Fall 2017

Examining Water Quality along Cozine Creek

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Senior Capstone ENVS 460: Fall 2017

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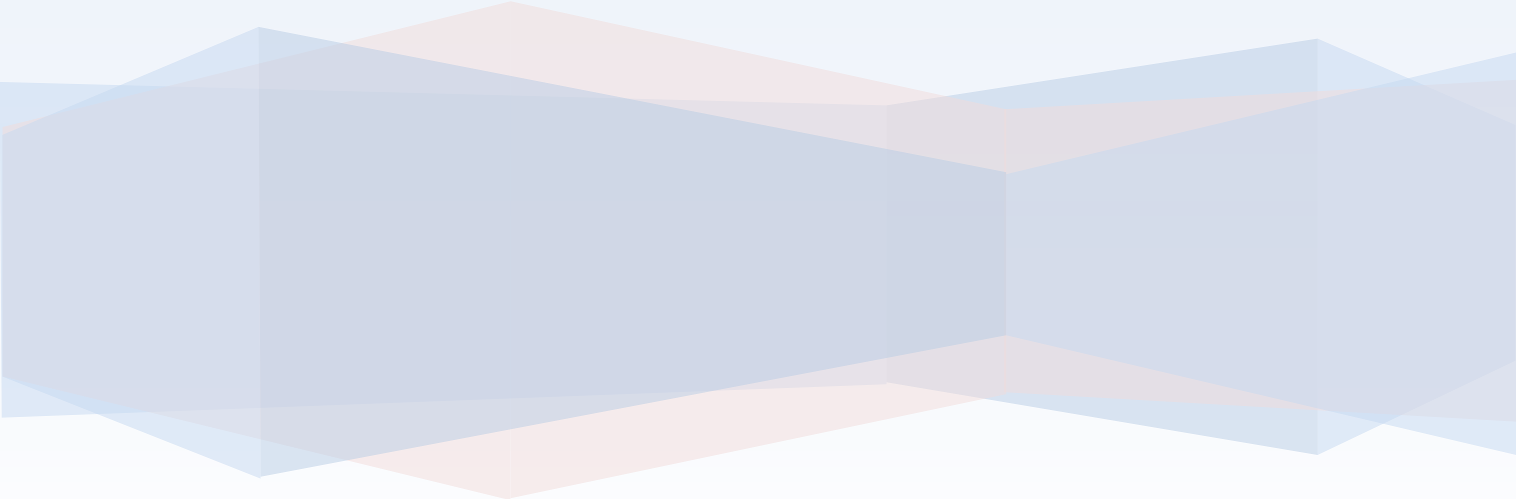

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Introduction

Water is an essential resource for all life. Water sustains ecological processes that are important to the survival of fish, vegetation, wetlands, and birds. It contributes to humans by providing drinking water, irrigation, and also is an inspiration for recreational, cultural, and spiritual practices (OEH 2017). Anthropogenic activities affect water quality in various ways, and a significant portion of the human population is currently experiencing water stress (Vorosmarty et al. 2000). The quality of water, as well as its social and economic value, share a positive relationship. Therefore, as water quality becomes degraded by pollution, the environmental, social, and economic value also decrease. The recognition of the importance of safe water has created crucial policies in the United States and internationally (WHO 2004).

The significance of water quality in the United States plays a larger role than one might expect. Citizens maintain a certain right to clean water for a variety of uses including recreation, agriculture, drinking, habitat, and industry. In 1972, the Clean Water Act (CWA) looked to solve the problem of cleaning up our nation's waterways by eliminating all pollution by 1985. Although the goal of total pollution elimination was never achieved, the Act did assist the United States in the beginning to restore its heavily impaired waterways (Salzman and Thompson 2014).

The CWA attempted to eliminate all point source pollution, which is defined by the U.S. Environmental Protection Agency (EPA) as “any single identifiable source of pollution from which pollutants are discharged,” but it has made much less of an impact on nonpoint source pollution (NOAA 2017). Nonpoint sources are those that do not come from an identifiable source. Nonpoint sources include runoff from industries and urban areas (EPA 2017a). In today’s battle on water quality, agriculture’s large-scale practices are the greatest contributor to nonpoint pollution. Although the CWA does require that states designate agencies to create management plans and monitor areas of specific importance under section 208, it does not require that the states execute their developed plans. Although there were efforts to enforce this legislation, the power of implementation stayed firmly with the states largely due to the massive lobbying power of the agriculture business (Salzman and Thompson 2014).

Despite the national implementation of the CWA, Oregon has taken ownership of the nonpoint problem and is in the vanguard of water quality management. Based on technological limitation, the CWA outlawed the discharge of any pollutant through the National Pollution Discharge Elimination System (NPDES). Even further, the designations given to the state’s waterways set daily discharge parameters for substances deemed harmful or threatening the ecosystem and human health. Toxic Release Inventories (TRIs) and Total Maximum Daily Loads (TMDLs) are the two major statutes that Oregon and the rest of the nation use to keep levels of harmful effluents at acceptable levels (Salzman and Thompson 2014).

Among the leading sources of pollution in Oregon, agriculture has been shown to increase nitrogen, phosphorus, and ammonia in stream ecosystem through runoff by fertilizers. Local dairies and animal farms may also contribute animal waste runoff, which also has been shown to increase unhealthy bacteria like *E. coli* and *Salmonella* in aquatic ecosystems (Dufour et al. 2012). Runoff from roads adds unwanted pollution to stream ecosystems that can disrupt key plant and animal populations (Hallberg and Renman 2004). Human waste and pollution also contribute to adverse streams if sewage and other means of waste transport are not adequately maintained (Cease et al. 2015).

Our study will look specifically into the water quality of Cozine Creek. The creek is located in Yamhill County, Oregon. As Cozine Creek flows eastward out of the hills west of McMinnville, it meanders through forests and farm fields until it eventually reaches the city and dumps into the South Yamhill River. As a result of flowing through both agricultural and urban areas, Cozine is exposed to numerous nonpoint pollutants (GYWC 2017). Agricultural and industrial land alters many important environmental factors regarding the aquatic structure in Cozine Creek (Novotny 2003). Agricultural and urban land uses, when improperly managed, can lead to unwanted negative ecological reactions (Vanni et al. 2013). Urban land use such as roads, housing, and businesses can potentially harm ecosystems that exist within their boundaries (Hallberg and Renman 2004). This process may lead to unwanted environmental, social, and economic costs to the community in which the stream lies (Jacobs and Timmons 1974).

As the largest westside tributary to the Willamette River, the Greater Yamhill Watershed covers 529,510 acres, 70% of which lie in Yamhill County in Oregon. It provides more than 350 miles of habitat for winter steelhead trout, coastal cutthroat trout, Pacific and brook lamprey, and Coho salmon. Spring Chinook salmon, listed as “threatened” under the Endangered Species Act, also rear in the Yamhill River. A 2009 to 2014 study found that the Yamhill River Watershed supports the highest population of naturalized Coho salmon in the Upper Willamette River. The watershed is not strictly protected, which puts waters at risk to pollution. The conversion of land to agriculture, urbanization, and other development has threatened native species in the area (GYWC 2017).

The goal of our study was to determine how water quality variables compare among our sampling sites this year and across the years from 2011 to the present. We are using the definition of water quality as determined by measuring physical, chemical, and biological characteristics (USGS 2014). We measured dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, temperature, flow, turbidity, macroinvertebrates, bacterial counts, nutrients, and surrounding vegetation (USGS 2016). To present a better understanding to the measurements of the water quality variables, we will compare the measurements to the scientifically known parameters of healthy salmonid habitat. The presence of salmon indicates a healthy watershed (EYC 2017).

Water Quality Variables

Dissolved oxygen (DO) is the amount of oxygen found in a body of water and is needed by all aerobic organisms to survive. Wind, waterfalls, and rapids result in higher amounts of dissolved oxygen. Photosynthetic aquatic organisms such as plants and cyanobacteria take in carbon dioxide and release oxygen. As organisms undergo respiration, they decrease the amount of oxygen in the water. The level of dissolved oxygen is a determinant of which species can survive in water (Breitburg et al. 1997). Dissolved oxygen below 9.0 ppm can significantly impair salmonid reproduction and survival (Wasowski et al. 2013).

Biochemical Oxygen Demand (BOD) measures the amount of oxygen consumed by microorganisms in decomposing organic matter, as well as by the chemical oxidation of inorganic matter (Delzer and McKenzie 2003). A higher BOD indicates low amounts of dissolved oxygen, which indicates low water quality. Effluents from wastewater treatment plants as well as agricultural and urban storm runoff increase BOD by increasing the amount of organic and inorganic material from the waste in waterways because more oxygen in the water is being used to break down the matter (EPA 2014).

The level of pH indicates the alkalinity or acidity of a body of water. It is calculated using the concentration of hydronium ions in moles per liter and is represented by a scale from 0 to 14 with low numbers representing acidity and high values indicating alkalinity; 7 is neutral. The pH of water is important in what species can live there. Low pH in the Stony River Watershed, Wisconsin, for example, reduced larval fish survival (Hafs et al. 2010). Many fish species such as trout can only survive in a pH range of 5.0 to 6.5. pH also can change the behavior of chemicals in water. As water becomes more acidic, the chemicals and minerals in the water change and can have a devastating impact on fish populations. For example, the concentration of ammonia increases to toxic levels for fish as pH decreases. The pH of a stream can be affected by contamination from chemicals in the runoff, and a low pH can result in death or reduction of growth for many species (Perlman 2016).

Water temperature influences biological activity as well. Water temperature varies with seasonal changes, the degree of shade, the flow rate, the depth, and the presence of thermal pollution (USGS 2016). Warm water temperatures have an inverse relationship with dissolved oxygen, so warmer water contains less dissolved oxygen than colder water (USGS 2014). At higher temperature, water holds less dissolved oxygen and has a lower pH. Warmer water temperatures affect the distribution, health, and survival of native salmonids in Oregon (EPA 2003).

Flow, also known as discharge, is the measure of the amount of water that moves across an area in a fixed period (EPA 2012a). Discharge plays a significant role in stream ecosystems. The amount of flow is directly related to the characteristics of a stream’s watershed and is affected by irrigation, rainfall, and seasons. Flow is minimal when dams, fallen branches or debris block streams. Woody debris, large rocks, and streamside vegetation slow down water speed and provide habitat for most fish. Fast moving streams have more dissolved oxygen and lower temperatures. Although some aquatic organisms prefer reduced flow, others prefer fast-moving streams. Areas of reduced flow have an increased mortality of juvenile salmon, trout, and grayling (Riley et al. 2009).

Turbidity is a measure of the clarity of water. Clarity can change due to suspended material found in any waterway. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. Because it is a measure of suspended material, turbidity increases with agricultural or other runoff. Higher turbidity increases water temperatures because suspended particles absorb more heat (EPA 2012b). More importantly, high turbidity has adverse impacts on fish. A report from the European Inland Fisheries committee found that turbid waters can reduce growth rate and eventually kill fish. Highly turbid waters can also affect fish migration and movement by delaying the development of fish eggs and larvae. Overall, turbidity reduces the amount of food available, leaving fish to compete for food (MPCA 2008).

Nitrate, ammonia, and phosphate are essential nutrients found in water, but an excess of these chemicals may have detrimental effects on aquatic and human life. Increased nutrients can lead to the destruction of valuable stream resources and deoxygenation. Excess nitrogen, ammonia, and phosphorus may enter the water from natural causes, such as organic material decay, and anthropogenic causes such as fertilizers, agricultural runoff, and sewage (Hardie and Bobbi 2017).

Nitrogen is abundant on earth. Earth's air contains 78 percent of nitrogen in its gaseous form (N_2), but most plants lack the ability to use the element in this form. Some plants prefer different forms of nitrogen. Nitrogen fixing bacteria convert the gas into ammonia that is then converted by other bacteria into nitrite. Nitrite is converted to nitrate by still other bacteria. Plants take up ammonia or nitrate from the soil. Although plants require nitrogen to make proteins, excess nitrogenous compounds can have detrimental effects on life (Behar 1997). Krueger and Waters found that higher nitrate levels in water may increase the protein content of leaves, making nitrate-rich leaves a more attractive food source to some organisms (Krueger and Waters 1983). Ingestion of high levels of nitrates by animals can restrict oxygen transport in the bloodstream, which can be exceptionally dangerous for infants (USGS 2017). The EPA standard for nitrate in water must be below 10 parts per million (ppm). (EWG 2017) Ammonia can be toxic based on temperature and pH of water. As pH or temperature increase, the toxicity of water increases because the un-ionized form of ammonia ($NH4^+$) is converted into the ionized form ($NH3^+$), which is more poisonous to aquatic life (SWRCB 2014). It is possible to find ammonia and nitrate at different levels because the contents may be in different parts of the nitrogen cycle and/or have different sources. Organisms living in water with high enough levels of ammonia have trouble excreting it, resulting in a buildup in tissues and blood, which may cause death (EPA 2013). Phosphate, although integral to plant growth and metabolic processes in plants and animals, can cause significant plant growth in water systems. Extra phosphate may enter water through fertilizers and erosion. In high concentrations, phosphate can pose a threat to human health (Behar 1997).

A balance of the three nutrients supports the growth of plants and algae that provide food and habitat for organisms that live in water. Eutrophication occurs when a high amount of nutrients in the water promotes plant and algae growth. As the organisms die, their decomposition depletes the oxygen in the water at a faster rate than the ecosystem can support (EPA 2017c). The lack of oxygen, hypoxia, kills fish and lowers biodiversity because many organisms cannot survive depleted oxygen levels. Phosphate, in particular, is the most common cause of eutrophication. These extra nutrients degrade aquatic ecosystems and increase human health risks of water use (Carpenter et al. 1998).

The levels of bacteria such as *Escherichia coli* (*E. coli*), *Aeromonas*, *Salmonella*, and other coliforms may indicate the presence of disease-causing coliform bacteria in a body of water. *E. coli* is found in the fecal matter of humans and other warm-blooded animals. Although most strains of *E. coli* are not pathogenic, their presence indicates fecal contamination; thus, any waterway with more than 406 *E. coli* colonies per 100 mL is considered a health risk according to the EPA. *E. coli* indicates that sources such as storm water runoff, disconnected sanitary sewers, animal wastes, broken sewer pipes, ineffective sewer treatment, or pet wastes may have entered the waterway (EPA 2015). *Aeromonas*, a ubiquitous coliform, is associated with some human and animal diseases. Species of *Aeromonas* related to human infections include *A. hydrophila*, *A. veronii*, *A. caviae*, and *A. dhakensis* (Chen et al. 2017). The EPA lists explicitly *A. hydrophila* on the first and second Contaminant Candidate List (CCL 1 and CCL 2) of potential waterborne pathogens (EPA 2006). *Salmonella typhi* and *S. enterica* are strains of pathogenic *Salmonella* that originate from fecal matter from infected humans and animals. Although the techniques used in our study limit our ability to identify species, any level of *Salmonella* in the water could indicate the water is unsafe to drink. Other coliforms found in water also could indicate fecal contamination. The EPA requires all drinking water systems to abide by the Total Coliform Rule, which states that coliforms should not be found in more than five percent of samples (EPA 2017b). Any sample that exceeds five percent must be reported to the state and public. Finding adverse counts of *E. coli, Aeromonas, Salmonella,* and other coliforms in a body of water suggests that recreational use should be approached with caution (Ishii and Sadowsky 2008).

Another way to determine water quality is by capturing and identifying species of macroinvertebrates, organisms that lack a backbone but are large enough to be seen by the naked eye. Examples of macroinvertebrates include snails, midges, and clams, all of which can be found in Cozine Creek. Depending on the species, macroinvertebrates can be found in various locations and can be exposed to a wide spectrum of pollution as they have limited mobility and spend all their time in the same area of a stream. Different macroinvertebrates are sensitive to various levels of pollution, allowing observers to deduce water quality based on which species are found in a body of water. There are two types of macroinvertebrate sampling based on the substrate or creek bottom. Rocky-bottom sampling is correlated with fast oxygen-rich water with a stream floor consisting mainly of rocks and boulders. The second form of sampling would be muddy-bottom sampling. Mostly found on flat land, these bodies of water tend to have a low flow rate and a substrate composed chiefly of mud or silt. The two types of sampling help illustrate the sharp differences in types of water quality, as many of the more sensitive species require a streambed with rocks for survival (EPA 1997).

The pollution tolerance index (PTI) of macroinvertebrates gives an indication of the overall pollution level of a body of water by assigning a numerical value to each species based on its tolerance to pollution (one being a high tolerance, two being a fair tolerance, three being a moderate intolerance, and four being an intolerant). After the macroinvertebrates are collected and identified, points are assigned to each collected taxa, and the scores of all the specimens are summed to generate a PTI number for the stream. Streams with scores higher than 23 are deemed to be in excellent shape whereas streams receiving a score lower than ten are deemed poor (Table 1) (IDEM 2017). Macroinvertebrates provide primary food for organisms on higher trophic levels. Thus, a higher diversity of macroinvertebrates indicates better water quality and habitat (Schumaker 2006).

Table 1. PTI values and the stream quality they indicate (IDEM 2017).

Pollution Tolerance Index (PTI)	Stream Quality
> 23	Excellent
17-22	Good
11-16	Fair
<10	Poor

Riparian vegetation also affects water quality. Streamside vegetation removes nutrients in runoff, stabilizes soil, and supplies organic matter to soils (Dosskey et al. 2010). Vegetation produces shade that helps reduce water temperature, provides fish cover from predation, stabilizes banks, reducing erosion, and generates habitat for insects and macroinvertebrates (Empfield 2001). Before European settlement, the Cozine Creek area was covered with oak savanna and prairie grasslands. Over time, introductions of invasive species altered the natural setting of the riparian habitat (GYWC 2017). Himalayan blackberry (*Rubus armeniacus*) has been recorded in many Cozine Creek sites (Yamhill Basin Council 2001). Once established, Himalayan blackberry can dominate an area and outcompete native plants. Invasive plants such as English ivy (*Hedera helix*) cover shrubs and herbs, preventing them from growing and developing into adult stages. Ivy also climbs trees, increasing their wind resistance and the probability of being uprooted (NPS 2010). The biodiversity of a site decreases as native species are displaced (Soll and Lipinski 2004).

Goals of Study and Hypothesis

We examined the water quality variables for values that indicate optimum healthy salmonid habitat. An optimum pH for salmonids is between 6.5 and 8.5. If the pH is too low, salmonids will have a reduced blood oxygen carrying capacity, which will raise stress and may lead to low reproductive capability (DFO 1983). Similarly, dissolved oxygen below 9.0 ppm can significantly impair salmonid reproduction and survival (Wasowski et al. 2013). However, DO decreases as water temperature increases. Also, the optimal temperature for salmon between 5.0 and 12 °C. When temperatures rise above optimal, diseases become more common in fish (DFO 1983). Additionally, salmonids may be affected by high turbidity because the suspended material may prevent the gills from functioning properly. High turbidity also can damage redds used for reproduction and create an imbalance in blood chemistry for the fish. A number of studies have indicated that turbidity as low as 10 to 25 FTUs can have deleterious effects on fish (Bash and Berman 2001). In addition, ammonia levels need to be less than 10 ug/L NH_3. More stringent maximum levels are required when the water temperature, dissolved oxygen, or pH are lower than optimal levels for survival (DFO 1983).

The students in the fall 2017 Senior Capstone Research Methods class (ENVS 460) measured water quality parameters at three locations along Cozine Creek and collected baseline vegetation data at three locations in the Cozine Creek area on campus. The main goal was to compare water quality at different areas in the creek, as well as over time at the campus site to help determine the best course of action to restore the creek and to assess if future restoration activities improve water quality. The vegetation data will allow us to track abundances of native and non-native species. Our information may help educate the community (neighbors and stakeholders) on how to better manage local creeks. We hypothesized that the Linfield College site would have the poorest water quality because it is downstream of the other two sites. We assumed that the Linfield College site would show the accumulation of pollutants over the creek's longer flow. We also expected the Old Sheridan Bridge site and the Library site to have significantly different water quality variables because the sites are on two different branches of the creek. Finally, we hypothesized that Cozine Creek would continue to have moderately poor water quality because there have not yet been significant strides in Cozine restoration since previous years that would improve the water quality since the collection of past years' data. (Weinbender et al. 2011; Bailey et al. 2012; Hollenbeck et al. 2013; Fahy et al. 2014; Blanco et al. 2015; Cowell et al. 2016).

Site Descriptions

Our study areas were in three areas along Cozine Creek: on the Linfield College property, downstream from the Old Sheridan Bridge located in Halloway Park, and in City Park near the McMinnville library (Figure 1). At each site, three subsites were randomly chosen to be the sampling locations. The GPS coordinates of each subsite were taken using a Garmin e-trex 30x GPS (Table 2).

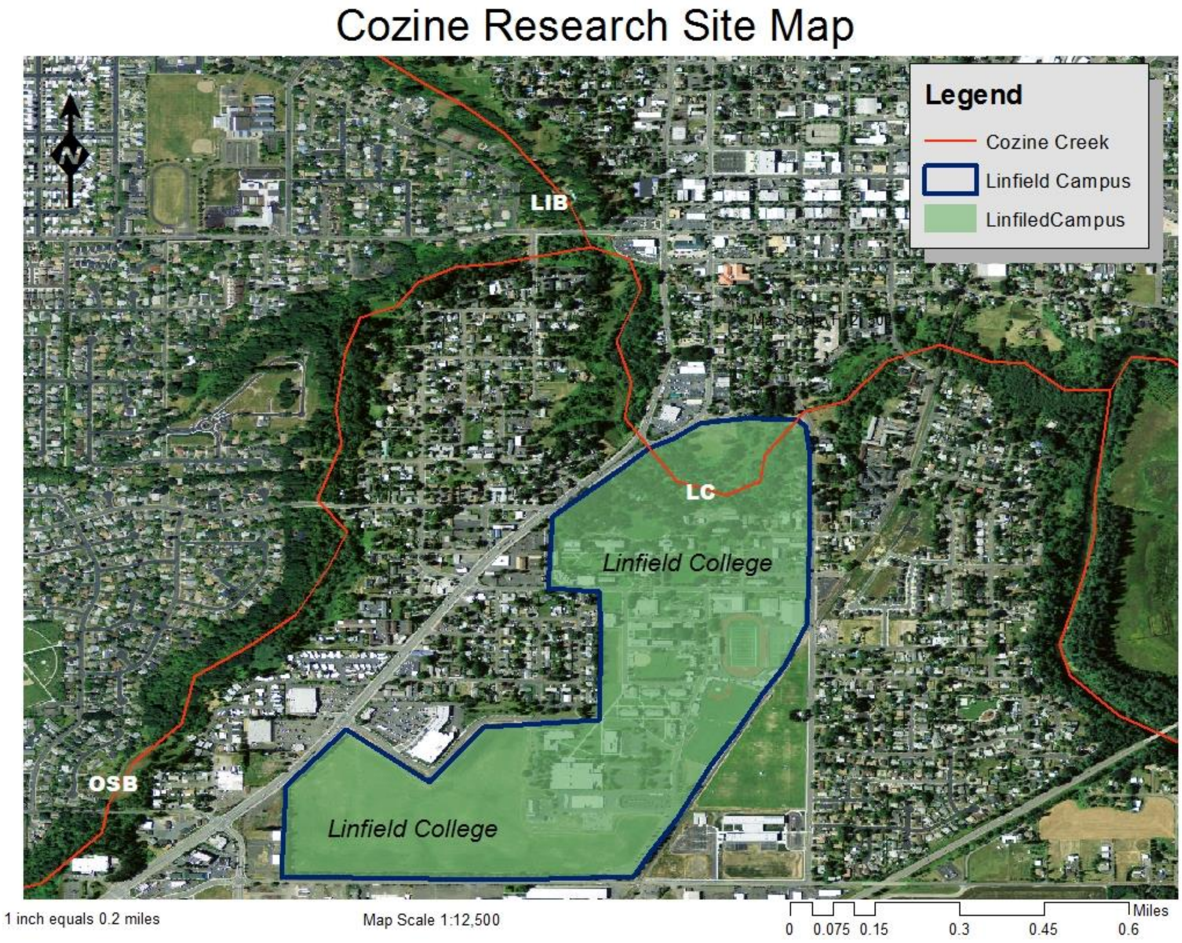

Figure 1. Aerial map created in Arcmap 10.5 showing the three sampling locations along Cozine Creek. LC – the Linfield College site, OSB – Old Sheridan Bridge site, and LIB – the City Park site. Cozine Creek feeds into the South Fork of the Yamhill River shown in red. (Created by Kyle Huizinga)

Table 2. GPS coordinates for creek sample locations for Fall 2017.

Site Name	Sampling Location	Latitude	Longitude
Linfield College	Site 1	45.25300	-123.19794
Linfield College	Site 2	45.20301	-123.19836
Linfield College	Site 3	45.20341	-123.19955
Old Sheridan Bridge	Site 1	45.19543	-123.21262
Old Sheridan Bridge	Site 2	45.19493	-123.21291
Old Sheridan Bridge	Site 3	45.19471	-123.2131
McMinnville Library	Site 1	45.20999	-123.20167
McMinnville Library	Site 2	45.2103	-123.20186
McMinnville Library	Site 3	45.12062	-123.20209

Linfield College

Site one at this location was the furthest downstream, and site three (seen in image 1) was the most upstream (Figure 2). Measurements at sites one and two at the Linfield College location were taken on a clear sunny day on September 13, 2017. The air temperature was 22.5℃. Site one was shaded by Oregon white ash (*Fraxinus latifolia*) with Himalayan blackberry (*Rubus Armeniacus*) on the banks. Plants such as reed canary grass (*Phalaris arundinacea*) and creek dogwood (*Cornus sericea*) also covered the banks. The stream was still and murky, but the bottom was visible. Stream depth in midstream was 17.5cm.

Site two had creek dogwood and thickets of Himalayan blackberry along the shore. Bittersweet nightshade (*Solanum dulcamara*) vines were in the shrubs. There were more rocks and Himalayan blackberry than at site one. There was a slight visible flow, and the stream depth midstream was 7cm.

Due to time constraints, we were unable to sample site three on the same day as sites one and two. We sampled site three a week later on September 20, 2017. The air temperature was 14.2℃, and it was partly cloudy. Site three was situated just after Cozine Creek flows through a culvert under SE Baker Street. The stream was shaded by Oregon white ash, willow (*Salix sp.*), and oceanspray (*Holodiscus discolor*). Himalayan blackberry and morning glory (*Ipomoea purpurea*) were also present. The stream had a rocky bottom with a stream depth midstream of

25cm. There also was a small side stream that channels runoff from SE Baker Street into the creek at this site. We also measured water quality in the side stream.

Image 1. Cozine Creek at Linfield College site three. Photo taken 2017 by Kyle Huizinga.

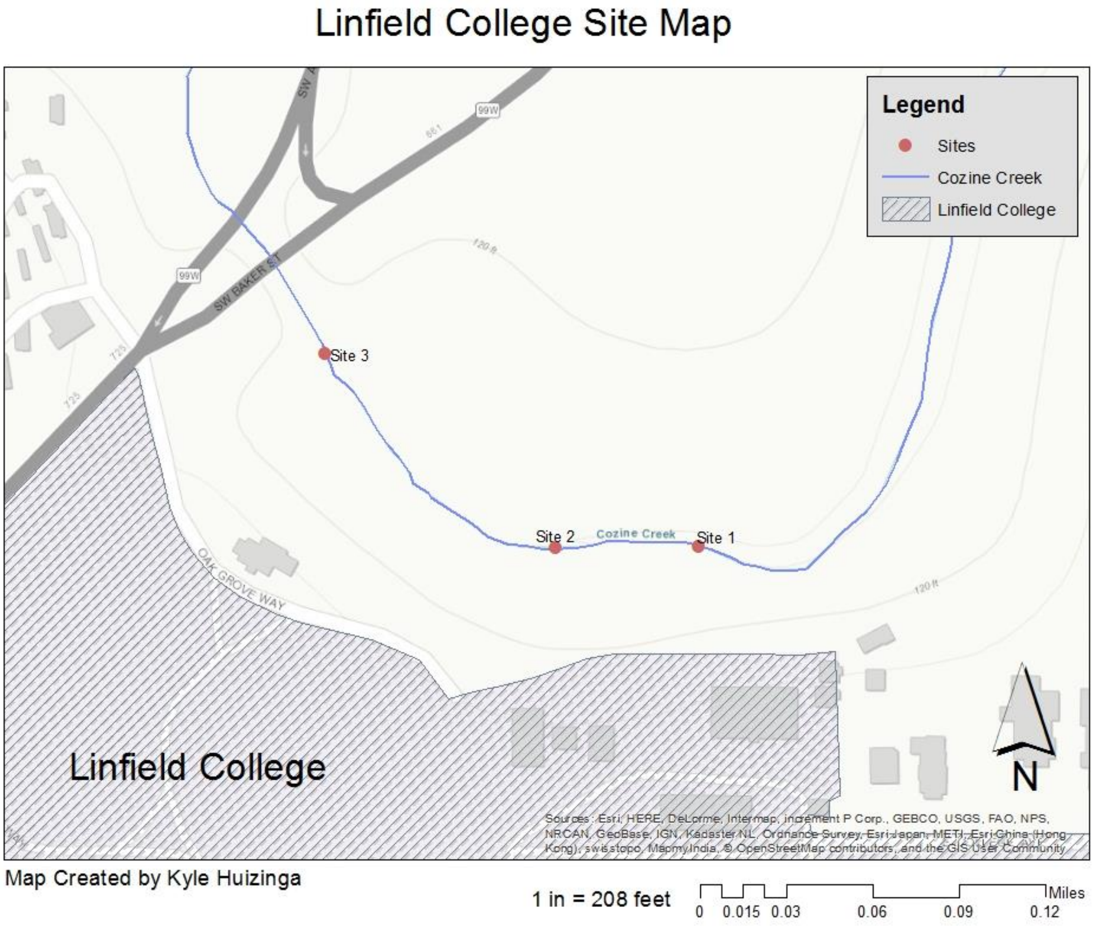

Figure 2. Three testing site locations based on GPS readings taken during testing for Linfield Cozine site. Map was created using Arcmap 10.5. (Created by Kyle Huizinga)

Old Sheridan Bridge

Site one at this location also was the furthest downstream, and site three was the most upstream (Figure 3). Samples from the Old Sheridan Bridge location were collected on September 20, 2017. The sky was partly cloudy and the air temperature was 14℃. The Old Sheridan Bridge location is on the south branch of Cozine Creek, upstream of the Linfield College location.

Site one at the Old Sheridan Bridge location had a grassy bank but was shaded by Oregon white oak (*Quercus garryana*) and Oregon ash. Reed canarygrass and Himalayan blackberry was growing on the opposite bank. There was a house located close to the site across the stream. The water was murky and the bottom was not visible. The stream was still, and random pieces of garbage could be seen in the water. Stream depth at midstream was 30cm.

Part of the grassy bank was covered with Himalayan blackberry, Oregon ash, and snowberry (*Symphoricarpos albus*). Unlike site one, there was a slight flow and stream depth at midstream was 58.5cm. The water was murky and trash also could be seen in the water. While collecting water samples from site two, it sprinkled.

Site three was located under and immediately downstream from the Old Sheridan Bridge (under the bridge view seen in image 2). The stream was flowing, and the rocky bottom was visible. Rubbish was found in and on the banks of the stream, similar to sites one and two. Grass and Himalayan blackberries grew on the bank in the areas not under the bridge. The stream depth at midstream was 9.75cm.

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 3. Three testing site locations based on GPS readings taken during testing for Old Sheridan Bridge site. Map was created in Arcmap 10.5.

Image 2. Cozine Creek as viewed looking upstream under the Old Sheridan Bridge at site three. Photo taken 2017 by Kyle Huizinga

McMinnville Library

As before, site one was the furthest downstream (Figure 4). Measurements at the Library location were taken on September 27, 2017. The day had clear skies with little to no cloud cover. The air temperature at the time of measurement was 26 ℃. The Library location is located on the north fork of Cozine Creek, also upstream from Linfield College.

Site one at the Library location had an abundance of reed canary grass and Canada thistle (*Circium arvense*). The area also had Himalayan blackberry, bittersweet nightshade, and tansy ragwort (*Tanacetum vulgare*) growing. The water had little to no movement and had muddy banks. The stream depth midstream was 14.2 cm.

Site two at the Library location also had reed canary grass, in addition to non-native cottonwood (*Populus sp*). The creek had slow-moving water with a muddy bottom visible. The stream depth midstream was 14.8 cm (image 3).

The banks at site three were overgrown with vegetation that included reed canary grass, Oregon white ash, non-native cottonwood, and willow. Similar to the other two sites, the water was slow moving. There also were large pieces of garbage in the water including old hubcaps and a lighter. The stream depth midstream was 7 cm.

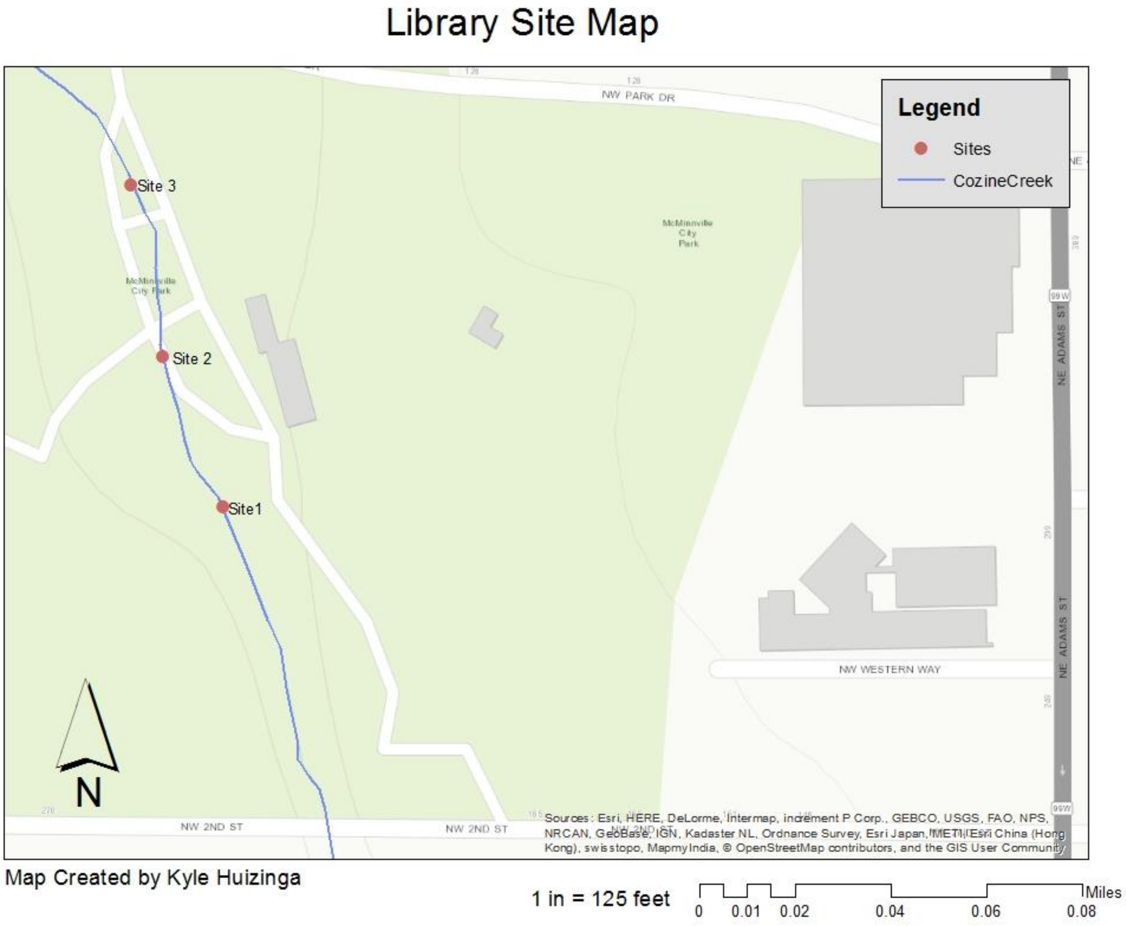

Figure 4. Three testing site locations based on GPS readings taken during testing for the Library site. Map was created in Arcmap 10.5.

Image 3. Cozine Creek as it flows through the McMinnville Library at site two. Photo taken 2017 by Kyle Huizinga

Methods

Field Procedures

All pieces of equipment were calibrated in the lab in the morning of the day we went into the field. At each site, the air temperature was recorded in Celsius using a thermometer.

Two water samples were collected at each site before any other measurements were done to minimize contamination. One was collected in a sterile 250 ml Nalgene bottle that was placed in an ice chest after collection. We also collected 250 ml of water in a BOD bottle (Image 4). The bottle was filled to the top and was capped after making sure all air bubbles were displaced. This bottle was covered with foil and placed in the cooler. Both water samples were taken back to the Environmental Studies Laboratory at Linfield College. The sterile samples were placed in the freezer to be used later for further analysis in the lab. The BOD bottle was placed in a dark cabinet for five days, at which time BOD was determined. Stream depth was measured at the location in the stream where the water samples had been taken using a meter stick.

Image 4. Nancy Broshot, Peri Muellner, and Gabi Esparza collecting BOD samples at subsite 2 of the City Park site. Photo taken 2017 by Kyle Huizinga.

Dissolved Oxygen (DO)

Dissolved oxygen was measured using an Oaklon DO 6+ DO meter. The probe was placed in the water and water temperature and DO were recorded as percent and ppm after the numbers had stabilized. DO was measured five times at each location with the probe being taken out of the water between each reading.

pH

pH was measured using a Hanna pH meter (Model HI98128). The probe was submerged in the water and measurements were recorded once the reading stabilized. pH was recorded five times with the probe taken out of the water between each reading.

Flow

Flow was measured at each site using a SwissFlow flowmeter (model: SF800). The probe was placed in the stream with the turbine facing upstream. Once the rate (cm/s) stabilized, the measurement was recorded. Flow was measured five times at each location, with the turbine taken out of the water between each reading.

Macroinvertebrates

Macroinvertebrates were collected at one subsite at each location. We randomly selected five sites in the stream at that location from which to collect macroinvertebrates. At each, macroinvertebrates were collected using two D nets. One net was positioned facing upstream, while the other was placed about a foot upstream from the first. Rocks between the two nets were rubbed to dislodge any attached macroinvertebrates. The upstream net was used to scrape the bottom substrate into the downstream net. Contents of the net were poured into shallow tubs. All macroinvertebrates in the tubs were collected and placed into jars containing 70% isopropyl alcohol (EPA 1997). The jars were taken back to the lab until a later date when the macroinvertebrates were identified and counted.

Vegetation Sampling

All areas chosen for vegetation sampling were located in the Linfield Campus Cozine Creek Natural Area. We located random vegetation transects in specific areas to collect baseline data. The first set of transects was located in an area where an accidental burn had happened during August of 2017. A second set was located in an area along the creek that had a recent invasive species removal project; this plot was in an area that last spring had many camas lilies (*Camassia quamash*) coming up under the Himalayan blackberry. The third set was run on the hillside between Newby Hall and the President's house where invasive plant removal parties had been working since August 2016. We did not collect any vegetation data before to the restoration work and hope to be able to use this data to quantify continued removal of invasive species.

At each of these three locations, we ran five 30 meter long transects. We recorded the percent cover by each plant species in each meter along each transect. Because Himalayan blackberry is one of the major invasive species in the area, we measured the height of each plant. We identified and measured the dbh or basal area of each tree or sapling, as well as the height of each seedling.

We were also interested in the cover by invasive Himalayan blackberry in the area. In spring 2016, an Environmental Studies student (Reese Yonemura) walked the Cozine Creek natural area with a handheld GPS to outline the locations of major Himalayan blackberry stands

(Yamhill Basin Council 2001). The Linfield grounds crew cleared blackberries from parts of this area in August 2017. We repeated Reese's mapping procedure to determine if we could document the removal by grounds. The tracking line was transformed to a satellite image in Geographical Information Systems software (GIS).

Laboratory Procedures

Biochemical Oxygen Demand (BOD)

After five days in the dark at room temperature, five aliquots were poured into small beakers from each BOD bottle. The DO in percent and ppm were measured using the same DO meter used in the field. BOD was calculated by subtracting the DO measured in the lab from the average DO measured in the field (Delzer and McKenzie 2003).

The frozen, sterile water samples were removed from the freezer and thawed on the day they were to be analyzed. These samples were used to measure turbidity, levels of nutrients, and coliform bacterial counts.

Turbidity

Turbidity was measured using a HANNA Instruments field turbidity meter (model: HI93703C). The water in each sample bottle was mixed well without shaking that would produce bubbles and an aliquot poured into the meter's glass cuvette. The cuvette was wiped with a lint free cloth, capped, and secured in the reading cell. We recorded the turbidity after the machine stabilized. Five reading were done for each sample with the cuvette inverted to mix the sample before each reading.

Nutrients

Levels of ammonia, nitrate, and phosphate were tested in the lab from the thawed sterile water sample. We used a LaMotte Ammonia-Nitrogen test kit to test our samples. Each test was done according to the directions in the kit. We ran each test five times. To convert the results to ppm ammonia, the recorded level was multiplied by 1.3 (LaMotte 2012a).

We used a LaMotte Nitrate Nitrogen Test Kit to test for nitrates. Each test was done according to the directions in the kit. We ran each test five times. The value was multiplied by 4.4 to convert to ppm nitrate (LaMotte 2012b).

We used a LaMotte Phosphate Test Kit to test for phosphate. Each test was done according to the directions in the kit (LaMotte 2012c). We ran each test five times.

Coliform Bacteria

The thawed water samples were tested for *E. coli*, *Salmonella*, *Aeromonas*, and other coliforms. Three milliliters of water were sterilely transferred into bottles of ECA Check Easygel using a pipette. The bottles were then inverted several times to distribute the inoculum, and the solution was poured carefully into labeled petri dishes. Five petri dishes were created for each subsite. The petri dishes were placed in an incubator for 48 hours at 35°C. After 48 hours, the petri dishes were removed from the incubator and the number of colonies per plate of each bacteria was counted. Dots that were dark blue were *E. coli*, teal green circular dots were *Salmonella*, magenta were other coliforms, and *Aeromonas* appeared as pink or red. The number of colonies of each bacterial type per plate was multiplied by 33.3 so that the data could be reported as colonies per 100 mL (Micrology Laboratories 2008).

Macroinvertebrates

The collected macroinvertebrates were identified to the most specific taxa possible using a dissecting microscope and an identification key (SWRC 2017; NW Nature 2015). Each jar was examined and counted by two students to ensure accuracy. The pollution tolerance index was determined from the counts. Macroinvertebrates were categorized into one of four groups, the total number of taxa in each group multiplied by the points designated to each pollution tolerance group, and the number of taxa in each group summed to give the PTI (Pollution Tolerance Index).

Statistical Analysis of Data

We used JMP 13 to statistically analyze our data. Water quality variables were compared among sites using a Oneway ANOVA, with Tukey Kramer HSD performed to elucidate which sites were significantly different from others. We used the same tests to compare water quality variables at the Cozine Linfield College location among the years. The Oneway ANOVA test determines whether there is a significant difference among the means, whereas Tukey Kramer HSD test compares among the pairs of means. For all statistical tests, p-values <0.05 were considered significant. Tukey Kramer HSD provides a connecting letters report showing which sites or years are significantly different from each other ($p<0.05$) by using different letters (JMP 2017a and JMP 2017b).

Results

We found DO (%) was significantly higher at the Library location (LIB) than either of the other locations (Table 3). pH and temperature were both significantly lower at Old Sheridan Bridge (OSB) than the other two sites, whereas turbidity and all bacterial counts were significantly higher at OSB than the other two sites. Flow was significantly higher at Linfield College (LC) than at LIB, and nitrate was significantly higher at OSB compared to LIB.

Table 3. Mean (standard deviation) and probability for water quality variables at the different locations based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. Bacteria are reported as colonies per 100mL.

Parameter	Cozine OSB	Cozine LIB	Cozine LC	P-value
DO (%)	69.58 (4.21)B	77.76 (2.53)A	72.16 (9.09)B	0.0018
DO (ppm)	7.43 (0.18)	7.40 (0.28)	7.08 (1.08)	0.2771
BOD (%)	23.89 (3.72)	21.71 (3.18)	22.41 (5.73)	0.3836
pH	4.97 (1.42)B	7.31 (0.08)A	7.17 (0.15)A	0.0001
Temp °C	10.19 (0.35)B	16.14 (2.46)A	16.25 (1.15)A	0.0001
Flow (cm/s)	17.87 (24.41)AB	2.6 (1.24)B	26 (30.51) A	0.0226
Phosphate (ppm)	0.27 (0.19)	0.21 (0.22)	0.20 (0.20)	0.6185
Nitrate (ppm)	1.61 (1.31) A	0.29 (1.14)B	0.8 (1.04)AB	0.0123
Ammonia (ppm)	0.13 (0)	0.20 (0.10)	0.14 (0.10)	0.0768
Turbidity (FTU)	16.61 (3.44) A	7.81 (2.22)B	6.43 (4.92)B	0.0001
E. Coli	392.6 (170.8)A	30.4 (36.1)B	47.4 (76.0)B	0.0001
Other Coliforms	304.4 (185.3)A	10.4 (18.6)B	43.7 (67.7)B	0.0001
Salmonella	281.5 (289.2) A	22.96 (34.0)B	52.6 (90.0)B	0.0001
Aeromonas	475.6 (356.8)A	92.6 (90.4)B	123.7 (206.3)B	0.0001

We found no significant differences among sites for pollution tolerance index (PTI) score, number of macroinvertebrates in each category, or the total number of taxa.

Table 4. Mean (standard deviation) and probability for macroinvertebrate results at the different locations based on ANOVA in fall 2017.

	Cozine OSB	Cozine LIB	Cozine LC	p-value
PTI	5.2 (4.1)	5.6 (2.1)	9.8 (3.4)	0.0864
# Tolerant	2.2 (1.8)	2.6 (0.6)	3.6 (1.3)	0.2682
# Fairly tolerant	0.8 (0.8)	0.6 (0.6)	0.4 (0.6)	0.6410
# Moderately intolerant	0.2 (0.5)	0.6 (0.6)	1 (0.7)	0.1328
# Intolerant	0.2 (0.5)	0	0.6 (0.6)	0.1005
# Total Taxa	3.4 (2.5)	3.8 (0.8)	5.6 (1.8)	0.1780

When comparing our data (2017) for the Linfield College (LC) location to previous years, we found DO (%) was significantly higher than in 2012, 2013, 2014, 2015, and 2016. DO (ppm) was significantly higher in 2017 than in 2015, 2014, or 2013. BOD (%) was significantly higher in 2017 than in 2016, 2013, and 2012. pH and temperature were both significantly higher in 2017 than in 2014, 2013, 2012, and 2011. Flow was significantly higher in 2017 than in 2016, 2015, and 2013.

Table 5. Mean (standard deviation) and probability for water quality variable at the Linfield College (LC) location in different years based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test.

Parameter	2017	2016	2015	2014	2013	2012	2011	p-value
DO (%)	72.16 (9.09) A	63.09 (3.73) B	58.84 (2.86) E	52.43 (10.07) CD	58.54 (6.45) DE	58.18 (0.10) BC	69.29 (2.95) AB	0.0001
DO (ppm)	7.08 (1.08) A	6.20 (0.35) A	2.92 (1.00) C	5.09 (1.15) B	6.42 (0.64) B	NA	NA	0.0001
BOD (%)	22.41 (5.73) AB	13.06 (5.73) BCD	24.85 (14.16) A	16.23 (16.78) ABCD	9.84 (6.01) CD	3.68 (3.76) D	6.28 (0.47) ABC	0.0001
pH	7.17 (0.15) A	7.30 (0.12) A	7.18 (0.04) A	6.30 (0.31) C	6.28 (0.47)C	6.49 (0.26) BC	6.84 (0.23) B	0.0001
Temp	16.3 (1.2) A	15.9 (0.6) A	16.6 (0.7) A	13.5 (1.2) B	11.5 (1.4)B	9.6 (0.4) C	12.3 (0.1) B	0.0001
Flow	26.0 (30.5) A	7.0 (7.6) B	3.0 (4.4) B	NA	0.7 (1.0)B	10.5 (8.6) AB	44.9 (73.6) AB	0.0007

When comparing our data for Cozine Linfield College to previous years, we found phosphate was significantly higher in 2017 than in 2015. *E. coli* and *Salmonella* were both significantly higher in 2017 than in 2016. *Aeromonas* was significantly higher in 2017 than in 2016 but was significantly lower than in 2012. Other coliforms were significantly higher in 2017 than in 2016 but were significantly lower than in 2013.

Table 6. Mean (standard deviation) and probability for nutrients and bacterial counts at the Linfield College location in different years based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. Bacteria are reported as colonies per 100mL.

Parameter	2017	2016	2015	2014	2013	2012	2011	p-value
Phosphate	0.2 (0.2) AB	0.1 (0.1) BC	0.3 (0.2) A	0.1 (0.2) BC	0.0 (0.1) BC	0.0 (0.0) C	0.2 (0.0) AB	0.0001
Nitrate	0.8 (1.0) A	2.5 (2.5) A	2.6 (3.9) A	1.9 (3.2) A	0.1 (0.2) A	0 (0) A	0 (0) A	0.0083
Ammonia	0.1 (0.1)	0.2 (0.1)	0.1 (0.1)	0.2 (0.1)	0.2 (0.1)	NA	NA	0.3938
Turbidity	6.43 (4.92) A	5.95 (0.86) A	9.49 (4.05) A	5.04 (0.65) A	5.95 (2.37) A	NA	NA	0.0176
E.Coli	47.41 (76.04) A	2.4 (4.1) B	NA	0 (9.6) AB	17.8 (9.6) AB	44.4 (9.6) AB	22.2 (9.6) AB	0.0004
Other Coliforms	43.70 (67.73) BC	5.6 (17.6) D	NA	22.2 (44.1) CD	55.6 (37.1) A	75.6 (44.5) AB	0 (0) CD	0.0001
Salmonella	52.59 (90.03) A	5.2 (14.5) B	NA	155.6 (34.1) AB	NA	0 (34.1) AB	17.8 (34.1) AB	0.0018
Aeromonas	123.70 (206.29) B	10.4 (29.4) C	NA	0 (0) BC	NA	1173.3 (465.8) A	8.9 (14.5) BC	0.0001

When comparing pollution tolerance index (PTI) score and total number of taxa at the Linfield College (LC) location in different years, we found 2015 had significantly higher PTI and total number of taxa than 2014.

Table 7. Mean (standard deviation) and probability for macroinvertebrate results at the Linfield College (LC) location at different years based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test.

	2017	2016	2015	2014	2013	p-value
PTI	9.8 (3.4) AB	8.4 (3.7) AB	9.2 (2.5) A	5.4 (2.7) B	7.1 (2.1) AB	0.0279
# Total Taxa	5.6 (1.8) AB	5.4 (2.0) AB	6.2 (1.2) A	4 (1.7) B	4.3 (1.7) AB	0.0442

Vegetation

We found 35 different species in our three locations, listed in Appendix A. The average percent cover of the five dominant species of vegetation varied on the five transects on Newby Hill (Figure 5). English ivy was dominant in transects 1, 4, and 5. Bare ground was dominant in transects 2 and 3. Wild blackberry was the only native species that was in the top five dominant species.

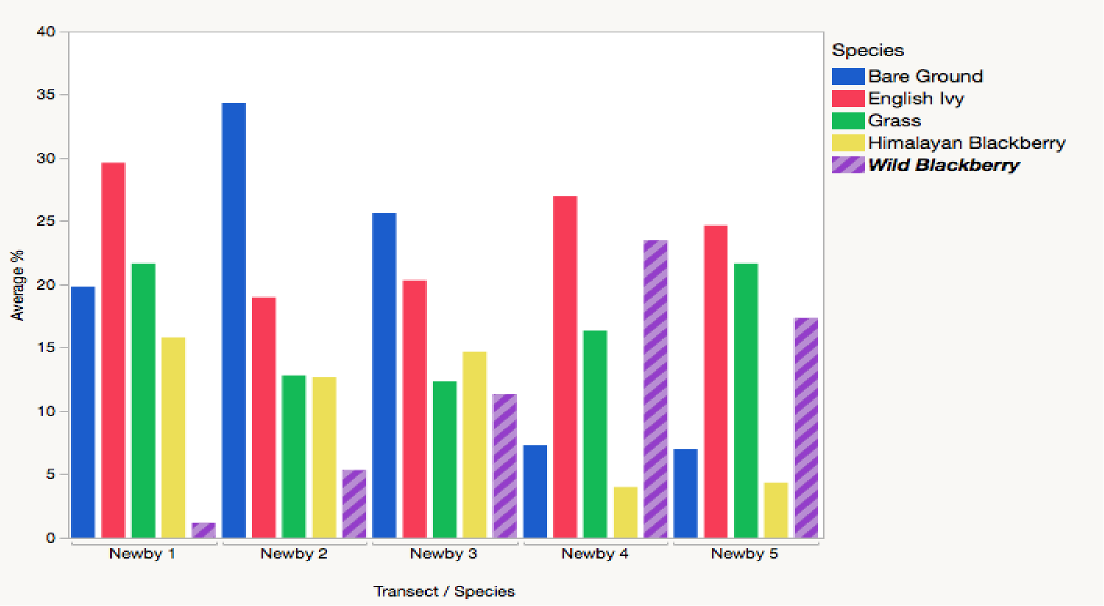

Figure 5. Average percent cover of different species found per transect on Newby Hill.

We compared the data sets mapped using GIS to see how the Himalayan blackberry boundary had changed (Figure 6). Mapping the current extent of the blackberry will allow us to document the success of any further restoration work.

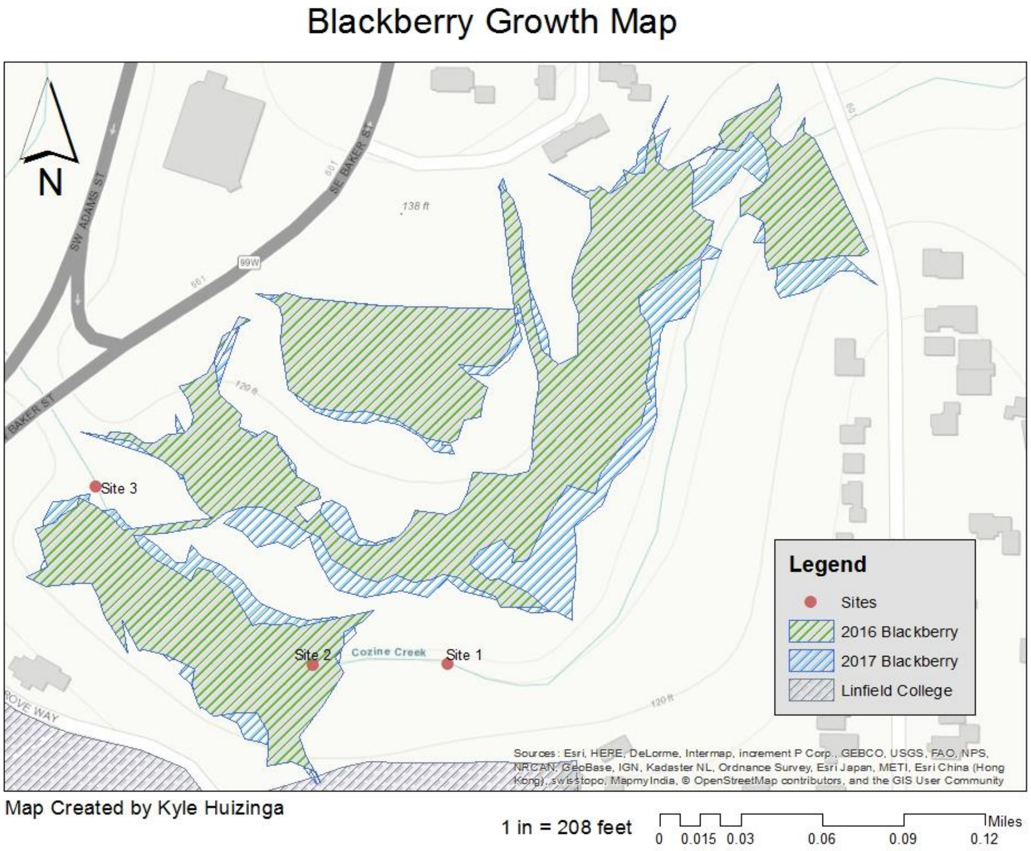

Figure 6. Aerial map created in Arcmap 10.5 showing the difference in Himalayan blackberry between the years 2016 and 2017. (Created by Kyle Huizinga)

Discussion

Our data suggest that the overall quality of our three sites along Cozine Creek is poor. All of the sites had low dissolved oxygen, high temperatures, low flow, high nitrate levels, and high bacteria levels. Our hypothesis that OSB and LIB site would have significantly different water quality can be accepted. Every water quality variable except for ammonia, phosphate, BOD, DO, and PTI were significantly different from one another at the two sites, however the Linfield College site was not significantly different from both of the upstream sites. Lastly, we can accept our hypothesis that overall, Cozine Creek continues to have relatively poor water quality. PTI at all sites showed the sites to be considered poor and there was little to no improvement of water quality when compared to previous years' data. It is likely that the water quality can be attributed to agricultural and urban runoff possibly containing waste, storm water, pesticides, fertilizer, and other chemicals.

Dissolved oxygen is significantly lower at Linfield College and Old Sheridan Bridge compared to the Library site (Figure 7). Low dissolved oxygen is dangerous for most aquatic life but can particularly hinder salmon reproduction and survival. Ideally, salmon would prefer at least 90% DO. Oxygenated water allows the fish to respirate and the smolts to develop properly (Wasowski et al. 2013). All of the sites were below threshold for healthy salmon to thrive. The low Do may be related to the low flow of the three sites, shown in Figure 11, does not allow oxygen to mix with the water (Breitburg et al. 1997). Also, as Figure 14 demonstrates, nutrients can catalyze the excessive growth of algae that uses oxygen to decompose, lowering oxygen levels and biodiversity (Carpenter et al. 1998).

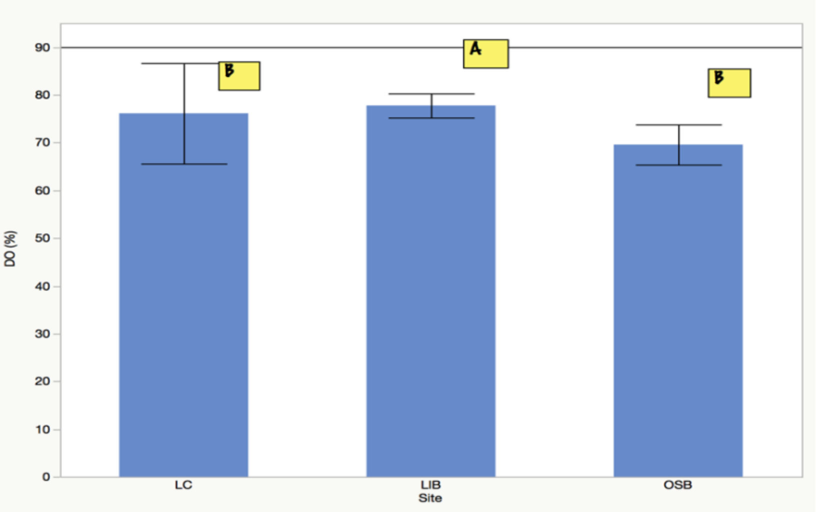

Figure 7. Mean (standard deviation error bars) for dissolved oxygen at the different locations based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. The black line at 90% DO represents the ideal value for salmon habitat (Wasowski et al. 2013).

The pH measured at the three sites was significantly lower at the Old Sheridan Bridge site (Figure 8), which shows the range of optimal pH (6.5-8.5) for salmon survival. If the pH of the water is not in the optimal range salmon are more likely to have reduced blood oxygen carrying capacity. This will make it more difficult for survival and reproduction (DFO 1983). The Linfield College and Library sites had pH values within the optimal range for salmon survival. The Old Sheridan Bridge site, on the other hand, had a pH lower than the optimal salmon range. pH can be altered by the agricultural runoff. Agricultural runoff can add things that lower the pH, becoming more acidic (Perlman 2016).

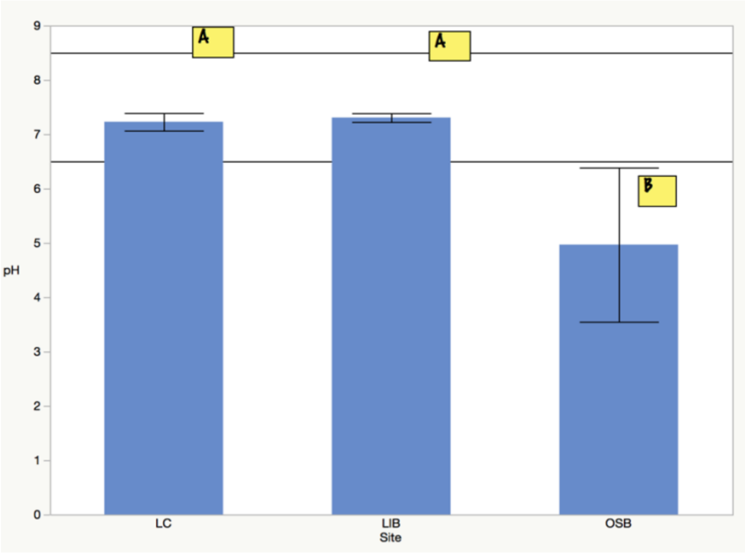

Figure 8. Mean (standard deviation error bars) for pH at the different locations based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. The area between the black lines represents the ideal range for salmon habitat (6.5-8.5 pH) (DFO 1983).

The Linfield College and Library site had significantly higher water temperatures than the Old Sheridan Bridge site (Figure 9). High temperatures could be due to the lack of streamside vegetation to shade the creek, as well as low flow and depth at both Linfield College and Library sites (USGS 2016). The maximum optimal temperature (12°C) for salmon, is exceeded at the Linfield College and the Library sites; only the Old Sheridan Bridge site is within the acceptable temperature range. Higher temperatures at the Linfield College and Library sites could cause stress in salmon, increasing their risk for disease. Additionally, higher temperatures reduce the amount of dissolved oxygen that can be present in water, which corresponds with the below ideal levels of dissolved oxygen (Figure 7). The lower levels of dissolved oxygen compound with the temperature stress on the fish (USGS 2014; EPA 2003).

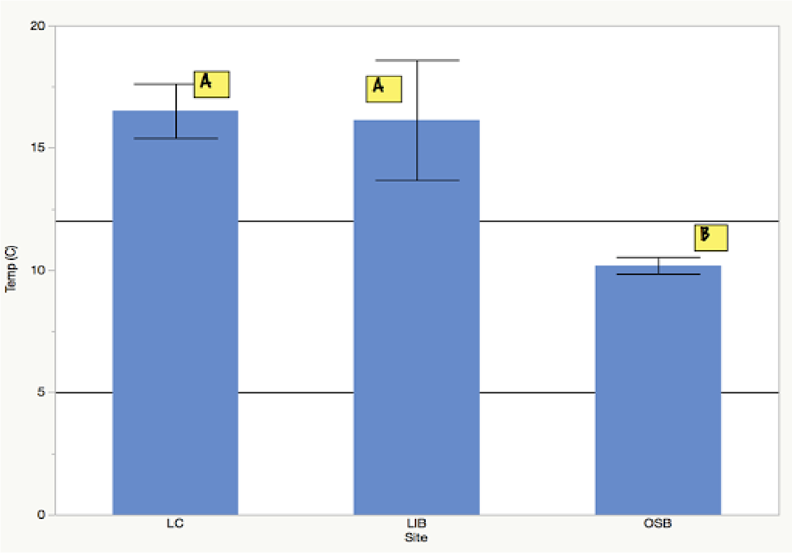

Figure 9. Mean (standard deviation error bars) for temperature at the different locations based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. The area between the black lines represent the ideal range for salmon habitat (5-12°C) (USGS 2014; EPA 2003).

Temperature has wide-ranging effects and has likely played a significant role in the water quality in Cozine Creek across the years. Warmer water holds less dissolved oxygen, results in a lower pH, and can affect the distribution, health, and survival of native salmonids in Oregon (EPA 2003). pH has not followed the expected trend with the changes in temperature across years, whereas phosphate has trended along with changes in temperature (Figure 10).

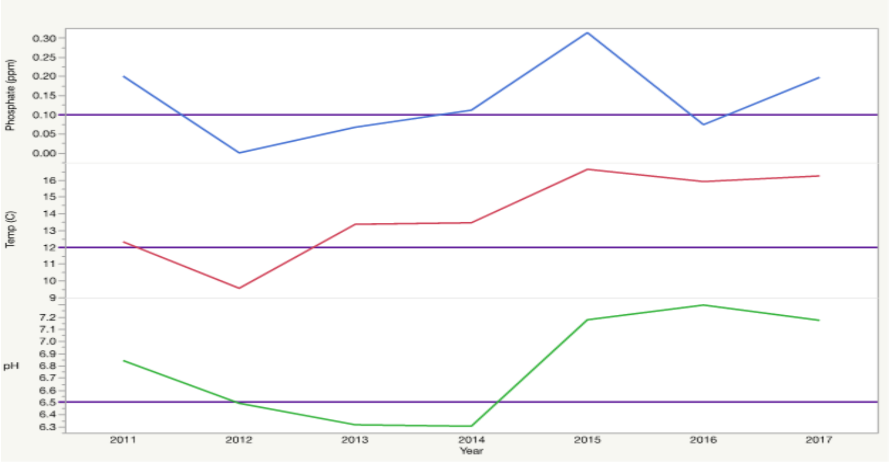

Figure 10. Comparing trends for mean temperature, pH, and phosphate level from 2011 to 2017 at the Linfield College site. The purple lines represent ideal values or ranges for salmon (<0.1 ppm, 5-12°C, and 6.5-8.5 pH) (EPA 2003).

Phosphate levels have oscillated over the years. In most years (including the last three) phosphate has been above the maximum acceptable for salmon (Behar 1997). The increased phosphate may be due to agricultural or urban run-off (EWG, 2017). The levels show that it will be important to work with our neighboring stakeholders to help reduce runoff.

Flow was significantly lower at the library site than at the Linfield College site (Figure 11). Flow, which probably plays a role in all the other variables we measured, has been inconsistent over the years. In 2011, the rate was high, but the following years show declines and increases; however, in all years, the flow rate was below the minimal optimal level for salmon (Figure 12). DO and flow both increased from 2016 to 2017. The increase in flow this year at the Linfield College site may be due to the fact that we collected data after a heavy rainfall. The increased flow should have an effect on other water quality variables. However, it is worth noting that the flow at all three sites (College, Library and OSB) was below the optimal minimum set by the EPA for salmon to exist in the stream (EPA 2012a).

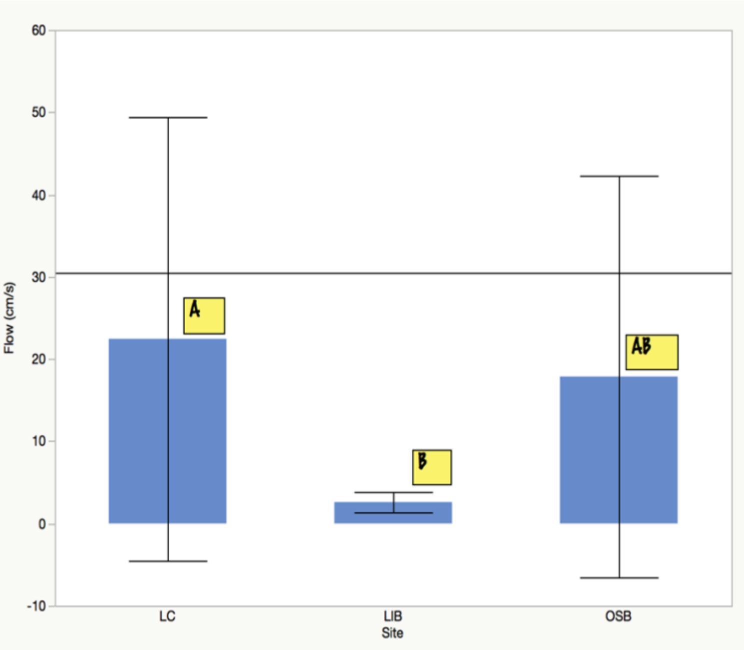

Figure 11. Mean (standard deviation error bars) for flow at the different locations based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. The black line represents the optimal minimum flow value for salmon (30.48 cm/s) (EPA 2012a).

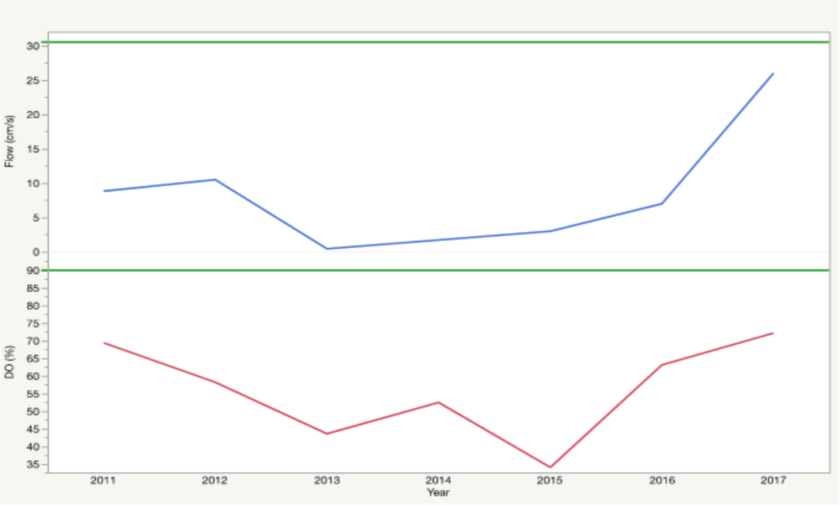

Figure 12. Comparing trends for mean dissolved oxygen and flow rates from 2011 to 2017 at the Linfield College site. The green lines represent ideal values or ranges for salmon (90% and 30.48 cm/s) (Wasowski et al. 2013; Riley et al. 2009).

Turbidity was significantly higher at the OSB site than the other two sites (Figure 13). A turbidity above 10 FTUs can cause negative impacts in salmon; Linfield College and the Library sites both were under that threshold. The high turbidity at OSB can make it difficult for gills to function well because of the high amount of suspended material in the water (Bash and Berman 2001) .

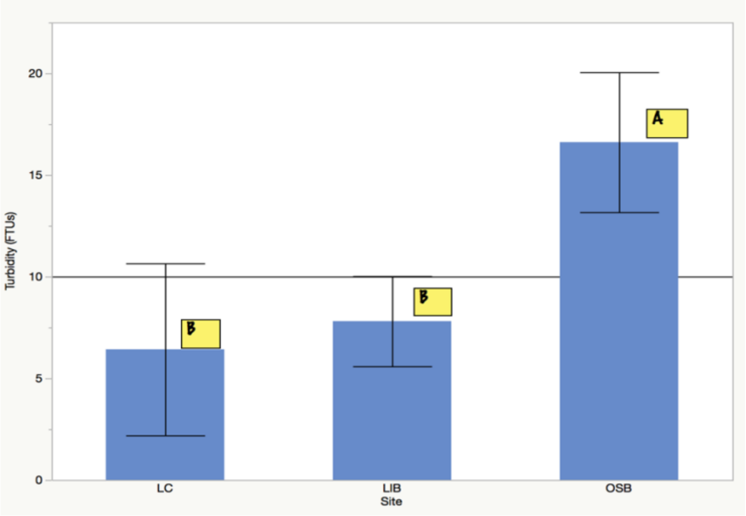

Figure 13. Mean (standard deviation error bars) for turbidity at the different locations based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. The black line represents the ideal range for salmon habitat (<10 FTU) (Bash and Berman 2001).

The higher turbidity at the Old Sheridan Bridge site could be due to agricultural runoff that occurs not too far upstream from that site. Agricultural runoff contributes to increased turbidity as it promotes the growth of algae. The agricultural runoff hypothesis is supported by the reduced pH at the Old Sheridan Bridge site. High turbidity can also be caused by increased levels of soil particles that become suspended due to higher flow due to rainfall events (EPA 2012b).

Nitrate was significantly higher at the OSB site than the Library site (Figure 14). However, all three sites had higher than the recommended level for (Behar 1997). High levels of nitrate may be due to agricultural or urban runoff (EWG 2017). Agriculture and urban land-use result in excess nutrients entering streams from non-point sources (Vanni et al. 2013).

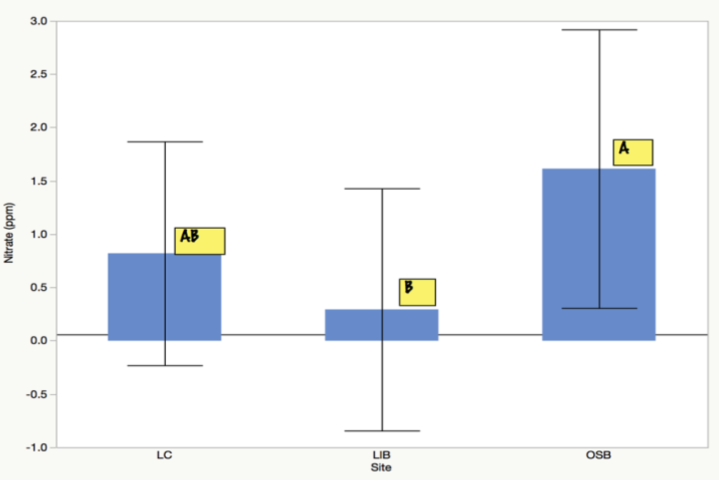

Figure 14. Mean (standard deviation error bars) for nitrate at the different locations based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. The black line represents the maximum level for salmon (<0.06 ppm) (Behar 1997).

Levels of all coliform bacteria (*E.coli*, *Aeromonas*, *Salmonella*, and other coliforms) were all significantly higher at OSB than at the Library or College sites (Figure 15). The presence of coliform bacteria indicates fecal contamination. The EPA has set a level of more than 406 *E.coli* per 100mL as being a health risk. The level of *E.coli* at the Old Sheridan Bridge was well above this, with a mean count of 393 colonies per 100mL. The presence of *E.coli* means there is fecal contamination from warm-blooded animals, including humans. It is possible that there are greater numbers of wildlife and/or pets at the OSB site. *E.coli* could come from a leaking sewer pipe. *Aeromonas*, which was also significantly higher at OSB than at LIB and LC, does not have a standard set by the EPA, even though some strains (e.g., *A. hydrophila*, *A. veronii*, *A. caviae*, and *A. dhakensis)* can cause human infections (Chen et al. 2017). *Salmonella* originates from infected humans and animals; humans should avoid drinking any water that contains this bacterium (EPA 2017b). Other coliforms also originate from fecal matter of humans and animals. Because we do not have the means to test different species or strains of bacteria, our data only indicates there is fecal contamination getting into Cozine Creek. Higher levels of coliform bacteria are often found in urban areas such as McMinnville because of increased runoff from impermeable surfaces, leaking sewage plants or septic systems, or fecal matter from pets or wildlife in the water (CDC 2012). Any of these could be the cause of high rates of *E.Coli*, *Aeromonas*, *Salmonella*, and other coliforms in the water at the Old Sheridan Bridge site.

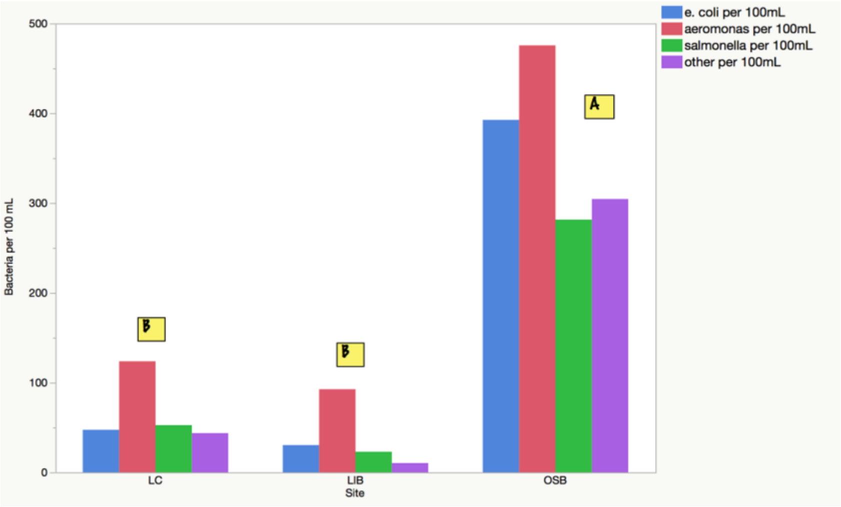

Figure 15. Mean for all four kinds of bacteria at the different locations based on ANOVA. Means with different letters are significantly different from one another as per Tukey HSD post hoc test.

Levels of bacteria have varied over the years (Figure 16). Factors including weather on the day sampled, leaking sewage pipes, or the number of animals in the area all play an important role in bacterial levels. All we can say is the bacterial data confirm that there is fecal matter from warm-blooded animals in Cozine Creek (EPA 2015).

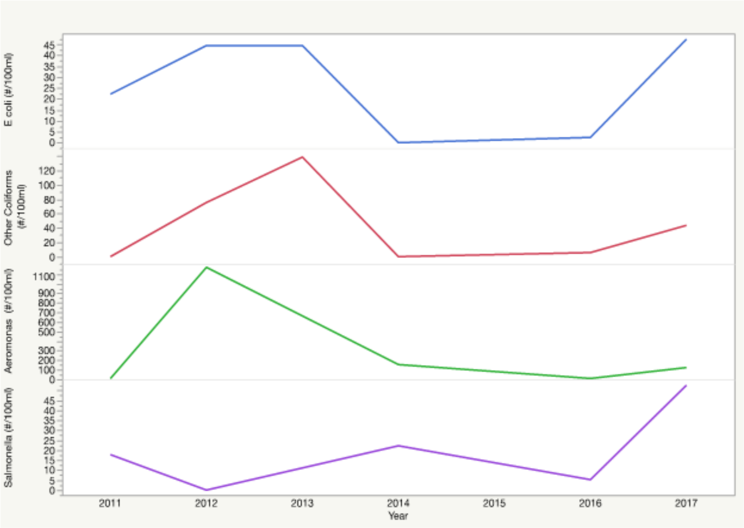

Figure 16. Comparing trends for mean bacterial counts between 2011 and 2017 at the Linfield College site.

Although we did not find significant differences in macroinvertebrate data among the sites, we did find that the PTI at all three sites indicated poor water quality (Table 4). The macroinvertebrates we found at all sites were either tolerant or fairly tolerant of pollutants. The PTI was higher at the Linfield College site than the other two sites, but the PTI at all three sties was below 10, indicating poor stream quality (IDEM 2017).

The PTI for the Linfield College site seems to be higher in recent years, however, it has always indicted poor water quality (Figure 17). Nonpoint source pollution is probably the cause of the low PTI values and poor water quality. Though most of our research has only been a snapshot from a single day of the water quality in the creek, macroinvertebrate data reveals the water quality over a year because macroinvertebrates are immobile and very species-specific with regards to water pollution (EPA 1997).

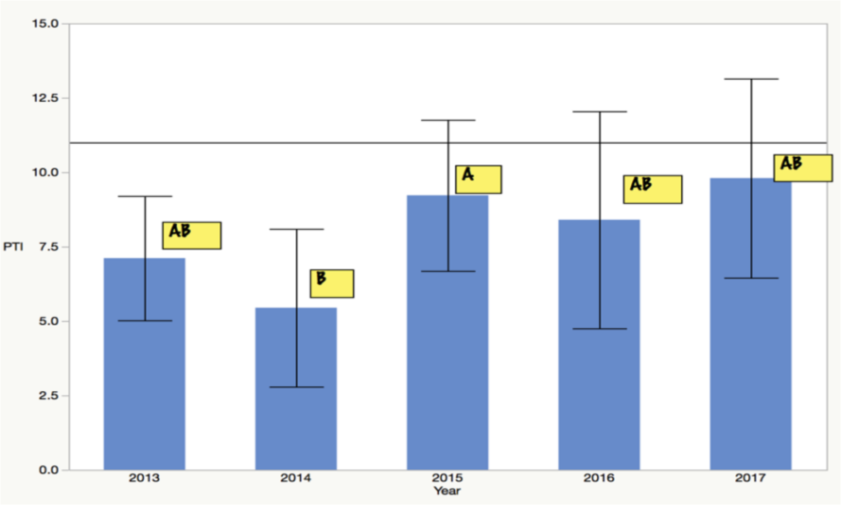

Figure 17. Mean (standard deviation error bars) for PTI from 2013 to 2017 at the Linfield College site. Means with different letters are significantly different from one another as per Tukey HSD post hoc test. The black line represents the level below which stream are considered to have poor stream quality (IDEM 2017).

Dissolved oxygen between 2011 and 2017 has remained below the recommended minimum amount for salmon (Figure 18). BOD has risen and fallen; there are not standards for it but it tends to be inversely correlated with DO (EPA 2014). Temperature has been above the maximum recommended level since 2013. Dissolved oxygen, BOD, and temperature are interconnected. As BOD increases, DO decreases because the oxygen is being consumed. Warmer water can hold less oxygen that cold water. Unless we can reverse these findings (decrease temperature and increase DO), the water quality in Cozine Creek will remain too poor for salmon (Wasowski et al. 2013; EPA 2003).

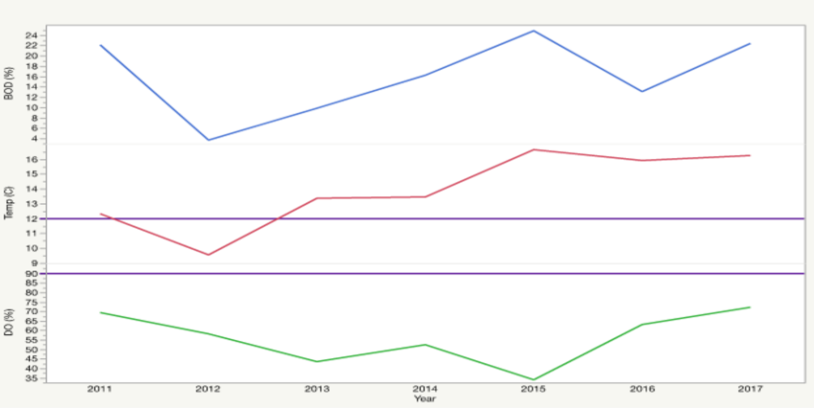

Figure 18. Comparing trends for mean temperature, biochemical oxygen demand (BOD), and dissolved oxygen (DO) between 2011 and 2017 at the Linfield College site. The purple lines represent ideal values, or ranges, for salmon habitat (5-12°C and 90%) (Wasowski et al. 2013; EPA 2003).

The vegetation data collected at the Linfield College site will be used as baseline data for future classes to compare future vegetation data against to determine the progress the area with restoration. The Newby Hill area was measured to attempt to discover the impact of past invasive species removal by work parties, while collecting baseline data to be used in the future. Our measurement showed Newby Hill contains a significant amount of bare ground; hopefully we will see native species move on to this cleared area. Future classes can determine the most prominent species, compare those to what we found, and be able to track changes in vegetation. These comparisons will provide a measure of the success the work parties have had in removing the invasive species that exist on the Linfield College site. Similarly, the blackberry cover data can be compared in the future to hopefully see the retreat and ultimate loss of that invasive species with restoration work.

Overall Water Quality

Overall, many of the water quality variables we measured at all three sites showed the water quality in the creek to be too poor for salmon. Over the years Linfield students have been testing the water as it flows through the campus, flow and dissolved oxygen always have been below levels that can support salmon while the temperature has also been too high. The lack of stream shading in many areas, combined with the higher than acceptable levels of nitrate (a prime cause of eutrophication), are serious issues that need to be solved to improve water quality.

Besides the water quality variables, there are other factors that limit the survival of salmon. Cozine Creek has a muddy stream bottom. Salmon prefer gravel creek beds to provide locations for redds (Wasowski et al. 2013). In addition, two culverts exist that are too high for salmon to migrate through, preventing them from reaching any of our three sites. The likely cause of the poor water quality we measured is nonpoint agricultural and urban runoff in Yamhill County (Dufour et al. 2012).

Figure 20 displays both phosphate and flow levels from 2011 to 2017. Over the years, both flow and phosphate have never been at the optimal point for salmon. When stream flow is high, phosphate tends to attach to suspended soil particles (MPCA 2007). Flow can also be influenced by increased rainfall upstream which causes higher amounts of agricultural runoff into the stream and an increased flow. Therefore, areas of high flow will have higher levels of phosphate and streams of low flow will have lower levels of phosphate.

Improving Water Quality

There are things that could be done to improve the quality of Cozine Creek. An active group of students on the Linfield College campus frequently visits the Cozine area to remove invasive species. Himalayan blackberry and English ivy are the main targets and present the greatest threat to native vegetation life. The removal of invasives and subsequent planting of native species such as Oregon ash and creek dogwood would help restore the vegetative community along the creek. These and other native species would increase the amount of shade, helping decrease water temperature that is linked to so many other water quality variables (Dosskey et al. 2010). Educating our neighbors as to the best ways to decrease urban and agricultural runoff is an important step to improve water quality. Engaging the public and helping raise awareness is crucial to restoring Cozine Creek.

Limitations

There were a number of limitations to our study. Our measurements were only taken once a week over the course of less than three months. If time and resources were not constraints, measurements could be recorded for more intervals, and over longer periods of time (e.g. data loggers that record temperature every hour for four months). Weather is always a limiting factor when taking data. Drought and/or heavy precipitation influence water quality measurement. And although our DO meters were calibrated before going into the field, we questioned the reliability of our DO meters when one of them stopped working. We also had a difficult time discerning the different colors on the EasyGel coliform bacterial plates, as the colors often look similar to each other.

This year we shifted from a three category PTI to a four category PTI to allow for finer distinction between species. As a result of the shift, we were unable to compare our results for the number of macroinvertebrates in each category to previous years. However, we were still able to compare the PTI scores because both systems use the same scoring scale. Another limitation was that not all the macroinvertebrate species we found would be placed into a category. We used a guide of macroinvertebrates in the Pacific Northwest for the designations of species. Some macroinvertebrates (e.g., Daphnia and hydra) were excluded from PTI analysis because they did not appear in either guide (IDEM 2017; Adam 2003). We also calculated the species diversity using the number of taxa collected. We would recommend to future classes to use the guide for the Pacific Northwest, but they can always compare the number of taxa collected. And our biggest limitation is that all of our data represents a brief snapshot of the water quality of Cozine Creek.

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Appendix A. List of plant species found during data collection

Common name	Scientific name
Ajuga	*Ajuga reptans*
Oregon ash	*Fraxinus latifolia*
Bracken fern	*Pteridium aquilinum*
Clematis	*Clematis vitalba*
Clover	*Trifolium sp.*
Creeping buttercup	*Ranunculus repens*
Creeping jenny	*Lysimachia nummularia*
Dandelion	*Taraxacum officinale*
Dock	*Rumex sp*
Douglas fir	*Pseudotsuga menziesii*
English ivy	*Hedera helix*
English laurel	*Prunus laurocerasus*
Everygreen huckleberry	*Vaccinium ovatum*
Grass	Multiple species
Hawthorn (non-native)	*Crataegus monogyna*
Him. Blackberry	*Rubus armeniacus*
Incense cedar	*Calocedrus decurrens*
Iris	*Iris pseudoacorus*
Italian arum	*Arum italicum*
Lemon balm	*Melissa officinalis*
Morning glory	*Convolvulus sepium*
Night shade	*Solanum dulcamara*
Nipplewart	*Lapsana communis*
OR white oak	*Quercus garryanna*
Plantain	*Plantago major*
Plum seedlings	*Prunus domestica*
Prunella	*Prunella*
Rhododendron	*Rhododendron sp*
Snowberry	*Symphoricarpos albus*
Vinca	*Vinca major*
Violet	*Viola sp*
Walnut	*Juglans nigra*
Wild blackberry	*Rubus ursinus*
Willow weed	*Epilobium ciliatum*