Examining Water Quality and Vegetation Along Cozine Creek
Senior Capstone ENVS 460: Fall 2018

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INTRODUCTION

Plants, animals, and humans all need freshwater to survive, making it arguably the most essential resource on the planet (Cominelli et al. 2009). Providing humans with drinking and irrigation water, it is an integral part of the overall health of society. Although clean water is critical for the human health, water systems around the world support unique ecosystems that host distinctive plants and animals. Water sustains ecological processes that are important to the survival of marine and freshwater biomes and their biota (OEH 2017).

In addition to environmental importance, water has a strong cultural dimension. The way water is used and valued constitutes a significant part of a society's cultural identity and is often the heart of historical practices, stories, etc. (WHO 2015). Water quality and its social and economic values are positively interrelated. As water suffers from the detrimental effects of anthropogenic activities like pollution, its environmental, social, and economic values decrease (EPA 2018c). Water is a source of food, income, electricity, recreation, etc. and should therefore be held in high importance relative to conservation, advocacy, and preservation (Evans 2018).

Freshwater makes up only 0.01% of the world's water, but supports and hosts 6% of all of the world's species. Because of this, freshwater biodiversity is a valuable natural resource and conservation is critical to humans, nations, and governments (Dudgeon et al. 2006). Society and governments are beginning to recognize the importance of safe water, which allowed for the creation and implementation of policies in the United States and internationally (WHO 2015). In 1972, the Clean Water Act (CWA) created the basic structure for regulating pollution by establishing quality standards for bodies of water throughout the United States. Under the Clean Water Act, the Environmental Protection Agency has been successful in implementing pollution control programs and setting wastewater standards for industry. The most notable amendment in the Clean Water Act, makes it illegal to discharge any pollutant from a point source into navigable waters (EPA 1972). Although this helped to eliminate some pollution in waterways, point source pollution is only a part of the issue. Another kind of pollution, non point source pollution is harder to identify and therefore clean due to the nature of what a nonpoint source pollutant is, pollution coming from an non specific source.(EPA 2018b). Nonpoint water pollution often contains fertilizers, pesticides, oil, and other toxic chemicals that come from an unknown and unconfined area. Nonpoint pollution can be produced on agricultural, industrial, or urban land and is affecting these areas all over the world (EPA 2018a).

A small change in water quality can have detrimental effects throughout the entire ecosystem. The vulnerability of freshwater ecosystems is displayed in their sensitivity to human activities such as overexploitation, water pollution, flow modification, destruction or degradation of habitat, and invasion by exotic species. These combined and interacting influences have resulted in subsequent population declines and range reductions of freshwater species and biodiversity worldwide (Dudgeon et al. 2006). Freshwater sites are hotspots for human activities, that results in detrimental anthropogenic impacts. One of the most notable impacts is the decline in range and abundance of many freshwater species to the point that they are more imperiled than their marine or terrestrial counterparts (Strayer and Dudgeon 2010).

The universal solvent, water, is highly vulnerable to pollution because more substances can dissolve in it than in other liquid. When harmful chemicals or microorganisms contaminate a body of water, pollution (a degradation of water quality) occurs. At a high enough level, such degradation can render the water toxic to humans (Denchak 2018). Although water pollution can occur in groundwater, the contamination of surface water is more prevalent. Covering about 70% of the earth’s surface, surface water fills the Earth’s oceans, lakes, and rivers (USGS 2016a). Fresh surface water is the source for more than 60% of the water delivered to U.S. homes. Unfortunately, many of our surface freshwater sources are in danger. According to the EPA, about 50% of rivers and streams and more than 33% of lakes are polluted and deemed “unfit for swimming, fishing, and drinking” (EPA 2009; Denchak 2018). The leading sources of contamination include nitrates and phosphates (nutrient pollution) from runoff containing fertilizer (MacMillan 2017).

In 2015, high levels of water pollution caused 1.8 million deaths worldwide (Landrigan et al. 2017), and every year unsafe water sickens about 1 billion people. People in low income communities have a disproportionately higher risk of being exposed to pollution because their homes are often closest to the most polluting industries. Although contaminated water has many harmful effects on humans, contaminated water can have rippling effects through ecosystems. Because healthy ecosystems rely on intricate webs of animals, plants, bacteria, and fungi, harm to any of these organisms can create a chain effect, causing a severe negative impact on an entire aquatic community (Denchak 2018). The most common and detrimental effect is the presence of pollution that stimulates algal blooms, reducing oxygen levels in the water. In anaerobic conditions, eutrophication of bodies of water suffocates plants and animals and creates “dead zones” where waters are essentially devoid of life (NOAA 2018).

Cozine Creek is located in Yamhill County and flows into the South Yamhill River on the East side of McMinnville. Throughout the years, Cozine Creek has been altered by development of the city of McMinnville and emerging agriculture. Cozine Creek and many other creeks in Yamhill County used to have wetland qualities which were filled and cultivated for agriculture. The overall water quality of Cozine Creek has been continually degraded as pollution from petrochemicals (roads), toxic heavy metals, stormwater, and fertilizer from urban gardens and the nearby golf course runoff into the Creek. The Oregon Department of Environmental Quality (ODEQ) declared the creek a Category 5 in 2012. This classification was due to the creek’s failure to meet required levels of dissolved oxygen, temperature and bacteria. In addition, they also determine the creek to be at risk for pH, sediments, toxins, and chlorophyll. ODEQ gave the creek these rating based on salmon proliferation and habitability. As a designated steelhead habitat, the culvert in the city of McMinnville prevents the movement of salmon upstream in the Cozine area. Although the culvert provides a physical barrier, restoring this creek to optimum salmon bearing water quality variables is still important because of downstream water quality.

Students in the Senior Capstone (ENVS 470) class in Spring 2018 successfully attained a grant that allocated funding for the restoration of a portion of Cozine Creek as it flows through the Linfield College campus. To support the restoration work, our class is collecting water quality and vegetation data to collect baseline data and help monitor how the restoration improves the overall quality and health of the Cozine Creek area (Berg et al. 2018).

Restoration Project Resulting from 2018 Grant

Students in the Environmental Studies Senior Capstone (ENVS 385 and 460) classes began analyzing water quality in 2011 in various creeks in McMinnville, Oregon. In 2016, the students began to focus on Cozine Creek. In 2018, the students in the Senior Capstone (ENVS 470 4) successfully wrote grants that amounted to $19,000 from the Oregon Watershed Enhancement Board (OWEB), the Yamhill Watershed Stewardship Fund, and the Associated Students of Linfield College (ASLC) for restoration efforts in the Cozine Creek area on campus. The grant was designed as an experiment to compare various techniques (herbicides, mowing, and/or hand removal) to control invasive species and best method to replant native species across the Cozine property. The money will pay restoration contractor (Upshot LLC) to spray and mow the property to remove invasive species. The hand pull method of removal will be done by volunteers. The grant will also pay to purchase native plants that will be planted by Linfield students and volunteers (Berg et al. 2018).

Water Quality Variables

The chemical and biological analysis of water is an important part of environmental monitoring. To examine the water quality in Cozine Creek we measured flow, temperature, dissolved oxygen (DO), pH, turbidity, biochemical oxygen demand (BOD), levels of nutrients (e.g., nitrate, ammonia, and phosphate), levels of coliform bacteria, and macroinvertebrates.

Flow (how fast the water is moving) is a fundamental property of streams that affects many variables and has impacts on temperature, turbidity, and oxygen level. Stream temperature increases during periods of low flow when stagnant water in low flow areas heats from the sun. The amount of sediment and debris in the water is affected can contaminants move out of the creek quicker during high flow. Additionally, faster flow rates increase the dissolved oxygen that diffuse into the water. Rate of flow fluctuates based on seasons, the surrounding topography, and objects blocking the stream such as fallen trees (USGS 2016c).

Water temperature also influences many other variables. Water temperature can affect the metabolic rates and biological activities of aquatic organisms. Most fish, including salmon, prefer colder water. The maximum optimal temperature for salmon is 12°C. When temperature increases the metabolic and respiratory rates of salmon increase, which can stress the animals and increase the incidence of disease (Fondriest 2014). Warmer water holds less dissolved oxygen and has a lower pH than cooler water (USGS 2016b).

Dissolved oxygen (DO) is another crucial parameter used to assess water quality. Dissolved oxygen enters water through surface contact; rapid water movement, and photosynthesis by aquatic plants and algae increase DO (Berlemann 2013). Lower levels of DO result from increased temperature and/or excessive demands for oxygen by aquatic plants and animals. Algal blooms deplete oxygen in the water when the organisms die and decompose. When DO drops below 9 ppm, salmon experience reduced reproduction rates and higher mortality rates (Wasowski et al 2013).

Biochemical Oxygen Demand (BOD) measures the amount of oxygen consumed by microorganisms in decomposing organic matter, respiration from aquatic organisms, and from chemical reactions (Delzer and McKenzie 2003). Bacteria decompose organic matter, using up oxygen. A high BOD will result in a low DO (Berlemann 2013, Delzer and McKenzie 2003).

pH is the measurement of how acidic or basic water is; $pH = -\log[H+]$ so the higher the hydrogen ion concentration the lower the pH. Changes in pH affect aquatic ecosystems because species are adapted to a specific range. According to the DEQ regulatory standards for the Willamette Basin, the ideal pH level for streams is the 6-8.5 range (Kidd 2011). As pH levels move away from this range, fish face physiological damage along with reduced hatching and survival rates. When pH drops below 6.0, salmon begin to suffer physiological damage and at levels around 5 salmonid eggs begin to die (Fondriest Environmental 2013b.).

Turbidity refers to the amount of suspended solids in water including leaf detritus and plankton (organic) and minerals and sediment (inorganic). Low turbidity indicates better water quality (Berlemann 2013). Turbidity levels above 10 FTU restrict light passing through the water, reducing the amount of oxygen released during photosynthesis (Kidd 2011). High levels of turbidity can clog fish gills causing them to suffocate (Berlemann 2013).

Nutrients (nitrogen and phosphate) are essential for plant and animal growth, but excess amounts cause problems in aquatic systems. Two forms of nitrogenous compounds, nitrate and ammonia, are common in water. Nitrate enters water through runoff from farms, golf courses, lawns, and gardens, as well as from the release of nitrogen oxides from vehicles. Ammonia enters water through runoff from farms and animal feedlots as well as agricultural fertilizer runoff. High levels of ammonia can build up in the blood and tissue of fish and can result in death (EPA 2017). Phosphates enter water in the form of organic waste and through soil erosion. Phosphate is commonly a limited resource in water (USGS 2018). Excess nitrogen or phosphate causes eutrophication that results in algal blooms. When that algae dies and decomposes, oxygen levels drop (USGS 2017).

Bacteria are natural components of water systems and most are harmless, although some cause disease. Coliforms are bacteria that are present in the fecal matter of vertebrates. One commonly tested for bacteria is *Escherichia coli (E. coli*) ; it is only found in fecal material from warm blooded vertebrates. *E. coli* is considered to be the best indicator of fecal contamination. Other coliforms we tested for included *Aeromonas* and *Salmonella,* both of which are found in water. *Aeromonas* is a human pathogen due to its ability to initiate gastrointestinal illness and other infections. In addition, *Aeromonas* also isolates injury or wound infection, nosocomial infections, septicemia, respiratory tract infections and peritonitis (Graf, 2015). *Salmonella* is another bacterium that causes illness such as diarrhea, fever, and abdominal cramps (CDC 2018). Because of the potential negative health effects ingesting water contaminated with coliforms can pose, they are used as an indicator that harmful bacteria may be present. Fecal coliform counts over 400 colonies per 100 ml of water increase the chance that pathogenic organisms are present, and thus such levels are labeled a health risk. A person swimming in such water has a greater chance of illness (MIT 2008).

Macroinvertebrates are organisms that lack backbones but can be seen with the naked eye. Macroinvertebrates are good indicators of ecological water quality because they spend most of their lives in water where they are sampled and have known pollution tolerances. Examples of common macroinvertebrates include stoneflies, snails, worms, and midges. Healthy water bodies will support a large number of pollution intolerant species. Water quality can be categorized from macroinvertebrates using the Pollution Tolerance Index (PTI); this lists species as pollution tolerant (aquatic worms and midge larva), moderately tolerant (scuds, dragonflies, and damselflies), or sensitive (mayflies, stoneflies, and caddisflies). The PTI uses a numerical scale to rate water systems from poor (0-10) to excellent (23 and above). (EPA 2016)

Vegetation

Riparian vegetation is important for water quality. Plant communities buffer inputs and cycling of nutrients. Besides providing homes to animals, vegetation helps protect banks from erosion, shades water to keep it cooler, provides food for animals, and filters runoff. An example of riparian vegetation along Cozine Creek is creek dogwood (*Cornus sericea*) . This species, along with other native plants, are being outcompeted by invasive plant species. The three most prevalent invasive species located in Cozine Creek are Himalayan blackberry (*Rubus armeniacus*) , English ivy (*Hedera helix*) and reed canary grass (*Phalaris arundinacea*). Invasive species often dominate areas leaving no growing space for native species (Oregon Conservation 2018).

Purpose of the Study

The main goal of our research was to compare water quality in two areas of Cozine Creek, as well as to compare water quality this year to the results from previous years. Examining trends in water quality over time can help determine future restoration needs, as well as determine the impact of current restoration work. We hypothesized that it is too early to see the results of the restoration work and make a conclusion on whether or not vegetation restoration activities have an effect on overall water quality and water quality variables. Although, we did hypothesis that the restoration work at Cozine Creek Linfield College as opposed to Cozine Creek Library will lead to better water quality at Linfield College as opposed to the Library.

Study Area

Our study locations are in the Willamette Valley. In the early nineteenth century, the Willamette Valley was described as primarily oak savanna and grassland. Oregon white oak (*Quercus garryana*) populations dominated in response to the practices of the Native Americans. These practices included low intensity fires that burned brush and trees that benefited oak trees because of their thick, fire resistant bark and deep root systems (Johannessen et al. 1971). European settlers who came to the area farmed to produce livestock and food. Today, the Willamette Valley is known for its production of wine grapes, hazelnuts, and grass seed (Towle 1982). The area produces two thirds of the total production of cool-season grasses in the United States. Its success in grass seed production has been linked to the valley's mild winters and dry summers that create ideal conditions for grass growth (Jessie 2018).

In addition to being important for agricultural production, the area also is key to many fish populations. The Willamette Valley is essential habitat for winter steelhead and Coho salmon. Coho salmon have not only been seen to reproduce in the area, but are returning in their natural migration patterns. Their ability to find natal streams depends on chemical distinction in the water. The fish rely on the Yamhill watershed, in which Cozine Creek is located. The Yamhill Watershed is also an important area for key vegetation to the Willamette Valley ecosystem. It has been found that thirty percent of the Yamhill Watershed is covered by grass and oak savanna habitat. Declines in species diversity has been linked to the loss of these prairie and oak savannas habitats (GYWC 2018).

Site descriptions

We measured water quality in Cozine Creek at two sites, Linfield College and City Park near the Library (Figure 1). At each site, we had three or four locations where we measured water quality. There were three sites along the main creek and one site at a side stream that flowed into Cozine Creek at Linfield College. We had three sites at a location further upstream, near the McMinnville Library in City Park . We recorded the GPS locations at each of these sites (Table 1).

Figure 1. Locations of testing sites on Cozine Creek at Linfield College and at the Library Site. Map created based off GPS readings during sampling using Arcmap 10.6 (Created by Sarah Schmidt).

Table 1: GPS locations for each locations where we collected water quality data.

Location	Site	Latitude	Longitude
Linfield College	1	45.2029	-123.19791
Linfield College	2	45.208	-123.19832
Linfield College	3	45.2035	-123.19952
Linfield College	4	45.2035	-123.19956
Library	1	45.20999	-123.20167
Library	2	45.2103	-123.20186
Library	3	45.21062	-123.20209

Linfield College Site

The Linfield College (LC) site was located where Cozine Creek flows through the campus. Three sampling locations were randomly selected by the ENVS 385 (Research Methods) students in the spring of 2011 (Colahan et al. 2011). The Cozine Creek property consists of riparian and remnant oak woodland. Parts of the area were treated with herbicides and mowed during the summer of 2018 as a result of the OWEB grant (Berg et al. 2018). Site one had slow flow and small to large rocks scattered along the bottom of the creek, creating ripples in the otherwise clear water. Next to the creek were large Oregon ash (*Fraxinus latifolia*) trees and creek dogwood (*Cornus sericea*) , as well as reed canary grass (*Phalaris arundinacea)*, Himalayan blackberry (*Rubus armeniacus*), and trailing blackberry (*Rubus ursinus*). The tree canopy shaded the site. At this site, herbicide use and a lawn mower where used on vegetation outside the initial tree line along the banks of the creek.

The second site, upstream from the first, had shaded, slow flowing, clear water. Bittersweet nightshade (*Solanum dulcamara*) , Oregon ash, creek dogwood, and both species of blackberry were at this site was well. Fallen logs lay across the creek (Figure 2). The surrounding area to this site had been mowed and treated with herbicides.

Figure 2. Cozine Creek as it flows through the Linfield Campus at subsite 2 (photo take September 5, 2018).

The third site was in an area classified as a future hand pull area for a removal of invasive species in the grant (Berg et al. 2017). The water was clear and slow flowing. The trees in the area included Oregon ash and Pacific willow (*Salix* sp.*)* and had an unknown grass on both sides of the banks and in the middle of the creek.

A fourth sampling site was a side stream leading into the third sampling area. The stream appears to flow from SE Baker street and the college campus. Both the third and fourth sites had Himalayan blackberry (*Rubus armeniacus*), trailing blackberry (*Rubus ursinus*), as well as an unknown species of grass.

McMinnville Library Site

The Library Site (upstream from Linfield College) was located on the North Fork of Cozine Creek, where it flows through City Park. This section of the creek has water that drains from the Michelbook Country Club golf course (Luke Westphal, personal communication, November 28, 2018). The three sampling locations were randomly selected in fall 2011 by the students in ENVS 385 (Colahan et al. 2011). Site one had stagnant water with an unknown grass along the banks and in the middle of the creek. Many water striders were on the water's surface, which was murky in color, and the bottom of the creek was muddy. This site was under the canopy of Oregon white oak trees (*Quercus garryana*) and an ash tree (*Fraxinus latifolia)*. Trailing blackberry (*Rubus Ursinus*), English ivy (*Hedera helix*), and bittersweet nightshade (*Solanum dulcamara*) covered the banks.

Site two was next to a pedestrian bridge over the creek. The area had some scattered larger rocks, but most of the creek bottom was mud. The water was slowly flowing. Trailing blackberry, English ivy, bittersweet nightshade, lemon balm (*Melissa officinalis*), and field mint (*Mentha arvensis*) were located on the bank.

At the third site, large rocks covered the creek bottom and the water was clear and slow moving. A crawfish was seen under a rock in the middle of the creek. English ivy, field mint, trailing blackberry, and bittersweet nightshade plants were along the creek (Figure 3).

Figure 3. Cozine Creek as it flows through the Library site at subsite 3 (photo taken on September 19, 2018).

Previous Water Quality Testing

Students in Linfield College's Research Methods courses (ENVS 385; ENVS 460) started annual monitoring of Cozine Creek water quality in spring 2011 (Colahan et al. 2018). Studies done in fall between 2011 and 2015 showed that Cozine Creek had the poorest water quality of the three creeks then being examined. In 2016, the students decided to focus only on Cozine Creek in efforts to find where clean water flows into the creek, and compare the health of the creek at various locations in McMinnville (Cowell et al. 2016). All studies conducted by the prior ENVS classes concluded that Cozine Creek had poor water quality due to high temperature and high levels of bacteria, nitrates, and phosphates, as well as low DO and flow at all Cozine sites. The 2016 and 2017 studies showed that the Linfield College site had poorer water quality than the library site (Berg et al. 2017). All locations along Cozine in all years had a poor Pollution Tolerance Index (PTI). Agricultural and urban runoff were theorized as the most likely cause of the poor water quality (Bailey et al. 2012). Storm events and periods of heavy rainfall can lead to poor water quality as the runoff brings pollutants and nutrients into the creek (Baralkiewicz et al. 2014).

METHODS - Field Procedures

All equipment was calibrated in the laboratory prior to going to the field. When we arrived at each site location we measured the air temperature (Celsius). At each sampling location, we then collected approximately 250 mL of water in a sterile Nalgene bottle. This was placed in a cooler. we also collected water in a BOD bottle. In order to have accurate BOD, the bottle was filled to the top and the cap placed on in such a manner that it displaced all air. The BOD bottle was wrapped in foil and placed in the cooler. Upon returning to the laboratory the sterile sample was placed in the freezer to be used later to measure nutrients, turbidity, and coliform bacteria. We also measured the stream depth in centimeters at each location where water samples were taken. The BOD bottle was placed in a dark location for five days (Delzer and McKenzie 2003). These samples were taken prior to any other data to minimize contamination.

Dissolved Oxygen (DO)

We measured DO in % and ppm using a Oaklon DO 6+ DO meter . The probe was placed in the water and the measurements take after the reading stabilized (Figure 4). The measurements were taken five times at each site with the probe removed from the stream between each reading.

Figure 4: Chris Stinchcomb using the DO meter at site 2 in Library park (photo taken September 19, 2018).

pH

The pH of the water at each site location was measured using a Hanna pH meter (Model HI9128). The pH probe was submerged in the water (making sure not to touch the substrate at the bottom of the stream) and the data recorded once the reading stabilized. pH was measured five times with the probe removed from the water between each reading.

Flow

We measured the flow at each site location using a SwissFlow flowmeter (Model SF800) (Figure 5). The instrument was placed in the stream with the propeller facing upstream; the propeller could not be touching anything to get an accurate reading. Once the rate stabilized, the measurement was recorded. Flow was recorded five times with the propeller removed from the water between each reading.

Figure 5: Chris Stinchcomb preparing the flow meter at subsite 3 on the LC site (photo taken September 5, 2018).

Macroinvertebrates

Macroinvertebrates were only collected at sample location 2 at the Library site in City Park. We randomly selected three areas along the stream at this location to sample. We measured the depth of the water at each sampling area. Macroinvertebrates were collected using two D nets. One net was positioned facing upstream; this net was used to collect samples that floated downstream. The other net was position facing downstream; this net was used to scrape the bottom substrate and removed any macroinvertebrates. Rocks between the nets were hand rubbed so that macroinvertebrates that fell off washed into the downstream net. The contents of both nets were emptied into a shallow tub, with the net rinsed to ensure all contents were removed. Each bucket was surveyed by students who removed all macroinvertebrates; these were placed in jars containing 70% isopropyl alcohol. The jars were then taken back to the lab to be sorted, counted, and identified at a later date (EPA 1997).

Vegetation Sampling

Vegetation sampling was only conducted at the Cozine Linfield College site. The 2017-2018 Senior Capstone ENVS students had collected baseline data prior to and while writing the grant. They had measured vegetation data at four locations on campus (Figure 6). One set of transects was located in an area where an accidental burn had happened in August 2017. Vegetation data collected there will us to see what species return after a fire. The second set of transects was along the north side of Cozine Creek where hand removal of invasive species (mostly Himalayan blackberry) had occurred. Another set of transects were on a hill between Newby Hall and the President's house. This site was the location of ongoing hand removal of invasive species beginning in August 2016; some native species were planted last spring. A fourth set of transects was located on the south side of the creek. In spring of 2018, when these transects were located they were covered completely by Himalayan blackberry.

Figure 6. Location of the vegetation sites on the Linfield College campus. Map created based off GPS readings taken at each location and using Arcmap 10.6 (created by Sarah Schmidt).

Last year's students recorded GPS locations of each transect; we located those transects using their coordinates to compare vegetation (Table 2). At each location we reran the transects as close to where they had been as possible. We recorded the percent cover of each plant species in each meter along each transect. We measured the height and basal area of all trees on each transect. We also attempted to find all of the surviving planted plants that were planted on Newby Hill; we identified the species of each found plant and measured the basal area and height.

Table 2: GPS Locations (Beginning Coordinates) of Vegetation Transect Sites and Length of Each Transect

Site	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
South Side Cleared	45.20279, -123.19801	45.20282, -123.19796	45.20259, -123.19820		
Burn Site	45.20290, -123.19726	45.2031, -123.19749	45.20295, -123.19735	45.20292, -123.19736	
North Side Bridge	45.20322, -123.19843	45.20324, - 123.19859	45.20325, -123.19865	45.20327, -123.19869	45.20330, -123.19874
Newby Hill	45.20262 -123.19880	45.20257 -123.19879	45.20257 -123.19824	45.20242 -123.19869	45.20240 -123.19869

In Laboratory Procedures

Biochemical Oxygen Demand (BOD)

After five days, five aliquots from each BOD bottle were carefully poured into beakers. Using the same DO meter, we measured the DO in each beaker as percent and parts per million. BOD was calculated by subtracting each DO measured in the lab after five days from the average DO measured in the field (Delzer and McKenzie 2003).

The sterile Nalgene bottles were removed from the freezer and allowed to thaw. We used this water to measure turbidity, levels of nutrients, and coliform bacteria.

Turbidity

We measured turbidity using a HANNA Instruments field turbidity meter (model: HI93703C). The water in each sample bottle was mixed well by gently inverting it and a small sample was poured into the turbidity meter cuvette. The cuvette was capped, wiped with a lint free cloth, and placed in the reading cell. Once the machine stabilized, the turbidity level was recorded. Five measurements were made for each sample with the cuvette being mixed and re-wiped down before every reading.

Nutrients

Using the thawed water sample from the sterile bottle, levels of ammonia, nitrate, and phosphate were tested in the lab.

To test for ammonia, we used the LaMotte Ammonia-Nitrogen test kit according to the procedure in the directions. Five samples of water were sampled for each site location. Values were then multiplied by 1.3 to convert to parts per million (LaMotte 2012a).

To test for nitrate, we used the LaMotte Nitrate-Nitrogen test kit according to the procedure in the directions. Each test was done five times, and the final value was multiplied by 4.4 to convert to parts per million (LaMotte 2012b).

To test for phosphate, we used the LaMotte Phosphate Test kit according to the directions. Each test was run five times. No conversion was needed as the kit gave readings in parts per million (LaMotte 2012c).

Coliform Bacteria

We used the frozen water sample to test for *E.coli* , *Salmonella*, *Aeromonas* , and other coliform bacteria. Using sterile technique, we pipetted 4 milliliters of water into bottles of ECA Check Easygel. The bottles were gently inverted to mix, and the gel was poured into petri dishes. Five petri dishes were made for each water sample. The petri dishes were placed in the incubator and colonies were counted after approximately 48 hours. Each student counted colonies. Dots that were dark blue were *E.coli*, teal green circular dots were *Salmonella* , *Aeromonas* appeared as pink or red, and blue or blue gray were other coliform bacteria. The raw colony counts were converted to colonies per 100 ml (Micrology Laboratories 2008).

Macroinvertebrates

The collected macroinvertebrates stored in isopropyl alcohol were examined in the lab. Using a dissecting microscope, the macroinvertebrates were identified to the most specific taxa using keys (SWRC 2017; NW Nature 2015). Each jar of macroinvertebrates was counted by two different people. From the counts, the pollution tolerance index was determined. The total number of taxa in each pollution tolerance group were multiplied by points designated to each pollution tolerance group and then these numbers were summed to determine the pollution tolerance index (IDEM 2017).

Statistical Analysis

In order to determine whether our results were statistically significant, we used JMP 13. Water quality variables were compared among sites using independent t-tests. For all of the statistical tests, a p-value less than 0.05 indicates statistical significance. The Oneway ANOVA (Analysis of Variance) test was used to determine whether or not there are significant differences among the means in different years of testing. Tukey Kramer HSD post hoc tests were done to show which years were significantly different from each other by using different letters (JMP 2017a; JMP 2017b).

RESULTS

We found that DO and temperature were significantly higher at the Linfield College site than at the Library site in 2018 (Table 3).

Table 3: Mean (standard deviation) and probability for water quality variables at different locations of Cozine Creek based on independent t-test. Highlighted probability values indicate a statistical significance.

Parameter	Site Location		P-Value
	Linfield College	Library	
DO (%)	77.78 (9.06)	66.94 (1.73)	0.0001
DO (ppm)	7.18 (0.69) (A)	6.54 (0.210)	0.0006
BOD%	20.39 (6.19)	20.43 (1.66)	0.9755
Temp (C)	18.79 (1.98)	16.35 (0.43)	0.0001
pH	7.11 (0.50)	7.08 (0.03)	0.8644
Flow (cm/s)	6.25 (6.51)	3.53 (3.34)	0.1501
Phosphate (ppm)	0.115 (0.081)	0.086 (0.083)	0.3227
Nitrates (ppm)	4.29 (3.15)	3.37 (1.14)	0.2408
Ammonia (ppm)	0.420 (0.542)	0.312 (0.197)	0.4177

The Library site had significantly higher amounts of all bacteria, including *E. coli* , than the Linfield college site (Table 4).

Table 4: Mean (standard deviation) and probability for bacteria (colonies per 100 ml) at different locations of Cozine Creek based on independent t-test. Highlighted probability values indicate a statistical significance.

Bacteria	**Linfield college**	**Library**	**P-value**
E. coli (#/100)	13.29 (31.22)	91.12(41.34)	0.0001
Aeromonas (#/100)	18.67 (43.57)	61.67 (56.31)	0.0001
Salmonella (#/100)	1.9 (6.67)	17.23 (20.52)	0.0001
Other coliforms (#/100)	20.57 (42.51)	78.89 (82.91)	0.0001

The greatest abundance of individual macroinvertebrates, as well as the highest PTI was found at Library site 1, resulting in a fair PTI. Both Library site 2 and 3 had poor PTI's (Table 5).

Table 5: Pollution tolerance Index of macroinvertebrates from the library site. A total PTI of 10 or below is poor, 11-16 fair, 17-22 good, and 23 and above is excellent. For each site the total points for each category is added together using the number of different species collected and the category they fall into, the resulting total PTI is the sum total of each category.

PTI	**Library 1**	**Library 2**	**Library 3**
Pollution Sensitive (3 points)	2	0	1
Moderately Tolerant (2 points)	1	0	0
Pollution Tolerant (1 point)	4	4	4
Total Individuals	249	159	23
Total PTI	12	4	7

We found all water quality variables but ammonia were significantly different between the side stream and main creek. DO, BOD, pH, and temperature were significantly higher in the side stream whereas flow, phosphate, and nitrates were significantly lower in the side stream (Table 6).

Table 6: Mean (standard deviation) and probability of water quality in the main Cozine Creek and the side stream at the Linfield College site based on an independent t-test. Highlighted probability values indicate a statistical significance.

	Main creek	**Side stream**	**p-value**
DO%	53.07 (38.42)	88.18 (1.17)	0.0033
DO (ppm)	7.01 (0.71)	7.69 (0.15)	0.0028
BOD	18.53 (6.09)	25.94 (0.74)	0.0003
Temp	17.71(0.55)	22.02 (0.42)	0.0001
pH	6.95 (0.49)	7.57 (0.07)	0.0003
Flow	8.33 (6.24)	0 (0)	0.0001
Phosphate	0.15 (0.05)	0 (0)	0.0001
Nitrates	5.28 (2.97)	1.32 (1.24)	0.0006
Ammonia	0.48 (0.62)	0.25 (0.11)	0.1838

DO, pH, flow, and the number of *Salmonella* were significantly greater in spring 2018 than in fall (Table 7). Temperature, phosphates, ammonia, *Aeromonas*, *E. coli,* and other coliforms were significantly greater in Fall 2018.

Table 7: Mean (standard deviation) and probability for water quality variables at the Linfield College site in Spring 2018 compared to Fall 2018 based on a paired t-test. Highlighted probability values indicate a statistical significance.

Variable	**SP2018**	**F2018**	**p-value**
DO%	87.14 (2.06)	73.13 (8.76	0.0001
DO (ppm)	9.23 (1.20)	6.90 (0.62)	0.0001
Temp (C)	12.83 (0.88)	17.74 (1.94	0.0001
pH	7.45 (0.27)	7.09 (0.38)	0.0006
Flow (cm/s)	17.00 (7.85)	5.09 (5.49)	0.0001
Phosphate (ppm)	0.04 (0.08)	0.15 (0.05)	0.0001
Nitrates (ppm)	6.27 (1.29)	5.28 (2.97)	0.1911
Ammonia (ppm)	0.18 (0.09)	0.48 (0.62)	0.0398
Turbidity (FTU)	3.79 (1.71)	4.44 (1.44)	0.2417
Salmonella (#/100)	3.16 (8.37)	1.89 (6.67)	0.0001
Aeromonas (#/100)	7.91 (15.20)	18.67 (43.57	0.0001
E.coli (#/100)	2.85 (10.58)	13.29 (31.22	0.0001
Other Coliforms (#/100)	9.49 (1.17)	20.57 (4.99	0.0001

Water quality variables in Fall 2018 compared to previous years showed significantly higher percent dissolved oxygen than in Fall 2012 to 2015 and 2017 (Table 8). Dissolved oxygen (ppm) was significantly higher in 2018 than in years 2013-2016. Biochemical Oxygen Demand (BOD), temperature, phosphate, and ammonia levels were significantly higher in 2018 than all previous years. Turbidity was significantly lower in 2018 than in prior years.

Table 8: Mean (standard deviation) and probability for water quality variables at the Linfield College Cozine location in the Fall term of years 2011-2018 based on ANOVA. Means with different levels are significantly different from one another as per Tukey HSD post hoc test.

Variable	**F2011**	**F2012**	**F2013**	**F2014**	**F2015**	**F2016**	**F2017**	**F2018**	**p-value**
DO%	69.39 (2.92) AB	58.18 (1.0) BC	43.54 (8.61) CD	52.43 (10.07) BCD	34.0 (12.16) D	63.09 (3.73) AB	56.22 (29.38) BC	77.78 (9.06) A	0.0001
DO (ppm)	N/A	N/A	4.67 (0.89) C	5.09 (1.15) BC	2.92 (1.00) D	6.2 (0.35) B	7.51 (1.20) A	7.18 (0.69) A	0.0001
BOD%	N/A	3.68 (3.76) D	9.84 (6.01) CD	16.23 (7.58) BC	24.85 (14.16) B	12.16 (6.23) CD	22.41 (5.73) B	57.39 (4.25) A	0.0001
Temp (C)	12.32 (0.11) CD	9.56 (0.35) D	13.37 (0.72) BCD	13.46 (1.22) BCD	16.64 (0.69) B	15.91 (0.62) BC	16.51 (1.11) B	20.39 (6.19) A	0.0001
pH	6.84 (0.23) BC	6.49 (0.26) BC	6.32 (0.53) C	6.30 (0.31) C	7.18 (0.04) BC	7.29 (0.12) BC	7.48 (0.57) B	7.37 (0.03) B	0.0001
Flow (cm/s)	8.83 (6.28) AB	10.5 (8.57) AB	0.44 (0.88) B	N/A	3.0 (4.41) B	7.0 (7.63) B	22.45 (26.97) A	7.11 (2.96) B	0.0003
Phosphate (ppm)	0.2 (0.0) B	0 (0) B	0.07 (0.05) B	0.11 (0.18) B	0.31 (0.18) B	0.07 (0.45) B	0.15 (0.64) B	6.25 (6.51) A	0.0001
Nitrates (ppm)	0 (0) AB	0 (0) AB	0 (0) AB	1.96 (3.19) AB	2.64 (3.19) A	2.5 (2.5) AB	0.82 (1.05) AB	0.15 (0.05) B	0.0009
Ammonia (ppm)	N/A	N/A	0.17 (0.05) B	0.15 (0.06) B	0.14 (0.33) B	0.19 (0.33) B	0.14 (0.28) B	5.28 (0.33) A	0.0001
Turbidity (FTU)	N/A	N/A	9.12(1.1) AB	5.04 (1.1) B	9.5 (0.85) A	5.95 (4.04) B	6.42 (4.23) AB	0.48 (0.85) C	0.0001

We found significantly fewer *Salmonella* in 2018 than in 2011 and 2017 (Table 9). We found significantly fewer *Aeromonas* in 2018 than in 2011 and 2012, and fewer *E.coli* i n 2018 than 2017, 2011, and 2012.

Table 9: Comparison of bacterial colonies in Cozine water samples taken each Fall from 2011 to 2018. Bacteria recorded as colonies per 100 mL.

Bacteria	**F2011**	**F2012**	**F2013**	**F2014**	**F2015**	**F2016**	**F2017**	**F2018**	**p-value**
Salmonella (#/100)	800 (447) A	0 (0) C	138.9 (60.7) BC	0 (0) C	25 (43.7) C	5.6 (25.8) C	204.0 (15.7) B	8.8 (16.7) C	0.0001
Aeromonas (#/100)	27288.9 (5210.7) A	1133.3 (487.1) B	NA	22.2 (44.1) C	30 (135.7) C	5.2 (11.9) C	122.5 (176.1) C	39.1 (52.0)C	0.0001
E.coli (#/100)	577.8 (636.0) A	51.1 (50.6) B	44.4 (50.6) BC	0 (50.6) BC	15 (19.6) C	2.4 (21.5) C	156.8 (13.1) B	44.5 (13.9) C	0.0001
Other Coliforms (#/100)	4977.8 (2307.5) A	80 (48.9) B	NA	155.6 (187.8) B	126.7 (257.7) B	10.4 (27.5) B	142.7 (230.7) B	46.2 (66.2) B	0.0001

Oregon grape and Indian plum seedlings planted in the spring by ENVS students had lower survivorship than seedlings planted by the GYWC (Table 10). Snowberry seedlings survivorship on Newby Hill was greater than 100%.

Table 10: Survivorship of native plants on Newby Hill in spring 2018 that were planted by ENVS students and the GYWC.

Species	**Number planted by ENVS Spring 2018**	**Number surviving Fall 2018**	**Survivorship**	**Number planted by GYWC March 2018**	**Number surviving Fall 2018**	**Survivorship**
Oregon Grape	47	8	17%	25	18	72%
Snowberry	29	35	130%	0	0	0%
Indian Plum	30	5	17%	5	5	100%

We found that percent cover by English ivy as well as by total invasive species was significantly lower on Newby Hill in fall 2018 compared to fall 2017 (Table 11).

Table 11: Mean (standard deviation) and probability of the percent cover by selected plant species on Newby Hill in Fall 2017 and Fall 2018. Total invasive species includes clematis, ivy, laurel, Himalayan blackberry, Italian arum, reed canary grass, and vinca.

Vegetation	**Fall 2017**	**Fall 2018**	**p-value**
Bare Ground	18.8 (11.8	25.8 (20.6	0.5303
Creeping buttercup	4.4 (2.8)	1.6 (1.9)	0.0909
English ivy	24.1 (4.5)	13.7 (4.5)	0.0064
Grass	17.0 (4.6)	10.9 (9.2)	0.2226
Himalayan blackberry	10.3 (5.7)	5.6 (3.9)	0.1707
Snowberry	4.2 (4.4)	5.6 (7.7)	0.7307
Trailing blackberry	11.7 (9.0)	23.9 (15.1	0.1602
Total invasive species	36.8 (6.8)	22.6 (6.0)	0.008

DISCUSSION – Water Quality

Fall 2018 Site Comparison

Our results showed that water in Cozine Creek at Linfield College had significantly higher DO and temperature than the water in the creek at the Library site (Figures 7 and 8). These results could be related to low flow, but are most likely due to higher water temperatures in the Linfield College section of the creek due to less vegetation shading the creek at Linfield College. Regardless DO and water temperature at both sites were outside of those acceptable for salmon.

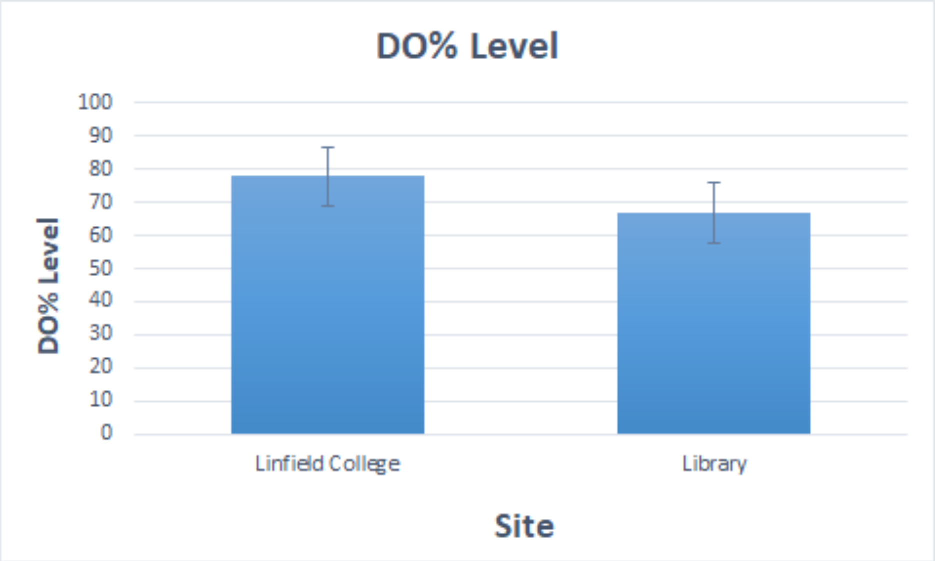


Figure 7: Mean (error bars are standard deviation) percent DO at each site. 90% DO represents the optimal level for salmon (Wasowski et al. 2013). $p<0.0001$.

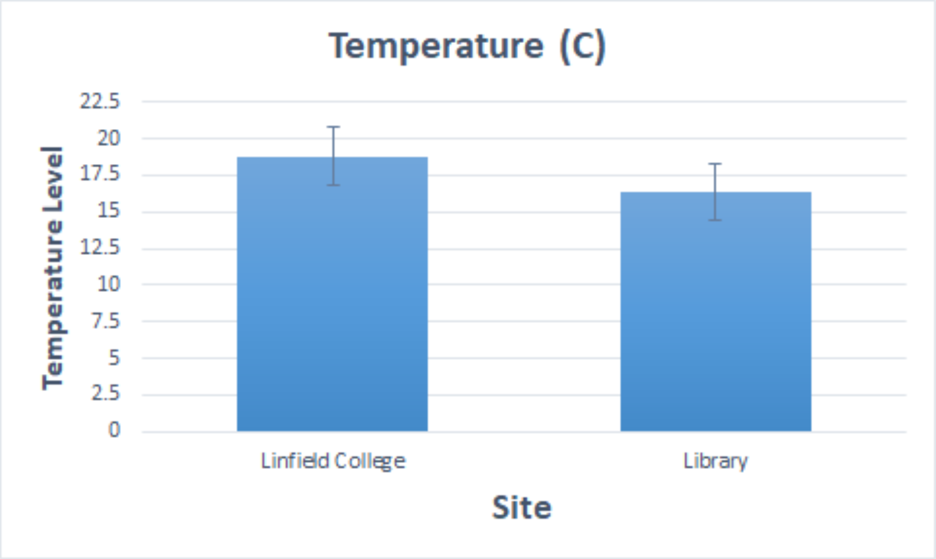


Figure 8: Mean (error bars are standard deviation) for temperature at each site. 12 degrees C is the upper temperature for salmon (USGS 2014; EPA 2003). p<0.0001.

Linfield College Main Channel versus the Side Stream in 2018

For the first time, our class examined the water quality in a side stream that enters the main channel of Cozine Creek at Linfield College. The side stream flows from SE Baker Street to the creek by the third sampling site (the most upstream site). We originally believed the water came from storm runoff and excess rainwater, but the presence of the flow without recent rainfall indicated another source of water. Percent DO, BOD, temperature, flow, and nitrates were all significantly greater in the side stream (Figure 9 and Table 6) than in the main channel. It is possible that Cozine Creek at Linfield College had better water quality than the library site on the north fork as a result of the water entering from the side stream above our sample sites. The source of the side stream is unknown; it may be coming from groundwater, run off of irrigation water from the college, or a water leak McMinnville public water pipes. The source of the side stream should be further investigated.

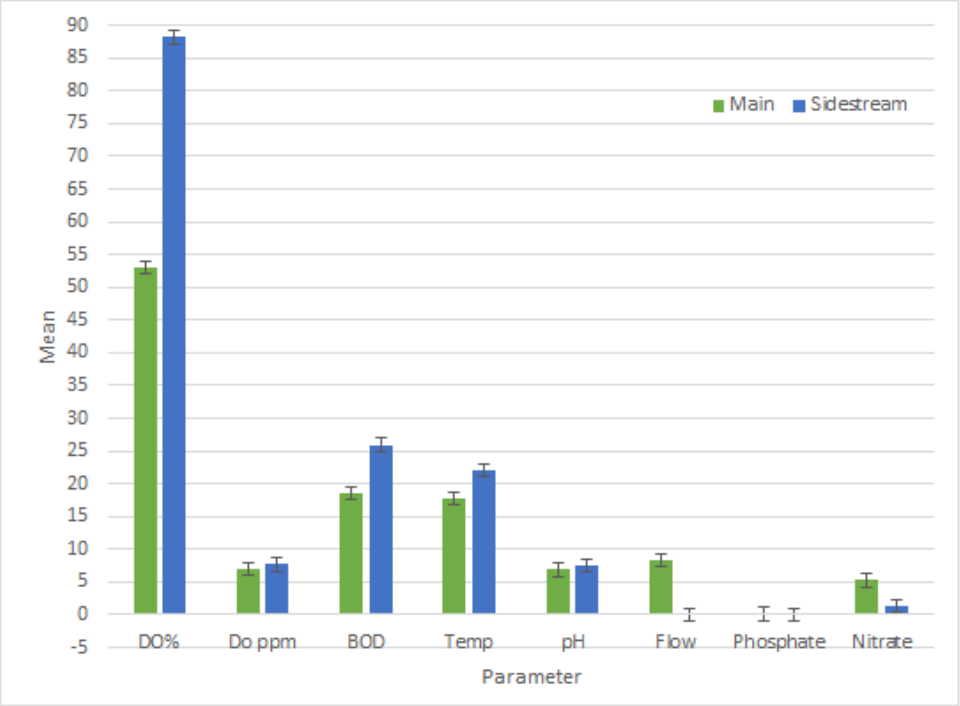


Figure 9: A comparison of water quality variables in Cozine Creek as it flows through the Linfield College site compared to the side stream that enters just above site 3. See Table 6 for statistical results.

Spring 2018 compared to Fall 2018

Some of the students in the ENVS 470 Senior Capstone course sampled water at our Cozine Creek sites in Spring 2018. When comparing the results from spring 2018 to fall 2018, we found that water quality was better in the spring. DO, pH, and flow were significantly higher in the spring; temperature, phosphate, ammonia, and all measure of bacteria were higher in the fall (Table 7). We believe this variation is most likely due to seasonal changes in precipitation and temperature. Lower air temperatures in the spring, combined with great levels of precipitation than in the spring could have led to our results.

Trends in data over the years (2011 - 2018)

Dissolved Oxygen (DO)

Although DO varied over the years, dissolved oxygen levels were significantly higher in 2018 compared to previous years. Even so, it remains below the optimal level for a salmon-bearing stream (Figure 10). Low DO is dangerous to aquatic life, especially salmon, posing problems with reproduction and survival. Well oxygenated water allows fish to thrive and their smolts to develop fully (Wasowski et. al 2013). Low levels of DO may be attributed to the low flow and high temperature every summer. Low flow reduces oxygen diffusion into the water, and along with high temperatures, leave the water less oxygenated and unable to support healthy salmon populations (Breitburg et al. 1997).

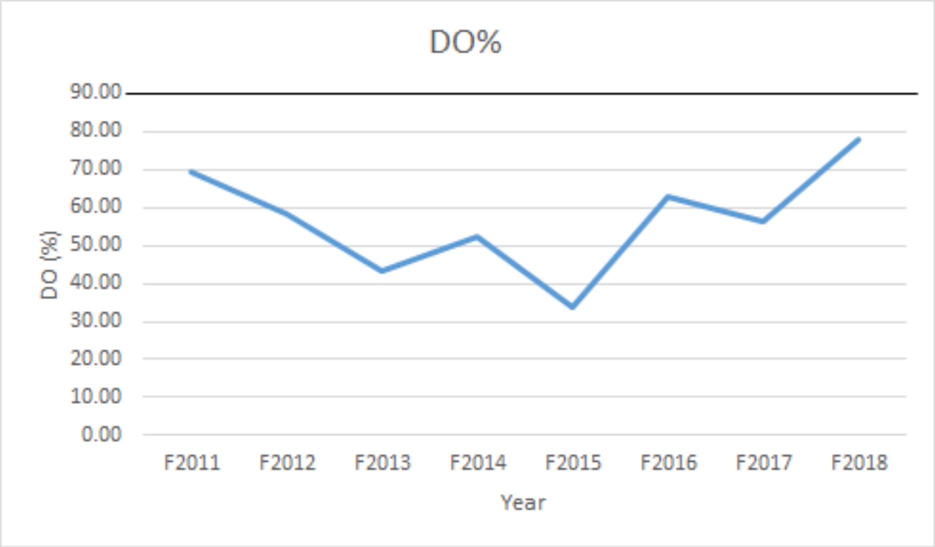


Figure 10: Mean DO (%) at the Linfield College site from fall 2011 through 2018. The black line represents the ideal dissolved oxygen level (90%) for a salmon-bearing stream (Wasowski et. al 2013).

Flow

Although flow has fluctuated widely, we found it was significantly lower in 2018 compared than 2017 (Figure 11). Even during higher recorded flows, it has remained under the optimal minimum rate set by the EPA for salmon, 30.48 cm/s (EPA 2012). A low flow correlates with higher water temperatures because stagnant water can absorb more sun. Because water movement disperses oxygen a lack of flow also relates to a lower DO. The low flow in Cozine Creek, along with high water temperature, are likely contributing factors to the low DO that has been a continuous trend. Flow also relates to the amount of precipitation that occurred prior to testing, so the observed fluctuations in flow could have been caused by different levels of rain prior to testing (USGS 2016c).

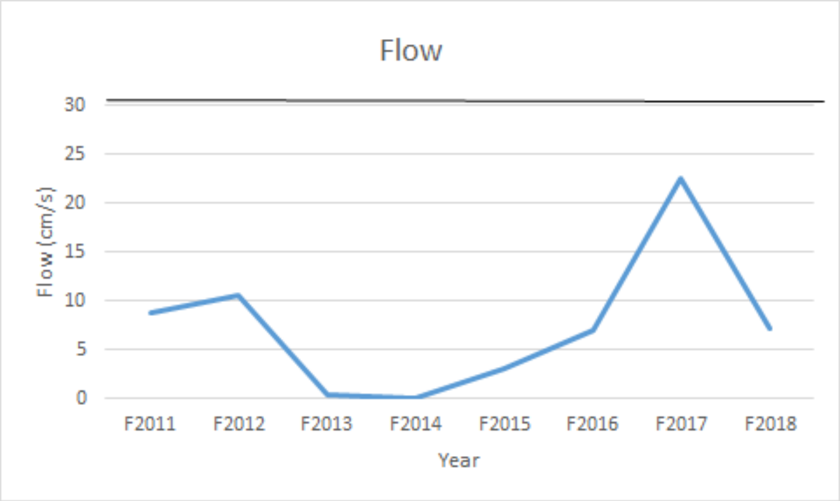


Figure 11: Mean flow at the Linfield College site from fall 2011 through 2018. The black line represents the optimal minimum flow value for salmon (30.48 cm/s) (EPA 2012).

Temperature

Temperature was higher in 2018 than in previous years of study and showed a tendency to increase over time (Figure 12). Temperature is a key factor in overall water quality. The maximum optimal temperature for salmon is 12°C (USGS 2014), which has been exceeded every year except 2012. Warmer water holds less dissolved oxygen and will affect the distribution, health, and survival of salmonids. High temperatures increase stress and disease in fish (EPA 2003). The increasing trend in temperature may be the result of warmer temperatures recorded in Oregon summers during the past decade (KOIN 6 2018).

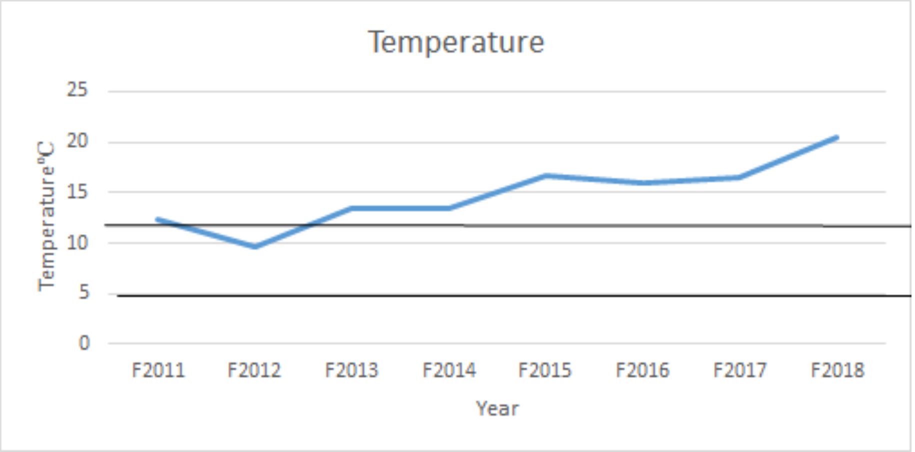
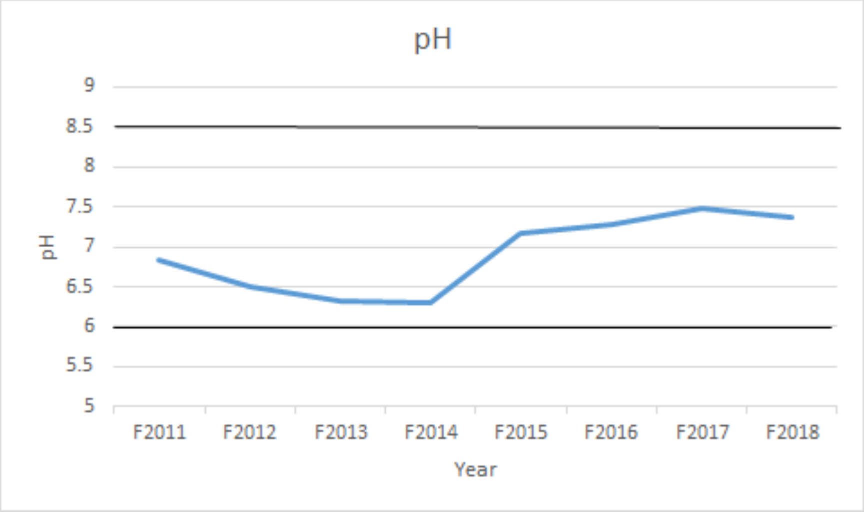


Figure 12: Comparison of mean temperature at the Linfield College site from fall 2011 to 2018. The black line represents the maximum temperature for salmon (USGS 2014; EPA 2003).

pH

pH has fluctuated over the years, but has remained in the acceptable salmon bearing range of 6.0 to 8.5 (Figure 13). pH levels outside of this range increase the likelihood of blood related issues such as reduced blood oxygen carrying capacity that can lead to issues related to reproduction and survival (DFO 1983). Cozine water had a pH 7.37. In the earlier years of study the pH was slightly more acidic; this difference could be a result of fertilizers used in nearby agricultural and urban areas (Fondriest Environmental 2013b).

Figure 13: Comparison of pH at the Linfield College site from fall 2011 to 2018. The black line represents the ideal range for salmon habitat (6.0-8.5) based on DFO 1983.



Turbidity

Turbidity has been variable, although the trend is downward (Figure 14). Turbidity levels have been below 10 FTU every year. Turbidity did decrease significantly in 2018 relative to previous years. This does not necessarily mean we have better water quality (since it only decreased in the most recent year), but it is an indicator that water quality might be improving.

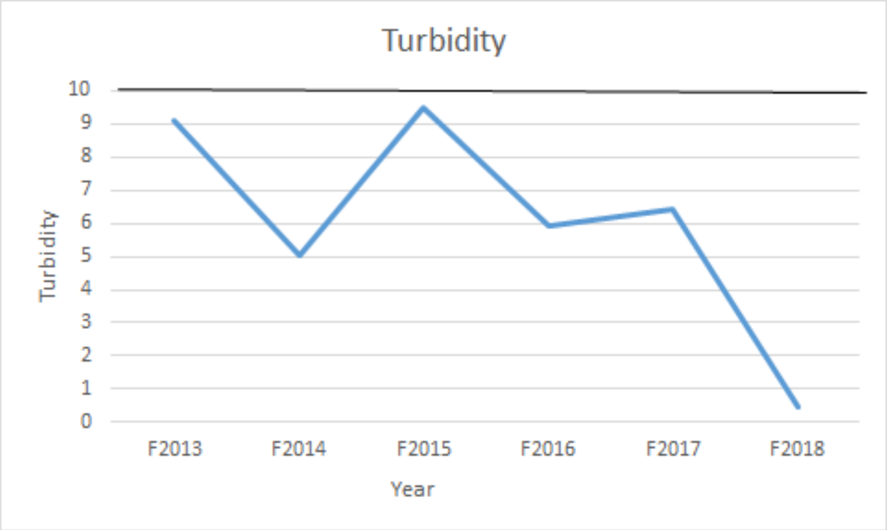


Figure 14: Comparison of mean turbidity at the Linfield College site in fall 2011 through fall 2018. Levels greater than 10 FTU prevent light from passing through the water (Minnesota Pollution Control Agency 2008).

Nutrients - Phosphate

In 2018, phosphate levels were significantly higher than had been previously measured (Figure 15). This level was above that acceptable for salmon (Jensen 2010).

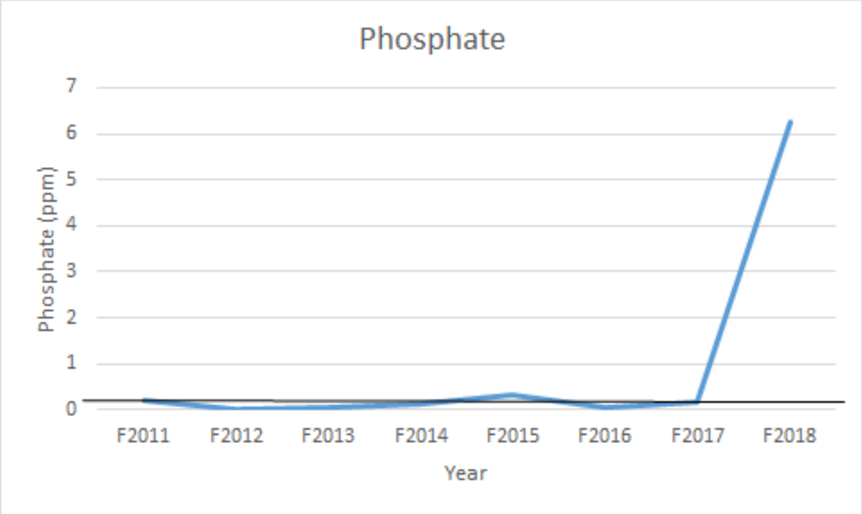


Figure 15: Mean phosphate at Linfield College from fall 2011 to fall 2018. The black line represents optimal level of phosphate for a salmon-bearing stream.

Nutrients - Ammonia

Similar to phosphate, ammonia increased significantly compared to previous years (Figure 16). This was much higher than the salmon tolerable level (approximately 0.25 ppm)

(Jensen 2010).

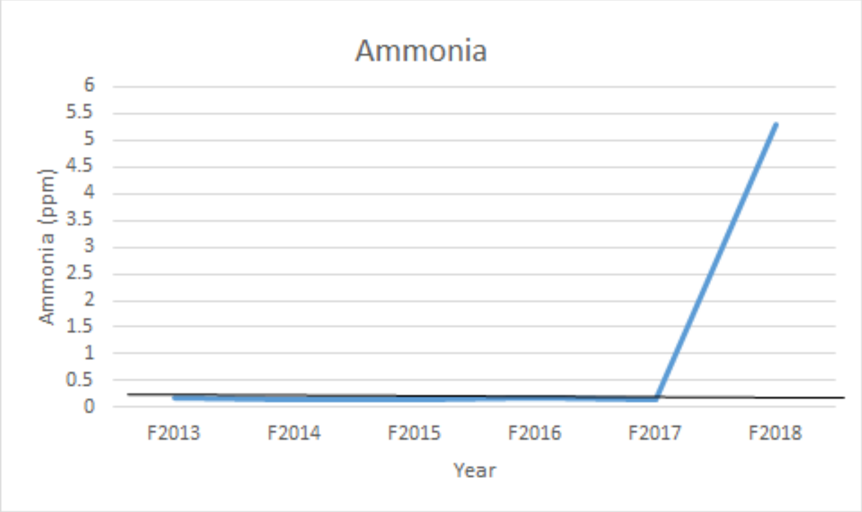


Figure 16: Mean ammonia at the Linfield College site from 2011 to 2018. The black line represents optimal level of phosphate for a salmon-bearing stream.

Nutrients - Nitrate

In comparison to the other two nutrients, nitrate concentration decreased in 2018 (Figure 17). It is now within the range tolerable for salmon (Jensen 2010).

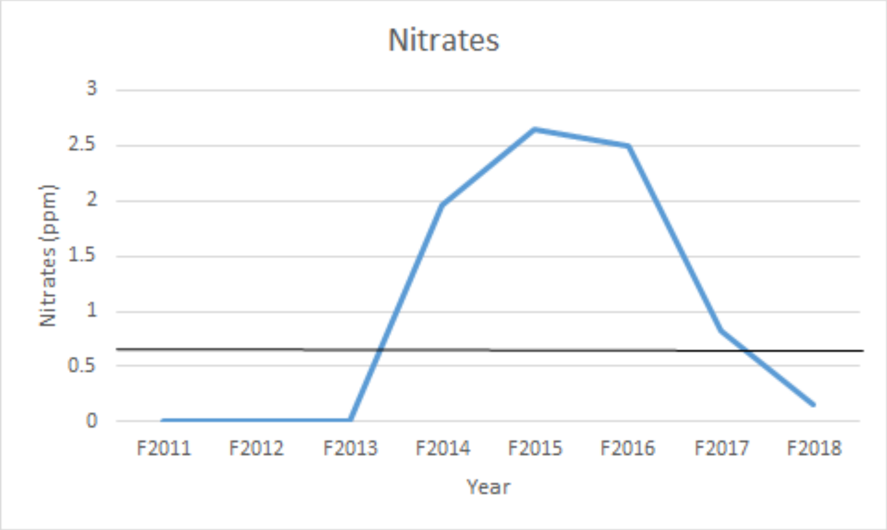


Figure 17: Mean nitrate at Linfield College from fall 2011 to 2018. The black line represents optimal level of phosphate for a salmon-bearing stream.

Our nutrient data was interesting because phosphate and ammonia increased whereas nitrate did not. Ammonia is found in commercial fertilizers, animal waste, and decomposing organic matter (EPA 2017). Both the Library site and the Linfield College site had higher levels of phosphate and ammonia leading us to believe the source was upstream on the North Fork of the creek (above both sites). The increase in these two nutrients may be due to an increase in the number of farms upstream that could serve as a source of ammonia or an increase in the number of animals on farms. In addition, runoff from Michelbook Country Club golf course drains into this branch of Cozine Creek, and the increase in ammonia and phosphate may have come from their fertilizer. Ammonia-nitrogen fertilizer is preferred over nitrate-nitrogen fertilizer by golf courses because the hydrogen ions in the solution allows for less volatilization especially in soils with a pH greater than 7 (Jensen 2010). Closer examination of the land use upstream could help give a better idea of the source of the increased nutrients.

Bacteria - *E. coli*

Levels of *E. coli* decreased in 2018 compared to fall 2017, and were much lower than the levels in 2011 (Figure 18). The decline over time suggests a major reduction in fecal contamination. The EPA has set safe *E.coli* levels in recreational waters to be less than 406 *E.coli* per 100mL . The *E. coli* levels found indicate Cozine Creek water would be safe for recreational use (EPA 2017b).

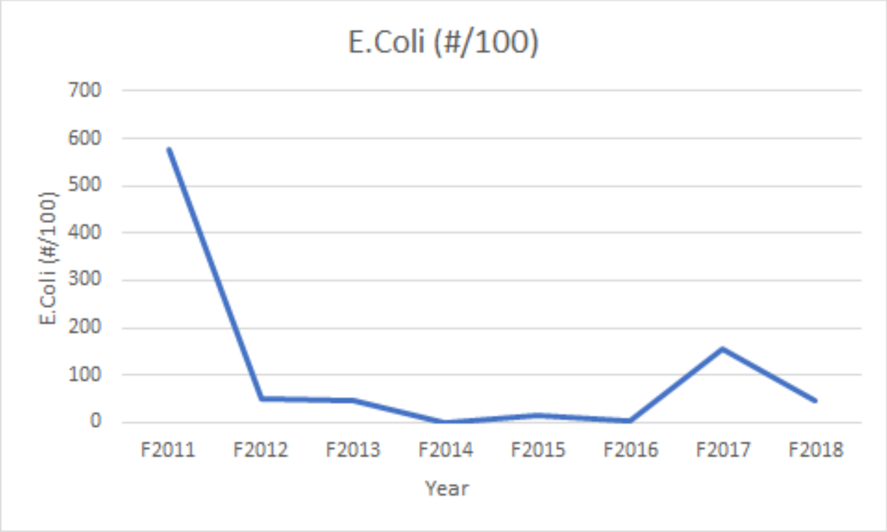


Figure 18: Mean *E. coli* counts at Linfield College from fall 2011 to fall 2018.

Bacteria - *Salmonella*

As with *E. coli, Salmonella* was lower in 2018 compared to 2011 and 2017 (Figure 19). This decrease further supports a major reduction in fecal contamination of the water.

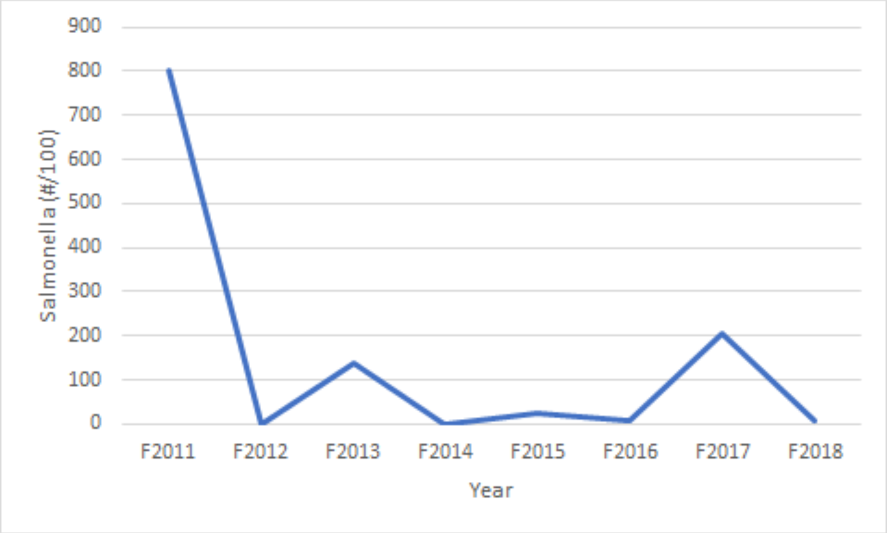


Figure 19: Mean *Salmonella* counts at Linfield College from fall 2011 to fall 2018.

Bacteria - *Aeromonas*

Aeromonas dropped dramatically in 2012 and 2013 and has remained near zero since (Figure 20). This further supports a decline in fecal contamination in the creek.

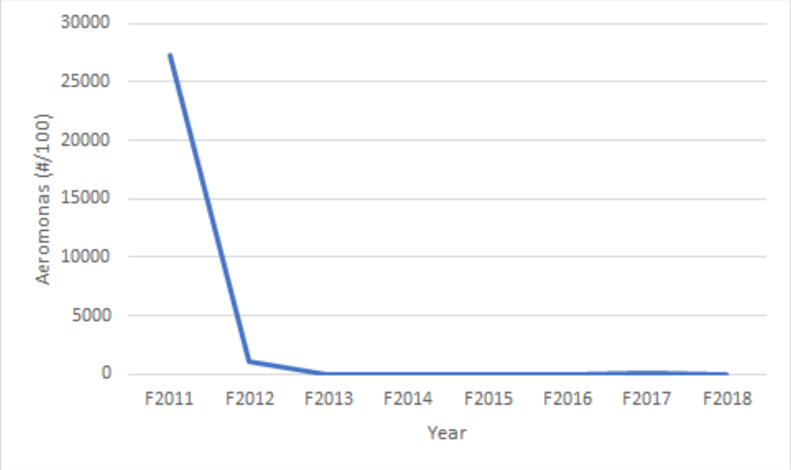


Figure 20: Mean *Aeromonas* counts at Linfield College from fall 2011 to fall 2018.

All coliform bacteria (e.g., *E. coli, Aeromonas, Salmonella,* and other coliforms) have been present in low levels in Cozine Creek since 2012 High levels of bacteria in 2011 was reported to be due to a sewage pipe leak upstream. After repairing the pipe, coliform bacteria levels dropped and are no longer a health risk (McMinnville Storm Drainage Master Plan). Current levels of bacteria indicate a lack of major fecal contamination from animals and humans.

Macroinvertebrates

Library site one had the highest diversity based on PTI, but the PTI was only fair. Library sites two and three had poor PTIs. It should be noted that Library site one had a larger amount of individuals collected, which could be a result of having more rocks and gravel along the creek floor, as opposed to the muddy creek bottom found at the other sites. The pollution sensitive species found at site one included caddisfly (*Trichoptera*) and alderfly (*Sialidae)*, however most species at site one (e.g., worms and snails) still fell under the pollution tolerant category. These species were reported in high quantities in previous years. The PTI in Cozine Creek always has been found to be low, indicating a continuing problem affecting the livability of Cozine Creek (Berg et al. 2017). The low PTIs found in Cozine may be the result of the low dissolved oxygen levels repeatedly seen in the creek. They also could be linked to high levels of phosphate, nitrate, and ammonia . High nutrient levels contribute to low dissolved oxygen because these nutrients promote algae growth, which results in lower DO (EWG 2017). The high numbers of pollutant tolerant species in Cozine Creek is a biological indicator of poor water quality because macroinverts are confined to a small area of the creek, and thus are continuously affected by pollution levels for long periods of time (EPA 2016).

Vegetation

The data suggest the cover by invasive species along Newby Hill has decreased, although only English ivy was significant at a species level. The survivorship of plants planted last spring by ENVS students and the GYWC suggests successful regrowth of native species along Newby Hill. Snowberries had over a 100% survivorship, which indicates natural regeneration by the previously present snowberry population on Newby Hill. The high death rate of the Oregon grape and Indian plum may be due to the weather conditions seen over the summer of 2018. The summer was the second hottest summer on record, having 31 days over 90 °F. The summer of 2018 broke records in Salem, Oregon (about 25 miles from Linfield College) for the most consecutive days without rain (KOIN 6 2018). In addition, none of the plants received any supplemental water. High temperatures and low levels of water can be detrimental to plant life, especially seedlings and recently planted ones (Oregon Conservation 2018) .

Overall Water Quality

Our study showed that the water quality of Cozine Creek at both the Linfield College and Library sites this fall was poor and can not support a healthy salmon population. Areas of concern include dissolved oxygen and temperature levels; the levels salmon can tolerate were exceeded at both sites. Levels of phosphate and ammonia highlighted a problem that is most likely linked to nonpoint source pollution from urban and/or agricultural runoff (EPA 2016). These factors will continue to inhibit salmon populations and pose serious water quality threats to the area until solved.

Our results however, did show that the creek water quality has been improving over the years, especially in this past year. Although dissolved oxygen levels and temperature remain below the optimum range for a salmon-bearing stream, we saw positive declines in bacteria and turbidity. Even though DO levels are not within the correct range, it has been steadily increasing, which also is a positive sign. We cannot say for certain that water quality is improving and will improve to levels healthy for salmon, but it is an indication that we may be moving in the right direction.

The restoration efforts so far may show a slight improvement in the surrounding vegetation. However, conclusions can not be drawn yet. A large portion of the plant population in the area surrounding the creek consisted of invasive species, especially Himalayan blackberry. Their removal could increase the amount of sediment in the stream and declines in in roots to stabilize the soil increase the likelihood of erosion (Minnesota Pollution Control Agency 2008), although we did not see this in our data. As the restoration efforts continue and native plants are planted, the erosion potential will decrease, thus this is more of a temporary concern.

Even if water quality in Cozine Creek was suitable for salmon, the creek has other issues that preclude salmon. There are many fish barriers including a culvert that stops movement upstream at Davis Street. Other fish barriers include dams, log jams, and anything that inhibits the ability of fish to migrate through the stream. Multiple fish barriers are seen along the creek and prevent salmon from reaching our study area (GWYC 2018).

Improving Water Quality in the Future

Water quality in Cozine Creek could be improved with increased community involvement. Having a dedicated group of students removing invasive species from the area could note new invasive species, what animals are present, issues with flooding, and other factors important to water quality. Such continual observations would be beneficial. The main invasive species present in the area are Himalayan blackberry, English ivy, reed canary grass, and Italian arum; these present a threat to the health of native plant species. Although some native species have been planted on Newby Hill, the banks of the stream have not been replanted because we are still in the process of removing the invasive species. An increased in native species along the stream banks would increase the amount of shade, which will reduce water temperature, thus improving DO. Educating students, neighbors, and residents of McMinnville will encourage behavior that could lead to a decrease in agricultural and urban runoff. If the residents of McMinnville become more aware of their impact on Cozine Creek, as well as what they can do to reduce that impact, we should see a positive change in the state of the Creek.

Limitations

There were a number of limitations in our study. Measurements could only be taken once a week over the course of less than three months due to the length of the course. Without the constraint of time, resources, class scheduling, etc., measurements could have been recorded in a more consistent time period and more often. This would have allowed for less of a seasonal change. Although weather was often a limiting factor when collecting data, our data collection conditions were fairly consistent - sunny with warm temperatures. Precipitation was low over the semester. Precipitation is important to many of the water quality measurements we took especially depth, flow, temperature, turbidity, and nutrients. In the lab, we had difficulty discerning the different colors on the EasyGel coliform plates so some of the colonies may have been misidentified or overlooked. We also had a hard time relocating the exact GPS coordinates of the start of the vegetation transects due to the inaccuracy of GPS measurements.

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