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Multi-level stressor analysis from the DNA/biochemical level to community levels in an urban stream and integrative health response (IHR) assessments

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The objectives of this study were to identify multi-level stressors at the DNA/biochemical level to the community level in fish in an urban stream and to develop an integrative health response (IHR) model for ecological health diagnosis. A pristine control site (S_c) and an impacted site (S_i) were selected from among seven pre-screened sites studied over seven years. Various chemical analyses indicated that nutrient enrichment (Nitrogen, Phosphorus) and organic pollution were significantly greater ($t > 8.783$, $p < 0.01$) at the S_i site compared to the S_c site. Single-cell gel electrophoresis (comet assays) of DNA-level impairment indicated significantly ($t = 5.678$, $p < 0.01$) greater tail intensity, expressed as % tail-DNA, at the S_i site and genotoxic responses were detected in the downstream reach. Ethoxyresorufin-*O*-deethylase (EROD) assays, as a physiological bioindicator, were 2.8-fold higher ($p < 0.05$, NK-test after ANOVA) at the S_i site. Tissue analysis using a necropsy-based health assessment index (NHAI) showed distinct internal organ disorders in three tissues, i.e., liver, kidney, and gill, at the S_i site. Population-level analysis using the sentinel species *Zacco platypus* showed that the regression coefficient (b) was 3.012 for the S_i site and 2.915 for the S_c site, indicating population skewness in the downstream reach. Community-level health was impaired at the S_i site based on an index of biological integrity (IBI), and physical habitat modifications were identified by a qualitative habitat evaluation index (QHEI). Overall, the model values for the integrative health response (IHR), developed using the star plot approach, were 3.22 (80.5%) at the S_c site and 0.74 (18.5%) at the S_i site, indicating that, overall, ecological health impairments were evident in the urban reach. Our study was based on multi-level approaches using biological organization and the results suggest that there is a pivotal point of linkage between mechanistic understanding and real ecological consequences of environmental stressors.

Keywords: Integrative health, stressor, genotoxic response, biological integrity, casual assessment, multimetric index.

Introduction

Recent studies of urban streams[1-5] have pointed out that ecological health has been rapidly degraded by various sources of pollution, such as industrial effluents,[6] municipal wastewater discharges,[5,7-9] and non-point source pollutants.[10] These sources result in nutrient enrichment of nitrogen and phosphorus,[11] increases in the concentrations of toxicants and heavy metals,[12,13] and physical habitat degradation by sediment release in urban streams.[1,14,15] Under these circumstances, various biological symptoms such as low biodiversity, changes in the composition of aquatic biota, and predominance of tolerant species are frequently reported, resulting in generally poor ecological health in urban streams.[16] For this reason, various stressors that influence stream health have received attentions for ecosystem conservation and protection.

Earlier studies that sought key factors that influence stream health focused on chemical contamination[1, 17-18] and physical habitat modifications.[15] Recent publications, however, have pointed out that chemical and physical approaches are not sufficient for assessing ecological stream health[19-21] and that biological monitoring is also required.[22] Also, numerous studies have suggested that some problems can arise when using conventional biological endpoints, such as the generation of simple diversity indices without considering stream size (order),[23] using one or two parameter analyses of species number and/or number

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