

**Effect of a reduction in mountain stream flow on the diversity and quantity of
benthic macroinvertebrates and the abundance of algae**

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Abstract:

The process of manually diverting water from stream channels for agricultural purposes, industrial uses, and other reasons is practiced universally worldwide. These diversions of water are primarily characterized by a reduction in total flow within the stream. This study examines the response of benthic algae and macroinvertebrates to an environment where total flow has been reduced by over 80% in four mountain streams in Gothic, Colorado. The effects on macroinvertebrate abundance, richness and diversity were measured as well as algal abundance. Results indicate that macroinvertebrate abundance and richness are negatively impacted, and algal abundance is positively impacted, by a reduction in stream flow. While this was a small-scaled study, it is clear that humans need to better understand the impact that our careless water use has on stream ecosystems.

Introduction:

Animal abundance and diversity are correlated to how well suited their habitats are to their needs, and any change in habitat conditions may impact the organisms that reside in them. In light of the current trend in global warming, environmental change is altering the habitats in which the plants and animals live. In the United States, average air temperatures have increased 0-2°C in the last century (Hansen *et al.*, 2001). Because of the warmer temperatures, organisms that live in the tropical and subtropical zone are advancing, while temperate species are retreating, northward (Hansen *et al.*, 2001). Climate change also influences precipitation patterns, causing a 5% to 20% increase in precipitation in many areas across the United States (Hansen *et al.*, 2001). However, there has been a 20% decrease in precipitation in the Rocky Mountains and California (Hansen *et al.*, 2001). Ecologists agree that these changes present new challenges for organisms; however, little is known about the extent to which these changes will alter community structure within a particular habitat.

Streams are particularly vulnerable to anthropomorphic influences, not just from climate change, but from water extraction as well. For thousands of years, humans have altered stream flow to satisfy agricultural needs, fulfill drinking water requirements, and for industrial purposes. Currently humans use over ½ of the earth's accessible water (Dewson *et al.*, 2007). We

artificially manage streams and rivers by creating dams, diverting water, and disrupting their natural flows to satisfy our own needs, with little thought to the consequences of our actions. The effects of climate change and our manipulations of natural water systems are especially pertinent to Rocky Mountain streams. Mountain streams are fed largely by snowmelt and a decrease in winter precipitation will likely reduce flow. Likewise, water extraction necessarily reduces the volume of water moving through streams.

The overall goal of this study is to identify the relationship between stream flow and the functionality of the stream, where functionality is defined as the stream's ability to produce algae and support the presence of aquatic invertebrates. Stream flow is a major factor that contributes to the special characteristics of a stream channel. Flow is the total amount of water traveling down the stream at a fixed point expressed in L/sec. This study is designed to track the physical changes in the stream as a consequence of reduced flow and assess algal production and invertebrate abundance and diversity.

I hypothesize that a reduction in stream flow will cause a subsequent reduction in the heterogeneity of the stream habitats. As stream flow declines, key characteristics of the streams anatomy will change. Current velocity will be reduced, and there will be less variation in actual current within the stream. As a result of a loss in stream habitat diversity, many organisms adapted to these disappearing niches may likewise disappear, reducing the diversity of the algae and the invertebrates living within the benthic environment.

Algal composition may be dependent on the current velocity of the stream (Biggs, 1996); high currents facilitate nutrient movement, which increases periphytic algal abundance. Conversely, high currents can scour filamentous algae, reducing their abundance (Biggs *et al*, 1998, Dewson *et al.*, 2007). Since decreased stream flow is characterized by a reduction in

current velocity, I predicted that there would be an increase in algae due to a reduction in scouring of algal colonies as the stream flow is reduced. However, because of the size of the streams studied, the initial current velocities may not be high enough to cause this scouring effect, and the algal communities may benefit from a reduction in flow.

Initially, I expect that there will be an increase in the abundance of macroinvertebrates after the stream diversion because the diminished wetted area, because of a decrease in stream volume, will concentrate organisms. I predict that the macroinvertebrate density will then decline because as habitat area decreases, predation will have a greater impact on the community as the attainable food source is reduced due to a loss of prey (McIntosh *et al*, 2002, Dewson *et al.*, 2007).

Materials and Methods:

In this experiment, four small streams on the west slope of Gothic Mountain (named: Ivy, Wilbur, Max, and Jade) South of the Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado were used as the field site. All four of these streams were manually modified and flow was reduced by 80-90% within the diverted section. At the diversion site a dam was constructed from rocks and sand bags to create an artificial pool where 10 cm plastic tubing was placed to divert the water. A similar plastic tube was also placed in the dam to allow the undiverted water to continue downstream. Approximately 15 meters of the stream was diverted, and at the end of the manipulated section, the diverted water was returned the stream. Flow was determined by measuring the amount of time it took for water from the diverted tube and water from the undiverted tube to fill a 5 L bucket. Total flow was the sum of these two values. Weekly visitations to the stream were made to assess changes in stream characteristics and biological

composition within the modified sections, and compared to the unmodified benthic environment upstream.

Physical stream characteristics (current velocity, stream depth, wetted area, water temperature, and vegetation cover) were taken once during the study both above and below the diversion. Current velocity was determined by taking three 1 meter plots above and below the diversion. Current was taken three time across the stream length at 10 cm intervals using a current meter, these values were then averaged together. Stream depth and wetted area were measured every meter along the length of the sampled segments, both above and below the diversion, and then averaged together. Water temperature was measured using Hobo data loggers, for a week, and the peak temperature was noted and averaged together. Percent cover of overhead foliage was assessed using a spherical densitometer, and taken every two meters. Stream segments were chosen so that there was similar vegetation cover in both the diverted and undiverted sections.

Six 15 cm x 15 cm Surber samples were taken in both the diverted and not diverted segments every week to collect invertebrates that were liberated from the streambed. Invertebrates were identified using a dissecting scope to determine diversity of samples, species richness, and overall abundance. Algal abundances were also assessed weekly. Algae was scraped off four stream cobbles in both the diverted and undiverted segments of the stream from a standardized area, filtered, and extracted with ethanol buffered with MgCO_3 for approximately 24 hours. Chlorophyll-a concentrations were determined via fluorometric analysis (Opti-Sciences GFL-1 Portable Fluorometer).

Results:

All physical parameters were impacted by the reduction in stream flow (Table 1). In the downstream diverted section flow was reduced to 12.88% of its total flow in Max, 18.84% in Jade, 15.98% in Ivy and 12.22% in Wilbur. On average, the diverted sections received 14.98% of the total flow in the undiverted sections. Daily peak temperatures were on average higher in the diverted segments of the stream (15.31°C) than they were in the undiverted segments of the stream (13.23°C). Looking at individual streams, three of the four sites (Max, Ivy and Wilbur) showed this trend. Universally, across all streams measured, there was a decrease in width of the downstream diverted reaches. On average the width in the undiverted segments was 52.49 cm while the average width in the diverted segments was 39.81 cm. Similarly, the depth of the stream also decreased. In the undiverted sections average depth was 4.67 cm, and in the diverted sections the average depth was 2.47 cm. Percent cover was similar in both the diverted (71.67%) and undiverted (70.06%) sections.

The average algal abundance, quantified by chlorophyll-a concentration (Figure 1) shows an initial increase in abundance in both the diverted and undiverted segments of the stream. By week two, there is more algae in the downstream reaches compared to the upper reaches, a trend that continues throughout the rest of the period, however the difference is not significant ($p>0.05$).

Species abundance is the total number of individuals, regardless of taxonomic classification, in a sample. In both the diverted and undiverted sections, species abundance initially increased for the first two weeks, and began decreasing by the third week (Figure 2). Throughout the course of the study, there were more macroinvertebrates in the undiverted segments. This trend only became significant in the third week ($p<0.05$). Species richness

remained fairly similar though out the sampling period (Figure 3). The only week that was significant between the upstream and downstream sections was the second week of sampling. Stream diversity was not significant ($p>0.05$) by the reduction in stream flow (Figure 4).

Discussion:

All physical characteristics that were measured in the study were impacted by the reduction in stream flow. Generally, maximum temperatures were higher in the diverted section, current velocity was lower and less varied, and width and depth was reduced. It has been shown that some algal communities grow better under higher current and the greater nutrients flow that is facilitated by the swift current (Dewson *et al.*, 2007), however, these results indicate otherwise. In this study, there was higher algal abundance in the diverted section that experienced lower current then in the undiverted section. The reason for this deviation from the expected can be explained by the interaction between the algae and the macroinvertebrates that feed on them. Over 80% of the macroinvertebrates in the samples were grazers who feed exclusively on the benthic algae. Because there was an overall reduction in the total number of macroinvertebrates in the diverted sections of the stream, there were less grazers consuming the algae, and thus the downstream segments had a higher abundance.

In general, the diversity of the stream was not effected by the diversion. In most streams, one taxa dominated, severely impacting the diversity of the stream. Since the study streams initially had low to moderate flow, it is possible that the all of the macroinvertebrates found at the sites were well adapted to these conditions and a further reduction in stream flow had little to no impact. Correspondingly, species richness was not effected by the reduction in stream flow.

Reduction in mountain stream flow had a complicated effect on the streams habitat. A longer term study might be beneficial to determine the effect of continual exposure to low flow has on a stream, as well as looking at larger sites that have higher diversity and more species specialization. Because this study was so short , the macroinvertebrate and algal communities may not of had enough time to respond to the changes in their environment. Since flow does not seem to be the only factor regulating the functionality of the stream, the next question to ask is what are these other limiting factors? And to what degree do they regulate the stream microenvironment?

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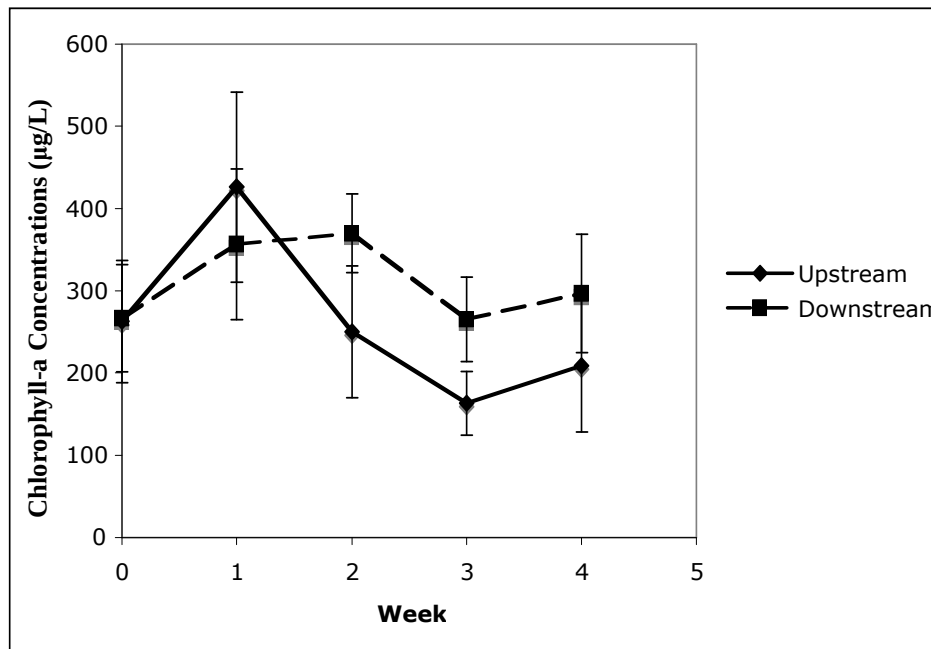


Figure 1: Graphs indicate average concentrations of chlorophyll-a in algal samples in the upstream undiverted sections and the downstream diverted sections per week. Data visually show that there is less algae in the diverted section in the streams, though differences between the upstream and downstream segments within a week are not significant. Error bars indicate ± 1 standard error.

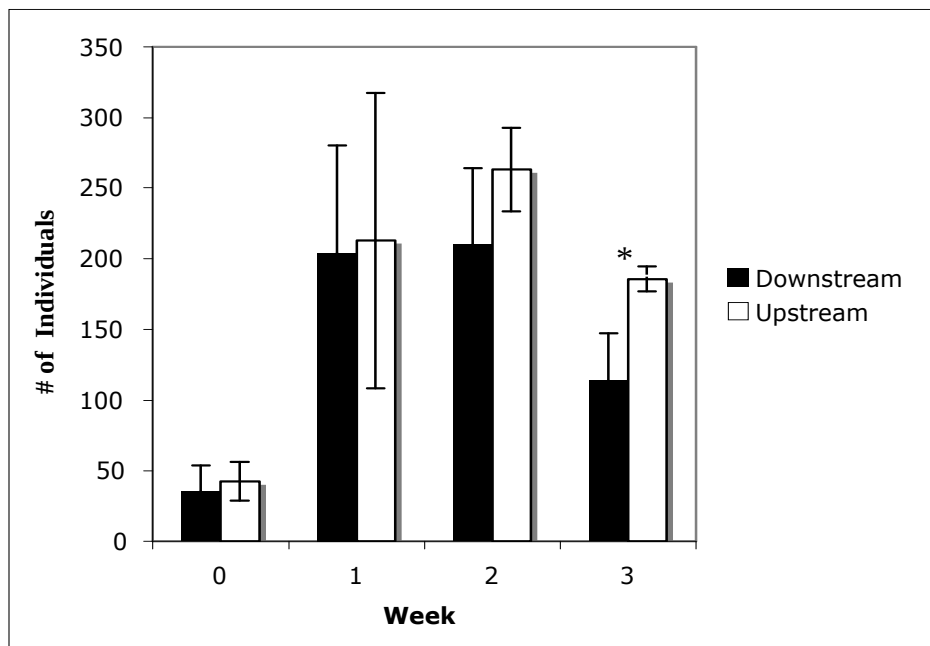


Figure 2: Total abundance across taxa per week. Significant differences in species abundance between treatments are indicated by an asterisk ($p < 0.05$). Error bars indicate ± 1 standard error.

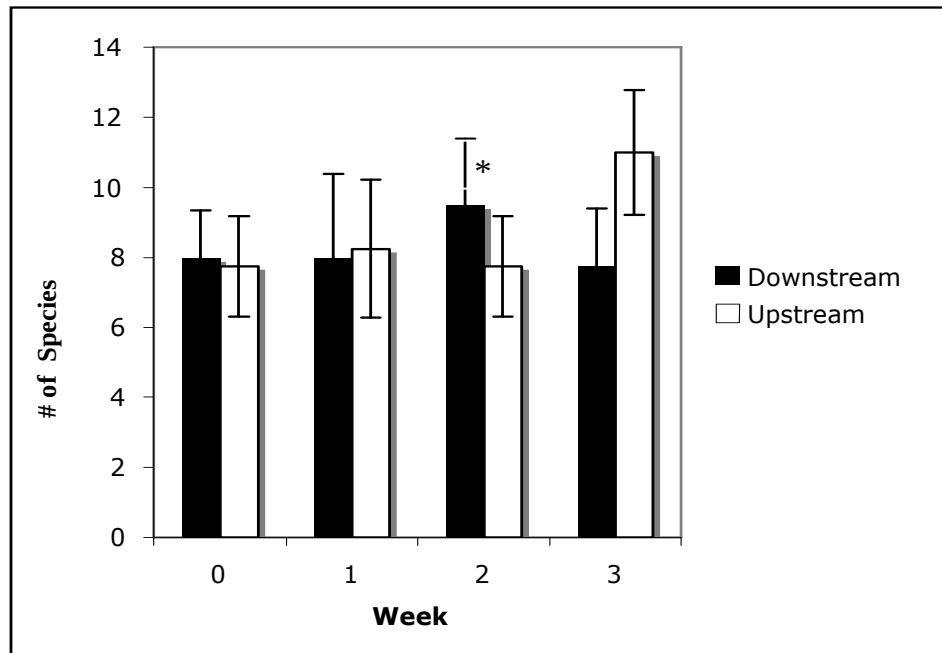


Figure 3: Species richness of streams across weeks. Significant differences in species richness are indicated by an asterisk ($p < 0.05$). Error bars indicate ± 1 standard error.

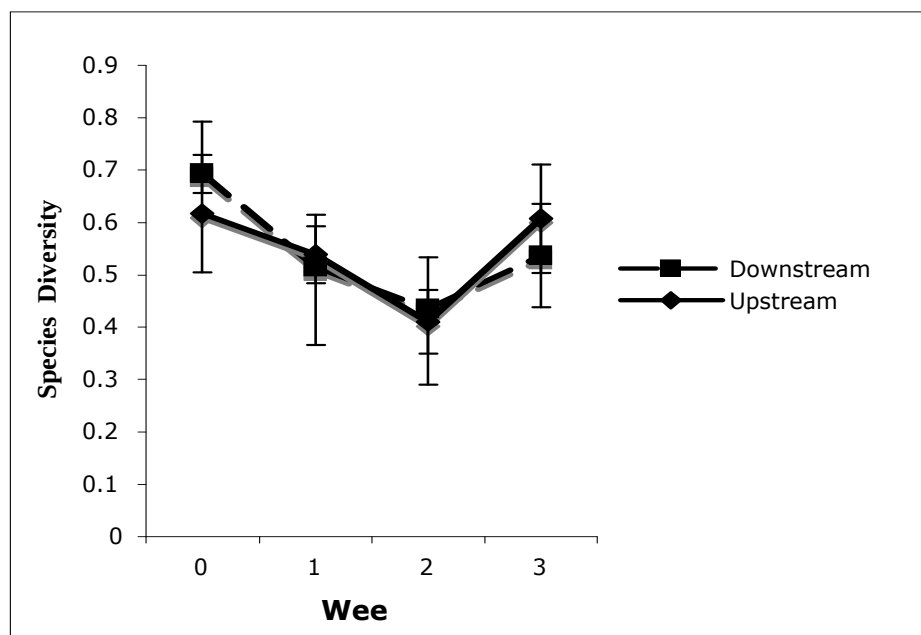


Figure 4: Stream diversity across weeks. Significant differences in species richness are indicated by an asterisk ($p < 0.05$). Error bars indicate ± 1 standard error

Table 1: Average change in physical stream characteristics for each of the four study streams. Values indicate the average $\pm$ 1 standard error of total measurements for the designated parameter. Empty cell indicate that measurements could not be taken for this parameter because the stream dried up before measurements could be taken.

Stream Name	Flow (L/sec)	% Total Flow	Maximum Temp (°C)	Current Velocity (m/s)	Width (cm)	Depth (cm)	% Cover
Max Upstream	4.50 $\pm$ 0.28		9.33 $\pm$ 0.19	42.36 $\pm$ 2.94	47.90 $\pm$ 3.19	6.02 $\pm$ 0.50	58.97 $\pm$ 11.86
Max Downstream	0.58 $\pm$ 0.04	12.88%	10.62 $\pm$ 0.43	35.67 $\pm$ 2.32	33.85 $\pm$ 0.21	2.84 $\pm$ 0.21	82.20 $\pm$ 5.91
Jade Upstream	2.76 $\pm$ 0.27		17.43 $\pm$ 0.58	24.08 $\pm$ 2.24	44.44 $\pm$ 5.25	3.08 $\pm$ 0.38	90.79 $\pm$ 3.32
Jade Downstream	0.52 $\pm$ 0.18	18.84%	13.49 $\pm$ 0.44	19.69 $\pm$ 1.42	32.25 $\pm$ 2.86	2.06 $\pm$ 0.28	81.87 $\pm$ 10.21
Ivy Upstream	1.94 $\pm$ 0.04		17.1 $\pm$ 1.20	24.56 $\pm$ 2.23	-	-	86.48 $\pm$ 5.00
Ivy Downstream	0.31 $\pm$ 0.01	15.98%	25.84 $\pm$ 2.88	19.04 $\pm$ 10.24	-	-	78.90 $\pm$ 5.89
Wilbur Upstream	5.81 $\pm$ 0.06		9.05 $\pm$ 0.14	41.19 $\pm$ 2.43	65.13 $\pm$ 7.99	4.9 $\pm$ 0.42	44.00 $\pm$ 12.26
Wilbur Downstream	0.71 $\pm$ 0.04	12.22%	11.29 $\pm$ 0.26	20.17 $\pm$ 1.25	53.33 $\pm$ 6.90	2.52 $\pm$ 0.42	43.69 $\pm$ 11.13
<i>Average Upstream</i>	3.75		13.23 $\pm$ 0.28	31.11 $\pm$ 3.00	52.49	4.67	70.06
<i>Average Downstream</i>	0.53	14.98%	15.31 $\pm$ 1.00	17.38 $\pm$ 2.47	39.81	2.47	71.67