Comparative Water Quality of Cozine, Gooseneck and Mill Creeks

Shelby Hollenbeck, Emily Isaac, Suzannah Klaniecki, Zach Lea,
Meghan Lockwood, and Xavier Reed

December 9, 2013
ENVS 385 Research Methods
Linfield College

INTRODUCTION

Water is an essential compound to the survival of all living organisms. Without it, life as we know it would not be able to flourish. Yet, it is not just water that is needed, but clean water free of pollution. Harmful pollutants caused by human sources such as fertilizer and/or chemical spills can become introduced into aquatic environments through runoff and underground seeps. Pollutants can be harmful to humans, animals, and aquatic life in the affected waters (Cunningham and Cunningham 2010). Water quality varied greatly over the past century in the United States, and national concern developed about dirty water. The concerns raised by the public led to the Water Pollution Control Act (WPCA) in 1948. The WPCA put the responsibility for water clean up in the hands of state and local agencies. The result limited the efficacy of the federal government in improving water quality across the nation. In 1972, the WPCA was changed into the Clean Water Act (CWA), which is still in effect today. The CWA had a new goal of restoring and maintaining water quality to federal standards enforced by the individual states. The main emphasis of the CWA was to require permits for point sources of pollution and to give

The environmental research methods class of fall 2013 analyzed the water quality of placed in category 3. Gooseneck was classified to be a category 4 with respect to flow, but a TMDL was not needed because flow is not considered a pollutant. The Gooseneck Creek data was collected between 1998 and 2004. The DEQ has conducted the most testing on Mill Creek. Sampling from different areas along Mill Creek from 2003 and 2004 revealed an unknown pollutant impairing biological systems, warranting a classification of category 3. Other places along the creek, however, were listed as category 2, which meets the DEQ standards for biological criteria. The creek was tested in 1998 for dissolved oxygen (DO), pH, temperature, and fecal coliforms and met the DEQ standards. It was noted that this was an improvement in Mill Creek from the 1980s, when testing showed standards were not met for some of the proposed parameters. Similar to Gooseneck Creek, Mill Creek was listed as category 4 for flow modification (ODEQ 2010).

All of the sites we sampled are located in the Yamhill Watershed within the Willamette Valley of Oregon. Kalapuya Indians, who originally inhabited the area, altered the ecosystem by selectively burning forests to mold the land to their purposes (Bower et al. 1999). The region is made up mainly of natural forest and grassland, which has led to it widely being used for farming and ranching. Cozine Creek is the exception, running through the heart of McMinnville, Oregon. Due to the urban environment the water quality of the creek has been negatively impacted. In 2009 it was determined to have *E. Coli* contamination. The source of the pollution, a sewer pipe discharging in the creek, was repaired. Since then, the *E. Coli* counts have dropped. It is normal to see trash on the banks and in the creek. Invasive species such as thistles (*Cirsium spp.*), English ivy (*Hedera helix*), and Himalayan blackberry (*Rubus armenicus)* dominate the riparian vegetation (ODA 2012). The riparian vegetation influences the organic matter that is deposited into streams and can change the amount of sunlight that is able to penetrate through to the stream, which in turn affects temperature. Urban streams tend to have higher rates of erosion of both the bed and banks, fewer pieces of large woody debris, and more simplified morphology, due to urban development, all of which can have negative effects on stream health (McBride and Booth 2005). Restoration of urban creeks 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 and Gooseneck Creeks are located in Polk County in a sparsely populated, rural area of private land ownership. Gooseneck joins Mill just downstream from our Gooseneck Creek 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 since been removed although remnants remain. A trench was dug from Mill Creek to the town of Sheridan to transport logs to the lumber mill there (Bower et al. 1999). Gooseneck Creek was straightened so logs could be floated down it. This led to increased flow rates that decimated the bottom of the creek so that only the underlying bedrock remained. This resulted in a lowered water table in the area. Gooseneck became the site of a restoration project conducted by the Greater Yamhill Watershed Council in 2009. Restoration efforts reopened a blocked side channel, (originally used to capture logs) in order to allow water runoff. Log weirs were constructed to slow the flow and create pools and riffles that would allow gravel to accumulate on the bottom of the creek and restore the original habitat (Waterways Consulting 2009). Gooseneck has multiple weirs and side channels creating pools that attract various organisms. Not all of the weirs survived heavy flow in the winter from 2012-2013, and those that have broken apart have been rendered useless. There is thick vegetation consisting mainly of bushes, thick grasses, deciduous trees and some conifers along the banks of both Gooseneck and Mill Creeks (Bower et. al. 1999). Today, the land surrounding Mill and Gooseneck Creeks is mostly agricultural. Within the whole of the Mill Creek Watershed, which includes Mill and Gooseneck creeks, there are ten Concentrated Animal Feeding Operations (CAFOs), eight of which are dairies with herds from 100 to 5,000 cows. These CAFOs constitute much of the land use surrounding Mill Creek and can be sources of fecal contaminants and nutrients (DEQ 2006). Testing the combination of these three sites will allow us to compare urban vs. rural effects on water quality.

Water Quality Variables

There are many different ways to determine how clean water is. Some common parameters for testing water quality include chemical, physical, and biological analyses (Resh and Unzicker 1975). We tested various aquatic indicators of water quality at Cozine, Gooseneck, and Mill creeks. We tested pH, DO, flow rate, temperature, depth, turbidity, Biochemical Oxygen Demand (BOD), macroinvertebrates, and levels of bacteria.

One measure used to determine overall quality of water is pH. Many biological life forms can’t survive if the conditions are too acidic or basic. pH ranges from 0 to 14, with 7 being neutral. Natural waterways typically range between 6.5-8.5. Added pollutants can change the pH, which in turn causes the levels of nutrients and metals to vary. This can lead to toxic conditions for organisms living in the water (USGS 2012b).

Temperature is another important factor in determining the water quality. Most aquatic life can only survive within a small range of temperatures. Depending on location and the type of organisms present, bodies of water can be classified and the ideal temperature range determined (WA DoE 2012). Temperature is directly related to flow rate and amount of shade. Changing these can raise the temperature, adversely affecting entire ecosystems. We also measured flow rate to determine the overall quality of water because flow affects the temperature of the water.

Dissolved oxygen (DO) is another important measurement to take into account when examining water quality. It is the amount of oxygen available to aquatic organisms. Flow can affect DO because water flowing over rocks and logs becomes aerated. Stagnant waters have lower levels of DO because they are typically warmer than faster moving water (Michigan DEQ 2012). Some animals, like trout, are able to thrive in areas where there are higher levels of oxygen in the water, so high DO indicates high water quality (Earth Force 2010a). Pools or slow waters are parts of the stream where the structure of the streambed and habitat create a spot where flow is slower and depth is deeper. Riffles are areas of the stream or river where water is more turbulent and running over rocks; they tend to be in the straighter parts of the stream (EPA 2012d). The wide array of habitat is necessary for high diversity in stream flora and fauna because of increased niches and available resources. Pools, for example, can help create a cooler temperature and slower moving water system for young fish to rest as they travel upstream (Palmer 1993). Slow and fast moving waters can be a defining feature of the stream and give insights into how the physical and biological factors play a role in the health of the stream.

Biochemical oxygen demand (BOD) is another factor we measured to examine water quality. BOD reflects the oxygen demand of the microorganisms and organic debris suspended in the water, as well as oxidants that chemically react to remove dissolved oxygen from the water. BOD is important because a high BOD combined with a low DO level can lead to depleted oxygen levels. BOD most often directly relates to runoff, detritus, sewage overflow, water treatment plant outflow, failing septic systems, feedlots, and food processing plants (EPA 2012c).

Turbidity is another important water quality parameter. Turbidity measures the amount of suspended particles in the water that block the passage of light to the benthic layer of the stream. These particles can include sediment, plankton, algae, and other materials. Higher turbidity results in higher water temperatures because particles in the water absorb the heat of solar energy. Because warmer water holds less DO than cold water, higher turbidity results in lower DO. Sources of turbidity include urban runoff, erosion, excessive algal growth and waste

Ginsburg 1977). Macroinvertebrates production is linked to the stream environment and has been shown to be positively correlated with nitrates and alkalinity (Krueger and Waters 1983). Macroinvertebrates help with decomposition of organic material in the streambed, whereas the level of nitrates and the alkalinity affect the rate of decomposition. A stream's physical and chemical characteristics are linked together, and macroinvertebrates are a way to look into these stream qualities.

METHODS

Site Selection and Description

Two creek locations were randomly selected by the 2011 spring ENVS 385 class at Cozine and Gooseneck Creeks. That class chose the area where the Gooseneck sample sites would be to study the impact of a restoration completed by the Greater Yamhill Watershed Council. The Cozine sites were chosen because they were adjacent to the Linfield College campus. In addition, Cozine is an urban stream and would allow comparison between a rural stream and an urban one. At each stream location, three sample sites were randomly chosen (Colahan et al. 2011). The fall 2012 ENVS 385 class added sites at Mill Creek for comparison to Gooseneck Creek. Again, individual sample locations were randomly selected. Each class took GPS readings at each site and placed flagging to ease locating sites in the future (Bailey et al. 2012). Our class (Fall 2013) used the same sample sites at each stream. We took GPS readings (Table 1).

Table 1: GPS Coordinates for Each Site Location (Fall 2013)

Site	Latitude	Longitude
Mill 1	N	

Samples at Mill Creek were taken on September 11 and October 9, 2013. Site 1 was characterized by slow moving water and pools that narrowed in width after an upstream riffle. The depth in this part of the creek was 20 to 30 cm deep, with some shallower areas on the rock beds and deeper depressions in the streambed. The stream bottom was mostly large cobbles and rocks with some gravel. Site 2 exhibited fast moving water, or a riffle, that was shallow and wide. This part of the stream was wider as the water from the upstream riffle spread over a flatter landscape. In dry seasons, the water level is usually not high and can result in a split stream. This portion of the stream was much shallower than sites 1 and 3, with most of our measured depths being less than 15cm. Site 3 also had fast moving water and as it was the riffle upstream from site 2. This part of the stream had a stronger flow and was much narrower than the rest of the stream. Mill Creek was shaded by a riparian buffer of mostly Red Alder (*Alnus rubra*) and willows (S*alix spdv* was a small plunge pool below where the weir had been placed, then it became shallower again. Our samples were taken in or just downstream from the plunge pool. The bed consisted of some large boulders and cobbles on the carbonate bedrock. An overgrown side channel that floods during high water began on the eastern bank of the stream just above site 2. This side channel would have emptied out at site 1. Site 3 was characterized by slow moving water and was located right after a weir that was still intact. It consisted of a wide spreading pool that concentrated into a single riffle immediately downstream. Most of the stream bottom consisted of bedrock, although there was gravel on the side of the streambed. The Gooseneck Creek site was surrounded by similar species as Mill Creek, including Red Alder (*Alnus rubra)* and Willow *(Salix spp.)*.

Oregon Ash (*Fraxinus latifolia*) and White Oak (*Quercus garryana*). In addition, Cozine creek is surrounded by dense thickets of Himalayan blackberry (*Rubus armeniacus)* and other non-native species. The stream is impacted by urbanization and runoff from the surrounding environment and trash is commonly found in the creek and on the shore. Figure 3 shows the approximate locations the three sites.

.

Figure 3: Aerial View of Cozine Creek. (Bailey, 2012)

Water Quality Sampling Methods

Dissolved Oxygen (DO) and Temperature

DO and temperature were measured at each site using a Hanna Instruments DO meter (model number: HI9146). The DO meter was calibrated to both 0% and 100% oxygen before leaving the laboratory to improve accuracy. The probe was placed in the stream. After the reading stabilized, temperature was recorded in degrees C; DO was recorded in both parts per million and as percent.

Biochemical Oxygen Demand

The BOD bottles were placed in a dark cabinet in the lab for five days. On the fifth day, DO measurements were taken in triplicate from each water sample using the DO meter. We calculated BOD by subtracting the five-day DO from the original DO (EPA 2012a).

Flow Rate

Rate of water flow was measured using a Geopack flow meter (model MFP51). The meter was submerged with the propeller facing oncoming water and held still. When the average flow over 6 seconds became stable, the reading was recorded.

Ammonia-Nitrogen

Each water sample was tested for ammonia-nitrogen using a LaMotte Ammonia-Nitrogen water test kit (model number 5864), using the directions provided with the kit (LaMotte 2012a). Each sample was analyzed in triplicate.

Phosphorus

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

Coliform Bacterial Sampling

Each thawed water sample was also used to assess the level of coliform bacteria (*E.coli* and other coliform bacteria). Using Easy Gel Kits as per directions, we pipetted 2 mL of water from the Cozine sample for September 18, 2013 and 5 mL of water from all other samples. Three plates were made from each water sample. The plates were placed in an incubator at 35°C for 48 hours. After that time, plates were removed and the colonies were counted. Colonies appearing dark blue or purple were counted as *E. coli*. Colonies that appeared pink were counted as other coliform bacteria (Micrology 2008).

Macroinvertebrate Sampling

Macroinvertebrates were not sampled until the October collection dates. Macroinvertebrates were collected from each sample site at three random locations determined by using a grid system. We used two D nets to collect organisms in a square foot area from the bottom of the creek. One net was placed along the bottom facing upstream in order to catch any organisms floating down with the current. The other was placed upstream facing the other and scraped along the bottom to loosen the organisms on rocks or in sediment. This process was repeated several times at each square foot. Rocks and large sediment were hand brushed to remove organisms that might be clinging to them. The nets were then emptied into tubs and all living organisms were collected and placed in jars with 95% isopropyl alcohol.

Preserved organisms were classified in the lab using dissecting microscopes. Macroinvertebrates were identified to the lowest taxa possible using stream macroinvertebrate field guides (Edwards pollution tolerance index (PTI) for each site. This was done by grouping the organisms into categories based on the Chesapeake Bay Water Initiative (Mitchell and Strapp 1997). Organisms in Group I that are very pollution intolerant (e.g., stoneflies and mayflies) received a score of three in the rating system. Group II organisms can live in a wide variety of conditions (e.g., craneflies and scuds) and received two points. Group III organisms can tolerate high levels of pollution (e.g., worms and snails) and received one point (Mitchell and Strapp 1997).

After species were identified, each species was grouped into an abundance category. Samples from each site were lumped together to examine abundance of species at each location. Species with numbers between one and ten were ranked as rare, species with numbers greater than 10 were considered common, and species with numbers greater than 100 were marked as dominant. The abundance category was then multiplied by an index value determined by the pollution tolerance group number for the species. The numbers were totaled, giving our PTI index number. That could be used to determine the quality of the stream. If the sum of the abundance index fell below 20 the stream was rated as poor, between 20 and 40 the stream was fair, and greater than 40 was a good quality stream (Mitchell and Strapp 1997).

Statistical Analysis

We used the statistical analysis program SPSS to analyze the data. We used a one-way ANOVA with a Tukey post-hoc test to test for significant differences in each water quality variable among the sites using October data. We used a two-tailed paired t-test to test for significant differences between fall 2011 and October 2013, fall 2012 and October 2013, and September 2013 and October 2013. In using one-way ANOVAs, we assumed the observations

Table 2: Mean (standard deviation) of water quality variables at Cozine, Mill, and Gooseneck Creeks in October 2013, as well as the probability from the ANOVA . Different letters denote significant differences among creeks as per Tukey Post Hoc test. Significant variables are highlighted.

Parameter	Cozine	Mill	Gooseneck	probability
DO(%)	58.5(6.5) a	90.1(1.7) b	96.7 (2.8) c	<0.0001
Phosphate (ppm)	0.04 (0.05) a	0.00 (0) b	0.00 (0) b	0.006
Nitrates (ppm)	0.11 (0.22)	0.0 (0.0)	0.0 (0.0)	0.123
Ammonia (ppm)	0.23 (0.08) a	0.04 (0.03) b	0.10 (0.06) b	0.00
Turbidity	5.95 (2.37) a	1.12 (0.23) b	2.43 (0.57) b	0.00
pH	6.3 (0.5)	6.7 (0.3)	6.5 (0.6)	0.249
Flow	0.7 (1.0) a	53.9 (35) b	12.3 (1.7) a	0.00
Temperature	11.5 (1.4) a	7.2 (1.3) b	8.2 (1.0) b	0.00
BOD	9.8 (6.0) a	1.1 (4.2) b	11.3 (6.3) a	0.001

Table 3: Mean (standard deviation) for water quality variables in September 2013 and October 2013 at Gooseneck, Mill, and Cozine Creeks. Probability is from two-tailed, paired t-test analyses. Significant variables are highlighted.

Parameter	**Site Location**	**September 2013**	**October 2013**	**probability**
pH	Cozine	6.3 (0.5)	6.3 (0.5)	0.6085
	Gooseneck	7.2 (0.2)	6.5 (0.6)	0.0167
	Mill	6.7 (1.2)	6.7 (0.3)	0.2548
Flow	Cozine	0.4 (0.9)	0.7 (0.3)	0.6811
	Gooseneck	1.1 (1.1)	12.2 (1.7)	<0.0001
	Mill	17.3 (14.4)	53.9 (34.7)	0.0009
Temp C	Cozine	13.4 (0.7)	11.5 (1.4)	0.0085
	Gooseneck	21.9 (1.9)	8.2 (1.0)	<0.0001
	Mill	15.8 (2.1)	7.2 (1.3)	<0.0001
DO (%)	Cozine	43.5 (8.6)	58.5 (6.5)	0.0002
	Gooseneck	93.3 (1.6)	96.7 (2.8)	0.0343

Table 4: Mean (standard deviation) for water quality variables comparing Fall 2011 to Fall 2013 and Fall 2012 to Fall 2013 at Gooseneck, Mill, and Cozine Creeks. Probability is from two-tailed, paired t-test analyses; with each pair of years having a posted p-value. Significant variables are highlighted.

Parameter	**Site**	**Fall 2011**	**Fall 2012**	**Fall 2013**	**Probability (2011 vs 2013)**	**Probability (2012 vs 2013)**
DO %	Cozine	69.3 (2.9)	58.2 (1.0)	58.5 (6.5)	0.001	0.912
	Gooseneck	97 (1.2)	89.42 (4.72)	96.7 (2.8)	0.750	0.808
	Mill	NA	90.22 (3.76)	90.1 (1.70)	NA	0.590
Temp C	Cozine	12.3 (0.1)	9.6 (0.35)	11.5 (1.4)	0.091	0.027
	Gooseneck	12.2 (0.2)	12.3 (0.71)	8.2 (1)	0.000	0.000
	Mill	NA	8.24 (0.58)	7.19 (1.34)	NA	0.005
pH	Cozine	6.8 (0.2)	6.49 (0.26)	6.3 (0.5)	0.001	0.036
	Gooseneck	6.6 (0.4)	7.12 (0.24)	6.5 (0.6)	0.807	0.001
	Mill	NA	6.53 (0.32)	5.19 (2.95)	NA	0.182
Flow (cm/s)	Cozine	44.9 (73.6)	10.5 (8.6)	0.7 (1.0)	0.108	

Table 5: Mean (standard deviation) of the number of coliform bacteria in October 2013 at Cozine, Mill, and Gooseneck Creeks, as well as the probability from the ANOVA. Different letters denote significant differences among creeks as per a Tukey Post Hoc test. Significant variable are highlighted.

	***E. coli* (colonies per 100mL) Sept 2013**	**Other coliforms (colonies per 100 mL) Sept 2013**	***E. coli* (colonies per 100mL) Oct 2013**	**Other coliforms (colonies per 100 mL) Oct 2013**
Cozine	44.4 (68.2)	138.9 (92.8) a	17.8 (27.3)	55.6 (37.1) a
Gooseneck	26.7 (28.3)	8.9 (14.5) b	26.7 (28.3)	8.9 (14.5) b
Mill	4.4 (2.9)	0.0 (0) b	4.4 (8.8)	0.0 (0) b
Probablity	0.1626	<0.0001	0.1466	<0.0001

There were significantly more other coliforms in Cozine Creek in October than in September 2013 (Table 7). But there were significantly more *E. coli* and other coliforms in Mill Creek in September than in October 2013.

Table 7: Mean, (standard deviation) and p value for results of paired t-tests for bacterial counts comparing September 2013 to October 2013.

	Cozine		**Gooseneck**		**Mill**	
	E.coli (colonies per 100mL)	**Other coliforms (colonies per 100mL)**	**E.coli (colonies per 100mL)**	**Other coliforms (colonies per 100mL)**	**E.coli (colonies per 100mL)**	**Other coliforms (colonies per 100mL)**
Sept 2013	11.1 (22.0)	0.0 (0)	26.7 (28.3)	8.9 (14.5)	38.9 (33.3)	22.2 (26.4)
Oct 2013	17.8 (27.3)	55.6 (37.1)	26.7 (28.3)	8.9 (14.5)	4.4 (8.8)	0.0 (0)
probability	0.638	0.002	--	--	0.022	0.035

Mill Creek had the greatest number of species of macroinvertebrates, but the results were not significantly different among the sites (Table 8).

Table 8 The number of macroinvertebrate organisms collected at each of the three creeks, as well as total number of species and total number of organisms per creek.

	Cozine	**Gooseneck**	**Mill**
Mayflies	2	48	20
Stoneflies	4	67	111
Netspinners	0	2	19
Scuds	47	1	4

Gooseneck and Mill Creeks had higher numbers of pollution sensitive species (Table 9) than Cozine Creek, but all three creeks had similar numbers of wide spread and pollution tolerant species.

Table 9. The number species in each of the three Pollution Tolerance Index group at each Creek.

Site	**Group I - Pollution Sensitive**	**Group II - Wide Spread**	**Group III – Pollution Tolerant**
Cozine	4	2	4
Gooseneck	9	2	4
Mill	9	3	4

Mill and Gooseneck Creeks had higher PTI levels than did Cozine Creek (Table 10), although the results were not significantly different among the sites (p=0.565)). Based on the average PIT, Mill and Gooseneck Creeks were rated fair, whereas Cozine Creek was rated poor.

Table 10. Pollution Tolerance Index (PTI) values per site, with mean and standard deviation per stream.

Site

Of note is the fact that this was the first year two collections were made, one in September and one in October. We compared the data from the two months to examine the differences. Temperature and turbidity tended to be higher in September, whereas flow and DO tended to be higher in October. Nutrient and bacterial levels varied by site. The week before the September sampling, there were 1.22 inches of rain. The week before the October sampling, there were only 0.5 inches of rain (Wunderground 2013). However, our stream depth data revealed that depths at all creeks were greater in October than in September. This may have been due to the reduced temperature that would reduce evaporation, as well as an overall accumulation of water.

The increased flow and decreased temperature may be the reason for an increase in DO observed at Cozine and Gooseneck Creeks as well as the decrease in BOD at Cozine and Mill Creeks due to the relationship between temperature and oxygen (Steichen et al 1979). It was interesting that turbidity decreased at all sites between September and October, because precipitation events often increase turbidity in streams by increasing nearby soil erosion due to runoff (Heinzel 1967).

pH only changed at Gooseneck when it decreased from September to October. The higher pH in September at this creek may be due to the fact that the creek bed is highly eroded down to carbonate bedrock (Bailey et al. 2012). Cozine Creek had increased *E.coli* and other coliform bacteria from September to October. Streams often have higher bacterial contamination on wet weather days or after large storm events, which may account for the increase in these numbers between September and October (Parks and VanBriesen 2009; Paul and Meyer 2001). Gooseneck Creek bacterial levels stayed the same, while Mill Creek levels decreased.

Overall, our data support our hypothesis that Cozine Creek has lower water quality than either Gooseneck or Mill Creeks. This is very likely due to its urban location, which contributes to higher nutrient and bacterial levels. Gooseneck and Mill, although located in agricultural areas, appear to be more buffered from the larger impacts of that land use, and have fair water quality. The data collected by our class are consistent with the findings of the 2011 and 2012 classes, suggesting that the streams are not improving.

Limitations

Like all studies, there are several limitations to this study. One limitation that became apparent when comparing our data to previous years is that three different DO meters have been used in the past three years. This presents a possible problem when comparing DO and BOD as we are unsure of the consistency among the meters.

Another major limitation is the impact of weather on stream water quality. The data we collected in September occurred after a major rain storm that was followed by a relative dry period. Another rain fall event occurred before we made our second collections in October. IN addition, the temperature had fallen significantly between the times of the collection. Although we attempted to account for this in our comparison the two sets of data, there may be some results that are not consistent due to this weather. We could only get weather data for McMinnville, which may not be accurate for Gooseneck and Mill Creeks.

A third limitation relates to identifying macroinvertebrates. All members of the class counted different jars. We each had different levels of knowledge about macroinvertebrates, so there may be inconsistencies and mistakes made in counting and identification. Two of the draw samples from Cozine Creek were brought into the lab, where we separated macroinvertebrates from the sediment under controlled conditions; all the others were completed in the field. This could have led to discrepancies in some of the Cozine data. In addition, the best time to sample macroinvertebrates in summer, which is the peak of larval abundance. By sampling in fall, we are not finding all the potential macroinvertebrate larvae that would be present several months earlier.

Finally, there is always the possibility of errors made recording or measuring data. Equipment may have been used improperly, or data may have ben written down incorrectly. Most of the equipment we used took a while to stabilize, so students may not always have waited for the most accurate reading. While we did our best to avoid these problems, there is always a chance that they occurred.

Recommendations for Future Classes

There are several recommendations we would suggest to future. First, adding a site upstream (preferably near the headwaters) of Cozine Creek would be beneficial in determining more about the quality of the headwaters and how it changes with urbanization. Adding headwater sites on Mill and Gooseneck would also be good. It might also be beneficial to use two urban streams to balance our two rural streams (Mill and Gooseneck). It would also be good to track the weather at our sites for a week before we sample the streams; that might be helpful in analyzing our findings. In the future, we should also test to see if nutrient levels are different in the lab than the field. We don't know how freezing the samples impacts the nutrient content although we do not believe it does. Also, for the best year to year comparisons, it would be important to use the same equipment every year.

Acknowledgements

We would like to thank Tom Rupers for allowing us to sample the sections of Gooseneck and Mill Creeks that run through his property. We would also like to thank the Greater Yamhill Watershed Council for their help in finding the site at Gooseneck Creek, as well as getting the class of Spring 2011 started on this project. We also would like to thank Barbara Van Ness for helping us in lab and the field.

References

Andreen W.L. 2004. Water Quality Today-Has the Clean Water Act Been a Success. Alabama Law Review 55: 537-593.

Bailey, Kourtney., Codd, Rachel., Holm, Katharine., O'Brien, Katie., Yarber, Morgan. 2012. Comparative Water Quality Study of Cozine, Gooseneck, and Mill Creeks. Linfield College. https://bblearn.linfield.edu/bbcswebdav/pid-189471-dt-content-rid-1405044_1/courses/2013FA-ENVS38501/ENVS385Fall2012FinalPaper.pdf

Booth, Derek B. 2005. Challenges and prospects for restoring urban streams: a perspective from the Pacific Northwest of North America. Journal of the North American Benthological Society. 24(3): 724-737.

Bower, Robert J., Chris Lupoli, and Tamara Quandt. 1999. Mill Watershed Assessment. Yamhill Basin Council.https://nrimp.dfw.state.or.us/web%20stores/dat%20libraries/files/Watershed%20Councils/Watersher%20Councils_230_DOC_MillCrkAssmnt.pdf.

CDC. 2012. Salmonella and Drinking Water from Private Wells. Available from: <http://www.cdc.gov/healthywater/drinking/private/wells/disease/salmonella.html>.

Cunningham, W. P. and Cunningham, M. A. 2010. *Environmental Science: A Global Concern.* McGraw Hill Higher Education Publishing, New York, NY.

DEQ (Department of Environmental Quality). 2006. Willamette Basin TMDL: Middle Willamette Subbasin. 89 pages. http://www.deq.state.or.us/wq/tmdls/docs/willamettebasin/willamette/chpt7midwill.pdf

DEQ (Department of Environmental Quality). 2012. Annual Performance Progress Report (APPR) for fiscal year (2011-2012). http://www.deq.state.or.us/about/PerformanceMeasures/10progressReport.pdf

Edwards, Patrick. 2008. *Stream Insects of the Pacific Northwest*. 43 pages.

Earth Force. 2010a. Dissolved Oxygen. http://www.earthforce.org/ViewResource.php?AID=3

Earth Force. 2010b. Nitrates. http://www.earthforce.org/ViewResource.php?AID=5

Earth Force. 2010c. Phosphates. http://www.earthforce.org/ViewResource.php?AID=7

EPA (Environmental Protection Agency). 2008. Fecal Coliform and *E.coli*. http://www.epa.gov/katrina/fecal.html

EPA (Environmental Protection Agency). 2012a. 5.2 Dissolved Oxygen and Biochemical Oxygen Demand. http://water.epa.gov/type/rsl/monitoring/vms52.cfm

EPA (Environmental Protection Agency). 2012b. 5.2 Nitrates. http://water.epa.gov/type/rsl/monitoring/vms57.cfm

EPA (Environmental Protection Agency). 2012c. The Clean Water Act: Protecting and Restoring our Nation's Waters. http://water.epa.gov/action/cleanwater40/cwa101.cfm

EPA (Environmental Protection Agency). 2012d. 4.1 Stream Habitat Walk. http://water.epa.gov/type/rsl/monitoring/vms41.cfm

EPA (Environmental Protection Agency). 2012e. 5.5 Turbidity. http://water.epa.gov/type/rsl/monitoring/vms55.cfm.

Heinzel, Lloyd. 1967. Storm Effects on Turbidity in Trinity Water Projects. American Water Works Association 59(7): 835-842.

Ishii, S. and MJ Sadowsky. 2008. *Escherichia coli* in the environment: Implications for water quality and human health. Microbes and Environment 23(2): 101-108.

Krueger, C. and Waters, T. 1983. Annual production of macroinvertebrates in three streams of different water quality. *Ecology*. Ecological Society of America. 64(4): 840-850.

LaMotte. 2012a. Ammonia-Nitrogen Test Kit. Code 5864.

LaMotte. 2012b. Low Range Phosphate in Water Test Kit. Model PAL. Code 3121-01.

LaMotte. 2012c. Nitrate Nitrogen Tablet Kit. Code 3354.

Lear, G., Boothroyd, I., Turner, S., Roberts, K., Lewis, G. 2009. A comparison of bacteria and benthic invertebrates as indicators of ecological health in streams. Freshwater Biology. 54: 1532-1543.

Lindbo, D. Torrey and Stacy L. Renfro. 2003. *Macroinvertebrates. Riparian and Aquatic Ecosystem Monitoring: A Manual of Field and Lab Procedures* 4th ed. Student Watershed Research Project. Saturday Academy.

McBride, M., D. Booth. 2005. Urban impacts on physical stream condition: effects of spatial scale, connectivity and longitudinal trends. Journal of the American Water Resources Association 41(3): 565-580.

Michigan DEQ (Department of Environmental Quality). 2012. Water Quality Parameters. http://www.michigan.gov/deq/0,4561,7-135-3313_3682_3713-10416--,00.html.

Micrology Laborites. 2008. Detection of Waterborne *E. coli*, Total Coliforms, *Aeromonas*, and *Salmonella* with ECA Check (Plus) Easygel.

MDNR (Missouri Department of Natural Resources). 2013. Water Quality Parameters. http://www.dnr.mo.gov/env/esp/waterquality-parameters.htm

Mitchell and Stapp. 1997. Volunteer Stream Monitoring: A Methods Manual. United States Environmental Protection Agency, Office of Water, Draft Document #EPA 841-B-97-003, Field Manual for Water Quality Monitoring. http://hydro.geog.udel.edu/DGA/resources/chesapeake_bay/Grade%207/Grade%207%20Pollution%20Tolerance%20Index%20work%20sheet.pdf

Mueller D. K. and Dennis R. Helsel. 2009. Nutrients in the Nation’s Waters—Too Much of a Good Thing? USGS. http://pubs.usgs.gov/circ/circ1136/circ1136.html#CONCERNS.

Mylinski, Elizabeth and Walter Ginsburg. 1977. Macroinvertebrates as indicators of pollution. American Waterworks Association. 69(10): 538-544.

ODA (Oregon Department of Agriculture). 2012. Oregon State Noxious Weeds List, [Online] Available: <http://www.oregon.gov/ODA/PLANT/WEEDS/pages/statelist2.aspx> [Accessed 8 October 2013].

ODEQ (Oregon Department of Environmental Quality). 2010. Water Quality Assessment Data base. http://www.deq.state.or.us/wq/assessment/rpt2010/search.asp.

Palmer, T. 1993.The Wild and Scenic Rivers of America. Island Press, Washington, D.C.

Parks, S. and J. VanBriessen. 2009. Evaluating temporal variability in bacterial indicator samples for an urban watershed. Journal of Environmental Engineering 135(12): 1294-1303.

Resh, Vincent H. and Unzicker, John D. 1975. Water quality monitoring and aquatic organisms: the importance of species identification. Water Pollution Control Federation 47(1): 9-19.

SciOly: Science Olympiad student center. 2013. Water Quality and Macroorganism list. http://scioly.org/wiki/index.php/Water_Quality/Macroorganism_List

SEPA (Scottish Environment Protection Agency). 2013. Ammonia. http://apps.sepa.org.uk/spripa/Pages/SubstanceInformation.aspx?pid=1

Steichen, James M., James E. Garton, and Charles E. Rice. 1979. The effects of lake destratification on water quality. American Waterworks Association 71(4): 219-225.

Stroud Water Research Center. 2013. Identification Guide to Freshwater Macroinvertebrates. http://www.stroudcenter.org/education/MacroKeyPage1.shtm

Sudduth, E., B. Hassett, P. Cada, E. Bernhardt. 2011. Testing the field of dreams hypothesis: functional responses to urbanization and restoration in stream ecosystems. Ecological Applications 21(6): 1972-1988.

USGS (United States Geological Survey). 2012a. Water Quality.______________________