Response of Stream Macroinvertebrate Community to Canopy-opening Manipulations

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Stream light availability is an important factor influencing aquatic food webs. In forested headwaters, stream algal production is highly light-limited, and an increase in light often enhances benthic algal growth, which in turn increases food availability for primary consumers in the stream. In headwater streams, light availability is almost entirely mediated by the canopy structure of stream-side vegetation. Over the last century, many streamside forests in the Pacific Northwest were heavily harvested, leaving dense second-growth vegetation for the time being. Under current conditions we would expect dense closed canopies, little primary production, and a low abundance of invertebrates that feed on stream algae. We investigated the response of benthic periphyton, stream macroinvertebrates, and prey consumption by trout to a release from light limitation in a paired-reach study design. We hypothesized that increases in light availability would have a positive response on grazing macroinvertebrates due to elevated algal production, and predicted that this change in community structure would be reflected in the diets of trout. We found that the presence of a canopy gap had little influence on the invertebrate community, and this lack of change was reflected in summer trout diets.

# Introduction

In forested systems, streams and their biota are intrinsically linked to riparian vegetation (Vannote et al. (1980)). Stream foodwebs depend on carbon subsidies from the terrestiral environment in the form of both leaf litter and terrestrial invertebrates, but riparian controls on stream systems aren’t limited to biological inputs. Riparian canopy cover also controls the light available for benthic primary production. In the Pacific Northwest (PNW) region of North America, riparian forests have changed substantially in the past half century. After a legacy of heavy harvesting, riparian forest protections have created dense second-growth vegetation along streams. The dense vegetation in these regenerating forests decreases light availability and limits benthic primary production. As forest stand development continues natural disturbances and individual tree mortality will increase canopy heterogeneity through the introduction of gaps. While studies on forest clearing at the reach level demonstrate a clear response in benthic primary producers, invertebrates, and trout to release from light limitation, the effects of localized light patches – that reflect a more realistic picture of future stream conditions in forested landscapes – have not been evaluated. To understand how aquatic food webs respond to an increase in light associated with canopy gaps, we investigate the response of macroinvertebrates and fish feeding to canopy-opening manipulations.

Clear cutting riparian forests and reach-level increases in light can result in an increase in stream primary and secondary productivity, but increases in light also leads to increases in temperature, and cutting to the stream edge can increase sediment loads. Given these negative impacts, clear cutting along streams is no longer a common practice in the Pacific Northwest–even in managed landscapes riparian buffers are left.

While increases in temperature and visibility from increased solar radiation can have direct impacts on invertebrate populations (*citation*) and trout feeding (Wilzbach et al. (1986)), this paper will focus on the trophic interactions that result from bottom up pathways driven by an algal response to release from light limitation.

Light is an important driver of stream ecosystems because autochthonous carbon production is disproportionately represented in higher trophic levels (Lau et al. (2009)). Relative to its availability, algae is preferentially assimilated by primary consumers even in the presence of abundant allotcthonous litter input (McCutchan and Lewis (2002)). Because algae is better than detritus, we expect that increases in algal biomass will confer a competitive advantage to primary consumers well-suited to consuming periphyton (members of the scraper guild). Such a community response would be based on the assumption that there is competition for space and resources…

Stream secondary production is dominated by aquatic macroinvertebrates which play an important role in assimilating and transducing energy to higher trophic levels such as insectivorous fish and other vertebrate predators. Because macroinvertebrates play a crucial role in mediating food web interactions, understanding their community dynamics can provide key insights into broader ecosystem functioning. Macroinvertebrate community data can be used as a metric of stream health,

In headwater streams trout are oportunistic foragers, but do show selectivity for larger prey items. Because salmonids are visual predators, their feeding efficiency can be influenced by light conditions and visibility (Wilzbach et al. (1986)).

We hypothesize that a canopy gap drives primary production up and causes the macroinvertebrate community to shift in response to resource availability, and any changes in the invertebrate community are reflected in the diets of opportunistic trout.

# Methods

## Study location

The study consists of five reach pairs on five separate streams in the western Cascade Mountains of Oregon. Each reach pair consisted of one treatment reach and one control reach. Two of the reach pairs (W-100, W-113) are located on private Weyerhaeuser Co. land, and three (LOON, CHUCK, MCTE) are located on U.S. Forest Service land, one of which (MCTE) is situated in the HJ Andrews Experimental Forest. Stream reaches were 90 meters in length and treatment gaps were 30 to 40 meters in diameter and situated approximately in the middle of treatment reaches. Reach pairs were spaced at least 30 meters apart to limit any effects of the upstream reach on downstream conditions.

All of the streams are wadeable, fish-bearing streams with bankfull widths of 1-8 meters. Fish-bearing streams were purposefully selected to provide management-relevant results for key species such as salmonids. The streams run through 40-60-year-old forests that had previously been harvested without leaving a riparian buffer. These forests have a homogenous canopy structure with heavy understory shading, as defined by their early seral stage. Small streams were chosen for ease of sampling and to maximize the effect of a canopy opening manipulation since small streams can be completely shaded by overhead vegetation.

Sampling lasted two years with pre-treatment data gathered during summer 2017 and post-treatment data gathered during summer 2018. Canopy gaps were cut in the treatment reach during the winter of 2017-18 to permit adequate time for response to the canopy manipulation. The reach-pair design with pre and post treatment years is intended to account for inherent environmental variation among streams and between years.

## Data Collection

Three benthic invertebrate samples were taken at each stream reach at meters 15, 45, and 75, or the closest area with non-boulder substrate. Samples were collected once per year over the course of one week using a Surber sampler with a .09 m2 sampling area. Substrate was disturbed to a depth of approximately 4 inches for one minute. The sample was then preserved in 95% ethanol for identification and enumeration in the lab. Fish diets were collected during three-pass depletion of fish standing stock and were only taken from a subset of fish greater than 100 mm in length. Fish were gastro-lavaged, and stomach contents were collected in filter paper and preserved in 95% ethanol for lab processing. In order to measure the response of primary producers to the canopy gap, three tiles were set out every ten meters for two weeks for each stream and Chlorophyll values were measured using a Bentho Torch™.

## Data Analysis

In the lab, the three benthic samples per reach were combined and subsampled by randomly sampling whole squares from a Caton tray until the cutoff of 300 individuals or greater was reached. Benthic invertebrates were then identified down to genus or the lowest taxonomic unit (LTU) for cryptic taxa. Counts from subsamples were then converted to densities using the formula where s is the fraction subsampled. Singleton taxa (taxa occurring in only one SU) were removed from the original matrix and density values were square-root transformed to reduce the effect of abundant taxa (Chironomidae, Baetis, Micrasema) on community relationships. The resulting matrix of benthic invertebrates at the LTU level of identification (20 reaches by 64 taxa) was then used for analysis.

All diets were processed (9 to 13 fish diets per reach) with aquatic invertebrates identified down to the family level and terrestrial invertebrates identified to order. Because the number of fish dieted in each reach varied, the average of all fish diets was used. The resulting matrix was then filtered for aquatic species and appended to a matrix of 2018 benthic invertebrate families (10 reaches by 38 families), producing a matrix of 20 sample units (SU’s) by 40 families consisting of both fish diets and benthic samples. Singleton taxa were then removed to create a matrix of combined diet and benthic families of 20 SU’s by 36 families. At this point, the combined matrix was relativized by row maxima to compensate for the difference between benthic sampling—measured in density per m2—and fish diets.

Statistical analyses were performed in PC-ORD (McCune and Mefford (2016)) and R (R Core Team (2018)) using the Vegan package (Oksanen et al. (2018)). Blocked multi-response permutation procedure (MRBP) was used to assess differences between treatment and control reaches in the pre and post treatment years. MRBP was followed up with blocked indicator species analysis (ISA) to determine underlying taxa driving any grouping detected by MRBP. This two-step procedure was performed twice for the benthic community, once with family level community data and once at the LTU level in order to compare any differences in results. The combined benthic and diet matrix was subsequently tested for any differences between treatment and control reaches using the same MRBP and ISA methods.

To test for any pre-treatment reach differences in 2017, MRBP was run on 2017 data only with Treatment as the two a priori groups and blocked by Stream. The 2018 post-treatment data was then assessed using the same MRBP grouping and blocking. MRBP is a nonparametric method used to test for differences between groups. This method accommodates paired or blocked study designs by accounting for variation related to study design variables that have little bearing on the question being addressed. In this case, MRBP accounts for any between-stream variation. MRBP outputs a p-value for the observed within-group distance (smaller distances constituting stronger grouping) by shuffling SU’s between groups to generate a distribution of possible within-group distances (McCune et al. (2002)).

The follow-up ISA calculates an indicator value (IV) for each species. The IV is a composite of a taxon’s fidelity and exclusivity to a group. If a taxon is consistently abundant in one group and never present in any other, then it would receive a high IV. Conversely, a taxon rarely abundant in SU’s of one group and present in other groups would receive a low IV (McCune et al. (2002)). A Monte Carlo test of 1,000 permutations of the taxa matrix was used to generate a p-value for each taxon’s IV.

The taxon resolution was lowered from the LTU level to family level for benthic samples in order to create a matrix of both fish and benthic samples. In order to judge the impact of reducing taxon resolution on interpreting benthic community relationships, two ordinations of benthic invertebrates were performed, one in LTU space and one in family space using nonmetric multidimensional scaling (NMS) in order to determine whether different conclusions would be drawn from lower levels of identification (Kruskal, 1964). Sorensen distance was used for both ordinations to reduce the impact of outliers. Ties were not penalized, although there were no ties in either matrix, and the ordination was rotated to maximize the environmental variable BenthoTotal along axis 1. A random start was used

and the real data were run 250 times to ensure an absolute stress minima was reached. A Monte Carlo test with 100 permutations was used to generate a p-value for the probability of the final ordination have a lower than expected p-value by chance.To further test for differences between the level of identification used, a mantel test was applied to the original family and LTU benthic distance matrices. The distance matrices were calculated using Sorensen distances and a Monte Carlo test of 1000 permutations was used to generate a p-value.

# Results

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| FFG | t-value | p-value |
| SH | 0.07 | 0.95 |
| P | 0.52 | 0.62 |
| SCe | -1.55 | 0.16 |
| CG | 0.60 | 0.57 |
| SCi | 0.86 | 0.42 |
| CF | 2.13 | 0.07 |
| All Bugs | 0.84 | 0.43 |

# Discussion

# References

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