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The potential use of muntum deformity of *Chironomus* spp. as water quality indicator in Gerado and Abeyi streams of Sebeta, Ethiopia

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Abstract: Streams are affected by different anthropogenic activities and often effects are reflected on the organisms living within these habitats. The response of organisms to stressors range from a decrease in abundance and diversity to the emergence of deformed structures. These responses of organisms are often used for stream health assessments. In this study, the incidence of *Chironomus* spp. muntum deformities was assessed to understand its potential use as a water quality indicator in Gerado and Abeyi streams in Sebeta town, Ethiopia. Chironomid and environmental data were sampled monthly from October 2016 to January 2017 at three sampling sites. The sampling sites were affected mainly by domestic activities and industrial effluents. The highest intensity of deformity (15%) was observed in GR1, a site affected by laundry activities, with TP 4.34±2.20mg/l, turbidity 32.1±9.44 NTU and conductivity 117.23±94.11 µS/cm followed by GR2 (12%) which receives effluents from the textile factory, with TP 29.29±9.58 mg/l, turbidity 50.8±40.62 NTU and conductivity 2518.00±2043.42 µS/cm. The least deformity was encountered in AB1 (9%), a site which was served as dumping of domestic wastes with TP of 4.10±1.86mg/l, turbidity 21.6±2.54 NTU and conductivity of 142.93±130.41 µS/cm. The frequency of deformity does not directly correspond with measured physicochemical parameters. Therefore, associating deformity with other factors like heavy metal measurements, the physical structure of the sediments, habitat type, feeding habit of the organism and geographical area are mandatory.

Keywords: anthropogenic activities, bioindicators, *Chironomus* spp., muntum deformity, water quality

Introduction

Natural and anthropogenic activities greatly impact on the health of aquatic ecosystems and consequently the organisms therein. The incidence of the impact is often reflected in organisms like the benthic invertebrates which are dwelling on the substratum (Barbour, 1999; Beneberu, 2014; Lakew and Moog, 2015ab; Mezgebu *et al*., 2019 ab). Organisms which live attached to the substrate often reflect local stress happening in the ecosystem (Barbour, 1999; Beneberu, 2014; Lakew and Moog, 2015ab; Mezgebu *et al*., 2019 ab) and in this regard, benthic invertebrates are ideal bioindicators (Barbour, 1999; Beneberu et al., 2014; Lakew and Moog, 2015ab; Mezgebu *et al*., 2019 ab). From benthic invertebrates, chironomids are the best choice for assessing the ecological health of water bodies due to their high abundance, diversity and wide range of tolerance to varying environmental conditions (Burt *et al*., 2003; Beneberu *et al*., 2014; Lakew and Moog, 2015ab; Mezgebu *et al*., 2019 ab). In most of the studies on macroinvertebrates of freshwater ecosystems, chironomids constitute 50% of the population and are encountered almost in all water quality classes (Harrison and Hynes, 1988; Epler, 2001; Beneberu *et al*., 2014; Mezgebu *et al*., 2019 ab). Additionally, Chironomidae possess a different degree of tolerance to organic pollution, acid mine drainage and heavy metal contamination. The responses of chironomids to stress range from a decrease in abundance and diversity to the emergence of morphological deformities (Martinez *et al*., 2002).

Identification of chironomids to lower taxonomic level reveals a good picture of the ecological health of aquatic ecosystems (Harrison, 1992; Beneberu *et al*., 2014; Mezgebu *et al*., 2019a). Different ecological studies revealing preferences of organisms for certain environmental conditions are often carried out at the species level because of the detailed information contained at this level (Li *et al*., 2010). Severity enumeration of deformities could predict the magnitude of pollution and deviates from the naturally occurring deformity in aquatic environments (Clarke *et al*, 1995; Burt *et al*., 2003). Uses of chironomid deformity structure to measure the impacts of agriculture and industrial effluents on the aquatic ecosystem were described by different reserchers (Hamilton and Saether, 1971; Beneberu *et al*., 2014). High incidence of the deformity was observed in Chironomus spp. compared to other taxa which help the sole use of the Chironomus spp. to assess the ecological health of aquatic ecosystems (Arimoro,

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2018). The extended toxic score index (ETSI) was developed based on morphological deformities in the mentum of Chironomidae, to assess deviation of ecological conditions at the affected sites from that of the reference site. It was described as the appropriate deformity-based tool which can be adopted in other rivers locally and internationally (Odume *et al*., 2016). Macdoland, (2003) evaluated the incidence of deformities and other morphometric variations in the mentum and wing of *Chironomus columbines* in the laboratory exposed to mining, agriculture, and cattle raising and four types of deformities like the absence of teeth, increased number of teeth, fusion and space between teeth, and none of them detected in the control. In this study, the impact of human activities in streams of Abeyi and Gerado was assessed using muntum deformity of the *Chironomus* spp..

Materials and Methods

Study sites

The study was conducted in three sites in Gerado and Abeyi steams from Sebeta town, Ethiopia (Fig. 1). Streams of the study area were used for various domestic activities (washing/bathing, drinking, raw leather moistening, dumping of domestic wastes) and industrial purposes like water usage in the production process and dumping of the final wastes. Sampling site AB1 is located in the upstream section of Abeyi stream with limited riparian vegetation coverage. It has no impact from factory effluent, but sizable quantities of household waste are dumped into it and utilized for cattle watering and domestic washing site. GR1 is in the upstream section of Gerado Stream with limited riparian vegetation. It is intensively utilized for domestic activities like cloth washing and bathing. GR2 is located downstream of Gerado stream and receives the effluent discharge of Ayka Textile Factory (Fig. 1).

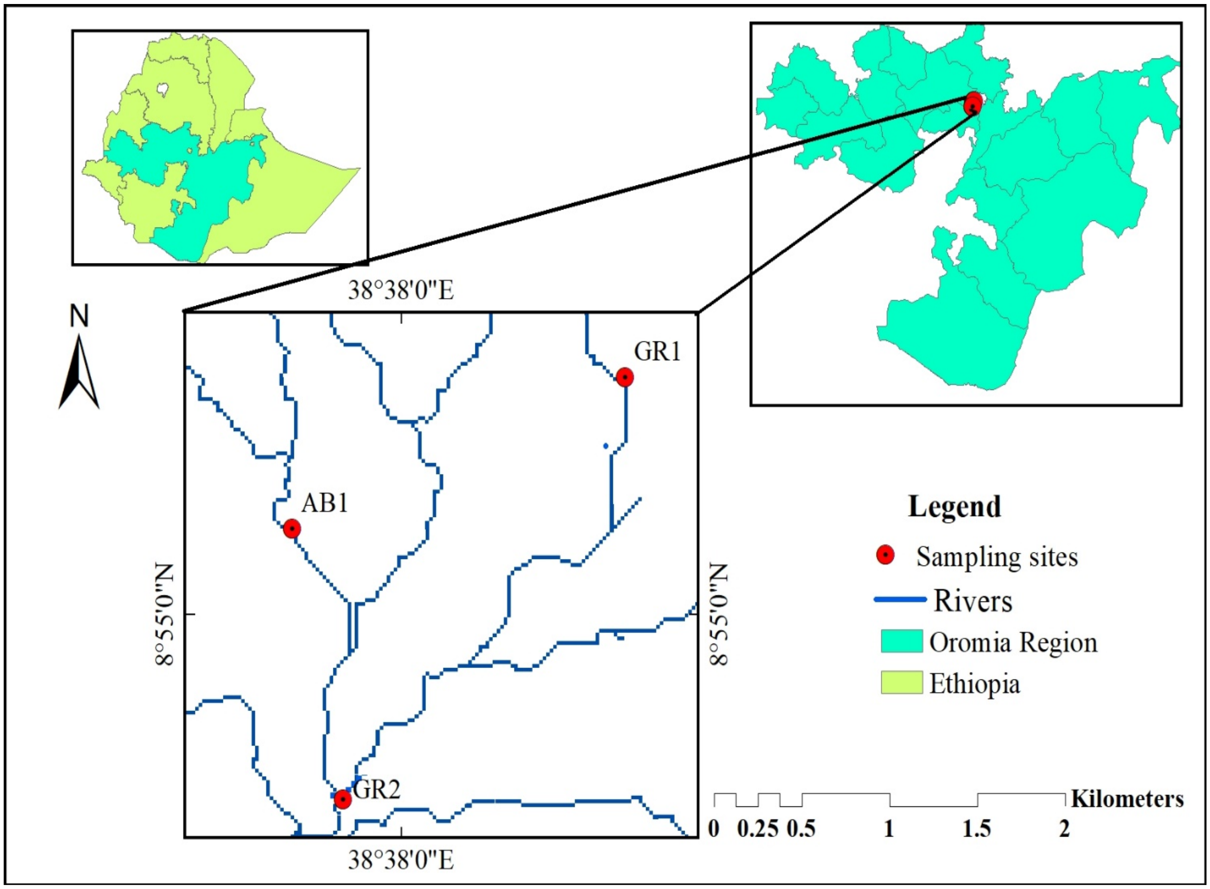

Fig. 1: Study area map.

Environmental variables

Environmental variables were collected monthly from December 2016 to January 2017. Latitude, longitude and altitude were determined with the help of a handheld Global Positioning System (GPS) instrument. Water quality parameters, including temperature, pH, dissolved oxygen, conductivity and turbidity, were measured in-situ using a portable WTW multiparameter probe (model HQ40d HACH Company). Nutrients like NH4+, NO3−, soluble reactive phosphorus (SRP) and total phosphorus (TP) were analyzed using standard procedures as outlined in APHA (1998). A 300 ml water sample was first filtered through glass fibre filters (GF/F) and then analysed for nitrate ($NO3^-$) with the Sodium salicylate method, ammonium ($NH4^+$) with indophenol blue method and soluble reactive phosphorus (SRP) using the ascorbic acid method. For total phosphorus (TP) a separate 50 ml unfiltered sample was first digested using potassium peroxodisulfate, and then autoclaved at 120 °C for 50 minutes and then measured, following the standard SRP procedure (APHA 1998).

Sample collection and analysis

Chironomid samples were collected using a square frame hand net with frame dimensions of 25 × 25 cm and a mesh size of 500 µm. A total of 300 *Chironomus* individuals were taken for deformity analysis. The collected *Chironomus* were picked from the preservative and heated in 10% KOH solution for 5 minutes using a hot plate to make their body to expose the muntum structures. Chironomid individuals were then washed with distilled water and finally mounted on slides with glycerine. Identification was made using a compound microscope with the help of various identification keys (Epler 2001; Eggermont and Verschuren 2003, 2004a; Beneberu *et al*. 2014). Images of specimens were taken with a digital camera (model YWCamera 1.4.3).

Result

Physicochemical parameters

The physicochemical parameters recorded during the study season are presented in Table 1. The Temperature and pH were insignificant along with sampling sites (P>0.05). The dissolved oxygen concentration was higher in AB1 and GR1 and lower at GR2. Conductivity and turbidity were significantly different (p>0.05) and were higher in sampling site receiving effluents of the textile factory (GR2). The $NH4^+$ and TP concentration was also significantly different among sampling sites with a higher concentration in the site receiving effluents of the textile factory (GR2) as shown in Table 2.

Tab. 1: Study sites with geographic location.

Site code	Latitude(E)	Longitude(N)	Altitude (m)
AB1	38.62773	8.92068	2234
GR1	38.64478	8.92776	2277
GR2	38.61691	8.83455	2169

Tab. 2: Mean and SD of physicochemical parameters along with sampling sites.

Physicochemical Parameters	Sampling Sites		
	AB1	GR1	GR2
Temp (°c)	20.83 (6.93)	20.70 (1.11)	21.57 (2.38)
pH	7.72 (1.29)	7.68 (1.17)	7.78 (1.31)
O2 (mg/l)	6.49 (0.73)	5.01 (0.90)	4.59 (0.92)
Conductivity (µS/cm)	142.93 (130.41)	117.23 (94.11)	2518.00 (2043.42)
Turbidity (NTU)	21.6 (2.54)	32.1 (9.44)	50.8 (40.62)
NH4+(mg/l)	0.14 (0.13)	0.11 (0.03)	4.63 (3.57)
TP (mg/l)	4.10 (1.86)	4.34 (2.20)	29.29 (9.58)

Deformed structures of chironomid taxa

Mouth part (mentum) deformity was observed in *Chironomus* spp. taxa through breakage of the median and lateral teeth (Plate 1). The sites were affected by domestic activities and effluents from textile factories. The deformity was observed at minimally impacted sites which are affected by instream activities (AB1 and GR1) and heavily impacted by textile effluent receiving sites (GR2). The highest intensity of deformity (15%) was observed in GR1, a site affected by laundry activities, with TP 4.34±2.20mg/l, turbidity 32.1±9.44 NTU and conductivity 117.23±94.11 µS/cm followed by GR2 (12%) which receives effluents from the textile factory, with TP 29.29±9.58 mg/l, turbidity 50.8±40.62 NTU and conductivity 2518.00±2043.42 µS/cm. The least deformity was encountered in AB1 (9%), which served as a dumping site for domestic wastes with TP of 4.10±1.86 mg/l, turbidity 21.6±2.54 NTU and conductivity of 142.93±130.41 µS/cm (Tab. 1).

Discussion

The growing human activities in and around Sebeta town are threatening the functionality of the river and

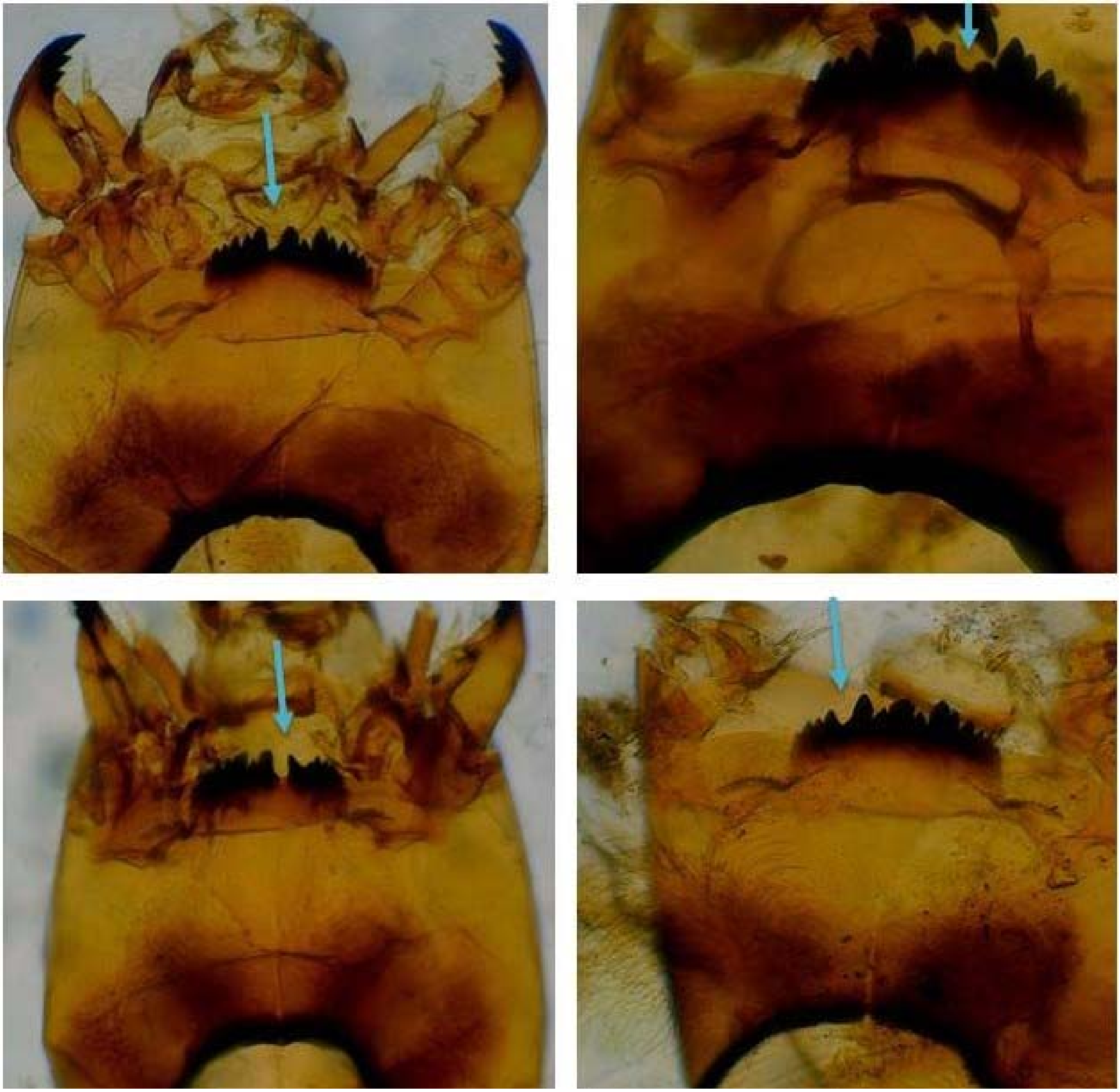

Plate 1: Muntum deformities of Chironomidae taxa from sampling sites.

stream ecosystems (Mezgebu *et al*., 2019ab). The expanding industrial activities and increase in human population in the town increased the entry of organic and inorganic wastes in the streams and rivers which have potential to cause ecological and human health impairments (Beneberu *et al*.2014; Lakew and Moog, 2015; Mezgebu *et al*., 2019ab). The effects of human activities are frequently observed through organisms in that ecosystem and the level of impact ranges from a reduction in abundance and diversity to morphological deformities. In this study, mouthpart deformities were evident in the muntum structure of *Chironomus* spp. in sites affected by domestic activities and industrial effluents.

The deformity can be encountered due to natural or human causes and set the natural threshold is very vital. According to Burt *et al*., 2003 the natural incidence of muntum deformities for *Chironomus* is 2.15%. Lenat (1993) described the ranges of the frequency of mouthpart deformities. If the incidence of deformity is >10%, the sampling site is considered contaminated, whereas >20% was considered highly contaminated. In this sense, sites affected by laundry activity and textile, effluents are beyond the threshold of naturally occurring deformity and are contaminated.

High turbidity, conductivity and phosphorus content were observed in textile waste receiving site (GR2), but the incidence of the deformity was high at a site affected by laundry activity, with relatively less turbidity, conductivity and phosphorus content (Tab. 1). Though identifying the triggering factor for deformity is very vital, Nazarova *et al*. (2004) pinpointed that deformity occurs due to heavy metals, pesticides, and organic pollution. Differential morphological deformities were observed in Chironomidae larva exposed to high concentrations of lead and zinc (Reynolds and Leonard, 2002). The relationship between morphological deformities of Chironomidae by heavy metal and pesticides contamination of aquatic ecosystem has been described by Hamilton and Sæther (1971) and Beneberu *et al* (2015). Nazarova *et al*. (2004) detected 21% of deformed Chironomidae in areas with low heavy metal concentration, which do not reach the triggering levels and the possible explanation for this deformity was synergism effect of several environmental stressors like organic pollution, the physical structure of the deposited sediments and pronounced nocturnal oxygen depletion. Likewise, in this study, the sampling site affected by laundry activity showed high deformity with relatively less physicochemical recordings. The plausible reason for the high incidence of deformity at this site is due to the physical structure of the habitat, which is filled with big rocks and different sediment sizes, which may affect the feeding structure and muntum. Therefore, Future research should focus on associating deformity with a specific stressor like heavy metal content, sediment load and other factors that potentially cause deformity.

Conclusions

The frequency of muntum deformity can serve as a water quality indicator. Research should focus on the bioindicator value of deformity by considering the percentage of deformity, and associating it with heavy metal data, habitat and feeding habit of the organism, geographical area and possibly with the explanations from the physiological processes of metabolism of the polluting chemicals.

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