The effects of wood surface complexity and current velocity on aquatic insect

colonization over time

BIOS 35502: Practicum in Environmental Field Biology

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Abstract

Wood in streams affects stream biological properties primarily by serving as habitats for biofilm and macroinvertebrates. Various factors may affect macroinvertebrate colonization. The effects of three of these factors—current velocity, surface complexity, and length of placement in stream—on macroinvertebrate abundance and functional feeding group composition was studied by placing tiles with and without bark in pools and riffles of a second-order stream in Gogebic County, Michigan. The number of aquatic insects found in a given area were identified to family and classified according to functional feeding group. Time was found to significantly affect abundance and proportion of predators. Surface complexity also significantly affected predator proportions. Mechanisms explaining these differences, as well as the general lack of significant results, strongly suggest that other factors not considered in this study drive differences in aquatic insect colonization. Such factors include wood type and conditioning, substrate covering of tile, and microscopic surface complexity. Further studies should be conducted testing the effects of these additional factors on colonization, using more replication and greater sampling frequency.

Introduction

Coarse woody debris has an integral effect on both the physical and biological properties of streams. Geomorphically, wood affects stream sediment routing and deposition, channel dynamics and processes, and channel

morphology. By serving as obstructions to water flow, wood creates scoured

pools and can cause bank erosion, consequently widening channels. Wood also

leads to the formation of bars by physically blocking sediment transport, forcing

sediment deposition that may narrow channels (Montgomery et al. 2003).

These geomorphic effects of wood affect the local biological

characteristics of the stream. By forming sites for sediment and fine organic

matter storage, wood affects stream nutrient availability and cycling (Bilby 2003;

Dolloff and Warren 2003). Wood also serves as an important habitat for biofilm

and macroinvertebrates, which can use wood during all stages of their life cycles.

Benke and Wallace (2003) describe the three main habitat types created by wood

in streams. Loose stream wood forms benthic habitats; it includes individual

braches that lay on the streambed. Wood dams are accumulations of wood that

disrupt water flow. Fallen trees and branches anchored by the bank on one end

are known as snags. Found primarily in medium to large rivers, snags also create

a distinct type of habitat for biota. They facilitate the use of various feeding

strategies, thus enabling increased exploitation of the available food resources

(Benke and Wallace 2003).

Various types of macroinvertbrates inhabit wood in streams, fulfilling

different niches according to feeding characteristics. Xylophagous species feed

on wood and are thus classified in the shredder functional feeding group.

Obligate xylophages depend solely on wood as a food source and are

consequently found only on wood substrates. Most obligate xylophages are shredders, including miners, gougers, and tunnelers. Facultative xylophages feed on leaf litter in addition to wood. They are common in streams where wood lies on the streambed. Nonxylophagous species have a preference for wood habitats but do not rely on wood as a food source. According to functional feeding group classifications, nonxylophages are primarily considered filterers, gatherers, scrapers (grazers), and predators (Benke and Wallace 2003).

Epixylic biofilms serve as an important source of food for macroinvertebrate populations. According to Benke and Wallace (2003), macroinvertebrate colonization and species abundance is directly related to biofilm development. Biofilm increases nutritional value of the wood by promoting colonization by wood-feeding organisms (Bilby 2003). Scrapers and gatherers are the primary consumers of these biofilms.

Coarse and fine particulate organic matter is also an important macroinvertebrate food source. Specifically, filterers rely on drifting organic particles produced upstream and carried to the macroinvertebrates by the current as their primary source of food (Benke and Wallace 2003).

According to the literature, overall invertebrate colonization begins immediately, but at least four weeks are required before maximum colonization is reached (Nilsen and Larimore 1973). Other studies, however, found that abundance can peak in as few as two weeks (Benke and Wallace 2003). Various

other factors besides biofilm development influence colonization. According to

Magoulick (1998), natural wood stream structures support a greater abundance of

macroinvertebrate life than artificial structures. More complex structures also

support a greater abundance of macroinvertebrates (Benke and Wallance 2003).

Benke and Wallace (2003) and Bilby (2003) describe how current velocity

impacts colonization. Benthic species colonize wood more rapidly in higher-

velocity currents because they are carried to the newly-submerged wood at higher

rates. Greater colonization also occurs because the amount of organic matter

transported increases with current velocity, as does the concentration of dissolved

oxygen. Macroinvertebrate abundance is also usually greater in faster currents.

Thus, wood in riffles generally supports larger macroinvertebrate populations and

are colonized at higher rates than wood in pools (Benke and Wallace 2003; Bilby

2003).

      The type of habitat created by the wood affects the composition of

macroinvertebrates according to functional feeding group. Wood lying on the

streambed and in dams is primarily inhabited by shredders. Filterers and

gatherers usually do not reach a high density on such wood because the structures

may become partially buried. Instead, these collectors are the primary inhabitants

of snags. Predators are also more common on snags. The biological and

environmental history of a stream also affects invertebrate composition on

artificial snags (Benke and Wallace 2003).

Thus, wood plays an essential role in developing the physical and biological properties of lotic systems. Many rivers and streams were cleared of such influential structures for logging and channelization purposes throughout the 19th and 20th centuries (Montgomery et al. 2003). Beginning with Michigan trout creeks in 1927, efforts have been made to restore these damaged waterways by introducing artificial wood structures to create additional bank cover, increase pool area, and alter stream flow (White 1996). However, few studies have compared the effectiveness of less complex artificial wood structures to that of more complex natural wood structures such as logs or branches. Therefore, the objective of this experiment is to investigate the effects of wood surface complexity on macroinvertebrate abundance and composition in differing current velocities over time. For the purpose of this study, "macroinvertebrate" refers specifically to aquatic insects, and "time" refers to length of structure placement in stream.

I hypothesized a positive correlation between macroinvertebrate abundance and each of three factors: current velocity, surface complexity, and time. Additionally, I hypothesized that functional feeding group composition will not be dependent on current velocity, surface complexity, or time. Due to the placement of experimental tiles in depositional habitats (i.e., on the stream bed), I expected shredders to be the dominant functional feeding group throughout the duration of the experiment.

Materials and Methods

The field experiment was conducted in Tenderfoot Creek on University of Notre Dame Environmental Research Center (UNDERC) property in Gogebic County, Michigan. Tenderfoot Creek is a low-gradient second-order stream. The study site was a section of the stream approximately 100 m long with uniform width (about 5 m). The riparian area was composed primarily of northern hardwood forest species, with speckled alder (*Alnus incana*) and sweet gale (*Myrica gale*) immediately along the banks. Afternoon stream temperature ranged from 20.54°C to 25.12°C, averaging 23.09°C. Conductivity and alkalinity remained fairly constant at 0.102 mS and 9.48, respectively.

Mean current velocity in the pools studied was 0.020 m/s, ranging from 0.000 to 0.100 m/s. Pool substrate consisted of fine and coarse benthic organic matter. The current velocity of the riffles studied ranged from 0.003 to 0.671 m/s, averaging 0.284 m/s. A mixture of gravel, cobble, and rock composed the riffle substrate. Depth varied with each pool and riffle.

This experiment was set up as a randomized-block design. One block was set up in each of three pools and riffles. Each block consisted of three pairs of wooden tiles. Every pair of had one structure for both levels of surface complexity—1) a barkless 10 cm x 10 cm x 3 cm block of untreated pine (*Pinus* spp.) and 2) a 10 cm x 10 cm x 3 cm block of pine covered with pine bark, both untreated. On May 31, 2006, the structures were secured on the creek bed by

drilling a hole on either side of the tiles. One side of a U-shaped metal bar was inserted through each hole and into the creek bed, inserting the other side only into the bed.

One pair of tiles was removed from each pool and riffle on June 7, June 14, and June 28, or 7, 14, and 21 days after initial placement, respectively. During removal, a macroinvertebrate sampler was used to collect macroinvertebrates in an 8 cm x 1 cm rectangle on the structure surface. The sampler was a syringe barrel with a mesh filter on one end, cut to measure the desired area. Upon removal, the sampler was held tightly against the structure surface while it was being lifted from the water. The surface sampled was squirted with deionized water running into the macroinvertebrate sampler until the area was visually clean. Collected macroinvertebrates were preserved in 70 % ethanol before and after identification.

Identification occurred within three weeks of collection. For each removed structure, the aquatic insects found in the sampled area were identified to family, counted, and classified according to functional feeding group. The proportion of macroinvertebrates belonging to each observed functional feeding group was calculated. Data were tested for normality using probability plots, normalized by rank, and statistically analyzed using a multi-way ANOVA in SYSTAT 11.0 (SYSTAT Software, Inc., Point Richmond, CA). The following factors were tested for their effect on macroinvertebrate abundance and for

interaction: current velocity, structure complexity, and time. The same factors
and interactions were also examined for their effect on functional feeding group
composition for each group observed. Due to the small sample size, $p < 0.100$
was considered significant.

Results

Current velocity and structure complexity had no significant effect on total
number of macroinvertebrates (Table 1). However, aquatic insect abundance
increased with time—between 7 and 14 days—and decreased between 14 and 28
days (Table 1, Figure 1). Current velocity, structure complexity, and length of
placement in stream had no significant effect on proportion of the following
functional feeding groups: gatherers/scrapers, filterers, and gatherers (Table 1).
Current velocity did not significantly affect the proportion of predators (Table 1).
However, predator proportions significantly tended to increase with surface
complexity (Table 1, Figure 2). Proportion of predators exhibited a significant
trend with time as well, increasing between days 7 and 14 and decreasing between
days 14 and 28 (Table 1, Figure 3). No significant interaction was found among
or between factors for any of the dependent variables (Table 2).

Discussion

These results fail to support my hypothesis that macroinvertebrate
abundance will be positively influenced by structure complexity and current
velocity. The results for surface complexity did not agree with the numerous

previous studies that have shown greater numbers of invertebrates on irregular than smooth surfaces. However, a similar study conducted by Magoulick (1998) found no significant difference in abundance between rough and smooth tiles. Similar microscopic texture in both the rough and smooth textures may have caused the lack of significant difference observed (Magoulick 1998). The same reasoning can be applied to the present study. Although the surface complexities examined differed macroscopically, they may not have differed microscopically, therefore having no significant effect on abundance. A study conducted with surface complexities differing in microscopic rather than macroscopic texture would be necessary to test this conclusion.

The lack of significant effect due to current velocity also disagreed with many studies in the literature. This may have occurred because the velocities of the selected riffles and pools were not sufficiently distinct due temporal differences within sites.

Time, however, significantly affected abundance, as it increased between days 7 and 14 and decreased between days 14 and 28. This peak indicates that maximum colonization requires at least 14 days, supporting studies that found maximum colonization between two and three weeks. A study with more frequent sampling intervals would be necessary to more accurately approximate the time required to reach maximum colonization. Although these results were not strongly significant, time may be found to significantly affect

macroinvertebrate abundance with more replication and thus more statistical power.

Factors besides the ones studied may have affected macroinvertebrate colonization and therefore abundance. The characteristic of the tile wood is one such factor. Wood with higher concentrations of sapwood and bark promotes faster biofilm development and consequently faster macroinvertebrate colonization, while higher concentrations of heartwood retard development and colonization. Additionally, the proportion of lignin in wood is correlated with slower decomposition rates and thus slower development and colonization rates. Gymnosperms such as pine have a particularly high proportion of lignin compounds (Bilby 2003). The tiles used in this experiment were primarily composed of pine heartwood. Thus, macroinvertebrate colonization of the tiles was probably reduced, as well as overall abundance. To confirm this conclusion, tiles made from angiosperm wood and primarily composed of sapwood and/or bark should be placed in the stream alongside pine, heartwood tiles.

Alternatively, the covering of tiles by detritus and/or substrate may be responsible for differences in aquatic insect colonization. Drifting organisms are more likely to grasp and inhabit wood as detrital layers develop (Nilsen and Larimore 1973). Thus, increased tile cover may increase abundance. Substrate cover also may reduce the effects of surface complexity on abundance by acting as a barrier between the tile surface and the current. Further studies should be

conducted to determine the effect of the covering of tiles on macroinvertebrate abundance.

Studies have also shown that tile depth is an important factor in determining macroinvertebrate colonization rate and abundance due to depth-related differences in the kinds and amounts of available food, as well as in light, temperature, and velocity. Differences in any of these conditions could alter both macroinvertebrate abundance and functional feeding group composition, as many invertebrates exhibit preference for specific depths (Nilesn and Larimore 1973). However, the literature lacks studies examining specific divisions in depth to determine exactly where these preferential differences occur. The individual depths of the pools and riffles used in this experiment may have varied enough to affect aquatic insect abundance and composition. This possibility should be investigated with further studies analyzing the effect of specific depths on abundance and composition.

Concerning functional feeding groups, current velocity, surface complexity, and time did not have a significant effect on the proportions of gatherers/scrapers, filterers, or gatherers. Also, current velocity did not significantly affect proportion of predators. My results support the second hypothesis that functional feeding group composition will not be dependent on structure complexity, current velocity, or time. However, the results do not support the prediction that aquatic insect shredders will remain the dominant

functional feeding group through the duration of the experiment because no aquatic insects were found that could be classified as shredders. The lack of insect shredders may have been due to numerous factors. Wood conditioning via previous submergence can affect macroinvertebrate composition. Specfically, species richness is generally greater on conditioned than unconditioned wood (Magoulick 1998). Some xylophagous species cannot inhabit wood unless it has been conditioned for several years (Benke and Wallace 2003). Because the wood used in this experiment was not conditioned, it may not have been soft enough to allow for immediate burrowing by gougers and others shredders. To test this conclusion, a study incorporating conditioned wood of the same type and approximate size would be necessary.

It is important to note that this study focused on aquatic insects. Shredders and scraper/shredders were found on the structures, but they were not included in the analysis because they did not fall within the parameters of the experiment. Future studies should incorporate non-insect orders into their study to gain a broader understanding of functional feeding group composition.

My results also indicate a significant biological trend for proportion of predators to increase with surface complexity. This is consistent with many studies within the literature. The previous distinction between macroscopic and microscopic differences in complexity may also apply to this case. Predators may be influenced by macroscopic rather than microscopic differences in texture, thus

leading to the observed trend. With more replication and thus more statistical power, macroscopic surface complexity may be found to significantly affect proportion of predators with a significance level of 0.050.

Another significant trend was observed between proportion of predators and time, with the proportion increasing between days 7 and 14 and decreasing between days 14 and 28. The same trend was observed between macroinvertebrate abundance and time. Thus, these results may be an indication that proportion of predators is positively correlated with abundance. A study with increased replication focusing on predator proportions and extending the overall sampling period should be conducted to more accurately define any possible relationship between time and predator proportions. Additional factors such as cover and depth also may have affected the proportion for the same reasons previously described.

Acknowledgements

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Tables

Table 1 Effects of velocity, surface complexity, and time on macroinvertebrate abundance and proportions of gatherers/scrapers, filterers, gatherers, and predators. None of the factors significantly affect the dependent variables. Significant biological trends ($p < 0.100$) are highlighted.

		Factor	F-ratio	df	p
Dependent variable	**Macroinvertebrate abudance**	Current velocity	0.006	1	0.939
		Surface complexity	0.896	1	0.353
		Time	2.605	2	0.095
	Proportion of gatherers/ scrapers	Current velocity	0.493	1	0.490
		Surface complexity	0.005	1	0.947
		Time	0.645	2	0.533
	Proportion of filterers	Current velocity	1.117	1	0.301
		Surface complexity	2.436	1	0.132
		Time	0.692	2	0.511
	Proportion of gatherers	Current velocity	0.255	1	0.618
		Surface complexity	0.041	1	0.842
		Time	1.604	2	0.222
	Proportion of predators	Current velocity	0.021	1	0.886
		Surface complexity	3.527	1	0.073
		Time	2.689	2	0.088

Table 2 Interaction among current velocity, surface complexity, and time with effect on macroinvertebrate abundance and proportions of gatherers/scrapers, filterers, gatherers, and predators. No significant interaction was detected.

|		Factors Interacting	F-ratio	df	p
Dependent variable	Macroinverte-brate abudance	Velocity + Surface complexity	1.213	1	0.282
		Velocity + Time	0.068	2	0.934
		Surface complexity + Time	0.549	2	0.584
		Velocity + Surface complexity + Time	0.168	2	0.847
	Proportion of gatherers/scrapers	Velocity + Surface complexity	0.004	1	0.953
		Velocity + Time	1.061	2	0.362
		Surface complexity + Time	1.896	2	0.172
		Velocity + Surface complexity + Time	0.481	2	0.624
	Proportion of filterers	Velocity + Surface complexity	0.008	1	0.931
		Velocity + Time	1.565	2	0.230
		Surface complexity + Time	0.329	2	0.723
		Velocity + Surface complexity + Time	0.209	2	0.813
	Proportion of gatherers	Velocity + Surface complexity	0.583	1	0.453
		Velocity + Time	0.252	2	0.780
		Surface complexity + Time	2.326	2	0.119
		Velocity + Surface complexity + Time	0.709	2	0.502
	Proportion of predators	Velocity + Surface complexity	1.023	1	0.322
		Velocity + Time	0.763	2	0.477
		Surface complexity + Time	1.244	2	0.306
		Velocity + Surface complexity + Time	0.281	2	0.758

Figures
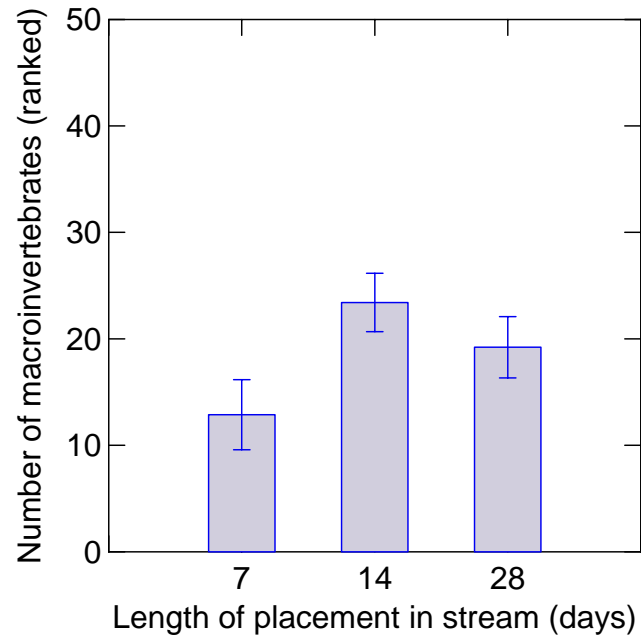
Figure 1 Effect of length of placement in stream on macroinvertebrate

abundance. The number of macroinvertebrates observed (N = 12) exhibits a

significant biological trend (F = 2.605, df = 2, p = 0.095), increasing between
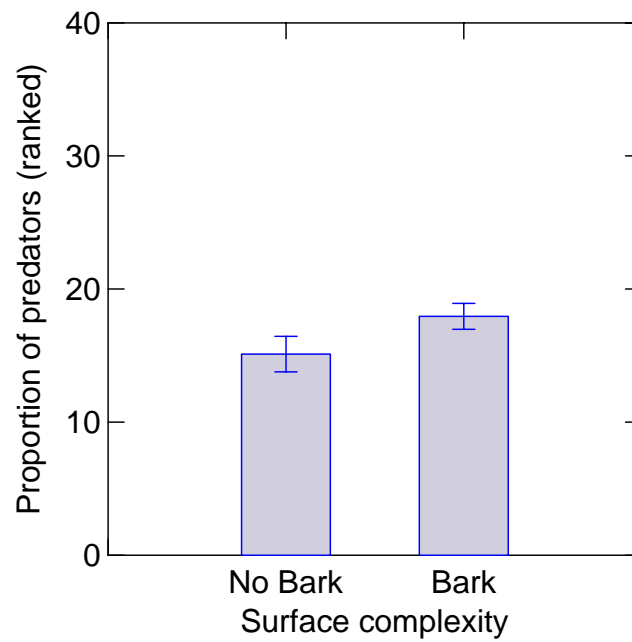
days 7 and 14 and decreasing between days 14 and 28.

Figure 2 Effect of surface complexity on proportion of predators. The proportion

of predators (N = 18) exhibited a significantl biological trend (F = 3.527, df = 1, p
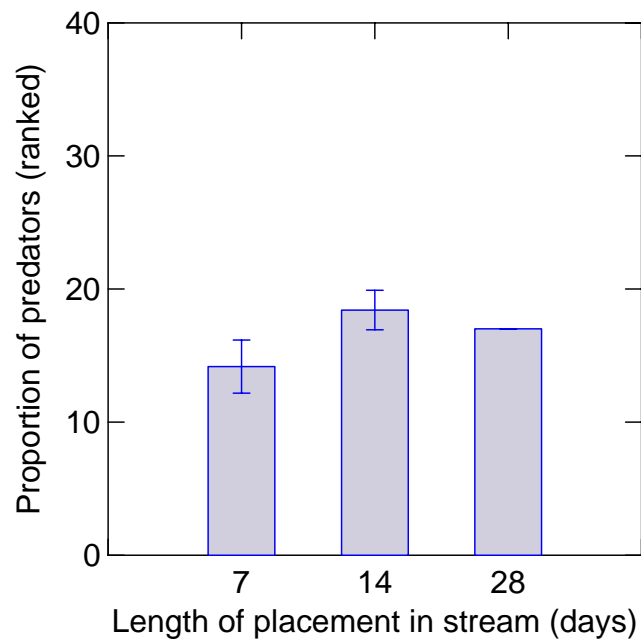
= 0.073) to increase with complexity.

Figure 3 Effect of time on proportion of predators. The proportion of predators

(N = 12) exhibits a significant biological trend (F = 2.689, df = 2, p = 0.088),

increasing between days 7 and 14 and decreasing between days 14 and 28.

Appendix

Appendix 1 Collected macroinvertebrates identified to family and classified according to functional feeding group. Oligochaeta and Platyhelminthes were only identified to order and functional feeding group. Copepods and cladocerans were only classified to order. Macroinvertebrates of the orders Gastropoda and Bivalvia were not included in this count.

Order	Family	FFG	Count
Amphipoda	Gammaridae	Shredder	41
Calanoida	-	-	3
Cladocera	-	-	53
Cyclopoida	-	-	95
Diptera	Chironomidae	Gatherer/Scraper	1031
	Simuliidae	Filterer	2
	Syrphidae	Gatherer	9
Ephemeroptera	Too young to determine	Gatherer/Scraper	42
	Baetidae	Gatherer/Scraper	33
	Caenidae	Gatherer/Scraper	42
Oligochaeta	-	Scraper/Shredder	80
Platyhelminthes	-	Gatherer	1
Plecoptera	Perlidae	Predator	1
Trichoptera	Hydropsychidae	Filterer	94