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## Chapter 6

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# Anthropogenically Altered Land and its Effect on $\delta^{15}\text{N}$ Values in Periphyton on a Fourth Order Stream in Utah's Cache Valley

[by] Chance Broderius

### SUMMARY

The Little Bear River is a tributary to the Bear River that drains the south end of the Cache Valley in Northern Utah. The upper elevations are more pristine and are made up of mostly forested mountainous terrain with some grazing activity. The lower elevations are comprised of low gradient agricultural and urban parcels. Anthropogenically influenced landscapes can result in higher nitrogen inputs to streams, and these increases are often marked by an increase in the heavy-nitrogen isotope,  $\delta^{15}\text{N}$ . This study looked at the concentration of  $\delta^{15}\text{N}$  in periphyton on the river bed. These concentrations were then compared to anthropogenic land use in the surrounding watershed.  $\delta^{15}\text{N}$  values in the periphyton were significantly correlated with increasing percentages of anthropogenically affected land use in the Little Bear River watershed. It is likely that anthropogenic land uses (manure fertilization and wastewater treatment) caused the enrichment in  $\delta^{15}\text{N}$  concentrations.

### INTRODUCTION

Increases in nitrogen levels in rivers and streams can cause eutrophication since nitrogen is frequently a limiting nutrient in aquatic ecosystems (Dodds 2010). Eutrophication can have dramatic effects on aquatic ecosystems including but not limited to excessive algal growth and alteration of food webs.

Land use has been tied to increases in nitrogen levels in rivers and streams. It is estimated that anthropogenic nitrogen sources produce as much nitrogen as natural sources (Vitousek 1997). Examples of land uses that increase nitrogen levels include livestock grazing, crop growth, livestock feed lots, and human waste treatment. Comparing the percentage of land used for these nitrogen-increasing activities within a watershed to the values of excess nitrogen within rivers and streams is important for water quality managers to pinpoint problematic land use practices. The nitrogen coming from the aforementioned sources is rich in the heavy isotope form of nitrogen,  $\delta^{15}\text{N}$ .

Several studies have documented how anthropogenic land use increases the heavy isotope concentration of nitrogen in watersheds. Harrington et al. (1998) studied the White River in Vermont and compared  $\delta^{15}\text{N}$  values from different drainages on a fourth order stream and concluded that drainages that were comprised of forested land had lower  $\delta^{15}\text{N}$  values than the drainages that were primarily made up of agricultural land. Additionally, Steffy et al. (2004) found significantly increased  $\delta^{15}\text{N}$  values in the biota of areas downstream from septic tank use. From this, it can be expected that increased  $\delta^{15}\text{N}$  values will correlate with increased anthropogenic uses such as wastewater treatment facilities and areas with septic tank usage. Finally, Luecke and Mesner (unpublished) demonstrated that  $\delta^{15}\text{N}$  values among periphyton and macroinvertebrates in the Little Bear River correlated positively with percent agricultural land use within the drainage. For this study, I also compared periphyton-derived  $\delta^{15}\text{N}$  values with percent anthropogenically-altered land along a continuum of the Little Bear River.

## STUDY AREA AND METHODS

### *Study Area*

As described in the Utah Department of Water Quality's Little Bear River TMDL, (Utah DWC 2000) the Little Bear River is located in Cache County, Northern Utah. The river's watershed is made up of 88 percent private land, 10 percent National Forest land, and 2 percent State land. The Little Bear River is a tributary to the Bear River and consists of two main drainages. "The South Fork originates in the low elevation foothills of the Wellsville Mountains and the Bear River Range." according to the TMDL. The East Fork drains National Forest land stored behind Porcupine Dam. There is an impoundment (Hyrum Reservoir) on the main stem as well. The Little Bear drains into Cutler Marsh/ Reservoir NE of the town of Mendon, Utah.

This project's study sites occurred entirely on the South Fork and main stem Little Bear River. A map of the study area can be viewed in Figure 1 of the Executive Summary. Stations 1 and 2 were on the South Fork above all major tributaries. Station 3 was located below the confluence of the South Fork and Davenport Creek. Station 4 was located near the town of Avon, UT and below the confluence with the East Fork. Station 5 was located in an agricultural valley with dispersed housing, and just 30 m downstream from a point source that use to be a trout hatchery and is now a stocked fishing and hunting preserve. Station 6 was located just above Hyrum Reservoir. Station 7 was 1.7 river kilometers downstream of Hyrum Reservoir. Station 8 was located at a bridge crossing on the eastern edge of the town of Wellsville, UT. Station 9 occurs a few hundred meters below the discharge of Wellsville's Wastewater Treatment facility. The facility was not discharging into the river on the day that it was sampled. However, the facility does discharge into the river regularly. Stations 10 and 11 were in low gradient agricultural areas just upstream of the river's entrance into Cutler Reservoir. The shapes and sizes of each site's contributing watershed is shown in Figure 1.

### *Field Sampling*

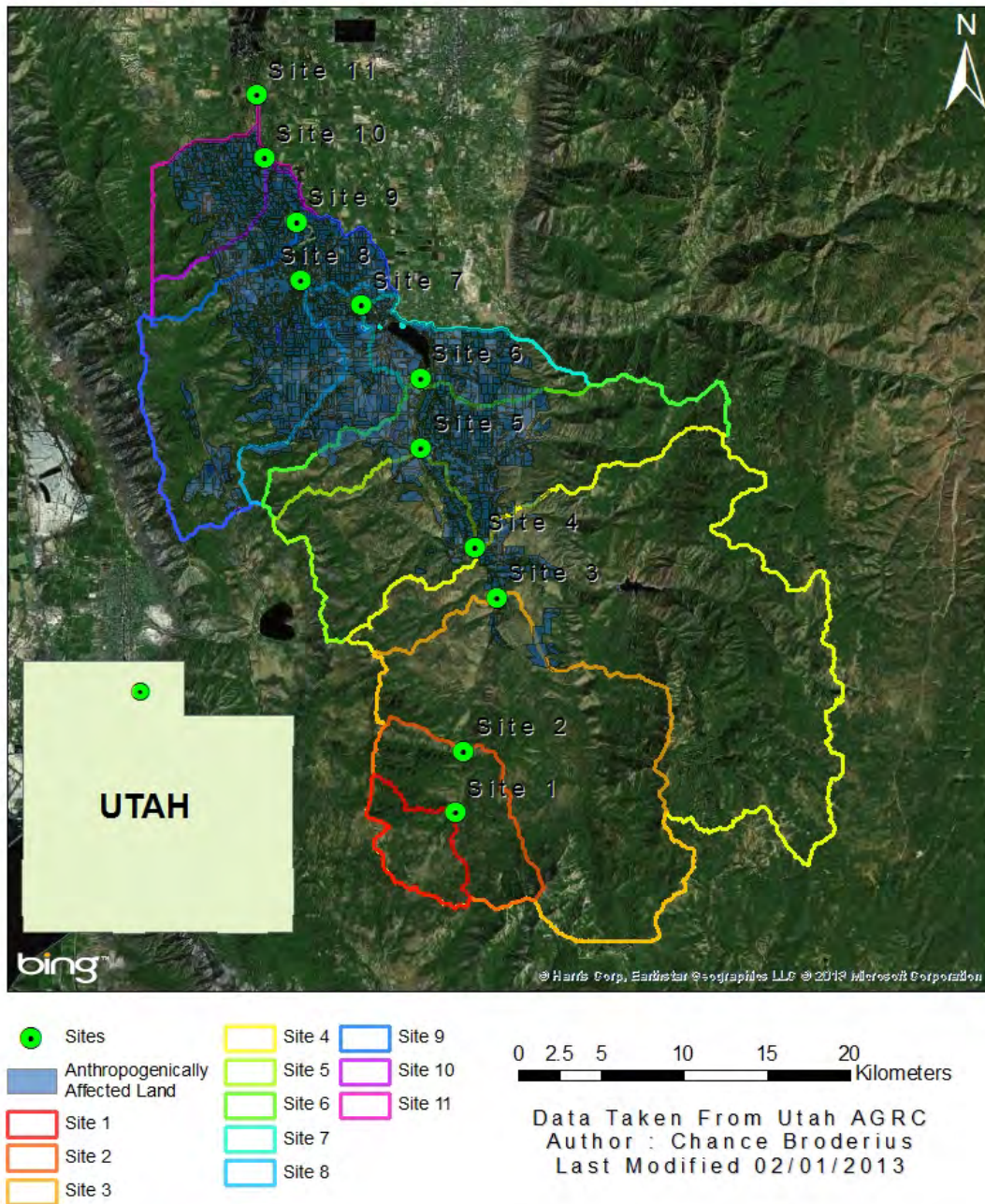
Periphyton samples were taken at eleven sites along the Little Bear River gradient and at a possible point source site between Stations 4 and 5 on 29 September 2012. Samples were collected between the times of 10:30 and 17:30 starting at Station 11 and primarily at Mendon Road and progressing upstream to Station 1 (Headwaters S. Fork). The possible point source site (White's Trout Farm) that was also sampled is located 30 meters upstream of Station 5: Pishgah Road Bridge. Two replicate samples were taken at each site.

Samples were collected by scraping a representative sample of periphyton from rocks collected from the river bottom and placing the scrapings into pre-labeled scintillation vials. Care was taken to exclude macroinvertebrates so as to not contaminate samples. Once collected, the vials were put on ice to ensure preservation in the field.

Cobble sized rocks were scraped at all Stations except 10, 11, and the point source site. At Stations 10 and 11 there was an abundance of fine sediments making it difficult to find representative samples of periphyton from cobbles. Consequently, I collected samples from a farmer's pump intake and a road-bridge support (Photo 1) at Stations 10 and 11, respectively. At both sites the samples were taken from

their respective structures approximately 3 centimeters below the surface of the water. The White's discharge site sample was scraped from the cement surface of the effluent channel shown in Photo 2.

**CONTRIBUTING WATERSHEDS FOR ELEVEN STUDY SITES ALONG THE LITTLE BEAR RIVER, CACHE COUNTY, UT**



**Figure 1.** Map showing contributing watersheds and anthropogenically affected land for each site. Anthropogenically affected land was placed using ArcMap 10.1 and water related land use data was taken from the Utah AGRC (<http://gis.utah.gov/data/planning/water-related-land/>). Contributing watersheds were calculated using GPS data collected at the time of sample collection and manipulated in ArcMap 10.1.



**Photo 1.** Road bridge support where sample for Station 11: Mendon Rd. was taken. A representative sample of periphyton was scraped off of the metal walls of the support approximately one inch below the surface of the water.



**Photo 2.** J. Fuller filtering water samples from the effluent of the possible point source (White's Trout Farm). The periphyton sample was scraped from the cement surface of the effluent channel. This site is located ca. 20 meters above Station 5.

All samples were frozen at the end of the sampling day for preservation purposes. They were subsequently placed in a drying oven for 24 hours. After drying, each sample was homogenized within its original scintillation vial. A weighed subsample was then placed into a tin capsule and sent to the University of California at Davis, where  $\delta^{15}\text{N}$  values were measured using mass spectrometry. The isotopic concentration is reported as  $\delta^{15}\text{N} = x.xx$  and represents a ratio of  $^{15}\text{N}$  to  $^{14}\text{N}$  isotopes on a ‰ basis.

It should be noted that one vial of periphyton from Station 2 was accidentally left out on the lab counter overnight while the other vials were in the drying oven. The following day the sample was placed in the drying oven for 24 hours, homogenized and encapsulated. The  $\delta^{15}\text{N}$  value reported by the mass spectrometry lab for this sample was not deemed abnormal and was included in the analysis.

### ***GIS Analysis of Catchment Area and Land Use Type***

GPS coordinates and elevation were taken at each sample site. Using these coordinates and a 30 meter Digital Elevation Model (DEM) taken from the Utah Automated Geographic Reference Center (AGRC) website, the contributing watershed for each site was delineated using the watershed tool in ArcMap 10.1 (Figure 1).

Water-related land use data was also taken from the Utah AGRC and applied to the study area. Land use parcels labeled as irrigated agricultural land (IR), non-irrigated agricultural land (NI), sub-irrigated agricultural land (Sub), and urban development (URB) were selected from the total data set as anthropogenically-affected land. The amount of anthropogenically-affected land within each contributing watershed was calculated using ArcMap10.1 and is shown in Figure 1. These values were compared with the contributing watershed for each site. A percentage of area from each contributing watershed that was made up of anthropogenically-affected land was calculated from the values calculated in the GIS.

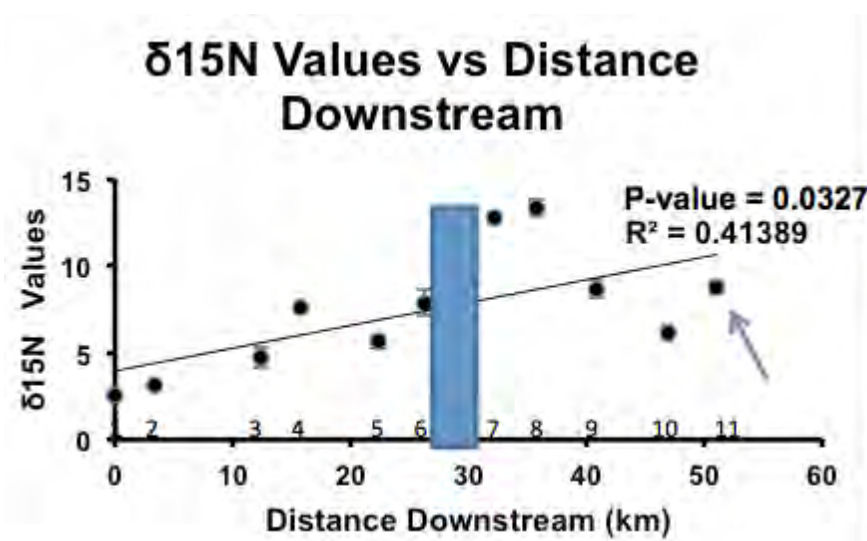
### Statistical Analysis

The significance of each comparable relationship was determined using the regression function in Microsoft Excel. Each comparable relationship was also graphed in a scatterplot, given an appropriate trend line, and  $R^2$  value.

## RESULTS

### Changes in $\delta^{15}\text{N}$ Along the River

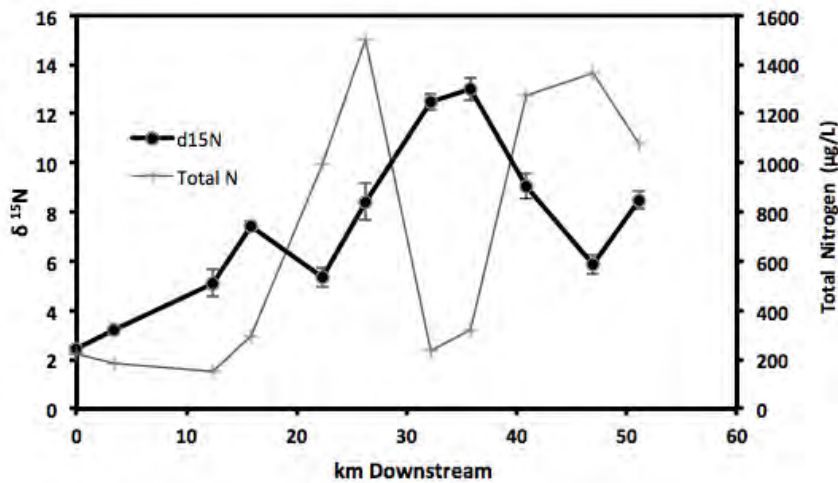
$\delta^{15}\text{N}$  values of periphyton generally increased with distance downstream (Figure 2; Appendix 1).  $\delta^{15}\text{N}$  from Station 1 through Station 4 increased steadily.  $\delta^{15}\text{N}$  values at Station 5 dipped back down to the level of Station 3 but increased again at Station 6. I found it peculiar to see a dip in  $\delta^{15}\text{N}$  values at Station 5 because Station 5 was only 30 meters downstream from the effluent of a private fishing reserve. There may be springs on the property that may have a resetting effect of the  $\delta^{15}\text{N}$  values in their effluent. The mean value of  $\delta^{15}\text{N}$  taken from the discharge canal of the private fishing reserve was 6.6. Upstream, at Station 4, the  $\delta^{15}\text{N}$  value was 7.6 and downstream, at Station 5,  $\delta^{15}\text{N}$  value was 5.6. This shows an unexplainable loss of  $\delta^{15}\text{N}$  enrichment in the periphyton at the site I expected to be a point source of enriched anthropogenic nitrogen. There was an increase of total nitrogen at Station 5 (Figure 3).



**Figure 2.** The figure shows the relationship between distance downstream and delta 15N values of periphyton samples taken from the Little Bear River. Station numbers are shown above the X-axis. Each point represents a mean value for  $\delta^{15}\text{N}$  values from two replicates. Error bars show  $\pm$  one standard deviation from the mean. The blue rectangle represents Hyrum Reservoir. The blue arrow notes Station 11.

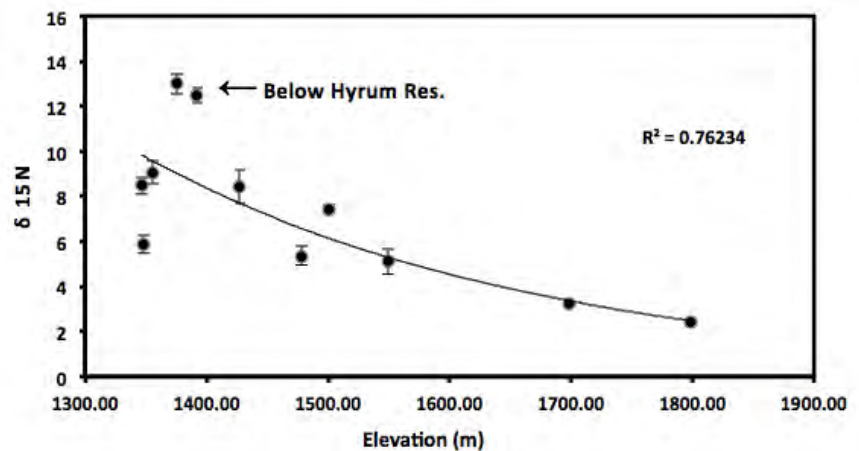
Periphyton-derived  $\delta^{15}\text{N}$  trends generally opposed those exhibited by total nitrogen (Figure 3). Approximately 27 kilometers downstream from Station 1, the river flows into Hyrum Reservoir. This occurs just downstream from Station 6. Station 7 was the site directly downstream from Hyrum Reservoir

and it had a marked increase in  $\delta^{15}\text{N}$  values. Station 7 also had very low levels of total nitrogen in the water column (Figure 3; also see chapter by J. Fuller). This is in opposition to the levels of  $\delta^{15}\text{N}$  found in the benthic periphyton samples. Similarly, Stations 7 and 8 had high  $\delta^{15}\text{N}$  values and relatively low total nitrogen. Stations 9 and 11 returned to  $\delta^{15}\text{N}$  values more in line with the overall increasing downstream trend. Station 10, however, had lower  $\delta^{15}\text{N}$  values than would be expected given the overall watershed trend. These three sites also followed an opposing pattern of the total nitrogen values (Figure 3). As expected, nitrogen levels increased at Stations 9 and 10 below the discharge point of the Wellsville wastewater treatment facility (Figure 3). One would also expect an increase in  $\delta^{15}\text{N}$  values due to the sewage effluent. However,  $\delta^{15}\text{N}$  values opposed that of total nitrogen at these locations.



3. The relationship between total nitrogen values (from J. Fuller) and  $\delta^{15}\text{N}$  values compared on the same x-axis (kilometers downstream). Data was taken from eleven sample sites along the Little Bear River. A pattern of opposing peaks and valleys is seen. Error Bars show  $\pm$  one standard deviation from the mean.

**Figure 4.** The relationship between  $\delta^{15}\text{N}$  value and the elevation of each site sampled along the Little Bear River. Error bars show  $\pm$  one standard deviation from the mean.



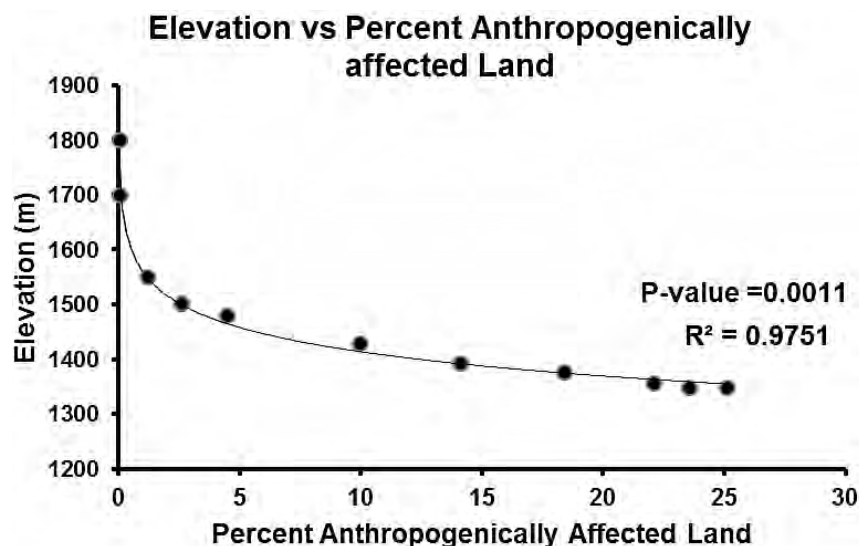
### Elevation

Elevation was a highly significant ( $P = 0.004$ ) predictive factor for  $\delta^{15}\text{N}$  values in the periphyton along the river's gradient. As elevation increased,  $\delta^{15}\text{N}$  values declined (Figure 4). However, outliers were observed at the two sites immediately below Hyrum Reservoir. Additionally, an outlier at Station 10 ( $\delta^{15}\text{N}$  6.1) had a lower  $\delta^{15}\text{N}$  value than would be expected with the trend line that is shown in Figure 4. It could be that this site is not an outlier at all but only seems that way due to the shift in the trend line caused by the outliers at the two sites below Hyrum. This could also be due to the nature of the surrounding land. Station 1 is considered the most pristine, as it is the highest in elevation, borders U.S. Forest Service land, and has little surrounding anthropogenically-influenced land.

There was a highly significant relationship between elevation and the percent anthropogenic land use within a sites catchment area (Figure 5;  $p = 0.001$ ,  $R^2 = 0.98$ ). This correlation could explain the significance of the relationship between elevation and  $\delta^{15}\text{N}$  values.

### ***Anthropogenically Affected Land***

The  $\delta^{15}\text{N}$  values of the periphyton samples can be explained most effectively by the percent of anthropogenically-affected land within the sample site's contributing watershed (Figure 6). The relationship between  $\delta^{15}\text{N}$  values and the percent of anthropogenically-affected land shows a significant positive correlation ( $P=0.043$ ) The only relationship with a higher P-value is that of the relationship between elevation and  $\delta^{15}\text{N}$  values which can be explained by the fact that lower elevations in this watershed, as with most watersheds, generally have more anthropogenically-affected land. However, the relationship between the two factors was not as tight ( $R^2 = 0.38$ ) indicating that additional factors contribute to the relationship. However, the variance around the trend line is generally similar.



**Figure 5.** Figure shows the correlation between percent anthropogenically affected land uses within the catchment area of a site and elevation for eleven sites along the Little Bear River. Anthropogenic land uses included: “irrigated”, “non-irrigated”, and “sub-irrigated” agricultural land, as well as land classified as “urban”. Land use types and area were calculated using ArcMap 10.1 and water related land use data was taken from the Utah AGRC (<http://gis.utah.gov/data/planning/water-related-land/>).

## **DISCUSSION**

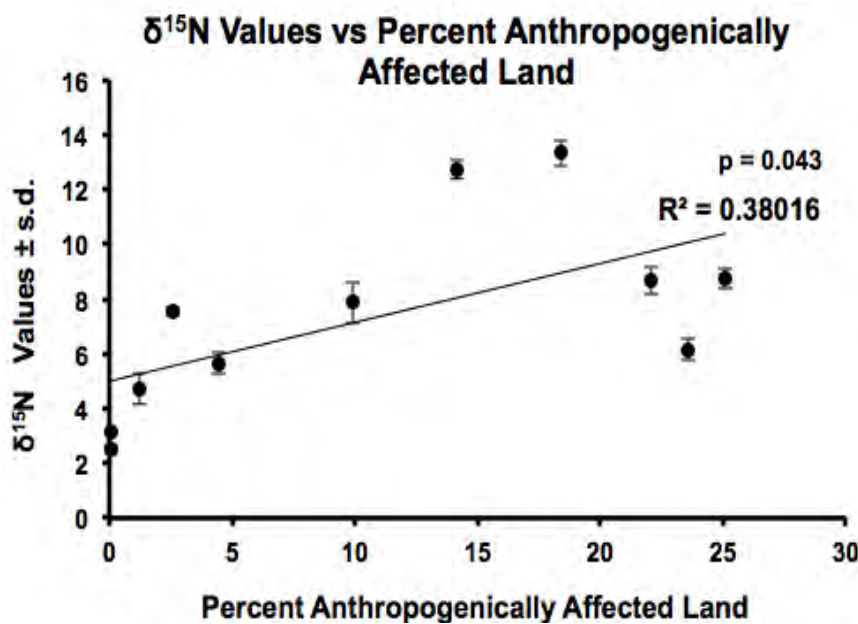
The percent of anthropogenically-affected land within a study site's contributing watershed can have a significant effect on the  $\delta^{15}\text{N}$  values within the periphyton (Anderson and Cabana 2005, Harrington et. al. 1998, Steffy et. al. 2004). The percent of anthropogenically-affected land in a sample site's contributing watershed had a positive significant effect ( $p= 0.043$ ) on  $\delta^{15}\text{N}$  values in periphyton samples along the gradient of the Little Bear River (Figure 6).  $\delta^{15}\text{N}$  enrichments in periphyton were generally higher when the contributing watershed had higher percentages of anthropogenically affected land. This effect can also be seen in upper levels of the food chain. Anderson and Cabana's (2005) study of 82 river sites on the St. Lawrence Lowlands of Quebec showed a significant correlation ( $p < 0.0001$ ) between percent agricultural land in the catchment and  $\delta^{15}\text{N}$  values of primary consumers, predatory invertebrates, and fish.



The distance downstream correlation with  $\delta^{15}\text{N}$  values could be caused by two possibilities. One factor could be that as distance downstream increases, so too does the opportunity for periphyton to accumulate heavy nitrogen isotopes. The heavy isotopes are more frequently accumulated than are the light isotopes of  $^{14}\text{N}$ . The other factor which is most likely the main contributing factor to the correlation of  $\delta^{15}\text{N}$  values and distance downstream is that as distance downstream increases so too does the amount of the contributing watershed that is made up of anthropogenically-affected land. Both of these factors are likely contributors to the significance of the correlation.

The only predictor of  $\delta^{15}\text{N}$  values that was more significant than percent anthropogenic land use was site elevation. As elevation decreased  $\delta^{15}\text{N}$  values increased. This could also be caused by the fact that anthropogenic land uses are more common at lower elevations.

In conclusion, the percent of a watershed's area that is being used by anthropogenically-affected land uses, which in this study included agricultural land and land classified as urban, can be an indicator of the level  $\delta^{15}\text{N}$  values in stream biota.



**Figure 6.** The relationship between  $\delta^{15}\text{N}$  values and percent of the Little Bear River catchment area that was made up of anthropogenically-affected land uses. Anthropogenic land uses included: "irrigated", "non-irrigated", and "sub-irrigated" agricultural land, as well as land classified as "urban". Land use types and area were calculated using ArcMap 10.1 and water related land use data was taken from the Utah AGRC (<http://gis.utah.gov/data/planning/water-related-land/>). Each point represents one of eleven sites along the Little Bear River. Error bars show standard deviations.

## REFERENCES

- Anderson, C.; Cabana, G. 2005.  $\delta^{15}\text{N}$  in riverine food webs: effects of N inputs from agricultural watersheds. *Canadian Journal of Fisheries and Aquatic Sciences*. 62:333-340. doi:10.1139/F04-191
- Dodds, W.; Whiles, M. 2010. *Freshwater Ecology: Concepts and Environmental Applications of Limnology*. Burlington, MA : Academic Press.
- Harrington, R.R.; Kennedy, B.P.; Chamberlain, C.P.; Blum, J.D.; Folt, C.L. 1998.  $^{15}\text{N}$  enrichment in agricultural catchments: field patterns and applications to tracking Atlantic salmon (*Salmo salar*). *Chemical Geology*. 147:281-294.
- Luecke, C.; Mesner, N. Use of nitrogen stable isotopes to assess effects of land use on nitrogen availability in freshwater ecosystems. Unpublished manuscript, Utah State University, Logan, UT.

Steffy, L.Y.; Kilham, S.S. 2004. Elevated  $\delta^{15}\text{N}$  in stream biota in areas with septic tank systems in an urban watershed. *Ecological Applications*. 14:637-641.

Utah Department of Environmental Quality, Division of Water Quality TMDL Section. (n.d.). Little Bear River watershed TMDL. Retrieved Dec. 6, 2012 from [http://www.waterquality.utah.gov/TMDL/Little\\_Bear\\_River\\_TMDL.pdf](http://www.waterquality.utah.gov/TMDL/Little_Bear_River_TMDL.pdf).

Vitousek, P.M.; Mooney, H.A.; Lubchenco, J.; Melillo, J. 1997. Human domination of Earth's ecosystems. *Science*. 277: 494–499.

Utah AGRC. [www.gis.utah.gov](http://www.gis.utah.gov). SGID Data Sets.(2012) Utah AGRC. <http://gis.utah.gov/data/>. 10/17/2012