COMPARISON AND SIGNIFICANCE OF CHIRONOMIDAE EMERGENCE FROM LAKE ERIE AND PRESQUE ISLE BAY, ERIE, PENNSYLVANIA, U. S. A.

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With 1 Figure and 2 Tables

ABSTRACT: Collections of surface-floating pupal exuviae were used to assess day-to-day variability in Chironomidae emergence from two sites with differing sediment qualities and to evaluate qualitative and quantitative approaches to measuring differences in emergence. Over a temporal scale of three days, pupal exuviae samples had low precision for estimating species richness, were more effective for biotic index metrics, and resulted in within-site estimates of variability ranging from 0.510 to 0.61 and cross-site similarities of 0.220 to 0.110. Quantitative estimates of similarity better discriminated differences in emergence from the study sites when compared to qualitative estimates, although both approaches were adequate.

RESUMO: Amostras de exúvias de pupas a flutuar à superfície foram usadas para calcular a variabilidade diária na emergência de Quironomídeos de dois locais apresentando diferentes tipos de sedimento e, para avaliar o efeito de aproximações qualitativas e quantitativas na medição da emergência. Numa escala temporal de três dias, as amostras de exúvias de pupas revelaram baixa precisão na estimação da riqueza específica, demonstraram ser mais adequadas para métricas de índices bióticos e revelaram uma variabilidade inter-local entre 0.510 e 0.61 e uma similaridade intra-local de 0.220 a 0.110. As estimativas quantitativas de similaridade demonstraram maior capacidade para discriminar as diferenças na emergência dos dois locais com diferentes tipos de sedimento, do que as estimativas qualitativas, apesar de ambas as aproximações serem adequadas.

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INTRODUCTION

Collections of surface-floating pupal exuviae (SFPE) are used in rapid bioassessment protocols (RBP) in both lotic (*e. g*., FERRINGTON 1987, FERRINGTON & CRISP 1989) and lentic habitats (*e. g.*, RUSE 2002, RUFER & FERRINGTON 2008) to measure changes in community structure across water quality gradients. FERRINGTON *et al.*'s (1991) work on the efficacy, efficiency and cost-effectiveness of SFPE to d-net collections found that the approach matched or exceeded d-net collections. Used on a monthly basis across a gradient of disturbed sites SFPE provided better resolution than a single set of d-net collections (SEALOCK & FERRINGTON 2008), similar to an RBP design recommended in BARBOUR *et al.* (1999). However, phenological emergence patterns meant that SFPE collections from June did not perform as well across the gradient as d-net collections. Consequently, it is necessary to better document the variability of results from SFPE collections at differing spatial and temporal scales that can be employed in RBP designs.

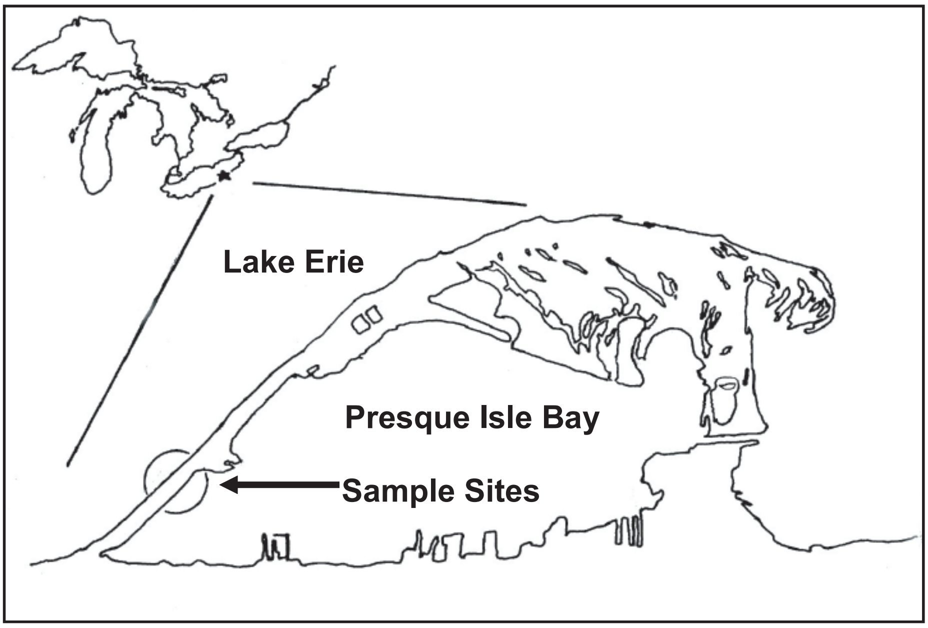

Figure 1. Location of sample sites on Lake Erie and Presque Isle Bay.

Presque Isle Bay (PIB) in Lake Erie is formed by Presque Isle, a large sand spit that extends approximately for 20 kilometres (Fig 1). PIB water and sediment quality has been contaminated by industrial and effluent water discharges from municipal sewage treatment for over a century although pollution control and effluent treatment have improved water quality in recent decades (DIZ 2005). However several contaminants associated with sediments of PIB may still be a concern. Although Lake Erie has been severely enriched over the past century, water and sediment quality in open lake areas has greatly improved. The contrasting sediment qualities of PIB and open lake areas on opposite sides of Presque Isle provide a natural opportunity to test small-scale temporal variations of the SFPE method for contrasting lentic conditions over a small spatial scale. In this study, collections of SFPE were made from opposite sites of Presque Isle on three consecutive days to measure day-to-day variability of data.

METHODS

SFPE were collected on 21, 22 and 23 June 2005 following FERRINGTON *et al.* (1991). Collections were standardized for effort, collected at the same time of day, and weather conditions were similar across all three days except for minor differences in wind speed and direction. Collections were taken in shallow water at two sites, referred to as bay-side and lake-side. Although separated by Presque Isle, the sites are less than 300 metres apart, allowing comparison of emergence from PIB and open water areas of Lake Erie.

Samples were sieved in the field, preserved in 80% ethanol, sorted under 12X magnification with a dissecting microscope and counted. Day-to-day variation in the number of exuviae collected ranged from 284 to 1,500 exuviae in single separate samples. After sorting, 284 specimens were randomly subsampled in order to calculate metrics based on identical numbers of specimens. All specimens were identified to lowest taxonomic levels achievable (genus, species-group or species-level depending on the taxon) without slide mounting, using a dissecting microscope at 50X magnification. Slide mounted voucher specimens are deposited in the Insect collection of the Department of Entomology at the University of Minnesota and the natural history collections of the Tom Ridge Environmental Science Center at Presque Isle in Erie, PA.

Species richness and biotic index metrics were calculated from SFPE collections, based on tolerance values tabled in BARBOUR *et al.* (1999). Best professional judgment was used to assign a tolerance value to taxa (not included in BARBOUR *et al.* (1999)), available on request from the corresponding author.

Similarity was determined using Jaccard's Coefficient and Whittaker's Percent Similarity, and all permutations of two-sample similarities were calculated. These coefficients provide alternative and complementary measures of similarity. Jaccard's Coefficient is a qualitative measure of similarity, calculated, using presence/absence data whereas Whittaker's Percent Similarity provides a quantitative measure of similarity based upon the relative frequencies of shared species. Both coefficients range from 0.0 (no similarity) to 1.0 (complete similarity) and can be multiplied by 100 to express results as percentage values. Within-site and cross-site similarities were calculated as arithmetic means, as were cross-site similarities based on same-day and different-day collections (Table 2).

RESULTS

Fifty-six taxa were identified from collections. Cumulative taxonomic richness (Table 1) of bay-side collections (43 taxa) was higher than lake-side collections (26). Bay-side daily richness estimates were consistently higher (26-34 taxa/day), but varied more than lake-side collections (16-19 taxa/day). Biotic index values for bay-side samples (average 5.08) were consistently higher across all three sample dates than for lake-side samples (average 3.76, Table 1).

TABLE 1—Taxonomic richness and biotic index values by site and day.

	Bay-side	**Lake-side**
Taxonomic richness		
21 June 2005	34	16
22 June 2005	26	18
23 June2005	31	19
Cumulative (all three days)	***43***	***26***
Biotic Index Values		
21 June 2005	5.19	3.62
22 June 2005	4.99	3.91
23 June 2005	5.06	3.80
Average (all three days)	***5.08***	***3.76***

Average qualitative and quantitative similarities of bay-side collections were similar (0.554 and 0.511, respectively) as were average qualitative similarities for lake-side samples (0.510). Quantitative similarity of lake-side samples was higher (0.671). Cross-site similarities were substantially lower than within-site similarities. The average qualitative cross-site similarity of 0.213 was approximately twice the average quantitative value calculated (0.112). Same-day comparisons of both average qualitative and average quantitative similarities were higher than different-day average similarities. Quantitative average similarities were only approximately one-half the value of the corresponding average qualitative similarities.

DISCUSSION

SFPE samples collected over restricted temporal scales should exhibit high precision for effectively assessing of change in chironomid emergence related community structure patterns from sediments with differing pollutant concentrations. Where samples were taken over three consecutive days in similar weather conditions, it can be assumed that most day-to-day variations at a given site are a result of sampling error rather than phenological differences and/or differential species responses to variable weather conditions.

TABLE 2. Similarities of emergence based on Jaccard's Coefficient and Whittaker's Percentage Similarity.

	Jaccard's	**Whittaker's**
Within Site Similarities		
Bay-side 21 June x Bay-side 22 June		
Bay-side 21 June x Bay-side 23 June		
Bay-side 22 June x Bay-side 23 June		
Average Bay-side similarity	0.554	0.511
Lake-side 21 June x Lake-side 22 June		
Lake-side 21 June x Lake-side 23 June		
Lake-side 22 June x Lake-side 23 June		
Average Lake-side similarity	0.510	0.671
Cross Site Similarities		
Bay-side 21 June x Lake-side 21 June*		
Bay-side 21 June x Lake-side 22 June++		
Bay-side 21 June x Lake-side 23 June++		
Bay-side 22 June x Lake-side 21 June ++		
Bay-side 22 June x Lake-side 22 June*		
Bay-side 22 June x Lake-side 23 June++		
Bay-side 23 June x Lake-side 21 June++		
Bay-side 23 June x Lake-side 22 June++		
Bay-side 23 June x Lake-side 23 June*		
Average cross-site similarity	0.213	0.112
Average same day, cross-site similarity	0.220	0.115
Average different day, cross-site similarity	0.209	0.110

* Same day, cross-site comparisons among sample sites

++ Different day, cross-site comparisons among sample site

Our results show that SFPE precision varied according to the type of metrics used. Taxonomic richness estimates had low precision, especially at the site with more highly contaminated sediments. This is also true for day-to-day estimates and day-to-day versus cumulative richness estimates. These findings challenge the Biotic Homogenization Theory (OLDEN & ROONEY 2006), which predicts lower species richness and higher redundancy of taxa over time. However, our data were strongly influenced by the presence of rare taxa in the bay-side samples where greater richness is probably due to the higher habitat heterogeneity provided by aquatic vascular hydrophytes in PIB compared to the macrophyte poor lake-side sample site. The biotic index metric performed well across the three sample dates, apparently distinguishing between different perceived contaminant conditions. This was due to the subsampling protocol, where we adjusted the number of specimens per "sample" to match the size of the smallest sample collected.

SFPE collections should exhibit high within-site similarity and low cross-site similarity. Maximum discrimination ability should occur when within-site similarities equal or approach unity and cross-site similarities equal or approach zero, with the difference between the two sets of comparisons representing a measure of community change resulting from environmental stress. Both qualitative and quantitative SFPE similarity measures have reasonably good potential in detecting emergence differences. Although within-site similarities values are substantially less than unity, the average qualitative similarity values (0.554 and 0.510) are more than twice as similar as the corresponding average cross-site similarities, and result in estimates of 29% to 34% differences in similarity of emergence for PIB versus open water areas of Lake Erie, even after day-to-day differences in emergence are considered.

Within-site similarities were strongly affected by taxa occurring with low frequency that were not detected by subsampling Within-site qualitative similarity could be improved by scanning the entire sample in order to detect these less abundant taxa without the need needing to estimate their frequency. This also allows very large samples to be assessed using presence-absence data for rapid bioassessment activities and may also reduce the effect of day-to-day variability in within-sites species richness estimates. However this approach would not permit the derivation of frequency based Biotic Index values.

Quantitative estimates of similarity better distinguished between emergence from PIB and open-lake areas of Lake Erie compared to qualitative methods, due to lower across-site average similarity values and increased average similarity of Lake-side samples. The differences between the two groups of similarities, which ranged from 39.9% to 55.9%, highlight the need to both individual taxon frequencies and presence-absence data (*i.e.,* min p_{ij} or p_{ik}) for better precision. However, this approach, which assumes that large samples can consistently be collected at field sites, requires random subsamples to be taken from larger samples collected in the field as well as more time and effort to identify all specimens in the subsamples.

Average cross-site similarity allows comparison of samples from both sites collected on the same days and from the two different sites on differing days. By calculating the averages for same-day similarities and the different-day similarities it is possible to isolate and quantify the variability in similarity related to sampling on different days. The day effect amounts to just 1.1% difference for the qualitative estimate of similarity and 0.5% difference for the quantitative estimate. Thus sampling over successive short temporal scales is not likely to substantially influence the efficacy of SFPE samples in detecting cross-site differences in emergence between sites. Although based upon only a three-day period with constant weather conditions, the low temporal variability for both qualitative or quantitative similarity measures is encouraging.

One last, but important aspect of our sample design is the effect of the sorting method used on taxonomic resolution (*i.e.* not all taxa were identified to species). Data patterns could change if species-level identifications could consistently be achieved. However we anticipated this would be difficult for large-scale monitoring and assessment programs likely to consider SFPE sampling as part of a RBP for monitoring water and/or sediment quality effects on chironomids.

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