学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Structural and functional assessments of hyporheic macroinvertebrates across multiple environmental gradients in rivers of Hokkaido, Japan

（北海道河川における複数環境傾度に沿った河床飽和間隙水域無脊椎動物の構造および機能評価）

Knowledge of organisms' diversity pattern and their ecological drivers is central to ecology, which may vary at local to spatial scales. Rivers are composed of benthic habitat and a vertically saturated area below the riverbed which can be a habitat for diverse macroinvertebrate communities known as hyporheic habitat. In rivers, understanding the contribution of macroinvertebrates in ecosystem structure and function is largely limited for hyporheic habitat across multiple environmental gradients. This study tested the contribution of hyporheic habitat to total diversity of macroinvertebrates and demonstrated how macroinvertebrate's structural and functional responses vary across multiple environmental gradients in the hyporheic zone. The first part of the research was conducted in 15 river reaches within eight river segments consisting of five rivers in Hokkaido, Japan (Toyohira, Horonai, Sorachi, Tokachi, and Satsunai river). The latter parts were conducted only in the Satsunai river.

The study first demonstrated the importance of habitat contribution from the hyporheic zone to the total diversity of macroinvertebrates and the factors that influence the contribution. Hyporheic and benthic samples were collected from August to November 2020 by installing colonization traps at 30 cm depth and a Surber sampler respectively. The macroinvertebrates were separated among segments, river reaches, and between benthic and hyporheic habitats. Habitat contribution (up to 25.9%) was mort clearly detected at the reach scale, suggesting that habitat contribution should be recognized more at relatively small local scales. The higher alpha diversity of the benthic habitat and together with the dominance of turnover between habitats, suggested the presence of unique species in hyporheic habitat. The variable contribution pattern across reaches did not vary under variable environmental gradients. The number of hyporheic specialist species predicted the contribution pattern across reaches and responded to environmental variables independently with the negative effect of fine sediment amount and positive effects of nitrate concentration, dissolved oxygen, and riverbed median particle size. Thus, the number of specialist species and their variable responses to the local environmental variables interactively cause varying contribution patterns across reaches.

The study then examined how fine sediment (particle size: <2 mm) influences the macroinvertebrates in hyporheic zone under different levels of nutrient pollution through experimental sediment addition in sites with different nutrient levels. The field survey and sampling were conducted in three sites in the Satsunai river and

one of its tributaries in 2019. The amount of fine sediments varied between habitat treatment types, indicating that sediment addition effectively manipulated the hyporheic zone. The responses of hyporheic macroinvertebrates were predictable for the independent stressors. Higher nitrate increased the taxonomic richness and relative abundance, whereas higher fine sediment increased the taxonomic richness of the hyporheic macroinvertebrates. The interaction between two stressors was not apparent. A community structure would have dominated under the higher nutrient levels that might offset any adverse effects of fine sediment. Thus, the effect of fine sediment was not appeared as strong adverse effects.

The study finally examined the effects of fine sediments and nutrients on hyporheic leaf litter decomposition rate and macroinvertebrates. The field survey and sampling were conducted in three sites in the Satsunai river and one of its tributaries in 2019. The field experiment was conducted by measuring the leaf litter decomposition of dried Alnus japonica leaves in benthic and hyporheic zones with and without sediment treatments at four sites with a gradient of nitrate concentration. The decomposition rate was comparable between the two zones but slowed down by sediment addition in the hyporheic zone. The leaf litter decomposition rate was highly predictable for the individual stressors. The detritivore invertebrate community was the main driving component of decomposition in the decreased leaf litter decomposition rate under higher sediment levels. Higher nitrate levels increased the leaf litter decomposition rate by stimulating microbe-driven decomposition and detritivore feeding. The adverse effects of fine sediment could be offset in the presence of nitrate and represented the additive effects of fine sediment and nitrate on leaf litter decomposition in the hyporheic zone.

The findings estimated habitat contribution to the total diversity of macroinvertebrates and how environmental stressors affect the structure and function of macroinvertebrates in the hyporheic zone. The finding showed that hyporheic habitat could add unique species to river macroinvertebrate diversity in particular when examined at smaller reach scale. Moreover, hyporheic macroinvertebrates' structural and functional properties were influenced by the fine sediment and nutrients in the hyporheic zone, in which functional responses were adversely affected by the fine sediment with a decrease in detritivore abundance. Conservation of hyporheic specialists is important as they could provide essential roles (e.g., role in the food web) in hyporheic habitat. Detritivore invertebrates might not be specialists in the hyporheic zone, but their role is crucial for providing hyporheic functions. Thus, effective conservation measures can vary based on observed community structure including specialists and taxa with more important functions, and multiple environmental gradients.