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# Habitat characteristics and trophic structure of benthic macroinvertebrates in a forested headwater stream

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ABSTRACT

Three channel reaches with different habitat characteristics were selected to test the variability in community structure of benthic macroinvertebrates by comparing the relative abundance of functional feeding groups among the reaches. The important factors influencing the spatial and temporal organization of community structure were explored using nonmetric multidimensional scaling (NMS). The habitat characteristics in the reaches were different in terms of habitat type, hydrological factors, and substrate composition. The first headwater reach was classified as a step-pool reach with similar relative areas of riffle and pool habitats. The second mid-reach and the third down reach had greater areas of pool habitat followed by runs and riffles whose proportions were similar between the latter two reaches. The relative abundances of functional feeding groups were different among the surveyed reaches. Gammarid shredders predominated in the upper reach, and chironomid collector–gatherers and collector–filterers were in greater abundance in the two lower reaches. The proportions of gammarids were minor in the mid and downstream reaches. NMS ordination indicated that the proportion of substrates<8 mm, discharge, and water depth mainly determined the spatial and temporal distribution of samples based on the macroinvertebrate community in the study reaches. These results suggest that different habitat characteristics result in a distinct community structure in each reach.


## Introduction

Aquatic organisms including stream insects are affected by various physical environments that can be organized hierarchically according to the spatial scale of the river network within landscapes (Minshall, 1988; Poff, 1997). The physical environments of rivers are controlled by landscape components whose relative importance varies according to spatial scale. Climate controls the hydrological cycle and river water temperature regimes at the greatest scale. Source of flow, watershed topography, and geology affect sediment supply and water chemistry in the meso-scale. Land cover, network position (e.g., stream order), and valley landform influence vegetation type, flood intensity, and morphodynamic processes (e.g., hydraulic geometry, habitat volume, sediment size range, and riparian condition) in the smallest scale (Snelder and Biggs, 2002). These physical factors allow many stream reaches to encompass diverse habitats (Frissell et al., 1986; Montgomery and Buffington, 1997) and exert influences not only on community structure but also on ecosystem functions (e.g., Minshall, 1984; Huryn and Wallace, 1987; Smock et al., 1992).

A number of studies have demonstrated the relationship between heterogeneity among habitat patches in stream reaches and benthic macroinvertebrate communities. Minshall and Robinson (1998) measured 21 environmental variables including physical, chemical, and organic matter resources and examined the relationship between habitat heterogeneity and macroinvertebrate community structure. They found that biotic properties such as the diversity index were dependent on habitat heterogeneity in a reach, and that the proportion of shredders was correlated with stream size, implying longitudinal changes in food availability. Similarly, a study in three segments of a Missouri stream, encompassing a full range of physical and hydraulic conditions, showed that community composition, diversity, and relative densities of some functional feeding groups were highly correlated with hydraulic variables and benthic organic matter (Doisy and Rabeni, 2001). They concluded that variation of local factors in a stream segment has the greatest influence on the invertebrate community.

Several researchers have been interested in examining the effect of habitat type on the function of stream ecosystems by considering the spatial distribution of invertebrates among various habitats.

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Benke et al. (1984) measured invertebrate productivity on snag, sandy bottom, and muddy benthic habitats in a subtropical blackwater river in the Lower Coastal Plain of Georgia. They found that the snag habitat was responsible for much higher taxa diversity and invertebrate biomass and for 15–16% of production, although the effective substrate area of the snag habitat was only about 6%. It was concluded that the community structure categorized by a functional feeding group (FFG) was different between snag and benthic habitats. In a study comparing distribution of FFGs among different habitats in an Appalachian mountain stream, Huryn and Wallace (1987) showed that the functional structure of benthic macroinvertebrates is the result of the relative contributions of each habitat (riffle, pool, or bedrock-outcrop) in the total stream area.

Benthic macroinvertebrates are one of the major biota in streams and are composed mainly of aquatic insects, crustaceans, and mollusks. These organisms are the link between primary food sources (algae, microorganisms, and detritus) and their predators (fish) in a stream food web (Cummins, 1974) and have been widely used as indicators to evaluate the quality of stream ecosystem health (e.g., Resh et al., 1996; Barbour et al., 1999). Under the physically heterogeneous environments of streams, benthic macroinvertebrates have evolved distinct morpho-behavioral feeding strategies that are the basis of categorizing diverse benthic macroinvertebrates into several functional groups (Cummins and Klug, 1979). The feeding mechanisms of different FFGs are adapted to the physical environment of different habitat types within a stream segment. For example, a higher proportion of shredders is observed in headwaters flowing through a deciduous forest with a dense canopy. Scrapers are abundant in mid-reaches with an open canopy (Webster et al., 1995; Grubaugh et al., 1996), whereas collector–gatherers dominate pool habitats (Lemly and Hilderbrand, 2000), and collector–filterers prefer to colonize high-flow water positions providing higher feeding rates (Huryn and Wallace, 1988; Georgian and Thorp, 1992). These observations suggest that variability among habitat types, if considered along with the feeding mechanism of different macroinvertebrate taxa, would result in different but predictable community structures according to the physical characteristics of different habitats.

A stream can be seen as a hierarchical system of several levels between stream segments and single substrate particles according to the channel classification and the associated spatial scale proposed by Frissell et al. (1986) and Montgomery and Buffington (1998). This classification system suggests that a stream segment ($10^2$–$10^4$ m scale) includes various types of channel reaches (10–$10^3$ m scale) composed of different habitat types or channel units (1–10 m scale). It is possible that a channel reach type may have a different combination of relative areas of channel units in a stream segment, resulting in channel reaches with different habitat characteristics even when the reaches are very short and are located at intervals of reach scale.

The objectives of this study were to determine i) if the distribution of macroinvertebrate FFGs changes according to variations in the type of channel reaches closely located within a short stream segment, and ii) which habitat characteristics are important in shaping the macroinvertebrate community structure in the spatial and temporal domain.

## Materials and methods

### *Study reaches*

This study was conducted in the headwater reaches of Bongseonsa Stream located in the Gwangneung Forest, Korean National Arboretum of the Korea Forest Research Institute (Pocheon-si, Gyeonggi-do, Republic of Korea; Fig. 1). This forest has been preserved for more than 500 years; thus, minimizing anthropogenic disturbances. The stream passes through the natural forest and has kept its undisturbed characteristics as a forest stream whose riparian zones are covered with dense mixed deciduous vegetation in varying degrees along the stream corridor from the source to downstream reaches. The main energy source of the stream ecosystem is provided by riparian vegetation in the form of organic detritus and associated microbial assemblages (Hall et al., 2000, 2001). Riparian vegetation mainly consists of red-leaved hornbeam (*Carpinus laxiflora*, Betulaceae), heartleaf hornbeam (*Carpinus cordata*, Betulaceae), and konara oak (*Quercus serrate*, Fagaceae) in the headwater reach, mixed with needle fir (*Abeis holophylla*, Pinaceae), Korean pine (*Pinus koraiensis*, Pinaceae), and Japanese larch (*Larix kaempferi*, Pinaceae) in the downstream reaches.

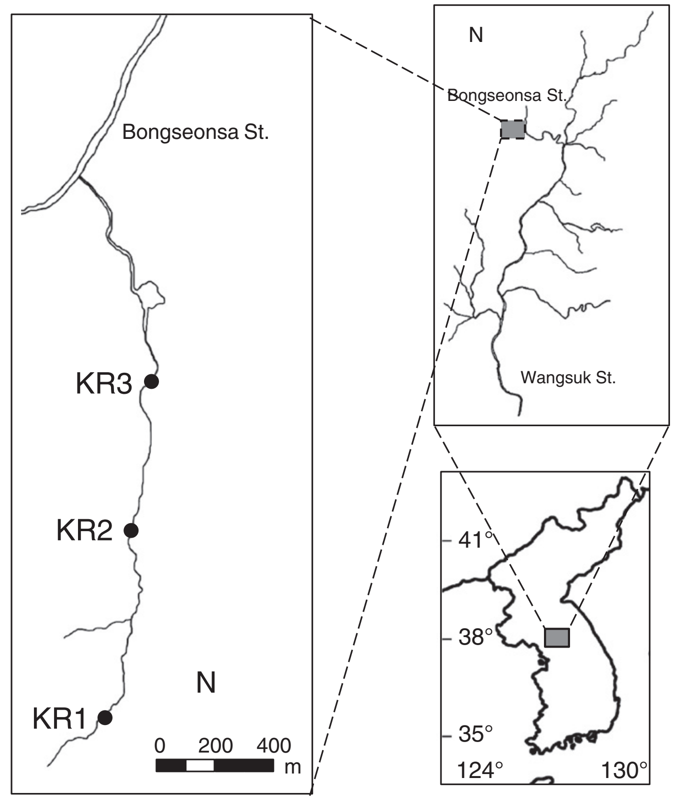


**Fig. 1.** Location of three study reaches in Bongseonsa Stream, Pocheon, Korea.

Three sampling reaches, KR1, KR2, and KR3, from upstream to downstream were surveyed, which were about 500 (between KR2 and KR3) to 600 m (between KR1 and KR2) apart from each other (Fig. 1). KR1 was located in the first-order headwater stream, which is close to the source of the stream, and KR2 and KR3 were in the second-order downstream. KR1 was relatively narrow and mainly composed of a chain of small pools and riffles connected by short runs. The KR2 and KR3 habitats (i.e., channel units) were dominated by pools followed by runs and short riffles. The riparian canopy of KR1 was almost completely closed but was less closed in KR2. The canopy at KR3 was partly closed.

### *Macroinvertebrates*

Three replicates of benthic macroinvertebrates were collected from each study reach using a Suber sampler (30 cm × 30 cm, 100 μm mesh size; Eaton et al., 2005). Samples were collected once every season from summer 2006 to spring 2009. All sediments from the randomly chosen sampling points in the reaches were washed in the current to separate the benthos and organic detritus into the net. The samples inside the net were rinsed on a sieve (100 μm mesh size) to remove silt and were preserved in 95% ethanol in the field. Macroinvertebrates were sorted under a dissecting microscope and were preserved in 70% ethanol in the laboratory for further analysis. The stored macroinvertebrates were identified to the lowest feasible