**The Evergreen State College**

**Graduate Program on the Environment**

### Thesis Prospectus

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | **Matthew Knox** | | | **ID Number** | **A00369218** |
| **Mailing Address** | | | **300 Kenyon St NW Apt Q7 Olympia WA. 98502** | | |
|  | | |  | | |
| **Telephone** | | **( 360 )860-1316** | |
| **E-mail** | | **Knomat01@evergreen.edu** | |

**STUDENT AGREEMENT:**

**SIGNATURE: Matthew L. Knox**

**DATE: 12-10-2020**

**FACULTY READER APPROVAL:**

**SIGNATURE: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ DATE\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**MES DIRECTOR APPROVAL:**

**SIGNATURE:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ DATE\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. **Provide the working title of your thesis[[1]](#endnote-1).**

Evaluating effects of green infrastructure on storm water quality in west Olympia

1. **In 250 words or less, summarize the key background information needed to understand your research problem and question.**

The city of Olympia has expanded along the wetland shoreline of Budd Inlet tributary, and over the years has increased its impervious surface area through the use of hard surfaces such as; parking lots, roads, and rooftops(NOAA, n.d; NOAA C-CAP n.d.;, NLCD n.d.).This produces an increasing volume of urban runoff, which has historically been diverted into Budd Inlet by use of the small streams, geological features present in the area, as well as engineered drainage systems (City of Olympia, 2018). Upon reviewing 22 streams located within Puget Sound, May et al. (1996) reported that a key index for determining urban impacts on streams was total impervious area of the urban zone. Increasing number of studies have begun to link the degradation of marine and riparian ecosystems to these anthropogenic sources, specifically; impacts that surface runoff originating from expanding impervious urban surface areas have on water quality in the form of pollutant loading and flow volume (Müller et al. 2020).

**Table 1:** Estimated total impervious surface area within Budd Inlet (NOAA, n.d.).

Buildout refers to maximum value of impervious surface area if all residential land were to be developed.



Currently, ecological concerns present within Budd Inlet include reduced vegetative cover, elevated concentrations of metals, increased impervious surfaces, as well as excess nutrient loads (Coast and Engineering 2016). A solution to this degradation of water quality may be the use of green infrastructure which is hydrological installation such as; check dams, channels, bioswales, and settling ponds (Capuana et al. 2020). This type of infrastructure is scheduled to be installed within the city limits of Olympia at West Bay Woods by the Olympia Coalition for Ecosystems Preservation 501(c) 3, in order to address the storm water runoff that originates from Northwest Olympia neighborhoods and discharged into Budd Inlet.

1. **State your research question(s).**

**I am studying:**

* Effects of green infrastructure (GI) on urban storm water runoff.

**Because I want to find out what / why / how (Question):**

* What contaminants are reduced at this site,
* How this site GI installations contributes to reducing contaminant concentrations

**In order to help my reader understand (Significance)**

* How current storm water discharge practices negatively impact ecosystems, and the value of green infrastructure as an treatment strategy for reducing urban storm water runoff and its associated contaminants.

1. **Situate your research problem within the relevant literature. What is the theoretical and/or practical framework of your research problem?**

Budd Inlet, located at the southernmost region of the Puget Sound, experiences extensive algal blooms which have been the cause of multiple Diarrheic Shellfish Poisoning (DSP) related events. Washington Department of Health (WDOH) has announced Budd Inlet beach closures as recently as July, 2021. Concentrations of the biotoxins that produce DSP have exceeded safety standards in Budd Inlet in 2020, 2019, 2016, 2015, (JOLT 2020; King5 2019; TCC 2016; TCC 2015). The occurrences of these algal blooms depend on several environmental factors such as; temperature, nutrient availability, and the stratification of the water column (Anderson et al., 2021). However, ongoing dinoflagellate algal bloom within waterways near urbanized zones have become increasingly linked to anthropogenically sourced nutrient pollution(Graneli and Moreira 1989, Prins et al.1999, Michalak et al. 2013). Furthermore, Sellner et al. (2003) observed that algal blooms are becoming more frequent in coastal waters, and although they can be related to various natural causes such as; circulation, upwelling, river/stream flow, it has become more attributed to anthropogenic nutrient loading of local waterways.

Due to the nature of impervious urban surfaces, much of the issue surrounding nutrient transport involves non-permeable surfaces which capture large volumes of composite storm water and deposits it into a small number of outfall locations. Nutrients are introduced to these surfaces through a variety of vectors such as; Atmospheric deposition, road transport emissions, pesticide/herbicide use, as well as leaf litter (Petrucci et al., 2014, Muller et al., 2020, WDoEKing 2011). Keeley et al. (2013) defined “gray storm water infrastructure” as engineered systems that route storm water directly into downstream water bodies, and “green infrastructure” as alternative managements which can generate both human and ecosystem services. Due to Budd Inlet’s proximity to urbanized zones, as well as legacy industrial pollution present in the area (Anchor2016, WaDoE2017), the implementation of green infrastructure as an alternative measure to the existing grey infrastructure may greatly increase water quality.

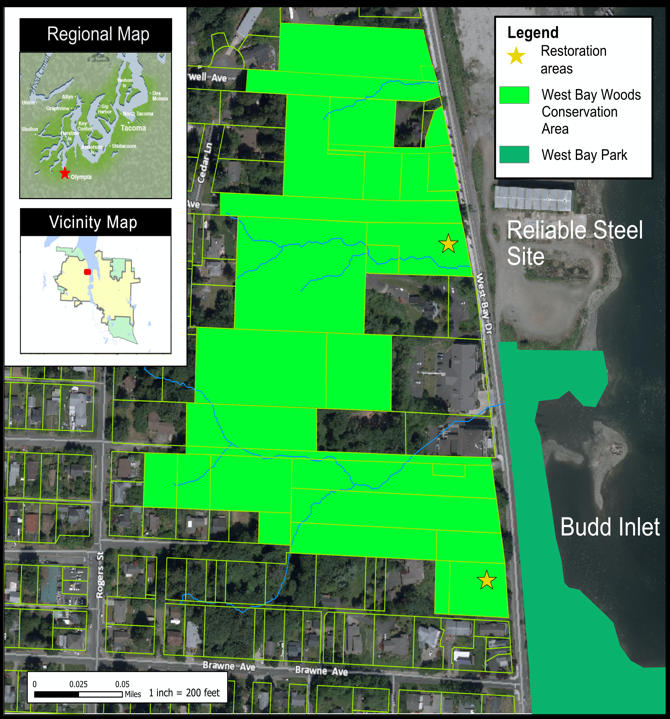
1. **Explain the significance of this research problem. Why is this research important? What are the potential contributions of your work? How might your work advance scholarship?**

In support of Olympia Coalition for Ecosystems Preservation (OCEP) GI monitoring project. OCEP purchased 3 acres of degraded land which facilitates storm water drainage from the Northwest Olympia neighborhoods into Budd Inlet for the purpose of ecological restoration. Project purpose includes the installation of GI within the West Bay woods in order to reduce erosion and transport of pollutants caused by urban storm water runoff. The results from this study ware expected to support this project proposal by tracking select chemical changes in water quality metrics, in order to determine if water quality of storm water outfall into Budd Inlet is improved or remains unchanged. Metrics evaluated will be relevant to shellfish, salmonids and other marine organisms present in Budd Inlet. Complete results are expected by March, and will provide context for a complete conclusion. However, based on literature reviewed, change in water quality is expected to be measurable, and that these conclusions may aid in future grant applications that may apply to the Budd Inlet region.

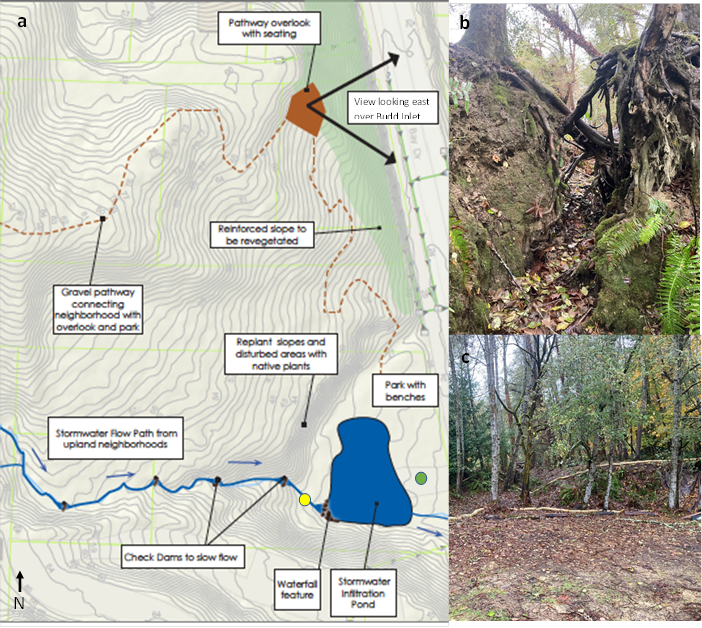
This research is important in that the West Bay Drive area is subject to storm water runoff originating from the slopes above which are populated with residential and commercial zones. It is likely this storm water runoff contains a number of contaminants, all which contribute to the overall decline in health of Budd Inlet.

The study will assess the impact GI has on urban storm water as it is transported through West Bay Woods, and attempt to answer the question; will GI help reduce the levels of contaminants flowing into Budd Inlet? The findings of this study may provide opportunity for further research in support of future GI installation proposals around Budd Inlet given the many creeks and streams that flow into it.

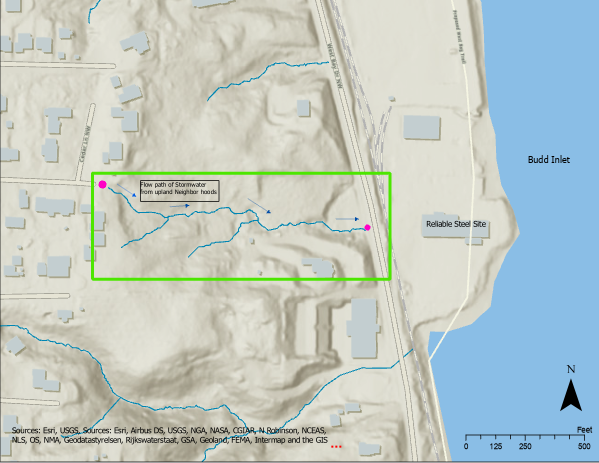
**Image 1**: from Olympia Coalition for Ecosystems Preservation (OCEP)grant application proposal, Hamman 2021. Samples would occur on the northern site which will be the location of multiple GI installations. This site collects runoff from the residential west side, drains through the contaminated Reliable Steel Site, which then is released into Budd Inlet.



Olympia



**Image 2:** from Olympia Coalition for Ecosystems Preservation (OCEP)grant application proposal, Hamman 2021. Storm water flow is highlighted; samples would take place at entry to and exit of the illustrated GI.



**Image 3:** created in ArcGISPro. Illustrates storm water flow; sample location is indicated by magenta dots.

1. **Summarize your study design[[2]](#endnote-2). If applicable, identify the key variables in your study. What is their relationship to each other? For example, which variables are you considering as independent (explanatory) and dependent (response)?**

Sample collection will be performed by grab samples as specified by Washington State Department of Ecology standard operating procedure for grab sample methods (State Department of Ecology, 2018). Water quality metrics of interest include total kjeldahl nitrogen, organic nitrogen, total phosphorus, biochemical oxygen demand, coliform bacteria, copper, lead, and zinc, due to their impacts on marine ecosystems (Hamman 2021). This will include collection of water samples above and below the green infrastructure features at preconstruction phase, as well as the post construction phase.

Comparison of metrics obtained from each location at the pre and post construction phase will provide insight as to the impacts that GI installed within West Bay woods has on water quality being discharged into Budd Inlet.

**Explanatory (Independent) Variable: Manipulated**

GI installations will be used to predict and or explain the differences in water quality. This variable will represent the sum of GI present within the site, which will consist of several engineered installations participating to the overall change in water quality. These installations include check dams for velocity reduction/erosion control, use of vegetation to reduce nutrient transport and increase ground water infiltration, and settling ponds for wastewater sedimentation.

**Response (Dependent) Variable: outcome following manipulation of E.V.**

Water quality at point of discharge will be the response variable representing the impact GI has on the water quality of urban runoff. Metrics evaluated will be relevant to salmonids and marine organisms and will include;

**Total Kjeldahl N:**

* Recommends targeting organic N with various treatment methods due to organic N comprising the largest percentage of TN, unlike previous treatments that targeted NOX (Lucke et al. 2018).

**Organic N:**

* Ecosystem-level changes are linked to anthropogenic fertilization of marine systems through excess nitrogen discharge into aquatic environments (Diaz and Rosenberg 2008).

**Total P:**

* Trapped in receiving marine waters. Unlike nitrogen, no analogous air-water exchange that exists in the P cycle (Paerl, 2009).
* Correlations between algal abundance and total P are stronger than that of algal abundance and total N (Lewis et al., 2011).

**Biochemical oxygen demand:**

* Land use is an important factor in altering storm water flow hydrology and may scale BOD export. Reducing first flush effect was noted as particularly effective (McCabe et al. 2021).

**Coliform bacteria:**

* May impact abundance and diversity of aquatic microbial organisms (Paruch et al. 2019).

**Cu:**

* For salmonids that cannot avoid storm water discharge, even short-term influxes of Cu into waterways may negatively impact olfactory nervous system(Baldwin et al. 2002).
* A threshold for tolerance in benthic insects was found to be 2.5 and 10μg L-1 CuT (Leland et al. 1989).
* Cu may interfere with enzymatic process within benthic invertebrates; species with higher gut pH may experience increased interference, echinoderms more so than polychaetes (Chen et al. 2001).

**Pb:**

* Waste water containing high levels of nutrients such as phosphates may influence Pb speciation (Mager 2011).
* The effects of Pb on fish is similar to mammals in that it interferes with enzymatic, hematological, and neurological processes (Demayo et al. 1982).

**Zn:**

* Toxicity to benthic organisms (Watzin and Roscigno 1997).
* Toxic to multiple organs of fish species (Ghiardina et al. 2009).

1. **Describe the data that will be the foundation of your thesis. Will you use existing data, or gather new data (or both)? Describe the process of acquiring or collecting data[[3]](#endnote-3).**

Water samples would be collected at the inlet drain. This would represent the source of contamination, and likely contain a mixture of most contaminants found in an urban environment. Additionally, water samples would be collected at outfall, or as the water leaves West Bay woods and moves towards Budd Inlet. This would be representative of both GI effectiveness and total contaminants presents at the geographical location.

Samples collected according to Wa.DoE Storm water sampling manual (WaDoE2015) as grab sample method. Grab sample is a discrete, individual sample that is usually collected within a 15 minute time frame. These represent characteristics of water quality at a given time within a storm water runoff occurrence.

A total of 24 samples, 12 taken above and 12 below the GI installations, which will include replicates for pre and post construction, at above and below the site.

Above GI Features: 6 preconstruction - 6 post construction (2 sets of 3)

Below GI Features: 6 preconstruction - 6 post construction (2 sets of 3)

Replicates for sample precision, pre/post sample to observe impact of GI, above/below to represent overall site impact on urban storm water. Measuring pH and turbidity can be completed on site, while the list of variables in Question #6 would require laboratory analysis.

Sample results will represent the level of contamination present in urban storm water within West Olympia as quantitative measurements, as well as the total impact West Bay woods GI has on that storm water.

1. **Summarize your methods of data analysis. If applicable, discuss specific techniques that you will use to understand the relationships between variables (e.g., interview coding, cost-benefit analysis, specific statistical analyses, spatial analysis) and the steps and tools (e.g., lab equipment, software) that you will take to complete your analyses.**

**Ho:** Green Infrastructure does not impact urban storm water runoff to any great extent, and does not improve water quality.

**Ha:** Green infrastructure does have an impact on urban storm water runoff, and does improve water quality.

Samples would be sent to a lab for quantitative analysis of target compounds. The results may be statistically analyzed with JMP software. Means comparison may be conducted by analysis of variance(ANOVA), followed by Tukey’s range test at significance levels of p<0.05 in order to observe the difference in means.

Samples taken above and below at the GI at “pre-completion” stage would provide an efficiency baseline for unaltered green space and be useful in determining the added efficiency of engineered GI when sampled above and below at post construction.

Above and below refers to the sample location being at the entrance of West Bay woods where urban runoff is collected, and at the discharge point below the settling pond near West Bay Drive. Proposed sample time frame would occur early winter (January/preconstruction) and early spring(March/post construction) , and would allow for sampling to be least impacted by first flush pollutant loadings.

1. **Address the ethical issues[[4]](#endnote-4) raised by your thesis work. Include issues such as risks to anyone involved in the research, as well as specific people or groups that might benefit from or be harmed by your thesis work, perhaps depending on your results. List any specific reviews you must complete first (e.g., Human Subjects Review or Animal Use Protocol Form).**

There are no known legal concerns for the collection of storm water for laboratory testing (EPA, 1992). However, the beneficiaries of this work may be OlyEcosystems, as they own the property the sampling would occur on.

1. **List specific research permits[[5]](#endnote-5) or permissions you need to obtain before you begin collecting data (e.g. landowner permissions, agency permits).**

Data collection would take place on agency owned property, as would be participating in the study.

1. **Reflect on how your positionality as a researcher could affect your results and how you will account for this in the research process[[6]](#endnote-6).**

I believe that current municipal storm water treatment is inadequate, and poses a threat to not only humans, but ecosystems and their inhabitants. Furthermore, the recurring urban storm water that drains into Budd Inlet contain high levels of contaminants and waste products, and that any level of GI would provide a reduction of these compounds.

* Disregarding sample data that does not fit into my proposed HA.
* Not reporting data that would be unfavorable to the organization that owns/operates the site.

This can bias my research in that I would expect predictable results. By including all observations and data sets in final report for transparency, as well as dedicating discussion to those discrepancies I may mitigate those possible biases.

1. **Provide at least a rough estimate of the costs associated with conducting your research.  Provide details about each budget item so that the breakdown of the final cost is clear.**

Known research cost for project is estimate at: $240 supplies + $2400 Analysis = $2640 Total

The cost of 24 x 500mL Polypropylene bottles at $10 each = $240(note that a few extra may need to be requested) much of this cost may be avoided as the TESC SSC offers these items at little to no cost. However, accredited laboratory analysis may require that their provided sampling bottles be used.

Water quality analysis entails laboratory analysis of collected samples for nine different water quality metrics. Cost is estimated to be $100 per sample x 24 samples = $2400

Cost for shipping samples to lab vary greatly, and can be hundreds of dollars. However, ESN Northwest and Dragon laboratories are located within Thurston County and provide services for storm water analysis.

1. **Provide a detailed working outline of your thesis.**

**Introduction---**

Development of Olympia and the impacts its impervious surface area has on local marine ecosystems.

Urban runoff contains high levels of nutrients and pollutants

Grey infrastructure has been the primary means of disposing of run off.

West Bay Woods in Olympia is implementing GI for the purpose of addressing runoff originating from West Olympia residential area.

This study will examine the impact West Bay GI has on urban storm water.

**Literature Review---**

**Introduction**

**Impervious surfaces**

* NOAA and NLCD data as well as volume of discharge associated with acres of impervious surface area.

**Increased populations (increased surfaces and waste)**

* Managing urban storm water, a new approach that considers predevelopment condition for natural hydrogeological features in conjunction with newer practices – Walsh et al., 2016

**Hydrogeological alterations**

* Grey infrastructure dominates urban regions, often through a series of channels that merely divert runoff into local water ways. This article evaluates the adaptation of green infrastructure in these regions, which is simply allowing runoff to filter through the soil rather than untreated discharge. – (Copeland, 2016)

**Legacy pollutants**

* Puget Sound Toxic Control report and stormwater data analysis – (WaDoE, 2017 )
* Surface runoff analysis/atmospheric deposition – (Wa.DoEKingCo.DNR. 2011)
* Global distribution(by atmospheric deposition) of persistant organo-compounds by economic status of region – (Simonich & Hites, 1995)

**Current pollutant analysis**

* N/P concentrations of urban runoff – (Lucke et al., 2018)
* Leaf Litter composition – (Aerts, 1997)
* First flush pollution load, N/P/TSS analysis – (Li et al., 2016)
* WaDoE. Report that provides a characterization of urban stormwater runoff – (Lubliner 2007)

**Public and Marine health indicators**

* Acceptable limits for nutrient loadings/contaminant levels in runoff and alternatives(Literature on nutrient load impacts on HABs).

**Climate factors**

* Projected rainfall frequency/intensity?

**Green Infrastructure**

* Focus on the impacts of impervious surfaces and collected discharge from urban areas. Proponent of utilizing green infrastructure to reduce total volume of runoff by intercepting precipitation and enhancing infiltration through use of bioswales, raingardens, and permeable pavements., (Berland et al., 2017)

**Impact of the use of trees and vegetation.**

* The use of trees and woody vegetation to reduce total runoff volume by evapotranspiration, and soil and ground water recharge - (Denman et al., 2011)
* Use of plants in urban settings may provide multiple benefits to the surrounding ecology and human health. This paper examines the repose of trees and shrubby/herbaceous species to soils containing elevated levels of contaminants. – (Capuana 2020)

**Summary**

**Methods ---**

**Intro**

The methods and procedures utilized in order to measure the impact West Bay woods GI has on urban storm water.

**Research methods**

Methods for this study will be based on Washington State Department of Ecology standard operating procedure in which grab samples will be obtained from a catchment located at the head of the West Bay Wood GI tract along with the discharge at its outfall. 2 sets of samples will be collected to represent pre and post construction status of GI installations being constructed.

Samples will be obtained by using grab sampling methods and stored in 250mL polypropylene/polyethylene bottles

**Field Sampling methods**

To be determined -dates for sampling to occur. Proposed sampling would occur at the catchment entrance that diverts urban storm water into the West Bay woods tract. Additionally, samples would be taken at the base of the slope, or the discharge point of West Bay woods GI tract.

**Sample Analysis Methods**

Dissolved oxygen, Temperature, pH and conductivity reading can be taken at time of sampling by use of portable meters.

Collected samples will be subject to laboratory analysis and will measure 8 different variables in order to provide comparison basis of GI impact on runoff.

Total Phosphorus analysis method will likely be according to EPA’s method 365.1

Total Kjeldahl Nitrogen analysis method will be determined by laboratory.

Metals analysis will be determined according to EPA’s method 200.8

**Results---**

BOD, pH, conductivity, and temperature measurements

Total Kjeldal Nitrogen

Total Phosphorus

Total Cu, Pb, and Zn

**Discussion----**

**Conclusion---**

1. **Provide a specific work plan and a timeline for each of the major tasks in the work plan. Be as realistic as you can, even though you will probably need to alter this schedule as you complete the tasks. Remember that faculty readers take time to return your drafts and that the final polishing and formatting of your thesis for binding will take longer than you ever imagined.**

Project proposal provides a timeline in which baseline water quality samples will be collected in Q1 of 2022(January). Q2(March) 2022 proposes a spring water quality analysis component, at which point further comparison analysis could be performed.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Thesis Timeline - Matt Knox | | | | | | |
|  | 2021 | 2022 | | | | |
| Dec | Jan | Feb | March | April | May |
| Intro |  |  |  |  |  |  |
| Literature Review |  |  |  |  |  |  |
| Methods |  |  |  |  |  |  |
| Results |  |  |  |  |  |  |
| Discussion |  |  |  |  |  |  |
| Conclusion |  |  |  |  |  |  |
| Data collection |  |  |  |  |  |  |
| Data Analysis |  |  |  |  |  |  |
| Refine Results |  |  |  |  |  |  |
| Draft to reader |  |  |  |  |  |  |
| Revisions and Edits |  |  |  |  |  |  |

1. **Who, beyond your MES faculty reader, will support your thesis? Indicate support both within and outside of Evergreen. Be specific about who they are and in what capacity they will support your thesis. If you are working with an outside agency or expert, be specific about their expectations for your data analysis or publication of results.**

Dr. Sarah Hamman – Can assist with field sampling, analysis and consultation/review on thesis. May also be able to provide some monetary support for laboratory analyses.

Olympia coalition for ecosystems preservation - <https://olyecosystems.org/>

1. **List the 3-5 most important references you have used to identify the specific questions and context of your topic, help with issues of research design and analysis, and/or provide a basis for interpretation. For each annotated reference, explain how your project specifically connects to the source by extending, challenging, or responding to the conclusions, methods, or implications. For any other sources cited in this document provide a complete bibliographic citation.**

**Capuana, M. 2020. “A Review of the Performance of Woody and Herbaceous Ornamental Plants for Phytoremediation in Urban Areas.” IForest - Biogeosciences and Forestry 13(1):139–51. doi: 10.3832/ifor3242-013.**

This paper was influential for me in that it highlighted the use of trees and herbaceous plants as means to reduce water and soil pollution being driven by increasing volume of surface runoff. Phytoremediation has been an interest for me for some time, and this paper illustrated ways in which vegetative planting can be used other than legacy industrial waste sites. The paper takes notes that often times these vegetative species are used as ornamental features, which may facilitate a widespread use of such mitigation methods. This paper also highlights the potential for trees in general to be exploited for the purpose of phytoremediation of soil and water, in many cases more efficient than herbaceous species. This can be attributed to the greater biomass growth potential that trees possess, which can be related to both extensive root developments, as well as above ground biomass. However, it was noted that trees are often thought of as having less variability, plasticity, as well as little opportunity for replacements. This only supports the proposed idea that both trees and herbaceous species should be used in conjunction for greatest impact on nutrient and contaminant reduction found in urban storm water. This paper highlights the advantages of this concept, referring to it as plant consociation, and its implications of rhizosphere structure modifications.

**Gobler, Christopher J., Owen M. Doherty, Theresa K. Hattenrath-Lehmann, Andrew W. Griffith, Yoonja Kang, and R. Wayne Litaker. 2017. “Ocean Warming since 1982 Has Expanded the Niche of Toxic Algal Blooms in the North Atlantic and North Pacific Oceans.” Proceedings of the National Academy of Sciences 114(19):4975–80. doi: 10.1073/pnas.1619575114.**

This paper examines the relationship between global warming, its impact on ocean temperatures, and the presence of toxic algal blooms in the North Pacific and North Atlantic. Referencing a variety of sources, it seems clear that anthropogenic nutrient input may become a more serious issue than considered. Changes in precipitation patters are also noted within this paper, which may alter nutrient delivery patterns especially in coastal regions. This leads to questions as to whether changes in nutrient loading (and many other processes) will act synergistically, or antagonistically with temperature increases, and those associated impacts on phytoplankton growth rates. Examples of North American HAB examined within the paper were often promoted by excess nutrient loadings and increased temperatures, which has prompted consideration of models that estimate changes in algal growth. This paper concludes that temperature is an important environmental factor that is central to the occurrence of HABs across large portions of the North Pacific. This paper highlighted the likely hood that as this temperature increase continues, harmful algal blooms(HAB) events will intensify globally. As a connection to my own research, this paper was influential as it provides consideration in what impacts anthropogenic sourced runoff may have on marine ecosystems.

**Xu, Bing, Xue Wang, Jia Liu, Jiaqiang Wu, Yongjun Zhao, and Weixing Cao. 2017. “Improving Urban Stormwater Runoff Quality by Nutrient Removal through Floating Treatment Wetlands and Vegetation Harvest.” Scientific Reports 7(1):7000. doi: 10.1038/s41598-017-07439-7.**

This paper examines the presence of excess nitrogen and phosphorus found in urban storm water, and the impacts vegetation has on nutrient reduction. This type of treatment methods would be applicable in constructed wetlands, or retention ponds. This paper was important in that it highlighted how plants could be implemented in a phytoremediation role through their ability for nutrient storage. This paper notes that N and P uptake will greatly vary by species, nutrient concentration and temperature. However, in those species that grow favorably within a specific environment, uptake rate is generally found to be highly efficient. Also noted was that species with greater root/shoot biomass production have the most impact on TN and TP uptake, and that nutrient removal is largely due to plant assimilation rather than microbial uptake. This supports the idea that plants can be effective in uptake of nutrients as well as metals and broadens the possibility of their use in urban settings for purpose of water and soil quality.

**Figures:**

**1.)** Hamman, S. (2021). Improving shoreline habitat and water quality through forest restoration and green infrastructure along Budd Inlet, Puget Sound, WA. . In Olympia Coalition for Ecosystems Preservation (OCEP). DUNS/EIN: 052754196

**2.)** Westbay storm water installation type and location: Image from City of Olympia – Private Storm water systems (https://www.arcgis.com/apps/webappviewer/index.html?id=e33702d6bb554f83b0ff19425baeb854)

**References**

Aerts, Rien. 1997. “Climate, Leaf Litter Chemistry and Leaf Litter Decomposition in Terrestrial Ecosystems: A Triangular Relationship.” Oikos 79(3):439. doi: 10.2307/3546886.

Anchor QEA, LLC. (2016). *FINAL INVESTIGATION REPORT PORT OF OLYMPIA BUDD INLET SEDIMENT SITE* (Final Report ed.). N.p.: Port of Olympia. Retrieved from <https://www.portolympia.com/DocumentCenter/View/2382/Final-Investigation-Report-Budd-Inlet-Sediment-Site-Aug2016?bidId>=

Anderson, Donald M., Elizabeth Fensin, Christopher J. Gobler, Alicia E. Hoeglund, Katherine A. Hubbard, David M. Kulis, Jan H. Landsberg, Kathi A. Lefebvre, Pieter Provoost, Mindy L. Richlen, Juliette L. Smith, Andrew R. Solow, and Vera L. Trainer. 2021. “Marine Harmful Algal Blooms (HABs) in the United States: History, Current Status and Future Trends.” Harmful Algae 102:101975. doi: 10.1016/j.hal.2021.101975.

APHA. 1992. *Standard methods for the examination of water and wastewater.* 18th ed. American Public Health Association, Washington, DC.

Baldwin, David H., Jason F. Sandahl, Jana S. Labenia, and Nathaniel L. Scholz. 2003. “SUBLETHAL EFFECTS OF COPPER ON COHO SALMON: IMPACTS ON NONOVERLAPPING RECEPTOR PATHWAYS IN THE PERIPHERAL OLFACTORY NERVOUS SYSTEM.” *Environmental Toxicology and Chemistry* 22(10):2266. doi: [10.1897/02-428](https://doi.org/10.1897/02-428).

Berland, Adam, Sheri A. Shiflett, William D. Shuster, Ahjond S. Garmestani, Haynes C. Goddard, Dustin L. Herrmann, and Matthew E. Hopton. 2017. “The Role of Trees in Urban Stormwater Management.” Landscape and Urban Planning 162:167–77. doi: 10.1016/j.landurbplan.2017.02.017.

Capuana, M. 2020. “A Review of the Performance of Woody and Herbaceous Ornamental Plants for Phytoremediation in Urban Areas.” IForest - Biogeosciences and Forestry 13(1):139–51. doi: 10.3832/ifor3242-013.

City of Olympia, Water Resources. (2018). *Storm and Surface Water Plan* (p. 4). Olympia, WA: Olympia City Council. Retrieved from <https://salishsearestoration.org/images/0/08/Olympia_2018_surface_and_storm_water_plan.pdf>

Copeland, Claudia. n.d. “Green Infrastructure and Issues in Managing Urban Stormwater.” 23.

Chen, Zhen; Lawrence M. Mayer; Donald P. Weston; Michael J. Bock; Peter A. Jumars (2002). *Inhibition of digestive enzyme activities by copper in the guts of various marine benthic invertebrates. ,* *Environmental Toxicology and Chemistry 21(6), 1243–1248.*doi:10.1002/etc.5620210618

Coast & Harbor Engineering, a Division of Hatch Mott MacDonald. (2016). Final Report. In *City of Olympia West Bay Environmental Restoration Assessment*. Retrieved from <https://portolympia.com/wp-content/uploads/2021/01/Full-Report-Final-West-Bay-Env-Rest-Assessment-2016-02-26.pdf>

Demayo, Adrian; Taylor, Margaret C.; Taylor, Kenneth W.; Hodson, Peter V.; Hammond, Paul B. (1982). *Toxic effects of lead and lead compounds on human health, aquatic life, wildlife plants, and livestock. C R C Critical Reviews in Environmental Control, 12(4), 257–305.*doi:10.1080/10643388209381698

Denman, E. C., P. B. May, and G. M. Moore. 2011. “The Use of Trees in Urban Stormwater Management.” 10.

Diaz, R. J.; Rosenberg, R. (2008). *Spreading Dead Zones and Consequences for Marine Ecosystems. Science, 321(5891), 926–929.*doi:10.1126/science.1156401

DoEKing 2011, Ecology and King County, 2011. Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011. Washington State Department of Ecology, Olympia, WA and King County Department of Natural Resources, Seattle, WA. Ecology Publication No. 11-03-055. www.ecy.wa.gov/biblio/1103055.html

DoE 2017, Washington State Department of Ecology . (2017). Puget Sound Toxics Control. In *Toxics Projects in Puget Sound, 2011-2018, Funded by the NEP Toxics and Nutrients Prevention, Reduction, and Control Cooperative Agreement* (17th ed., Vols. 03 - 003). Olympia, WA: Toxics Studies Unit. Retrieved from https://apps.ecology.wa.gov/publications/SummaryPages/1703003.html

Dragon Analytical Laboratory, located https://www.dragonanalyticlab.com/testing-services

EnviroVision Corporation; Herrera Environmental Consultants, Inc.; Washington Department of Ecology. Phase 2: Improved Estimates of Toxic Chemical Loadings to Puget Sound from Dischargers of Municipal and Industrial Wastewater. Ecology Publication Number 08-10-089. September 2008. Olympia, Washington.

EPA 1992, (United States Environmental Protection Agency. (1992). EPA 833-8-92-001 . In *NPDES Storm Water Sampling Guidance Document*. N.p.: Office Of Water(EN-336). Retrieved from https://www3.epa.gov/npdes/pubs/owm0093.pdf)

ESN Northwest Laboratories, located <http://www.esnnw.com/fixedlab.html>

Giardina, Andrea; Sandra F. Larson; Brian Wisner; John Wheeler; Matthew Chao (2009). *Long-term and acute effects of zinc contamination of a stream on fish mortality and physiology. , Environmental Toxicology and Chemistry 28(2), 287–0.*doi:10.1897/07-461.1

Graneli, E., & Moreira, M. O. (1989, November 7). Effects of river water of different origin on the growth of marine dinoflagellates and diatoms in laboratory cultures. *Journal of Experimental Marine Biology and Ecology*, *136*. doi:10.1016/0022-0981(90)90189-J

Hamman, S. (2021). Improving shoreline habitat and water quality through forest restoration and green infrastructure along Budd Inlet, Puget Sound, WA. . In *Olympia Coalition for Ecosystems Preservation (OCEP)*. DUNS/EIN: 052754196

JOLT Biotoxin shuts down shellfish harvesting in Budd Inlet. (2020, November 30). *Journal of Olympia, Lacey, & Tumwater*. Retrieved from <https://www.thejoltnews.com/stories/biotoxin-shuts-down-shellfish-harvesting-in-budd-inlet,920>(23um per 100 g of shellfish)

Keeley M, Koburger A, Dolowitz DP, Medearis D, Nickel D, Shuster W. Perspectives on the use of green infrastructure for stormwater management in Cleveland and Milwaukee. Environ Manage. 2013 Jun;51(6):1093-108. doi: 10.1007/s00267-013-0032-x. Epub 2013 Apr 24. PMID: 23612718.

King5 Budd Inlet in Olympia closed to shellfish harvesting because of toxin [Editorial]. (2019, November 23). *King5News*. Retrieved from https://www.king5.com/article/news/local/budd-inlet-in-olympia-closed-to-shellfish-harvesting-because-of-toxin/281-54debd04-0f09-495d-b0fd-03afdc66b232

LELAND, HARRY V; STEVEN V. FEND; THOMAS L. DUDLEY; JAMES L. CARTER (1989). *Effects of copper on species composition of benthic insects in a Sierra Nevada, California, stream. , 21(2), 163–179.*doi:10.1111/j.1365-2427.1989.tb01356.x

Li, Dongya, Jinquan Wan, Yongwen Ma, Yan Wang, Mingzhi Huang, and Yangmei Chen. 2015. “Stormwater Runoff Pollutant Loading Distributions and Their Correlation with Rainfall and Catchment Characteristics in a Rapidly Industrialized City” edited by R. A. Coulombe. PLOS ONE 10(3):e0118776. doi: 10.1371/journal.pone.0118776.

Lubliner, B. 2007. Characterizing stormwater for total maximum daily load studies: a review of current approaches. Washington Department of Ecology, Lacey, WA.

Lucke, Terry, Darren Drapper, and Andy Hornbuckle. 2018. “Urban Stormwater Characterisation and Nitrogen Composition from Lot-Scale Catchments — New Management Implications.” Science of The Total Environment 619–620:65–71. doi: 10.1016/j.scitotenv.2017.11.105.

Mager, Edward M. (2011). *[Fish Physiology] Homeostasis and Toxicology of Non-Essential Metals Volume 31 || Lead. , (), 185–236.*doi:10.1016/s1546-5098(11)31026-6

May, C., C. Cooper, R. Horner, J. Karr, B. Mar, E. Welch, and A. Wydzga. 1996. Assessment of Cumulative Effects of Urbanization of Small Streams in the Puget Sound Lowland Ecoregion. A paper presented at the Urban Streams Conference held at Arcata, CA on November 15-17, 1996.

McCabe, K. M., Smith, E. M., Lang, S. Q., Osburn, C. L., & Benitez-Nelson, C. R. (2021). *Particulate and Dissolved Organic Matter in Stormwater Runoff Influences Oxygen Demand in Urbanized Headwater Catchments. Environmental Science & Technology, 55(2), 952–961.* doi:10.1021/acs.est.0c04502

Michalak, A. M., E. J. Anderson, D. Beletsky, S. Boland, N. S. Bosch, T. B. Bridgeman, J. D. Chaffin, K. Cho, R. Confesor, I. Daloglu, J. V. DePinto, M. A. Evans, G. L. Fahnenstiel, L. He, J. C. Ho, L. Jenkins, T. H. Johengen, K. C. Kuo, E. LaPorte, X. Liu, M. R. McWilliams, M. R. Moore, D. J. Posselt, R. P. Richards, D. Scavia, A. L. Steiner, E. Verhamme, D. M. Wright, and M. A. Zagorski. 2013. “Record-Setting Algal Bloom in Lake Erie Caused by Agricultural and Meteorological Trends Consistent with Expected Future Conditions.” Proceedings of the National Academy of Sciences 110(16):6448–52. doi: 10.1073/pnas.1216006110.

Müller, Alexandra, Heléne Österlund, Jiri Marsalek, and Maria Viklander. 2020. “The Pollution Conveyed by Urban Runoff: A Review of Sources.” Science of The Total Environment 709:136125. doi: 10.1016/j.scitotenv.2019.136125.

(NLCD) National Land Cover Database (http://www.trpc.org/regionalplanning/environment/Pages/HealthyWatersheds.aspx

Citing <http://www.mrlc.gov/>, a 20gb data set)

NOAA - Average annual precipitation, OLYMPIA 1.5 NW, WA US (US1WATH0027)Retrieved from: <https://masoncountywa.gov/forms/Env_Health/stormwater.pdf>,

NOAAC-CAP, Land Cover and Impervious surface area within Thurston county--- (https://coast.noaa.gov/digitalcoast/data/) NOAA C-CAP, NOAA regional coastal land cover maps.

OCEP, Hamman, S. (2021). Improving shoreline habitat and water quality through forest restoration and green infrastructure along Budd Inlet, Puget Sound, WA. . In *Olympia Coalition for Ecosystems Preservation (OCEP)*. DUNS/EIN: 052754196

Paerl, Hans W. (2009). Controlling Eutrophication along the Freshwater–Marine Continuum: Dual Nutrient (N and P) Reductions are Essential. , 32(4), 593–601. doi:10.1007/s12237-009-9158-8

Paruch, Lisa; Paruch, Adam M.; Eiken, Hans Geir; Sørheim, Roald (2019). Faecal pollution affects abundance and diversity of aquatic microbial community in anthropo-zoogenically influenced lotic ecosystems. Scientific Reports, 9(1), 19469–. doi:10.1038/s41598-019-56058-x

Petrucci, Guido, Marie-Christine Gromaire, Masoud Fallah Shorshani, and Ghassan Chebbo. 2014. “Nonpoint Source Pollution of Urban Stormwater Runoff: A Methodology for Source Analysis.” Environmental Science and Pollution Research 21(17):10225–42. doi: 10.1007/s11356-014-2845-4.

Prins, Theo C., Vincent Escaravage, and Aad C. Smaal. n.d. “Effects of Different N- and P-Loading on Primary and Secondary Production in an Experimental Marine Ecosystem.” 17.

Simonich, S., and R. Hites. 1995. “Global Distribution of Persistent Organochlorine Compounds.” Science 269(5232):1851–54. doi: 10.1126/science.7569923.

Sellner, Kevin G., Gregory J. Doucette, and Gary J. Kirkpatrick. 2003. “Harmful Algal Blooms: Causes, Impacts and Detection.” *Journal of Industrial Microbiology and Biotechnology* 30(7):383–406. doi: [10.1007/s10295-003-0074-9](https://doi.org/10.1007/s10295-003-0074-9).

TCC 2013:Thurston County Commissioners. (2013, July 25). Budd Inlet Closed for Shellfish Harvesting Diarrhetic Shellfish Poison (DSP) at unsafe levels . In *PUBLIC HEALTH AND SOCIAL SERVICES DEPARTMENT*. Retrieved from https://www.co.thurston.wa.us/health/ehrp/pdf/07252013ShellfishClosureBuddInletFINAL.pdf(17um 100g of shellfish)

TCC 2016: Thurston County Commissioners. (2016, June 16). Biotoxin Closure in Budd Inlet Expands to Surrounding Areas. In *NEWS RELEASE*. Retrieved from https://www.co.thurston.wa.us/health/ehrp/pdf/6\_16\_BiotoxinClosure.pdf(>16 um per 100g shellfish)

Walsh, Christopher J., Tim D. Fletcher, and Matthew J. Burns. 2012. “Urban Stormwater Runoff: A New Class of Environmental Flow Problem” edited by J. A. Gilbert. *PLoS ONE* 7(9):e45814. doi: [10.1371/journal.pone.0045814](https://doi.org/10.1371/journal.pone.0045814).

Watzin, Mary C.; Pasquale R. Roscigno (1997). *The effects of zinc contamination on the recruitment and early survival of benthic invertebrates in an estuary. , Marine Pollution Bulletin, 34(6), 0–455.*doi:10.1016/s0025-326x(96)00132-4

1. You are not locked into this title; its purpose is to help you identify the main point or topic of your thesis at an early stage. [↑](#endnote-ref-1)
2. You might discuss selection of case studies, sampling methods, experimental design, and/or specific hypotheses you will test. You should also address any specialized knowledge or skills that are necessary to complete the research. [↑](#endnote-ref-2)
3. If you are planning to use existing data, explain the specific source, contact information, arrangement with collaborating agencies, and expectations about use of data and final products of your research. If you are planning to gather new data, describe specific methods, time, place, and equipment that will be required. [↑](#endnote-ref-3)
4. If you’re not sure where to start, consult a ‘Code of Ethics’ or other similar document from an academic society in an applicable field of study. [↑](#endnote-ref-4)
5. If you are collecting ANY samples or data, even observational data, on public lands (city, county, state and/or federal) it is your responsibility to find out the permit requirements BEFORE you collect data. Conducting research with tribal members/on tribal lands will have different and additional requirements. [↑](#endnote-ref-5)
6. Your *positionality as a researcher* refers to the fact that one’s “…beliefs, values systems, and moral stances are as fundamentally present and inseparable from the research process as [one]’s physical, virtual, or metaphorical presence when facilitating, participating and/or leading the research project…” (The Weingarten Blog 2017). [↑](#endnote-ref-6)