How is Primary Productivity Affected by Disturbance in Wilderness Streams of Central Idaho?

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Abstract – In the western U.S., changing climate has been linked to shifts in terrestrial and hydrologic disturbance regimes such as fire and floods, and these may affect stream ecosystems by altering factors that control aquatic primary production. However, there have been few investigations of the mechanisms by which this may occur, largely because measurements of primary production can be methodologically challenging and surrogates for this process (e.g., biomass of primary producers) are usually used instead. I propose to investigate drivers of primary production in an effort to assess impending effects on this process of climate change and shifts in natural disturbance regimes. Using metabolism microcosms, I will measure primary production in six streams of the Big Creek watershed in the Frank Church 'River of No Return' Wilderness, central Idaho. These streams encompass diverse gradients of solar insolation, temperature, substrate stability, and hydrologic regime within a relatively small area accessible from the Taylor Wilderness Field Station, which will allow me to analyze the relative role of these various factors for stream productivity. In particular, past research has suggested that variation in light (largely a function of past wildfire disturbance) and streambed disturbance (driven by flow regime and substrate character) may play important roles in governing both primary and secondary (invertebrates and fish) production in these streams, but an explicit test has not been conducted due to a lack of direct measures of primary production. Therefore, in addition to primary production, in each stream, I will measure light input, streamflow, and streambed disturbance to evaluate their relative effects, but will also assess other factors that affect primary production and must be accounted for as covariates, such as temperature, nutrients and potential grazing pressure. My study will provide basic information about primary production in these wilderness streams and may provide insight into how this important ecosystem process may occur under future conditions.

Objectives

This project will help determine the factors that regulate primary production in wilderness streams of central Idaho, and, within this domain of streams, will characterize the relationship between biomass and rates of production. As global climate change is likely to alter the drivers of primary production via changes in disturbance and hydrologic regimes, this study will help assess how climate change may impact primary production in the future. Objectives encompassed in the study will include:

1) Measure and monitor periphyton (primary producers attached to the streambed) standing crop biomass and rates of primary production in six tributaries of Big Creek within the vicinity of Taylor Wilderness Field Station.
2) Measure and monitor a suite of environmental factors which have the potential to affect periphyton biomass and primary production. This objective will include the analysis of both explanatory and covariate environmental factors. Explanatory components encompassed in this study will include solar insolation and streambed disturbance affected by fire and high flows. Covariate factors of temperature, nutrient concentration, and invertebrate grazing will also be addressed to assess their underlying importance to lotic primary production.

By accomplishing these objectives, the study aims to address the working hypothesis that gross primary production (GPP) increases with solar insolation and streambed disturbance, but that the relationship is interactive and non-linear, such that as disturbance increases beyond a threshold, GPP stabilizes or declines.

Importance of Research

Climate change is expected to lead to multiple ecological impacts for stream ecosystems in response to decreased winter snowpack, increases in snow line elevations, and increased natural disturbance frequency (Davis and Baxter et. al *unpubl. manuscript*). Rising global temperatures have been correlated with increased fire frequency and consequent changes in hillslope and riparian vegetation (Westerling et al. 2006). Collectively, effects will contribute to multiple influences on stream ecosystems such as changed flow regimes, highly responsive runoff events, earlier peak flows, a thinning or loss of riparian vegetation, increased streambed mobility, and greater stream temperature variability. In mountain streams, many hydrographs, previously dominated by snowpack, may experience altered hydrograph characteristics largely governed by rainfall ascendancy (Stewart 2009, Kunkel and Pierce 2010). Changes in peak flows may also alter streambed morphology, as late-winter or early spring flow disturbances may become more common. This trend may not only be accompanied by higher flow events triggered by hastened snow runoff, but winter rain events may be accompanied by more frequent scouring of the streambed and erratic peaks of sediment load and turbidity.

Primary production in mountain streams provides basal energy resources that support higher trophic levels in aquatic food webs (Allan and Castillo 1995) and is related to variation in light, temperature and nutrients, as well as disturbance from streambed scour and removal by grazers (Odum 1956, Bott et al. 1985, Bott 1996). Intriguingly, rates of gross primary production may differ among streams whose standing crop biomass of primary producer organisms is similar. In fact, it is likely that the relationship between biomass and production is non-linear, such that low levels of disturbance may stimulate productivity (much as mowing a lawn can cause faster rates of grass growth) over what would occur if biomass accumulated to high levels, whereas more severe disturbance could result in diminished productivity (Bott 1996). Moreover, adaptation to changing climate may involve shifts of species assemblages to those that are adapted to disturbance and can capitalize on variability in ecosystem conditions (e.g., Lamberti et. al 1987, Minshall et al. 1998, Malison and Baxter 2010). Understanding the relationship between primary producer biomass and production is important, since biomass, which is easier to measure and monitor, is often used as an index of productivity. Thus, there is a need to investigate the response of primary producers to factors that may change with altered disturbance regimes, and to do so in terms of production rather than biomass alone.

This project will build on past and on-going studies conducted in the Big Creek watershed and contribute new information and understanding regarding factors influencing variation within stream primary production. The natural variation in flow regime, substrate mobility, light, temperature, nutrients and benthic macroinvertebrates (the dominant grazers) within the Big Creek watershed will allow for comparisons that will improve understanding regarding the controls and driving mechanisms of the primary producer foundation of stream ecosystems in this region. As climate change will likely alter these factors, my study may provide insight into how primary production may change in these streams under future conditions.

Methods

Objective 1: Measure and monitor periphyton standing crop biomass and rates of primary production in tributaries of Big Creek in the vicinity of Taylor Wilderness Field Station. To accomplish this objective, I will conduct repeated measures at each of six streams (Rush, Cliff, Pioneer, Cougar, Goat and Dunce creeks) whereby individual rocks are collected, placed in small chambers within which they are isolated from atmospheric reaeration, submerged in the stream, and the dynamics of oxygen are used to estimate rates of metabolism by the biota on the rocks (Bott et. al 1996, Hoellein et. al 2009). Rocks to be placed in microcosms will be chosen as representative of the particle sizes that are found at each site and that are typically used to measure biomass of periphyton during annual monitoring of these streams conducted by Drs. Baxter and Minshall. Stream water used in microcosms will be filtered through a 54 micrometer sieve to eliminate the inclusion of fine sediment that might affect periphyton productivity. To fill each microcosm, rocks will be carefully (to avoid disturbance of the periphyton) placed in microcosms and then submerged in a bucket of filtered stream water to rid the chamber of air bubbles. Dissolved oxygen concentrations will be measured systematically using an optical dissolved oxygen probe (YSI Inc. SonTek). Water in each chamber near the rock surface will be tested for initial temperature and dissolved oxygen and microcosms will be tightly sealed. In order to eliminate the effect of dislodged periphyton in the chambers, fresh, filtered stream water will be repeatedly added to a large container (bucket) used to submerge microcosms before sealing. The sealed microcosm chamber will be removed from the bucket of filtered stream water, carefully inverted, and placed into the stream. Microcosms will be placed in randomized locations within patches of streambed that receive light inputs representative of the site. Microcosm chambers will be left in the stream for a two-hour production incubation period (Hoellein et al. 2009).

After incubation, temperature and dissolved oxygen will be measured again in each microcosm. The chambers will then be filled with fresh, filtered stream water to prevent nutrient depletion, and the same rock will be incubated in a similar manner in the dark to obtain dissolved oxygen readings during respiration (Odum 1956, Bott 1996). After data have been collected for net ecosystem production, periphyton will be scrubbed from the rocks used in the experiment and a subsample will be filtered through a 0.7 μm glass-fiber filter. Standing crop biomass of periphyton will be estimated by using standard methods (Steinman et. al 1996, Davis et al. 2001) to quantify chlorophyll-*a* concentration and ash-free dry mass (AFDM). Tracing the planar area of the rock onto paper and then weighing these paper cutouts will allow me to estimate the rock area sampled for periphyton and express rates of production on a per area basis.

The chamber measurements will be conducted three times throughout the summer for each tributary to incorporate potential changes that may occur during the season. Chamber measurements will be conducted across sites within a single week in randomized order but within consistent periods of the day. Thirty chambers will be utilized per sample set and the number of each of three different chamber sizes (4, 32, and 64 oz.) will be assigned according to the size of rocks found in each stream (Hoellein et. al 2009). In the process of conducting chamber experiments, care will be taken to avoid excessive disturbance of the streambed, and the exact sites where long-term monitoring are conducted will be avoided so as to prevent confounding those efforts.

Objective 2: Measure and monitor a suite of environmental factors that have the potential to affect periphyton biomass and primary production. I will measure a combination of factors that may be influenced by disturbance and could affect stream GPP via changes in conditions for both photosynthesis and respiration. Solar radiation delivered to each site will be estimated using a light meter the measures photosynthetically active radiation (PAR) and a Solar Pathfinder, an instrument that can be used to estimate the total potential solar input to a site over an integrated time period (Davis et. al 2001). In addition to obtaining estimates for each site as a whole (from whence rocks were collected), light measures will be made using the PAR meter at the location of each microcosm chamber at the time of incubation.

Streambed mobility will be investigated by relocating rocks that have been marked in each stream as part of a previous study (M. Schenk, 2010 DeVlieg Research Internship Project) using passive integrated transponder (PIT) tags. The tagged rocks will be relocated using a portable PIT tag reading device and their locations surveyed so that estimates of their distance traveled can be obtained.

Tributary hydrologic regimes will be monitored using pressure transducers which have been installed on Rush, Pioneer, Cliff, Cougar, Goat, and Dunce Creeks at sites established by previous ISU DeVlieg graduate researcher N. Olson (Olsen 2010). The pressure transducers record tributary water levels at fifteen-minute intervals and allow for continual hydrologic monitoring. Monthly discharge measurements and stream profiles will be recorded to construct a complete hydrologic flow regime for individual tributaries. In addition to water level, these sensors also record stream temperature, which I will also use in my analysis of factors affecting primary production.

Nutrient (N and P) concentrations will be determined by collecting water samples from each site during each of the periods during which primary production is estimated. Samples will be stored frozen and returned the analytical chemistry laboratory of the Center for Ecological Research and Education (CERE) at Idaho State University.

The relative productivity of invertebrates that graze periphyton in each stream has been estimated from a combination of previous studies by DeVlieg graduate researcher Rachel Malison (Malison and Baxter 2010a; b) in 2005-2006 and undergraduate researcher Matthew Schenk in summer 2010. These data will be compared to biomass estimates obtained from this year’s annual monitoring by Dr. Baxter to evaluate possible differences among years, and will be used in my analysis to evaluate the superimposed effects of grazing on primary production.

In addition, Taylor Wilderness Field Station installed a RAWS (remote automated weather station) in 2008 that independently records climate measurements made available to the National Weather Service. This station measures hourly temperature, dew point, relative humidity, wind velocity, solar radiation, and accumulated precipitation. Data from the weather station will be utilized to further monitor meteorological conditions of the study area.

I will use a comprehensive comparative framework for my analysis. By accessing the individual and synergistic relations of the study’s key variants, the project will work to develop a greater understanding of the influence of these factors (e.g., Lamberti et al 1987). The combination of explanatory and covariate environmental variables will be used collectively to improve understanding of the mechanisms controlling gradients of mountain stream primary production.

Career and Educational Goals

As an undergraduate Earth and Environmental Systems student, I have focused my studies on both the geological components of the environment as well as the underlying biological processes within the critical zone. With an emphasis in Global Environmental Change, I aim to incorporate an integrated understanding of biotic and abiotic processes to further understand and assess earth system responses regarding climate change.

Through this project, I plan to improve my understanding of ecological systems, while maximizing the unique opportunity to obtain expert advising for involved research in scenic and rugged, wilderness conditions. This research will also provide experience in designing and implementing a field-based experiment, working to help me devise graduate school and career goals. Ultimately, I would love to pursue a master's degree and a career within earth and environmental systems through which I would have the privileged opportunity to aid in the broadening of society's understanding of earth systems while also enjoying the exceptional opportunity of working in the great outdoors.

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Project Timetable

A) April-May 2011

  i) Formulate research design and proposal

B) May 2011

  i) Continue to develop background knowledge and refine framework for research

  ii) Prepare equipment and learn techniques for use in research

C) June 2011

  i) Fly personal gear and research equipment into Taylor Wilderness Field Station

  ii) Conduct repeated microcosm/chamber measurements of primary production and collect data on environmental factors

  iii) Begin continued monitoring of stream flow

D) July 2011

  i) Continue measurements of primary production and environmental factors

  ii) Continue stream discharge monitoring

E) August 2011

  i) Continue monitoring and experimentation as necessary

  ii) Fly out of Taylor Wilderness Field Station

F) Fall-Winter 2011

  i) Develop analysis and dissemination of project results

Additional Support

Additional support for the project will be derived from the ISU Stream Ecology Center. Dr. Colden Baxter who will provide assistance with fieldwork, project design, and data analysis. Dr. Baxter's broad expertise in stream ecology will help to provide a strong experienced advising foundation for the research. Additional guidance and support will also be sought from Dr. Baxter's team of skilled graduate students. Nearly all equipment needed for studies will be provided by the ISU Stream Ecology Center.

Dissemination

The final report will be sent to the DeVlieg Foundation and will be presented at the ISU undergraduate research symposium in the spring of 2012. Additional opportunities for presenting research findings will also be explored, such as presentation at the Society for Freshwater Science 2012 annual meeting.

Budget

As part of this proposal, funding is requested from the DeVlieg Foundation for equipment, travel, and salary. Funding will be employed to cover costs of equipment maintenance as well as for transportation of minor equipment and personal gear.

Category	**DeVlieg Foundation Request**	
	($4500)	
Materials	$350	Polyethylene jars, glass fiber filters Buckets, containers, aluminum foil, and other miscellaneous gear
Travel	$200	Flights in and out of TWFS
Lodging Fees at Taylor Wilderness Field Station	60 days @ $15/night = $900	June 22-August 16, 2011
Salary & Fringe	290 hrs @ $10/hr = $2800 fringe (8.9%) = $250	Project preparation, execution, and dissemination

Total	$4500