Establishing chironomids as paleo-indicators for Lake Tanganyika: a preliminary qualitative assessment of chironomid distribution in the Kigoma Bay Region

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Introduction

This paper presents the results of a preliminary qualitative study on the distribution and diversity of live larval chironomids (Insecta: Order Diptera, non-biting midges) in the Kigoma Bay Region of Lake Tanganyika. In recent years, fossil midges have been used extensively, both as ecological indicators of anthropogenic impacts on lakes, and as proxies in paleoclimate/paleoecological studies (Eggermont & Verschuren, 2003a). Nevertheless, the majority of these studies have been restricted to the Northern Hemisphere, and with several exceptions, their use in limnological examinations in tropical East Africa (and Lake Tanganyika in particular) has been rather limited (Eggermont & Verschuren, 2003a). Indeed, three recent studies by Eggermont and Verschuren (2003a,b,c) represent the first known work of this kind in Lake Tanganyika. Two of these papers focused on the taxonomy of sub-fossil chironomids (Eggermont & Verschuren, 2003a & b), while a third examined impacts of sediment pollution in areas adjacent to several tributary drainage basins inferred by the chironomid fauna (Eggermont & Verschuren, 2003 c). The results of these studies advocate for the value of chironomids in recent ecological and paleontological examinations of this and other East African lacustrine ecosystems.

Since the *living* chironomid fauna of Lake Tanganyika has never been comprehensively examined (Eggermont & Verschuren, 2003a), it is important to establish chironomid taxa distribution patterns across habitat and depth gradients. Doing so will ensure that shifts in the relative abundance of taxa in sediment cores can be relied upon to infer both past and recent environmental and climate changes. Therefore, there were two main objectives to this study. The broad purpose of this investigation was to collect preliminary qualitative data on the spatial distribution and diversity of the live chironomid fauna in different Lake Tanganyika habitats. Additionally, a more immediate goal was to experiment with different methods for finding, collecting, identifying and preserving chironomid larvae.

The number of aquatic species in the family Chironomidae far surpasses that found in most other insect *orders*, making it by far the largest aquatic insect family (Hilsenhoff, 1991). Similar to most dipterans, the vast majority of chironomid adults are terrestrial, but the larvae of most species are aquatic and are known to inhabit all types of lotic and lentic habitats. Adults are short-lived, and often emerge from water bodies in tremendous numbers (Hilsenhoff, 1991). Chironomids can usually be differentiated from other dipterans because most species possess both anterior and posterior proleg pairs, and have fully emerged, sclerotized head capsules (Hilsenhoff, 1991). Confident identification to lower taxonomic orders usually requires the study of mounted head capsules under high magnification in order to recognize differences in various mouth structures (Dirk Verschuren, personal communication).

There is a wide variation in the feeding behavior of larval chironomid species, with members occupying herbivore, detritivore, filter-feeding, and carnivore guilds (Hilsenhoff, 1991). Most predatory larvae are free-living, while many other types live in the upper substrate layer (Hilsenhoff, 1991). Still others can be found attached to macrophytes (personal observation). In addition, most species are able to tolerate extremely low levels of dissolved oxygen (Hilsenhoff, 1991). Due to these factors, it may be reasonable to assume that chironomid larvae inhabit a variety of littoral and sub-littoral habitats in Lake Tanganyika. Therefore, this study focused on sampling a diverse array of habitats.

Methods

I experimented with a variety of sampling methods in different habitat types to address the objective of effective chironomid sampling and to identify chironomid habitats. This was largely a qualitative study, as volumetric or areal sampling proved impractical in this exploratory phase.

A total of 15 sites were sampled. By observing overall physical characteristics, each sample site was assigned to 1 of 5 substrate/habitat categories. Four of the five groups were categorized by noting size differences in dominant substrate, as defined by the American Geologist Grain Size Scale. These include: Silt/Mud, Sand/Pebble/Shell, Pebble/Cobble and Cobble/Boulder. A fifth category Macrophytes, included rooted, non-emergent aquatic plant habitats.

In areas where the substrate was dominated by large rocks and cobbles, several of each were collected and immediately placed in ziplock bags. The same technique was used for the sampling of macrophytic plant habitats. For areas characterized by silt/mud or sandy bottoms, specimen jars were used to 'scrape' and simultaneously store the top few centimeters of substrate. A similar technique was employed for sampling pebbly, coarse gravel, and shelly substrates, although in many cases it was more effective to simply grab handfuls of sediment and place them in ziplock bags or specimen jars. Additionally, a hand-operated suction pump device constructed by Simone Alin (University of Arizona) was used at several sampling sights to 'vacuum' aquatic organisms from rocky substrate. Finally, an attempt was made to collect specimens using a Surber sampler according to the methods described by Hauer & Resh (1996).

Seven of the fifteen samples were retrieved by the author while snorkeling. The remaining eight samples were collected by members of the Nyanza Project Biology Team using SCUBA.

Recovered samples were rinsed through a 63-micron mesh sieve and all residues were placed in specimen jars containing 70% ethanol. Larval chironomids and other aquatic organisms were located and identified using Olympus and Leica dissecting microscopes at powers ranging from 6.4x to 64x. Photographs were taken of specimens using a Nikon microscope-mounted digital camera. All picked specimens were preserved in 70% ethanol. Based on observed morphological features, specimens were assigned to one of six temporary taxonomic groups, which were referred to in open nomenclature as Taxon A-F. Collected data was tabulated and summarized using Microsoft Excel spreadsheets and SigmaPlot 8.0 graphing software.

Results

A total of 75 live chironomid larvae were found in examining samples from the 15 separate sites, which ranged from 0.1-m to 9.3-m of water depth. (Table 1). Furthermore, 31 unidentified/crumpled members of other dipteran families were recovered. For each site, total number of chironomids found, number of taxa observed, and the substrate/habitat category was recorded (Table 1 & Figure 2).

The chironomid community of all sites combined was dominated by Taxon C, which comprised 52% of the total, followed by Taxon A and Taxon B, which represent 24% and 15% of total chironomids respectively (Figure 1). Taxon D (7%), Taxon E (1%), and Taxon F (1%) make up the remaining 9% of specimens found.

On a site-by-site basis, Tafiri 4 and Tafiri 5 yielded the highest abundance of chironomids (14 and 19 specimens respectively) and were tied with four other sites for highest taxic diversity (3). Each of these two sites was dominated by a different plant type (genus and species yet to be determined). Samples from three sites (Tafiri 1, Tafiri 2, and Hilltop B) contained no specimens (Table 1).

Of the five substrate/habitat categories, only the samples taken from Pebble/Cobble areas (five sites total) combined to produce members of all six taxa, making this category the most diverse (Figure 2). Three other sample categories, including Sand /Pebble/Shell (two sites), Cobble/Boulder (five sites), and Macrophytes (two sites) all produced members of 4 taxa (A-D). Finally, a fifth sample category (Silt/Mud) was only represented by one sample site. This site contained no chironomids (Table 1), and therefore the Silt/Mud category was not presented graphically.

Discussion

Since data for this study was not collected in a quantitative manner, the graphs and figures presented here are meant only to suggest *possible* trends in diversity and distribution of chironomid taxa. These trends may or may not be borne out when detailed quantitative studies containing standardized sample sizes and replicates are conducted in the future.

Nevertheless, several interesting patterns emerge. The two sample sites which produced the most chironomids overall (Tafiri 4 & 5) and had high taxa diversity were both characterized by macrophytes (Table 1). Together, they contained members of four taxa, including 26 representatives from Taxon C (Figure 2). It may be that these chironomids are leaf miners, or perhaps filter feeders. Although most herbivore and detritivore chironomids are bottom-grazers, some filter-feeding chironomid species are known to construct webs, which they use to filter fine particles from the water (Hilsenhoff, 1991). Perhaps by attaching to plant stalks and leaves, members of these four taxa are able to feed higher up in the water column (rather than at bottom-level), and are thus filling separate feeding niches not utilized by species living on the bottom substrate.

In light of the large number of Taxon C specimens found on macrophytes, it is also interesting to note that individuals from Taxon A have also been found attached to crabs. Saskia Marijnissen (University of Amsterdam) reports finding these chironomids (as well as other dipterans) attached to the lateral carapace margins of *Platythelphusa conculcata* and *P. armata* specimens recovered from the Kigoma Bay area and *P. conculcata* specimens from Jakobsen's Beach. This phenomenon raises interesting questions regarding the relationship between the two organisms (mutualistic, commencialistic, or parasitic?), as well as Taxa A and C's propensity for attaching themselves to various sessile and mobile organisms. It may also have important implications/limitations for employing Taxon A as a paleoclimate indicator, since host organisms may be transporting these chironomids across various habitats that will be used to interpret past lake level changes. Similarly, it raises the questions of how frequently this behavior occurs, what other organisms (if any) are they attaching themselves to, and whether or not this behavior occurs among other chironomid taxa. Together, all of these queries are worthy of further investigation, both from an ecological and paleoecological perspective.

Taxon A warrants additional interest, since indications are that it may be the most adaptable of the 6 observed taxa, as it was found in ten of fifteen samples comprising 4 out of the 5 substrate/habitat categories (Table 1, Figure 2).

Although the Pebble/Cobble substrate category was dominated by rocks in the size class indicated by its name, lesser amounts of sandy/pebbly/shelly substrate were often present at these sites, particularly in crevices between cobbles (personal observation & Biology/Benthic Team reports). It may be that this wide range in substrate type creates a variety of habitat niches, thus resulting in the high species diversity (members of all 6 taxa were found) that occurred in samples retrieved from these areas (Figure 2). In the future, quantitative sub-sampling of these sites using more precise substrate criteria will be useful to more accurately determine the distribution and habitat preferences of various chironomid taxa.

The scarcity of specimens from Taxa E & F (only one representative of each was found) may be suggestive of low densities, or may just be do to the sampling bias already discussed. Additional, more structured analysis is needed to answer this question.

Among the other taxa, no clear pattern can be seen suggesting any substrate/habitat preference (Figure 2), but once again, this question will best be answered by quantitative examination.

As a result of my experiences in gathering data for this study, it appears that the most effective method for collecting larval chironomids in a qualitative fashion is to simply remove substrate or habitat structure by hand from sample sites, and immediately (while still underwater) store it in ziplock bags or specimen jars for later examination. Although some chironomids were retrieved from several sites using the suction pump, this device proved to be time-consuming and logistically difficult to operate when compared to the above-mentioned method, which produced equal or better results with much less effort. Devices such as Surber samplers and kick nets that are commonly used to survey stream habitats were unproductive, since lentic environments such as Lake Tanganyika lack the constant, unidirectional current flow required for their effective use. Finally, soft sediments in deeper water can be sampled by using Eckman grabs or Ponar samplers (several samples were retrieved by these methods for later analysis).

Generally speaking, it quickly became apparent that the number of live chironomid larvae per unit of substrate sampled was much lower than expected, a fact that should be taken into account when planning quadrat sizes for future qualitative work.

It is important to note that specimens were identified to temporary taxa after having been preserved in 70% ethanol, which can often cause significant discoloration of specimen tissues, and thus confound confident identification. Another problem that made identification problematic is that four molts occur before larval chironomids reach adulthood. The morphological differences between instars are often of sufficient magnitude as to make members of the same taxon at different developmental stages appear quite dissimilar, thus clouding delineation between taxa.

It is also unclear exactly what taxonomical resolution the six observed categories represent. According to Eggermont & Vershuren (2003 A&B), there are 3 known sub-families of Family Chironomidae currently known to exist in Lake Tanganyika (Tanypodinae, Orthocladinae, and Chironominae), containing 5 tribes with numerous genera and species. The 6 temporary taxa that I identified may well be members of just one sub-family or tribe, or any combination of the above taxonomical groups. I will be in a position to do more conclusive taxonomical identification of the study specimens in future months, after learning more details on the methods for preserving and identifying head capsules.

Conclusions

As is often the case, much was learned during the course of this study by trial and error. An ideal, comprehensive sampling method for all substrate/habitat types still remains elusive, although significant success with several techniques tailored to specific sites was experienced. Realistically, it may be that no comprehensive sampling method exists for all habitat types, and that different techniques will need to be employed for widely disparate sites.

Future studies consisting of standardized samples taken from transects crossing a depth gradient from the shallow, sandy splash-zone sandy areas, through the pebble/shell/cobble/boulder substrates to the deeper, lower oxygen mud/silt zone are needed. Examinations of macrophyte habitats, as well as the host-organism-chironomid transport phenomenon also deserve further attention. Answering these questions will go a long way towards establishing chironomids as reliable paleo indicators for Lake Tanganyika.

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Reference*s*

Eggermont, H., Verschuren, D. 2003a. Sub-fossil Chironomidae from Lake Tanganyika, East Africa. 1. Tanypodinae and Orthocladinae. Journal of Paleolimnology, 29: 31-48.
Eggermont, H., Verschuren, D. 2003b. Sub-fossil Chironomidae from Lake Tanganyika, East Africa. 2. Chironominae (Chironomini & Tanytarsini). Journal of Paleolimnology, 29: 423-458.

Eggermont, H., Verschuren, D. 2003c. Impact of soil erosion on disturbed tributary drainages on the benthic invertebrate fauna of Lake Tanganyika, East Africa. Biological Conservation, 113: 99-109.
Hauer, F. R., Resh, V.H. 1996. Benthic Macroinvertebrates. In: Hauer, F.R., Lamberti, G.A. (Eds.), Methods in Stream Ecology. Academic Press, San Diego, pp. 339-369.
Hilsenhoff, W.L., 1991. Diversity and Classification of Insects and Collembola. In: Thorp, J.H., Covich, A.P. (Eds.), Ecology and Classification of North American Invertebrates. Academic Press, San Diego, pp. 593-663.

Site	Total Chironomids	Taxa Present (Diversity)	Depth (m)	Dominant Substrate/Habitat
Tafiri 1	0	0	0.50	pebble/cobble
Tafiri2	1	1 (A)	0.50	cobble/boulder
Tafiri 3	0	0	1.00	silt/mud
Tafiri 4	14	3 (A,C,D)	2.00	macrophytes
Tafiri 5	19	3 (A,B,C)	6.00	macrophytes
Hilltop1	3	3 (A,C,D)	5.00	sand/pebble/shell
Hilltop 2	10	3 (A,B,C)	9.30	sand/pebble/shell
Hilltop A	3	3 (A,D,F)	0.10	pebble/cobble
Hilltop B	0	0	0.75	pebble/cobble
Kala 3	5	3 (A,B,C)	5.50	boulder
Punda Millila	1	1 (D)	5.00	boulder
Lemba	6	2 (A,C)	5.00	boulder
Katongwe	2	2 (A,C)	5.00	pebble/cobble
Jacobsen	1	1 (D)	5.00	boulder
Katabe North	10	3 (A,B,C)	5.00	pebble/cobble

Table 1: Summary of chironomid, depth, and substrate data for all 15 sights.

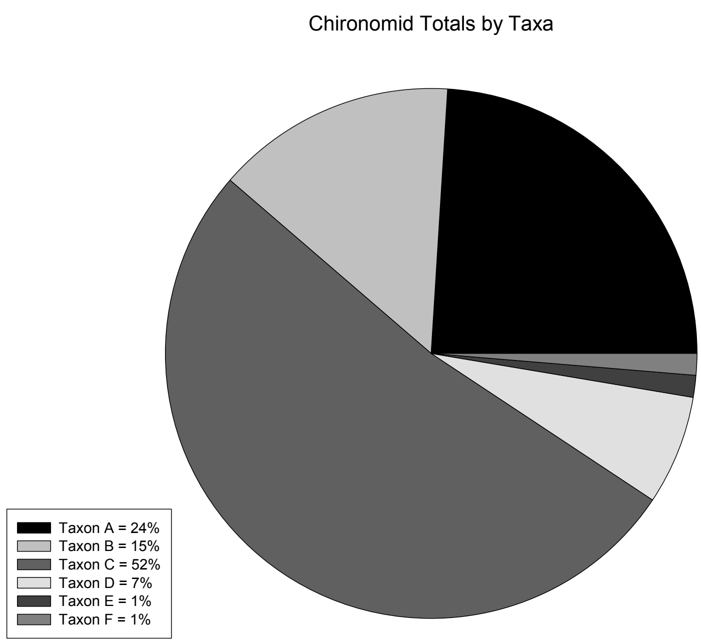

Figure 1: Percent of total chironomids found by morphological taxa at all 15 sample sites.

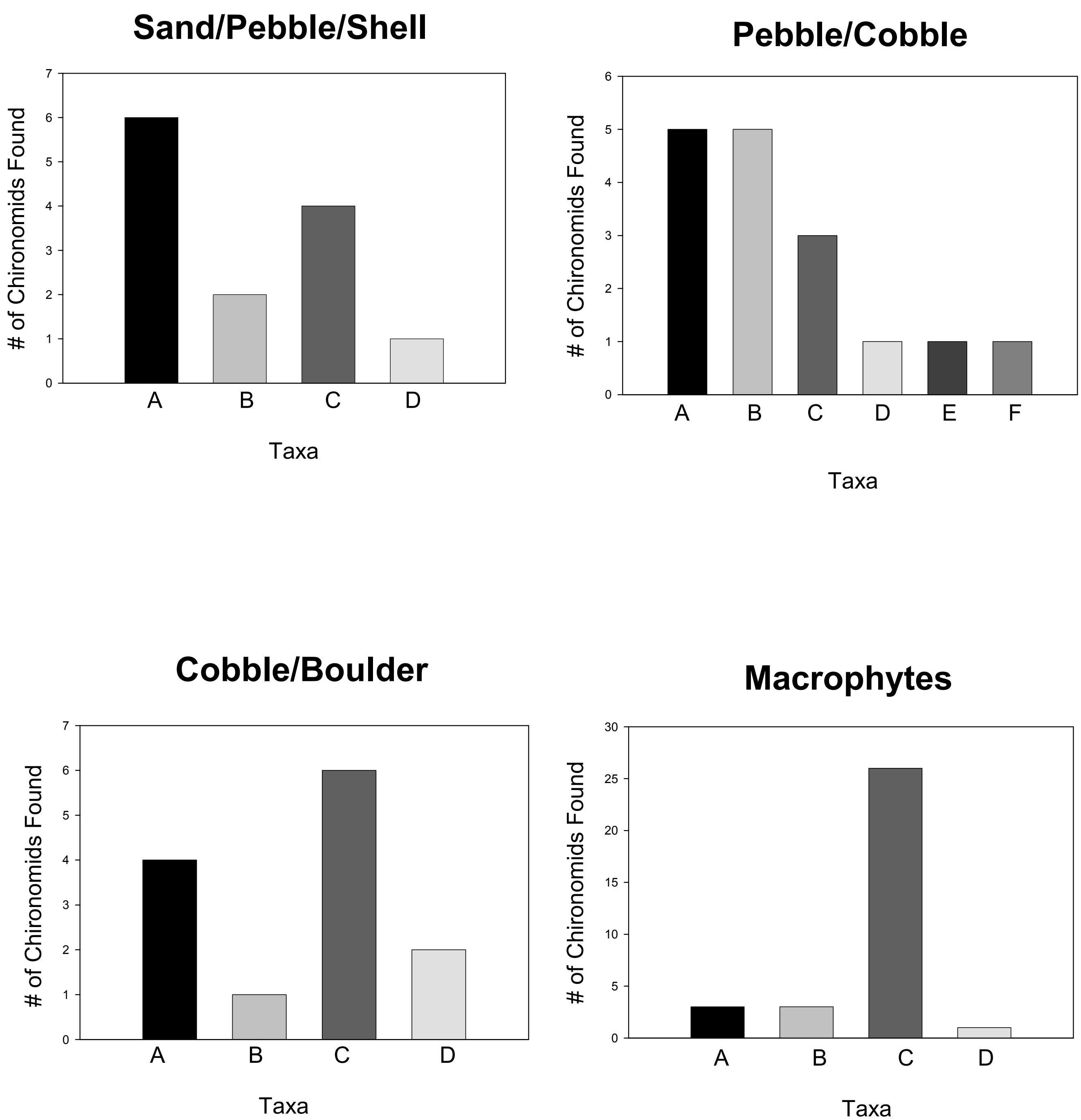

Figure 2: The number of chironomids found and assigned to six morphological taxa in four separate substrate/habitat categories. Note: no chironomids were found in a fifth substrate category (silt/mud) consisting of only one sample site.