TAXONOMIC DISTINCTNESS PROVIDES AN ALTERNATIVE VIEW OF THE DIVERSITY OF CHIRONOMIDAE (DIPTERA) ASSEMBLAGES.

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With 2 tables and 2 figures

ABSTRACT: The taxonomic diversity, Δ*, of an assemblage measures the degree to which individuals represent species from a range of disparate taxonomic groups, vs. a small number of similar taxa. Taxonomic breadth, Δ^+, likewise quantifies the distribution of species across a variety of higher taxa. Chironomid assemblages from an urban stream in Minnesota, USA, were used to compare the performance of Δ*, Δ^+, species richness and Simpson's diversity index (λ) as measures of biodiversity. Observed and estimated species richness values differed due to the large variation in cumulative emergence among sites, whereas Δ^+ varied little. Dominance of *Thienemanniella*, *Corynoneura* and *Nanocladius* species at some sample sites lead to much lower values of Δ* compared to λ. Taxonomic distinctness, Δ*, was sensitive to the distribution of individuals among sub-families and provided a complementary perspective on chironomid diversity.

RESUMO: A diversidade taxonómica, Δ*, de uma amostragem mede o grau para a qual indivíduos representam espécies de uma classe de grupos taxonómicos desiguais, versus um número reduzido de taxa análogos. De maneira semelhante, a amplitude taxonómica, Δ^+, quantifica a distribuição de espécies através da variedade de taxa superiores. Usou-se a amostragem de quironomídeos de um ribeiro urbano do Minnesota, EUA, para comparar a representação de Δ*, Δ^+, a riqueza de espécies e o índice de diversidade de Simpson (λ), como medidas de biodiversidade. Os valores da riqueza específica observada e estimada são diferentes devido à ampla variação existente entre os sítios no que diz respeito à eclosão cumulativa, ao passo que a Δ^+ variou pouco. A dominância de espécies de *Thienemanniella*, *Corynoneura*

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e *Nanocladius* nalguns sítios de amostragem levou a valores muito mais baixos de Δ* comparado com λ. A diferenciação taxonómica, Δ*, foi sensível à distribuição de indivíduos entre sub-famílias e favoreceu uma perspectiva complementar no que diz respeito à diversidade de quironomídeos.

INTRODUCTION

The high species richness of many chironomid communities requires one to consider how biodiversity should be best quantified. Do indices of species richness and evenness (MAGURRAN 2004) provide sufficient information about an assemblage of species, or should measures of taxonomic, functional or evolutionary diversity also be included? Taxonomic distinctness (Δ*) is defined as the average distance or path length within a taxonomic hierarchy, between all pairs of individuals in a sample given that they are not of the same species (WARWICK & CLARKE 1995). The taxonomic breadth (Δ^+) of a sample is defined similarly, as the average distance among all pairs of species in a sample. Because Δ^+ can be calculated with species' presence/absence data, it is of particular interest in conservation biology for comparing habitats when only lists of species are available. A valuable characteristic of both indices is that they are unbiased by sample size, in contrast to most traditional diversity indices. The estimates of both Δ* and Δ^+ do not change with increasing sample size, although the precision of the estimates improves with larger sample sizes (WARWICK & CLARKE 2001). In contrast, comparison of the intrinsic species richness of two areas requires either that samples contain equal numbers of individuals, or that rarefaction, a random re-sampling process, be used to adjust the data to a constant sample size (MAGURRAN 2004).

For analysis of marine benthic communities, Δ* and Δ^+ have been proposed to be more sensitive to environmental degradation and less responsive to natural environmental gradients (e.g., substrate grain size) than species richness (WARWICK & CLARKE 1995). Taxonomic breadth, Δ^+, shows promise for comparisons of biodiversity between locations, because it appears to increase with the number of different habitats at a site. Studies of many, but not all marine benthic assemblages found Δ* to be uncorrelated with species richness (WARWICK & CLARKE 2001). In contrast, there has been little application of Δ* and Δ^+ to freshwater assemblages. HEINO et al. (2005) have examined the degree of redundancy between Δ* and species richness, for lotic and lentic assemblages in Finland. Here, we apply Δ*, Δ^+, and two traditional indices, species richness and Simpson's index, to four chironomid assemblages from an urban stream, to determine how the diversity-ranking of these sites is influenced by choice of index.

METHODS

We surveyed chironomid diversity along Minnehaha Creek (Minnesota, U.S.A.), which flows 22 miles through predominantly residential neighborhoods in the Minneapolis-St. Paul metropolitan area. Chironomid emergence was analyzed at four sites (identified by nearest road crossing) in the upper reaches of Minnehaha Creek: Bridge Street (Minnetonka, MN), West 34th Street (St. Louis Park, MN), Excelsior Boulevard (St. Louis Park, MN) and a small tributary draining Lake Harriet (Minneapolis, MN). Surface-floating pupal exuviae were collected for ten-minute periods of time using a shallow pan and a 165 micron mesh seive, along a standard reach at each site. Sampling was done at 3-week intervals during the ice-free season of 2003. The size distribution of streambed substrate was quantified by measuring the median diameter ("girth") of 100 bed particles chosen at random while walking a zig-zag course down the stream channel (KONDOLF 1997). Exuviae were sorted to genus/species and a subsample of each group was slide-mounted in Euparal and identified to species, where possible.

Diversity indices were calculated using Primer v.6 software (CLARKE & GORLEY 2006). The aggregation file describing chironomid taxonomic relationships included sub-genus, genus, tribe, and subfamily designations for each species, based on OLIVER et al. (1990). Values of Δ^* and Δ^+potentially range from 0 (if only one species is present) to 100, if all species pairs are in different subfamilies (CLARKE & WARWICK 2006).

RESULTS

Based on the substrate grain size (Fig. 1), we predicted that the chironomid assemblages at Bridge Street and 34th Street (sites with a mixture of cobble, gravel and sand substrate) would be more similar than assemblages from Excelsior Blvd. and Lake Harriet outlet (LHO), which had mostly sand substrate. However, at Excelsior Blvd. Minnehaha Creek is wide and bordered by wetlands, whereas LHO, a tributary, is less than 2 m wide and is heavily shaded. The total number of exuviae collected by standardized sampling over 10 dates varied from 18,975 at 34th Street, to only 961 at LHO. At all sites, the majority of individuals belonged to the Orthocladiinae, although the species observed at each site were more equitably distributed among the Orthocladiinae, Chironomini and Tanytarsini (Fig. 2). Similarity of chironomid assemblages, based on shared species, was greatest for Excelsior Blvd. and 34th St. (Sorensen similarity index = 73.7). The assemblage from LHO generally had low similarity to the other sites, and was least similar to that of Excelsior Blvd. (Sorensens index = 48.8).

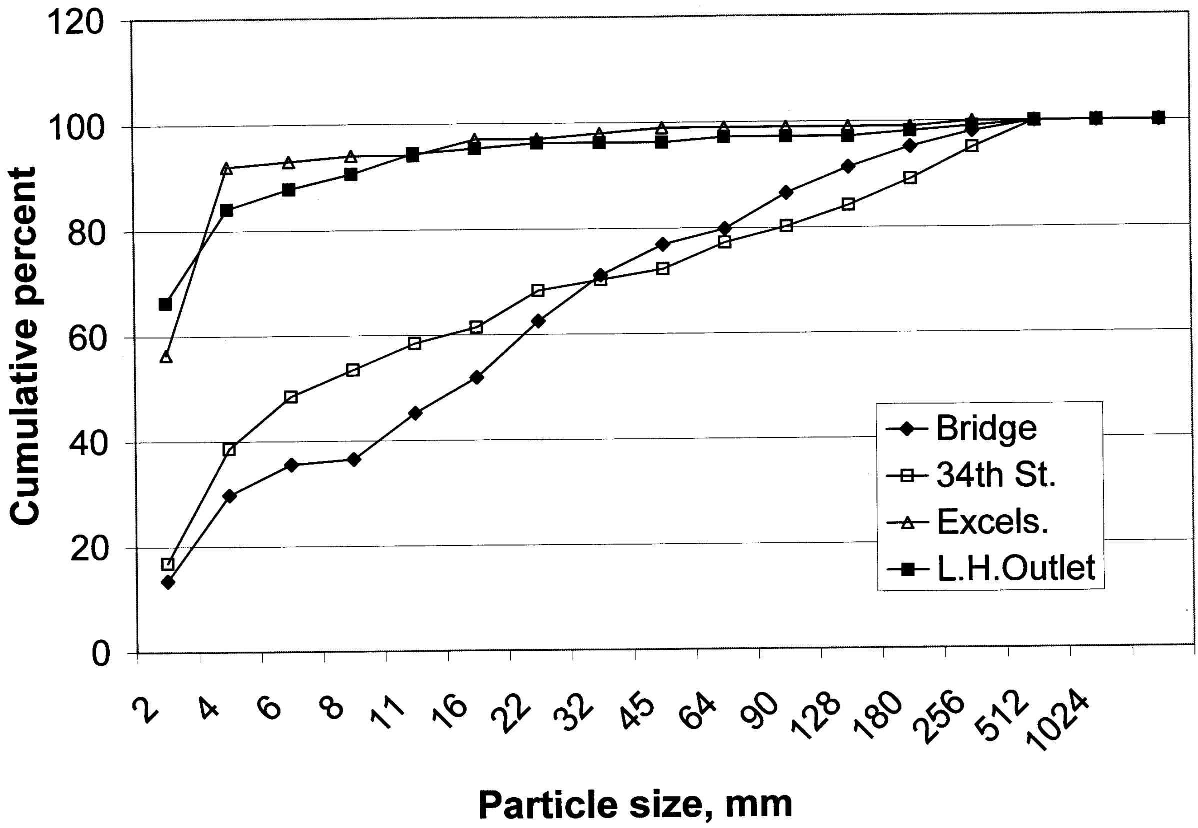

Fig. 1. Distribution of sediment particle size at the four sampling sites along Minnehaha Creek. The percent of particles smaller than a given median diameter is plotted.

The ranking of sites, from highest to lowest diversity, differed greatly depending on the diversity index used (Table 1). Because only the four sampling sites were treated as independent units, no statistical tests of significance among sites were performed. The highest number of observed species (100) was found at Bridge St. whereas LHO had the lowest observed species richness (40). In contrast, intrinsic species richness (estimated using rarefaction analysis, in which all sample sizes were adjusted to 961 individuals) gave LHO a higher ranking than 34th St., which dropped to lowest rank. Simpson's index, emphasizing the evenness of distribution of species, ranked Excelsior Blvd. as most diverse, and 34th St. as least diverse. Taxonomic distinctness (using quantitative data) gave the ranking most divergent from that of observed species number: LHO was ranked as most taxonomically diverse, and 34th St. was again ranked lowest (Table 1). The value of Δ^* was noticeably smaller for 34th St. than for the remaining sites. Taxonomic breadth (using presence/absence data) gave the same ranking of sites as did observed species number, except that the values of Δ^+ for all sites were more similar in magnitude (Table 1).

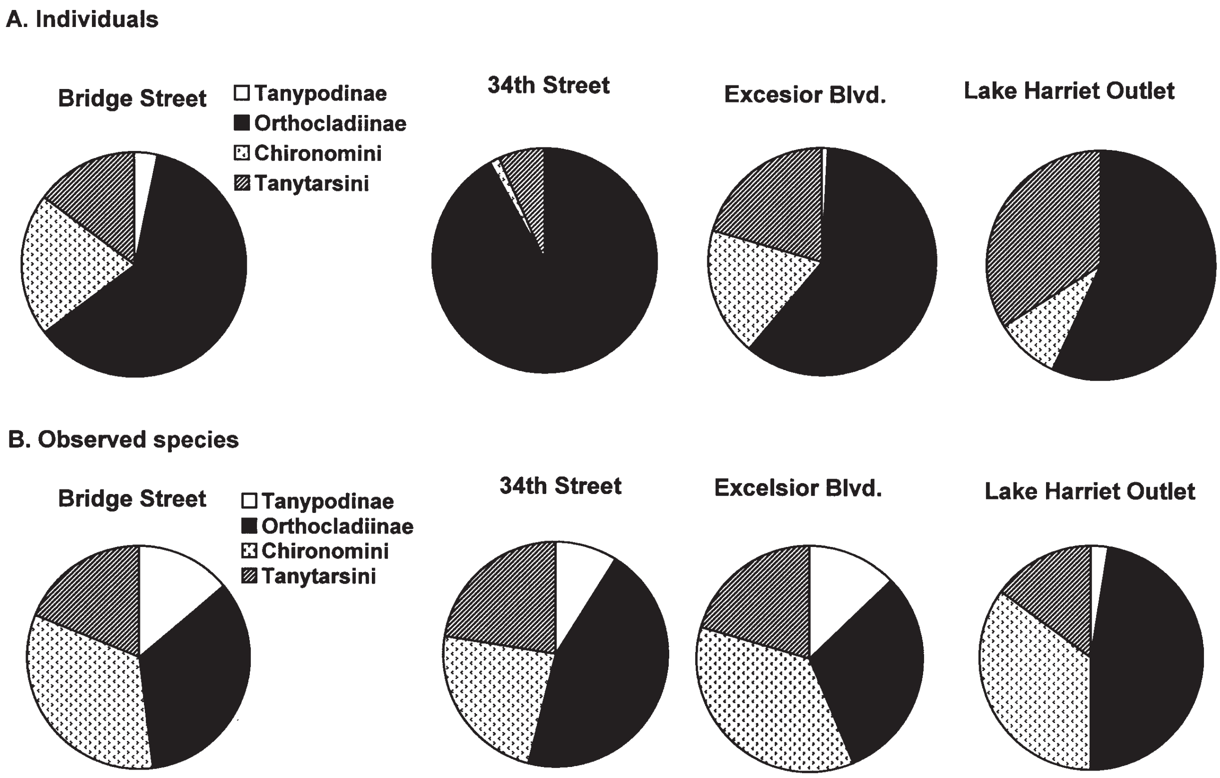

Fig. 2. Cumulative annual emergence of chironomid subfamilies/tribes expressed as number of individuals (A) and as number of species observed (B). The total numbers of exuviae collected per site were: 4,409 from Bridge St., 18, 975 from 34th St., 7, 088 from Excelsior Blvd. and 961 from Lake Harriet Outlet.

Table 1. Ranking of sites by different measures of diversity. Traditional diversity indices include observed and estimated species richness, and Simpson's index (1- λ).

Index	Site	Bridge	Excels.	34thSt	LHO
S_{obs}		100	87	79	40
	Site	Bridge	Excels.	LHO	34thSt
S_{est}		73	56	40	37
	Site	Excels.	Bridge	LHO	34thSt
1-λ		0,931	0,926	0,712	0,596
	Site	LHO	Bridge	Excels.	34th St
Δ*		86,7	85,5	84,2	68,7
	Site	Bridge	Excels.	34thSt	LHO
Δ^+		86,4	85,8	85,4	84,1

Dominance by a few highly abundant species greatly influenced the diversity ranking of sites (Table 2). *Thienemanniella xena* Roback was often the most abundant species in the mainstem of Minnehaha Creek, and along with *Corynoneura* sp. 2 and *Nanocladius rectinervis* Kieffer contributed to the large variation in cumulative emergence, i.e., sample size, among sites. *Nanocladius distinctus* Malloch and *Micropsectra nigripila* Johannsen were the most abundant species at LHO and are responsible for the high values of Δ^* at LHO. These two species are members of sub-families Orthocladiinae and Chironominae respectively, and consequently most pairs of individuals were separated by great taxonomic distance. Although *M. nigripila* was also numerous at 34th St., it was vastly outnumbered by three species of *Thienemanniella, Corynoneura* sp. 2 and *N. rectinervis* (Table 2); this led to the lowest value of Δ^*, because most taxonomic distances were between pairs of closely related Orthocladiinae.

Table 2. Cumulative annual emergence of the ten most abundant chironomid taxa by sample site on Minnehaha Creek, MN, during 2003.

Bridge Street

Total	Species
934	*Thienemanniella xena*
399	*Nanocladius distinctus*
290	*Einfeldia* sp. gr. B
260	*Eukiefferiella claripennis* gr.
221	*Cricotopus trifascia* Edwards
197	*Polypedilum obtusum* Townes
166	*Cricotopus sylvestris* Fabricius
152	*Micropsectra nigripila* Johannsen
152	*Paratanytarus dissimilis* Johannsen
147	*Nanocladius rectinervis*

34th Street

Total	Species
11786	*Thienemanniella xena*
1614	*Corynoneura* sp. 2
1480	*Nanocladius rectinervis*
993	*Thienemanniella lobapodema* Hestenes & Saether
687	*Thienemanniella similis*
401	*Paratanytarus dissimilis*
267	*Micropsectra nigripila*
219	*Rheotanytarsus distinctissimus* Brundin
129	*Nanocladius crassicornus* Saether
126	*Rheotanytarsus exiguus* Johannsen

Excelsior Blvd.

Total	Species
934	*Corynoneura* sp. 2
788	*Orthocladius dorenus* Roback
732	*Thienemanniella xena*
655	*Paratanytarus natvigi* Goetghebuer
566	*Polypedilum scalaenum gr.*
495	*Thienemanniella similis* Malloch
393	*Corynoneura* sp. 3
207	*Paratanytarus dissimilis*
196	*Micropsectra nigripila*
195	*Hydrobaenus pilipes* Malloch

Lake Harriet Outlet

Total	Species
405	*Nanocladius distinctus*
313	*Micropsectra nigripila*
42	*Nanocladius rectinervis*
26	*Nanocladius spiniplenus* Saether
25	*Parachironomus varus gr.*
22	*Thienemanniella xena*
19	*Paratendipes albimanus* Meigen
16	*Polypedilum scalaenum gr.*
10	*Cricotopus annulator* Goetghebuer
10	*Cricotopus tristis* Hirvenoja

DISCUSSION

Sample size, i.e., cumulative annual emergence per site, had a large impact on the diversity-rankings. The chironomid assemblage at 34th St. had the highest cumulative annual emergence, but was ranked least diverse by both intrinsic species richness and Δ^*. In contrast, the assemblage from LHO had far lower cumulative emergence, but was ranked most diverse by Δ^*. There is no evidence that the streambed substrate texture influenced the performance of either Δ^* or Δ^+, because the rankings of the two sandy sites (Excelsior Blvd. and LHO) versus the sites with diverse substrate show no consistent pattern. Although the number of independent sites/assemblages compared in this study is limited, HEINO et al. (2005) found that Δ^* and species richness usually had very different responses when measured along natural environmental gradients; depending on the type of taxonomic assemblage and the type of environmental gradient, richness and Δ^* may or may not show any particular type of correlation.

The relatively high overall diversity, especially at Bridge St., reflects the high chemical water quality in the headwaters of Minnehaha Creek. This is due to the trapping of sediment and particulate phosphorus upstream by Lake Minnetonka (MCWD 2003). Although suburban land use dominates the upper watershed, some wetlands still border the Creek, also preserving water quality. Estimated nutrient input rates increase downstream (MCWD 2003), which may account for the higher values of similarity of assemblages at Excelsior and 34th St. The inputs to stream foodwebs are probably more dynamic and spatially patchy than those to marine benthic communities, and the potential responses of Δ^* and Δ^+ to such variation in trophic status will influence the utility of taxonomic indices in assessment of freshwater biodiversity.

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