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Stressor identification and health assessment of fish exposed to wastewater effluents in Miho Stream, South Korea

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Abstract

This study evaluated the effects of an industrial wastewater treatment plant (IWTP) and a municipal wastewater treatment plant (MWTP) effluents on a variety of bioindicators ranging from biochemical, organism, and population-level responses in pale chub (*Zacco platypus*) and fish community structure. The Index of Biotic Integrity (IBI) indicated that the site upstream of these wastewater treatment plant discharges is in fair–good condition and downstream of the plant is in poor condition. The EROD (ethoxyresorufin-*O*-deethylase) activity, condition factor, and liver somatic index were significantly increased at the downstream site compared to those of the upstream site. The most significant change observed in pale chub population in the downstream site of the Miho Stream, relative to the upstream population, was the total absence of an younger age group. Stressors impacting the downstream site were identified as mostly organic or nutrient enrichment and habitat degradation associated with wastewater treatment plants. The results of causal analysis suggest that the primary causes affecting fish population in the downstream site are through both size-selective mortality caused by ammonia toxicity and recruitment failure caused by habitat degradation and reproduction problem due to an IWTP and MWTP effluents.

Keywords: Multi-response bioindicator; Wastewater effluent; Fish health; Stressor identification

1. Introduction

Even though most local governments and companies operate wastewater treatment plants to reduce the potential for pollution of receiving waters and to comply with discharge consent conditions, many rivers and streams in South Korea have become contaminated with nutrients and organic and inorganic compounds associated with industrialization and urbanization. Exposure to industrial wastewater treatment plant (IWTP) and municipal wastewater treatment plant (MWTP) effluents is known to cause a variety of stress-related changes in fish health (Adams et al., 1992; Kosmala et al., 1998; Porter and Janz, 2003). The impacts of IWTP and MWTP effluents have been well documented in fish including biomolecular/biochemical responses (Munkittrick et al., 1992; Kosmala et al., 1998; Folmar et al., 2001), individual organism and population effects (Munkittrick, 1992; Gibbons and Munkittrick, 1994), and community level disturbances (An et al., 2002; Karels and Niemi, 2002; Kovacs et al., 2002). The bioindicator approach, using several levels of biological organization from the biomolecular and biochemical to the community levels, has also proven successful in assessing and evaluating the effects of IWTP (Adams et al., 1992, 1996; Siligato and Böhmer, 2001) and MWTP effluents (Triebskorn et al., 2001; Porter and Janz, 2003) on the

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health and integrity of aquatic organisms. The previous studies have focused primarily on the assessment and evaluation of point-source impacts (e.g. pulp and paper mill effluents, and municipal wastewater treatment effluents) on fishes collected in reference and contaminated sites. However, until recently there was relatively little information available from field studies based on the bioindicator approach for the impact assessment of multipoint source pollution on fish health.

The Miho Stream is a small stream in central Korea, which empties into the Kum River. The upstream site is influenced primarily by non-point agricultural runoff and can be classified as slightly influenced by organic pollutants (Korean water quality class II in 2002) according to the water environmental information system (WEIS) of the Korean Ministry of Environment (KMOE) (<http://water.nier.go.kr/weis/>). The downstream site is impacted by effluents of the industrial complex and the municipal wastewater treatment plants and has to be characterized as moderately or heavily polluted stream (Korean water quality class III–IV in 2002). Despite the extensive knowledge on the effects of IWTP and MWTP effluents on fish health, recent researches on the Miho Stream have focused on the ichthyofauna of the fish community (Son and Byeon, 2005).

The objective of this study, therefore, is to apply the bioindicator approach to assess the effects of stress in environments impacted by multipoint discharges, including IWTP and MWTP effluents and to identify potential casual relationships between these effluents and various responses of fish to these stressors. Toward this end, pale chub (*Zacco platypus*) was chosen as a suitable sentinel species because of their relatively high abundance in the Miho Stream (Son, 1983) and preliminary survey. This species has high mobility (Yamazaki et al., 1996), lives in riffles of midstream and downstream, prefers sand and gravel bottom conditions, and feeds mainly on insects, algae, detritus, and microcrustaceans (Nakamura, 1952; Kim, 1997). Sexual maturity of female is attained by the second year, but by the third or fourth year for male. Spawning of this species occurs from May through June, but its peak activity is observed during approximately 20 days when water temperature ranges from 18 °C to 22 °C. During the spawning period they are widely scattered in the water from 30 to 50 cm deep (Nakamura, 1952). In winter, however, most fishes migrate to the deeper and warmer water column (Nakamura, 1952; Kim, 1997).

2. Materials and methods

2.1. Study sites

Studies were conducted at two selected sites in the Miho Stream, a warm-water system, which is located in the Chungchungbuk-do province and Cheongju city, Central Korea (Fig. 1). The upstream site is located approximately 30 km upstream from the confluence with the Seoknam Stream and this site is a low-contamination area. The upstream site is 30–70 cm in depth, 30–40 m in width, and 3.0–4.0 $m^3 s^{-1}$ in stream flow. The downstream site is located approximately 0.5 km downstream from the confluence with the Seoknam Stream and this is influenced by effluents of IWTP and MWTP. The downstream site is 20–100 cm in depth, 70–100 m in width, and 8.4–12.0 $m^3 s^{-1}$ in stream flow. The two sampling sites are similar in bottom substrate (i.e., gravel and sand) (Fig. 1).

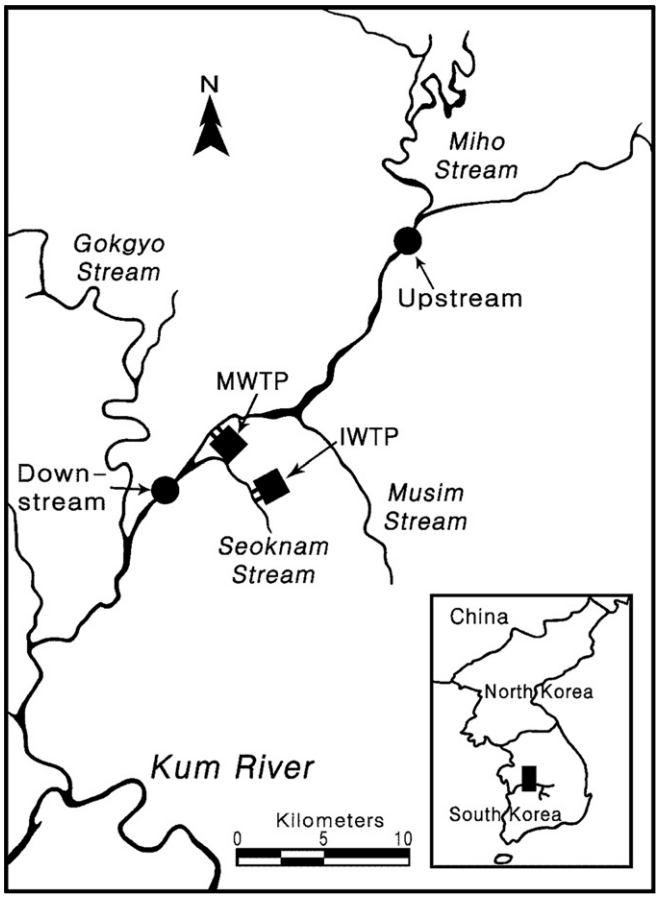

Fig. 1. Sampling sites on the Miho Stream for assessing effects of wastewater effluents on fish populations and communities.

The wastewater treatment plant of the Cheongju industrial complex discharges about 0.4 $m^3 s^{-1}$ (32 000 $m^3 d^{-1}$) of treated effluents to the Seoknam Stream. The wastewater facility receives industrial waste from 200 companies in the industrial complex area, engaged in the metal related industry (51%), petrochemical (20%), textile (10%), food (8%), paper (5%), and others (6%) (<http://my.cb21.net/cjic/>). In addition, the Cheongju city's municipal wastewater treatment plant is located approximately 0.5 km upstream from the confluence with the Seoknam Stream, and directly discharges approximately 2.9 $m^3 s^{-1}$ (2 50 000 $m^3 d^{-1}$) of treated effluents into the Miho Stream.

2.2. Sampling and analytical methods

Fish samplings in upstream and downstream of the Miho Stream were conducted in May 2003. Fish were