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Do lake littoral benthic invertebrates respond differently to eutrophication, hydromorphological alteration, land use and fish stocking?

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Abstract – In order to provide adequate guidelines in freshwater management, managers need reliable bioindicators that can respond differently to varied stressors. Managers also have to consider hierarchical structure of environmental factors. Thus, our research aims to test the independence of taxa responses along environmental gradients and to examine in what order natural and anthropogenic factors constrain the structure of littoral benthic assemblages. The rank of explained variance of littoral benthic assemblage's variable group hierarchy was: land use > landscape characteristics > eutrophication > fish stocking > hydromorphological alteration. We determined nine gradients (two natural and seven stressor gradients), separated into five groups based on statistically significant differences in responsiveness of taxa. Apart from responsiveness to natural factors, littoral benthic invertebrates could be used as bioindicators for stressors reflecting urbanization, eutrophication, hydromorphological alteration and fish stocking. The taxonomical composition of littoral benthic invertebrates, especially when taxa with preference for certain relatively narrow environmental conditions along gradients are present, can be used to identify effects of key stressors. Our findings have profound implications for ecological assessment and management of lakes, as they indicate that benthic invertebrates can be used when the effects of multiple stressors need to be disentangled.

Keywords: macroinvertebrates / multiple stressors / bioindication / lakes / multihabitat sampling

Résumé – Est-ce que les invertébrés benthiques d'un littoral lacustre réagissent différemment à l'eutrophisation, la modification hydromorphologique, l'utilisation des terres et l'empoissonnement ?

Afin de fournir des lignes directrices adéquates en matière de gestion d'écosystèmes d'eau douce, les gestionnaires ont besoin de bioindicateurs fiables qui puissent répondre différemment à des facteurs de stress variés. Les gestionnaires ont également à considérer la structure hiérarchique des facteurs environnementaux. Ainsi, notre recherche vise à tester l'indépendance des réponses des taxons le long de gradients environnementaux et d'examiner dans quel ordre les facteurs naturels et anthropiques influent sur la structure des assemblages benthiques littoraux. L'ordre dans la variance expliquée du groupe des variables de l'assemblage benthique littoral était : l'utilisation des terres > les caractéristiques du paysage > l'eutrophisation > l'empoissonnement > l'altération hydromorphologique. Nous avons déterminé neuf gradients (deux naturels et sept gradients de stress), séparés en cinq groupes en fonction des différences statistiquement significatives dans la réactivité des taxons. En dehors de la réactivité à des facteurs naturels, les invertébrés benthiques du littoral pourraient être utilisés comme bioindicateurs pour les facteurs de stress reflétant l'urbanisation, l'eutrophisation, l'altération hydromorphologique et l'empoissonnement. La composition taxinomique des invertébrés benthiques littoraux, en particulier lorsque les taxons, avec une préférence pour certaines conditions environnementales relativement importante, sont présents le long des gradients, peut être utilisée pour identifier les effets des principaux facteurs de stress. Nos résultats ont des implications profondes pour l'évaluation et la gestion écologique des lacs, car ils indiquent que les invertébrés benthiques peuvent être utilisés lorsque les effets de multiples facteurs de stress doivent être dissociés.

Mots clés : macroinvertébrés / facteurs multiples de stress / bioindication / lac / échantillonnage multihabitat

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1 Introduction

Freshwater ecosystems are subject to accelerated rates of transformations and are some of the most endangered types of ecosystems in the world (Monroe *et al.*, 2009). In order to address this problem international laws, such as the European Water Framework Directive (WFD) (European Union, 2000), attempt to regulate and protect water bodies through the assessment and management of human-caused stressors (e.g., land use, release of chemical toxins, nutrient loading) in freshwater ecosystems (Allan, 2004; Schinegger *et al.*, 2012; Verdonshot *et al.*, 2013). Since multiple human activities contribute to environmental degradation (Crain *et al.*, 2008; Bozelli *et al.*, 2009), we need to understand the relative influences of these different activities in order to optimize freshwater management. Accordingly, management of freshwaters has been approved through development of bioassessment programs using different biotic indicators (Borisko *et al.*, 2007; Johnson and Hering, 2009).

Factors operating across a wide range of spatial and temporal scales can impact the structure and function of vulnerable aquatic assemblages (Johnson *et al.*, 2006; Sandin and Solimini, 2009; Li *et al.*, 2010). Therefore, a common approach for freshwater ecosystem assessment uses aquatic assemblages grouped according to their perceived tolerance to different environmental factors (Yuan, 2004; Mazzoni *et al.*, 2014). This generally involves determining taxon tolerance (sensitivity) values (scores) and calculating ratios of disturbance sensitive taxa to insensitive taxa (Solimini *et al.*, 2006; Donohue *et al.*, 2009a; Urbanič, 2014a). If measured environmental variables reflect different anthropogenic disturbance gradients, then species scores can help to identify the effects of different types of anthropogenic stressors (EPA, 2006).

Benthic invertebrates are commonly used in bioassessment when considering the wide range of natural habitat preferences, high biodiversity and high sensitivity to diverse environmental factors (Sandin and Johnson, 2000; Jyväsjärvi *et al.*, 2011; 2012; Miler *et al.*, 2014). Associations have been demonstrated between benthic invertebrates and variables such as submerged plant abundance (Hanson *et al.*, 2012), substratum (Donohue and Irvine, 2003), total phosphorus, chlorophyll *a* (O'Toole *et al.*, 2008), dissolved oxygen concentration (Williams, 1996), water level variability (Zohary and Ostrovsky, 2011) and availability of food resources and interspecific interactions among benthic invertebrates, such as competition and predation (Walker, 1998). Benthic invertebrates integrate the effects of various stressors, including hydromorphological changes, due to their long life cycles and low mobility, and as such may have a substantial practical advantage over other aquatic assemblages as indicator organisms (Friberg, 2014).

Whereas consolidated ecological studies based on benthic invertebrates exist for rivers (e.g., Longing *et al.*, 2010; Pavlin *et al.*, 2011; Petkovska and Urbanič, 2015), fewer similar studies exist for assessment of the ecological quality of lakes (e.g., Nöges, 2009; Jyväsjärvi *et al.*, 2011), and even fewer studies have examined littoral benthic invertebrates (e.g., Solimini *et al.*, 2006; Pilotto *et al.*, 2015). Settlement on lake shores and numerous activities makes the littoral a highly threatened zone in lakes (Vadeboncoeur *et al.*, 2001;

Jenkins, 2003; Peterlin and Urbanič, 2013). Anthropogenic disturbances, such as eutrophication (White and Irvine, 2003; Donohue *et al.*, 2009b; Bazzanti *et al.*, 2012), fish stocking (Pierce and Hinrichs, 1997; Leppä *et al.*, 2003), hydromorphological alterations (Gabel *et al.*, 2012; Jurca *et al.*, 2012; Peterlin and Urbanič, 2013; McGoff *et al.*, 2013; Urbanič, 2014b) and land use (McGoff and Sandin, 2012), may have profound effects more on the littoral zone than the profundal, and thus warrant closer considerations in lake assessments.

To fully understand the extent to which anthropogenic disturbances affect littoral benthic assemblages, it is important to understand their relationships to the environmental factors that provide the basic ecological template structuring the assemblages. Studies on species–environment relationships can also help tease apart the anthropogenically derived disturbances from the influence of natural landscape features. Identifying the relative importance of different environmental factors on littoral benthic assemblages can help prioritize management and restoration actions. We hypothesized that littoral benthic invertebrates are sensitive enough to serve as bioindicators of changes in environmental conditions. To test this hypothesis we aim to:

- examine in what order do natural and anthropogenic factors of different spatial scales constrain the distribution of littoral benthic invertebrates in lakes,
- determine group-specific environmental gradients: landscape characteristics, land use, eutrophication, fish stocking and hydromorphological alteration, and investigate the differences among responses of benthic invertebrates along environmental gradients in order to identify stressors whose effects can be disentangled using benthic invertebrates, and
- evaluate bioindication potential of littoral benthic invertebrate taxa to recognized environmental gradients through their preference for certain relatively narrow environmental conditions (*i.e.*, sensitivity).

2 Materials and methods

2.1 Study area and sampling

We included all lakes that are part of the assessment system development program for the implementation of the WFD in Slovenia (European Union, 2000). Two lakes are natural in origin and eleven are constructed lakes, which provide various ecosystem services, such as sports fishing, flood protection or irrigation. The investigated lakes are located from lowlands to the mountain foothills, and they differ considerably in their characteristics (Fig. 1, Tab. 1). Altogether, we collected data from 13 lakes (comprising 114 sites) between 2006 and 2012. Benthic invertebrate data and physico-chemical parameters were collected in the same years. However, benthic invertebrates were collected in the summer months (July–August), whereas water for physico-chemical analyses was collected four times a year in a vegetation season (March–October/November). All data were obtained as part of the national monitoring and assessment system development programs of Slovenia (e.g., Remec Rekar, 2009; Urbanič *et al.*, 2013).

We sampled benthic invertebrates using a proportional stratified sampling approach in the littoral zones

Fig. 1. Locations of study lakes in Slovenia.

Table 1. Characteristics of study lakes.

Lake	Size (km ²)	Catc (km ²)	Mean_dp (m)	t _{ret} (days)	TP (μg/L)	I-AG (%)	NAT (%)	No. Sam. 1	No. Sam. 2
Bled	1.43	6.5	19	548	10–16	4	66	26	5
Bohinj	3.28	94.3	28	146	3–11	0	98	28	4
Družmirje	0.70	32.1	24	463	22	6	68	3	1
Gajševci	0.77	124.5	3	4	99–222	57	32	8	3
Klivnik	0.36	7.8	9	214	9–12	26	67	5	2
Ledava	2.18	108.1	3	49	64–135	50	36	8	3
Mola	0.68	20.7	6	74	19–22	19	67	5	2
Pernica 1	0.66	127.7	3	60	80–224	42	25	3	3
Pernica 2	0.57	127.7	3	13	80–224	42	25	5	2
Slivnica	0.84	30.1	5	63	33–86	34	45	5	2
Šmartno	1.07	12.4	6	347	33–96	30	46	11	3
Velenje	1.35	20.4	19	885	22–52	12	58	6	2
Vogrsko	0.82	10.9	10	41	8–46	29	49	9	2

Size – lake surface area, Catc – catchment area, Mean_dp – mean depth, t_{ret} – retention time, TP – minimum and maximum value of mean annual range total phosphorous concentration, I-AG – percentage of intensive agricultural land use in the catchment, NAT – percentage of natural areas in the catchment, No. Sam. 1 – number of samples included in survey and No. Sam. 2 pooled samples as lake-year.

(Urbanič *et al.*, 2012). Sampling was conducted once a year for each lake in different years: Bled and Bohinj were sampled in 2006, 2007, 2008 and 2010; Gajševci, Ledava, Šmartno, Pernica 1 and Pernica 2 were sampled in 2006, 2007 and 2011; Klivnik and Mola in 2007 and 2012, Slivnica in 2007, 2012; Družmirje in 2011, Velenje in 2009 and 2011 and Vogršček in

2006, 2007 and 2012. Selection of sampling sites in natural lakes was determined according to the proportion of hydro-morphologically changed shoreline, which is expressed in classes of LMI, whereas in artificial lakes the determination was based on lakeshore characteristics. Each sampling site covered an area of 10 m lakeshore length and toward the open

water to 1 m depth or until a distance of 10 m was reached. To define depth strata, we divided the sampling sites into four water-depth classes: <0.25 m depth, 0.26–0.50 m, 0.51–0.75 m and >0.75 m depth. We defined the substrate categories according to the AQEM consortium (2002) with modifications for defining substrate types/strata following Urbanič (2014a). Substrate microhabitat types were defined as a combination of depth class and substrate category, scaled proportionately to their coverage at the sampling sites.

At each sampling site, we sampled benthic invertebrates in microhabitat types that covered at least 10% of the area. Each invertebrate sample was collected using a 500 μm mesh-size hand net and consisted of ten sampling units of an area of 0.625 m². We preserved samples in the field using 4% formaldehyde solution. We identified all benthic invertebrates to the lowest possible taxonomic level (usually to species or genus except for Chironomidae and Tubificidae, which were identified to family or sub-family) and determined abundances by counting all organisms from the sample. We subsequently stored all invertebrates in 70% ethanol.

2.2 Environmental variables

Composite samples were taken four times a year to measure eutrophication parameters (total phosphorus concentration, Secchi depth, orthophosphate concentration, nitrate concentration, ammonium concentration, total nitrogen concentration and chlorophyll *a*) and mean annual values were calculated prior to analysis. At the time of invertebrate sampling, we also simultaneously measured physico-chemical parameters such as water temperature, conductivity, pH, dissolved oxygen concentration and dissolved oxygen saturation. All analysis and measurements of physico-chemical parameters followed protocols in the Official Gazette of the Republic of Slovenia, which conform to international standards (e.g., ISO) (OGRS, 2009). For each sampling site, we calculated the Lakeshore modification index (LMI) (Peterlin and Urbanič, 2013) and percentage of substrate category coverage. We created four new variables combining substrate categories. To generate a lithal variable, we summed up coverage percentages of megalithal, macrolithal, mesolithal and microlithal. To generate a fine substrate variable we summed coverage percentages of akal, psammopelal, pelal and psammal substrate. To generate a phytal variable, we summed coverage percentages of macrophytes, macroalgae and filamentous bacteria. Fine particulate matter, coarse particulate matter and debris were combined to generate a particulate organic matter variable. We also determined the percentage of land use types in the lakes' catchments. Variables describing land use in catchments were calculated with GIS tools, using the Corine Land Cover classification (CLC, 2006). We distinguished six categories of land use: natural areas (CLC categories 3.4 and 5), urban areas (CLC class 1), areas with extensive agriculture (CLC categories 2.3.1 and 2.4.3), areas with intensive agricultural practice (CLC categories 2.1, 2.2 and 2.4.2), arable land (CLC categories 2.1.1 and 2.4.2) and land use defined as plantations (CLC categories 2.2.1 and 2.2.2). The Fisheries Research Institute of Slovenia provided the information on stocked fish species and their biomass for each lake-year. We then calculated the number of stocked fish species and biomass of stocked fish species feeding types. For

fish species feeding types we used information from Dušling *et al.* (2004). Altogether we extracted a set of 38 environmental variables, which have previously been shown to shape benthic invertebrates assemblages. Based on the range of multiple stressors affecting lakes worldwide (Stendera *et al.*, 2012), we divided the variables into five groups: landscape characteristics, land use, hydromorphological alteration, eutrophication and fish stocking (Tab. 2). We selected landscape characteristic variables as parameters unaffected by humans (e.g., altitude and lake size) and other variables as parameters affected by humans (stressors). In an individual stressor group, we included variables of different spatial scales. In order to elucidate contribution of pseudo replication of lake-level and catchment-level variables, we split our data in two sub-sets. One subset represented hydromorphological alteration variables for single sampling sites (122 samples) and abundances of benthic invertebrates at these sites. In the second subset, we pooled data of lake- and catchment-level variables to lake-year units. Together we had 32 samples for single lake-level or catchment-level variables, including averaged abundances of benthic invertebrates. We calculated separate Spearman correlation coefficients within each group of environmental variables (Tab. 2) in order to identify and exclude strongly correlated variables ($R_s > 0.75$). Correlation coefficients (Appendix 1) were calculated using the software package R version 3.2.1 (R Development Core Team, 2011). Statistical analysis revealed strong correlations among variables within each group. Lake mean depth and both maximum depth ($R_s = 0.95$; $p < 0.001$) and lake volume ($R_s = 0.81$; $p < 0.001$) strongly correlated. After exclusion of lake volume and maximum depth, five variables were included in the landscape characteristic group. Within the group of variables reflecting eutrophication, strong correlations were found for total phosphorus and both Secchi depth ($R_s = -0.86$; $p < 0.001$) and chlorophyll *a* ($R_s = 0.85$; $p < 0.001$). Secchi depth and chlorophyll *a* respond to nutrient concentrations and were thus excluded. Five variables of water phosphorous and nitrogen compounds comprised the eutrophication group. Among land use variables, strong correlations were found between intensive agriculture and arable land ($R_s = 0.99$; $p < 0.001$) and a strong negative correlation was found between intensive agricultural and natural land use ($R_s = -0.91$; $p < 0.001$). Thus, four variables remained in the land use group. Within the group of hydromorphological alteration variables, the strongest correlation was between LMI and Shoreline alteration ($R_s = 0.77$; $p < 0.001$). After exclusion of Shoreline alteration, the hydromorphological alteration group consisted of ten variables—six describing substrate and four LMI values calculated for different lakeshore zones. There was one strong correlation among variables representing fish stocking: omnivorous fish and biomass of stocked fish ($R_s = 0.82$; $p < 0.001$). In the fish stocking group, we included five variables: four representing fish feeding groups and one representing number of stocked fish species.

2.3 Statistical analysis

We conducted five environmental group-specific partial canonical correspondence analyses (pCCA) to determine the relationship of littoral benthic assemblages (dependent variables) to environmental factors (independent variables) with

Table 2. Five groups of environmental variables included in Spearman correlation analysis (Abbrev. – abbreviation, Med – median, Min – minimum and Max – maximum) and the data transformations that we applied (Trans.).

Group	Variable	Abbrev.	Unit	Med	Min	Max	Trans.
Landscape characteristics	Altitude	(Alt)	m	292	101	526	
	*Max depth	(Max_dp)	m	17	4	87	$\ln(x + 1)$
	Mean depth	(Mean_dp)	m	7	3	28	$\ln(x + 1)$
	*Volume	(Vol)	$\text{m}^3 \cdot 10^6$	6.5	1.2	92.4	$\ln(x + 1)$
	Lake size	(Size)	km^2	0.96	0.36	3.28	$\ln(x + 1)$
	Catchment size	(Catc)	km^2	25.4	6.5	127.7	$\ln(x + 1)$
	Retention time	(t_ret)	days	110	4	885	$\ln(x + 1)$
	Littoral zone	(Z_Litt)		0.35	0.00	0.85	
	*Shoreline zone	(Z_Shor)		0.00	0.00	0.75	
	Riparian zone	(Z_Rip)		0.25	0.00	1.00	
Hydromorphological alteration	Lake shore zone	(Z_LShor)		0.25	0.00	1.00	
	Lakeshore modification index	(LMI)		0.89	0.15	2.66	
	Lithal			44	0	100	$\arcsin(\sqrt{x})$
	FineSubs			0	0	98	$\arcsin(\sqrt{x})$
	Argyllal			0	0	99	$\arcsin(\sqrt{x})$
	Phytal			3	0	100	$\arcsin(\sqrt{x})$
	Xylal			1	0	60	$\arcsin(\sqrt{x})$
	POM			1	0	90	$\arcsin(\sqrt{x})$
	Urbanization	(URBAN)	%	1	0	11	$\arcsin(\sqrt{x})$
	Intensive agriculture	(I-AG)	%	29	0	57	$\arcsin(\sqrt{x})$
Land use	Extensive agriculture	(E-AG)	%	19	1	31	$\arcsin(\sqrt{x})$
	*Arable land	(FIE)	%	25	0	54	$\arcsin(\sqrt{x})$
	Plantations	(PLANT)	%	0	0	11	$\arcsin(\sqrt{x})$
	*Natural areas	(NAT)	%	49	25	99	$\arcsin(\sqrt{x})$
	Piscivorous	(Pisci)	kg/ha	3.36	0	18.53	$\ln(x + 1)$
	Omnivorous	(Omni)	kg/ha	3.57	0.00	1000	$\ln(x + 1)$
Fish stocking	Invertivorous–Piscivorous	(InvPisci)	kg/ha	0.11	0.00	21.33	$\ln(x + 1)$
	Invertivorous	(Inv)	kg/ha	0.01	0.00	11.38	$\ln(x + 1)$
	Herbi- and planktivorous	(HerPlank)	kg/ha	0.00	0.00	2.38	$\ln(x + 1)$
	*Stocked biomass	(kg/ha)	kg/ha	14.89	0.00	1000	$\ln(x + 1)$
	Number of fish species	(NoFishSp)	number	6.00	0.00	14.00	
	*Secchi depth	(SecD)	cm	1.96	0.22	9.78	$\ln(x + 1)$
Eutrophication	Total phosphorous	(TP)	$\mu\text{g PO}_4\text{-P/l}$	27.7	3.5	224.0	$\ln(x + 1)$
	Orthophosphate	(PO ₄)	$\mu\text{g PO}_4\text{-P/l}$	2.5	0.8	191.8	$\ln(x + 1)$
	Nitrate	(NO ₃)	$\mu\text{g NO}_3\text{-N/l}$	0.59	0.14	4.53	$\ln(x + 1)$
	Ammonium	(NH ₄)	$\mu\text{g NH}_4\text{-N/l}$	108	5	811	$\ln(x + 1)$
	Total nitrogen	(TN)	mg N/l	0.80	0.08	6.95	$\ln(x + 1)$
	*Chlorophyll <i>a</i>	(Chl_a)	$\mu\text{g/l}$	5.8	0.9	61.4	$\ln(x + 1)$

* Indicate variables which were excluded after Spearman correlation analysis.

removed spatial and/or temporal effects (covariables). When the effects of covariables are omitted from the pCCA, we are able to explain taxa variability and show important patterns of variation in the benthic invertebrate assemblage composition on account of the selected variables. To consider spatial and temporal dependence structure, latitude and longitude of the sampling sites in the Slovenian national grid and sampling year, respectively, were used as covariables (Zuur *et al.*, 2010). All samples were collected in the summer season, and thus season was not considered. We used lake-year data to conduct four pCCA separately using the following groups of environmental variables: landscape characteristics, fish stocking,

eutrophication and land use, and sampling year as a covariable. A subset with 122 benthic invertebrate samples was used in a pCCA with hydromorphological alteration variables and coordinates, with sampling year as the covariable. Prior to analyses, we selected appropriate transformation for each environmental variable to correct for heteroscedasticity in the data, whereas biological data were $\log(x + 1)$ transformed (Tab. 2). In order to give emphasis to more commonly distributed species, we downweighted rare species. In the pCCA, we used variables that individually significantly ($p < 0.1$) explained a portion of the benthic invertebrate variance after fitting covariables. Thus, the number of environmental variables was

additionally reduced prior to the pCCA environmental gradient determination. The significance of environmental variables used for littoral benthic invertebrate assemblages was defined with a Monte Carlo permutation test (999 permutations). For each selected variable, the individual contribution to the explained variance of the benthic invertebrate assemblages (λ_1) and the environmental group-specific relative portion of considered variables defined as $Rs = \lambda_1 / \lambda_{1\max}$ were calculated. Because we used CANOCO 5 for the pCCA, both environmental group-specific non-adjusted explained variances and adjusted explained variances of benthic invertebrate assemblages also were calculated (Ter Braak and Šmilauer, 2012). In order to compare taxa environmental gradient preferences, first and second pCCA axes (environmental group specific species scores) were used (Appendix 2). Species scores were normalized to a common scale of 0 to 1, where 0 indicates the most degraded/lowest and 1 the pristine/highest value. Prior to normalization, direction of environmental gradient increasing was defined (Fig. 4). Normalisation was done according to equation (1):

$$\text{Value} = \frac{\text{SC_CCA}_{e-i} - \text{SC_CCA}_{e-LA}}{\text{SC_CCA}_{e-REF} - \text{SC_CCA}_{e-LA}}, \quad (1)$$

where SC_CCA_{e-i} is the environmental group specific species score (biplot scaling) of the i th taxon and SC_CCA_{e-REF} is the pristine/highest value of the environmental group specific species score and SC_CCA_{e-LA} is the most degraded/lowest value of the environmental group specific species score. In calculation of highest and lowest environmental group specific species score, extremes and outliers were not considered. In order to determine the relationship between recognized environmental gradients and littoral benthic assemblage structure in more detail, we determined taxa tolerance values that are frequently used in bioassessment (e.g., Zelinka and Marvan, 1961; Urbanič, 2014b). We determined tolerance values using the pCCA ordination axis species tolerance (root mean squared deviation for species) according to Table 3. To detect differences in the mean species score values and mean tolerance values among environmental gradients, we used Friedman tests followed by a post-hoc multiple comparison Wilcoxon signed-rank tests. For this type of analyze we used SPSS Statistics 21 (IBM, 2012) for Windows.

3 Results

3.1 Benthic invertebrate assemblages

A total of 136,358 individuals, representing 253 taxa (Appendix 2) were recorded at the 114 sampling sites and 32 lake-years (Fig. 2). Diptera was the most abundant group (48,504), followed by Oligochaeta (33,272) and Heteroptera (16,924) (Fig. 2). The most diverse group was Coleoptera (37), followed by Diptera and Trichoptera (both 36) (Fig. 2). More than 15 taxa were recorded in each of the following four groups: Oligochaeta (27), Odonata (28), Gastropoda (19) and Ephemeroptera (18). Other groups were less diverse. Differences in diversity also reflected the varied taxonomic resolution of the groups.

3.2 Effects of environmental gradients

Gradient analyses were run separately for each variable group with four (land use group) to nine variables (hydro-

Table 3. Determination of tolerance values of 253 taxa (Tv) derived from pCCAs analyses.

pCCA tolerance values	Tv
<0.4	5
0.4–0.6	3
0.6>	1

morphological alteration group) (Tab. 4). The first axis individually and all canonical axis together were statistically significant ($p < 0.05$) in each environmental variable group (Tab. 5). In the land use group, the highest proportion of variation in the benthic invertebrates was explained by intensive agriculture (17.5%). Other variables of the land use group showed moderate (relative $\lambda_1 = 0.5–0.75$) or relatively weak (relative $\lambda_1 < 0.5$) explanatory power. In the landscape characteristic group, mean depth explained the highest proportion (16.2%). Additionally, lake size and altitude showed relatively high (relative $\lambda_1 > 0.75$) explanatory power, whereas retention time and catchment size were approximately half as explanatory as mean depth. Total phosphorus (15.4%) was the best explanatory variable in the eutrophication group. Other variables of that group were moderately explanatory (relative $\lambda_1 = 0.5–0.75$). In the fish stocking group, the highest variance of the benthic invertebrates was explained by omnivorous fish (10.3%). In the hydromorphological alteration group, the variable littoral zone contributed significantly less to explaining variance (2.5%), likely because of the higher number of samples, which resulted in higher total inertia (1.995) compared with other environmental groups (1.636). Also, two variables of the hydromorphological alteration group (LMI and lithal) showed relatively high (relative $\lambda_1 > 0.75$) explanation power, whereas all other variables were moderately explanatory.

The partial variation in the benthic macroinvertebrate taxa (253) data was 1.995 using the 122 samples (hydromorphological alteration group) and 1.636 including the 32 lake-years (for all other environmental groups) (Tab. 5). Comparable amounts (29–38%) of the total variation in littoral benthic assemblages were explained individually by land use, landscape characteristics, eutrophication and fish stocking variables, whereas hydromorphological alteration variables explained substantially less (14%) (Fig. 3). Adjusted values of the explained variance revealed bigger differences among variable groups and provided the following ranking scheme: land use (29%) > landscape characteristics (24%) > eutrophication (17%) > fish stocking (15%) > hydromorphological alteration (6%).

3.2.1 Landscape characteristics gradients

Examination of the landscape pCCA ordination diagram indicated two gradients (Fig. 4a). The first landscape gradient represented lake morphometry and explained a majority of the variance in the taxa–environment relationship (53%). Along the first pCCA axis shallow, small and mostly lowland lakes on the right hand side are separated from the deep, mid-sized and mid-altitude lakes on the left-hand side. Nevertheless, a gradual taxa turnover is found along the lake morphometry

Fig. 2. Abundance (black bars) and diversity (gray bar) composition of major taxonomic groups of littoral benthic invertebrates in the dataset.

gradient. Lake catchment size is reflected by the second pCCA axis (23% of variance explained), and thus separating lakes along the catchment dimension gradient. Lakes with a big catchment area were found in the lower part, whereas lakes with a small catchment area were distributed in the upper part of the ordination plot. Along the second axis, most taxa were distributed in the central part of the ordination plot, showing weak effects of catchment size on specific littoral benthic invertebrate taxa.

3.2.2 Land use gradients

Two gradients were determined after inspection of the land use pCCA ordination diagram (Fig. 4b). Intensive agriculture was reflected by the first axis, which explained half of the variance in taxa (50%). Along the first pCCA axis, lakes with a high share of intensive agricultural land use and a high share of plantations in lake catchments on the left-hand side are separated from a few lakes with less agricultural land use on right-hand side. Separation of taxa into two groups along the first gradient implies profound effects of agriculture. The second axis indicates a gradient of urbanization (26% of variance explained). Lakes with a big share of urbanization land use are found in the upper part along second axis, whereas lakes with a small share of urbanization land use are distributed in the middle of the ordination plot. Along the second axis, taxa are mostly distributed in the central part of the ordination plot with few in the upper part, indicating a specific effect of urbanization on specific littoral benthic invertebrate taxa.

3.2.3 Eutrophication gradients

Eutrophication pCCA ordination diagram reflected two gradients (Fig. 4c). The first gradient represented nutrients and explained the majority of variance in the taxa–environment relation (51%). Along the first pCCA axis, lakes were evenly distributed. On the other side, taxa were clearly separated in two groups along first gradient, which implies the high effect of nutrients on littoral benthic invertebrates. Ammonium gradient was determined along the second axis of pCCA ordination diagram (20% of variance explained). Lakes are evenly distributed along the ammonium gradient. Taxa were mostly distributed in the central part of the diagram along the second axis, indicating a weak relation to ammonium.

3.2.4 Fish stocking gradient

Only one gradient was determined from the fish stocking pCCA (Fig. 4d). The gradient along the first axis represents biomass of omnivorous fish, explaining 39% of variance of benthic invertebrates. A majority of lakes and taxa were distributed in the central part along the omnivorous fish gradient. The centralized position of taxa implies that the omnivorous gradient fish had a weak effect on the littoral benthic invertebrates.

3.2.5 Hydromorphological alteration gradients

The hydromorphological alteration pCCA revealed two gradients (Fig. 4e). Along the first axis, littoral alteration gradient explained 27% of variance of littoral benthic

Table 4. Marginal effects of environmental variables (λ_1) including covariables, significance (p -value) and group specific relative importance of each environmental variable (relative λ_1) for the littoral benthic invertebrate assemblage composition.

Environmental variable	Variable group	λ_1 (explained %)	Relative λ_1	p -value
Mean depth	Landscape characteristics	16.2	1.0	0.001
Lake size	Landscape characteristics	12.9	0.8	0.001
Altitude	Landscape characteristics	12.4	0.8	0.001
Retention time	Landscape characteristics	9.2	0.6	0.001
Catchment size	Landscape characteristics	8.6	0.5	0.001
Intensive agriculture	Land use	17.5	1.0	0.001
Extensive agriculture	Land use	11.8	0.7	0.001
Urbanization	Land use	10.2	0.6	0.002
Plantations	Land use	7.7	0.4	0.003
Total phosphorous	Eutrophication	15.4	1.0	0.001
Nitrate	Eutrophication	9.5	0.6	0.001
Ammonium	Eutrophication	9.1	0.6	0.002
Total nitrogen	Eutrophication	7.8	0.5	0.003
Orthophosphate	Eutrophication	7.5	0.5	0.005
Omnivorous	Fish stocking	10.3	1.0	0.002
Herbi- and planktivorous	Fish stocking	6.8	0.7	0.008
Invertivorous	Fish stocking	5.7	0.6	0.055
Number of fish species	Fish stocking	5.2	0.5	0.054
Piscivorous	Fish stocking	4.8	0.5	0.097
<i>Invertivorous–Piscivorous</i>		2.4	0.2	0.829
Littoral zone	Hydromorphological alteration	2.5	1.0	0.001
Lakeshore modification index	Hydromorphological alteration	1.9	0.8	0.001
Lithal	Hydromorphological alteration	1.9	0.8	0.002
Riparian zone	Hydromorphological alteration	1.8	0.7	0.001
Xylal	Hydromorphological alteration	1.6	0.6	0.005
Lakeshore zone	Hydromorphological alteration	1.5	0.6	0.004
Fine substrate	Hydromorphological alteration	1.3	0.5	0.025
Phytal	Hydromorphological alteration	1.3	0.5	0.020
Argyllal	Hydromorphological alteration	1.1	0.4	0.060
<i>Particulate organic matter</i>		1.0	0.4	0.198

Variables that are not significant are italicized.

Table 5. Results of five partial CCAs. Analyses were conducted separately with fish stocking, land use, hydromorphological alteration and eutrophication variables with covariables. Groups of variables differ in spatial scale.

Spatial scale	Group of variables	Covariables	Total inertia	Eigenvalues pCCA1	Eigenvalues pCCA2	p -value	p^* -value
Catchment scale	Land use	Year	1.636	0.31	0.17	0.001	0.001
Catchment scale/within lake	Landscape characteristics	Year	1.636	0.31	0.14	0.001	0.001
Within lake	Eutrophication	Year	1.636	0.26	0.11	0.001	0.001
Within lake	Fish stocking	Year	1.636	0.19	0.12	0.014	0.002
On site	Hydromorphological alteration	Year, coordinates	1.995	0.07	0.05	0.001	0.001

Year – sampling year, coordinates – geographical coordinates, p -value – significance of first axis and p^* -value – significance for all axis.

invertebrates. Samples are concentrated on the right-hand side of the diagram, which represents highly hydromorphologically altered sites. On the left-hand side, where hydromorphological alteration is absent, we only have one site. Comparable variance was explained along the second axis (17%), and reflected a substratum gradient along which sites and taxa were evenly distributed.

3.3 Taxa along environmental gradients

A partial CCA for separately tested groups of environmental variables suggested that there were two landscape gradients: one combination of landscape and stressor gradient, and six evident stressor gradients explaining the variance of littoral benthic invertebrates. Distribution of

Fig. 3. Percentage of non-adjusted and adjusted explained variance in the littoral benthic invertebrate assemblages by each of the five groups individually.

benthic invertebrate taxa significantly differed in more than half of the gradients (Friedman test, $\chi^2(8)=196.929$; $p<0.0001$, Fig. 5). Pairwise analysis revealed significant differences in species scores between combinations of gradients ($Z=-1.508$ to 3.223 ; $p<0.037$ to <0.0001), which resulted in five established groups of gradients (Appendix 3; Fig. 5). The first group consisted of three gradients—lake morphometry, catchment size and urbanization. The second group was represented by urbanization and ammonium. The third group included ammonium, nutrients, intensive agriculture and littoral alteration. The fourth group included nutrients, intensive agriculture, littoral alteration and substratum. The distribution along gradient of omnivorous fish was unique and alone represented the fifth group. Besides observed differences in distribution of taxa, there was also a significant difference in sensitivity of taxa to landscape characteristics and stressors (Friedman test, $\chi^2(8)=292.686$; $p<0.0001$) (Appendix 3; Fig. 6). Significant differences occurred in few gradients pairs ($Z=0.789-1.603$; $p=0.043$ to <0.0001) and resulted in four established groups of gradients (Appendix 3; Fig. 6). Higher sensitivity of taxa was detected

in the first group, which consisted of lake morphometry, intensive agriculture, nutrients, omnivorous fish and urbanization. Intensive agriculture, nutrients, omnivorous fish, urbanization and catchment size formed a second group. The third group included nutrients, omnivorous fish, urbanization, catchment size, ammonium and littoral alteration. The fourth group was represented by ammonium, littoral alteration and substratum, and was characterized by taxa with higher tolerance values.

4 Discussion

This study has potential to support progress in indicator development, which at the moment is imperative for effective lake management. Identifying widely applicable bioindicators in multiple stressor environments will have a profound impact on management performances not only through separately assessing stressors' effects, but also through lowering the costs by defining hierarchy of actions, which prevent decline in ecological quality of lakes.

Fig. 4. Results of pCCA ordination (axes 1 and 2) of littoral invertebrate assemblages from 114 sampling sites and 32 lake-years. Next to the gradient explained fitted variation of axis is added. (a) Triplot of landscape characteristics, species and lake years. (b) Triplot of species, land use variables and lake years. (c) Triplot of species, lake-years and eutrophication variables. (d) Triplot of species, lake-years and fish stocking variables. (e) Triplot of species, sampling sites and hydromorphological variables. For abbreviations see Table 2 (● – sampling sites or lake-years; Δ – taxa).

Fig. 5. Box plot showing the distribution of taxa based on normalized species scores along nine different gradients. Analysis is by Friedman test—letters indicate homogenous subgroups. The dark line inside each box represents the median; error bars show the minima and maxima except for outliers (open circles). The color of each box indicates the category of gradient along which littoral benthic invertebrates responded.

4.1 Teasing apart drivers of littoral benthic assemblages

Our sampling sites exhibit a wide range of chemical and physical factors, reflecting differences in landscape characteristics and anthropogenic disturbances among lakes and sampling sites. Environmental variables occur at different spatial scales—catchment zone (land use variables), catchment-within lake zone (landscape characteristics variables), within lake zone (eutrophication and fish stocking variables), riparian zone (hydromorphological alterations variables) and site zone (substrate variables). Comparison of stressors with lake-years units revealed that land use (29%) and landscape characteristics (24%) explained more variation in littoral benthic assemblage structure than eutrophication (17%) and fish stocking (15%). The pCCA results indicated a dominance of catchment scale variables over lower spatial scale variables, which corroborate the hypothesis of a hierarchical complexity of environmental factors (Poff, 1997). Johnson and Goedkoop (2002) also found this and argued that catchment variables define the upper limits for local factors representing closely cascading effects of environmental variables. Although in our

case, we cannot directly compare explained variation of two different subsets (*e.g.*, hydromorphological alteration vs eutrophication). Our results seemingly support the conclusion of Urbanič (2014b), indicating the possible dominance of eutrophication when assessing hydromorphological alterations of different lake types. In contrast to our findings, many researchers reported that local (morphological/habitat) variables dominate over within-lake variables (eutrophication) in shaping littoral benthic assemblages (Tolonen *et al.*, 2001; McGoff and Sandin, 2012; Pilotto *et al.*, 2015). The reason for discrepancy might be that in the mentioned studies temporal and spatial variability were not taken into consideration. Based on our results, it is evident that the factors at catchment and lake scale may be crucial for local littoral benthic invertebrate assemblage distribution. The latter also emphasizes the importance of using a hierarchical approach in management of lakes, especially when dealing with the effects of co-occurring environmental factors. Further, when assessing the effects of environmental factors, a prioritization of such factors at larger spatial scales is needed. However, since the distribution of littoral invertebrates is governed by the interplay of habitat structure, nutrient quantity and landscape

Fig. 6. Histogram showing the dispersion of taxa based on tolerance values grouped in ranges along nine different gradients. Analysis is by Friedman test – letters indicate homogenous subgroup.

characteristics, one should acknowledge factors on numerous spatial scales.

Comparison of littoral benthic invertebrates' responses with multiple environmental gradients simplifies mechanisms explaining relationships between different environmental factors and littoral benthic assemblage. As the structure of assemblages is a reflection of the on-site conditions and the influences of the catchment conditions, which are expressed directly and indirectly, responses along some gradients are not independent. According to previous studies (Brodersen *et al.*, 1998; Stefanidis and Papastergiadou, 2012; Mehner *et al.*, 2007), the morphology of lakes is one of the most important factors controlling the trophic status, physico-chemistry, productivity and distribution of aquatic organisms. This was supported in our study, where littoral benthic invertebrates tended to be gradually distributed along a lake morphology gradient. Lake mean depth explained the highest variance of littoral benthic assemblages, which supports previous findings of mean depth as a key predictor for benthic invertebrates (Brodersen *et al.*, 1998). A possible explanation lies in differences of nutrient mixing, thermal stratification and usually vegetation cover (Wetzel, 2001), all of which are linked to food availability and habitat quality. The same explicit interpretation cannot be made for the catchment size gradient. We did not find any study revealing the direct impact of catchment size on littoral benthic assemblages. However, the influence of the catchment size effects should be greater when the catchment is larger and impaired. Hence, many researchers focus rather on the effects of land use in catchment on assemblages. Generally, land use depends on suitability of the area for urban and agricultural development (Petek, 2004). Thus, coinciding responses along urbanization gradient and gradients within landscape characteristics variables were expected. Urbanization and intensive agriculture seems to

be related to ammonium as the commonest sources of ammonium are sewage effluents and effluents associated with industries producing coals, gas, coke and fertilizers (Hall *et al.*, 1999; Wang *et al.*, 2006). Usually the effect of ammonium is interpreted through the depletion of oxygen (Rosenberg and Schleifer, 2006) or a toxic effect (Camargo *et al.*, 2005), which influences littoral benthic assemblage structure (Verdonschot and Verdonschot, 2014). Pattern of responses along intensive agriculture, nutrients, littoral alteration and substratum gradient, where no differences were recognized, could be interpreted through a few mechanisms. Effects of intensive agriculture on littoral benthic assemblages are indirect, such as habitat destruction and nutrient loading, which leads to eutrophication processes (e.g., Fraterrigo and Downing, 2008; Kovalenko *et al.*, 2010). Consequently, the responses of littoral benthic invertebrates to nutrients are partially integrated in responses to agricultural land use. Furthermore, nutrient enrichment promotes the changes in habitat structure (Donohue *et al.*, 2009a). More specifically, this indicates that nutrients are surrogates for increased allochthonous material (litter fall), which affect substratum composition. Substratum is also strongly related to hydromorphological changes (McGoff *et al.*, 2013; Peterlin and Urbanič, 2013; Urbanič, 2014b), more precisely to littoral alteration, which causes direct impacts on littoral benthic assemblages (Johnson and Goedkoop, 2002; Porst *et al.*, 2016).

Benthic invertebrates' responses along an omnivorous fish gradient, which show distinction among gradients, are not so evident. Independent responses of littoral benthic invertebrates along an omnivorous fish gradient should serve as a reminder for taking a holistic approach, especially while assessing the impact of stressors, and highlight underestimation of some stressors' effects. We assume that the differences in responses along the omnivorous fish gradient reflect the ubiquitousness

of the fish stocking stressor, which is independent from natural lake characteristics and other alterations. Although several researchers focused on the impact of biomanipulation in lakes (e.g., Eby *et al.*, 2006), our knowledge on the effects of fish stocking on littoral benthic assemblages in different types of lakes is scarce. Presence of fish can influence littoral benthic invertebrates in several ways, including biological interactions, nutrient dynamics, sedimentation, and oxygen dynamics (Brönmark and Hansson, 2005; Bernes *et al.*, 2013). Despite the short length of our fish stocking gradient (0–1000 kg/ha) compared with other studies, importance of fish stocking was supported by our findings (e.g., Berg *et al.*, 1997; Nasmith *et al.*, 2010). Nonetheless, the second unrecognisable gradient may point out the unavailability of detailed predictors data like fish population density of each lake.

Some processes still make separation of littoral benthic assemblages' responses among gradients difficult. However, five groups of gradients represented responsiveness along three categories of gradients: from natural through mixture of natural and stressors over to stressor gradients. Despite the fact that correlations among stressors might be present, independent responsiveness provides good evidence about applicability of littoral benthic invertebrates as a bioindicator tool. As a bioindicator, they can help identify stressors reflecting urbanization (masking the effect of ammonium), stocking of omnivorous fish and eutrophication, which might be caused by intensive agriculture or littoral alteration which affects the regrowth of primary producers (e.g., macrophytes) and contributes to primary production. Taxa also showed different responses to littoral alteration and substratum gradients, independent from activities in catchment, implying that morphological changes might be identified separately. Taken together, littoral benthic invertebrates show potential in disentangling multiple stressors, which would likely solve one of the key issues in freshwater management.

4.2 Bioindication

Benthic invertebrates have a long history of use in bioassessment due to their sensitivity to different environmental changes (Furse *et al.*, 2006). Based on three tolerance groups of taxa, our analysis revealed preeminence of specialists on generalists along six gradients. Specialists are the most useful environmental indicator species, due to the preference for certain relatively narrow environmental conditions (Soininen, 2007). Hence, our results imply that benthic invertebrates could be good indicators for gradients along natural characteristics of lakes, intensive agriculture, omnivorous fish, urbanization and nutrient concentrations. The tolerance structure of benthic invertebrate taxa along substratum gradient exhibited a surprisingly bigger share of generalists, which is contrary to many studies, which show relatedness of invertebrates to substratum type (e.g., Pilotto *et al.*, 2015). One possible reason for divergence in conclusions may be different sampling technique. While we used a proportional stratified sampling approach, others used habitat specific sampling. Moreover, the dominance of generalists was found also along ammonium, littoral alteration and substratum gradients, consistently supporting the assumption about dominance of large scale stressor effects over small

scale stressor effects (Urbanič, 2014b). However, one has to consider that lentic invertebrates have developed a wide array of adaptations in order to cope with changes in environment, resulting in significant tolerance values (Sharitz and Batzer, 1999). Due to the long term of anthropogenic alteration, shifts have happened in assemblage composition, resulting in species adapted to low stressor (e.g., nutrient) environments being replaced by stress tolerant species.

Sensitivity of taxa to varying stressors serves as the basis for index development for use in assessing quality of lakes. Considering one to three taxon characteristics (indicative value, indicative weight based on tolerance values and abundance), robust indices might be developed (Saprobien index, Zelinka and Marvan, 1961; Urbanič, 2014a). According to our results, a bigger share of specialists than generalists along the majority of gradients should encourage the use of littoral benthic invertebrates in lake bioassessment.

5 Conclusions

In order to enhance lake status while dealing with multiple stressors, managers strive to use bioindicators that can respond to various stressors and identify the hierarchical structure of environmental factors. We recognized that the order of natural and anthropogenic factors indicates that catchment-scale factors should take precedence over local scale factors when anthropogenic interventions are necessary to improve ecological conditions of lakes. Differences in responses along nine environmental gradients indicate that littoral benthic invertebrates can be used to independently assess the impact of varied stressors (hydromorphological alterations, fish stocking, eutrophication and urbanization), and thus fulfill the requirements for the effective stressor-specific biotic indices. Occurrence of relatively high numbers of sensitive taxa along gradients implies that the key stressors can be assessed using a taxonomical composition of littoral benthic invertebrates. There is no similar study, to our knowledge, based on a diverse data set from lowland lakes to alpine lakes, which simultaneously considers spatial and temporal variability. Hence, our findings have practical implications for ecological assessment and effective management of lakes, as they indicate that benthic invertebrates can be used when the effects of multiple stressors need to be disentangled. We advocate development of varied littoral benthic invertebrate based stressor-specific indices in order to maximize cost-effectiveness of lake management.

Conflict of interest. The authors declare that they have no conflict of interest.

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Appendix 1

Spearman's rank correlation coefficients between environmental variables within each group.

Landscape characteristics	Alt	Max_dp	Mean_dp	Vol	Size	t_ret				
Max_dp	0.65**									
Mean_dp	0.71**	0.95**								
Vol	0.60**	0.84**	0.91**							
Size	0.39*	0.41*	0.47**	0.75**						
t_ret	0.72**	0.69**	0.67**	0.64**	0.35					
Catc	-0.33	-0.55**	-0.55**	-0.51**	-0.09	-0.66**				
Fish stocking	Pisci	Omni	InvPisci	Inv	HerPlankt	kgha				
Omni	0.19									
InvPisci	0.38*	-0.27								
Inv	0.30	0.18	0.17							
HerPlankt	0.49**	0.59**	0.15	0.30						
kgha	0.47**	0.82**	-0.01	0.01	0.58**					
NoFishSp	0.39*	0.37*	0.35*	0.64**	0.58**	0.15				
Eutrophication	SecD	TP	PO ₄	NO ₃	NH ₄	TN				
TP	-0.86**									
PO ₄	-0.64**	0.69**								
NO ₃	-0.52**	0.58**	0.30							
NH ₄	-0.31	0.44*	0.28	0.12						
TN	-0.64**	0.73**	0.57**	0.71**	0.44*					
Chl_a	-0.86**	0.85**	0.78**	0.47**	0.41*	0.61**				
Land use	URBAN	I-AG	E-AG	FIE	PLANT					
I-AG	-0.05									
E-AG	0.19	0.26								
FIE	-0.12	0.99**	0.20							
PLANT	0.38*	0.44*	0.42*	0.34						
NAT	-0.24	-0.91**	-0.47**	-0.87**	-0.58**					
Hydromorphological changes	Z_Litt	Z_Shor	Z_Rip	Z_LShor	LMI	Lithal	FineSubs	Argyllal	Phytal	Xylal
Z_Shor	0.60**									
Z_Rip	0.38**	0.53**								
Z_LShor	0.23**	0.33**	0.38**							
LMI	0.66**	0.77**	0.74**	0.68**						
Lithal	-0.11	0.26**	-0.01	-0.11	0.01					
FineSubs	-0.11	-0.12	-0.04	0.03	-0.03	-0.44**				
Argyllal	0.15	-0.14	0.08	-0.04	-0.01	-0.53**	-0.03			
Phytal	0.19*	-0.14	0.07	0.09	0.06	-0.66**	-0.13	0.62**		
Xylal	0.09	-0.15	0.04	0.05	-0.02	-0.41**	0.15	0.17	0.16	
POM	-0.32**	-0.46**	-0.28**	-0.13	-0.34**	-0.34**	0.28**	0.21*	0.01	0.26**

Significance is shown as asterisks (***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$). Bold values are strong correlations ($R_s > 0.75$). For environmental variable codes see [Table 2](#).

Appendix 2

Benthic invertebrate taxa (with main taxonomic groups their number and occurrence at sampling sites) recorded at 114 sampling sites of lakes in Slovenia, used in analyses.

Code	Taxa and taxonomic group	Num	Occ	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs	
Turbellaria													
Den_alb	<i>Dendrocoelum album</i>	15	4	Ss	-0.8533	1.5693	-0.5421	0.8729	2.0636	0.5744	1.3994	0.5944	-0.3404
Den_lac	<i>Dendrocoelum lacteum</i>	42	14	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7731	1.1163
				Ss	-1.0089	1.2072	-0.6796	0.9982	1.6081	0.7320	1.0248	0.4132	-0.6535
Dug_l_p	<i>Dugesia lugubris/polychroa</i>	28	6	Tv	0.3830	1.0759	0.2913	0.3616	1.3608	0.3769	0.9332	1.6081	0.8042
				Ss	0.1357	-0.3205	0.7789	-0.1931	0.1947	-0.3635	0.0369	0.7434	-1.2291
Dug_tig	<i>Dugesia tigrina</i>	788	14	Tv	1.0241	1.3888	1.3676	1.1260	1.5510	0.9977	1.2580	1.2499	1.1289
				Ss	0.1770	-0.0343	0.6849	-0.2041	0.4550	-0.4777	0.0560	0.4263	-0.8797
Plan_tor	<i>Planaria torva</i>	19	4	Tv	0.9028	1.3960	1.0571	0.9582	1.4329	0.9546	1.5666	0.9503	0.9385
				Ss	-0.6903	1.3190	-0.4619	0.8025	1.9827	0.4529	1.5182	1.1374	-0.6112
Poy_fel	<i>Polycelis felina</i>	2	2	Tv	0.6254	0.9605	0.3078	0.2703	0.3106	0.4659	0.4556	0.8993	0.8864
				Ss	-0.1556	1.0205	-0.4126	0.0928	0.1930	0.5608	0.3698	-0.3991	0.0283
Poy_t_n	<i>Polycelis nigra/tenuis</i>	36		Tv	0.7720	0.4955	0.3343	0.7849	1.7819	0.2022	0.5645	0.2659	0.4393
				Ss	-1.6448	-0.5899	-1.0819	1.6022	-0.6648	1.3472	-0.2079	-0.3680	-0.6069
				Tv	0.4206	1.1410	0.2866	0.3855	1.4417	0.5139	0.9744	0.4731	0.7116
Nematoda													
Nem_oda	Nematoda	55	29	Ss	0.2061	-0.3062	0.3398	-0.1409	0.0372	-0.2394	0.2194	0.1237	-0.0290
				Tv	1.0731	0.9555	1.2221	1.0227	0.9919	1.0740	0.8504	1.1475	1.1424
Oligochaeta													
Ench_dae	Enchytraetidae	340	26	Ss	-0.7300	-0.4240	-0.6018	0.6807	-0.3628	0.6459	-0.1482	-0.4510	0.1313
				Tv	1.2503	0.9626	0.8090	1.2525	1.0936	1.2067	0.7186	0.7253	0.9306
Hap_gor	<i>Haplotaxis gordioides</i>	1	1	Ss	-1.8174	-0.9944	-1.1608	1.7420	-1.1737	1.3954	-0.1809	-0.3292	0.6313
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Eis_tet	<i>Eiseniella tetraedra</i>	239	33	Ss	-1.0309	-0.1504	-0.7392	0.9925	-0.2082	0.9485	-0.1886	-0.0692	-0.1775
				Tv	0.9493	1.1356	0.6874	0.9633	1.3562	0.8324	0.9423	1.1466	0.8754
Lub1_dae	<i>Lumbriculidae</i> – single pointed setae	32	4	Ss	-1.3587	0.2772	-0.8656	1.3135	0.4337	0.9998	0.4084	0.6076	0.3532
				Tv	0.6487	1.7983	0.4175	0.6060	2.2733	0.5594	0.8334	1.3819	0.7651
Lub_var	<i>Lumbriculus variegatus</i>	1030	49	Ss	-0.8929	-0.2026	-0.6354	0.8771	-0.2062	0.7849	-0.1252	-0.3335	-0.0888
				Tv	1.0918	1.1365	0.8575	1.0930	1.3127	1.0073	1.0801	0.8754	0.8793
Rhn_spp	<i>Rhynchelmis</i> sp.	15	1	Ss	1.1692	-1.0756	2.3824	-0.9959	-0.0898	-1.5180	0.6143	-1.1310	0.0019
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sto_her	<i>Sylodrilus heringianus</i>	1216	33	Ss	-1.6238	-0.5719	-1.0931	1.5942	-0.6434	1.3837	-0.4240	-0.3536	-0.0663
				Tv	0.3738	1.0363	0.2766	0.3491	1.3102	0.5328	0.9949	0.8440	0.6801
Sto_spp	<i>Sylodrilus</i> sp.	148	9	Ss	-1.5360	-0.8191	-1.0769	1.5677	-0.7877	1.4963	-0.5549	-0.6902	-0.3679
				Tv	1.1241	0.7388	0.6962	0.7724	1.7301	1.1410	1.8860	0.6054	0.4383
Cht_spp	<i>Chaetogaster</i> sp.	1	1	Ss	0.0311	0.2110	-0.1068	0.4907	1.6244	-0.0846	2.0438	0.9029	0.5264
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix 2. Continued.

Code	Taxa and taxonomic group	Nun	Occ	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Der_spp	<i>Dero</i> sp.	722	20	Ss 0.8923	-0.5993	0.7664	-0.8228	-0.2093	-0.9019	-0.2501	-0.0477	-0.0246
Nai_spp	<i>Nais</i> sp.	898	45	Tv 0.5015 Ss -0.2443	0.7007 -0.4871	1.0238 -0.1401	0.2164 0.2172	0.3068 -0.3169	0.5636 0.1211	0.9728 -0.2199	0.5999 -0.2408	1.3481 0.0027
Oph_ser	<i>Ophidonais serpentina</i>	222	19	Tv 1.2141 Ss 0.7540	0.7060 -0.3254	1.0541 0.7408	1.2463 -0.8397	0.8778 -0.1324	1.1966 -0.8040	0.9580 -0.0375	0.7298 -0.1681	0.9607 -0.1069
Pri_lon	<i>Pristina longiseta</i>	1	1	Tv 0.1803 Ss -1.7474	0.8254 -0.9636	0.9162 -1.2127	0.0697 1.7238	0.3480 -1.1401	0.4263 0.9960	0.8430 -0.9986	0.7995 -0.3378	1.2943 0.3964
Pri_spp	<i>Pristina</i> sp.	4	3	Tv 0.0000 Ss -0.0466	0.0000 0.2508	0.0000 -0.3088	0.0000 0.2420	0.0000 0.2148	0.0000 0.7381	0.0000 0.8055	0.0000 0.2231	0.0000 0.8296
Sla_app	<i>Slavina appendiculata</i>	1	1	Tv 1.1015 Ss 0.7576	0.8046 -0.9155	0.5093 1.3758	1.0581 -0.8209	1.3485 -0.4608	0.7622 -0.7850	1.1469 -0.2082	0.4336 0.0717	0.3552 -1.2766
Sty_lac	<i>Sylaria lacustris</i>	720	43	Tv 0.0000 Ss -0.4502	0.0000 -0.4221	0.0000 -0.2413	0.0000 0.4524	0.0000 -0.0444	0.0000 0.2479	0.0000 -0.1451	0.0000 -0.2526	0.0000 -0.2338
Unc_unc	<i>Uncinails uncinata</i>	21	5	Tv 1.1822 Ss -1.7778	0.9349 -0.9770	1.0215 -1.1974	1.1910 1.7317	1.2178 -1.1547	1.2674 1.3159	1.1872 -0.7040	0.8553 -0.2878	0.9385 -0.0231
Der_fur	<i>Dero furcatus</i>	2	2	Tv 0.0382 Ss 0.6724	0.0168 -0.1655	0.0344 0.6206	0.0099 -0.8539	0.0183 -0.3196	0.3691 -1.0460	0.4823 -0.6160	0.8033 -0.6186	0.6992 -0.6144
Ham_wal	<i>Haemonais waldvogeli</i>	23	3	Tv 0.1030 Ss 1.0934	0.9066 -1.0071	0.9129 2.2964	0.0400 -0.9558	0.1706 -0.1779	0.3155 -0.7016	0.4930 0.6465	0.9762 -0.0620	0.9364 -1.9123
Aul_plu	<i>Autodrilus pluriseta</i>	128	5	Tv 0.4560 Ss 0.1251	0.0407 -0.9283	0.7853 0.7326	0.1664 -0.1796	0.3415 -0.6326	0.1739 -0.1506	1.2427 -0.4467	0.1445 -0.2839	0.1488 -0.6958
Bru_sow	<i>Branchiura sowerbyi</i>	1305	53	Tv 1.5642 Ss 0.3090	0.0285 0.3351	1.6387 0.4654	1.6016 -0.2812	0.4209 0.3765	1.6292 -0.3427	0.5430 0.6558	0.7539 0.3281	1.7071 -0.0832
Pel_spp	<i>Peloscolex</i> sp.	378	21	Tv 0.8257 Ss -1.5576	1.0178 -0.4021	1.1176 -1.0644	0.8532 1.5363	1.0590 -0.4292	0.7223 1.3296	0.8875 -0.4490	1.0680 -0.5597	1.0003 -0.2662
Spir_fer	<i>Spirosperma ferox</i>	138	5	Tv 0.4163 Ss -1.8144	1.1826 -0.9931	0.3098 -1.1623	0.3971 1.7412	1.4960 -1.1723	0.5855 1.4127	1.0708 -0.2101	1.1592 -0.3927	0.8047 0.2144
Psa_alb	<i>Psammoryctides albicola</i>	1	1	Tv 0.0660 Ss 1.8405	0.0290 -1.1429	0.0337 -0.1264	0.0171 -1.0200	0.0317 -0.0450	0.3804 -1.2803	0.6428 0.4635	0.2947 -0.4478	0.4213 1.6971
Tubb_dae	<i>Tubificidae</i> -juv. without setae	18,833	95	Tv 0.0000 Ss 0.3156	0.0000 -0.0838	0.0000 0.1521	0.0000 -0.2837	0.0000 -0.2188	0.0000 -0.1475	0.0000 -0.0793	0.0000 0.0002	0.0000 0.2214
Tubz_dae	<i>Tubificidae</i> -juv. with setae	6636	89	Tv 0.9430 Ss -0.1000	0.9836 -0.1305	1.1096 0.0413	0.9006 0.1160	0.6954 0.1166	0.9924 0.0124	0.8924 0.0464	0.7427 -0.0343	0.9915 -0.0766
Tub_ner	<i>Tubificex nerthus</i>	217	6	Tv 1.0575 Ss -0.9467	1.0238 1.5283	1.1351 -0.7551	1.0621 0.8970	1.1197 2.0188	1.0612 0.7680	1.0855 0.9482	0.9808 0.8691	0.9268 -0.7096
	Hirudinea			Tv 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.7644	0.8685
Din_lin	<i>Dina lineata</i>	12	2	Ss 0.7197	-0.6691	-0.1383	-0.7823	0.3265	-0.8890	0.0051	-0.4151	-0.4822
Erp_oet	<i>Eirpobdella octoculata</i>	528	59	Tv 0.0825 Ss -0.2011	0.0363 -0.2024	0.1547 0.2824	0.0213 0.2483	0.0396 0.2948	0.4453 0.0333	0.6532 0.3320	0.8492 0.0249	0.6109 -0.3224
				Tv 1.1465	1.1003	1.3968	1.1143	1.2770	1.1425	1.1180	1.1178	0.9029

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs	
Erp_spp	<i>Erpobdella</i> sp.	46	4	Ss	-0.8968	1.4434	-0.5754	0.9151	1.9043	0.6422	1.2752	0.6271	-0.1869
Erp_tes	<i>Erpobdella testacea</i>	44	9	Tv	0.6157	1.7838	0.4711	0.5974	2.2575	0.9609	1.7603	0.8082	1.2296
Alb_het	<i>Alboglossiphonia heteroclita</i>	37	7	Ss	-0.9045	1.5468	-0.5735	0.8862	2.0390	0.6095	1.2818	0.8547	-0.3259
Alb_hya	<i>Alboglossiphonia hyalina</i>	11	7	Tv	0.0383	0.0168	0.1764	0.0099	0.0184	0.1518	0.5097	1.5199	0.9472
Glo_com	<i>Glossiphonia complanata</i>	82	23	Ss	0.9904	-0.9974	1.9978	-0.9181	-0.2553	-1.0870	0.0328	-0.2359	-1.1590
Glo_con	<i>Glossiphonia concolor</i>	6	3	Tv	0.2956	0.0704	0.6299	0.1145	0.2383	0.4475	1.2089	0.5703	1.0576
Glo_neb	<i>Glossiphonia nebulosa</i>	2	1	Ss	-0.2394	0.5700	-0.0598	0.1906	1.1582	-0.0683	0.1180	0.1823	-0.3876
Heb_sta	<i>Helobdella stagnalis</i>	833	67	Tv	0.9244	1.3154	0.9039	0.9479	1.2169	1.0456	1.4086	0.8697	1.2314
Hec_mar	<i>Hemiclepsis marginata</i>	23	10	Ss	-1.1654	-0.4187	-0.6187	1.1279	-0.3476	1.0211	-0.2185	-0.4922	-0.1314
Thr_tes	<i>Theromyzon tessulatum</i>	2	2	Tv	0.9875	1.1230	1.0253	1.0022	1.3879	1.0350	1.0884	0.6713	0.7908
Bran_spp	<i>Branchiobdella</i> sp.	1	1	Ss	-0.2425	-0.9991	0.7007	0.3519	-0.5926	0.5616	0.0933	-0.7944	-0.9353
Gastropoda				Tv	2.1613	0.0357	2.7254	1.9487	0.7902	1.6827	1.5239	0.6267	0.9919
Acro_lac	<i>Acrololoxus lacustris</i>	37	5	Ss	-0.9000	1.5488	-0.5704	0.8850	2.0412	0.6043	0.9977	-0.3296	-0.6816
Anc_flu	<i>Ancylus fluviatilis</i>	15	7	Ss	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bth_ten	<i>Bithynia tentaculata</i>	39	4	Tv	0.0860	-0.3256	0.3566	-0.0788	0.0750	-0.1904	-0.0939	-0.0303	-0.0958
Byt_sch	<i>Bythinella schmidtii</i>	2	1	Ss	1.0631	0.9053	1.2430	1.0701	1.0093	1.1104	1.1137	0.9612	1.0112
Lith_nat	<i>Lithoglyphus naticoides</i>	5	2	Ss	0.3250	0.1532	0.4329	-0.4600	0.1816	-0.4717	0.0646	0.2946	-0.0612
Sad_flu	<i>Sadleriana fluminensis</i>	1634	9	Tv	0.7131	1.0819	0.9472	0.7920	1.1169	0.7492	0.9306	0.7453	0.9705
Rad_aur	<i>Radix auricularia</i>	48	10	Ss	0.7440	-0.9215	1.3544	-0.8173	-0.4673	-1.2028	-1.1727	0.2404	-0.7375
Rad_bal	<i>Radix balhica</i>	280	22	Tv	0.0165	0.0073	0.0258	0.0043	0.0079	0.5051	1.1658	0.0400	1.7897
Rad_lab	<i>Radix labiata</i>	24	6	Ss	-0.8767	1.5591	-0.3707	0.8789	2.0524	0.4379	1.9520	-0.1944	-0.7823
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	-1.4024	-0.5217	-1.0517	1.3484	-0.4722	1.3115	-0.5562	-0.2525	-0.0425
				Tv	0.9417	1.2065	0.3799	0.9738	1.5575	0.8549	0.9329	1.1567	1.0950
				Ss	-0.7556	-0.6828	-0.4261	0.6736	-0.8141	0.1676	-1.1681	-0.5576	-0.1497
				Tv	1.4236	0.6374	1.2310	1.5134	0.4763	1.5743	0.4233	0.6041	0.7872
				Ss	-0.6059	-0.2063	-0.6795	0.9256	0.6510	0.3607	0.6838	-0.3625	1.1166
				Tv	1.0575	0.7064	0.5252	0.7491	1.6830	1.5034	1.6924	1.1027	0.4494
				Ss	-1.7241	-0.9533	-1.2084	1.7178	-1.1289	1.9333	-1.0900	-1.2344	1.2569
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	-1.7708	-0.9739	-1.2265	1.7299	-1.1513	1.7514	-0.9843	-1.1937	-0.0274
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1283	0.1857
				Ss	-1.7851	-0.9802	-1.1833	1.7336	-1.1582	1.2814	-0.5461	-0.4628	0.0464
				Tv	0.0501	0.0221	0.0346	0.0130	0.0241	0.3480	0.5614	0.4698	0.8211
				Ss	0.3812	-0.7430	0.8407	-0.4997	-0.3744	-0.5326	-0.5123	-0.1066	-0.6929
				Tv	0.9008	0.6401	1.1595	0.9471	0.6479	1.0529	0.4754	0.5290	1.2627
				Ss	-1.0859	-0.5099	-0.9335	0.9735	-0.7298	1.0298	-0.3516	-0.8255	-0.0788
				Tv	1.1366	0.8135	0.4343	1.2677	0.8531	0.9382	0.8595	0.7379	0.7264
				Ss	0.2575	-0.1747	0.1905	-0.4372	-0.4331	-0.8048	-1.1359	-0.6808	-0.5223
				Tv	1.1679	0.8478	1.0622	1.2565	0.4342	1.5228	0.5891	0.6115	0.7759

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs	
Rad_spp	<i>Radix</i> sp.-juv.	27	11	Ss	-0.4787	-0.7708	-0.3647	0.4315	-0.4446	0.2961	-0.5576	-0.3233	-0.1732
Rad_tru	<i>Galba truncatula</i>	2	1	Tv	1.3421	0.5424	1.0901	1.3773	0.8885	1.2127	0.6711	0.4663	1.0661
Phy_fon	<i>Physa fontinalis</i>	161	13	Ss	-1.7708	-0.9739	-1.2265	1.7299	-1.1513	1.7514	-0.9843	-1.2739	-0.1435
Phs_acu	<i>Physella acuta</i>	211	12	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gyr_alb	<i>Gyraulus albus</i>	78	13	Ss	0.6789	-0.0734	0.4047	-0.6646	0.2278	-0.7869	0.6336	-0.2570	0.5144
Gyr_cri	<i>Gyraulus crista</i>	110	22	Tv	0.4251	0.8917	1.1522	0.5528	0.6915	0.5558	0.5014	0.8150	0.8358
Hipp_com	<i>Hippetis complanatus</i>	260	31	Ss	0.3666	0.5692	0.1816	-0.3115	0.4516	-0.4420	0.6846	-0.1050	0.2294
Plan_pla	<i>Planorbis planorbis</i>	103	10	Tv	0.5141	0.5697	0.4821	0.7594	1.0591	0.6780	1.3868	0.7887	0.9515
Fer_ele	<i>Ferrissia clessiniana</i>	4	3	Ss	-0.0931	-0.4854	0.2328	0.0828	-0.4004	0.0226	-0.2998	-0.3241	-0.0608
Val_pis	<i>Valvata piscinalis</i>	433	23	Tv	1.2380	0.7963	1.2251	1.2674	0.8047	1.3474	1.1878	0.6140	1.0949
Bivalvia				Ss	-0.9130	0.1689	-0.4922	0.8984	0.4391	0.7885	0.1909	0.0819	-0.4172
Psid_spp	<i>Pisidium</i> sp.	2566	56	Tv	0.9426	1.3230	0.9632	0.9371	1.6101	0.9667	1.1277	1.6253	1.0621
Sph_cor	<i>Sphaerium corneum</i>	2	1	Ss	-0.7768	-0.4268	-0.2326	0.7556	-0.2738	0.5751	-0.3498	-0.4774	-0.2964
Anod_ana	<i>Anodonta anatina</i>	5	4	Tv	1.2223	1.0828	1.3568	1.2082	1.2578	1.3347	1.0904	1.2529	0.9784
Anod_cyg	<i>Anodonta cygnea</i>	3	3	Ss	-0.8866	1.5547	-0.5605	0.8815	2.0477	0.5952	1.2777	0.2463	-0.9585
Unio_pic	<i>Unio pictorum</i>	11	4	Tv	0.0387	0.0170	0.1267	0.0100	0.0186	0.1096	0.4001	1.1872	0.5030
Arachnida				Ss	0.7039	-0.4423	0.8993	-0.8417	-0.3717	-0.9497	-0.4655	-0.3493	-0.3620
Hyd_idia	<i>Hydrachnidia</i>	1164	97	Tv	0.1030	0.9066	0.9129	0.0400	0.1706	0.3155	0.4930	0.7691	1.2810
Syu_amb	<i>Synurella ambulans</i>	11	4	Ss	-1.6044	-0.5162	-1.0863	1.5755	-0.5729	1.4661	-0.4155	-0.4944	-0.1361
Gam_fos	<i>Gammarus fossarum</i>	4	2	Tv	0.3948	1.1038	0.2816	0.3713	1.3958	0.5466	1.0113	0.6617	0.7188
Gam_lac	<i>Gammarus lacustris</i>	73	13	Tv	-0.9140	-0.0555	-0.4730	0.8892	0.0415	0.7404	0.0008	-0.0857	-0.0290
				Ss	1.0324	1.2298	1.0216	1.0337	1.4664	1.0396	1.0752	1.1886	0.8815
				Tv	0.6410	-0.9668	1.5172	-0.7907	-0.5168	-0.8741	-0.5866	0.1442	-2.0127
				Ss	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Tv	0.7092	-0.9367	1.4160	-0.8083	-0.4840	-1.0198	-0.8121	0.0162	-0.5509
				Ss	0.0636	0.0280	0.0945	0.0165	0.0306	0.3738	0.8320	0.1701	1.3425
				Tv	0.3131	0.0947	0.2662	-0.4732	0.1454	-0.2281	0.2852	0.2775	0.5249
				Ss	0.7934	1.1621	1.1183	0.8760	1.2273	0.6516	0.5684	1.5044	0.5016
				Tv	0.7182	-0.4769	1.1016	-0.7869	-0.4115	-0.5313	-0.0651	-0.0072	0.2358
				Ss	0.0849	1.0524	0.7250	0.1308	0.1423	0.7714	0.5492	0.3723	1.1155
				Tv	-0.0503	0.1783	-0.1065	0.0433	-0.0219	0.0880	0.0383	-0.0424	-0.0222
				Ss	0.9512	0.9571	0.8736	0.9956	1.0256	0.9842	1.0989	1.0580	0.9081
				Tv	0.1981	0.4094	-0.1019	0.1700	1.1862	-0.3920	1.5083	0.4019	0.4254
				Ss	0.4948	0.5192	0.7547	0.7979	1.0146	0.3518	0.3661	1.8212	0.8665
				Tv	0.7576	-0.9155	1.3758	-0.8209	-0.4608	-0.7850	-0.2082	0.1702	-1.6398
				Ss	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1393	0.5137
				Tv	-0.8913	1.5526	-0.5786	0.8827	2.0454	0.6112	1.2659	0.2366	-0.5779
				Ss	0.0432	0.0190	0.1408	0.0112	0.0207	0.1225	0.3981	1.2544	0.8951

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	Ss	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Nip_spp	<i>Niphargus</i> sp.	33	1	Ss	-1.8174	-0.9944	-1.1608	1.7420	-1.1737	1.3954	-0.1809	-0.3292	0.6313
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ase_aqu	Isopoda <i>Aseillus aquaticus</i>	7964	36	Ss	-0.1356	0.5756	0.1082	0.0994	1.0233	-0.0301	0.5679	0.6185	-0.4584
				Tv	0.8782	1.2205	0.9774	0.9014	1.1957	0.8069	1.0962	1.2884	0.9963
Ast_ast	Decapoda <i>Astacus astacus</i>	6	4	Ss	-0.0035	1.3112	0.1668	-0.0230	0.9110	0.2687	1.2074	1.1673	-0.4063
				Tv	1.0847	0.2798	0.8975	1.0900	1.3481	0.4256	0.3939	1.5026	0.5403
Bae_f_s	Ephemeroptera <i>Baetis fuscatus/scambus</i>	1	1	Ss	-1.7241	-0.9533	-1.2084	1.7178	-1.1289	1.9333	-1.0900	-0.4331	0.0446
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cen_lut	<i>Centropilum luteolum</i>	653	41	Ss	-1.3219	-0.1174	-0.9650	1.3016	-0.2191	1.2445	-0.1593	-0.3292	-0.1712
				Tv	0.7497	1.2305	0.3818	0.7110	1.4878	0.5207	1.0260	0.8306	0.7720
Clo_dip	<i>Cloeon dipterum</i>	510	22	Ss	0.5984	-0.3711	0.3501	-0.6605	0.0483	-0.8008	-0.2927	-0.2442	0.1137
				Tv	0.2233	0.6455	0.7745	0.4138	0.6484	0.4650	0.9898	0.5891	1.2678
Cae_sppN	<i>Caenis</i> sp.	302	3	Ss	0.6418	0.0518	0.3903	-0.8621	-0.2810	-1.2965	-1.1372	-0.8369	-0.0218
				Tv	0.0865	0.9139	0.8871	0.0442	0.1785	0.1896	0.6729	0.8040	0.5764
Cae_hor	<i>Caenis horaria</i>	5405	75	Ss	-0.2174	0.1288	-0.2161	0.1756	-0.1045	0.1332	-0.1801	-0.0842	-0.1512
				Tv	1.0678	1.0362	0.8811	1.1013	1.0647	1.0706	1.0246	0.9435	0.8855
Cae_lac	<i>Caenis lactea</i>	2221	27	Ss	0.6427	-0.3096	0.4648	-0.6922	-0.0493	-0.5953	-0.2630	-0.0281	0.1092
				Tv	0.2138	0.7641	0.7026	0.3354	0.4111	0.5249	0.9752	0.7100	1.2571
Cae_luc	<i>Caenis luctuosa</i>	1987	47	Ss	0.4523	0.2865	0.0904	-0.5244	-0.0567	-0.3181	-0.0097	0.0696	0.0839
				Tv	0.4484	0.8871	0.6859	0.4951	0.6602	0.6361	0.7819	0.7798	1.0564
Cae_mac	<i>Caenis macrura</i>	211	9	Ss	-0.3687	1.2896	-0.3872	0.4030	1.2702	0.7334	1.0685	0.7558	0.0264
				Tv	0.9199	0.5256	0.2608	0.8881	1.4947	0.3348	0.7758	0.9310	1.0505
Epm_ign	<i>Serratella ignita</i>	1	1	Ss	-0.8767	1.5591	-0.3707	0.8789	2.0524	0.4379	1.9520	1.5681	-0.6284
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Eph_dan	<i>Ephemera danica</i>	135	15	Ss	-0.4696	0.0022	-0.4650	0.4988	-0.4573	0.7303	-0.3977	-0.0629	-0.3273
				Tv	1.0508	1.0582	0.7729	0.9936	0.8517	0.6832	0.9084	1.0419	0.7662
Eph_spp	<i>Ephemera</i> sp.	2	1	Ss	-1.7241	-0.9533	-1.2084	1.7178	-1.1289	1.9333	-1.0900	-1.2344	1.2569
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Eph_vul	<i>Ephemera vulgata</i>	5	2	Ss	0.7195	-0.6691	0.1319	-0.7823	0.3265	-0.7808	-0.4695	-0.2002	-0.0039
				Tv	0.0165	0.0073	0.2104	0.0043	0.0079	0.1849	0.5533	0.6505	1.6022
Hab_fus	<i>Habrophlebia fusca</i>	1	1	Ss	-1.7474	-0.9636	-1.2127	1.7238	-1.1401	0.9960	-0.9986	-1.3213	0.4641
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hab_lau	<i>Habrophlebia lauta</i>	41	3	Ss	-1.8090	-0.9907	-1.1651	1.7398	-1.1697	1.4441	-0.2632	-0.6040	-0.0516
				Tv	0.0660	0.0290	0.0337	0.0171	0.0317	0.3804	0.6428	0.3820	0.0785
Pal_sub	<i>Paraleptophlebia submarginata</i>	25	2	Ss	-0.0261	0.6654	-0.3666	-0.0377	-0.5590	0.5285	0.0459	0.0213	-0.6825
				Tv	1.3383	1.2665	0.6578	1.3695	0.4518	0.3634	0.8121	0.1272	1.2606
Pom_lut	<i>Potamanthus luteus</i>	1	1	Ss	-0.8767	1.5591	-0.3707	0.8789	2.0524	0.4379	1.9520	3.1968	2.6192
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	Ss	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Sip_lac	<i>Siphonurus lacustris</i>	2	2	Ss	-1.7371	-0.9591	-1.2108	1.7212	-1.1352	1.4094	-1.0389	0.0595	0.1631
Sip_spp	<i>Siphonurus</i> sp.	1	1	Tv	0.0165	0.0073	0.0031	0.0043	0.0079	0.6628	0.0646	0.1350	0.6776
				Ss	-1.7474	-0.9636	-1.2127	1.7238	-1.1401	0.9960	-0.9986	-1.3213	0.4641
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Plecoptera												
Leu_spp	<i>Leuctra</i> sp.	84	6	Ss	-1.3591	-0.5811	-1.0004	1.3037	-1.0133	1.3578	-0.5243	-0.6341	-0.1811
				Tv	1.0006	0.9367	0.4786	1.0086	0.3407	0.6237	0.6133	0.4654	0.6895
Nem_spp	<i>Nemoura</i> sp.	65	9	Ss	-1.7616	-0.9698	-1.2224	1.7275	-1.1469	1.6914	-1.0007	-0.7051	-0.2308
				Tv	0.0262	0.0116	0.0111	0.0068	0.0126	0.4001	0.0567	0.4454	0.6663
	Odonata												
Aes_spp	<i>Aeshna</i> sp.	3	3	Ss	0.4897	-0.7922	1.2036	-0.5002	-0.3552	-0.4533	-0.9948	-0.3270	-0.1619
				Tv	0.2970	0.3427	0.6153	0.5700	0.3172	0.8259	0.8011	0.2924	1.3373
Anx_imp	<i>Anax imperator</i>	12	4	Ss	0.5172	0.5329	-0.0412	-0.6813	-0.1125	-0.9515	-0.6145	-0.3022	-0.1028
				Tv	0.4742	0.4315	0.2784	0.5887	0.7507	0.6819	0.8004	1.7800	1.0436
Hem_eph	<i>Hemianax ephippiger</i>	2	2	Ss	0.0311	0.2110	-0.1068	0.4907	1.6244	-0.0846	2.0438	-0.0023	0.3763
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.2800	0.2123
Coe_mer	<i>Coenagrion mercuriale</i>	11	1	Ss	-0.9000	1.5488	-0.5704	0.8850	2.0412	0.6043	0.9977	-0.6628	-1.0669
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Coe_pue	<i>Coenagrion puella</i>	27	5	Ss	0.6045	0.0666	0.2585	-0.7904	-0.1911	-1.1184	-0.9946	-0.9052	0.0026
				Tv	0.1846	0.7377	0.6291	0.3595	0.2719	0.6477	0.7296	0.6193	0.5804
Coe_spp	<i>Coenagrion</i> sp.	10	4	Ss	0.2991	0.5601	0.0004	-0.4973	0.1667	-0.0904	0.4727	0.2620	-0.5521
				Tv	0.7415	0.9143	0.8731	0.8225	1.0981	0.5839	0.5747	0.9087	1.1489
Ery_vir	<i>Erythronna viridulum</i>	6	3	Ss	0.5647	-0.1605	0.3242	-0.8297	-0.3593	-0.4019	0.0270	-0.1899	-0.0238
				Tv	0.0865	0.9139	1.3521	0.0442	0.1785	0.5352	0.6954	0.2365	1.4057
Isc_ele	<i>Ischnura elegans</i>	51	7	Ss	0.6734	-0.7307	1.0514	-0.7544	-0.3496	-1.0766	-1.0759	0.1340	-1.2370
				Tv	0.2528	0.6003	0.6491	0.2242	0.3689	0.6149	1.0775	0.1326	1.0148
Isc_pum	<i>Ischnura pumilio</i>	6	1	Ss	0.7380	-0.6610	-0.1039	-0.7871	0.3354	-0.9881	0.1505	-0.6770	-0.6706
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Isc_spp	<i>Ischnura</i> sp.	145	6	Ss	0.6600	-0.8894	0.9615	-0.7896	-0.2379	-0.7376	-0.5895	-0.0497	-0.6491
				Tv	0.1624	0.1769	1.2869	0.0692	0.5235	0.4192	0.4018	0.3847	1.3310
Pyr_nym	<i>Pyrhosoma nymphula</i>	12	1	Ss	-0.8533	1.5693	-0.5421	0.8729	2.0636	0.5744	1.3994	-0.9035	-0.7990
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Coe_dae	<i>Coenagrionidae</i> -juv.	948	29	Ss	0.5772	-0.1712	0.4495	-0.6429	-0.0024	-0.7326	-0.2967	-0.0917	0.1442
				Tv	0.3501	0.8286	0.8912	0.4633	0.6743	0.5234	0.9823	0.5925	1.2308
Cora_aen	<i>Cordulia aenea</i>	3	2	Ss	-0.8852	1.5553	-0.5614	0.8812	2.0483	0.5948	1.1250	0.0081	-0.5849
				Tv	0.0330	0.0145	0.0200	0.0085	0.0159	0.0212	0.2841	1.2263	0.8809
Epi_bim	<i>Epitheca binaculata</i>	1	1	Ss	0.6410	-0.9668	1.5172	-0.7907	-0.5168	-0.8741	-0.5866	-0.2662	0.4749
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Som_mer	<i>Somatochlora meridionalis</i>	18	1	Ss	-1.8174	-0.9944	-1.1608	1.7420	-1.1737	1.3954	-0.1809	-0.5734	-1.2876
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	Ss	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Som_met	<i>Somatochlora metallica</i>	98	14	Ss	-1.7262	-0.8902	-1.2034	1.6998	-1.0468	1.5838	-0.9617	-0.6647	-0.3849
Cor_dae	<i>Cordulidae</i>	3	2	Tv	0.1688	0.5186	0.0966	0.1722	0.6574	0.4824	0.4133	0.4571	0.4756
				Ss	0.8479	1.0917	0.8636	-0.8788	-0.1474	-0.0531	1.1496	1.1335	-0.7555
Cor_Lib	<i>Cordulidae/Libellulidae-juv.</i>	62	6	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.6766	0.2614
				Ss	-0.8740	-0.2560	-0.4442	0.8143	-0.8104	0.8827	0.2900	-0.5307	-0.0455
Gom_spp	<i>Gomphus</i> sp.	3	2	Tv	1.8846	1.4751	1.4314	1.8531	0.7257	1.0242	0.9408	0.2717	1.1140
				Ss	0.4184	1.3476	-0.7177	-0.2951	-0.5952	0.5452	0.2881	-0.0960	-0.0445
Gom_vul	<i>Gomphus vulgatissimus</i>	16	7	Tv	0.3130	0.3074	1.1199	0.5538	0.3920	0.8317	0.5298	0.2827	0.3410
				Ss	-0.4877	0.5207	-0.6361	0.4604	-0.4072	0.7474	0.2382	-0.2044	-0.3772
Lib_dep	<i>Libellula depressa</i>	2	2	Tv	1.0000	1.1054	0.5340	0.9730	1.1135	0.5109	0.5495	0.6083	0.8345
				Ss	0.7478	-0.7882	0.6360	-0.8040	-0.0627	-0.8865	-0.0288	-0.2765	0.7436
Lib_qua	<i>Libellula quadrimaculata</i>	1	1	Tv	0.0138	0.1799	1.0463	0.0239	0.5629	0.1436	0.2536	0.2018	0.4647
				Ss	0.8479	1.0917	0.8636	-0.8788	-0.1474	-0.0531	1.1496	-0.3438	1.4139
Orte_albi	<i>Orthetrum albisylum</i>	120	23	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	0.7279	-0.1006	0.4534	-0.7231	-0.2312	-0.6086	-0.3139	-0.2393	0.1951
Orte_bru	<i>Orthetrum brunneum</i>	12	4	Tv	0.3830	0.9872	1.0028	0.3192	0.3211	0.8070	0.9816	0.5689	1.3096
				Ss	0.0301	0.4341	-0.0345	0.2249	0.7633	-0.0384	1.4349	0.3857	-0.2800
Orte_can	<i>Orthetrum cancellatum</i>	8	5	Tv	0.0018	0.3996	0.1295	0.4762	1.5427	0.0828	1.0908	0.5675	1.2526
				Ss	0.7412	-0.1701	0.3362	-0.7738	0.0263	-0.4967	0.3079	-0.3307	0.8945
Orte_coe	<i>Orthetrum coerulescens</i>	2	2	Tv	0.0958	0.9838	0.7401	0.1355	0.3968	0.8657	0.5463	0.4789	1.3997
				Ss	0.7717	-0.0927	0.8706	-0.8389	-0.3419	-1.2842	-0.7521	0.0329	1.0727
Symp_fon	<i>Sympetrum fonscolombei</i>	1	1	Tv	0.0638	1.4193	0.7984	0.0410	0.2216	0.3665	1.8824	0.2535	0.7703
				Ss	0.7380	-0.6610	-0.1039	-0.7871	0.3354	-0.9881	0.1505	-0.6770	-0.6706
Ply_pen	<i>Platycnemis pennipes</i>	391	50	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	0.2177	0.1319	0.0656	-0.2471	-0.1296	-0.1316	-0.1033	-0.0070	0.0789
				Tv	0.8584	0.9740	0.8664	0.8875	0.7827	0.8314	0.9701	0.9275	1.1788
Heteroptera													
Aph_aes	<i>Aphelocheirus aestivalis</i>	1	1	Ss	-0.8767	1.5591	-0.3707	0.8789	2.0524	0.4379	1.9520	0.1291	0.2895
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cori_nae	<i>Corixinae</i>	118	4	Ss	0.7188	-0.9325	1.3837	-0.8108	-0.4794	-1.2353	-1.2843	0.1123	-0.5555
				Tv	0.0554	0.0244	0.0946	0.0143	0.0266	0.4387	0.9615	0.1391	1.3065
Mir_spp	<i>Micronecta</i> sp.	16,780	68	Ss	0.5733	-0.0144	0.3734	-0.5377	-0.2900	-0.4039	-0.1113	0.0828	0.0392
				Tv	0.6280	0.9756	1.0810	0.5815	0.4075	0.9203	0.8731	0.7027	1.0885
Par_spp	<i>Paracorixa</i> sp.	1	1	Ss	0.7147	-0.6713	0.1937	-0.7810	0.3241	-0.7266	-0.6319	0.0055	2.3624
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Aqu_spp	<i>Aquarius</i> sp.	1	1	Ss	0.4315	0.6908	0.0309	-0.4684	-0.3247	0.1408	0.4278	0.7812	-0.3105
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ger_spp	<i>Gerris</i> sp.	3	3	Ss	0.7085	-0.8423	0.7638	-0.7978	-0.1941	-0.6313	-0.4118	-0.0046	0.1054
				Tv	0.0963	0.1436	1.2010	0.0452	0.5233	0.3017	0.3995	0.2368	1.9720
Mev_fur	<i>Mesovelia furcata</i>	2	1	Ss	0.6120	0.3667	0.0847	-0.8774	-0.2195	-1.2312	-0.9054	-1.3088	0.0477
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix 2. Continued.

Code	Taxa and taxonomic group	Nurn	Oce	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs	
Ilyo_cim	<i>Ilyocoris cimicoides</i>	5	4	Ss	0.5554	-0.3596	0.7662	-0.5774	-0.0038	-0.7884	-0.0364	-0.0790	-0.6866
Nep_cin	<i>Nepa cinerea</i>	4	4	Tv	0.3072	0.7222	0.8327	0.6103	0.9380	0.4523	1.2284	0.8618	1.0297
				Ss	0.4204	-0.0576	0.6104	-0.5089	-0.4959	-0.4537	-0.4385	0.1495	-0.6083
Plea_min	<i>Plea minutissima</i>	9	2	Tv	0.3785	1.0025	0.8754	0.3581	0.0404	0.9338	1.0909	0.1273	1.1754
				Ss	0.6311	0.2108	0.0561	-0.8637	-0.1354	-1.1943	-0.7453	-1.1573	-0.1245
				Tv	0.0891	0.7267	0.1334	0.0638	0.3923	0.1719	0.7466	0.4467	0.5079
Megaloptera													
Sia_ful	<i>Stalis fuliginosa</i>	29	9	Ss	-1.7858	-0.9805	-1.1960	1.7338	-1.1586	1.4523	-0.6483	-0.5652	-0.3920
				Tv	0.0354	0.0156	0.0382	0.0092	0.0170	0.3463	0.4998	0.4297	0.6311
Sia_lut	<i>Stalis lutaria</i>	208	37	Ss	-0.1958	-0.3445	0.0796	0.1953	-0.1332	0.1337	-0.2161	-0.2251	-0.1123
				Tv	1.1605	0.9594	1.2194	1.1471	1.0273	1.1733	0.9035	0.7924	0.9038
Sia_nig	<i>Stalis nigripes</i>	7	5	Ss	-1.1163	-0.4964	-0.9052	1.1169	-0.8999	1.5975	-0.5397	-0.4078	-0.3634
				Tv	1.3347	0.9872	0.6145	1.2816	0.5083	0.4897	0.7968	0.4529	0.3973
Sia_spp	<i>Stalis</i> sp.-juv.	6	1	Ss	-1.8174	-0.9944	-1.1608	1.7420	-1.1737	1.3954	-0.1809	-0.9915	-0.5368
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Planipennes													
Sis_spp	<i>Sisyra</i> sp.	2	2	Ss	-0.9233	1.5385	-0.6628	0.8910	2.0300	0.6861	0.9730	0.3949	-1.2076
				Tv	0.0330	0.0145	0.1307	0.0085	0.0159	0.1158	0.0350	1.4957	0.1990
Coleoptera													
Dryo_spl	<i>Dryops</i> sp. Lv.	15	2	Ss	0.8166	0.5920	0.5878	-0.8526	-0.0098	-0.3197	0.8647	-0.4906	1.4627
				Tv	0.0777	1.2393	0.6841	0.0649	0.3414	0.6611	0.7064	0.3531	0.1174
Agb_spl	<i>Agabus</i> sp. Lv.	1	1	Ss	0.7576	-0.9155	1.3758	-0.8209	-0.4608	-0.7850	-0.2082	0.2687	-2.0030
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bid_spa	<i>Bidessus</i> sp. Ad.	10	4	Ss	0.2088	0.7051	-0.2121	-0.2475	-0.4431	-0.0202	0.0081	0.2179	-0.8178
				Tv	0.5585	0.4177	0.3096	0.5238	0.2323	0.7159	0.4814	0.7795	0.9777
Grp_spa	<i>Graptodytes</i> sp. Ad.	8	5	Ss	-0.9354	-0.2208	-0.6767	1.1349	0.3180	0.6697	0.5410	-0.4984	0.0798
				Tv	0.9862	0.9711	0.6263	0.6909	1.6848	0.8669	1.7855	0.9856	0.5890
Grp_spl	<i>Graptodytes</i> sp. Lv.	1	1	Ss	-1.7241	-0.9533	-1.2084	1.7178	-1.1289	1.9333	-1.0900	-0.7838	-0.5737
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hyd_nael	<i>Hydroporinae</i> Lv.	1	1	Ss	0.5715	0.7524	-0.1282	-0.5046	-0.2574	1.0720	0.3020	0.2042	1.4204
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ily_spa	<i>Ilybius</i> sp. Ad.	1	1	Ss	0.7576	-0.9155	1.3758	-0.8209	-0.4608	-0.7850	-0.2082	0.0717	-1.2766
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Lacc_spa	<i>Laccophilus</i> sp. Ad.	1	1	Ss	0.7380	-0.6610	-0.1039	-0.7871	0.3354	-0.9881	0.1505	-0.8433	1.5799
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Lacc_spl	<i>Laccophilus</i> sp. Lv.	5	2	Ss	0.2191	0.2614	-0.0448	0.0479	1.0276	-0.4557	1.0893	0.4323	0.1295
				Tv	0.4108	0.1101	0.1354	0.9674	1.3039	0.8108	2.0854	1.1053	0.9321
Neb_spa	<i>Nebrioporus</i> sp. Ad.	1	1	Ss	-0.8767	1.5591	-0.3707	0.8789	2.0524	0.4379	1.9520	-0.1944	-0.7823
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Neb_spl	<i>Nebrioporus</i> sp. Lv.	18	9	Ss	-1.7527	-0.9659	-1.2047	1.7252	-1.1427	1.5779	-0.9022	-0.5741	-0.2772
				Tv	0.0392	0.0172	0.0242	0.0101	0.0188	0.4608	0.3815	0.5205	0.6116

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Plt_macA	<i>Platambus maculatus</i> Ad.	9	4	-0.3601	-0.7243	0.2912	0.2683	-0.7431	0.0928	-0.3982	-0.2272	-0.1050
Plt_macL	<i>Platambus maculatus</i> Lv.	2	1	1.4709	0.8092	1.5523	1.5157	0.4483	1.1710	0.7604	1.4740	0.8766
				-1.7241	-0.9533	-1.2084	1.7178	-1.1289	1.9333	-1.0900	-0.7327	-0.8129
Elm_spA	<i>Elmis</i> sp. Ad.	7	6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				-1.0257	1.1960	-0.6628	1.0037	1.5950	0.6643	0.9550	0.9003	0.5161
Elm_spL	<i>Elmis</i> sp. Lv.	3	3	0.3403	1.0141	0.3080	0.3383	1.2844	0.2123	1.0394	1.9785	1.4926
				-0.3784	1.0171	-1.0931	0.4933	-0.2139	0.8834	0.0585	-0.6375	0.0357
Lin_spA	<i>Limnius</i> sp. Ad.	8	5	1.1015	1.2805	0.2396	0.9454	1.5915	0.0975	0.8277	0.8581	0.5284
				-1.7697	-0.9734	-1.2117	1.7296	-1.1508	1.4340	-0.8681	-0.8232	-0.1813
Lin_spL	<i>Limnius</i> sp. Lv.	99	5	0.0292	0.0129	0.0288	0.0076	0.0140	0.4407	0.3724	0.5518	0.7312
				-1.7763	-0.9763	-1.2012	1.7313	-1.1540	1.3885	-0.7439	-1.0045	-0.0357
Otl_spA	<i>Oulimnius</i> sp. Ad.	4	2	0.0357	0.0157	0.0335	0.0092	0.0172	0.3876	0.4562	0.4205	0.7337
				0.5703	0.3338	0.1690	-0.5684	-0.3279	-0.6334	-0.3587	0.7742	-0.5383
Otl_spL	<i>Oulimnius</i> sp. Lv.	4	3	0.0656	1.2084	1.2526	0.2065	0.1755	0.2237	0.2117	0.6682	1.5638
				0.7404	-0.8634	1.0202	-0.8099	-0.2863	-1.2214	-1.0278	-0.0451	-1.5632
Rio_spA	<i>Riotus</i> sp. Ad.	211	16	0.0122	0.1417	0.7871	0.0163	0.4352	0.4041	1.1867	0.4914	0.6937
				-1.1207	0.8874	-0.7337	1.1055	1.2035	0.7032	0.6719	0.3768	-0.6375
Rio_spL	<i>Riotus</i> sp. Lv.	237	21	0.4248	1.2515	0.3465	0.4181	1.5846	0.2246	1.1919	1.4684	1.0847
				-0.9115	1.4865	-0.5484	0.9045	1.9614	0.5932	1.3179	1.0264	0.0143
Ore_vilA	<i>Orectochilus villosus</i> Ad.	1	1	0.1619	0.4689	0.1930	0.1568	0.5937	0.2182	0.6557	1.5320	1.4155
				-0.8533	1.5693	-0.5421	0.8729	2.0636	0.5744	1.3994	3.0456	-1.6716
Hai_linA	<i>Haliphtus lineatocollis</i> Ad.	3	2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				-1.8011	-0.9872	-1.1837	1.7377	-1.1659	1.5196	-0.4612	-0.6947	0.3316
Hai_spA	<i>Haliphtus</i> sp. Ad.	18	6	0.0330	0.0145	0.0465	0.0085	0.0159	0.2518	0.5681	0.6680	0.5479
				0.5466	-0.4899	0.8638	-0.7174	-0.4302	-0.9500	-0.8297	-0.3704	-1.0311
Hai_spL	<i>Haliphtus</i> sp. Lv.	82	10	0.5973	0.7611	0.9539	0.6296	0.2457	0.7461	0.5100	0.7433	1.1206
				-0.7649	-0.6571	-0.3084	0.8076	-0.4315	0.6241	0.0422	-0.3355	0.1140
Pet_caelL	<i>Pelodytes caesus</i> Lv.	1	1	1.2504	0.6512	1.1927	1.2137	1.1669	1.1841	1.1853	0.8045	1.2510
				0.7576	-0.9155	1.3758	-0.8209	-0.4608	-0.7850	-0.2082	0.2687	-2.0030
Hel_spL	<i>Helophorus</i> sp. Lv.	2	2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				0.5768	-0.4426	0.9523	-0.2465	0.7561	-1.0579	1.0674	-1.2580	0.1817
Och_spA	<i>Ochthebius</i> sp. Ad.	20	5	0.8378	0.8952	2.0224	1.0597	1.1963	0.6507	0.6407	0.1796	0.2543
				-1.7716	-0.9742	-1.2026	1.7301	-1.1517	1.5999	-0.7809	-0.8097	-0.6449
Och_spL	<i>Ochthebius</i> sp. Lv.	10	3	0.0399	0.0175	0.0323	0.0103	0.0192	0.3494	0.4496	0.4003	0.7284
				-1.7975	-0.9856	-1.1813	1.7368	-1.1642	1.5318	-0.4612	-0.6891	-1.0939
Col_orbA	<i>Coelostoma orbiculare</i> Ad.	1	1	0.0434	0.0191	0.0416	0.0112	0.0209	0.2810	0.5622	0.1732	0.2725
				-0.8533	1.5693	-0.5421	0.8729	2.0636	0.5744	1.3994	1.0714	0.1789
Eno_spL	<i>Enochrus</i> sp. Lv.	2	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				0.6410	-0.9668	1.5172	-0.7907	-0.5168	-0.8741	-0.5866	-0.0698	-1.6986
Helo_spL	<i>Helochaeres</i> sp. Lv.	4	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				0.7243	0.3165	0.2866	-0.8526	-0.0409	-0.7783	0.0612	-0.6341	0.9375
				0.1231	0.8387	0.5037	0.0502	0.2908	0.6335	1.0711	0.5224	0.7090

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	Ss	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Lacb_spA	<i>Laccobius</i> sp. Ad.	7	4	Ss	0.6355	0.0837	-0.1215	-0.5463	-0.1460	-0.3593	0.1923	-0.0461	-0.1471
Lacb_spL	<i>Laccobius</i> sp. Lv.	19	4	Tv	0.3932	1.3965	1.5139	0.4872	0.6364	1.2648	0.2371	0.7747	0.6940
Note_claA	<i>Noterus clavicornis</i> Ad.	4	1	Tv	0.8267	-0.6485	0.5713	-0.8351	0.1427	-1.0032	0.2644	-0.1425	-0.2457
Note_craA	<i>Noterus crassicornis</i> Ad.	3	3	Ss	0.2259	0.6712	1.3498	0.1095	0.3806	0.4608	0.4451	0.8704	1.3276
Note_spL	<i>Noterus</i> sp. Lv.	26	3	Ss	0.7380	-0.6610	-0.1039	-0.7871	0.3354	-0.9881	0.1505	-0.4193	1.0722
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	0.7023	-0.7855	0.4285	-0.7897	-0.0148	-1.0147	-0.9503	-0.1374	0.3759
				Tv	0.0643	0.1472	0.9488	0.0297	0.4742	0.5834	1.0354	0.2876	1.9711
				Ss	0.7818	-0.7652	0.5087	-0.8147	0.0875	-0.9820	0.0975	-0.0809	0.3477
				Tv	0.1715	0.2070	1.2240	0.0826	0.4916	0.2671	0.3161	0.6565	1.4102
Trichoptera													
Bde_min	<i>Beraeodes minuta</i>	1	1	Ss	-1.7708	-0.9739	-1.2265	1.7299	-1.1513	1.7514	-0.9843	-1.0925	0.1191
Ecn_ten	<i>Ecnomus tenellus</i>	1743	59	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	0.5448	0.0421	0.3019	-0.5408	0.1476	-0.5078	0.0097	0.1873	0.2200
Goe_pil	<i>Goera pilosa</i>	8	5	Tv	0.5215	0.8941	0.7346	0.5615	0.7518	0.6393	1.0430	1.0511	1.1706
				Ss	-0.8880	1.5541	-0.5625	0.8819	2.0470	0.5970	1.2483	-0.1831	-0.4992
				Tv	0.0376	0.0165	0.1215	0.0097	0.0181	0.1051	0.3939	0.8934	0.4038
Hdt_sppS	<i>Hydropila</i> sp.	65	22	Ss	-1.5794	-0.3843	-1.0455	1.5340	-0.4041	1.2769	-0.1347	-0.0275	0.0405
Ort_spp	<i>Orthotrichia</i> sp.	2	2	Tv	0.4242	1.2221	0.3039	0.4095	1.5465	0.5075	1.0169	1.1989	1.0235
				Ss	0.6240	-0.1868	0.6792	-0.8414	-0.3429	-1.0830	-0.7731	-0.5823	-0.9825
Oxy_spp	<i>Oxyethira</i> sp.	1	1	Tv	0.0205	0.9429	1.0129	0.0613	0.2102	0.2525	0.2254	1.0274	1.4570
				Ss	0.6120	0.3667	0.0847	-0.8774	-0.2195	-1.2312	-0.9054	-1.3088	0.0477
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ath_ate	<i>Athripsodes aterrimus</i>	45	14	Ss	-1.7628	-0.9704	-1.2027	1.7278	-1.1475	1.6546	-0.8302	-0.9546	-0.0758
				Tv	0.0427	0.0188	0.0293	0.0111	0.0205	0.3573	0.4365	1.0716	0.8595
Ath_bil	<i>Athripsodes bilineatus</i>	6	4	Ss	-1.6326	-0.5320	-1.0573	1.5838	-0.5908	1.3248	-0.0272	-0.4458	0.2240
				Tv	0.5233	1.4058	0.3454	0.4757	1.7758	0.5671	1.0533	0.2959	0.3439
Ath_cin	<i>Athripsodes cinereus</i>	15	7	Ss	-1.6331	-0.6500	-1.1535	1.6180	-0.7438	1.6019	-0.8209	-0.4708	-0.2641
				Tv	0.3686	1.1690	0.2138	0.3869	1.4826	0.6923	0.9508	0.4455	0.7824
Ath_spp	<i>Athripsodes</i> sp.	5	4	Ss	-1.5345	-0.3734	-1.0586	1.5250	-0.3940	1.5692	-0.4839	-1.0316	-0.0783
				Tv	0.4746	1.3517	0.3595	0.4537	1.7099	0.6988	1.3115	1.8335	1.3463
Mys_azu	<i>Mystacides azurea</i>	1101	65	Ss	-0.5475	0.5353	-0.4768	0.5447	0.4284	0.5113	0.4370	0.1512	-0.1169
				Tv	0.9389	1.0880	0.5837	0.9335	1.3726	0.8146	1.0192	1.1616	0.8772
Mys_lon	<i>Mystacides longicornis</i>	155	11	Ss	0.6993	-0.7870	0.7771	-0.8006	-0.2017	-0.8146	-0.4353	-0.0207	-0.3136
				Tv	0.0769	0.3130	0.9048	0.0285	0.4164	0.3756	0.6645	0.4609	1.5459
Mys_nig	<i>Mystacides nigra</i>	10	1	Ss	-0.8533	1.5693	-0.5421	0.8729	2.0636	0.5744	1.3994	1.1306	0.4851
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oec_lac	<i>Oecetis lacustris</i>	34	10	Ss	0.7170	-0.8149	1.0949	-0.7778	-0.2057	-0.9323	-0.5065	-0.0035	-0.1986
				Tv	0.3085	0.4284	0.7912	0.2900	0.5465	0.4041	0.9733	0.2940	1.5645
Oec_och	<i>Oecetis ochracea</i>	6	5	Ss	0.4636	0.4016	0.5551	-0.5197	0.1339	-0.4644	0.5325	0.7640	-0.0829
				Tv	0.7443	1.2339	0.8413	0.7864	1.0993	0.6493	0.7273	1.6209	1.5673

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Oec_tes	<i>Oecetis testacea</i>	3	3	Ss -0.1366	0.2879	0.4702	0.0490	0.7588	-0.1297	0.4138	-0.2414	0.1607
Ana_fur	<i>Anabolia fureata</i>	6	4	Tv 0.9846	1.5879	1.3360	1.0627	1.6144	0.9536	1.3430	0.3588	0.3947
Cha_fus	<i>Chaetopteryx fusca</i>	16	8	Ss 0.7038	-0.8302	0.8218	-0.7950	-0.1531	-0.7128	-0.4730	0.0979	-1.1622
Hal_d_t	<i>Halesus digitatus/tesellatus</i>	1	1	Tv 0.0658	0.1439	0.8642	0.0285	0.4582	0.1995	0.2727	0.2330	1.3531
Limn_nae	<i>Limnephilinae-juv.</i>	4	3	Ss -1.7555	-0.9671	-1.2105	1.7259	-1.1440	1.3768	-0.9355	-0.5942	-0.6097
Lim_lun	<i>Limnephilus lunatus</i>	6	4	Tv 0.0304	0.0134	0.0211	0.0079	0.0146	0.4908	0.2993	0.4858	0.5672
Agri_var	<i>Agrypnia varia</i>	1	1	Ss -1.7474	-0.9636	-1.2127	1.7238	-1.1401	0.9960	-0.9986	-1.3213	0.4641
Phg_bip	<i>Phryganea bipunctata</i>	7	1	Tv 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cyr_tri	<i>Cynurus trimaculatus</i>	228	39	Ss -1.7611	-0.9696	-1.2227	1.7274	-1.1467	1.7890	-1.0061	-0.9797	0.2365
Neu_bim	<i>Neureclipsis bimaculata</i>	1	1	Tv 0.0330	0.0145	0.0128	0.0085	0.0159	0.1286	0.0748	0.4568	0.5718
Pol_irr	<i>Polycentropus irroratus</i>	60	12	Ss -1.7787	-0.9773	-1.1805	1.7319	-1.1551	1.6187	-0.5582	-1.2132	0.1870
Lyp pha	<i>Lype phaeopa</i>	14	5	Tv 0.0660	0.0290	0.0337	0.0171	0.0317	0.3804	0.6428	1.5301	1.3061
Lyp_red	<i>Lype reducta</i>	61	12	Ss -1.7708	-0.9739	-1.2265	1.7299	-1.1513	1.7514	-0.9843	-1.0925	0.1191
Psy_pus	<i>Psychomyia pusilla</i>	2	2	Tv 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Tm_spp	<i>Tinodes</i> sp.	3	1	Ss -0.9467	1.5532	-0.5555	0.8824	2.0460	0.5920	1.3256	0.3368	-0.8620
Tm_wae	<i>Tinodes waeneri</i>	1276	24	Tv 0.0394	0.0173	0.1471	0.0102	0.0189	0.1266	0.4444	1.2943	0.5435
Not_cil	<i>Notidobia ciliaris</i>	82	10	Ss -1.0032	0.5729	-0.6880	1.0705	1.0203	0.8304	0.5828	-0.2417	-0.1434
Ser_spp	<i>Sericostoma</i> sp.	26	10	Tv 0.7769	1.4426	0.5017	0.5847	1.8399	0.8388	1.4062	1.2440	0.8769
Lisp_spp	<i>Lispe</i> sp.	1	1	Ss -1.2004	0.4287	-0.8483	1.2099	0.6986	0.7472	0.3895	-0.0988	-0.1624
Atri_spp	<i>Atrichopogon</i> sp.	2	2	Tv 0.5831	1.3791	0.3520	0.5032	1.7621	0.4728	1.2137	1.2666	1.0351
	Diptera			Ss 0.2272	-0.9314	0.8138	-0.2924	-0.6075	-0.7913	-1.6988	-0.2885	-1.3309
				Tv 1.7383	0.0195	1.8014	1.7908	0.4645	2.4272	0.5423	0.6281	0.7325
				Ss -0.8767	1.5591	-0.3707	0.8789	2.0524	0.4379	1.9520	1.5681	-0.6284
				Tv 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss -0.8896	1.5534	-0.5378	0.8823	2.0462	0.5774	1.3938	0.9039	-0.0138
				Tv 0.0383	0.0168	0.1578	0.0099	0.0184	0.1352	0.4803	1.3981	1.1681
				Ss -0.8862	1.5549	-0.5881	0.8814	2.0479	0.6179	1.2099	0.4542	-0.8922
				Tv 0.0452	0.0199	0.1124	0.0117	0.0217	0.1002	0.3059	1.3832	0.5795
				Ss -1.7708	-0.9739	-1.1967	1.7299	-1.1513	1.6896	-0.7367	-0.5162	-0.2692
				Tv 0.0482	0.0212	0.0339	0.0125	0.0232	0.2823	0.5086	0.3712	0.6978
				Ss 0.5715	0.7524	-0.1282	-0.5046	-0.2574	1.0720	0.3020	0.4960	1.1478
				Tv 0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss 0.3698	-0.0783	0.1260	-0.4189	-0.1663	0.0883	-0.6613	-0.4731	0.6780
				Tv 0.2105	0.5712	0.7368	0.6142	0.1387	0.2907	1.4966	0.2433	0.0848

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	Ss	LaMo	CsSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Cera_nae	<i>Ceratopogoninae</i>	844	56	Ss	-0.1367	-0.0856	-0.2555	0.1530	-0.3731	0.2724	-0.3952	-0.2647	0.1127
Das_spp	<i>Dasyhelea</i> sp.	97	4	Tv	1.0626	0.9563	0.9764	1.0708	0.7951	1.1021	1.0258	0.8121	0.9086
For_spp	<i>Forcipomyia</i> sp.	1	1	Ss	-1.7256	-0.8470	-1.1930	1.6872	-0.9909	1.7003	-0.8888	-0.3757	-0.5584
Chb_spp	<i>Chaoborus</i> sp.	8	4	Tv	0.4776	1.3846	0.3599	0.4637	1.7523	0.6388	1.0913	1.0182	0.7094
Ano_spp	<i>Anopheles</i> sp.	16	3	Ss	0.7380	-0.6610	-0.1039	-0.7871	0.3354	-0.9881	0.1505	-0.6770	-0.6706
Cul_spp	<i>Culex</i> sp.	52	1	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Doli_dae	<i>Dolichopodidae</i>	1	1	Ss	0.4207	0.9765	0.3409	-0.5135	0.2879	-0.2641	0.5557	1.6755	-0.0415
Epy_dae	<i>Ephydriidae</i>	6	2	Tv	0.8388	0.5375	0.7091	0.8890	1.1264	0.8342	1.1773	1.8328	0.6392
Chio_nae	<i>Chioneinae</i>	8	1	Ss	0.6614	-0.1739	-0.0958	-0.8263	0.0608	-0.9132	-0.1331	-0.6413	0.6860
Lino_nae	<i>Limnophilinae</i>	1	1	Tv	0.1099	0.6506	0.2052	0.0534	0.3670	0.4863	0.6730	0.5292	0.5510
Limo_nae	<i>Limoniinae</i>	6	2	Ss	0.7380	-0.6610	-0.1039	-0.7871	0.3354	-0.9881	0.1505	-0.4193	1.0722
Psd_spp	<i>Pseudolimnophila</i> sp.	1	1	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Per_ini	<i>Psychodidae</i>	1	1	Ss	0.8479	1.0917	0.8636	-0.8788	-0.1474	-0.0531	1.1496	-0.3438	1.4139
Chrp_spp	<i>Chrysopilus</i> sp.	7	2	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Scat_dae	<i>Scatophagidae</i>	10	3	Ss	-0.8767	1.5591	-0.3707	0.8789	2.0524	0.4379	1.9520	3.1968	2.6195
Sci_dae	<i>Sciomyzidae</i>	2	1	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bes_spp	<i>Beris</i> sp.	1	1	Ss	0.3258	0.6922	-0.9461	-0.2823	-0.4395	0.2359	-0.7483	0.2930	0.1175
Odt_spp	<i>Odontomyia</i> sp.	1	1	Tv	0.3178	1.5105	0.6703	0.5103	0.7729	0.6390	0.0268	0.6408	0.8855
Oxe_spp	<i>Oxyecera</i> sp.	47	3	Ss	0.5961	-0.1860	0.5513	-0.6862	-0.0981	-0.9693	-0.3217	-0.3777	-0.3049
Str_spp	<i>Stratiomys</i> sp.	1	1	Tv	0.3071	0.7965	0.9246	0.5728	0.8306	0.3237	0.9812	0.9783	1.2308
				Ss	0.7380	-0.6610	-0.1039	-0.7871	0.3354	-0.9881	0.1505	-0.4193	1.0722
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	-1.7474	-0.9636	-1.2127	1.7238	-1.1401	0.9960	-0.9986	0.1550	0.6423
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	0.5187	0.3256	-0.3950	-0.8532	-0.2643	-0.1172	0.3969	-0.3010	0.6180
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				Ss	0.7340	-0.3729	0.0112	-0.8064	0.2245	-0.9263	0.1242	-0.5146	1.0124
				Tv	0.0915	0.9695	0.4765	0.0623	0.3585	0.4944	0.7937	0.4313	0.5555
				Ss	0.0311	0.2110	-0.1068	0.4907	1.6244	-0.0846	2.0438	0.9029	0.5264
				Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix 2. Continued.

Code	Taxa and taxonomic group	Num	Occ	Ss	LaMo	CaSi	Omni	I-AG	Urban	Nutri	Ammon	Litt	Subs
Syrp_dae	<i>Syrphidae</i>	1	1	Ss	0.8479	1.0917	0.8636	-0.8788	-0.1474	-0.0531	1.1496	-0.3438	1.4139
Chrs_spp	<i>Chrysops</i> sp.	29	6	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Tab_spp	<i>Tabanus</i> sp.	2	1	Tv	0.2193	0.1957	0.0789	-0.2434	-0.5775	0.2240	-0.1018	-0.2022	-0.3870
Tip_spp	<i>Tipula</i> sp.	77	9	Tv	0.7441	1.1590	1.2001	0.7693	0.2235	0.9821	0.4235	0.5521	1.2809
Bri_bif	<i>Brillia bifida</i>	1	1	Ss	-1.7241	-0.9533	-1.2084	1.7178	-1.1289	1.9333	-1.0900	-1.2344	1.2569
Chir_ini	<i>Chironomini</i>	21,826	120	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chi_plu_sk	<i>Chironomus plumosus</i> -Gr.	225	22	Ss	-1.3511	-0.7033	-1.0523	1.3385	-0.8431	1.3974	-0.6570	-0.5536	0.0336
Chi_thm_sk	<i>Chironomus thummi</i> -Gr.	78	12	Tv	1.0862	0.7108	0.4535	1.0751	0.9456	0.9768	0.9656	0.6917	0.5548
Cor_spp	<i>Corynoneura</i> sp.	15	6	Ss	-1.7241	-0.9533	-1.2084	1.7178	-1.1289	1.9333	-1.0900	-0.4005	0.9562
Orth_nae	<i>Orthocladiinae</i>	2693	90	Tv	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Prd_oli	<i>Procladius olivacea</i>	12	2	Ss	0.1976	0.0738	0.0684	-0.1609	0.0237	-0.1027	0.0897	0.0916	0.1477
Tany_nae	<i>Tanyptodinae</i>	8411	109	Tv	0.9343	1.0074	1.0211	0.9084	0.9403	0.9427	0.9951	1.0940	1.0557
Tan_ini	<i>Tanytarsini</i>	14,016	107	Ss	0.7223	-0.2108	0.6121	-0.7006	-0.1574	-0.6020	0.0219	-0.0754	0.5802
Syl_spp	<i>Sylvicola</i> sp.	4	2	Tv	0.3975	0.9726	1.1321	0.3388	0.4140	0.7713	0.7976	0.5181	0.9965
Maxillopoda				Ss	0.4860	-0.2030	0.3254	-0.4367	0.3480	-0.4123	0.1644	-0.0811	0.7295
Arg_spp	<i>Argulus</i> sp.	1	1	Tv	0.5148	0.8220	1.0297	0.6383	0.7783	0.6436	1.1698	0.8283	0.9223
Lepidoptera				Ss	0.2754	0.2690	-0.1008	-0.3780	0.3164	-0.7432	-0.1071	-0.4433	0.0568
Parapoxn_spp	<i>Parapoxyn</i> sp.	4	1	Tv	0.8460	0.8320	0.3843	1.0021	1.1287	0.9100	1.3865	1.0761	0.6861
Nym_nym	<i>Elophila nymphaeata</i>	3	2	Tv	0.0891	-0.0615	0.0708	-0.0477	0.2034	-0.1062	0.0797	0.2507	0.2519
				Ss	0.9879	1.0044	0.9698	0.9712	1.0558	1.0004	1.1298	1.2343	1.1651
				Tv	0.0311	0.2110	-0.1068	0.4907	1.6244	-0.0846	2.0438	-0.5125	0.2916
				Ss	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.2800	0.2123
				Tv	0.0840	0.2846	-0.0962	-0.0630	-0.0061	0.0437	0.0430	0.0370	0.0954
				Ss	0.8610	0.9937	0.8811	0.8815	0.9855	0.9261	1.0383	0.9301	0.9625
				Tv	0.0429	0.3344	-0.1915	-0.0400	-0.0076	0.1101	0.0756	-0.0005	0.1463
				Ss	0.8549	0.9466	0.7948	0.8884	0.9800	0.8613	0.9950	0.9271	0.8863
				Tv	0.8479	1.0917	0.8636	-0.8788	-0.1474	-0.0531	1.1496	0.0500	1.2339
				Ss	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.8355	0.3818
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Appendix 3

Table of Friedmans test values with species scores and tolerance values.

Gradient 1–Gradient 2	Results for indicator values			Results for tolerance values ranges		
	Test statistic (Z)	Std. test statistic	Adj. sig. (ρ)	Test statistic (Z)	Std. test statistic	Adj.sig (ρ)
Urbanization–Littoral alteration	0.998	4.099	0.001	0.709	2.914	0.129
Urbanization–Omnivorous fish	1.508	6.193	<0.0001	–0.053	–0.219	1.000
Ammonium–Urbanization	0.753	3.092	0.071	0.771	3.165	0.056
Ammonium–Littoral alteration	0.245	1.006	1.000	–0.061	–0.252	1.000
Ammonium–Omnivorous fish	2.261	9.285	<0.0001	0.717	2.946	0.116
Catchment size–Intensive agriculture	1.636	6.720	<0.0001	–0.735	–3.019	0.056
Catchment size–Nutrients	1.532	6.290	<0.0001	–0.263	–1.079	1.000
Catchment size–Ammonium	0.881	3.620	0.011	0.403	1.656	1.000
Substratum–Catchment size	1.844	7.573	<0.0001	0.789	3.238	0.043
Substratum–Intensive agriculture	0.208	0.852	1.000	1.524	6.258	<0.0001
Substratum–Nutrients	0.312	1.282	1.000	1.051	4.318	0.001
Substratum–Ammonium	0.962	3.953	0.003	0.385	1.583	1.000
Substratum–Urbanization	1.715	7.045	<0.0001	1.156	4.748	<0.0001
Substratum–Littoral alteration	0.717	2.946	0.116	0.447	1.834	1.000
Substratum–Omnivorous fish	3.223	13.238	<0.0001	1.103	4.529	<0.0001
Catchment size–Littoral alteration	1.126	4.626	<0.0001	0.342	1.404	1.000
Catchment size–Omnivorous fish	–1.379	–5.665	<0.0001	–0.314	–1.291	1.000
Catchment size–Urbanization	0.128	0.528	1.000	–0.368	–1.510	1.000
Intensive agriculture–Littoral alteration	–0.510	–2.094	1.000	1.077	4.423	<0.0001
Intensive agriculture–Omnivorous fish	3.016	12.386	<0.0001	–0.421	–1.729	1.000
Intensive agriculture–Nutrients	–0.105	–0.430	1.000	0.472	1.940	1.000
Intensive agriculture–Urbanization	–1.508	–6.193	<0.0001	0.368	1.510	1.000
Intensive agriculture–Ammonium	–0.755	–3.100	0.070	1.138	4.657	<0.0001
Nutrients–Ammonium	–0.650	–2.760	0.273	0.666	2.735	0.224
Nutrients–Urbanization	1.403	5.763	<0.0001	0.105	0.430	1.000
Nutrients–Littoral alteration	–0.405	–1.664	1.000	0.605	2.484	0.468
Nutrients–Omnivorous fish	2.911	11.955	<0.0001	0.051	0.211	1.000
Lake morphometry–Substratum	1.761	7.232	<0.0001	1.603	6.582	<0.0001
Lake morphometry–Catchment size	–0.083	–0.341	1.000	0.814	3.344	0.030
Lake morphometry–Intensive agriculture	1.553	6.380	<0.0001	0.079	0.325	1.000
Lake morphometry–Nutrients	1.449	5.949	<0.0001	0.551	2.264	0.848
Lake morphometry–Ammonium	0.789	3.279	0.037	1.217	5.000	<0.0001
Lake morphometry–Urbanization	0.045	0.187	1.000	0.447	1.834	1.000
Lake morphometry–Littoral alteration	1.043	4.285	<0.0001	1.156	4.748	<0.0001
Lake morphometry–Omnivorous fish	–1.462	–6.006	<0.0001	0.500	2.053	1.000
Littoral alteration–Omnivorous fish	2.506	10.292	<0.0001	0.656	2.695	0.254

Bold values are statistically significant ($p < 0.05$).