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Short Research Note

Effect of season on the impact of ecosystem engineers in the New River, NC

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Abstract

The importance of biotic interactions in structuring communities can depend on seasonal changes in abiotic context. The crayfish and benthic-feeding fish of the headwaters of the New River have been shown to be ecosystem engineers due to their ability to reduce the amount of sediment accumulation in cobble beds during the summer. However, the temperature-driven seasonal reduction in the activity level of these organisms may reduce their impacts during the colder months. I measured the impact of benthic-feeding fish and crayfish on sediment accrual in the headwaters of the New River during the winter using a field exclosure experiment. I found that during the winter there was no effect of benthic-feeding fish and crayfish on the amount of sediment accumulating in cobble beds in the headwaters of the New River. These findings suggest that seasonal changes in the effect of ecosystem engineers need to be quantified for a complete understanding of the effect of these organisms.

The importance of biological interactions in structuring ecological communities depends on the abiotic context in which the interactions are occurring (Power et al., 1988; Poff & Ward, 1989). In temperate aquatic communities, water temperature varies seasonally, and since the rate of many biological processes vary as a function of temperature, the importance of biological interactions may vary seasonally as this context changes.

Crustaceans and fish have been shown to function as ecosystem engineers (*sensu* Jones et al., 1994) and affect the structure and function of many aquatic systems (Huryn & Wallace, 1987; Pringle et al., 1993; Creed, 1994; Flecker, 1996; Usio, 2000; Ewing, 2002; Creed & Reed, 2004; Helms & Creed, 2005). However, seasonal differences in the activity levels of ecosystem engineers in temperate streams may result in a reduction in their effects during cold months (Huryn & Wallace, 1987; Creed & Reed, 2004). Thus, the quantification of ecosystem engineering effects during a single season may exaggerate (or downplay) the importance of these processes throughout the year.

The headwaters of the New River contain two groups of macroconsumers (crayfish and benthic-feeding fish) that have been identified as ecosystem engineers due to their ability to significantly reduce the amount of sediment accumulating in cobble beds during the summer and affect the composition and biomass of sediment-associated macroinvertebrates (Helms & Creed, 2005). The crayfish species *Cambarus chasmodactylus* and *Orconectes cristavarius* coexist in high densities (up to 3 m^{-2}) in the headwaters of the New River as adults (Helms & Creed, 2005). The benthic feeding fish likely to be affecting sediment accumulation in this system are central stonerollers (*Campostoma anomalum*), northern hogsuckers (*Hypentelium nigricans*), and white suckers (*Catastomus commersoni*) which occur at approximately 0.5–1.0 m^{-2}, ~0.01–0.02 m^{-2}, and ~0.001–0.002 m^{-2}, respectively (Helms, 2000; Helms & Creed, 2005). A more detailed description of the study area and the taxa present in the system is found in Helms & Creed (2005), Helms (2000), and Fortino (2000). In this system, both benthic-feeding fish and crayfish are most active in the summer months (KF pers. obs.) and thus, their influence may diminish during other seasons when they are less active.

To evaluate whether the ecosystem engineering effects of fish and crayfish on sediment accumulation in the New River follow the same seasonal patterns as their activity levels, I conducted a field exclosure experiment of very similar design to that of Helms & Creed (2005) during the winter of 2001. Sediment accumulation was measured in a $30 \times 30 \times 5$ cm basket made from 6 mm mesh hardware cloth and lined with 1 mm mesh fiberglass window screen. An 9×9 cm unglazed ceramic tile was placed in the center of each basket and surrounded by 5–7 scrubbed cobbles. The tile was originally intended to provide a uniform substrate to quantify periphyton growth but in all replicates and treatments the tile was completely covered with sediment by the end of the experiment and thus the volume of sediment accumulated on the tile was simply added to that of the rest of the basket. The experiment consisted of three treatments replicated four times. Large animals (i.e., fish and crayfish) were either excluded entirely from the basket by a hardware cloth cage (Exclosure Treatment), allowed access to the basket through the open downstream end of an otherwise complete cage to simulate the physical conditions of the cage (Cage Control), or allowed access to an unenclosed basket (Open Basket). The cages used in the Exclosure and Cage Control treatments were $50 \times 50 \times 15$ cm and were constructed of 12 mm mesh hardware cloth. In both the Exclosure and Cage control, the baskets were placed in the center of the cage and surrounded by cobbles. The treatments were anchored to the substrate in a randomized complete block design in a run ($\sim$15 m wide) in the South Fork of the New River near Boone NC. The treatments were arranged in rows approximately 1–2 cage-widths apart and rows were staggered and separated by sufficient distance to prevent upstream cages from affecting the flow to downstream cages. The experiment ran from 24 February to 11 March 2001 during which the cages were cleaned for debris approximately once a day with a stiff plastic brush. The current velocity and depth were measured upstream of each cage on 11 March 2001. At the end of the experiment the baskets were collected by gently lifting them onto an 'L' shaped frame covered in 250 μm Nitex mesh and carrying them to shore. Once on shore, the tiles were removed from the basket, placed in individual plastic containers and transported back to the lab. The remaining sediment in the basket was rinsed from the cobbles, mesh, and Nitex into glass jars. In the lab, the sediment that had accumulated on each tile was removed by rinsing and scrubbing with a toothbrush. The volume of sediment that had accumulated on each tile or basket was determined by resuspending the sediment in water and allowing the slurry to settle in a graduated cylinder. The log of the total amount of sediment collected on both the tiles and baskets was used as the response variable.

The mean volume of sediment that accumulated on the tiles and baskets in each treatment, as well as, the mean depth and current velocities of each treatment are shown in Table 1. There was no significant difference in the current velocity (log transformed) ($F_{2,9} = 0.207$, $p = 0.82$) or depth ($F_{2,9} = 0.1781$, $p = 0.84$) between treatments. A two-way ANOVA on log sediment volume as a function of treatment and block found no significant effect of treatment or block on the accumulation of sediment in the baskets (Table 2).

There was no effect of the exclusion of fish and crayfish on the accumulation of sediment in the New River during late February and early March (Tables 1 and 2). This contrasts with the findings of Helms & Creed (2005), who found that the exclusion of these taxa significantly increased the amount of sediment accrual in a nearby reach of the New River during August. The most likely explanation for the difference in findings is seasonal differences in the activity level of fish and crayfish. In the section of the New River where this study took place, both crayfish and fish are less active during cold periods (KF pers. obs.). The range of stream water temperature during my study was 0.11–9.8 °C with a mean of 5.27 °C whereas, the range and mean of stream water temperature during Helms & Creed's (2005) study was 12.2–22.8 and 18.9 °C, respectively (Helms, 2000). The considerably lower stream water temperatures during February and March relative to August likely resulted in reduced activity levels of

Table 1. Mean and standard error (SE) of accumulated sediment volume (ml) in each treatment

Treatment	Mean (SE) sediment vol. (ml)	Mean (SE) depth (cm)	Mean (SE) current velocity (cm/s)
Open basket	492.25 (13.04)	35.5 (1.32)	31 (3.46)
Cage control	776.5 (134.03)	34.5 (1.26)	28.25 (4.64)
Exclosure	960.75 (221.98)	34.75 (1.11)	29.5 (2.02)

Table 2. Results of two-way ANOVA with treatment and block as the factors and log sediment accumulation as the response

Baskets	Source	DF	SS	MS	*F*	*p*
	Treatment	2	0.1411685	0.07058425	2.71301442	0.1448
	Block	3	0.02117794	0.00705931	0.27133562	0.8441
	Error	6	0.15610145	0.02601691		
	Total	11	0.31844789			

fish and crayfish. Since bioturbation during movement and foraging is the principal mechanism by which benthic organisms are thought to reduce sediment accrual (Usio & Townsend, 2004), a reduction in their activity level would result in increased sediment accumulation.

My study did not quantify differences in invertebrate community composition or density within the treatments thus, it is unknown whether the reduction in bioturbation by fish and crayfish resulted in changes in benthic community structure, i.e., the undoing of the ecosystem engineering effect. However, bioturbation alone has been shown to impact lotic community structure (Usio & Townsend, 2004) and Helms & Creed (2005) conclude that the effect of fish and crayfish on benthic community structure in the South Fork of the New River during the summer is largely due to changes in sediment accrual. Therefore, the cessation of bioturbation during the colder months of the year may undo the effect of the engineers. It is likely that although crayfish and fish may be important in structuring the benthic communities of the New River during the warmer months (Helms & Creed, 2005), factors other than ecosystem engineering by crayfish and fish may structure benthic communities during colder months. These findings suggest that in seasonally variable systems where changes in the abiotic milieu potentially affect the behavior of strongly interacting organisms, a complete understanding of the impacts of these organisms requires quantification in all seasons.

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