Affect of Irrigation Inflows on Mission Creek

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By Chris Eagleman

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Abstract

Less than 1 percent of all water is fresh water (Miller, 2000) and more than 90% of all fresh water has been modified in some way (World Resources Institute, 2009). This study shows the affect of irrigation water from agricultural ditches on Mission Creek which is located in west-central Montana on the Flathead Reservation. I looked at diversity of macro invertebrates, nutrients and physical stream characteristics within, upstream and downstream of four agricultural run-off inflows. The inflows were least diverse but did not impact the Mission Creek significantly at the sites sampled. Cluster analysis indicated that the macroinvertebrate community composition clusters with regard to distance downstream from the first site to the last as well as in the inflows. The inflows also differed in temperature, conductivity, and phosphate but, these differences were not impacting the Mission Creek significantly. The studies final results show that there are differences between the inflows and the Mission Creek but, the locations that were studied with relation to the inflows, are not being significantly impacted by them and there is no observed impact that accumulates as water moves downstream.

Introduction

Although all forms of terrestrial life require fresh water for survival, less than 1 percent of all water on earth is fresh water (Miller, 2000). Of this water 20 percent is held in Lake Baikal in Asia and 20 percent is held in the Great Lakes (USGS, 2009) leaving only 60 percent in other water bodies worldwide. 90 percent of all freshwater has been modified (Miller, 2000) for human use. The United States alone uses 408 billion

gallons of water per day (Bgal/d) (Hutson et al, 2000), 52 percent of this water is used for thermoelectric power and 65 percent of the remainder is used for irrigation (Hutson et al, 2000). The US additionally loses 5 percent of our total water through evaporation from our reservoirs and crops (Miller, 2000). Although people generally think of groundwater wells for drinking water and home use, only 83.3 (Bgal/d) comes from groundwater, while 262 (Bgal/d) is used directly from surface freshwaters. Even with our extreme dependence on our surface freshwater we are continually degrading our freshwater supply through our agricultural practices.

Agricultural water runoff is one of the major contributors of chemicals in our stream and rivers. Run-off fertilizers that add nitrogen and phosphorous to streams can cause an increase in macrophytes. These macrophytes can increase to a point of slowing water velocity in streams and rivers. These macrophytes act as barriers to water flow if they become too dense or large. Macrophytes also have the potential to diminish the water level through evapo-transpiration. By slowing the water down or even reducing the water level small micro-environments, providing habitat for invasive colonizers. Macrophytes also hinder the movement of large fish attempting to capture small fish and of small fish attempting to capture macro-invertebrates. Nitrogen can also get into our drinking supply at unsafe levels. According to Hubbard et al. (2004), an increase in nitrogen could potentially cause methemoglobinemia (blue baby disease). Also at high levels nitrite is considered to be carcinogenic. The addition of phosphorous can cause eutrophication of surface water bodies if phosphorous is the limiting factor (2004). Eutrophication is an increase in the ecosystem's primary productivity, and has further

adverse effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.

Water velocity and total suspended solids (TSS) can also be greatly affected by irrigation. Directly, channelization of streams leads to an increased velocity of water and this higher velocity of water is capable of carrying larger sediment and particulate loads. As water passes through an irrigation system the TSS is usually increased due to a continual disturbance of the substrate. This occurs because water is constantly being pumped or dumped from the canal. As this occurs the water is being pulled up causing the sediments to rise, or much like a waterfall, as the water returns to the canal it is dumped and splashes against the bottom of the ditch. This could potentially lead to the mortality of some fish because turbidity is increased with an increase in TSS (Breitburg 1988). . As the velocity of the river changes species of aquatic plants and animals may not immediately adapt and this may also allow invasive species to enter the water system.

Temperature and oxygen levels can also be affected greatly by agricultural lands. As the water passes over the agricultural land it is heated. With this increase in temperature many plant and animal species will relocate and new species will enter the area. This is due to the very temperature specific requirements of many plants and animals. With all of the above factors taken into consideration we will have a decrease in oxygen. This is due to eutrophication of the water system, an increase in temperature, the loss of velocity and thus aeration of the water, and just the overall diminishment of water quality.

The fresh water system sampled was the Mission Creek. The Mission Creek is of significant importance because of the many agricultural factors influencing it. The

Mission Creek is dammed above the agricultural regions in the valley. The water is drawn from the bottom of the reservoir to feed the creek downstream. The water below the dam was diverted into many different irrigation channels. The area that was sampled was located in the National Bison Reserve that had numerous continuous and intermittent inflows from the previously diverted irrigation channels. The samples that were collected, due to the considerable agricultural land and water flowing into the Mission Creek, expected patterns were that as you moved further down the creek, the water in Mission Creek would then take on the physical characteristics of the agricultural water.

Methods

Four sites were chosen within Mission Creek based on the presence of persistently flowing agricultural irrigation canal inflows. Three sample sites were located within the National Bison Range and one was located just downstream of the range. The sites were located at UTM zone11T E 0713004 N 5240937 2661ft, UTM zone 11T E 0711441 N 5249462 2637 ft, UTM zone 11T E 0710444 N 5249370 2615ft, and UTM zone 11T E0706744 N 5250184 2544ft. These sites were sampled July 17, 2009 – August 7, 2009. Macro-invertebrates were sampled on July 17, 19, 22, and 24. All of the other samples were collected on August 6 and 7. Each irrigation entry varies in substrate or volume of water entering Mission Creek. I used qualitative classifications to quantify the different types of substrate as rock, gravel, sand, clay, or organic matter. Substrate is defined as the base on which an organism lives (Merriam-Webster 2009). Two of the locations pass through a measurable distance of a wetland. The other two sites pass through a wetland area.

To characterize the irrigation ditch and stream habitats at each site, I measured surface velocity, total suspended solids (TSS), DO, conductivity, water temperature, NO3, NH4, PO4, and benthic macro-invertebrates. Samples were taken from the inflow of the irrigation ditches just prior to entering the Mission Creek. At these inflow locations, 3 samples were taken at 10ft to 20ft above the inflow in the inflow waters. At each sampling location 3 sample sets were taken in the Mission Creek at high flow regions. Samples were taken above the inflow in Mission Creek at a distance of 40ft to 50ft Sets of samples were taken below the inflow location at the same distance as mentioned above as well as an additional set of measures at 100ft to 120ft. This gave us a total of twelve samples per inflow site.

Velocity was measured using an orange, due too its partial negative buoyancy, a tape measure, and a stop watch. A 25 foot distance was measured from the mouth of the inflow into the inflow. 45 foot sections were measured at each sampling location within Mission Creek. The orange was placed in the water at each location and then timed to determine the amount of time that it took to travel the distance measured. Velocity was determined using the equation V=d/t. V = velocity, d = distance and t = time.

Total suspended solids or TSS were sampled within each inflow and at each sampling location above and below the inflow within Mission Creek. Three, 3 liter water samples were collected for each sample location. The collected samples were poured through previously dried and weighed paper filters. The filters were then oven dried for 60 hours. The weight of the filters was then subtracted from the weight of the solid plus filter weight. This gave the mass of the TSS.

DO, conductivity, and water temperature were measured using the YSI model 85 multi-probe. The probe was inserted in the water to a depth of 10cm. Three separate readings were taken at all of the sampling locations. NO3 and PO4 were measured at all of the sampling locations using a DR/890 colorimeter from HACH. The protocol used for NO3 was the mid range using the NitraVer5 Nitrate Reagent Powder pillow. This protocol is known as the Cadmium Reduction Method. The protocol used for PO4 was the low range PhosVer 3 (Absorbic Acid Method).

Three separate benthic macro invertebrate samples were collected at all of the sampling locations. A standard 0.5m D ring net was placed in the water and the rocks and sediments immediately in front of the net were disturbed for a period of 1 minute. The macro-invertebrates were then identified to family or genus using a 10 x Zeiss dissecting microscope and a count of total macro invertebrates were also recorded for each sampling location. Identification of the macro-invertebrates was completed using *Aquatic Insects of North America* (Merritt and Cummins, 1996).

Macro invertebrate diversity was estimated using a Shannon diversity index multiple similarity indices were run for the macro invertebrates to look at how similarity varies within and among sites and locations. A repeat of measures ANOVA was run testing various dependent factors (Macro invert diversity, DO, TSS etc.) Between locations within sites and site were treated as the repeated measure going from upstream to downstream. A multiple regression was run for TSS, DO, conductivity, temperature, NO3, and PO4, using the Shannon diversity index as the dependent variable for each sampling location. A regression was run for the substrates compared to macro-invertebrate diversity.

RESULTS

Agricultural run-off inflows consistently differed in numerous biological and physical characteristics from Mission Creek. All characteristics (macro-invertebrate, dissolved oxygen, temperature, and PO_4) varied significantly between the inflows and Mission except for conductivity which showed no pattern. Macro-invertebrates were less diverse in the inflow than in Mission Creek (Bonferroni: $p=0.0960$) (table 1. and fig 1). Dissolved oxygen was less abundant in the inflow than in the creek (Bonferroni adjustment $p<0.0001$) (table 1 and fig 2). The temperature was higher in the inflow than in the creek (Bonferroni adjustment $p<0.0001$) (table 1. and fig 3). PO_4 was more abundant in the inflow (Bonferroni adjustment $P=0.0008$) (table 1. and fig). Conductivity did vary from Mission Creek but, not in a predictable pattern (fig??). NO_3 showed no discernable pattern (fig.??). The significant interaction of site and location for conductivity measurements seem to be driven by the substrate. Sites with larger substrates have a lower conductivity ($p_{df=6}=0.0005_{F=5.1961}$). Additionally conductivity increases as you move further downstream ($p_{df=2}=0.0262_{F=4.0043}$).

The four different sites did differ significantly from each other in three sampled physical characteristics (temperature, dissolved oxygen, and conductivity) (table 1), however; they did not differ in the expected pattern. The expected pattern was that the four sites would differ in a cumulative manner from up to down stream. Temperature was higher in sites two and four (fig. 3) likely because these two sites were sampled in the afternoon during the hot part of the day. Dissolved oxygen was higher in sites two and four, likely because they were sampled in the afternoon as well (fig 2). This could be

due to primary productivity levels being higher in the afternoon than the morning. Conductivity varied, but not in a predictable pattern across sites (fig 5).

The cluster analysis of macro invertebrates species composition showed three groupings (fig 7). Cluster A includes the furthest upstream locations within Mission Creek (Sites 1 and 2) with the exception of only one downstream location from Site 3. One upstream location did not cluster with the other upstream locations. It was location 1D1. Cluster B includes the downstream locations within Mission Creek (Sites 3 and 4). Cluster C includes all the inflow locations except the furthest downstream inflow. A regression was also run comparing the diversity of species as it related to the substrate as well (fig. 8).

A Jaquard's Similarity Index was run comparing all locations at all sites. The similarity index was run to see the relationship within sites compared to sites as we move within the creek. An ANOVA comparing similarity within sites vs. the similarity between upstream locations indicates that similarity is higher within sites (fig 9). A second comparison of similarities between inflow and downstream 1 sites vs. downstream 2 sites demonstrates that there was no significant difference of the impact of the inflow on the first downstream location compared to the second downstream location (fig 10). (This section looks really good. It is very clear with the revisions you have already done.)

Discussion

The agricultural inflows of Mission Creek are much different than Mission Creek itself. Macro invertebrates are much less diverse in the inflows than in Mission Creek. This could occur for a couple of different reasons. Quite a few macro invertebrates are

sensitive to water quality change, accumulation of organic matter, and anoxia, though Chironomids are less sensitive to these factors than many other species (Acharyya, Mitsch 2000). My results showed that the majority of the macro-invertebrates located within the inflows were amphipobs and that dissolved oxygen was lower in the inflows. Macro invertebrates are a direct indicator of stream health because they are generally sedentary and are in constant contact with the water (Acharyya, Mitsch 2000). In a study completed by Quinn et, al. (1997), pasture-land stream invertebrate densities were much higher than native pine forest streams. However; this was due to the high number of Chironomids in the pasture land stream. The number of mayflies, stoneflies, and caddis flies was much higher in pine forest systems than in pasture land streams. This could be directly attributed to the amount of sunlight that the pasture land stream receives compared to the pine forest streams. The temperature of the pasture land streams was about 2.2 deg C higher. My study also showed almost equivalent temperature difference between the Mission Creek and the inflows. I also had about the same difference in Chironomids as well as amphipods compared to the levels in the inflow compared to the levels in Mission Creek. Mission Creek also had about the same difference in mayflies, stoneflies, and caddis flies. This suggests that the inflow is less healthy than Mission Creek.

The inflow, although quite different than Mission Creek itself, does not appear to be having a great effect on the creek as a whole. This may be due to a one-dimension transport of inflow solutes (Runkel, 1998). Runkel (1998) found that solutes from inflows were being temporarily detained by the rivers in small eddies and comparatively stationary pockets of water with relation to the faster moving waters near the center. The

majority of solutes were trapped until the region was saturated. After this point, the solute storage moves down to fill the next section of the creek that is slow moving and so on. This could explain what was observed in Mission Creek. Tannins were visible along the shore below some of the stained inflows, but not in the faster water in the channel. I did not sample the area along the shore because the experiment was set up to determine if the inflows were having an over-all impact on Mission Creek. I would suggest a study that sampled further down stream after significant bends in the creek. This might show areas where solutes were able to mix within the creek because the river would be impacting the shoreline.

My study showed that the inflows did vary from each other, not only with flow but, with levels of dissolved oxygen, conductivity, and temperature. This could be determined by the different substrates. Some were primarily silt, or low flow, while others, with higher flow, had small pebbles and gravel. The higher flow would suggest a more channelized system which would wash more solutes downstream changing the physical characteristics of the inflows. Inflow 4 on the cluster tree (fig. 7) shows that a recently disturbed area had the fewest invertebrates and was the least healthy. This would support Runkel's model because this system has been channelized and has not yet developed natural barriers to slow the water down enabling the water to retain the solutes.

This study did not show that the inflows were negatively affecting Mission Creek. However, if the creek were channelized in the future, natural meanders would be eliminated, causing more sediments and nutrients to wash downstream into our drinking supply, in addition to the damage that could occur to our natural environment. Further studies should investigate a potential accumulation of nutrients in the sediments of the

creek bed as well as along the shoreline. If this is the case, a flood or a mass erosion event could cause the release of these nutrients and overload the system. I would suggest a continuous monitoring of the Mission Creek and rigorous observation of agricultural inputs to maintain this limited level of impact.

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References

Acharyya, Swarnali and William J. Mitsch. Macro invertebrate diversity and its ecological implications in two created wetland ecosystems Environmental Science Graduate Program, the Ohio State University 2000

Breitburg, D. L. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society. 117:72-77.

Hubbard, R.K., G. L. Newton†, and G. M. Hill. Water Quality and the Grazing Animal1. *Southeast Watershed Research Laboratory, USDA-ARS, Tifton, GA 31793 and Department of Animal and Dairy Science, University of Georgia, Tifton 31793, 2004

Hutson, Susan S., Nancy L. Barber, Joan F. Kenny, Kristin S. Linsey, Deborah S. Lumia,

and Molly A. Maupin. Estimated Use of Water in the United States in 2000 USGS Circular 1268, 15 figures, 14 tables (released March 2004, revised April 2004, May 2004, February 2005)

Merriam-Webster. Dictionary http://www.merriam-webster.com/dictionary/substrate. 2009

Merrit, R.W., K.W. Cummins. Aquatic Insects of North America. Kendall/Hunt Publishing Company, Iowa. 1996

Miller, A., P.S. Hooda, M. Moynagh, IF. Syoboda. Macroinvertebrates as bioindicators of water pollution in streams draining dairy farming catchments. Chemistry and Ecology [Chem. Ecol.]. Vol. 17, no. 1, pp. 17-30. 2000.

Quinn, J.M., Cooper, A.B., Davies-Colley, R.J., Rutherford, J.C. and Williamson, R.B., Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill-country streams. Hamilton, New Zealand. 1997.

Runkel, Robert L. ONE-DIMENSIONAL TRANSPORT WITH INFLOW AND STORAGE (OTIS): A SOLUTE TRANSPORT MODEL FOR STREAMS AND RIVERS U.S. GEOLOGICAL SURVEY. U.S. GEOLOGICAL SURVEY. Denver, Colorado, 1998

U.S. Geological Survey. The Water Cycle: Freshwater Storage. http://ga.water.usgs.gov/edu/watercyclefreshstorage.html. 2009

	DIVERSITY	TSS	DO	CONDUCTIVITY
SITE	$df_{=1}P=0.750_{f=0.103}$	$df_{=1}P=0.386_{f=0.7691}$	$df_{=1}P=0.001_{f=2.392}$	$df_{=1}P=0.004_{f=9.142}$
LOCATION	$df_{=3}P=0.081_{f=2.403}$	$df_{=3}P=0.574_{f=0.673}$	$df_{=3}P=0.001_{f=8.689}$	$df_{=3}P=0.006_{f=4.767}$
SITE & LOCATION	$df_{=3}P=0.684_{f=0.500}$	$df_{=3}P=0.913_{f=0.174}$	$df_{=3}P=0.280_{f=1.324}$	$df_{=3}P=0.000_{f=6.919}$

	TEMPERATURE	NO3	PO4
SITE	$df_{=1}P=0.001_{f=2.146}$	$df_{=1}P=0.816_{f=0.055}$	$df_{=1}P=0.480_{f=0.509}$
LOCATION	$df_{=3}P=0.010_{f=4.292}$	$df_{=3}P=0.494_{f=0.814}$	$df_{=3}P=0.027_{7f=3.370}$
SITE & LOCATION	$df_{=3}P=0.100_{f=0.010}$	$df_{=3}P=0.365_{f=1.088}$	$df_{=3}P=0.483_{f=0.834}$

Table 1 Multiple factors of two way analysis of variants. Tests were run independently.

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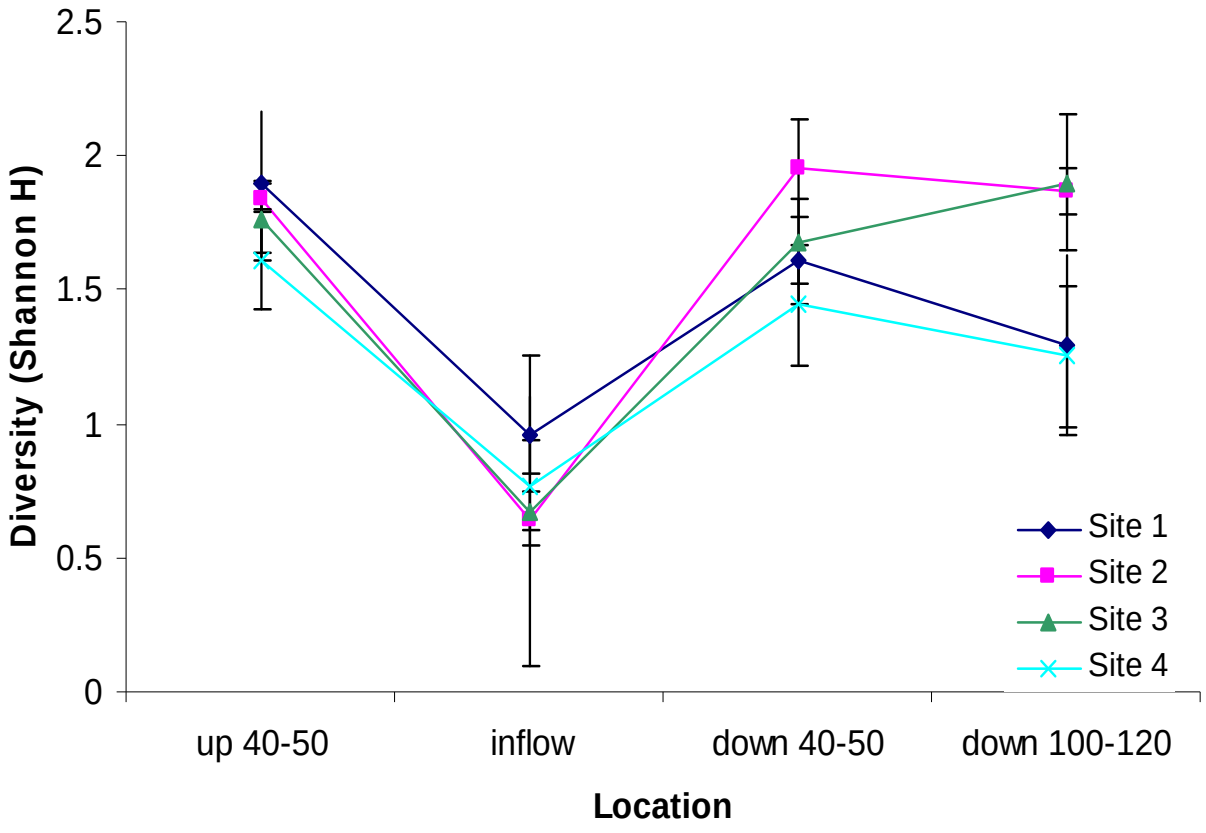

Fig. 1 A Shannon Diversity presented by site and location.

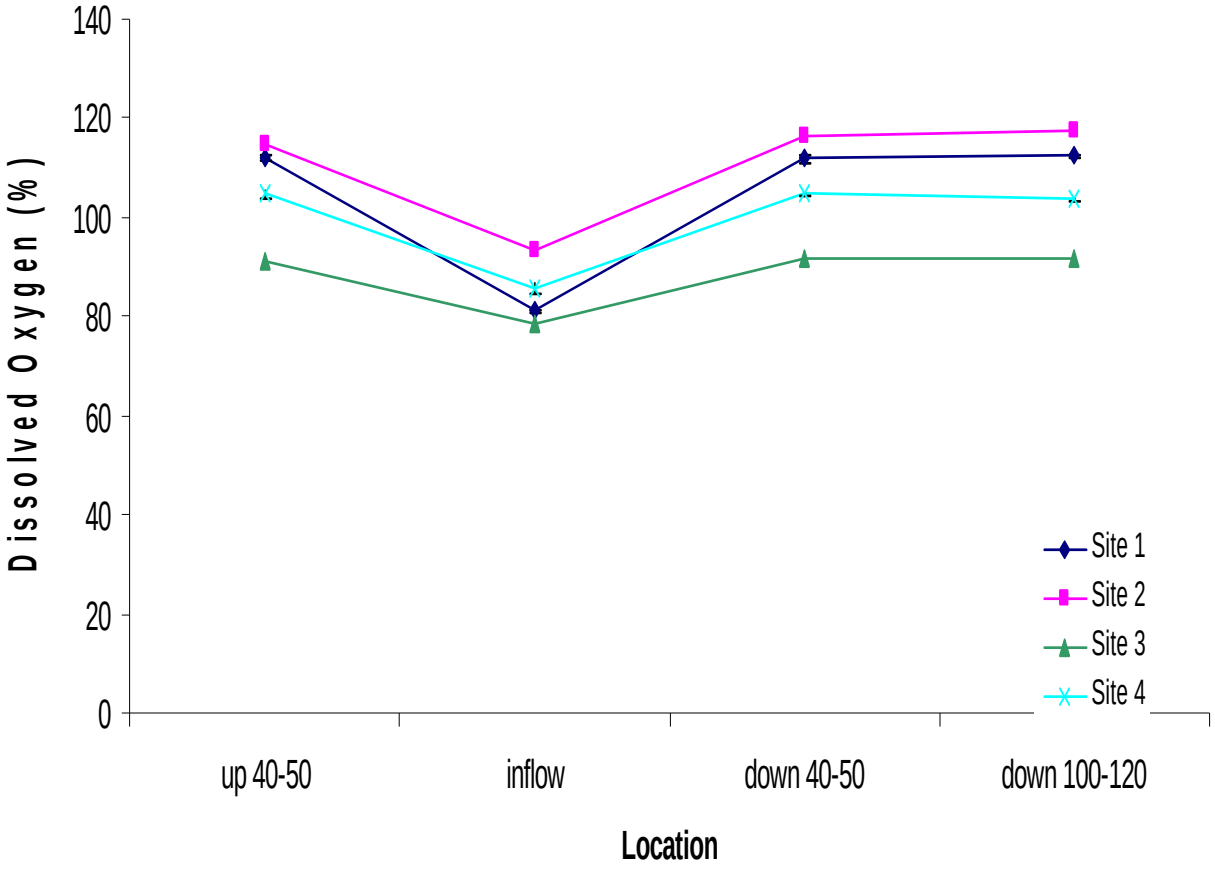

Fig. 2 Dissolved Oxygen % presented by site and location.

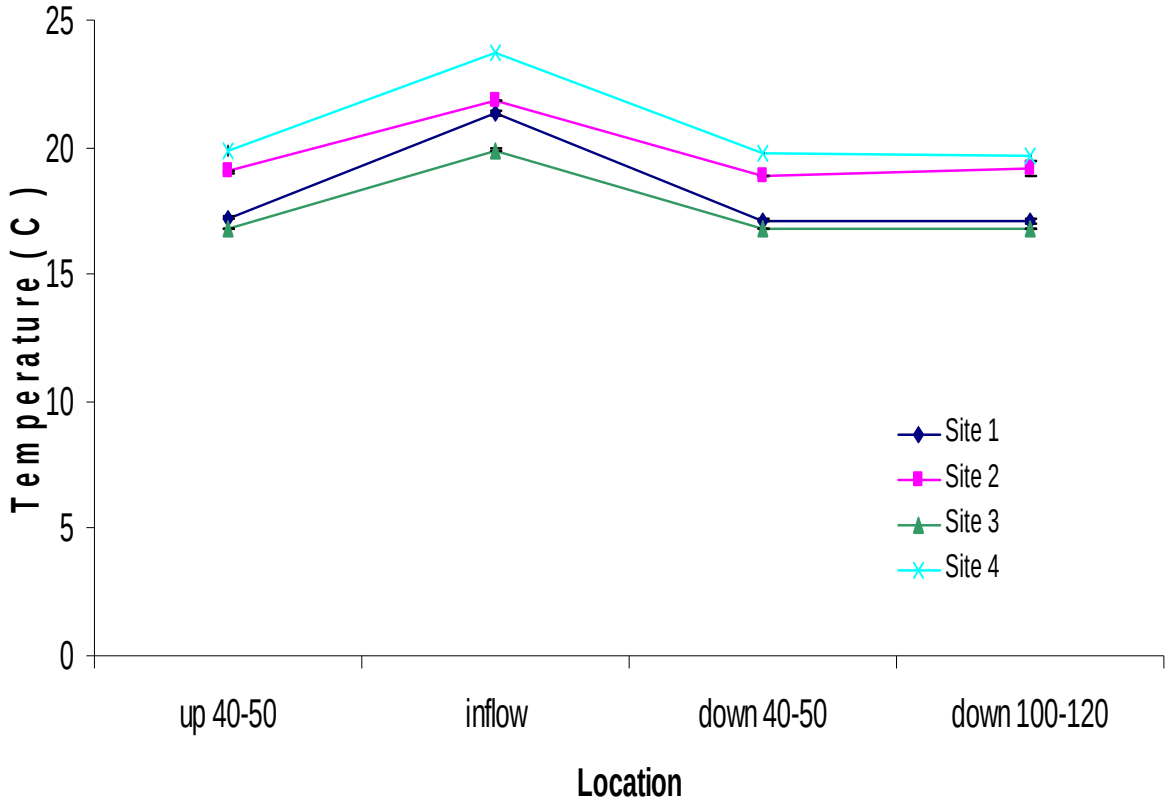

Fig. 3 Temperature (ºC) presented by site and location.

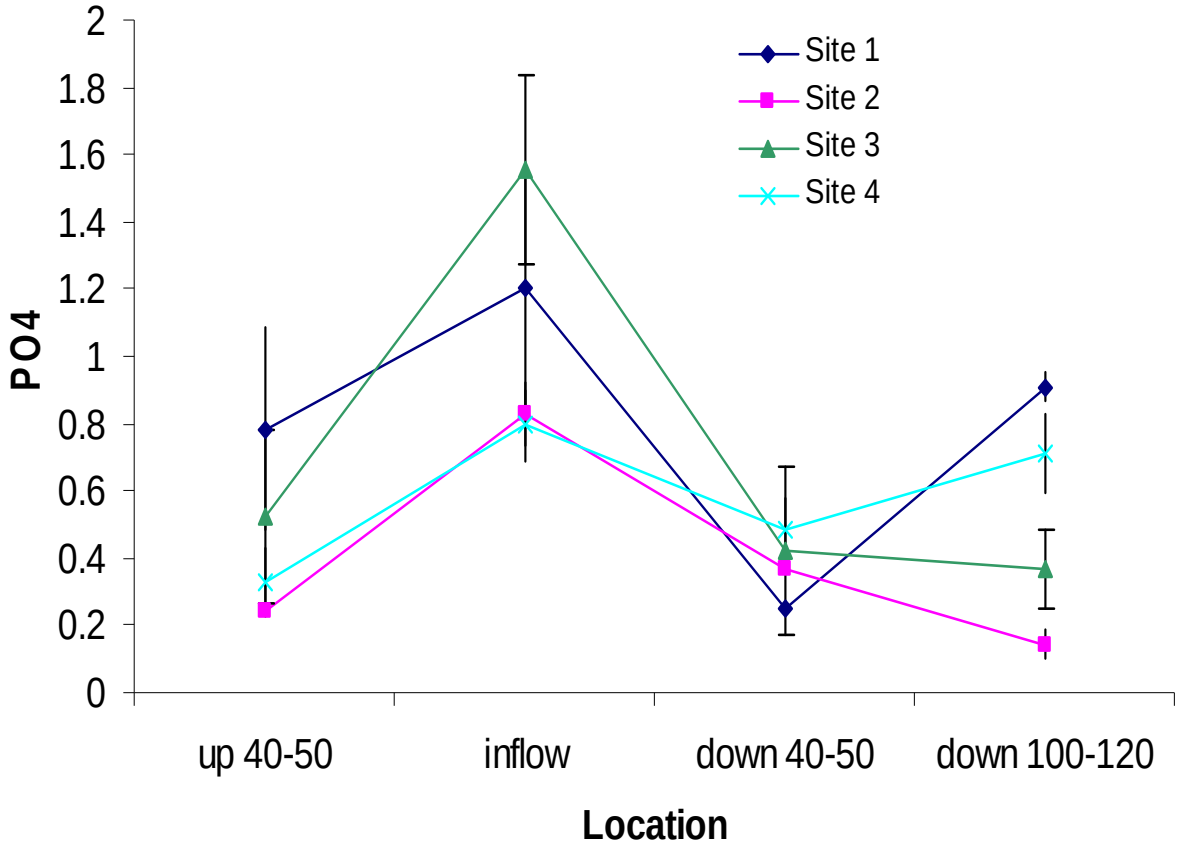

Fig. 4 PO_4 presented by site and location.

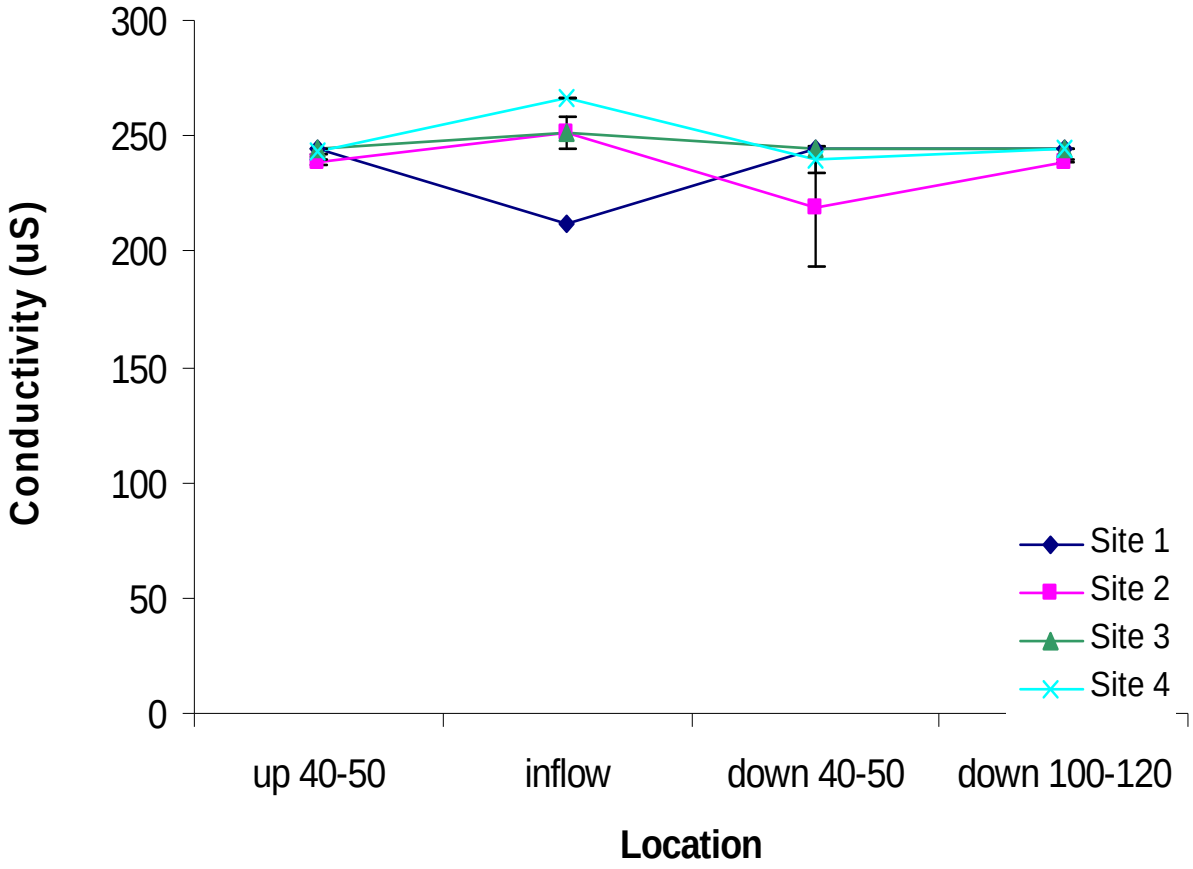

Fig. 5 Conductivity (uS) presented by site and location.

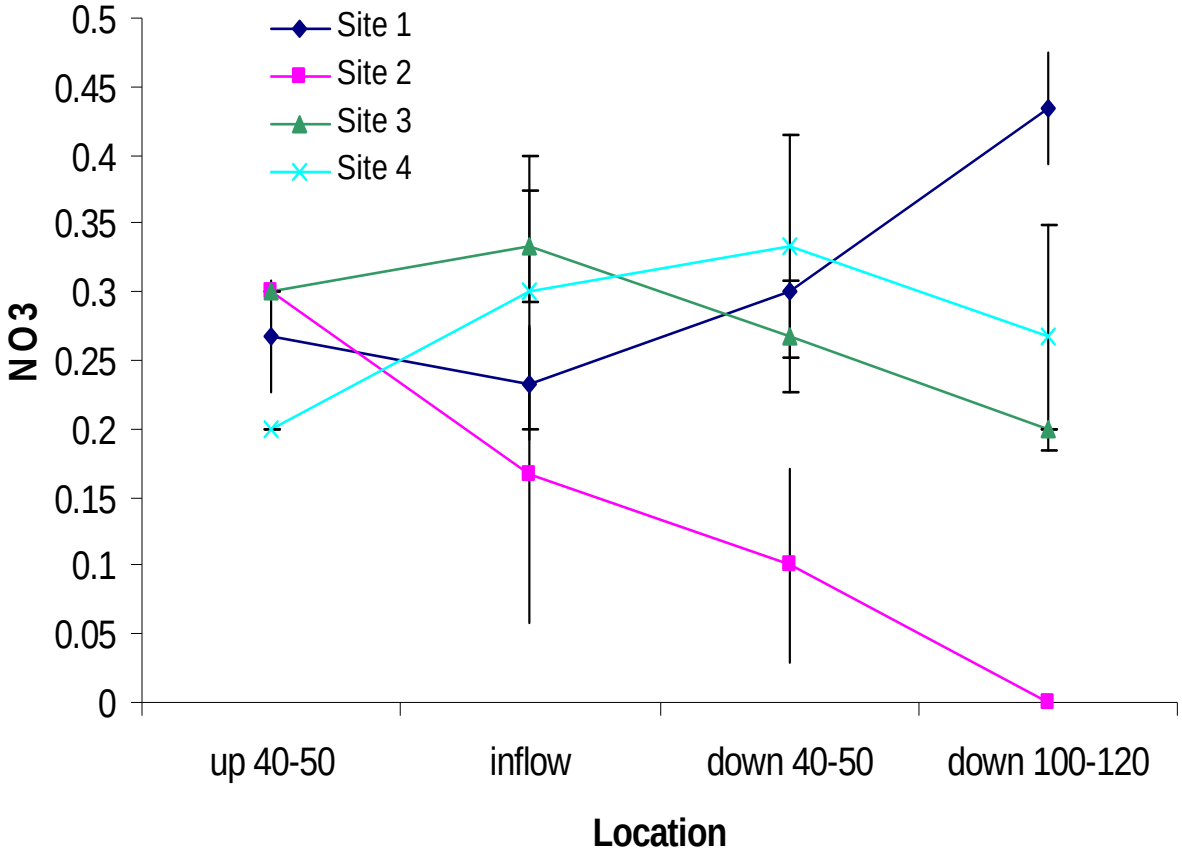

Fig. 6 NO_3 presented by site and location

Fig. 7 Cluster analysis of macro-invertebrates presented by site.

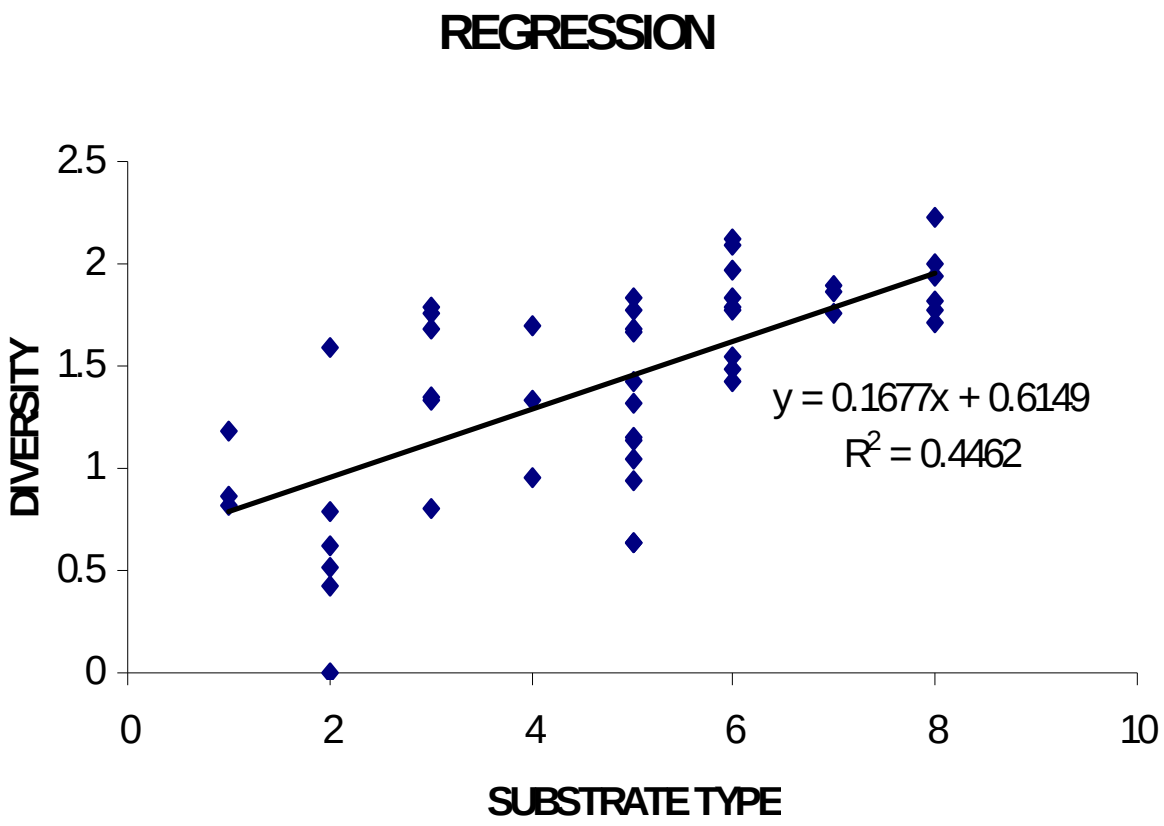

Fig. 8 Macro-invertebrate diversity regression from smallest to largest substrate.

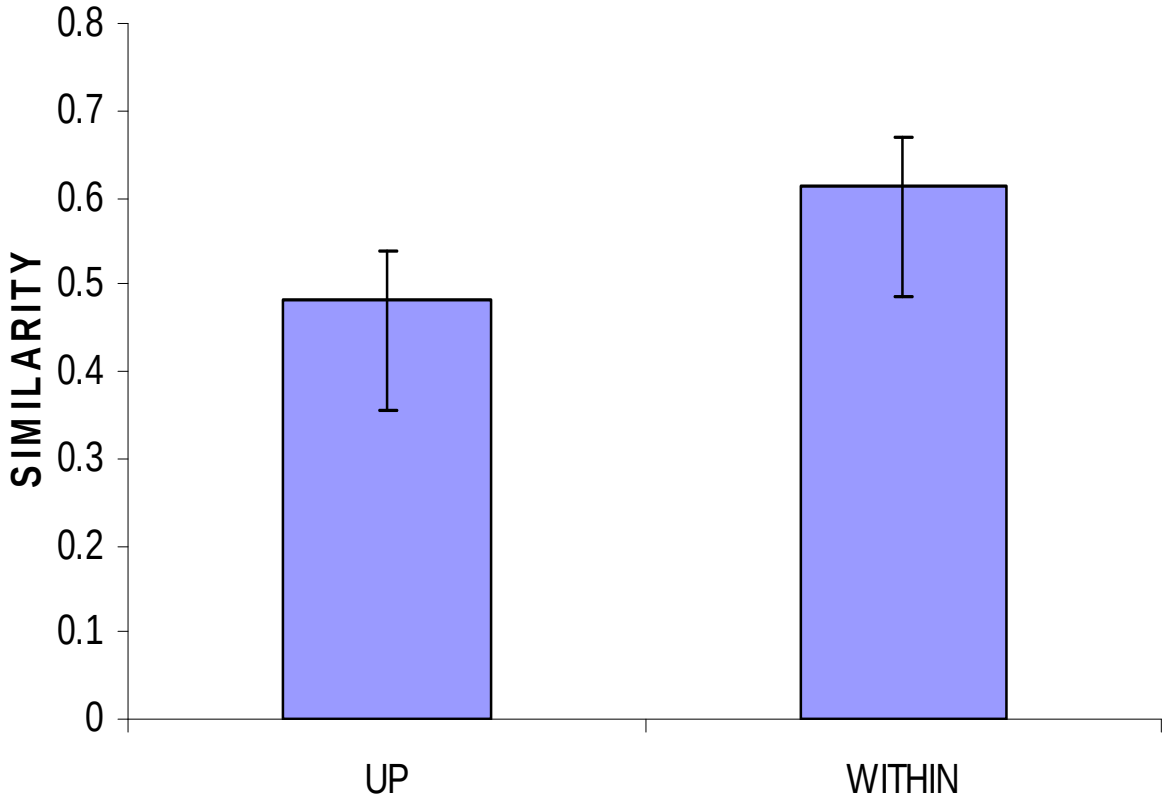

Fig. 9 Similarity of macro-invertebrate species was greater within sites than the similarity of upstream locations.

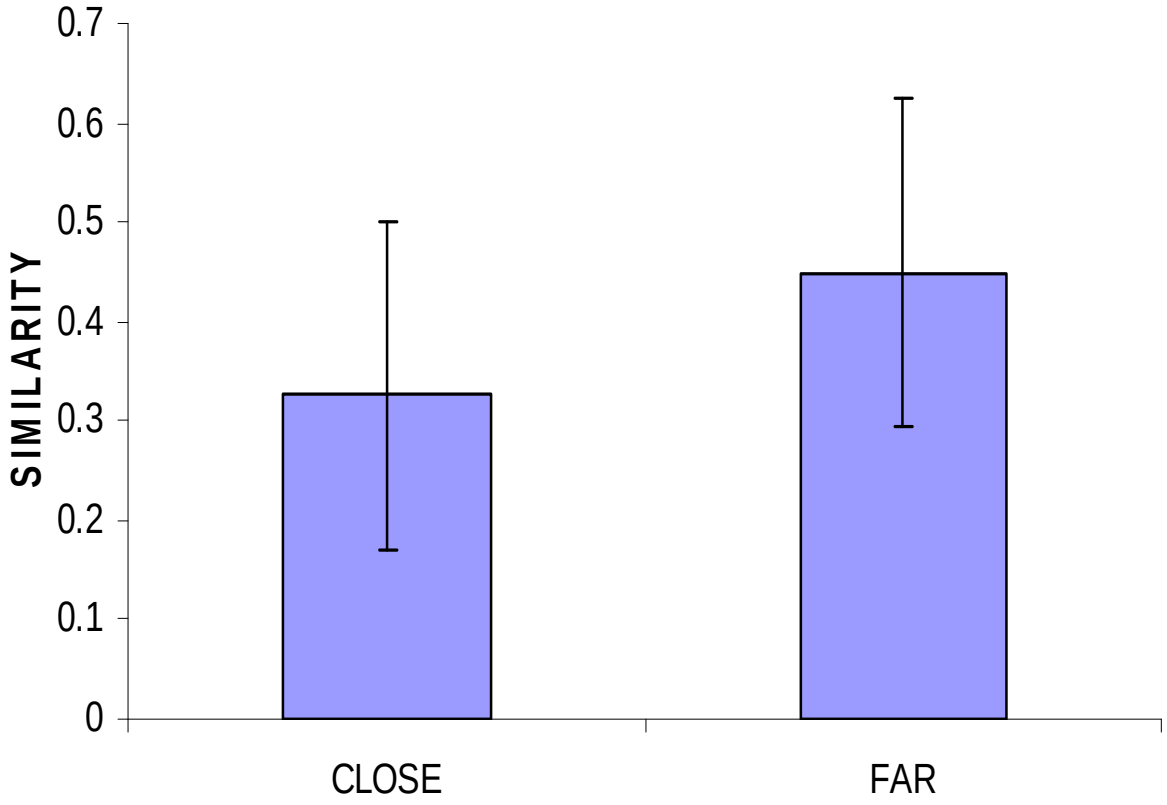

Fig. 10 No significant difference of impact of inflow on down stream locations.