Comparative Water Quality Study of Cozine, Gooseneck, and Mill Creeks

INTRODUCTION

Water is an essential part of any ecosystem and to the survival of all living organisms. All things need water to survive. And it is not just water that is essential, but good, clean water with little pollution. Pollution, primarily due to human activity, occurs from runoff, spills, fertilizers, and other chemicals that are either applied directly to the water, or become mixed with the water due to runoff or underground seepage. This pollution can be dangerous to humans, animals, and aquatic life (Cunningham and Cunningham, 2010). Water quality in the United States has fluctuated over time and many tactics have been used to attempt to clean up the waterways. In

met, measurements are taken by various government organizations and presented by the states to the Environmental Protection Agency (DEQ, 2012).

The ENVS 385 class of fall 2012 analyzed the water quality in three streams in the vicinity of McMinnville, Oregon. This is a continuation of the project of the previous two classes, spring 2011 and fall 2011 (Colahan et al., 2011; Weinbender and Crane, 2011). These classes examined the water quality at Gooseneck Creek, in Polk County, Oregon, and Cozine Creek, in McMinnville, Oregon. Our class collected data from these creeks as well as from Mill Creek in Polk County. The overall goals of the study were to gain a better understanding of water quality at the test sites, to see how the sites differ, as well as to examine changes in water quality over time. We compared our data to other water quality data at these sites in the past to reveal any improvements or increased pollution. We looked at the data from two years to reveal any trends in the overall quality of the stream. We hypothesized the water quality of Cozine Creek would be lower than that of Gooseneck or Mill Creek due to the surrounding urban environment. We also hypothesized the water quality of Cozine Creek would be about the same as last year. We further hypothesized the quality of Gooseneck Creek might be slightly improved, due to the continuing impacts of the restoration project conducted there by the Greater Yamhill Watershed Council.

All three study sites are located in the Yamhill Watershed in the Willamette Valley of Oregon. This area was originally inhabited by Kalapuya Indians, who altered the ecosystem by using fire as a way of maintaining the land for their purposes (Bower et al.,1999). The region is natural forest and grassland. Cozine Creek is located in the city of McMinnville in Yamhill County, Oregon. The portion that we sampled runs through the Linfield College campus after passing under Highway 99W. Much of Cozine Creek is in an urban area, which has negatively impacted its water quality. It previously was contaminated with *E. coli* in 2009, but the pipe that was discharging sewage into the creek was located and fixed, and the *E. coli* counts since have gone down. Garbage in the creek is commonplace, and the riparian vegetation is dominated by invasive species (Colahan et al., 2011). These invasive species include, but are not limited to thistle, English Ivy, Himalayan Blackberry, and large nutria (ODA, 2012).

Urbanization has characteristic impacts on stream quality that are evident in the case of Cozine Creek. Pollution from cities from myriad sources is carried with storm runoff into streams. The presence of lots of pavement contributes to storm runoff because water cannot be absorbed into pavement and has to flow elsewhere. The invasive species that are frequently

dominant in urban streams like Cozine do not merely crowd out native species, but can also impact water quality. The riparian vegetation influences the organic matter that is deposited into streams and can change the amount of sunlight that penetrates to the stream, which in turn affects temperature. Restoration of creeks in urban areas is challenging because urbanization affects a stream so immensely that small-scale projects do not often lead to major improvements in water quality (Booth, 2005).

Mill Creek and Gooseneck Creek are located in Polk County in a sparsely populated, rural area of private land ownership. Gooseneck joins Mill just downstream from our surveying sites (DEQ, 2006). In the late 1800s and early 1900s, humans altered Gooseneck and Mill Creeks to facilitate logging. Dikes and dams were built along Mill Creek; these have been removed although remnants remain. A mill race, or trench, was dug from Mill Creek to the town of Sheridan to transport logs to the lumber mill (Bower et al., 1999). Gooseneck Creek was straightened for logs to be floated down it. This led to increased flow rates that scoured the bottom of the creek down to the underlying bedrock resulting in a lowered water table in the area. Gooseneck Creek was the site of a restoration project conducted by the Greater Yamhill Watershed Council in 2009. This project reopened a blocked side channel. Log weirs were constructed

maximum daily load (TMDL), which is the maximum amount of a pollutant that the body of water can tolerate while still meeting standards. A TMDL is an important step towards reducing the level of a pollutant in a particular water body so that standards can be met. Category 1 meets the DEQ water quality standards for all parameters of water quality measured. Category 2 meets some of these standards. Category 3 means that the data available is not sufficient to determine the status of the water body. This could mean that enough data has simply not been attained, or that it is suspected that a certain standard is not being met, but the pollutant causing the problem is not known. Category 4 signifies that the water quality of the water body is limited, or not meeting standards, but that a TMDL is not needed, either because there already is one or the standards are not being met on account of a non-pollutant factor, such as low flow rate. Category 5 does not meet water quality standards to the extent that a TMDL is needed (ODEQ, 2010).

Bodies of water that have been tested by the DEQ can be placed in several different categories at once, based on different factors. For example, a hypothetical stream could meet standards for most parameters measured, and be classified as category 2. However, the same stream could have a fecal contamination problem and be classified as category 5 with regards to

smaller. This fluctuation is due to many factors including land use, climate change, and weather, and most likely affects our three test sites (DEQ, 2012). Because of this, it is important that we test multiple sites frequently so we can compare them for general trends.

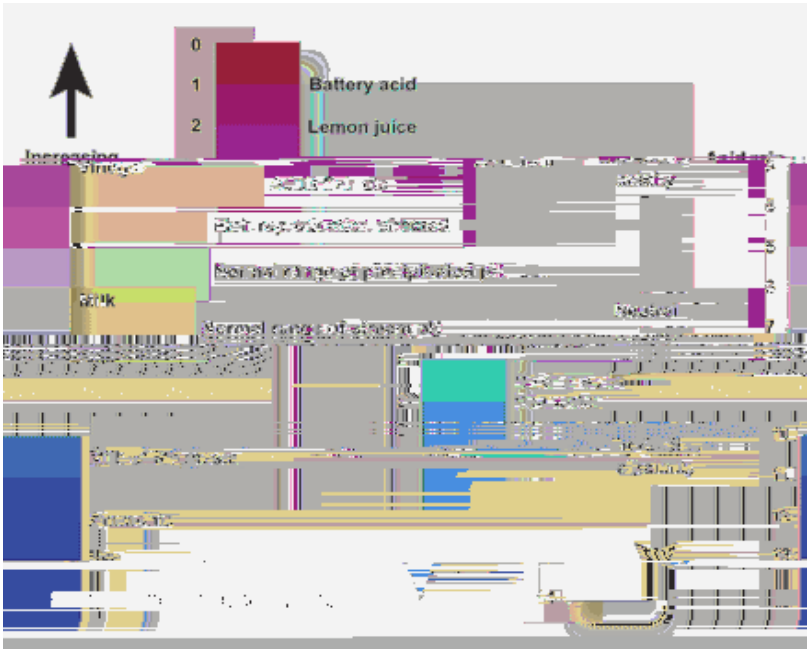
Water quality is affected by many factors including geology and the types of soil and rocks present. Nutrient concentrations are often highest in areas where soil has little drainage because nutrients cannot seep into the ground and therefore accumulate in surface water (Mueller and Hensel, 2009). The rock surrounding Mill and Gooseneck Creeks is mainly sedimentary rock found near the surface and volcanic rock at the bedrock level. Gooseneck Creek is eroded down to the sedimentary bedrock, which contributes to higher pH because it is rich in carbonate. The soil in the area consists of poor draining silt-clay and silt loam (Bower et al, 1999). Cozine Creek has similar silt-clay loam soil (USDA, 2012). These features can contribute to certain water quality issues.

There are many parameters that indicate how clean water is. At each site, we took tests of some aquatic indicators to assess water quality of each creek. We tested for coliform bacteria, pH, temperature, flow rate, dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), nitrates, phosphorus, and macroinvertebrates.

Bacteria are natural and abundant in water, but some forms can be harmful. Enterobacteria tests are used to determine the level of coliform bacteria such as *E. coli*. These tests can pinpoint pollution from septic tanks, sewage, or agricultural or natural animal waste. Fecal coliforms may be dangerous to humans because they can cause infections that can lead to death (EPA, 2012c). *Salmonella* is another dangerous

metals so they become too high or low, which can be toxic (USGS, 2012b). Natural waterways typically have a pH between 6.5 and 8.5. Pollution can influence the pH of water and make it less hospitable for organisms. Forms of pollution such as emissions from the burning of fossil fuels contribute nitrogen oxides and sulfur dioxide that form nitric and sulfuric acid in the atmosphere and return to the ground as acid precipitation or dry deposition. Discharge from wastewater treatment plants or other industrial processes can also contribute to increased acidity. Alkalinity can increase naturally due to the presence of limestone or other carbonate minerals. A pH of about 4.5 is the threshold below which fish cannot survive (Michigan DEQ, 2012). Figure 1 illustrates the pH scale and the impact on biological organisms.

Figure 1: The pH scale and impacts on aquatic systems.



(USGS, 2012b)

Temperature is another important parameter because most aquatic life only can tolerate a small range of temperatures. Depending on the location of the stream and the organisms in it the stream can be classified and the ideal temperature range for the stream determined (WA DoE, 2012). The temperature of the stream is directly related to the flow rate, the amount of shade, and where the origin of the headwaters is located. Changing any of these features can destroy an entire stream ecosystem if the water gets too warm (WA DoE, 2012). Colder water is indicative of higher water quality than warmer water because it can hold more dissolved oxygen, which is then available for use by organisms. As temperature increases, plant and algal growth often increases, which can lead to oxygen depletion when these organisms die. Water used for cooling in industrial processes and discharged into waterways is a source of thermal pollution (Michigan DEQ, 2012).

We also measured flow rate at each site, which similar to temperature, also influences dissolved oxygen. Water that moves faster and flows over logs and rocks becomes aerated by picking up oxygen. Stagnant waters have lower levels of dissolved oxygen (Michigan DEQ, 2012). Flow rate is the volume of water moving through a point over a certain amount of time. It can be affected by many things including weather, season, water use, depth of the creek and vegetation. Larger, faster moving creeks are more able to dilute pollution while smaller, slower

streams will be affected more by the pollution. Similar to pH, flow rate has a role in determining the kinds of organisms that live in the water because some are more suited to faster flow rate whereas others are more suited for a slower flow rate (EPA, 2012b).

Another parameter of water quality that is very important to test is dissolved oxygen (DO) in the water. DO is essentially the amount of oxygen dissolved in the water that is available for organisms to utilize. DO is related to flow rate because fast moving streams tend to have higher DO whereas slow flowing streams have a lower value. This is due to the faster flow resulting in cooler temperature and more churning of the water mixing in oxygen. When there are high enough levels of oxygen, animals and plants thrive, but when DO declines organisms are unable to survive and eventually the water will no longer support life. Dissolved oxygen declines due to eutrophication that results in rapid growth and death of living organisms; the bacteria involved in decomposition use oxygen. Because excess nutrients can result in eutrophication, the amount of DO is a good indicator of water quality (USGS, 2012a). Certain species of fish such as salmon need higher oxygen levels than other species and cannot live in oxygen-depleted water (Michigan DEQ, 2012). Due to the link between temperature and oxygen solubility in water, DO rises and falls as the seasons change (USGS, 2012a).

Biochemical oxygen demand, or BOD, determines the oxygen demand of the microorganisms and organic debris suspended in the water as well as oxidants that chemically react to removed dissolved oxygen from the water. BOD is important because a high BOD combined with a low DO level can stress and deplete oxygen levels. BOD most often directly relates to, runoff, detritus materials, sewage overflow, water treatment plant outflow, failing septic systems, feed lots, and food processing plants (EPA, 2012a).

Dissolved oxygen depletions are linked to increases of nitrates and phosphates in the water. Although naturally present and vital to ecosystem function an excess of nitrate and phosphorus can disrupt the balance of the ecosystem (Michigan DEQ, 2012). Nitrate and phosphorus levels are important to test for because an excess of these nutrients in the water can indicate pollution and degraded water quality for that area. Nitrogen and phosphorus most often come from fertilizers and animal urine and waste (USGS, 2012a). The EPA states the maximum amount of allowable nitrogen in water is 10mg/L (Self and Waskom, 2008) and the limit for phosphorus is 0.07mg/liter (ODEQ, 1992). Greater levels may cause harm (Self and Waskom, 2008).

Many macroinvertebrate species are biological indicators of water pollution. Macroinvertebrates also indicate the water quality over time because they live in the water constantly and need to be able to survive to reproduce. Biodiversity in macroinvertebrates is also important to look at because high diversity is indicative of good water quality because many organisms can survive in the water (Lindbo and Renfro, 2003). Because certain macroinvertebrates are better at tolerating pollution than others, looking at the species tells a person a lot about the water quality in a stream. Some, such as scuds and leaches, can tolerate extremely polluted waters, whereas others, such as stoneflies and mayflies, can only tolerate clean or slightly polluted waters. A rating system, the Pollution Tolerance Index (PTI), categorizes macroinvertebrates in terms of how well they respond to pollution and disturbance. Group 1 (pollution intolerant organisms) species are awarded 3 points and are sensitive to pollution and disturbance from different sources; they do not respond well to large changes in their environment. Group 2 (the wide ranging organisms) are given 2 points and can adapt to changes and survive in a wide range of parameters. Group 3 (pollution tolerant organisms) are given 1 point and can tolerate high levels of pollution (Lindbo and Renfro, 2003). Macroinvertebrates can be surveyed and analyzed to see their response to pollution. The numbers and types of macroinvertebrates change depending on pH, flow rate, pollution levels, and more (Water and Rivers Commission 2001). Macroinvertebrates, along with the previously discussed parameters of water quality, create a picture of the overall water quality, which is why we chose to sample them in Cozine, Gooseneck, and Mill creeks.

METHODS

Site Selection and Description

Three sample sites were selected at each creek. The spring 2011 ENVS 385 class selected the sites at Cozine and Gooseneck Creeks. Their method was to run a transect along each creek, and choose three numbers from a random numbers table. These numbers were used to select the location along the transect tape as to where each sampling site would be located (Colahan et al. 2011). The ENVS 385 class in Fall 2011 used the same sites, with the exception of Cozine site #2, which had to be moved due to unsafe conditions from changed water levels (Weinbender and Crane, 2011). Our class used the same sites as the Fall 2011 class. Using the same locations to

year, we selected the sites using the same transect/random number method. The GPS coordinates of each site are in Table 1.

Table 1: GPS Coordinates of Sample Sites Locations.

e Data had been collected by the fall 2011 class at Cozine and Gooseneck Creeks. The f

Figure 2: Satellite image showing Cozine creek with sites used in fall 2012 labeled. (Google, 2012).

Gooseneck Creek was sampled in the area where the Greater Yamhill Watershed Council had done the previously mentioned restoration project in 2009. This site is a short distance upstream from where the creek flows into Mill Creek

pH

pH was measured at each site using a Hannah Instruments pH meter (model number: H198128). The probe was submerged completely under the water and the measurement recorded after the pH reading stabilized. Triplicate readings were taken at each site.

Dissolved Oxygen and Temperature

DO and temperature were measured three times at each site with an YSI Incorporated DO meter (Model 55/12 FTSN: 95H36442). The DO meter was calibrated to both 0% and 100% oxygen before leaving the laboratory to improve accuracy when recording. The instrument was further calibrated to 100% oxygen at each site before data was collected. The probe was placed in the stream and the measurement recorded after the reading stabilized.

Biological Oxygen Demand

The water sample collected in the BOD bottle as described earlier was placed in a dark cabinet in the laboratory for five days. On the fifth day we measured the DO three times per sample using the calibrated YSI Incorporated DO meter. We calculated BOD by subtracting the five-day DO from the initial DO taken at the site.

Nitrate Nitrogen

The collected water samples were taken out of the freezer and thawed. We then used a LaMotte Nitrate Nitrogen water test kit (model number 3354) to determine the level of nitrate nitrogen in each sample of water. We followed the directions in the LaMotte test kit (LaMotte, 2012b). Triplicate samples were run.

Phosphorus

We used a LaMotte Low Range Phosphorus water test kit (model PAL, code: 3121-01) to determine the level of phosphorus in each thawed sample of water. Triplicate samples were analyzed according to the directions in the LaMotte test kit (LaMotte, 2012a).

Flow Rate

Rate of water flow was measured using a Geopack flow meter (model MFP51). The flow meter was placed under the surface of the water with the propeller facing the oncoming water, and held still. When the flow rate stabilized, the reading was taken. Flow rate was measured in triplicate at each site.

Macroinvertebrate Sampling

Macroinvertebrates were sampled at each site at five nonrandom placed locations along the stream. We used two D nets to collect organisms in a one square foot area at the bottom of

the creek. One net was placed against the bed of the creek facing upstream to catch anything floating down. The second net was placed one foot upstream from the first and scraped across the bottom of the creek towards the other net disrupting the creek bed. We also used our hands to rub organisms off large rocks and when the second net was unable to cover the entire creek bottom due to rocks (Lindbo and Renfro, 2003). The nets were dumped into plastic tubs. Snails were counted but not collected and other macroinvertebrates were collected, transferred to a jar containing isopropyl alcohol, and brought back to the laboratory for identification and counting using dissecting microscopes. Macroinvertebrates were identified to the most specific classification level using a stream macroinvertebrate field guide (Edwards. 2008).

Coliform Bacterial Sampling

Each thawed water sample also was used to sample for coliform bacteria (*E. coli, Salmonella, Aeromonas* and other enteric bacteria). We used Easy Gel kits according to the directions. We pipetted 5 mL of water into each bottle of agar. Three plates were made from each water sample. The petri dishes were incubated in an incubator at 35^{o}C for 24 hours. After that time they were removed and the colonies counted by bacterial type, which could be determined by the color of the colony. *E. coli* appeared as dark blue or indigo colonies. Other coliforms appeared as blue or blue grey and were smaller in size than *E. coli*. *Aeromonas spp.* appeared as pink or red, and *salmonella spp*. appeared as teal or green colonies (Micrology Laboratories, 2008).

Statistical Analysis

We used the statistical analysis program JMP 9.0 to analyze the data. We used a two-way ANOVA with a Tukey-Kramer HSD post-hoc test to determine significant differences in each variable among the sites. We used a two-tailed paired t-test to determine significant differences between fall 2011 and fall 2012. In using two-way ANOVAs, we assumed that the observations were independent and not related to one another, that the dependent variables were normally distributed, and that their variances were equal across groups. For the two-tailed paired t-tests, we assumed that the dependent variables were normally distributed and that the independent variables were dichotomous and had paired groups (Morgan et al., 2011).

RESULTS

The temperature was significantly higher at Gooseneck Creek than the other two sites, and the temperature at Cozine Creek was significantly higher than at Mill Creek (see Table 2).. PH was significantly higher at Gooseneck Creek than either Cozine or Mill Creeks. DO was significantly lower at Cozine than either of the other two sites. The levels of *E.Coli*, *Aeromonas*, and other coliform bacteria were significantly greater at Cozine than at Gooseneck or Mill Creeks.

Table 2. Mean (SD) of each factor at each creek. Probability is given for results of a two-way ANOVA. Sites with different letters are significantly different from one another as determined using a Tukey Kramer HSD Post Hoc test.

Water Quality Factor	**Cozine**	**Gooseneck**	**Mill**	**Probability**	**N**
Temp (C)	9.6(0.3) b	12.3 (0.7) a	8.2(0.6) c	<0.0001	9
pH	6.5(0.3)b	7.1(0.2)a	6.5(0.3)b	<0.0001	9
DO (%)	58.2(1.0) b	89.4(4.7)a	90.2(3.8)a	<0.0001	9
BOD	3.7(3.8)a	4.1(7.8)a	10.6(6.4)a	0.0476	9
Flow rate (cm/s)	10.5(8.6)	10.0(0.0)	16.1(10.1)	0.1912	9
Nitrate	0	0	0	/	9
Phosphorus	0	0	0	/	9
E. Coli	3.1(1.7) a	0.1(0.3) b	0.1(0.3) b	<0.0001	18
Other coliforms	4.7(2.4) a	0.3(0.6)b	0.4(0.7) b	<0.0001	18
Aeromonas	56.4(19.4) a	0.3 (0.8) b	0.4(0.5) b	<0.0001	18
Salmonella	0	0	0	/	18

In Gooseneck Creek, we found that DO, BOD, flow rate, and *Aeromonas* levels were all significantly lower in 2012 than in 2011 (Table 3). pH was significantly higher in 2012.

Table 3. Mean (SD) comparing water quality parameters at Gooseneck Creek in fall 2011 to fall 2012. Probability was found using paired t-tests.

Water Quality Factor	**Fall 2011 (Weinbender and Crane 2011)**	**Fall 2012**	**Probability**
Temp (C)	12.2 (0.2)	12.3 (0.7)	0.8011
pH	6.6 (0.4)	7.1(0.2)	0.0283
DO (%)	97.2 (0.0)	89.4(4.7)	0.0031
BOD	33.0 (0.3)	4.1(7.8)	<0.0001
Flow rate (cm/s)	50 (40)	10.0(0.0)	0.0009
Nitrate	0.5 (.0)	0	/
Phosphorus	0.0(0.0)	0	/
E. Coli	24.4(29.6)	0.1(0.3)	0.073
Other Coliforms	13.3(26.5)	0.3(0.6)	0.2755
Aeromonas	26.7(26.5)	0.3 (0.8)	0.0212
Salmonella	6.7(20.0)	0	0.3466

In Cozine Creek, we found DO, temperature, PH, and BOD were significantly lower in 2012 than in 2011 (Table 4). The levels of *Aeromonas* and other coliform bacteria were significantly higher in 2012.

Table 4. Mean (SD) comparing water quality parameters at Cozine Creek in fall 2011 to fall 2012. Probability was found using paired t-tests.

Water Quality Factor	**Fall 2011 (Weinbender and Crane 2011)**	**Fall 2012**	**Probability**
Temp (C)	12.3 (0.1)	9.6(0.3)	<.0001
pH	6.8(0.2)		

For macroinvertebrates, we found significantly more mayflies and stoneflies in Mill Creek than in Cozine Creek (see table 5).The Pollution Tolerance Index was calculated for each site which can be compared even though we were not able to do statistical analysis.

Table 5. Mean (SD) of numbers of each macroinvertebrate type at each creek. Probability is given for results of an ANOVA. Sites with different letters are significantly different from one another as determined using a Tukey Kramer HSD Post Hoc test. The Pollution Tolerance Index value for each type is also noted as well as for each site (Lindbo and Renfro, 2003).

Macroinvertebrate	**Cozine**	**Gooseneck**	**Mill**	**Probability**	**Pollution Tolerance Index (PTI)**
Cranefly larvae	1.6 (2.9)	0.7 (0.6)	4.7 (4.6)	0.3396	2
Mayflies	0.7 (0.6) b	5.3 (3.5) ab	29.7 (19.0) a	0.0394	1
Stoneflies	0.3 (0.6) b	2.7 (3.1) ab	13.7 (8.1) a	0.036	1
Worms	0.7 (0.6)	0.3 (0.6)	7.0 (8.9)	0.2785	3
Riffle Beetles	1.7 (2.9)	0.7 (1.2)	1.0 (1.0)	0.8097	2
Mites	2.0 (2.6)	0.3 (0.6)	0.7 (1.2)	0.4891	3
Midges	3.0 (2.6)	1.0 (1.7)	0.3 (0.6)	0.2638	3
Snails	26.0 (14.0)	73.3 (123.6)	27.7 (23.0)	0.6834	3
Net Spinner Caddisfly	1.0 (1.7)	0 (0)	0 (0)	0.4219	1
Alderflies	0 (0)	1.0 (1.0)	0 (0)	0.125	2
Scuds	3.3 (5.8)	0 (0)	0 (0)	0.4219	3
Mosquito larvae	0.3 (0.6)	0 (0)	0 (0)	0.4219	3
Total	40.7 (6.4)	85.3 (128.8)	84.7 (48.6)	0.744	
PTI	25	20	18		

We sampled macroinvertebrates at each creek, identified the species, and identified the Pollution Tolerance Index for each species for comparisons (see Figure 5).

Figure 5. Macroinvertebrate species by site and Pollution Tolerance Index

Discussion

Gooseneck and Mill Creeks appear to have better water quality than Cozine Creek based on the pH, DO and, coliform bacteria results. These findings were expected and support our first hypothesis. We believe the water quality of Cozine Creek is being impacted negatively by the surrounding urban environment. We also hypothesized that the water quality of Cozine Creek would be about the same as last year, which we found to be true. We further hypothesized that the quality of Gooseneck Creek might be slightly improved due to continuing impacts of the

September 26th with a high of 74ºF, which was warmer than when we sampled at Cozine on October 17th with a temperature of 63ºF. We found no significant difference between stream temperature in fall 2011 versus fall 2012 in Gooseneck Creek. Cozine Creek was significantly warmer in fall 2011. This difference may be due to the weather conditions of the collection day.

Table 6. High temperature at the McMinnville airport on collection dates.

Site	Year

ANOVA significance is doubtful. We found that BOD was significantly higher in 2012 than 2011 at both creeks. These results may be due to the previously mentioned DO meter issues and we are not certain the difference is valid.

The rate of flow was not significantly different among the sites in fall 2012. It also was not different between 2011 and 2012 for Cozine Creek, although we did find it was significantly slower at Gooseneck Creek in fall 2012. The 2012 flow data is limited by the fact we measured flow in meters per second at Gooseneck and in centimeters per second at Cozine and Mill. This may have led to our data being skewed. In addition, we used a different flow meter than last year, which raises the question as to the validity of comparing the data between the two years.

We detected no nitrate or phosphorous at any site this fall. In fall 2011, a very low level of nitrate was detected at Gooseneck Creek and a very low level of phosphorus was detected at Cozine Creek, however there were no significant differences between the years for either nutrient. High nutrient levels are often associated with man-made substances and chemicals such as fertilizers. The absence of nutrients in all three creeks may illustrate that the creeks have a low level of pollution from contaminants such as fertilizers and human wastes (Dubrovsky and Hamilton, 2010). It may also relate to the fact that we sampled near the end of a long dry streak, which would have limited run off into the streams.

One major difference in water quality among the creeks was demonstrated by the differential enteric8 -1loglong dry st

meter allows for dual calibration to both zero and 100 percent oxygen, whereas the GYWC DO meter only can be calibrated to 100%. The use of different meters could have been the reason for any changes.

We also used a new flow meter in fall 2012. The meter used in 2011 had to be timed using a stop watch whereas the new meter keeps track of flow per time. In addition, flow rate at Gooseneck Creek was measured in meters/second, but the meter was switched to centimeters/second to more accurately measure flow rate in Cozine and Mill Creeks. We converted the flow at Gooseneck Creek to centimeters/second, but the results may be less accurate.

There also may have been human errors. It is always possible recordings were written down incorrectly or that a piece of equipment was used improperly. This could have skewed our results.

Finally, when we sampled macroinvertebrates we did not use a random method to collect samples. We simply went to five different locations at each site, which could have introduced bias. We also did not double check the identification of the macroinvertebrates in the laboratory

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