## Update Report

Period: 2/1/2014 - 1/31/2015

**Project: R/RCE-3 - *The Biological Effectiveness of Bioretention for Stormwater Pollution Control***

### STUDENTS SUPPORTED

**Brown, Maria**, bromar3@evergreen.edu, Evergreen State College, *no department*, status: new, *no field of study*, *no advisor*, degree type: MS, degree date: 2015-06-01, degree completed this period: No
Student Project Title:
Bioretention as a reducer or contributor to toxicity for urban runoff
Involvement with Sea Grant This Period:
Research for MS thesis
Post-Graduation Plans: *none*

**Manley, Andrew**, andmanley@gmail.com, Sumner High School, *no department*, status: new, *no field of study*, *no advisor*, degree type: High School, *no degree date*, degree completed this period: Yes
Student Project Title:
Critical window of exposure for reproductive effects in C. dubia exposed to urban runoff
Involvement with Sea Grant This Period:
Research for Science Fair - ended up placing first at State!
Post-Graduation Plans: *none*

### CONFERENCES / PRESENTATIONS

Trout Unlimited - Washington Chapter, Issaquah, WA
Invited to present on the risks of urban stormwater runoff to salmon and the potential for green stormwater infrastructure to prevent toxicity, public/profession presentation, 30 attendees, 2014-04-09

APWA Stormwater Managers Committee Monthly Meeting
Invited to talk to the regional managers about the risks of stormwater runoff to aquatic animals and the potential for low impact development to ameliorate these effects, public/profession presentation, 40 attendees, 2014-04-15

Skagit Valley Planning Commission, Mt Vernon, WA
Invited to present on 'Solutions to Stormwater Pollution' to educate the commission about the risks of stormwater runoff to aquatic species, public/profession presentation, 20 attendees, 2014-09-09

Sound Living - a community education event by Snohomish Beach Watchers, Everett, WA
Talk Title: Solutions to Stormwater Pollution - Invited Presentation, public/profession presentation, 20 attendees, 2014-10-25

PNW-SETAC (Society for Environmental Toxicology and Chemistry), Tacoma, WA

Talk Title: Does green stormwater infrastructure prevent toxicity in aquatic animals exposed to urban runoff?, public/profession presentation, 100 attendees, 2014-04-25

Joint Aquatic Sciences Meeting, Portland, OR, May 21, 2014
Talk Title: Does green stormwater infrastructure prevent toxicity in aquatic animals exposed to urban runoff?, public/profession presentation, 100 attendees, 2014-05-21

STORMCON, Portland, OR
Talk Title: Does green stormwater infrastructure prevent toxicity in aquatic animals exposed to urban runoff?, public/profession presentation, 100 attendees, 2014-08-06

USGS Seminar Series, Tacoma, WA
Talk Title: Does green stormwater infrastructure prevent toxicity in aquatic animals exposed to urban runoff? - Invited presentation, public/profession presentation, 15 attendees, 2014-09-25

Salish Sea Conference, Seattle, WA
Talk Title: Can bioretention treatment prevent toxicity to aquatic animals exposed to PAH-enriched stormwater runoff?
Talk Title: The biological effectiveness of bioretention: Preventing toxicity to aquatic animals exposed to highway runoff
, public/profession presentation, 100 attendees, 2014-05-02

South Sound Science Symposium, Shelton, WA
Talk Title: Stormwater toxicity and green stormwater treatment - Invited presentation, public/profession presentation, 300 attendees, 2014-10-23

SETAC Annual North American Meeting, Vancouver, BC
Presentation Title: Reduced toxicity in aquatic animals exposed to coal tar runoff treated with soil bioretention filtration
, public/profession presentation, 100 attendees, 2014-11-10

## ADDITIONAL METRICS

| | |
|---|---|
| **P-12 Students Reached:** | **P-12 Educators Trained:** |
| **Participants in Informal Education Programs:** | **Volunteer Hours:** |
| **Acres of coastal habitat protected, enhanced or restored:** | **Resource Managers who use Ecosystem-Based Approaches to Management:** |
| **Annual Clean Marina Program - certifications:** | **HACCP - Number of people with new certifications:** |

## ECONOMIC IMPACTS

*No Economic Impacts Reported This Period*

**SEA GRANT PRODUCTS**

*No Sea Grant Products Reported This Period*

**HAZARD RESILIENCE IN COASTAL COMMUNITIES**

*No Communities Reported This Period*

**ADDITIONAL MEASURES**

| | |
|---|---|
| Number of stakeholders modifying practices: | Sustainable Coastal Development<br><br>**# of coastal communities:** |

**PARTNERS**

| |
|---|
| Partner Name: NOAA Northwest Fisheries Science Center, Montlake |
| Partner Name: Suquamish Tribe |
| Partner Name: US Fish and Wildlife Service (US DOI, FWS) |

**IMPACTS AND ACCOMPLISHMENTS**

Title: **Washington Sea Grant research shows that bioretention systems save juvenile and adult salmon from deadly urban runoff**
Type: accomplishment
Description:
Relevance: Juvenile salmon in urban creeks and adult salmon returning to spawn suffer devastating mortality rates—up to 90 percent of adults die before spawning. One culprit is stormwater runoff that carries metals, petroleum products, and other toxins from roads and impervious surfaces into urban water bodies. Bioretention systems that filter runoff through soil are often used to treat stormwater in low-impact development and can prevent hazardous materials from reaching salmon-bearing streams. But can they also protect salmon?

Response: Washington Sea Grant-supported researchers tested the effects of highway runoff on juvenile and returning adult coho salmon. They also exposed juvenile coho and embryonic zebrafish to runoff from an asphalt test patch coated with a widely used coal-tar sealcoat. Both types of untreated runoff were then filtered through soil bioretention systems resembling those used in rain gardens, and the fish exposure tests were repeated using the filtered runoff.

Results: Each type of untreated runoff killed all exposed juvenile and adult salmon and zebrafish within 24 hours, but all fish exposed to soil-filtered runoff survived. Bioretention significantly reduced suspended solids, ammonia, copper, and zinc in the highway runoff and polyaromatic hydrocarbons in the runoff from the asphalt test

patch. These findings, presented at numerous meetings and conferences, elicited widespread newspaper, magazine, and radio coverage, alerting a large national audience to the impacts of runoff and the benefits of bioretention.
Recap:
Recap: Washington Sea Grant-supported research documents the lethal effects on fish of highway and coal-tar-sealant runoff and shows that rain garden-style soil filtering can mitigate those effects.
Comments:
Primary Focus Area: RCE
Secondary Focus Area: HCE
Associated Goals: Coastal water resources sustain human and ecosystem health. (RCE)
Ocean and coastal habitats are protected, enhanced and restored. (HCE)
Partners:
NOAA Northwest Fisheries Science Center, Montlake
Suquamish Tribe
US Fish and Wildlife Service (US DOI, FWS)
Related Partners: NOAA Northwest Fisheries Science Center, Montlake, US Fish and Wildlife Service (US DOI, FWS), Suquamish Tribe

**PUBLICATIONS**

Title: **Soil bioretention protects juvenile salmon and their prey from the toxic impacts of urban stormwater runoff**
Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2015
Uploaded File: McIntyre._2015._Soil_b....y.pdf, 616 kb
URL: http: //www.sciencedirect.com/science/article/pii/S0045653514014805
Abstract:
Green stormwater infrastructure (GSI), or low impact development, encompasses a diverse and expanding portfolio of strategies to reduce the impacts of stormwater runoff on natural systems. Benchmarks for GSI success are usually framed in terms of hydrology and water chemistry, with reduced flow and loadings of toxic chemical contaminants as primary metrics. Despite the central goal of protecting aquatic species abundance and diversity, the effectiveness of GSI treatments in maintaining diverse assemblages of sensitive aquatic taxa has not been widely evaluated. In the present study we characterized the baseline toxicity of untreated urban runoff from a highway in Seattle, WA, across six storm events. For all storms, first flush runoff was toxic to the daphniid Ceriodaphnia dubia, causing up to 100% mortality or impairing reproduction among survivors. We then evaluated whether soil media used in bioretention, a conventional GSI method, could reduce or eliminate toxicity to juvenile coho salmon (Oncorhynchus kisutch) as well as their macroinvertebrate prey, including cultured C. dubia and wild-collected mayfly nymphs (Baetis spp.). Untreated highway runoff was generally lethal to salmon and invertebrates, and this acute mortality was eliminated when the runoff was filtered through soil media in bioretention columns. Soil treatment also protected against sublethal reproductive toxicity in C. dubia. Thus, a relatively inexpensive GSI technology can be highly

effective at reversing the acutely lethal and sublethal effects of urban runoff on multiple aquatic species.
Citation:
McIntyre, J. K., et al. "Soil Bioretention Protects Juvenile Salmon and Their Prey from the Toxic Impacts of Urban Stormwater Runoff." Chemosphere In Press.doi: 10.1016/j.chemosphere.2014.12.052 (2015). Print.
Copyright Restrictions + Other Notes:
Journal Title: Chemosphere

Title: **Zebrafish and clean water technology: Assessing soil bioretention as a protective treatment for toxic urban runoff**
Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2014
Uploaded File: McIntyre._2014._Zebraf....y.pdf, 902 kb
URL: http: //www.sciencedirect.com/science/article/pii/S0048969714012455
Abstract:
Urban stormwater contains a complex mixture of contaminants that can be acutely toxic to aquatic biota. Green stormwater infrastructure (GSI) is a set of evolving technologies intended to reduce impacts on natural systems by slowing and filtering runoff. The extent to which GSI methods work as intended is usually assessed in terms of water quantity (hydrology) and quality (chemistry). Biological indicators of GSI effectiveness have received less attention, despite an overarching goal of protecting the health of aquatic species. Here we use the zebrafish (Danio rerio) experimental model to evaluate bioinfiltration as a relatively inexpensive technology for treating runoff from an urban highway with dense motor vehicle traffic. Zebrafish embryos exposed to untreated runoff (48–96 h; six storm events) displayed an array of developmental abnormalities, including delayed hatching, reduced growth, pericardial edema, microphthalmia (small eyes), and reduced swim bladder inflation. Three of the six storms were acutely lethal, and sublethal toxicity was evident across all storms, even when stormwater was diluted by as much as 95% in clean water. As anticipated from exposure to cardiotoxic polycyclic aromatic hydrocarbons (PAHs), untreated runoff also caused heart failure, as indicated by circulatory stasis, pericardial edema, and looping defects. Bioretention treatment dramatically improved stormwater quality and reversed nearly all forms of developmental toxicity. The zebrafish model therefore provides a versatile experimental platform for rapidly assessing GSI effectiveness.
Citation:
McIntyre, J.K., et al. "Zebrafish and Clean Water Technology: Assessing Soil Bioretention as a Protective Treatment for Toxic Urban Runoff." Science of the Total Environment 500-501 (2014): 173-80. Print.
Copyright Restrictions + Other Notes:
Journal Title: Science of the Total Environment

**OTHER DOCUMENTS**

*No Documents Reported This Period*

**LEVERAGED FUNDS**

Type: influenced Period: 2014-02-01: : 2015-01-01Amount: $125000
Purpose:
Funding for research partners and supplies and equipment.
Source: EPA Region 10

**UPDATE NARRATIVE**

Uploaded File: Stark_9756_update_narr....7.pdf, 430 kb

## Task 1: Verifying and validating the biological effectiveness of bioretention

### Publications

Prior to the reporting period (Sep 2012), we had conducted a single test of bioretention effectiveness using large columns with or without plants at Washington State University. Two papers were published during the reporting period on this first runoff event (Event 1) - one on zebrafish in *Science of the Total Environment* (500:173-178), and one on 'target species' (including juvenile coho salmon) in *Chemosphere* (online Jan 6 2015). Both articles are Open Access publications, freely available to the public. One additional article on molecular tools is being prepared for submission to *Environmental Science & Technology*.

### Event 2 Runoff

Building on our pilot test conducted in 2012, we conducted a second bioretention test using highway runoff from a storm on June 13, 2014 following an antecedent dry period of 15 days. This runoff was characterized as being less contaminated with solids and metals than Event 1, but more contaminated with PAHs. Runoff used in Event 2 was lethal to 97% of juvenile coho salmon within 12 h of exposure, and 100% of salmon within 24 h.

### Filtration Efficiency

As with the first runoff test (Event 1), filtration through the bioretention columns significantly reduced many of the contaminants of concern in the runoff from Event 2, including total suspended solids (TSS), ammonia, and dissolved copper and zinc. Unlike the previous runoff test, the effluent from the bioretention columns was not significantly reduced in dissolved nickel or lead. Although this is partially due to the lower concentrations of these contaminants in the Event 2 runoff, there appeared to be a significant mobilization of dissolved nickel from the columns with plants, and a significant mobilization of dissolved lead from the columns without plants. The column media are known to contain these and other constituents at low levels and more tests will be needed to see if mobilization of these metals from the columns continues.

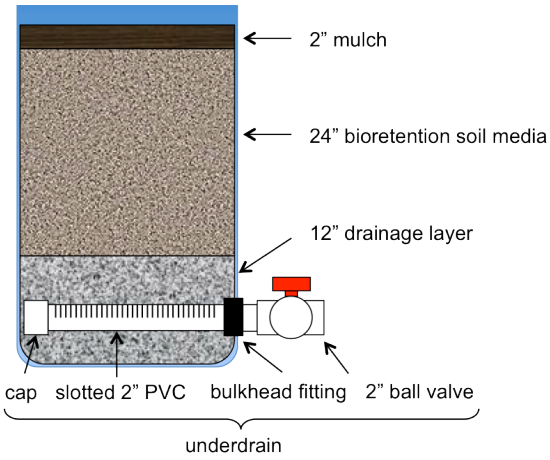
### Biological Effectiveness

As with Event 1, filtration through the bioretention columns prevented all mortality in juvenile coho salmon. We again saw no additional benefit of plants over bioretention soil alone.

### Next Steps

Three more runoff tests are planned for the coming year.

## Task 2: Bioretention to prevent PSM in adult coho spawners




In October 2013 we constructed a portable bioretention treatment system for use at Grover's Creek Salmon Hatchery (Poulsbo, WA). In September 2014, the bioretention system was emptied of treatment media used in 2013. The new drainage layer (12") was a Seattle Type 26 mixed gravel aggregate. The bioretention soil media (BSM) was a mixture of 60% sand and 40% Cedar Grove compost topped with 2" of bark mulch.

During the 2013 spawning season (Sep-Dec), we tested the ability of bioretention to prevent pre-spawn mortality in adult coho at the end of the run (November) for highway runoff during one 4-h and one 24-h exposure for two separate storms. During the 2014 spawning season (Oct-Dec), we completed three exposures, focusing on the early part of the run (October). All exposures were 24 h duration with an observation period at 4 h. Additionally, in 2014 an exposure was run comparing well water exposure with well water passed through the bioretention cells.

Healthy adult coho returning to the Suquamish Tribal Hatchery on Grovers Creek were randomly selected and placed in individual PVC holding tubes. Only fish exhibiting normal behavior and with no obvious signs of trauma, disease, or poor condition were included. Four fish per treatment were placed in 440L of experimental water. Each holding tube was equipped with a hose to pump water (4L/min) across the fish's head and each treatment tank was aerated to maintain dissolved oxygen at optimum levels for adult coho health during exposures.

In both years, all of the coho exposed to the unfiltered runoff were dead at the end of the exposure period, whereas all of the coho exposed to the filtered runoff or to well water were still alive at the end of the exposure period. All fish exposed to well water or filtered well water were alive and behaving normally at 24 h. During 2014, nearly all (11/12) coho exposed to unfiltered runoff were dead within 4 h of exposure. By the end of the 24 h trials, not only was there 0% mortality in the filtered runoff exposure, we did not observe any of the overt symptoms of 'pre-spawn mortality' that were observed in coho exposed to unfiltered runoff prior to death.

**Task 3: Exploring PAHs as drivers of toxicity**

In Sep 2013, we applied a coal tar based sealcoat (CTSC) to an existing asphalt plot at WSU. During Sep and Oct 2013, runoff from three simulated rain events was collected and tested. During the reporting period, we simulated two additional rain events; one on the CTSC plot (Apr 2014) and a 'control' event on an asphalt plot immediately adjacent the CTSC plot (Aug 2014). For each event, runoff was split into two samples: 100 L remained unfiltered, and 100 L was filtered through soil bioretention columns containing 60% sand and 40% compost. Runoff toxicity was tested with juvenile coho salmon and zebrafish embryos.

PAHs were highest in runoff from Event 1 and an order of magnitude lower for Events 2-4. PAHs from the asphalt 'control' plot were another order of magnitude lower. Filtering CTSC runoff removed most PAHs, lowering concentrations by two orders of magnitude.

Unfiltered runoff from the CTSC plot caused significant mortality of juvenile coho salmon for most runoff events (Figure 1). All juvenile coho died within 5 h of exposure to unfiltered Event 1 runoff. Event 1 runoff also caused 100% mortality in developing zebrafish embryos. We documented sublethal toxicity of unfiltered runoff in zebrafish embryos, primarily including cardiotoxicity such as atrioventral blood pooling and cranial hemorrhaging.

Filtering runoff through bioretention prevented all mortality in coho (Figure 1) and zebrafish, and also prevented all evidence of sublethal toxicity in zebrafish embryos (Figure 2).

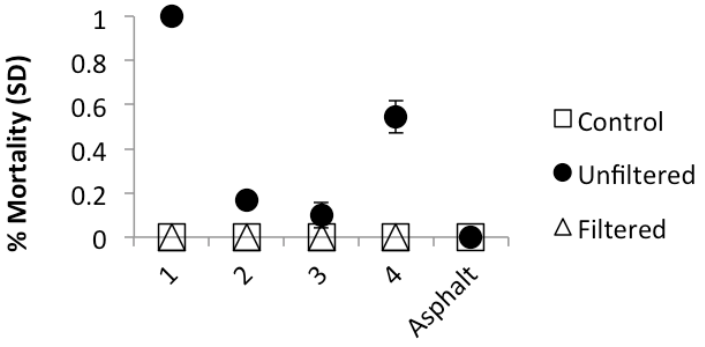



Figure 1. Mortality of juvenile coho salmon for each simulated rain event on the CTSC or asphalt control plot.

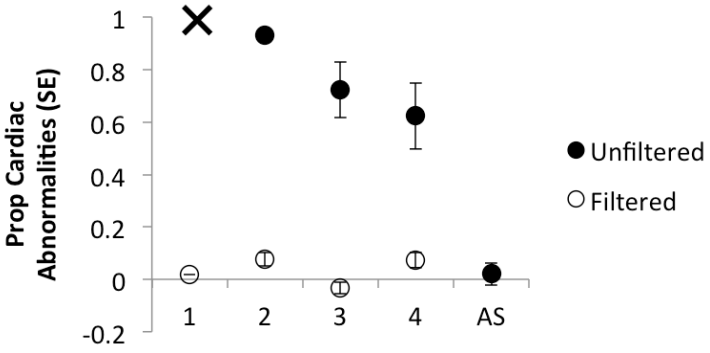



Figure 2. Proportion of zebrafish embryos with cardiac abnormalities for each runoff event, relative to embryos raised in laboratory control water. AS = asphalt control plot.