The research was conducted in two stages on the River Hanjiang, the longest branch of the River Changjiang, People's Republic of China. The first stage was to carry out a general investigation of the physico-chemical and biological status along the river. The sampling stations along the lengths of the river and main tributaries were of sufficient number and appropriately distributed to give a clear profile of the prevailing physico-chemical conditions, including the effects of known discharges. The selected sampling stations were essentially the same as those sampled routinely by respective local monitoring stations. It was decided to use and incorporate data collected by these local stations. Eight common chemical parameters available from each station were selected and retabulated in Table 1. The second stage was to research two relative serious pollution belts from two sewage discharge outlets to thoroughly understand how pollutants were gradually degraded and removed by self-purification of the water body and the relationship between this and the changing biotic quality. The same eight chemical parameters were selected and shown in Table 2.

The field sampling of protozoan communities was conducted by the PFU (Polyurethane Foam Unit) method (Cairns et al. 1969). In the first stage, 358 species of protozoa were classified from the samples collected at 42 stations. In the second stage, 332 species of protozoa were classified. The two tables of protozoan distribution (see Shen et al. 1995, tables 6–17 and 7–11) are not relisted here, but form the basis of the present biotic index.

To make the biotic index based directly on chemical parameters, a simple standard of chemical characteristics of the water environment is needed because of the widely varying value of each chemical parameter for each sampling station. The comprehensive chemical pollution index described here is such a summative standard.

A comprehensive chemical pollution index based on chemical data from a reference station is not considered here because water quality from each reference station is different and hence makes the index incomparable. Therefore we selected a comprehensive chemical pollution index (*Pb*) based on the Grade II standard for surface water (Environmental Quality standard of People's Republic of China for surface water, GB3838–88, see Table 1). The Grade II standard of surface water is mainly for water suitable for drinking. *Pb* is calculated by the following formulae:

$$Pb = \sum_{i=1}^{n} Pi \tag{1}$$

$$Pi = \frac{Cd}{Co} \tag{2}$$

where: *Pb* is the comprehensive chemical pollution index based on the Grade II standard for surface water; *Pi* is the chemical pollution index for a single chemical parameter based on the Grade II standard for surface water; *Cd* is the concentration of the tested chemical parameter at the sampling station; *Co* is the upper limit of the concentration of the chemical parameter in the Grade II standard for surface water; *n* is the number of contributing parameters (here $n = 8$).

According to the formulae above, each station's *Pb* is calculated (in the case of dissolved oxygen (DO), *Pi* was calculated as *Co*/*Cd* because oxygen decreases in response to pollution) and is shown in Tables 1 and 2.

The species pollution value (SPV) of each protozoan is calculated by:

$$\text{SPV} = \frac{\sum_{i=1}^{n} (\ln^{10Pb}/_{n})i}{N} \tag{3}$$

Table 1 Chemical and physical characteristics and measurements for each sampling station of the first stage. (COD, chemical oxygen demand; BOD, biochemical oxygen demand; DO, dissolved oxygen; U, M, L, upper, middle, and lower reach respectively; 1, 2, 3, etc, main courses; and a, b, c, etc, tributaries.)

Stn	COD_{Cr} Grade II <15	BOD <3	DO >6	NH_3 <0.02	Nitrite <0.1	Nitrate <10	Volatile phenol <0.002	Cyanide <0.05	*Pb*	ln (10*Pb*/*n*)	CPV_1	CPV_2	CPV	Current velocity (m/s)
L-2	225.60*	108.10	0.02	1.9562	0.0009	0.15	0.759	0.0446	857.32	6.97	3.24	4.72	3.69	0.0000
M-b	4.73	9.29	7.20	2.2331	0.0390	0.55	0.001	0.0020	118.11	4.99	2.27	4.16	2.71	0.0750
M-9	302.60	166.15	8.50	0.1037	0.0020	1.08	0.026	0.0040	95.37	4.78	2.88	4.69	3.39	0.2845
U-c	18.74*	15.10	6.33	0.9241	0.5340	0.60	0.002	0.0020	60.24	4.32	2.66	4.10	3.01	
M-h	8.99	7.58	2.00	0.0764	0.0020	0.45	0.069	0.0020	44.91	4.02	2.32	4.13	2.73	0.3864
L-5	8.90	2.02	9.05	0.0000	0.0001	1.02	0.052	0.0000	33.03	3.72	2.23	4.08	2.66	0.0353
U-b	15.80*	17.84	1.90	0.1377	0.4730	1.90	0.004	0.0020	24.36	3.41	2.63	4.26	3.07	
M-g	13.30	10.46	3.20	0.1725	0.0850	0.85	0.001	0.0220	20.71	3.25	2.41	4.24	2.99	0.0451
L-8	77.40	18.17	9.34	0.0226	0.0004	0.92	0.013	0.0006	19.71	3.20	2.31	4.28	2.85	0.0621
L-9	57.00	10.27	6.70	0.1665	0.0002	0.59	0.005	0.0001	19.02	3.17	2.18	4.17	2.62	0.0830
L-3	15.40	2.60	9.39	0.0789	0.0001	0.81	0.022	0.0031	18.20	3.12	2.24	4.07	2.66	0.0356
M-3	13.90	16.8	5.7	0.0003	0.0070	0.65	0.018	0.0020	17.13	3.06	2.42	4.13	2.84	
M-j	14.50	5.93	4.2	0.2029	0.0040	1.06	0.001	0.0060	16.29	3.01	2.25	4.35	2.80	0.2845
M-f	22.15	5.58	4.60	0.1118	0.0070	1.80	0.004	0.0080	14.08	2.86	2.12	3.99	2.58	0.0625
M-m	6.96*	3.86	5.05	0.0007	0.0830	0.23	0.011	0.0060	11.80	2.69	2.13	4.20	2.72	0.103
M-7	11.14	2.88	6.40	0.0591	0.0060	0.68	0.008	0.0020	10.12	2.53	2.30	4.42	2.86	0.0366
U-g	4.95*	4.80	7.30	0.0963	0.0040	0.30		0.0020	9.30	2.45	2.12	3.86	2.65	
M-i	16.96	5.79	3.70	0.0074	0.0020	0.19	0.005	0.0020	7.99	2.30	2.12	3.85	2.58	0.5042
M-e	13.50	5.36	4.90	0.0311	0.0130	0.64	0.001	0.0060	7.36	2.22	2.24	4.45	2.82	0.0500
U-d	5.52*	7.94	4.90	0.0009	0.0040	0.28	0.002	0.0020	6.40	1.91	1.99	3.86	2.45	
M-n	2.82*		5.80	0.0085	0.0640	2.01	0.003	0.002	4.90	1.81	2.14	4.22	2.76	0.1363
M-8	6.23	1.85	8.70	0.0435	0.0020	0.60	0.001	0.0020	4.88	1.81	1.98	3.94	2.51	0.0717
U-1	1.08*	1.48	7.40	0.0004	0.1300	0.25	0.002	0.0020	3.96	1.60	1.94	3.95	2.41	
M-2	1.58	1.9	9.10	0.0185	0.0030	0.71	0.001	0.0020	3.59	1.50	2.09	4.14	2.64	
M-12	7.74	1.43	7.30	0.0003	0.0700	0.06	0.001	0.0020	3.49	1.47	1.97	3.93	2.48	
L-7	9.00	2.27	9.38	0.0026	0.0003	0.78	0.002	0.0001	3.24	1.39	2.01	4.31	2.60	0.0493
L-12	9.00	2.32	9.90	0.0094	0.0002	1.22	0.001	0.0002	3.11	1.35	1.98	4.20	2.57	0.0508
M-10	4.49	2.60	8.70	0.0055	0.0020	0.55	0.001	0.0020	3.11	1.35	2.10	4.02	2.66	0.0424
M-d	0.34	0.50	6.05	0.0166	0.0100	0.89	0.001	0.0020	3.10	1.35	1.91	3.94	2.40	
L-10	13.50	2.07	10.75	0.0035	0.0005	1.25	0.001	0.0002	3.00	1.32	1.96	4.13	2.52	0.0000
U-2	2.42*	0.69	8.50	0.0056	0.0070	0.21	0.002	0.0000	2.91	1.29	1.94	4.20	2.57	0.0333
L-6	8.70	2.27	10.07	0.0053	0.0001	1.10	0.001	0.0001	2.83	1.26	1.94	4.04	2.44	0.0485
M-11	2.38	1.20	7.00	0.0037	0.0150	1.50	0.001	0.0020	2.80	1.25	1.90	3.87	2.42	
M-6	4.00	0.85	7.90	0.0087	0.0030	0.79	0.001	0.0020	2.75	1.23	1.88	3.94	2.31	0.0521
M-4	3.15	2.00	7.60	0.0013	0.0060	0.42	0.001	0.0020	2.73	1.22	1.83	4.03	2.37	
M-5	4.57	1.15	7.90	0.0048	0.0030	0.68	0.001	0.0020	2.68	1.21	1.81	3.90	2.33	0.0688
L-4	11.80	1.51	9.76	0.0000	0.0001	0.95	0.001	0.0000	2.64	1.19	1.91	3.85	2.28	0.1021
M-k	3.44	1.35	8.70	0.0047	0.0020	0.94	0.001	0.0020	2.62	1.18	1.91	4.32	2.61	
L-11	9.00	2.34	10.77	0.0018	0.0003	1.17	0.000	0.0000	2.20	1.01	1.95	4.07	2.43	0.0365
M-a	1.45*		12.35	0.0005	0.0120	1.51	0.001	0.0020	2.05	0.94	1.82	3.85	2.33	0.3330
M-c	1.26*		13.60	0.0005	0.0110	1.46	0.001	0.0020	1.94	0.88	1.86	3.86	2.36	1.5056
L-1	7.40	1.45	10.73	0.0009	0.0001	0.81	0.000	0.0004	1.67	0.73	1.96	3.77	2.33	0.0827

*COD_{Mn} Grade II is <2.

where: SPV is the species pollution value; *Pb* is the comprehensive pollution value; *n* is the number of chemical parameters; and *N* is the number of stations.

The Community Pollution Value (CPV), or the biotic index, used to evaluate the pollution degree of each station, is calculated by:

$$CPV = \frac{\sum_{i=1}^{n} SPV_i}{n} \quad (4)$$

where: CPV is the community pollution value; and *n* is the number of species in a community.

According to formulae above, the SPV_1 of the first stage and the SPV_2 of the second stage are calculated and listed in Appendix 1. CPV_1, calculated from the SPV_1 for the first stage, and CPV_1, calculated from the SPV_2 for the second stage, are listed in Table 1 and Table 2 respectively.

The correlation coefficients between CPV and *Pb* of the two stages are calculated as follows:

First stage: $CPV_1 = 1.50510 + 0.199676 \ln Pb$, $r = 0.91$, $n = 42$

Second stage: $CPV_1 = 2.80642 + 0.267443 \ln Pb$, $r = 0.99$, $n = 12$

Both the coefficients are significant at $P<0.00001$.

To cross-check the applicability of this method across the whole river, the CPV_2 (Table 2) for the second stage was calculated using the SPV_1 (Appendix 1) of the first stage. The correlation coefficient between the CPV_2 and the *Pb* of each station of the second stage is 0.93 (12 samples). Similarly, the CPV_2 (Table 1) for the first stage was calculated according to the SPV_2 (Appendix 1) of the second stage, and the correlation coefficient between the CPV_2 and the *Pb* of each station of the first stage is 0.61358 (42 samples). Both the coefficients are significant at $P<0.00002$. This clearly suggests that the application of the SPV established by this method is reliable.

Since the SPV of the species that were identified in both stages are identical, an adjustment of the SPVs of these species is needed to combine the results of the first and the second stages. The method of adjustment was to combine tables 6–17 and 7–11 from Shen's original paper (Shen et al. 1995) into one, and all the species of the two stages are listed. According to the method introduced above (Equation 3), the final SPV of each species is obtained and shown in Appendix 1. Calculated from the SPV, the CPV of all stations of the two stages are listed in Tables 1 and 2. The correlation formula between the *Pb* and the CPV of all the sampling stations is as follows:

$$CPV = 2.03231 + 0.200429 \ln Pb, \ r = 0.92 \ n = 54$$

The coefficient between CPV and ln*Pb* is significant at $P<0.00001$.

Evaluation standard of water quality

There is no doubt that the higher the CPV, the higher the degree of water pollution. Shen et al. (1995) have given an evaluation of the degree of water pollution for each sampling station by the analysis of biological and physico-chemical characteristics. Taking account of their results as well as the relationship between the CPV obtained from the final SPV (Appendix 1) and the *Pb*, the following standard is proposed:

CPV	Pollution status of water
<2.67	Unpolluted or clean water generally suitable for drinking after treatment
2.67–2.81	Slightly polluted water
2.81–2.89	Moderately polluted water
2.89–2.95	Heavily polluted water
>2.95	Severely polluted water

Table 2 Chemical characteristics and measurements for each sampling station of the second stage. (COD, chemical oxygen demand; BOD, biochemical oxygen demand; DO, dissolved oxygen; A, B, stations of the two polluted belts respectively.)

Stations	DO	COD_{Cr}	BOD	NH_3	Nitrite	Nitrate	Volatile phenol	Cyanide	*Pb*	ln(10*Pb*/*n*)	CPV_1	CPV_2	CPV
B-2	3.47	172.56	31.96	13.270	<0.001	0.731	0.146	0.3333	765.44	6.86	4.57	2.36	3.68
B-3	5.06	89.63	13.72	11.770	<0.001	0.445	0.119	0.2110	663.25	6.72	4.86	2.35	3.71
B-4	4.08	93.29	14.16	11.770	<0.001	0.440	0.1060	0.2910	658.34	6.71	4.39	2.22	3.50
A-2	4.62	1447.2	263.20	7.190	<0.001	1.082	0.1089	0.0304	598.87	6.62	4.84	2.40	3.59
B-5	8.93	14.02	3.09	2.140	<0.001	1.023	0.0590	0.0360	139.31	5.16	4.70	2.27	3.07
A-3	8.66	238.77	104.67	0.825	<0.001	0.153	0.0663	0.0105	125.40	5.05	4.38	2.11	3.36
A-4	9.37	80.18	14.98	0.324	<0.001	0.248	0.0279	0.0099	40.78	3.93	4.02	2.12	3.08
B-6	9.95	10.97	1.16	0.310	<0.001	1.088	0.0060	0.0580	20.90	3.26	3.77	2.10	2.94
A-5	9.39	22.69	5.04	0.178	<0.001	0.467	0.0100	0.0017	17.19	3.06	3.96	2.13	3.07
A-1	9.57	7.04	1.01	0.139	<0.001	0.517	0.0002	0.0000	7.93	2.29	3.61	2.02	2.82
A-6	9.40	7.82	1.66	0.107	<0.001	0.547	0.0007	0.0007	6.86	2.15	3.49	2.08	2.72
B-1	10.11	10.06	1.38	0.025	<0.001	1.118	0.0006	0.0200	3.21	1.88	3.46	2.03	2.77

DISCUSSION

The biotic index developed here is based on the identification of species collected by PFUs. First, it is suggested that it is appropriate to select the PFU method to collect protozoa and second, the methods of calculating the SPV listed in Appendix 1 and the subsequent calculation of the CPV for polluted sites is valid. Since the pollution of the River Hanjiang is mainly organic, the SPV and CPV are generally suitable for evaluating organic pollution.

The species number observed in both stages was 201, which was 56% of the total species number of the first stage and 60% of the total species number of the second stage. This shows that if no less than 56% of the species in a sample has SPV listed in Appendix 1, the CPV will be applicable.

The biotic index (CPV) is based on all protozoa occurring in the community as all species identified in a sample contribute to the assessment. This avoids the weakness of using only indicator organisms to evaluate the quality of water. A number of different communities could be formed by the animals listed in Appendix 1. The index has no fixed levels but expresses the biological quality of the sampling stations as a CPV that depends on the animals present, which makes the index a continuous gradation from clean to polluted water. It is not impossible that completely different communities may have the same CPV.

The biotic index present here takes no account of the abundance of the animals because the index is calculated by presence only. The CPV is the average of the SPVs for all the species identified and therefore the presence of single individuals cannot greatly alter a station's index. In addition, we often see that certain taxa frequently occur in very large numbers in samples and so would dominate numerical assessment such that the absolute abundance would obviously be of little use. Relative abundance is, on the one hand, subjective and, on the other hand, unnecessary because the CPV is given by dividing the total SPV obtained for a station by the number of species. Several authors (Balloch 1976; Murphy 1978) have reported that the non-pollutional stresses, such as the increasing water velocity, may make some indices correlate poorly with water quality because the number of species decreases with the increasing non-pollutional stress. For this reason, Balloch et al. (1976) and Murphy (1978) recommended the modification of the Chandler's biotic score. Balloch et al. stated that the significance of this modification "lay in the fact that upper unpolluted stations will even out, which would give values commensurate with water quality". The CPV developed here is also the average value of SPVs for each station, and in the stations with rapid current, the CPV does not tend to overestimate the pollution degree in application because the correlation coefficients between CPV_2 and current velocity (Table 1) are not significant at $P<0.05$.

Many authors tend to use bottom dwelling macroinvertebrates as indicator organisms because of their easy identification and numeration, and depend on them to develop biotic indices. As an indicator of water quality however, bottom macroinvertebrates have some obvious disadvantages. First, the conditions of bottom substrates in different rivers or different areas of the same river are greatly different, such as stones-in-current, stones-out-of-current, and different types of sediment, etc. Each of these biotopes has, in a natural watercourse, a characteristic fauna and may therefore be treated as a separate entity (Chutter 1972). This is why Chutter claimed repeatedly that his index applies only to collections of animals from the stones-in-current biotope. This situation makes the application of these indices difficult because it is difficult to find an area in which the bottom substrate is the same as the areas from which the indices originated. Also, it is difficult to suppose that we will develop different biotic indices in the same river to monitor the water quality of different sectors. Second, bottom macroinvertebrates show a very different distribution in different geographic zones, e.g., the system of Woodiwiss (1980) is not easily applicable to South African streams and rivers because no less than three of the key groups determined by Woodiwiss are absent or are of a very restricted occurrence (Chutter 1972). This limits the application of these indices dependent on bottom macrovertebrates as well. With the use of PFU, substrate is not a problem because of the sample collection method. The PFU method gives a uniform substrate for protozoan colonies. However, Thorne et al. (1997) have used artifical substrate samplers for macroinvertebrates that overcome the river substrate problem and have demonstrated that an easy-to-use biotic index can be developed for Thailand, Ghana, and Brazil using a multimetric method based on unpolluted reference sites. Their method overcomes some of the criticism on the limited geographic range of indicator species. However, unpolluted reference sites may be difficult to find for lowland rivers.

Protozoa served as indicators as early as the beginning of water quality studies 100 years ago (see

Sladecek 1973); Kolkwitz & Marsson (1908) applied them mainly for characterising polluted waters and nearly all successors of the saprobic system followed them. More than 400 species of protozoan were listed and each was given its valency, indicative weight, and saprobic index by Sladecek (1973). Protozoa, especially ciliates, were widely used in Europe to evaluate water quality (Stossil 1978; Bock & Scheubel 1979; Madoni & Ghetti 1981; Wiackowski 1981; Grabacka 1985; Albrecht 1986; Foinsser 1988; Madoni 1993). The two disadvantages of benthic macroinvertebrates are overcome by the use of protozoa. Protozoa are distributed worldwide in comparison, e.g., most of the ciliated protozoa (Italy) listed by Madoni et al. (1981, 1993) can be found in Appendix 1 (China). Protozoa are movable and react rapidly to the changing water environment. Abrupt changes can rapidly cause protozoan community structure to change. Consequently, protozoa are a better indicator of water quality at the time of sampling, and especially indicate the abrupt change and continuing changes over a short period of time. In comparison, macroinvertebrates are better at reflecting the incidence of occasional or intermittent pollution events that chemical sampling may miss and from which protozoa rapidly recover. Thorne et al. (1997) sent a questionnaire to all GEMS (Global Environmental Monitoring System) water quality monitoring stations and found that expertise on protozoa was very limited and hence recommended macroinvertebrates. This is indeed a disadvantage of protozoa, but we think that protozoa are also recommendable as discussed.

Although the precise calculation of the biotic index presented here can be debated because of the decision to base the comprehensive chemical index on the standard of Grade II for surface water, it is our belief that it provides a comparatively more objective pollution index than those previously described and that the use of the CPV is simple and economical. Four hundred and eighty-six species of protozoa and their SPVs are listed in this report. As data for more protozoan species accumulates and their SPVs are calculated, they can be used to supplement Appendix 1. Other biogroups such as *Rotifera*, *Cladocera*, and *Copepoda* could be given SPV values using similar methodology if their distribution in relation to the chemical quality index is available now or in the future. It is hoped that the SPV and CPV developed in this paper will be applicable elsewhere, or at least the method of handing biotic data according to chemical parameters will be useful worldwide.

ACKNOWLEDGMENT

This project was partly supported by Guangdong Provincial Natural Science Foundation of China 990874.

REFERENCES

Albrecht, J. 1986: Periphyton (aufwuchs) communities of ciliated protozoa in salt-polluted running water of the Weser River basin. Their structure and indicator value. *Hydrobiologia 71*: 187–224.

Balloch, D.; Dames, D. E.; Jones, F. H. 1976: Biological assessment of quality in three British rivers: the North Esk (Scotland), the Ivel (English) and Taf (Wales). *Water Pollution Control 75*: 92–114.

Beak, T. W. 1965: A biotic index of polluted streams and its relationship to fisheries. *Advance of Water Pollution 1*: 191–210.

Beck, W. M. 1955: Suggested method for reporting biotic data. *Sewage and Industrial Wastes 27*: 1193–1197.

Bock, K. J.; Schiubel, J. B. 1979: die biologische Messug der Wassergute. *Naturwissenschasften 66*: 505–512.

Bray J. R.; Curtis J. T. 1957: An ordination of the upland forest communities of Southern Wisconsin. *Ecological Monographs 27*: 325–349.

Cairns, J. Jr; Dahlberg, M. L.; Dickson, K. L.; Smith, N.; Waller, W. T. 1969: The relationship of freshwater protozoan communities to the MacArthur-Wilson equilibrium model. *American Naturalist 103*: 439–454.

Chandler, J. R. 1970: A biological approach to water quality management. *Water Pollution Control 69*: 415–421.

Chessman, B. C.; Growns, J. E.; Kotlash, A. R. 1997: Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: application to the Hunter River system, New South Wales. *Marine and Freshwater Research 48*: 159–172.

Chutter, F. M. 1972: An empirical biotic index of the quality of water in South African streams and rivers. *Water Research 6*: 19–30.

Foissner, W. 1988: Taxonomic and nomenclatural revision of Sladecek's list of ciliates (Protozoa: Ciliophora) as indicators of water quality. *Hydrobiologia 166*: 1–64.

Grabacka, E. 1985: Ecology of some waters in the forest agriculture basin of the River Brynica near the Upper Silesian industrial region. *Acta Hydrobiology 27*: 521–533.

Graham, T. R. 1965: Lothians River Purification Board Annual Report. England.

Hellawell, J. M. 1978: Biological surveillance of rivers. A biological monitoring handbook. Stevenage, Water Research Centre. 332 p.

Hilsenhoff, W. L. 1977: Use of arthropods to evaluate water quality of streams. *Technical Bulletin. No. 100*. United States Department of Nature Research. 16 p.

Hilsenhoff, W. L. 1982: Using a biotic index to evaluate water quality in streams. *Technical Bulletin No. 132*. Madison, Wisconsin, Department of Natural Resource.

Kolkowitz, R.; Marsson, M. 1909: Okologie der tierischen Saprobien Beitrage zur Lehre von der biologischen Gewasserbeurteilung. *International Review of Hydrobiology 2*: 126–152.

Lawrence, T. M.; Harris, T. L. 1979: A quantitative method for ranking the water quality tolerances of benthic species. *Hydrobiologia 67*: 193–196.

Madoni, P. 1993: Ciliated protozoa and water quality in the Parma River (Northern Italy): long-term changes in the community structure. *Hydrobiologia 264*: 129–135.

Madoni, P.; Ghetti, P. F. 1981: Ciliated protozoa and water quality in the Torrente Stirone (Northern Italy). *Acta Hydrobiology 23*: 142–154.

Murphy, P. M. 1978: The temporal variability in biotic indices. *Environmental Pollution 17*: 227–236.

Myslinske, E.; Ginsburg, W. 1977: Macroinvertebrates as indicators of pollution. *Journal of American Water Works Association 69*: 538–544.

Pantle, R.; Buck, H. 1955: Die biologische Uberwachung der Gewasser und die Darstell ung der Ergebnisse. *Gas und Wasserfach 96*: 604.

Patrick, R. 1950: Biological measure of stream conditions. *Sewage und Wastes 22*: 926–939.

Thorne, R. St. J.; Williams, W. P. 1997: The response of benthic macroinvertebrates to pollution in developing countries: a multimetric system of bioassessment. *Freshwater Biology 37*: 671–686.

Samiullah, Y. 1990: Biological monitoring of environmental contaminants: animals. GEMS—Monitoring and Assessment Research Centre. King's College, University of London. Pp. 241–259.

Shen, Y. F.; Tan, Y. Y.; Gu, M. R.; Feng, W. S.; Wu, J. Z. 1995: Monitoring of river pollution. Beijing, China Architecture & Building Press. Pp. 69–308.

Sladecek, V. 1973: System of water quality from the biologischen klassifikation der Reinheit flie ender Gewasser. *Archives of Hydrobiology 57*: 389–407.

Sladecek, V.; Tucek, F. 1975: Relation of the saprobic index to BODS. *Water Research 9*: 791–794.

Stossel, F. 1979: Ciliates as bioindicators in Swiss streams. *EAWAG News 10*: 7–10.

Walley, W. J.; Hawkes, H. A. 1996: A computer-based reappraisal of the Biological Monitoring Working Party scores using data from the 1990 river quality survey of England and Wales. *Water Research 30*: 2086–2094.

Washington, H. G. 1984: Diversity, biotic and similarity indices. A review with special relevance to aquatic ecosystems. *Water Research 18*: 653–694.

Woodiwiss, F. S. 1960: Trent biotic index of pollution. 2nd quinquennial abstract of statistics relating to the Trent watershed. Trent River Authority.

Woodiwiss, F. S. 1980: Biological monitoring of surface water quality. Summary Report. Brussels, European Economic Community ENV/787/80–EN.

(*Appendix 1 overleaf*)

Appendix 1 List of protozoan species and their species pollution value (SPV).

Species	SPV_1	SPV_2	SPV
Acanthocystis aculeata	1.99		1.99
A. brevicirrhis	2.09	3.91	2.55
A. erinaceus	1.05		1.05
A. pectinata	1.29		1.29
A. spinifera	1.69		1.69
Actinomonas mirabilis	1.01	3.29	2.15
Actinophrys sol	1.97	2.74	2.11
Achnophrys sp.		2.92	2.92
Actinosphaerium eichhorni	1.23		1.23
Amoeba proteus	2.60		2.60
Anisonema acinus	1.76	3.48	2.26
A. dexiotaxum	1.86	3.93	2.55
A. prosgeobium	1.60	2.98	2.06
Anisonema sp.		4.90	4.90
A. strenuum		2.56	2.56
Anthophysis vegetans	1.74	3.36	2.16
Arcella hemisphaerica	2.58		2.58
A. megastoma		3.15	3.15
A. vulgaria	1.85	2.36	1.91
Aspidisca costata	1.87	3.73	2.27
A. lynceus	1.76	3.10	2.03
A. sulcata	2.30	3.93	3.12
Astasia klebsii	2.31	5.00	3.21
A. parvula	1.88	4.62	3.59
Astasin sp.		5.06	5.06
Bicoeca lacustris	1.32		1.32
Bodo amoebinus	1.63	5.93	3.35
B. angustus	2.06	5.02	2.80
B. caudatus	2.32	4.38	2.83
B. celer	3.21	3.73	3.56
B. compressus	3.22		3.23
B. cruzi		4.08	4.08
B. edax minimus n. spp.	2.23		2.23
B. edax		4.38	2.59
B. fusiformis	2.28	4.14	3.40
B. globosus	2.06	4.56	2.85
B. ludibundus		3.10	3.10
B. minimus	2.30	4.38	2.79
B. mutabilis		3.89	3.89
B. obovatus	2.91	6.71	3.86
B. ovatus	2.32	3.24	3.01
B. parvus	2.68		2.68
B. putrinus	2.46	4.80	3.46
B. repens	1.72	4.35	2.38
B. rostratus		3.29	3.29
B. saltans		6.86	6.86
B. triangularis	3.14	4.51	4.05
B. uncinatus	4.78	5.27	5.15
B. variabilis	3.41	4.45	4.28
Caenomorpha medusula	2.37		2.37
Carchesium polypinum	2.44		2.44
Carteria globosa	1.29	2.44	2.16
Cashia angelica	1.35	2.91	2.39
C. limacoides	2.53	4.62	3.03
Centropyxis aculeata		3.10	3.10
Cercomastix parva		5.28	5.28

Species	SPV_1	SPV_2	SPV
Cercomoans longicauda		4.19	4.19
C. agilis	1.77	4.38	3.14
C. bodo	2.26	5.07	3.20
C. crassicauda	1.32	4.18	3.22
C. longicauda	2.85	5.75	3.97
C. ovatus	3.06	2.23	2.65
C. radiatus		4.91	4.91
C. simplex	2.84	4.53	3.83
Chilodonella acuta		2.23	2.23
C. algivora	2.14	4.47	3.07
C. aplanata	2.53	4.96	4.35
C. bavariensis	2.28	3.01	2.47
C. capucina		2.23	2.23
C. caudata	2.09	3.83	3.09
C. cucullulus	2.32	4.97	3.17
C. dentata		2.67	2.67
C. labiata	2.45	2.23	2.34
C. nana	2.45	3.33	3.20
C. turgidula	3.20		3.20
C. uncinata	2.39	4.30	2.88
Chilodontopsis muscorum		3.58	3.58
C. vovax		2.23	2.23
Chilomonas paramecium	2.03		2.03
Chlamdydomonas komma			1.95
Chlamydomonas asymmetrica	1.80		1.80
C. braunii	2.47		2.47
C. globosa	1.90	3.84	2.48
C. komma	1.95	4.04	4.04
C. microsphaera	1.99	3.81	2.42
C. mutabilis		2.74	2.74
C. ovalis	2.15	3.73	2.56
C. pertusa		5.16	5.16
C. pseudlunata	1.83	2.48	1.92
C. reinhardi	2.26		2.26
C. simplex	1.93	4.57	2.81
Chlamydomonas sp.	2.51		4.22
C. stellata	2.04	2.74	2.16
C. tornensis	1.06		1.06
Chlorogonium sp.		6.86	6.86
Chromulina elegans		4.25	4.25
C. ovalis	1.54	4.14	2.99
C. pseudonebulosa		3.29	3.29
Chromulina sp.	2.86		2.86
Chroomonas acuta	1.79	4.38	2.60
C. caudata		2.74	2.74
Chroomonas sp. 1	1.17		1.17
Chroomonas sp. 2	1.66		2.23
Cinetochilum margaritaceum	1.93	4.56	2.62
Clautriavia mobilis		6.72	6.72
C. parva	1.79	4.02	3.46
Cochliopodium bilimbosum	3.22	6.86	4.13
C. minutum	1.57	3.77	2.67
Cochlipodium n. sp.		3.88	3.88
Codosiga botrytis		2.74	2.74
C. umbellata	1.41	2.36	1.73
Cohnilembus fusiformis		3.29	3.29
C. pusillum		3.67	3.67

Species	SPV_1	SPV_2	SPV
Coleps hirtus	1.86	4.54	2.75
Collodictyon tricilatum	2.47	5.06	3.34
Colopa reniformis		6.71	6.71
Colpidium campylum	2.74	4.38	3.41
Colpidium colpoda	1.18	5.02	4.06
Colpoda reniformis	2.54		2.54
C. steini	2.22		2.22
Colponema loxodes		3.14	3.14
Cothurnia annulata	1.81		1.81
Cristigera minuta	1.51	6.72	4.12
C. setosa	1.18	3.41	3.09
Cristigera vestita	2.19		2.19
Cryptomoans pyrenoidifera		2.36	2.36
C. erosa	1.82	4.13	2.45
C. marssonii	1.27	4.43	2.42
C. ovata	1.58	3.83	2.19
Ctedoctema acanthocrypta	1.60	3.01	2.54
Cyathomonas truncata	2.11	4.27	2.59
Cyclidium centrale	2.02	3.01	3.02
C. citrullus		2.58	2.58
C. elongatum	1.82	2.56	1.98
C. glaucoma	2.59	4.13	3.29
C. lanuginosum	2.86	2.23	2.54
C. litomesum		2.23	2.23
C. muscicola	2.20	3.19	2.63
C. oblongum	1.90	5.05	2.85
C. simulans		3.29	3.29
C. singulare	2.18	2.61	2.46
C. versatile	1.25	3.69	3.42
Cyphoderia ampulla		2.36	2.36
Cyrtolophosis major	1.91	2.74	2.33
Desmarella moniliformis	1.33	3.35	2.68
Dichilum cuneiforme		3.10	3.10
D. balbianiinanum	1.19	2.23	1.71
Difflugia acuminata		2.36	2.36
D. avellana	0.94		0.94
D. elegans	0.88		0.88
D. globulosa	1.31	2.66	1.77
D. lucida		2.36	2.36
Dileptus anser		6.72	6.72
Dinobryon sociale	1.43	3.29	2.05
Dinobryon sp.	1.26		1.26
Dinomonas vorax	3.20	5.01	4.40
Diplophrys archeri	1.21		1.21
Diplophrys sp.		2.74	2.74
Discamoeba guttula	1.21	2.66	2.18
Distigma proteus	2.30		2.30
Drepanomonas obtusa	3.16	2.66	2.91
D. revoluta		3.10	3.10
D. sphagin		4.01	4.01
Dysmorphococcus variabilis.		2.36	2.36
Echinamoeba silvestris		4.70	4.71
Enchelys simplex	1.91		1.91
Entosiphon obliquum	1.60	2.30	1.80
E. sulcatum	1.78	2.66	2.03
Epalxella sp.	0.88		0.88
Epistylis articulata	1.29		1.29
E. plicatilis	1.81		1.81

Species	SPV_1	SPV_2	SPV
E. urceolata	3.41		3.41
Eudorina elegans	2.36	2.74	2.49
Euglena lucens	3.10		3.10
E. acus	2.36	4.80	2.97
E. caudata	3.12		3.12
E. chlamydophora		6.72	6.72
E. clara	1.19		1.19
E. clavata	2.22		2.22
E. deses	2.15	5.01	2.96
E. geniculata		3.29	3.29
E. gracilis	3.26	2.74	3.09
E. intermedia	1.72	5.20	3.03
E. oxyuris	3.41		3.41
E. pisciformis	1.41	3.01	1.77
E. proxima	1.33		1.33
Englena sp.	6.97		6.84
E. tristella		2.74	2.74
E. viridis	2.16	4.69	2.86
Euglypha laevis		2.23	2.23
E. tuberculata		3.94	3.94
Euplotes affinis	1.76	2.69	2.16
E. eurystomus	1.19	2.56	1.65
E. muscicola	1.71	2.66	2.03
E. novemcarinatus		3.21	3.21
Filamoeba sp.	4.32		4.32
Frontonia acuminata	1.12		1.12
F. depressa	1.51	2.36	1.94
F. leucas		2.36	2.36
Frontonia sp.	1.35		1.35
Furgasonia sorex		3.02	3.02
Glaeseria mira		6.72	6.72
Glaucoma frontata	1.81		1.81
G. macrostoma	2.49	3.84	3.07
G. scintillans	2.97	4.30	3.59
Glenodinium gymnodinium		2.36	2.36
G. pulvisculus	1.91	6.71	4.31
Gonium peotorale	3.72	3.29	3.50
Gonostomum affine		3.29	3.29
Gymnodinium aeruginosum	1.87	3.08	2.11
G. excavatum	1.22		1.22
Halteria grandinella		2.30	2.29
Hartmannella cantabrigiensis	1.99	4.67	2.72
Hastatella radians		3.10	3.10
Hemiophrys agilis		2.36	2.36
H. fusidens	2.02	5.89	3.95
H. meleagris	1.51		1.51
H. pectinata	3.25		3.25
H. pleurosigma	2.14	5.16	2.65
H. procera	1.47		1.47
Heteronema acus	1.56	2.44	1.85
H. discomorphum	1.89	2.98	2.50
H. polymorphum		3.29	3.29
H. tortum	2.70	2.44	2.57
Heterophrya sp.	1.81		1.81
H. fockei		2.36	2.36
H. radiata		6.71	6.71
Hexamastix batrachorum	2.53	6.86	4.70
Hexamita crassus	2.22		2.22

Species	SPV_1	SPV_2	SPV
H. inflatua	0.88	5.98	5.26
H. pusillus		4.68	4.68
Histriculus complanatus	4.32		4.32
H. muscorum	4.32		4.32
H. similis	1.51	3.47	3.14
Holophrya simplex	2.45		2.44
Holophyra sp.		2.74	2.74
H. sulcata	1.39	6.71	4.05
H. kessleri	1.70	3.54	2.53
Holotrcha sp.		6.72	6.72
Hyalodiscus actinophorus		3.08	3.08
Hyalosphenia cuneata	2.22		2.22
H. minuta		3.94	3.94
Hymenomonas roseola	1.29		1.29
Hypotricha sp.	2.40		2.40
Keronopsis monilata	1.87	3.51	2.53
Khawkinea breviflagellata	2.16		2.16
Lacrymaria olor O.F.	0.95	2.74	1.31
Lagynophrya conifera		3.93	3.94
Lembadion bullinum	1.81	2.36	2.08
L. lucens	1.55	2.84	1.90
Lepocinclis fusiformis	3.12		3.12
L. ovum	4.01		4.01
Lepocinclis sp.		6.71	6.71
Leptopharynx eurystoma		2.23	2.23
Lieberkuhnia sp.		2.56	2.56
Litonotus carinata	2.24	2.74	2.32
L. cygnus	1.97	2.23	2.06
L. fasciola	1.64	3.48	2.50
L. lamella	2.35		2.35
L. obtusus	2.69	2.87	2.76
Litonotus sp.	1.23		1.23
Loxocephalus ellipticus	2.69		2.69
Mallomonas elongata		2.36	2.36
Mastigamoeba invertans		5.06	5.06
Mastigamoeba sp.	4.87		5.48
Mastigella commutans		6.71	6.71
M. penardii	2.22	3.09	2.60
M. radicula	1.60		1.60
M. simplex	2.91		2.91
M. ambulans	2.30		2.30
M. bicornifrons	2.30		2.30
M. cypressa	1.98	3.51	2.36
M. hohuensis	2.78		2.79
M. penardi	2.13	3.67	2.77
M. riparia		4.54	4.54
Mastigella sp.	1.25		1.25
Merotrichia bacillata	1.91	2.36	2.13
Mesodinium pulex	1.24	3.92	3.15
Metachaos discoides	1.21	2.23	1.72
Metopus es	2.46	5.23	4.13
M. ovalis	1.51		1.51
M. pulcher	3.41		3.41
Microthorax simulans	0.91	2.76	1.83
M. viridis		3.71	3.71
Monas amoebina	4.78	3.87	3.99
M. arhabdomonas		2.74	2.74
M. elongata		4.70	4.70

Species	SPV_1	SPV_2	SPV
M. guttula	1.97	3.90	3.26
M. minima	2.20	4.56	2.75
M. sociabilis	2.53	3.55	3.29
M. socialis	2.04	4.56	2.67
M. vivipara	2.48		2.48
Monosiga ovata	1.81		1.81
M. robusta	1.89	3.81	2.73
Naegleria gruberi	2.25	4.59	2.82
Nassula aurea		2.23	2.23
N. gracilis	4.32	2.36	3.34
N. muscicola		2.36	2.36
Notosolenus orbicularis	2.28	4.23	2.63
N. sinuatus		2.36	2.36
Nuclearia sp.	3.72		3.72
Ochromonas simplex	1.25	4.72	2.99
Ochromonas sp.	1.80		1.92
O. vallesiaca		2.74	2.74
Oikomonas excavata	2.70	3.39	3.09
O. obliqua		6.72	6.72
O. ocellata	1.98	4.02	2.48
O. rostrata		2.74	2.74
O. socialis	1.96	4.36	3.06
Oikomonas sp.	1.91		1.91
O. steinii	2.06	3.95	2.81
O. termo	1.83	4.28	2.51
Ophryoglena utriculariae		4.12	4.12
Opisthotricha euglenivora		3.29	3.29
O. similis	1.94	4.69	3.32
Opisthotricha sp.		2.91	2.91
Oscillosignum proboscidium		2.23	2.23
Oxytricha fallax	2.05	4.13	2.85
O. setigera	1.75	4.28	2.74
Pandorina morum	1.18	2.44	1.81
Paracineta sp.		2.23	2.23
Paramecium aurelia	2.21	6.71	3.34
P. caudatum	2.70	4.45	3.35
P. trichium	2.46	3.19	2.83
Paruroleptus caudatus	1.39		1.39
P. musculus		3.10	3.10
Parurostyla weissei	1.22	3.14	2.19
Peranema deflexum	1.60	4.06	2.42
P. trichophorum	1.91	3.51	2.18
Peridinium bipes	1.18		1.18
P. pusillum	1.49		1.49
Peridinium sp.	1.60		1.60
Petalomonas currata	2.86		2.86
P. involuta	1.89	4.48	3.19
P. mediocanellata	1.99	3.42	2.37
P. prototheca	1.89		1.89
P. pusilla	2.11	4.36	2.60
Petalomas sp.	1.16		1.56
P. steinii	2.33	5.00	3.00
P. vulgaris	2.30		2.30
P. angusta	0.94		0.94
Phacotus lenticularis	1.32	6.72	2.40
Phacotus sp.	1.18		1.18
Phacus acuminatus	2.44		2.44
P. agilis	1.22		1.22

Species	SPV_1	SPV_2	SPV
P. anomalus	2.30		2.30
P. granum	3.72		3.72
P. hamatus	3.72		3.72
P. pyrum	1.87		1.87
Phacus sp.	3.85		3.85
P. stokesii	3.72		3.72
P. triqueter	1.22		1.22
Phyllomitus amylophagus		5.89	5.89
P. undulans		3.10	3.10
Phytomastigophorea sp.	1.60		3.43
Plagiocampa mutabilis	1.29		1.29
Plagiocampa sp.	3.41		3.41
Platyamoeba placida	1.83	3.40	2.28
Platynematum solivagum		2.74	2.74
Pleuromonas jaculans	2.20	4.38	2.67
Pleuronema cornatum	1.14	4.33	3.13
Podophrya fixa	1.25		1.25
Podophrya maupasi	1.23		1.23
P. nitidubium	3.23		3.24
Podophrya sp.		3.10	3.10
Polytoma uvella		3.29	3.29
Pronodon ovum	2.91		2.92
P. teres	2.22		2.22
P. armatus		3.10	3.10
P. discolar	3.23		3.24
P. teres	3.06		3.06
P. viridis	3.06		3.06
Pseudodifflugia gracilis	1.08		1.08
Pseudodifflugia sp.	1.19		1.19
Pseudoglaucoma musorum		5.16	5.16
Pseudoprorodon armatus		2.36	2.36
Pteromonas angulosa	1.32		1.32
Raphidiophrys pallida	1.55		1.55
R. viridis	1.45		1.45
Rhabdomoans spiralis	1.42		1.42
R. incurva	0.88		0.88
Rhagadostoma campletum	2.28		2.29
Rhynchomonas nasuta	2.19	4.38	2.69
Saccamoeba gongornia		2.23	2.23
S. limax	2.45	2.56	2.54
S. wakulla		2.67	2.67
Salpingoeca buetschlii	1.91		1.91
S. fusiformis	3.03		3.04
Saprodinium putrinium	1.91		1.91
Sarcodina sp.		4.31	4.31
Sathrophilus muscorum		2.23	2.23
S. oviformis	1.21		1.21
Solenophrya flavescens	2.69		2.69
Spathidium caudatum	4.32		4.32
S. lucidum	1.51		1.51
S. mnsicola	4.32		4.32
Sphaeroeca volvox		2.67	2.67
Sphaerophrya soliformis	2.07		2.07
Sphenomonas quadrangularis	3.41		3.41
Spirostomum minus	2.91		2.92
S. teres	3.01		3.01
Stentor coeruleus	1.36	3.29	2.00
S. roeseli	2.17		2.17

Species	SPV_1	SPV_2	SPV
Stichotricha aculeata	2.45	2.23	2.34
S. secunda	2.86		2.86
Striamoeba striata	1.90	2.66	2.21
Strobilidium gyrans	2.13	4.03	2.94
Strombidium acumintum	1.22		1.22
Strombidium sp.		2.36	2.36
S. viride	1.54	3.26	2.07
Strombomonas urceolata	0.73		0.73
Stylonychia mytilus	1.57		1.57
Suctorida sp.	2.66		2.67
Tachysoma pellionella	2.04	3.48	2.39
Tetrahymena pyriformis	2.18	3.74	2.51
Tetramitus pyriformis	4.04	5.15	4.78
T. rostratus		5.06	5.06
T. sulcatus		3.82	3.82
Thecamoeba sphaernucleolus	3.06		3.06
Thylacomonas compressa	2.20	6.71	2.77
Tintinnidium fluviatile		2.74	2.74
Tintinnidium sp.	1.47		1.47
Tintinnopsis sp.	1.60		1.60
Tokophrya lemnerum	3.41		3.41
T. quadripatita	3.87		3.87
Trachelius sp.		2.23	2.23
Trachelocerca tenuicollis		2.29	2.29
Trachelomonas abrupta		3.02	3.02
T. armata		2.74	2.74
T. crebea		6.86	6.86
T. hispida		6.86	6.86
T. lacustris	1.91		1.91
T. oblonga	3.01	5.00	4.34
T. pusilla		3.29	3.29
Trachelomonas sp.	1.49		1.49
T. spinubosa		4.25	4.25
T. velvocina	1.92	4.60	3.11
Trachelophyllum chilense	3.32	2.74	3.18
T. pusillum	2.35	4.13	2.93
T. sigmoides		2.74	2.74
Trepomonas agilis	3.47	4.72	4.31
T. rotans	3.25	6.67	5.53
T. steinii	3.11	4.95	3.94
Trichamoeba cloaca	3.17		3.17
T. villosa	1.23		1.23
Trinema enchelys		3.10	3.10
Trochila palustris		3.10	3.10
Trochilia minuta	2.06	3.50	2.44
Urceolus cyclostomus		2.67	2.67
U. parscheri	1.75	3.69	2.33
Urocentrum turbo	2.38		2.38
Uroleptus caudatus	1.91	2.74	2.02
U. dispar	3.06		3.06
U. longicaudatus	0.91		0.91
Uronema marinum		4.28	4.28
U. nigricans	2.28	4.21	3.41
Uronema sp.		2.74	2.74
Urophayus rostratus		4.50	4.50
Urostyla multipes	1.21		1.21
U. agilis	1.89	2.23	1.97
U. armata		2.87	2.87

Species	SPV_1	SPV_2	SPV
U. farcta	2.66		2.66
U. globosa		3.01	3.02
Urostyla sp.	3.06		2.65
Vahlakmpfia avare		2.67	2.67
V. inornata	6.97	6.72	6.80
V. vahlkampfia	2.58	3.90	2.85
Vannella miroides	3.77		3.77
V. platypodia	2.63	4.32	3.15
Vexillitera bacillipedes	2.53		2.53
Vorticella alba	1.23		1.23
V. campanula	1.68	2.30	1.85
V. convallaria	2.04	2.91	2.33
V. cupifera	1.51		1.51
V. extensa	1.51		1.51
V. microstoma	2.91	5.96	4.44
V. octava	4.32		4.32
V. picta	1.23		1.23
V. putrina	1.51		1.51
V. similis		2.30	2.29
Vorticella sp. 1	2.01		2.01
Vorticella sp. 2		3.14	3.14
V. striata	2.03		2.03
Xiantao sp.	2.92	5.06	4.24
Zoomastigaphorea		5.00	5.00
Zoothamnium arbuscula		2.74	2.74