Physics and Chemistry of the Earth 50–52 (2012) 140–148

Contents lists available at SciVerse ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Mentum deformities in Chironomidae communities as indicators of anthropogenic impacts in Swartkops River

O.N. Odume *, W.J. Muller, C.G. Palmer, F.O. Arimoro

Unilever Centre for Environmental Water Quality, Institute for Water Research, Rhodes University, P.O. Box 94, Grahamstown, South Africa

ARTICLE INFO

Article history:
Available online 24 August 2012

Keywords:
Chironomidae
Deformities
South Africa
Swartkops River
Water quality

ABSTRACT

Swartkops River is located in Eastern Cape of South Africa and drains a heavily industrialised catchment and has suffered deterioration in water quality due to pollution. Water quality impairment in the Swartkops River has impacted on its biota. Deformities in the mouth parts of larval Chironomidae, particularly of the mentum, represent sub-lethal effects of exposure to pollutants, and were therefore employed as indictors of pollution in the Swartkops River. Chironomid larvae were collected using the South African Scoring System version 5 (SASS5) protocol. A total of 4838 larvae, representing 26 taxa from four sampling sites during four seasons were screened for mentum deformities. The community incidences of mentum deformity were consistently higher than 8% at Sites 2–4, indicating pollution stress in the river. Analysis of variance (ANOVA) conducted on arcsine transformed data revealed that the mean community incidence of mentum deformity was significantly higher ($p < 0.05$) at Site 3. ANOVA did not reveal statistically significant differences ($p > 0.05$) between seasons across sites. Severe deformities were consistently higher at Site 3. Strong correlations were found between deformity indices and the concentrations of dissolved oxygen (DO), total inorganic nitrogen (TIN), orthophosphate–phosphorus (PO_4–P), electrical conductivity (EC) and turbidity.

1. Introduction

Integrated water resources management (IWRM) requires a holistic approach to assess the impacts of water quality deterioration on in-stream biota (NWRS, 2004). Such an approach would require that effects of contaminants on aquatic ecosystems are detected early enough in order to take appropriate mitigation measures. Biological monitoring of rivers and streams is used to assess the impacts of water quality deterioration on in-stream biota (Rosenberg and Resh, 1993; Bonada et al., 2006; Odume and Muller, 2011). Most biological water quality monitoring tools employed in South Africa (e.g. the South African Scoring System version 5, Dickens and Graham, 2002) are based on community responses to water quality impairments. However, community structure assessments are essentially measures of lethality, and concentrations of contaminants must be high enough to result in the disappearance, or reduced abundances and diversities of sensitive taxa before community response approach would detect impacts of water quality stressors. Lethal end points are not suitable for use as early warning indicators of water quality deterioration in freshwater systems (Faria et al., 2006). Therefore, there is need for improved and holistic early warning biological water quality monitoring tools, capable of detecting sub-lethal in-stream effects on biological communities. Morphological deformities in the mouth parts of larval Chironomidae, particularly of the mentum, represent sub-lethal response to in-stream pollutants and are therefore considered early warning indicators of water quality deterioration (Janssens de Bisthoven and Gerhardt, 2003; Nazarova et al., 2004; Ochieng et al., 2008; Odume, 2011).

The term "deformity" refers to morphological features that depart from the normal Chironomidae larval configuration (Warwick, 1985; Nazarova et al., 2004; Ochieng et al., 2008), and effects produced by mechanical wear, breakage or abrasion are usually not included in deformity screening, and are recognised by their "chipped" or "rough" edges (Vermeulen, 1995; Bird, 1997; Nazarova et al., 2004). Based on fossils records, the natural incidences of chironomid deformities in unpolluted water bodies were reported to range between 0% and 0.8% from the Bay of Quinte, Canada (Warwick, 1980). However, because of increased industrialisation, urbanisation and agricultural activities, pristine water bodies are scarce and numerous field studies (e.g. Warwick, 1988; Nazarova et al., 2004; Ochieng et al., 2008) have reported background levels of deformities in least impacted sites to range between 0% and 8%, above which a site could be considered contaminated. Expressions of morphological deformities in larval Chironomidae inhabiting variety of aquatic environment have been used as indicators of pollution arising from different pollutants

* Corresponding author. Tel.: +27 730302687.
E-mail address: nelskaro@yahoo.com (O.N. Odume).

1474-7065/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.pce.2012.08.005

such as heavy metals (Diggins and Stewart, 1998; Jeyasingham and Ling, 2000; Martinez et al., 2002; Ochieng et al., 2008), acid mine drainage (Janssens de Bisthoven et al., 2005) and organic contaminants (Servia et al., 1998, 2000; MacDonald and Taylor, 2006). Therefore, assessment and quantification of morphological deformities in larval Chironomidae offer an effective and cost friendly means of investigating impacts of environmental stressors on aquatic ecosystems (Meregalli et al., 2002). Although several structures including the mentum, mandible, ligula, paraligula, pecten epipheryngis and antennae in Chironomidae larvae have been examined for deformities in other studies (Warwick, 1985; Janssens de Bisthoven and Gerhardt, 2003; Bhattacharyay et al., 2005; Veroli et al., 2008), only the mentum was chosen for this study because it has proven to be the most useful structure as it appears to have a wider response range, easy to prepare for examination and deformities quantified rapidly (Odume, 2011).

The Swartkops River located in Eastern Cape of South Africa is an important ecological asset that supports an estuary that provides important breeding habitats for water birds and fish, and also serves as a recreational field (Taljaard et al., 1998). However, the increasing human activities in the catchment have resulted in the discharge of pollutants into the river, which have negatively impacted on its biota (Odume, 2011; Odume and Muller, 2011). Consequently, morphological deformities in the mentum of Chironomidae communities were applied as a tool to evaluate sub-lethal effects of pollution on the Swartkops River biological benthic community. Although Chironomidae larval deformities have been successfully used in other parts of the world as a biomonitoring tool, its potential as an indicator of pollution stress in South African fresh water resources has not been explored. The aims of this study therefore were to: document and illustrate deformities in mentum of larval of different genera or species of Chironomidae; compare incidences of mentum deformities between genera/species of Chironomidae; evaluate seasonal variations in the incidences of mentum deformities; and contribute baseline information for using Chironomidae mentum deformities as a biomonitoring tool in South African freshwater resources.

2. Materials and methods

2.1. Study area description and sampling sites

Swartkops River is located in Eastern Cape of South Africa and drains a catchment of about 1555 km^2, and has its origin in the Groot Winterhoek Mountains (DWAF, 1996; Odume, 2011). The river arises from the confluence of the Kwazunga River to the north and the Elands River to the southwest. Both the Kwazunga and Elands Rivers originate in the Groot Winterhoek Mountains and join just above Uitenhage in an area called Kruisrivier to form the Swartkops River, which discharges into the India Ocean at Algoa Bay in Port Elizabeth (Fig. 1).

Although the upper catchment of the Swartkops River lies within a pristine inaccessible area of the Groot Winterhoek Mountains, the lower catchment is subjected to different sources of pollution including discharges from wastewater treatment works, effluents from tannery, wool processing factories as well as run-off from informal settlements and storm water canals (Taljaard et al., 1998; DWAF, 1996; Bornman and Klages, 2005). These combined sources of pollution contribute to the overall poor water quality status, and reported elevated heavy metal concentrations in the river (Binning and Baird, 2001; Odume, 2011; Odume and Muller, 2011).

Climate in the catchment is generally temperate and warm, but receives rain throughout the year with a minimum monthly average of 60 mm (Nelson Mandela Bay Municipality, 2006). The geology of the catchment consists of cretaceous shale of mudstones overlain by marine sedimentary deposits in the high lying regions and by various alluvial deposits on the floodplain (Fromme, 1988).

The study was undertaken in four seasons at four sampling sites (Sites 1–4) over a period of 1 year. Site 1 (S33°45′08.4″E25°20′32.6″) is located upstream of Uitenhage and represents least impacted conditions (reference site) within the accessible areas of the river. It was selected in agreement with criteria by Reynoldson et al. (1997) and based on an expert judgment taking into consideration the quality and quantity of macroinvertebrate habitats, extent of human impacts as well as accessibility. Site 2 (S33°47′29.0″ E25°24′26.4″) is located in the industrial city of Uitenhage and is impacted by run-off from surrounding informal settlements, and by agricultural activities including livestock farming. Site 3 (S33°47′11.8″E25°27′58.7) is located further downstream of the industrial city of Uitenhage. The site is impacted by industrial and wastewater effluents as well as by agricultural activities such as live stock farming and crop cultivation. The wastewater effluent input at this site has resulted in elevated nutrient levels leading to extensive growth of aquatic weeds. Site 4 (S33°47′34.0″ E25°27′58.7″) is located at despatch close to a sand mining area, and is impacted with agricultural and municipal runoff, which have consequently resulted in a thick growth of aquatic weeds and discoloured water. A fifth site further downstream could not be selected for system self recovery monitoring because the tidal mark at Perseverance is a short distance downstream of Site 4 (Fig. 1).

2.2. Physicochemical variables

Water chemistry variables were measured once per season for four seasons at the four sampling sites over the study period. On site, mid-channel dissolved oxygen (DO), electrical conductivity (EC), turbidity, temperature and pH were measured using Cyberscan DO 300, Cyberscan Con 300, Orbeco-Hellige 966, mercury-in-glass thermometer and Cyberscan pH 300 metres respectively. Water samples collected in acid washed bottles were transported to the laboratory, preserved at 4 °C, and analysed within 24 h for 5-day biochemical oxygen demand (BOD_5), orthophosphate–phosphorus (PO_4–P), nitrite–nitrogen (NO_2–N), nitrate–nitrogen (NO_3–N), ammonium–nitrogen (NH_4–N) and total inorganic nitrogen. Five-day biochemical oxygen demand (BOD_5) was analysed according to APHA (1992), while NO_3–N and NO_2–N were analysed according to Velghe and Claeys (1983), and APHA (1971) respectively. Spectroquant® phosphate and ammonium concentration test kits were used to analysed for orthophosphate–phosphorus and ammonium–nitrogen according to manufacturer's instructions. Palmer et al. (2005) method was adopted for the calculation of total inorganic nitrogen (TIN).

2.3. Chironomid sampling and screening head capsule for mentum deformities

Concurrent with physicochemical sampling, Chironomidae larvae were sampled at the four sampling sites in accordance with the SASS5 protocol (Dickens and Graham, 2002). Chironomid larvae were collected from three distinct biotopes, namely: stones (stones in- and out- of current), vegetation (marginal and aquatic vegetation) and sediment (gravel, sand and mud). Chironomidae larvae were preserved in 70 % ethanol and transported to the laboratory for sorting, identification, abundance counts and deformity screening. Sorted chironomids were kept in specimen vials containing 70% ethanol to prevent the head capsule from becoming dry as dried and shrunken head capsules are difficult to mount (Dickman and Rygiel, 1996). The head capsules were mounted for taxonomic identification using mouth parts and other structures according to the keys described by Wiederholm (1983), Cranston (1996) and