Environmental Pollution 158 (2010) 1741–1747

Contents lists available at ScienceDirect

Environmental Pollution

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

Assessment of nematode community structure as a bioindicator in river monitoring

H.C. Wu, P.C. Chen, T.T. Tsay*

Department of Plant Pathology, National Chung Hsing University, 250 Kuo Kuan Rd, Taichung 402, Taiwan

Nematode community structure in rivers is related to the contamination source and level.

ARTICLE INFO

Article history:
Received 30 April 2009
Received in revised form
13 November 2009
Accepted 17 November 2009

Keywords:
Nematode community structure
Bioindicator
Maturity index
Nematode channel ratio
River pollution

ABSTRACT

Nematode communities from river water and sediments were assessed for the abundance, feeding types, maturity indices and nematode channel ratio (NCR). The sampling sites studied included different levels of pollution and contamination from agricultural, industrial and sewage sources. The nematode abundance found in the sediment samples was more than that in the water samples. The lowest nematode abundance in sediment samples and the lowest NCR in water samples were both found at the industrial pollution site. Water samples showed positive correlation between the NCR and river pollution index (RPI). Mean maturity indices in sediment samples were inversely correlated with RPI. The pollutant source determined the relationship between NCR and pollution level, while maturity index always showed negative correlation with pollutant level regardless of the pollutant sources. The nematode abundance and its community structure were both reliable bioindicators for monitoring long-term river pollution in both qualitative and quantitative aspects.

1. Introduction

River are essential for human life but are easily disturbed by pollutants from agriculture, industry and sewage, thus chemical parameters and organisms in the river are used to assess the water quality. The universal parameters used to describe the water quality were temperature, dissolved oxygen (DO), turbidity, pH, nitrates, suspended solids (SS), biological oxygen demand (BOD_5), chemical oxygen demand (COD) and fecal coliforms. These parameters were included in the water quality index (WQI) developed by Horton (1965) in the United States (Palupi et al., 1995; Bordalo et al., 2001). River Pollution Index (RPI) containing DO, BOD_5, SS and ammonia nitrogen (NH_3–N), was used to describe river water quality conditions in Taiwan (Liou et al., 2003; Environmental Protection Administration, Executive Yuan, ROC, 2005).

The water quality is primarily assessed by chemical parameters. Accuracy, standard and reliability are advantages of RPI, but it only provides information about water quality at the time of measurement. It cannot determine the impact of previous events on the ecology (Spellman and Drinan, 2001). Bioindicators, on the other hand, could provide information about past and episodic pollution, and can be a useful tool to assess real environmental impacts by pollution (Spellman and Drinan, 2001).

It is possible to qualitatively determine the level of water quality impairment based on what fauna are present and their abundances at a point in time. The representative samples of an ecosystem that can provide quick, yet reliable, information are known as bioindicators. The biotic index is a systematic survey of bioindicators. Because the diversity of species in a river is often a good indicator of the presence of pollution, the biotic index can be correlated with river quality (Lenat, 1993).

Nematodes have the characteristics of diversity of species, abundance and presence of several feeding types. They can be found in any environment, under all climatic conditions and in habitats that vary from pristine to extremely polluted (Bongers and Ferris, 1999; Yeates et al., 1993). The Maturity Index (MI) is commonly used to assess environmental quality (Bongers, 1990). Neher (2001) suggested that nematodes with colonizer–persister (*c*–*p*) values between 2 and 5 are more stable temporally and may provide long-term information about environmental conditions. Nematode community structure has been successfully used to assess agricultural practices, forestry practices, mining restoration, urbanization, pesticide, air pollution and heavy-metal pollution impacts on environments (Dmowska and Ilieva-Makulec, 2004; Hohberg, 2003; Neher, 2001; Neher et al., 2005; Mulder et al., 2005; Pavao-Zuckerman and Coleman, 2007; Roessink et al., 2006; Shukurov et al., 2005).

---

* Corresponding author. Tel.: +886 4 22873791; fax: +886 4 22876712.
E-mail address: tttsay@nchu.edu.tw (T.T. Tsay).

0269-7491/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envpol.2009.11.015

The Nematode Channel Ratio (NCR) is the relative contributions of bacterial-feeding and fungal-feeding nematodes to total nematode abundance (Yeates, 2003). NCR has been used to assess heavy metal and fertilizer pollution, the values of NCR are known to negatively correlate with acidification and heavy-metal-induced stress (Bakonyi et al., 2003; Bongers and Bongers, 1998; Zhang et al., 2007).

Nematodes of river sediments were used in water quality assessment in the 1970s (Zullini, 1976). Heininger et al. (2007) studied the relationship between nematode community structure and sediment pollution (anthropogenic contamination with heavy metals and organic pollutants), and found nematode community structure of river sediments to be related to pollution and site structure. No studies had focused on the relations between nematode community structure, river contamination sources and RPI.

The objective of this study was to investigate *in situ* nematode communities and their correlation with RPI. In this study, nematode community structure and its correlation to contamination sources and RPI was analyzed. The most appropriate criterion for using nematodes to monitor river pollution was investigated. Nematode communities of 40 sediment samples and 40 water samples from five sites on the Huwei and Beigang rivers were characterized over the period of 2 years. The most appropriate criterion for monitoring the quality of river was analyzed by comparing structural and functional parameters of nematode communities.

2. Materials and methods

2.1. Sampling site description

The sampling sites coincided with the stations in a monitoring network which were operated by the Environmental Protection Administration, Executive Yuan, Taiwan. Five sites consisting of Shihliuban Bridge (SLB, TM2_X: 206489.66, TM2_Y:2623924.96), Dosang Bridge (DS, TM2_X:205878.34, TM2_Y:2622171.03), Tokooda Bridge (TK, TM2_X:190705.63, TM2_Y:2619866.33), Beigangda Bridge (BG, TM2_X:178693.05, TM2_Y:2606752.95), and Yunchiada Bridge (YC, TM2_X:166048.46, TM2_Y:2601419.25) located on the rivers Huwei (three sites, DS, SLB, TK) and Beigang (two sites, BG, YC) were selected (Fig. 1). All sampling stations were still water zones, so that water and fresh sediments could be collected separately. The rivers and sites were selected with different pollution levels and sources according to previous RPI values. Site DS was affected by fecal matter from animal breeding farms, and the distance to estuary was 73.8 km. Site SLB was subjected to direct inputs from long-term contamination from industry and the distance to estuary was 70.6 km. Waste from sites SLB and DS converged on site TK, which was 55.2 km to estuary. The sewage of urbanization impacted on the properties of site BG, and the distance to estuary was 28.7 km. The site YC was near estuary and the distance was 2.9 km.

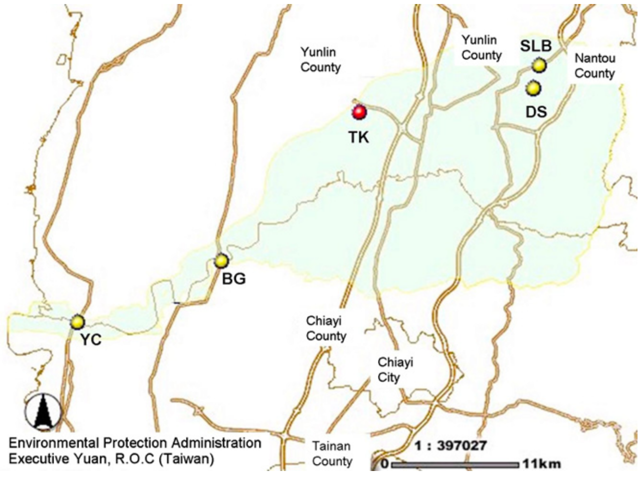

Fig. 1. Location of research sites at Beigang River Basin. Solid circles represent the sampling sites under Shihliuban Bridge (SLB), Dosang Bridge (DS), Tokooda Bridge (TK), Beigangda Bridge (BG) and Yunchiada Bridge (YC).

2.2. Sampling methods

Water and sediment samples were collected once per season between September 2004 and June 2006. The sampling periods for each site were the first two weeks of September, December, March and June that synchronize with RPI values taken by the Environmental Protection Administration. Eight sets of data per site were collected. All samples were collected near the bank using self-designed sampling tools. One tool was a metal scrapper and the other was a small bucket chained to the end of a 0.9 m stick which could be extended to 2.4 m. The scrapper could hold 500 g of sediments and the bucket 1500 ml of water. Sampling sites were about 1.5 m from the river bank. At each site, three samples of water and sediments were randomly taken from 10 cm in depth. All samples were placed in individual plastic bags and containers, and transported using ice chests. For nematode community study, 100 g sub-samples of sediments and 500 ml of water from each sampling site were extracted by modified Baermann funnel method (Tsay et al., 2004). Extracted nematodes were stored at 4 °C prior to identification.

2.3. Nematode identification

All nematodes were examined under a dissecting microscope (10 fold–80 fold magnification). A total of 5971 nematodes were identified at family and genus level (40 fold–1000 fold magnification) under the light microscope (OLYMPUS UPLAN F1). The classification of feeding types was based on known feeding habitats or stoma and esophageal morphology (Yeates et al., 1993). Nematode families were assigned a *c–p* value from 1 to 5 based on whether they were fast or slow reproducers (Bongers, 1990; Bongers and Bongers, 1998).

2.4. Data analysis

2.4.1. Water sample

Chemical parameters of the water samples were assessed by the Environmental Protection Administration, Executive Yuan, Taiwan by standard methods (NIEA). The values of water pH were measured by NIEA W424.51A, temperature by NIEA W217.51A, conductivity by NIEA W203.51B, DO by NIEA W421.56C, BOD_5 by NIEA W510.54B, SS by NIEA W210.56A, NH_3–N by NIEA W448.51B and heavy metals [As by NIEA W434.53B, Hg by NIEA W330.51A, Cr by NIEA W320.52A, Se by NIEA W341.50B, Ag by NIEA W313.50C, Cd, Pb, Cu, Mn, and Zn by NIEA W313.50C (by NIEA W311.51B or NIEA W308.22B if water salinity > 1 psu)] were used for analysis. The values of parameters DO, BOD_5, SS and ammonia nitrogen (NH_3–N) were used for calculation of RPI values, and assessment of the pollution level. The RPI was calculated as $1/4\,\Sigma Ni$, where N is the value of parameters based on the degree of pollution, i is parameters. RPI values ranged from 1 to 10. According to the RPI, rivers in Taiwan are assigned to four classes of pollution level, unpolluted ($RPI < 2.0$), slightly polluted ($RPI = 2.0–3.0$), moderately polluted ($RPI = 3.1–6.0$) and seriously polluted ($RPI > 6.0$). The monitoring results of RPI were obtained from the website http://www.epa.gov.tw/.

2.4.2. Sediment sample

Sediment pH was measured by NIEA S410.60T and three grain size fractions (0.2–0.02 mm; 0.02–0.002 mm; <0.002 mm) were analyzed by Day's methods (1965).

2.4.3. Nematode sample

For nematode community analysis, data of three sub-samples from each site were combined as one. Three ecological indices of nematode communities were calculated: (1) Maturity Index (MI) is the weighted mean colonizer–persister (*c–p*) value of the individuals in a representative sample (Ettema and Bongers, 1993; Bongers et al., 1995; Bongers, 1999; Bongers and Bongers, 1998). $MI = \Sigma v(i)f(i)$, where v(i) was the *c–p* value of taxon i (including *c–p*1 group), f(i) was the frequency of taxon i in a sample (Bongers, 1990). (2) Maturity Index 25 (MI25), $MI25 = \Sigma v(i)f(i)$ where v(i) was the *c–p* value of taxon i (excluding *c–p*1 group) (Bongers, 1990; Korthals et al., 1996). Popovici (1992) suggested removing *c–p*1 from the MI, because *c–p*1 increase rapidly in response to disturbance and may not necessarily reflect long-term changes. (3) Nematode Channel Ratio (NCR), $NCR = B/(B + F)$, where B and F are the proportions of the nematode fauna allocated to bacterivorous and fungivorous groups (Yeates et al., 2003).

2.5. Statistics

All multivariate statistical data were analyzed according to Clarke and Warwick (2001) using PRIMER software (Plymouth Routines in Multivariate Ecological Research; Version 6.0). The relative abundance of nematode genera were square-root transformed into Bray–Curtis similarities to increase the importance of rare genera for multivariate analysis. The contaminant concentrations were log transformed into normalized Euclidean distance. LINKTREE, SIMPER analysis ("similarity percentages") and RELATE were performed as described by Clarke and Warwick (2001) to analyze whether nematode community structure was correlated with RPI.