Duwamish River Floating Wetlands

2019 Monitoring Report

Green Futures Lab
University of Washington

December 2019

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Project Attribution Table

Project Dates	UW Floating wetlands seminar: Spring quarter 2018 Construction: May - August, 2018; Feb - March, 2019 Monitoring Period: April 25 - July 26, 2019
Project Partners and Support	University of Washington Green Futures Research & Design Lab King County Waterworks Grant Rose Foundation Puget Sound Stewardship & Mitigation Fund Port of Seattle University of Washington Campus Sustainability Fund Global Diving and Salvage UW Soil Analytics Lab & Service Center UW Departments of Landscape Architecture and Civil & Environmental Engineering, Schools of Aquatic & Fisheries Sciences, Marine & Environmental Affairs, and Environmental & Forest Sciences
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Partners in Community Science & Outreach	Rose Foundation Port of Seattle King County ECOSS Duwamish River Cleanup Coalition UW Doris Duke Conservation Scholars Program Pacfic Science Center University of Washington Program on the Environment

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Citation	Suggested Citation: Duwamish River Floating Wetlands: 2019 Monitoring Report. 2019. University of Washington Green Futures Research and Design Lab, Seattle WA.

Acronyms

BOLMAR - *Bolboschoenus maritimus*
CFW - Constructed floating wetland
DO - Dissolved oxygen
FWL - floating wetland
GFL - Green Futures Lab
RM - River mile
ROV - Remote operated vehicle
SCHACU - *Schoenoplectus acutus*
SCHAME - *Schoenoplectus americanus*
SCHTAB - *Schoenoplectus tabernaemontani*
T-105 - Terminal 105
T-108 - Terminal 108
UW - University of Washington

Glossary

BioBarge - a constructed floating wetland designed for this project that includes a buoyant wooden frame holding the Biofilters. The BioBarges were designed as a towable research platform and provided the external structure for the floating wetlands (see Section 3 for images).

substrate - describes various substrates of natural organic matter used in the floating wetlands that may provide invertebrate habitat and perform water quality functions, such as chelating and suspended metals.

Fallout trap - Fallout traps are plastic bins filled with a small amount of water mixed with a few drops of biodegradable, unscented dish soap.

Floating wetland - a general term that describes a buoyant substrate that supports wetland plants growing hydroponically, with roots suspended below the water surface. Floating wetlands have been designed and implemented around the world and can take various forms. In this study, floating wetlands (FWLs), or constructed floating wetlands (CFWs) refer to the wetland system designed for this project, which included barge frames (see BioBarge above) and wetland biofilters anchored within the frames (see Section 3 for images, may be interchanged with BioBarge or biofilter).

Puck - a small version of a floating wetland, constructed from a smaller wire cage and the same layers of substrate.

Wetland biofilter or biofilter - A 1m3 bright (untreated) 16ga wire gabion containing various biodegradable media including (from the bottom up) willow brush, BioFoam™, WoodStraw™, MycoBoard™, and native wetland plants. See Figure 3b.

1. Executive Summary

This report summarizes the results of the 2018-2019 Duwamish River Floating Wetlands research and community science program. Constructed floating wetlands (CFWs) are an innovative form of green infrastructure that may be used to enhance water quality and provide a range of other ecosystem services. In this project, an interdisciplinary team designed, built, and deployed four towable research platforms called "BioBarges", each containing four CFWs. These were monitored at two field study sites from April to July 2019 in the Lower Duwamish River, located in Seattle, Washington.

The goal of Duwamish Floating Wetlands project is to determine if constructed floating wetlands can increase salmon habitat and improve water quality to support the survival of outmigrating juvenile salmon. The scientific objectives of the monitoring program were to gather information about juvenile salmon interactions with the BioBarges, invertebrate production, plant growth, and water quality. The social objectives of the program were to encourage collaboration between student and community scientists to perform the field research and engage community scientists in the project.

The results from the 2019 monitoring season included observations of juvenile salmon interacting with the BioBarges. The constructed floating wetlands supported the growth of both terrestrial and aquatic invertebrates, including chironomids and other dipteran flies which are a known food for juvenile salmon smolts. All four species of native bulrush survived the growing season although only saltmarsh bulrush (*Bolboschoenus maritimus)* and hardstem bulrush (*Schoenoplectus acutus*) flowered. All plants declined over the study period as the salinity of the Duwamish River increased as freshwater inputs from the Green River and regional stormwater decreased with the onset of the dry season.

In general, juvenile salmon were found in lower numbers at the Biobarges compared to natural shorelines with intertidal wetlands and riparian plant communities. Invertebrate densities and diversity, plant diversity and cover were also lower at the BioBarges than natural shorelines. Water quality field measurements showed that temperature, dissolved oxygen, and light were within tolerable ranges for juvenile salmon. However, it was not clear whether the BioBarges reduced or improved these water quality measures. Laboratory analysis of the rooting substrates of the CFW's revealed the accumulation of certain metals (e.g. copper, lead, zinc) and nitrogen. Several other metals yielded inconclusive results because concentrations in controls and treatments were below analytical detection limits (arsenic, cadmium, chromium).

As a core element of the project, the community science program involved over 13 individuals in weekly field monitoring, and more participants through other community science activities. In addition, the team led and joined several outreach and education endeavors, participated in community events, and fostered independent projects for early career researchers.

The project demonstrated that CFWs can provide habitat for juvenile salmon by producing food items including aquatic and terrestrial invertebrates. Recommendations for 2020 include 1) locating the BioBarges further upstream in the transition zone with a lower salinity level of the Lower Duwamish

River; 2) increasing the access to and the total area of CFW's by attaching more of them to the outside of the BioBarges; and 3) testing new CFW designs.

2. Introduction

This report summarizes the results of the 2018-2019 Duwamish River Floating Wetlands research and community science program. This report documents the basis of design for the constructed floating wetlands, field monitoring methods and results and community science approach. It also provides recommendations for CFW design, deployment, field monitoring methods and student and community science participation in 2020.

The program included designing and building four BioBarges each containing four constructed floating wetlands, installing them in the Duwamish River in Seattle, Washington, monitoring the wetlands throughout the spring and summer, and building and implementing a community science program around the project. A primary purpose of this project was to explore the potential for using floating wetlands to provide habitat for outmigrating juvenile salmon in the Duwamish River. However, given that 2018-2019 was the first year of study, this report provides additional background on existing conditions in the Lower Duwamish River, the rationale and architecture for the constructed floating wetland designs.

Constructed floating wetlands (CFWs) are an ecosystem restoration technology that can be used to enhance degraded urban shorelines by providing wetland ecosystem services. Throughout this report, the terms floating wetland, BioBarge, and Wetland Biofilter are used to refer to these structures. In general, floating wetlands consist of a buoyant substrate that supports wetland plants growing hydroponically, with roots suspended below the water surface. Floating wetlands can withstand a wide range of environmental conditions and can be designed for purposes including to improve water quality, provide bird and wildlife habitat, protect and beautify shorelines, reduce flood risk, sequester carbon and conserve economically important fisheries. Floating wetlands may provide a cost-effective approach for retrofitting urban shorelines without the cost of cleaning up contaminated sediments and relocating waterfront buildings and infrastructure and may complement other restoration projects in the Duwamish River.

This is the first study of floating wetlands in the Duwamish River, and in the City of Seattle, and provides a starting place for future research on shoreline enhancements of this kind. This report is intended as a living document, and may be updated with further analyses or additional recommendations.

2.1. Project Background

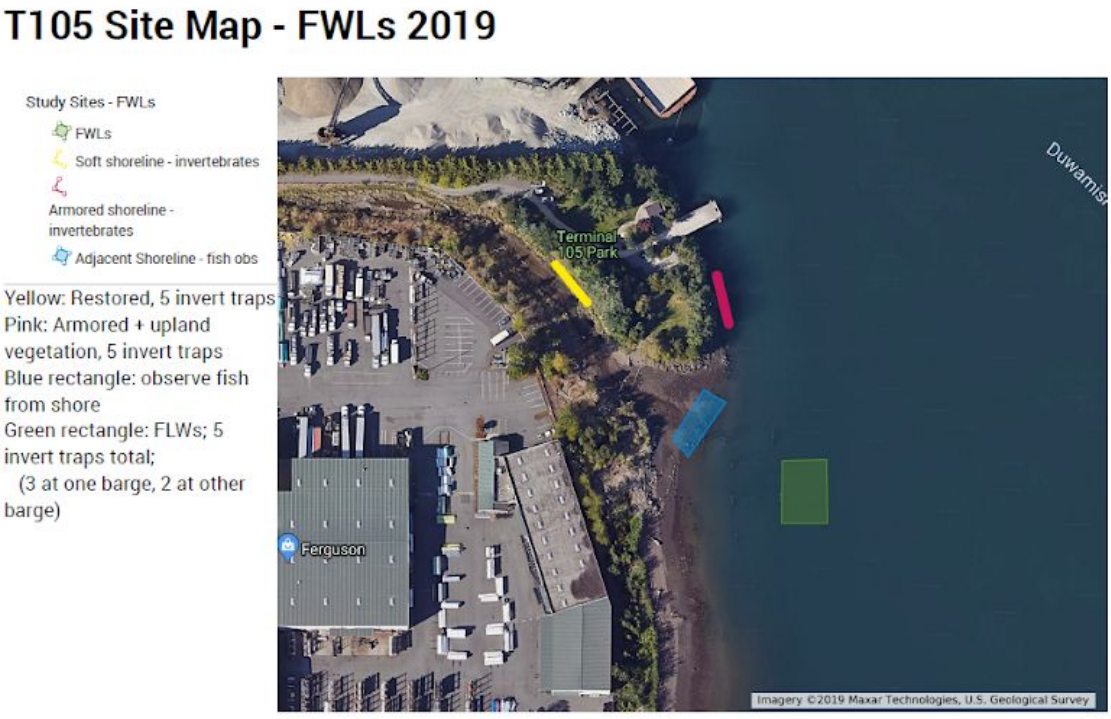
In 2015, the University of Washington's Green Futures Research and Design Lab (GFL) was awarded a $154,000 King County Wastewater Treatment Division Waterworks grant to study the potential for using floating wetlands to improve water quality and enhance habitat for salmonids. The focus of this research study is located on Port of Seattle property in the transition zone of the Duwamish River, within City of Seattle jurisdiction. The Port of Seattle also indicated they would provide funding in the amount of $35,000 related to receipt of a final report of water quality findings. The use of innovative approaches, like floating wetlands, was identified as a top recommendation in the Duwamish Blueprint (Ostergaard 2014) and the development of these technologies is considered to be a critical action for the recovery of

Chinook salmon populations in the Green/Duwamish River. In 2018, the GFL was awarded a $50,000 Rose Foundation grant for a Community Scientist monitoring program. The focus of this grant is to engage community members in monitoring activities through training and engagement in regularly scheduled field observations.

In 2018, the team secured a Seattle Department of Planning and Development Shoreline Exemption permit, a Washington Department of Fish and Wildlife Hydraulic Project Approval, and Site Use Agreement from the Port of Seattle for hosting the floating wetlands at three Port of Seattle operated locations. The main staging area for the BioBarges was at Harbor Island Marina/Terminal 102 (T-102) in the Duwamish River.

2.2. Study Sites: Terminal 105 and Terminal 108

In April 2019, the floating wetland BioBarges were deployed to two locations in the estuary of the Duwamish River. Two BioBarges (BioBarges D and B) were located near Terminal 105 (T-105), while the other two BioBarges (BioBarges C and A) were located near Terminal 108 (T-108). Throughout the spring and summer of 2019, an interdisciplinary team worked with staff from the Port of Seattle and community scientists to develop and implement a monitoring program to study the floating wetlands in the Duwamish River at these locations.



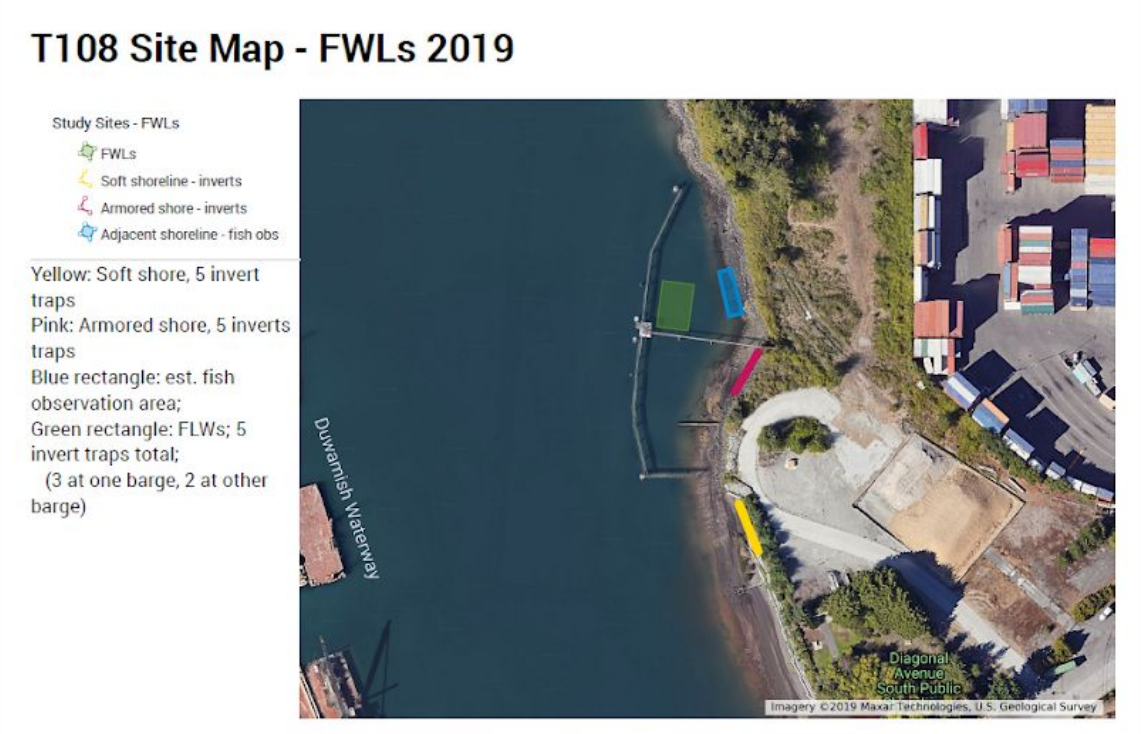


Figure 1. Approximate BioBarge and shoreline monitoring site locations at T-105 (pg 10) and T-108 (pg 11).

2.3. Project Area

The project is located in the estuary of the Lower Duwamish River in Seattle, Washington, between river mile (RM) 0 and 1. The Duwamish River begins at the confluence with the Black River at RM 11 and extends downstream to the river mouth where it meets Elliott Bay. The Duwamish River transition zone extends from RM 9 at the upstream end, to RM 1 (downstream of Kellogg Island) at the downstream end, a reach where salinity levels vary seasonally and with tides. The Duwamish River estuary is vitally important to the region, both as an integral ecological link between the Green River and Puget Sound and as a center of trade and commerce that supports local industry, jobs, recreation, and Washington's economy. The Port of Seattle owns the bed and banks of the Lower Duwamish River, and supports the fifth largest port operation in the U.S.

An estimated 97% of the original marsh, estuarine, and tidal mudflat habitat that made up the Duwamish River estuary has been lost over the past 150 years. The shoreline has been dramatically altered: 21,000 feet of shoreline has been lost due to straightening of the channel and 53,000 feet converted to developed shoreline. Only 19,000 feet of vegetated riparian shoreline remains in the Duwamish Estuary (Collins and Sheikh 2005). The once extensive 3,850 acres of tidal mudflats, marshes, and swamps have been reduced to only 25 acres (USACE 1997). Furthermore, decades of industrial pollution created an Environmental Protection Agency Superfund cleanup site in the lower 5.5 miles of the river.

Salmon rear throughout the near-shore coastal estuaries of the Salish Sea. These are some of the most productive ecosystems on the planet, receiving nutrient-rich sediment and water from the freshwater streams that drain the Cascade and Olympic watersheds. Under natural conditions these estuaries support patchy landscapes of forested uplands, scrublands, and near-shore emergent wetlands. The near-shore emergent wetlands form sinuous edge habitat with colonies of bulrush, sedges, and rushes that tolerate fluctuating tidal changes, mixed fresh and saltwater characteristics, and elevated nutrient runoff in the springtime. In these systems, wetland plants provide an important feeding and refuge habitat for juvenile salmonids. Opportunities for salmon to feed before completing their migration to salt water have been shown to greatly influence marine survival rates (Duffy and Beauchamp 2011).

Decreased habitat quality, fragmentation, and loss of habitat in the estuary and transition zone is a limiting factor for Chinook populations in the Green-Duwamish watershed (WRIA 9 Steering Committee 2005). The transition zone is defined as the area most important for juvenile fish making the physiological transition from freshwater to salt water as they migrate to Puget Sound from upriver. The transition zone encompasses areas that should support increased juvenile salmon survival and life history diversity. These include mudflats, tidal marshes that produce food for fish, and riparian trees and other diverse plants. Creating more transition zone habitat was identified as the top recommendation in the Duwamish Blueprint (Ostergaard 2014), and is considered to be a critical action for the recovery of Chinook salmon populations in the Green/Duwamish River that are listed as Threatened under the Endangered Species Act. While efforts are underway to reclaim and restore riparian shorelines in order to provide near shore rearing habitat for juvenile salmon, these efforts are confounded by the high costs of land acquisition, remediating contaminated sediments, permitting and regulatory requirements, operation and maintenance. In addition, juvenile must be able to access restored nearshore habitat; narrow channels may restrict access and prevent salmon from gaining the benefits of restoration (Toft and Cordell 2017).

3. Constructed Floating Wetlands Design

3.1. Design Objectives

The design objectives of the proposed Duwamish FWL demonstration project were to:

- Build constructed floating wetlands that are modular and moveable;
- Utilize biodegradable and recyclable materials;
- Incorporate natural organic matter to support microbial activity,
- Support the reproduction of native bulrush species;
- Minimize energy use and mechanical system complexity;
- Incorporate educational and interpretive value into the system;
- Follow a “safe-to-fail” design approach;

A towable pontoon-hull barge design was developed in order to support constructed floating wetlands. These BioBarges (Figure 2) consist of an exterior barge frame constructed of 8” x 2” Alaskan yellow cedar wooden planks that are attached to 10 inch diameter, corrugated double walled N-12® High Density Polyethylene (HDPE) pipe with butt-fused ends, to create a 20’ x 10’ pontoon-style floating frame. The BioBarges were designed as towable research platforms that can be moved to and studied in

a variety of sites. Each BioBarge had four Wetland Biofilters, free-floating within the interior of the BioBarge, and attached to the frame with bungee straps and carabiners.

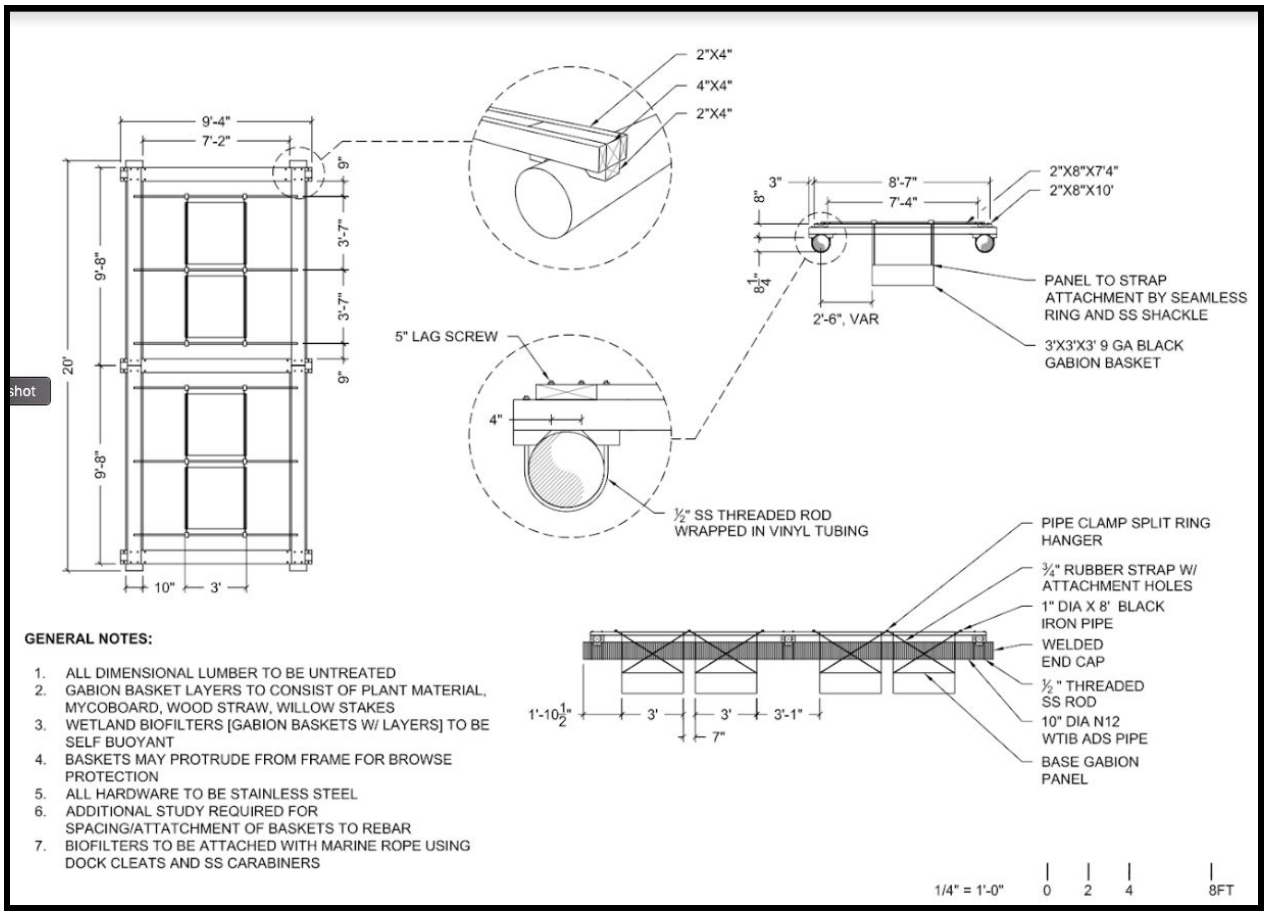


FIGURE 2. BioBarge Design

The BioBarges are capable of supporting four CFW's of approximately 3 feet^3 and weighing approximately 300 lbs each (Figure 2). The CFW's consist of buoyant substrate substrates and native bulrush species protected by gabion baskets. They are designed to support emergent and submergent habitat and have the unique capability of providing underwater habitat. The gabion baskets are fabricated of 0.83-meter (3-feet) untreated 16-gauge wire. The gabion baskets provide a durable envelope that protects plants from browse predation by geese and small mammals, allows for their placement in a variety of settings (e.g. adjacent to stormwater outfalls), and also offer protection from aquatic predators.

The Wetland Biofilter was designed to provide a high surface-area-to-footprint ratio to allow plant roots to promote sedimentation, microbial decomposition, nitrification, and denitrification. The matrix of plant roots and small woody debris also provides refugia for small fish. The gabion baskets provide a durable envelope that protects plants from browse predation by geese and small mammals, allows for their placement in a variety of settings (e.g. adjacent to stormwater outfalls), and also offer protection from aquatic predators. The substrates consist of materials derived from natural organic matter that

may provide invertebrate habitat and perform water quality functions, such as chelating and suspended metals. The substrate used within the wetland biofilters include the materials described in Table1.

Table 1. Descriptions of substrate used for the floating wetlands

Substrate	**Structure**	**Function**
Sphagnum moss, Usnea lichen	Partially decayed plant matter	packing for plant plugs
MycoBoard™	Fungal mycelium particle board	floatation, plant rhizome anchoring
WoodStraw™ wrapped in burlap	Chipped wood veneer	rooting substrate,
BioFoam™	Air-pop polylactic acid board	Flotation, plant rhizome anchoring
Willow branches	Native cuttings of willow	'green brush' support of periphyton

The substrates were designed to support the growth of bulrush, or tule, a rhizomatous wetland macrophyte that includes species endemic to Puget Sound that are capable of tolerating a wide range of salinity, water level fluctuation, water velocities, and sedimentation. Some native tule, such as Schoenoplectus tabernaemontani, are capable of growing up to 18-feet tall, as an adaptation to intertidal water level fluctuation (S. Cooke personal communication). Species such as Schoenoplectus pungens, commonly known as Sweetgrass, also have significant value to Coastal Salish tribes as a heritage fiber used in the production of traditional and ceremonial garments. Bulrush have a long history of use in treatment wetlands, starting in 1957 when Käthe Seidel, a researcher at the Max Planck Institute, successfully demonstrated that constructed wetlands vegetated with Schoenoplectus lacustris could clean up polluted water. Most bulrushes are also generally unpalatable to predatory browsers like Canada geese.

The Biofilters were suspended inside the frame of the BioBarges to occupy 50% of the total open water area, allowing light penetration through the water column for the uncovered areas. This design follows recommendations from the Washington Department of Wildlife and Seattle Department of Construction & Inspections to minimize risks of creating overwater coverage that could adversely affect juvenile salmon by providing ambush habitat for unspecified predators.

The Wetland Biofilters consist of 3ft-cubed untreated 16 gauge wire gabion baskets that contained the substrate materials in which layered as follows:

- Four species of Puget Lowland bulrush sourced from Fourth Corners Native Plant Nursery as bare-root and planted into MycoBoard™ with Sphagnum moss packing on 6-inch triangular spacing centers, for a total of approximately 42 plants per Biofilter.
- 3-inches of MycoBoard™; an engineered wood product consisting of wood particles fused together with mushroom mycelium (https://ecovativedesign.com/). This material is designed to provide a substrate for the plants rhizomes to anchor into;

- 5-inches of Woodstraw™, an engineered wood-strand (http://www.woodstraw.com/). This material is designed to provide a substrate for plants roots to colonize;
- A 2-inch wooden pallet used to support the superior materials;
- 3-inches of BioFoam™, an engineered air-pop foam comparable to polystyrene but derived from biopolymers which are which are made of vegetable materials (https://www.synbratechnology.com/biofoam/). This material provides buoyancy.
- 6-inches of green brush, or willow branches designed to support periphyton growth.

Sixteen Wetland Biofilters were constructed at the University of Washington Hatchery, along with 8 'pucks'— mini Biofilters intended for metals analysis at the end of the season. The wetland plants were grown in freshwater from June 2018 through April 2019 in outdoor pool raceways.

3.1.1. Deployment in the River

The Wetland Biofilters and pucks were then placed into four BioBarge frames (BioBarge) at T-102. In April, 2019, the four BioBarges were deployed at two locations in the Lower Duwamish River estuary: two at T-105 on the west side, and two at T-108 on the east side (Figure 1). The BioBarges were secured to existing pilings near the shorelines, and adjusted so that they would not bottom out during low tides. The structures were far enough from shore that they were only accessible by boat. At a typical mean tide height, the barges were an average of 15 - 20 meters from shore; the closest location possible without bottoming out at low tide.

FIGURE 3a. Biofilter construction at UW hatchery (left), BioBarge construction at T-102 (middle), and deployment at T-108 (right)

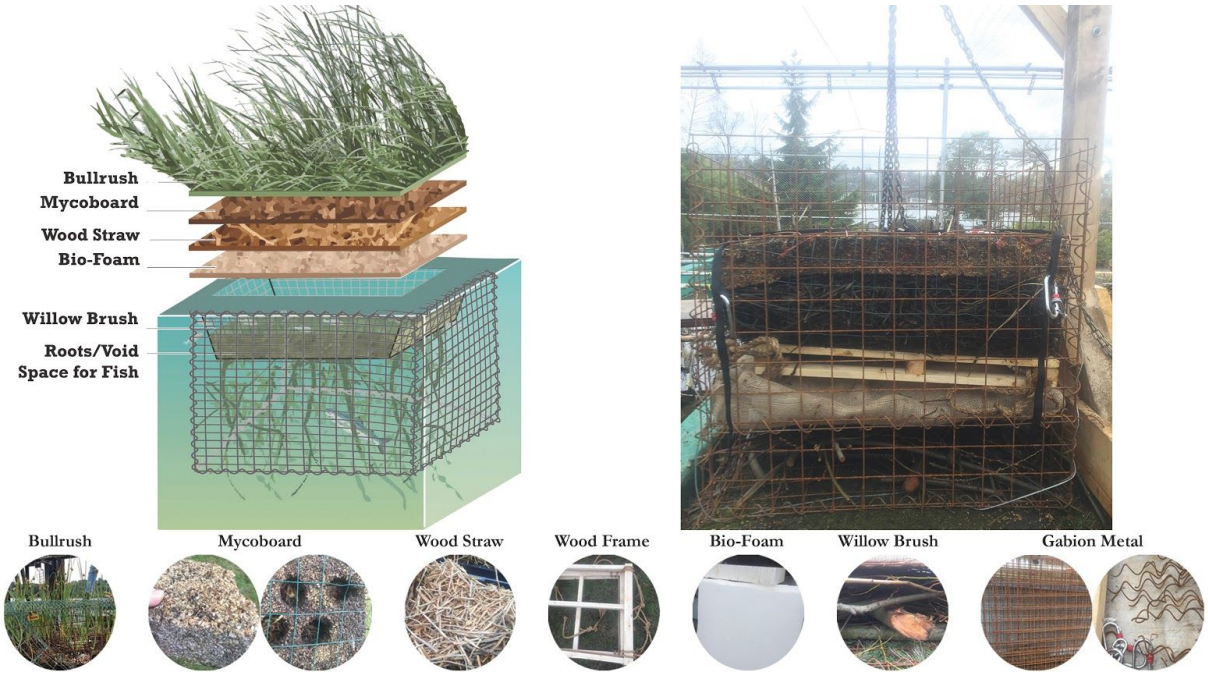


FIGURE 3b. Cross-section of a Wetland Biofilter showing substrate layers (left); Wetland Biofilter layers during construction at the old UW Hatchery (right); Material details of layers (below).

Research Questions for Design and Construction:

- Is the Wetland Biofilter structural design performing as desired?
- Are the layers of the Wetland Biofilter remaining intact?
- Is the Wetland Biofilter design benefiting salmon and monitoring methods?

3.2. Methods for Design, Construction and Prototype Structure Monitoring

To determine if the Wetland Biofilters remained securely attached to the BioBarge frame, the bungies holding them to the frame were monitored regularly. Bungees did occasionally break, or carbineers came off of the frame, raising concern that there was potential for the Biofilters to tip over and/or flip upside down. Over the course of the monitoring season, one Biofilter tipped over and needed to be righted.

To assess the degree to which Biofilters were remaining intact, the substrate was monitored weekly to track any degradation of the material. The 36” x 36” gabion panel on the top of the Mycoboard was a 3” x 3” (12 sqaures x 12 squares) metal grid, which was used to assess degradation. The number of degrading squares were rounded to the nearest half square and recorded. Any large cracks occurring in the substrate were also noted. The team also recorded and communicated general observations about the condition of the structures over the course of the monitoring season.

3.3. Findings

The bungies at T-108 broke significantly more often than T-105. The wave action generated at T-108 was stronger than that at T-105 which showed as the bungees were not able to fully hold together. Additionally, as researchers gathered data on the BioBarges, the wave action felt more significant at T-108. During monitoring and scheduled repair and maintenance on the BioBarges on July 26th, two Wetland Biofilters in BioBarge A were flipped upside down. The team worked to turn them right-side up and resecure the Wetland Biofilters to the BioBarge.

Some of the Mycoboard substrates began falling apart early in the monitoring zone. Those that began breaking down early continued to degrade throughout the monitoring period. Those that held strong during the early phase, continued to hold strong to the end. There were two grades of Mycoboard used (A and B), which could explain why some degraded and other didn't.

As the monitoring period stretched on, the mini-biofilter samples, or "pucks," in the BioBarges did not remain upright as initially designed. The pucks were attached to the outside of the Wetland Biofilters between the Wetland Biofilter and the outside edge. Some pucks tipped sideways and lost significant amounts of material in the current.

FIGURE 4. Photos of ABS piping in the wetland biofilters (upper left); goose netting on wetland biofilter (upper right); degrading substrate (middle); puck (1’ x 1’ wetland biofilters) showing the material layers.

4. Floating Wetlands Research and Monitoring

4.1. Overview

This section describes the results of weekly monitoring of fish use and response, invertebrate production, water quality, and plant growth at the floating wetlands. Where applicable, we also describe monitoring for fish and invertebrates at adjacent shoreline reference sites. As described in *Section 3* above, two BioBarges, each containing four Wetland Biofilters, were installed at each study site in April 2019, for a total of eight Biofilters at each site. The study sites were located at T-105 on the west bank of the river at about river mile 0.7, and at T-108 on the east bank of the river, slightly further south from T-105. The BioBarges were attached to pilings about 15-30 feet offshore at T-105; at T-108 they were connected to pilings and anchored to the river bottom, about 20-35 feet offshore. Distance from shore changed with the tides. The nearest shoreline adjacent to the BioBarges at each study site was used as a reference site to compare fish use of the shoreline with fish interactions with and use of the BioBarges, at low to mid tides. The shoreline could be classified as muddy bank with rocks and limited vegetation, much of which was rockweed or other algae. Two shoreline reference sites were used at T-105 and T-108 to compare invertebrate production by the plants on the FWLs to invertebrate production at each of the two shoreline types. One soft shoreline with intertidal marsh plants and one riprap or armored shoreline that was bordered by upland vegetation ("vegetated riprap") served as the shoreline reference sites at T-105 and at T-108.

Weekly monitoring was conducted from April 25 through July 26 of 2019. Researchers and community scientists conducted fish observations, collected invertebrate samples, measured and assessed water quality parameters, tracked ongoing plant growth, and conducted relevant observations and sampling at shoreline reference sites. Monitoring was generally split over two days per week, with one day focused on observing fish and collecting or placing invertebrate traps, and the other day focused on measuring water quality and plants. We accessed the monitoring sites by the Port of Seattle boat, the "Portfolio," and a smaller dinghy. Research questions, methods, and results are separated by topic and described in the following sections.

4.2. Monitoring Fish Use and Response

4.2.1. Introduction

Seven species of anadromous salmonids migrate through the Duwamish River estuary, traveling as juveniles from various upriver spawning grounds and hatcheries to saltwater habitat in Elliot Bay and the greater Puget Sound (Morley et al. 2012). The Puget Sound Chinook salmon, an ESA-listed population unit, is of particular interest for scientists and restoration practitioners, as the fall stock juveniles have been shown to spend more time feeding in estuarine areas before continuing their migration to salt water (Healey 1991, Cordell et al. 2011). Degraded near-shore habitat and limited quantity of available high-quality habitat in the Duwamish River estuary is a contributor to low returns of spawning adult salmon. Early-stage growth is an important factor for salmon survival at sea, and growth rates of naturally-occuring Duwamish River salmon may be affected by poor habitat quality (i.e., lack of opportunity or space to feed and rest) and competition with hatchery fish. Restoration projects along the river have focused on increasing food availability, providing protection from predation, and

increasing the amount of high-quality habitat where salmon transition from freshwater to saltwater (Cordell et al. 2011). In addition to salmon, there are many other resident and seasonal fish populations in the Duwamish River, including several species of perch, flounder, stickleback, and sculpin.

The research team was interested in understanding if and how juvenile salmon utilize the floating wetland structures as a potential source of food and/or shelter. The primary research questions are described below.

Research Questions for Fish Monitoring:

- How are juvenile salmon responding to and utilizing floating wetlands?
    - What is the initial response of a school of fish to the FWL structure?
    - What is the behavior of juvenile fish utilizing the FWL structure?
    - How many and what species of fish are observed?
- How does observed juvenile salmon response and behavior at FWLs differ from behavior at the adjacent shoreline?

4.2.2. Fish Monitoring Methods

Overwater observation was the primary method of fish observation, and Gopro video cameras were used to record footage below the BioBarges, both while conducting overwater observation and when observers were not present. Three researchers snorkeled on one day in early August to look more closely at the underwater structures, and to confirm fish species identification. *Appendix A* provides more detail on fish monitoring methods.

Observation Protocol

Fish observations were conducted once per week. On each observation day, the goal was to conduct observations for 30 minutes at both T-105 and T-108 BioBarges and reference shorelines. We timed our observation periods to be as close to the low tide as possible, based on early observations and knowledge that juvenile salmon swim very close to the shore, and our speculation that they might not encounter or swim out to the floating wetlands at higher tides, due to the distance of the FWLs from shore. Typically, two observers and one scribe worked together during observation periods, though the number of team members varied occasionally with the inclusion of community scientists.

Reference shorelines for the fish observation study were immediately adjacent to the BioBarge and approximately the same dimensions as the BioBarge structures (roughly 60 feet by 10 feet). At T-108, the reference shoreline was a sandy/muddy beach with some small rocks, seaweed, and remnant concrete bits; at T-105, the reference shoreline had a riprap/rock ledge exposed at low tide and a sandy shoreline above, connected to a “soft” restored side channel (see Figure 1 for reference).

There were two platforms on each BioBarge, on the outside edges of the central support beam. Typically, two observers sat or stood on the upstream BioBarge (one per platform), and one observer sat or stood on the downstream BioBarge (Figure 5). A timer was set for 30 minutes, and observers watched for fish and recorded observations throughout this time, using the data sheet designed to capture

various factors, described in more detail below. In some instances, the observation period was shortened to 20 or 25 minutes if no fish had been observed by that time, or if visibility became extremely limited, and to accommodate other data collection needs, such as setting or retrieving invertebrate traps.

FIGURE 5. A team of one observer and one scribe monitors fish from the BioBarges at T-105.

Data Collection

The unit of observation for this study was a school of fish, which included anywhere from one fish to 200+. The size of the school was recorded, and reported in small, medium, and large school sizes. Schools of less than 10 fish were categorized as small and the exact number was recorded. Schools between 10 and 50 fish were considered to be medium, and large schools were those with over 50 fish. For each observation, we recorded the time observed, the approximate number of fish in each school, fish behavior, location in relation to the BioBarge or shore, approximate depth, and any additional notes to help with species identification. Whenever possible, we recorded the fish species. For salmonid observations, we focused on identifying Chinook and chum salmon, using indicators including body shape, feeding behavior, location in relation to the surface, and size to differentiate between the two species. Species identification was challenging due to the visibility limitations of overwater observation. Additional challenges included a learning curve for identifying juvenile salmon species for all team members and working with newcomers to gather fish data throughout the season. We began seeing a greater diversity of fish species later in the season, which further complicated fish identification.

Previous fish sampling studies conducted in the spring and early summer in the Duwamish River have found primarily chum, Chinook, and pink salmon (Toft and Cordell 2017). We expected to observe

primarily chum and Chinook, given that pinks spawn during odd years in Puget Sound. In many cases, we were able to differentiate salmonids from other types of fish (e.g., perch, sculpin, stickleback) but not able to identify the species of salmon. We did not record any confirmed observations of coho salmon, which may have been due to the challenge of identifying species using overwater observation. The Soos Creek Hatchery and the Keta Creek Complex located on the Green River near the town of Auburn, and the Fish Restoration Facility, proposed to release yearling coho between April and June 2019, and a smaller number of fry in January (NOAA 2019, Appendix F). Therefore, it is possible that some of the unidentified salmon or unidentified fish, particularly in earlier months, were coho, based on the duration between hatchery release and when we began observations. However, the exact release dates may not match what was proposed; hatchery staff at Soos Creek indicated that they released all coho yearlings by early to mid-April, before we began monitoring. Furthermore, yearling hatchery coho would likely not be confused with sub-yearling chum and Chinook. To our knowledge, precisely how long it takes for juvenile salmon to swim from hatcheries or natural spawning grounds to the lower Duwamish River estuary is not known, and travel and residence times for fish within the estuary can vary greatly (Ruggerone and Volk 2004).

In addition to collecting data on salmon, we generally recorded observations and notes of other (non-salmonid) species present, including perch, sculpin, and stickleback species.

Data Analysis

The primary goal of conducting fish observations was to understand how outmigrating juvenile salmon responded to and utilized the BioBarges, so the analysis focused on salmon observations and other fish species were treated separately.

In many cases, field observers did not record a fish species, instead writing descriptive notes. In analyzing the data, where possible, we recorded a best guess for the species based on notes recorded and any confirmed species identified for that day. In some cases where visibility was bad or we had observed more than one species of salmonid that day, we identified only that the observation was an unknown salmonid (see Table 3 below). Where we present fish counts, these are sometimes exact counts reported by data collectors, and sometimes the midpoint of the range of the number of fish marked on data sheets.

4.2.3. Results of Fish Monitoring

Table 2 below provides a summary of fish observations at T-105 and T-108. We conducted 12 days of observation at T-105, and nine days at T-108. We often first conducted observations at T-105 and then at T-108, though we did vary the order on some days. Due to time constraints and early challenges fine-tuning the boat logistics and observation methodology, we conducted fewer days of observation at T-108 than at T-105.

Fish were not always observed at both the shore and the barge on each day, and more specifically, salmon were not observed on many of the field days. In addition, relatively few observations of salmon were made at the floating wetlands. We considered fish observed within one meter of the BioBarge to be a barge observation; this required reviewing the distance notes during data analysis and removing observations noted as further than one meter from the barge.

TABLE 2. Fish Observation Data Summary, both sites.

Summary of Fish Occurrence	**T-105**	**T-108**
Total # of field observation days	12	9
Total # of days salmon observed (shore or barge)	8	5
Total # of salmon school observations at the floating wetlands and shore	59	56
Total # of salmon school observations at floating wetlands	13	6

Results from Terminal 105 - West Side

In this section, we present results from fish monitoring at T-105. Table 3 below summarizes salmon observations for each observing day at both the shoreline reference site and observations of fish from the floating wetland. At T-105, we generally observed more salmon from both the barge and the shoreline earlier in the monitoring season, and were no longer seeing salmon by the end of June at both sites. Chum were predominant in April and early May, and more Chinook than chum were seen by mid-May. Figure 6 below shows the salmon school observation counts as a graph. Observers found it easier in some cases to observe fish from shore because fish were more visible against the bottom than in deeper water. Most observations of schools feeding were made from the shoreline reference site.

TABLE 3. T-105 Salmon Observation Results.

Date	**Location**	**Total # of Salmon Schools**	**Approximate # of Individual Salmon**	**Salmon Species**	**# of Schools Feeding**
4/25/19	Barge	1	15	Chum	1
	Shore	10	439	Chum	1
5/9/19	Barge	0	0	None	0
	Shore	16	241	Chum	3
5/16/19	Barge	4	32	Chinook	0
	Shore	15	385	Chinook, Unknown Salmon	4
5/24/19	Barge	0	0	None	0
	Shore	0	0	None	0
5/31/19	Barge	4	111	Chinook, Unknown Salmon	0
	Shore	1	1	Unknown Salmon	1
6/6/19	Barge	0	0	None	0
	Shore	0	0	None	0
6/14/19	Barge	2	7	Chinook, Unknown Salmon	1
	Shore	0	0	None	0
6/20/19	Barge	0	0	None	0
	Shore	0	0	None	0

6/26/19	Barge	2	2	Unknown Salmon	0
	Shore	1	4	Unknown Salmon	0
7/1/19	Barge	0	0	None	0
	Shore	0	0	None	0
7/9/19	Barge	0	0	None	0
	Shore	0	0	None	0
7/15/19	Barge	0	0	None	0
	Shore	0	0	None	0

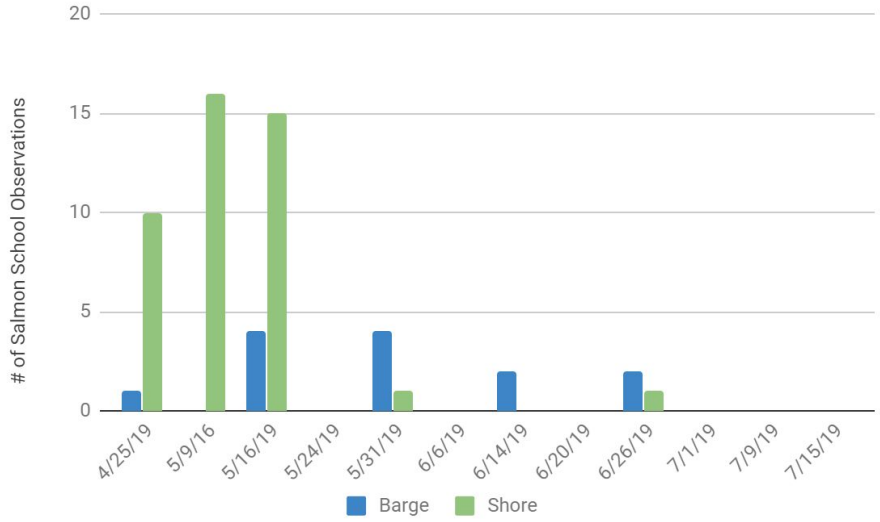


FIGURE 6. Salmon school observations on each monitoring day at T-105.

In addition to recording the number of salmon schools observed, we recorded a school size range based on estimating the number of fish in each school. Table 4 provides the school sizes for the observations included in the table above. Small schools contained less than 10 fish, medium schools contained between 10 and <50 fish, and large schools contained over 50 fish. We most frequently saw small and medium-sized schools of chum and Chinook. Counts or estimates of the number of fish in a school were challenging when visibility was low.

See next page.

TABLE 4. Observed salmon school sizes at T-105.

Date	Total # of Schools Observed	Chum School Sizes			Chinook School Sizes			Unknown Salmon School Sizes		
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
4/25/19	11	0	8	3	0	0	0	0	0	0
5/9/19	16	7	7	1	0	0	0	0	0	0
5/16/19	19	0	0	0	8	6	2	0	1	0
5/31/19	5	0	0	0	0	3	0	1	1	0
6/14/19	2	0	0	0	0	0	0	2	0	0
6/26/19	3	0	0	0	0	0	0	3	0	0

Results from Terminal 108 - East Side

This section describes results from fish monitoring at T-108. Table 5 below summarizes salmon observations from each day, at the shoreline reference site and from the floating wetland. Similar to T-105, we observed more salmon schools from the shore than from the barge. Visibility from the barge was particularly challenging at T-108, and species identification was more difficult at both the barge and the shore. We did not observe salmon after mid-June at T-108, however several monitoring sessions were cut short due to time constraints towards the end of June. For some of the days where we observed high counts from shore (e.g., 5/31/2019), we found it difficult to differentiate unique schools due to visibility, and may have been observing a large school(s) of fish utilizing the area during the observation window, rather than many unique or separate schools passing through as is recorded. We observed more feeding behavior at the shore than at the BioBarges. Figure 7 below shows only the salmon school observation counts as a graph.

TABLE 5. T-108 Salmon observation results.

Date	Location	Total # Salmon Schools	Approximate # of Individual Salmon	Species	# of Schools Feeding
5/9/19	Barge	0	0	Chum	0
	Shore	3	6	Chum	0
5/24/19	Barge	0	0	None	0
	Shore	4	19	Chum	3
5/31/19	Barge	5	8	Chinook	1
	Shore	25	163	Chinook, Unknown Salmon	18
6/6/19	Barge	1	1	Unknown Salmon	1

	Shore	8	11	Unknown Salmon	8
6/14/19	Barge	0	0	None	0
	Shore	10	111	Chum, Unknown Salmon	5
6/20/19	Barge	0	0	None	0
	Shore	0	0	None	0
6/26/19	Barge	0	0	None	0
	Shore	0	0	None	0
7/9/19	Barge	0	0	None	0
	Shore	0	0	None	0
7/15/19	Barge	0	0	None	0
	Shore	0	0	None	0

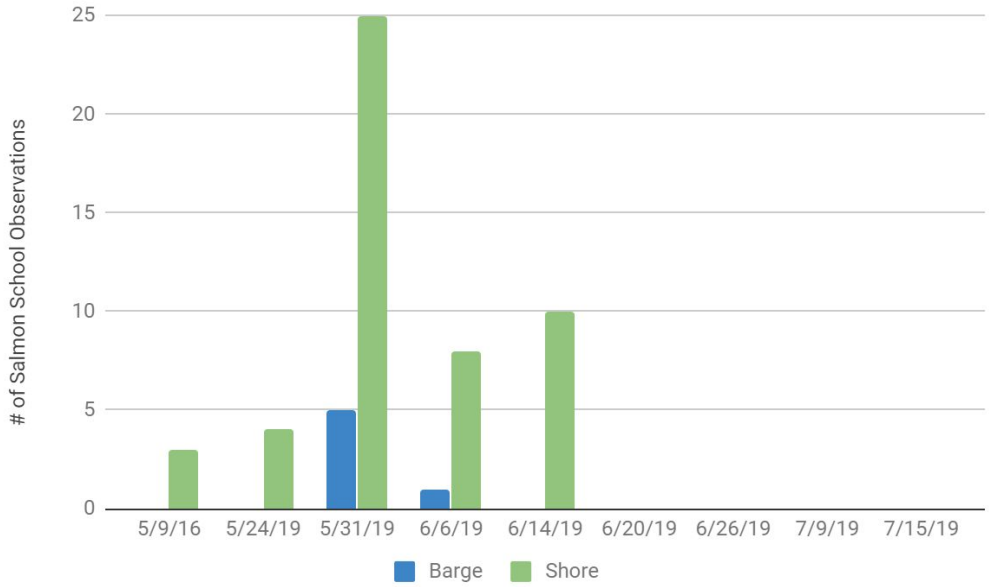


FIGURE 7. Salmon school observations on each monitoring day at T-108.

Table 6 below lists the school sizes for the observations at T-108. Only small and medium-sized schools (i.e., up to 50 fish) were observed at T108, whereas some larger schools were observed at T-105, on the west side of the river.

See next page.

TABLE 6. Observed salmon school sizes at T-108.

Date	Total # of Schools Observed	Chum School Sizes			Chinook School Sizes			Unknown Salmon School Sizes		
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
5/9/16	3	3	0	0	0	0	0	0	0	0
5/24/19	4	3	1	0	0	0	0	0	0	0
5/31/19	30	0	0	0	14	2	0	12	2	0
6/6/19	9	0	0	0	0	0	0	9	0	0
6/14/19	10	1	4	0	0	0	0	5	0	0

Combined Results of Site Locations

One of the primary questions we sought to examine in this study was how schools of outmigrating juvenile salmon respond to the floating wetlands. Response types were recorded as one of four behaviors: avoid, no response, edge (utilized outside edge), or entered. Table 7 below summarizes the initial response of all schools of salmon observed at the BioBarges. A total of 19 schools, of varying sizes, often just a single fish, were observed across both sites at the barges. Very few schools avoided the BioBarge (n=3), the highest number showed no response (e.g., kept swimming, n=9) and an equal number utilized the edge of the BioBarge by swimming alongside (n=4) as did those that entered into the frame of the BioBarge (n=4).

TABLE 7. Initial responses of salmon schools to the BioBarge.

Barge Site	Total Schools	Initial Response Behavior			
		Avoid	**No Response**	**Edge**	**Entered**
T-105	13	3	5	3	3
T-108	6	0	4	1	1
Total	*19*	*3*	*9*	*4*	*4*

In addition to observing salmon utilization of the floating wetlands, we recorded observations of other fish species at the shore and BioBarge structure. Other fish observed included perch, sculpin, and stickleback. Figure 8 below shows how the fish that were observed at each site changed over the course of the monitoring season. Beginning in late May, many more non-salmonid species began to be observed. We observed perch swimming and darting back and forth at depths of 1’ to 4’ or more, and they often stayed within the general vicinity of the shore and BioBarges during the observation period.

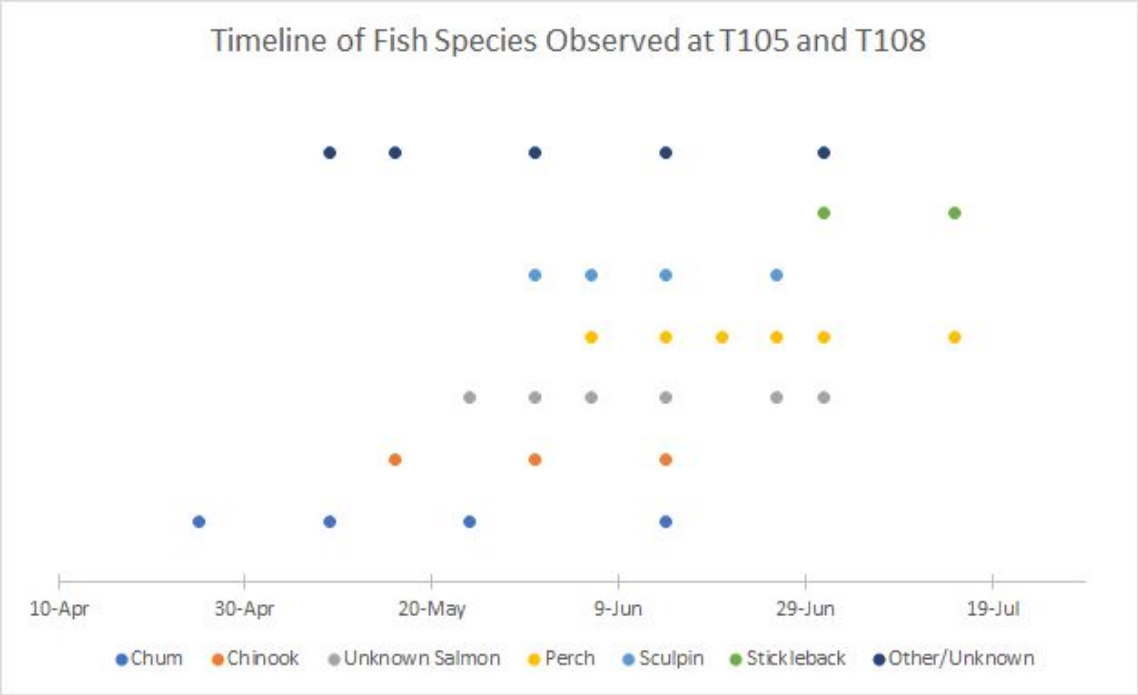


FIGURE 8. Timeline of fish species observed at both locations throughout the monitoring season

Go-Pro Observations

GoPro cameras were used at both BioBarges to record video clips at intervals throughout one to two days per week, and to record continuous video while we were conducting visual observations (see Appendix A for a more detailed description of methods). GoPro observation methods evolved during the season; we initially started with one camera with a "Blink" timer at T-105, and eventually added a second camera with a timer to record video clips at T-108, as well as an additional two cameras per site to record continuous video during overwater observation. We analyzed about 75% of the video recordings, looking for presence/absence of fish, and included notes on species when possible. 340 video clips of varying lengths were recorded; 257 have been reviewed to some degree (note that species ID was not attempted or confirmed for some reviewed clips). Fish were observed in 33% of video recordings. We recorded no salmon observations; however, species identification was not possible or not attempted for some video clips. The majority of identified species in the videos were perch, primarily shiner perch and striped sea perch. Perch typically appeared to swim back and forth from the shore to the BioBarges, usually at depths at least one foot below the surface. This was consistent with what was observed during overwater observation. We discuss benefits, limitations, and recommendations to using GoPros in Section 5 below.

Underwater Observations

In addition to recording video, we snorkeled the BioBarges in early August to observe fish and underwater habitat created by the BioBarges. We observed large schools of stickleback at both T-105 and T-108, consistent with visual observations of stickleback beginning in early July. We also observed perch at both sites. Anecdotally, the stickleback appeared to be using the BioBarge as shelter, and possibly as a food source, as they would swim away from snorkelers but not leave the site. We also observed one larger fish - potentially a sculpin - within the gabion cage. Snorkeling seemed to be an

effective method to see if fish are utilizing the space within the gabion cages. Though the gabion cages were visible in most of the GoPro footage, we did not observe fish within the cages in the reviewed videos. Future studies could test repositioning one GoPro to more directly view the cages to see if fish are within the wire and willow.

In addition to snorkeling, we also used a remote operated vehicle (ROV) equipped with a camera to record under the barges on the same day we snorkeled. The ROV was a useful one-time monitoring tool to understand what is happening underneath the wetland biofilter. The ROV provided knowledge of algae growth on the gabion structures, confirmation of open space being maintained in the loose willow branches, understanding of the biofilters working as desired and not catching debris, and no sign of root growth. While this information is beneficial, there are logistics that go into having the ROV out on the water. Use of the ROV for sonde measurements should be used to test water quality under wetland biofilters. It is recommended that the ROV be used two or three times in the monitoring season. This allows additional sonde information to be collected and compared to each other without overtaxing the efforts to have the equipment out in the water.

Predation and Interaction Observations

Terns are known predators of juvenile salmon in the Duwamish River, and were observed catching juvenile salmon in the main channel. However, we observed no instances of predation by terns, other birds, fish, or mammals on juvenile salmon at the floating wetlands. We also did not observe any direct interactions between salmon and other fish. Shiner perch typically eat small crustaceans, mollusks, worms, gammarid amphipods, barnacle tentacles, and fish eggs. Threespine stickleback eat small crustaceans, worms, copepods, larvae of adult aquatic insects, small fishes, and occasionally their own eggs and fry (Aquarium of the Pacific n.d.). However, the stickleback that were observed were generally smaller than the juvenile salmon that were observed.

4.2.4. Discussion of Fish Monitoring Results

There were few occurrences of juvenile salmon near the floating wetlands; more salmon were observed swimming back and forth and feeding along the shore. When salmon were observed at or near the barges, they typically showed no response to the floating wetland structure, i.e., they kept swimming down the river. More specifically, if a school was swimming past the structure, it continued swimming by without approaching or avoiding (e.g., darting away, changing direction). In total, four schools of salmon entered the structure and four schools swam along an edge, and slightly fewer avoided the BioBarge. Here we discuss possibilities for the lack of salmon observed at the Biobarges during this monitoring season.

Shade and Shelter

One consideration of this project was whether or not the shade generated by the barge structure would deter salmon, which are visual predators and may avoid shady areas due to risk of predation and inability to see prey. While it did not appear that the structures themselves deterred salmon, the shade created by the barges and associated infrastructure could have contributed to the low numbers of schools observed actively utilizing the BioBarges. This can be further tested in phase 2 of the project in 2020. Juvenile salmon are known to generally avoid overwater structures once they reach the estuary (Toft et al. 2004). The schools that did enter the barge were infrequently observed feeding, compared to

schools observed at the shoreline reference sites. Schools observed from the barges were frequently swimming and occasionally resting. Though salmon were observed only a few times inside/underneath the barges, they were more sheltered from predators such as diving terns during this time.

Visibility and Counting

Chum, Chinook, and unidentified salmonids were observed at both the barges and the shoreline reference sites. At T-105, we observed an estimated 1200 juvenile salmonids, of which about 14% were observed at or within 1 meter of the BioBarge. At T-108, we observed an estimated 319 individual salmon, of which about 3% were observed at the BioBarge. As previously described, there were greater challenges with visibility at T-108, and fewer observation days. On at least one instance, a high number of juvenile chum were observed feeding at the shore, and due to limited visibility the number of schools may have been overcounted instead of counting larger school(s) utilizing the area for a longer duration.

Distance from Shore and Location

Typically, juvenile salmon remain very close to the shoreline and swim in shallow water when possible while outmigrating from their home river to the bay. We suspected that the distance of the BioBarges from shore, along with the relatively deep water that the barges were located in (between 10 and 20 feet or more depending on the tide), may have contributed to the lack of access or use by juvenile salmon. More specifically, we suspect that salmon swimming along the shorelines adjacent to the barges would not be drawn to swim away from shore, through deeper water, out to the barges. This assumption is based on what has been observed in other studies regarding salmon behavior and migration patterns. Given the nature of salmon outmigration from rivers to bays being shore-oriented, the distance of the BioBarges from shore may have been one of the main factors contributing to the low number of juvenile salmon that were observed by researchers.

We also hypothesized that the location of the BioBarges in the river may have contributed to few observations of salmon accessing the BioBarges. Both study sites were located at about river-mile one, which is roughly at the end of the transition zone and the beginning of higher-salinity habitat in Elliot Bay. Juvenile salmon spend more time feeding in the transition zone, where they undergo physiological changes to adapt to saltwater environments. Studies have documented salmon utilizing restored nearshore areas in the Duwamish River, many of which are located further upriver from the 2019 study sites.

Other Species and Novel Habitat

In addition to salmon observed at the BioBarges, we observed several other species of fish present at the structures, including perch and stickleback. We observed perch consistently at T-105 from the BioBarge and between the BioBarge and the shore, starting in early June. In late June, the team started seeing small fish schooling around the BioBarges, which appeared to remain in place at the barge, utilizing it for protection and possibly for feeding. On one occasion, fish eggs attached to kelp that had washed into the BioBarge structure were found. The team collected a small portion of the eggs, which hatched a few hours after collection (Figure 9). GoPro video and snorkeling confirmed the frequent presence of perch and three-spine stickleback, which may have been somewhat “resident” at the site due to the frequency with which they were observed. It is important to note that perch and stickleback

are considered very common in the Duwamish River estuary and throughout Puget Sound. The attraction of shiner perch and stickleback to the BioBarges may not be representative of other fish.

FIGURE 9. The monitoring team found a piece of kelp caught on the BioBarge, with fish eggs attached on the blade just above the air-bladder.

Additionally, the team utilized an ROV from the Port of Seattle to make underwater observations on the same day we snorkeled the sites in August. The ROV observed perch at the BioBarges and at the adjacent pilings at T-108. After we removed the "pucks" from the water, we observed on two occasions a long, thin fish, which may have been a type of gunnel or eel, that had been living in the puck. We also observed dead flounders left by otters on the biofilters, and otters swimming in and around the BioBarges. The gabion cages and attachment bungees experienced significant biofouling by brown algae.

Considering all of these observations, the BioBarges appeared to create a novel habitat in the lower estuary, which anecdotally seemed to aggregate numerous small to medium sized fish species. However, it is important to note that many of these fish (e.g., shiner perch) are common. We did not observe any instances of predation on juvenile salmon by terns or other salmon predators at the BioBarges. In phase 2 of the study, researchers may want to develop a more systematic approach for assessing the Biobarges as novel habitats. This could include tracking changes in algae growth and resident-like fish use of the structures. Assessing the floating wetlands as novel habitats is discussed in more detail in the Recommendations section.

4.3. Invertebrate Monitoring

4.3.1. Introduction

In this study, we sampled terrestrial invertebrates using fallout traps as a way to measure the input of insects into the aquatic system at the floating wetlands and adjacent shoreline sites. Terrestrial invertebrates, including dipteran flies, can make up an important percentage of salmon diets in the

Duwamish River, along with benthic and planktonic taxa (Cordell et al. 2001; Cordell et al. 2011). The primary research question guiding invertebrate monitoring is included below.

Research Questions for Invertebrate Collection
How do invertebrate densities and taxa richness at floating wetlands compare to adjacent shorelines?

4.3.2. Methods

Below, we provide an overview of the methodology used for sampling and processing invertebrates and analyzing data.

Sampling Approach
We sampled invertebrates a total of ten times during the monitoring season, approximately weekly from May 24th to July 16th, 2019 using fallout traps. Fallout traps are plastic bins (0.34m by 0.21m) filled with a small amount of water mixed with a few drops of biodegradable, unscented dish soap. We alternated sampling between T-105 and T-108 each week, for a total of five sampling days per location. For each sampling day, we set out five fallout traps on the BioBarges, five fallout traps on an adjacent vegetated riprap shoreline, and five fallout traps at an adjacent soft shoreline, for a total of 15 traps per sampling day. However, samples were lost most days due to traps tipping over, being moved, or being swamped by waves (at the barges), or missing adequate numbers of trap bins to set out. We deprioritized analyzing lower sample count days. Some samples from days where the number of collected samples were already low were ultimately used for educational activities (e.g., samples from 5/24 vegetated riprap in Table 7). Table 8 below shows the numbers of samples obtained and included in this analysis. For days with low sample counts, we prioritized processing the barge samples in order to compare invertebrate densities and plant growth, and deprioritized processing the other samples because low sample counts are less ideal for comparing across sites (see 5/24, 6/14). We included sampling days in the comparisons among sites when sample counts were four or greater at all sites (see 5/31, 6/20, 6/25, 7/1, and 7/16). Note that samples from 6/7 and 7/10 were not included at all due to time constraints on processing samples.

TABLE 8. Summary of fallout traps per sampling day

Monitoring Day and location	# of samples from BioBarge	# of samples from vegetated riprap site	# of samples from soft shoreline site	Total # samples	Total # of samples included in analysis	Notes
5/24/19 at T-108	5	1	4	10	5	5 barge samples included in barge analysis only
5/31/19 at T-105	5	5	4	14	14	None
6/7/19 at	5	4	2	11	1	1 barge sample

T-108						included in barge analysis only
6/14/19 at T-105	5	4	2	11	5	5 barge samples included in barge analysis only
6/20/19 at T-108	5	4	5	14	14	None
6/25/19 at T-105	4	4	4	12	12	None
7/1/19 at T-108	4	4	5	14	14	None
7/10/19 at T-105	5	2	3	10	2	2 barge samples included in barge analysis only
7/16/19 at T-108	5	5	4	14	14	None

Fallout Trap Placement

At the BioBarges, traps were attached to the sides of the gabion cages above the water level using bungee cords. We randomized which biofilters and which side of the biofilters we attached the traps to each day. Along the shoreline, traps were randomly placed along a roughly 60 foot transect above the high tide line to sample an area approximately the same length as the two BioBarges, located as close as possible to the BioBarges. Shoreline traps were placed along vegetated riprap and soft shorelines (e.g., restoration areas) to represent different types of shoreline habitat in the Duwamish River. At T-108, we placed shoreline traps on a riprap wall beneath a blackberry hedge immediately adjacent to the BioBarges (vegetated riprap), and along an area where logs have been anchored for restoration and plants are growing in front and behind the logs (soft shoreline). At T-105, we placed shoreline traps in low vegetation along a side channel (soft) and at the top of a riprap wall below the T-105 park (vegetated riprap). Due to the limitations of needing to locate reference sites as close as possible to the BioBarges and placing the traps about the high tide line, the T-105 vegetated riprap site may be more vegetated than other armored sites along the Duwamish River. At this location, traps were placed directly below trees, which may explain the composition of these samples. Figure 10 shows examples of trap placement; more images are included in Appendix B.

FIGURE 10. Images showing fallout traps placed at BioBarge B and the soft shoreline reference site at T-105. See Appendix B for more images.

Invertebrate Sample Collection

The project team left fallout traps for approximately 24 hours at each location. To collect the samples, we poured the contents of the trap through a 106-µm sieve, washed the sample into collection jars, and fixed with 70% isopropyl alcohol. We then transported the samples via boat and car back to the lab for storage. Traps that appeared to have been tipped over or swamped by waves were not collected.

Sample Processing

We identified samples to the family level where possible, and in some instances to the superfamily or order level. We prioritized processing samples from dates with the highest sample counts (4 or 5), which are included in the comparative analysis below (see Table 8). We secondarily prioritized processing barge samples for the purposes of comparing invertebrate density with plant growth (see Figure 26 in the plant section below). Some samples were processed before we prioritized dates, and have not been included in this analysis.

Sample Analysis

Taxa and counts for each sample were recorded and entered into an excel workbook. We calculated average densities per meter squared and average taxa richness for each location at each site, as well as percent composition of primary taxa. In addition, we calculated densities and richness across three dates at T-108 to consider changes over the course of the summer. Average taxa richness is simply the number of taxa in each sample, averaged across all samples. Average density is the number of invertebrates within a sample divided by 0.0725, averaged across all samples. The dimensions of the traps used in this study are about 35cm by 21cm (surface area) which is about 0.07 of a square meter. *At this point, we have not conducted any statistical analysis on the results.*

4.3.3. Results

Table 9 below includes average invertebrate density per square meter, average taxa richness, and number of samples for barge, vegetated riprap, and soft shorelines at T-105 and T-108. At T-105, the vegetated riprap site had the highest average invertebrate density and the highest average taxa

richness, though taxa richness was similar at the soft shoreline. At T-108, the soft shoreline site had the highest average invertebrate density and average taxa richness.

TABLE 9. Invertebrate density, taxa richness, and sampling across locations and sites.

	T-105 Barge	T-105 Veg. Riprap	T-105 Soft	T-108 Barge	T-108 Veg. Riprap	T-108 Soft
Average Density/m²	87	894	190	182	345	413
Average Taxa Richness	3.3	8.7	7.3	4.2	6.3	8.4
# Samples	9	9	8	14	13	14
# Sampling Days	2	2	2	3	3	3

Figures 11 and 12 below show average invertebrate densities per square meter and average taxa richness at the barge, vegetated riprap and soft shorelines across three sampling days at the end of June, early July, and mid-July. Both the barge, vegetated riprap, and soft shoreline show increasing invertebrate density during this sampling period, though more information and/or analysis would be required to determine a trend. Taxa richness was more variable during the same time period.

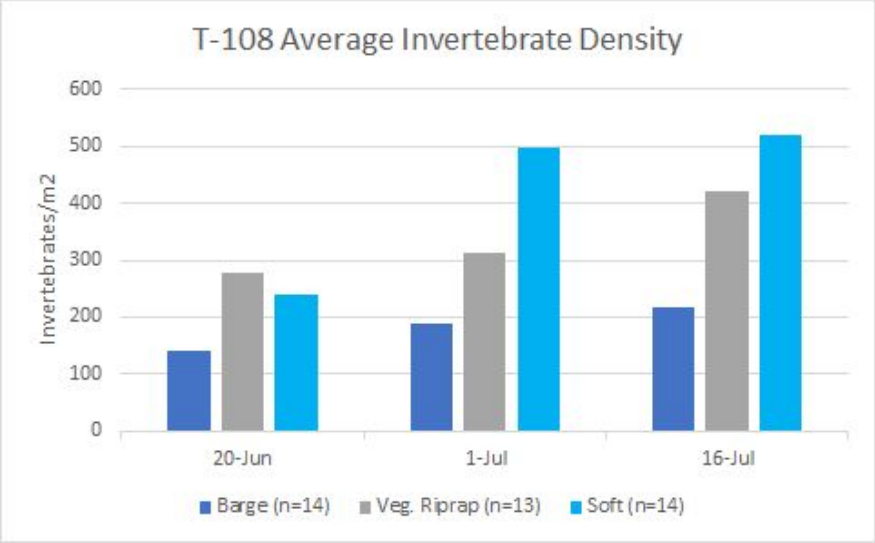


FIGURE 11. Invertebrate densities over three sampling dates at T-108.

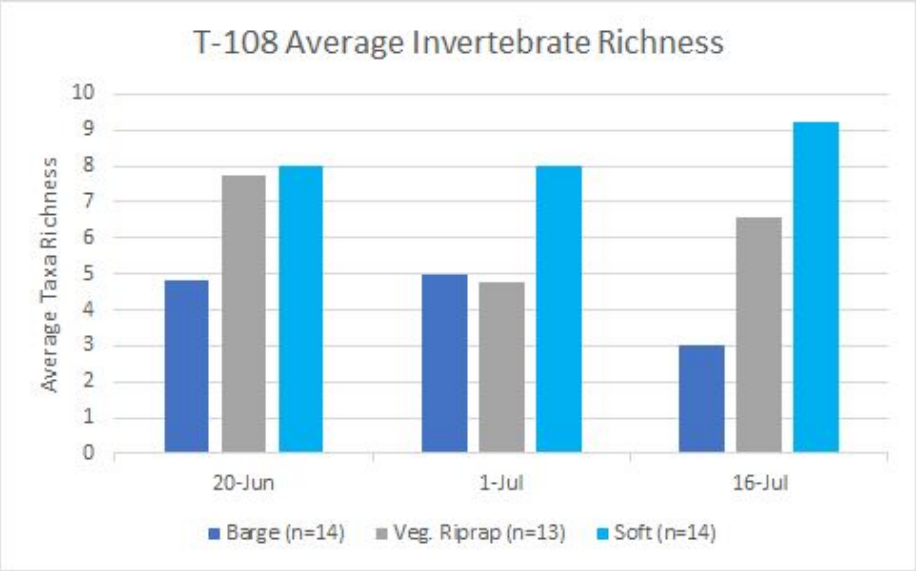


FIGURE 12. Taxa richness over three sampling dates at T-108.

Figures 13 and 14 below show the percent composition of major taxa at T-105 and T-108. Percent composition was calculated as the density per meter squared of each major group divided by the site density. Chironomid flies and other dipteran flies comprise the majority of the barge samples at both T-105 and T-108. Talitridae and chironomid flies make up the majority of the riprap samples, and densities are more even across major taxa groups at the soft shoreline.

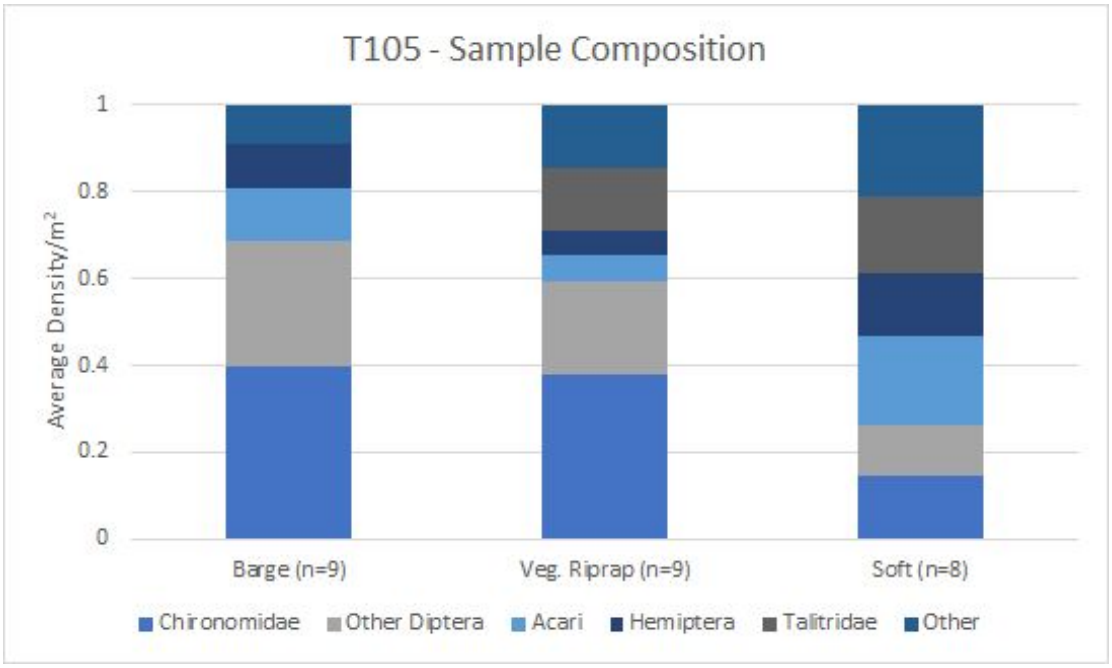


FIGURE 13. Percent composition of taxa at T-105

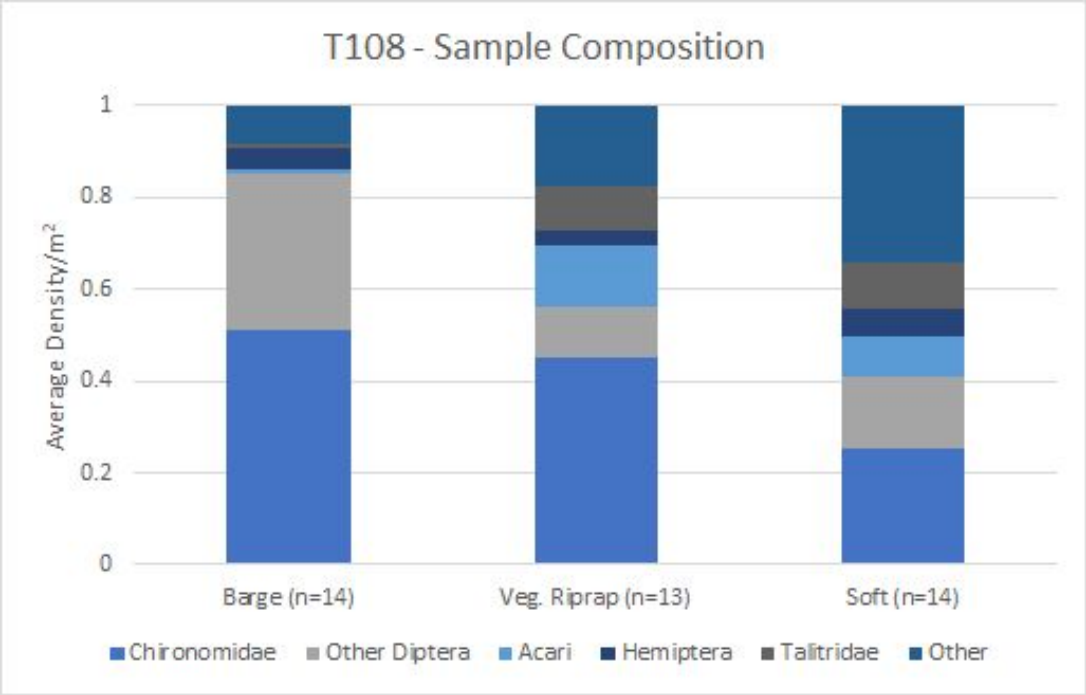


FIGURE 14. Percent composition of taxa at T-108

In addition to comparing across sites, we also analyzed how the density and taxa richness changed over time at the barge sites. Tables 10 and 11 below shows the average invertebrate density and average taxa richness at T-105 and T-108 at the barges over the monitoring season. There does not appear to be a trend in density or richness at either location. In general, densities are higher at T-108 than at T-105. Note that some dates (i.e., 6/7 and 7/10) have a low sample size.

TABLE 10. Average invertebrate density and taxa richness at T-105 over the monitoring season

	5/31/19	**6/14/19**	**6/25/19**	**7/10/19**
Average Density/m²	110	187	59	103
Average Taxa Richness	3.4	3.25	4.0	3.5
# Samples	5	5	4	2

TABLE 11. Average invertebrate density and taxa richness at T-108 over the monitoring season

	5/24/19	**6/7/19**	**6/20/19**	**7/1/19**	**7/16/19**
Average Density/m²	287	83	140	189	218
Average Taxa Richness	4.0	4.0	4.8	5.0	3.0
# Samples	5	1	5	4	5

4.3.4. Discussion of Invertebrate Monitoring Results

Juvenile salmon are known to consume a diversity of invertebrates in estuarine environments. A recent study of nine Pacific Northwest estuaries found that salmon most frequently consumed dipterans (flies) and amphipods; fish diets also contained hemipterans (plant hoppers), coleopterans (beetles), and hymenopterans (wasps, bees, and ants), and crustaceans such as cumaceans, mysids, and copepods (David et al. 2016). Analyses of Chinook and chum salmon diets in the Duwamish have found varying reliance on terrestrial invertebrates versus marine or benthic food sources. Morley et al. (2012) found that terrestrial insects dominated the diets of Chinook salmon sampled from armored and unarmored sites in 2004, while chum diets included terrestrial insects and copepods. Chironomidae, aphididae, and other taxa were important contributors to Chinook and chum diets. Cordell et al. (2001) found adult dipterans to be an important contributor to salmon diets, as well as other terrestrial invertebrates and benthic and water column food sources. Given the importance of terrestrial invertebrates in salmon diets and the importance of connectivity between aquatic and terrestrial habitats in a healthy estuary, it is important to assess the invertebrate productivity of the floating wetlands. The invertebrates sampled from the floating wetlands included chironomids, other dipteran flies, acari (mites), and other terrestrial invertebrates that salmon are known to consume. Chironomids made up 40-50% of invertebrates sampled from the barges at T-105 and T-108. However, invertebrate density and taxa richness were lower at the barges than at shoreline reference sites.

Over two-thirds of the shoreline of the Duwamish River is armored, and riprap is the most prevalent form of shoreline armoring. Shoreline characterization and production studies indicate that extensive armoring and lack of intertidal riparian vegetation has decreased habitat availability and negatively impacted the connection between terrestrial and aquatic habitats (Morley et al. 2012). Given this context, we hypothesized that we would find lower densities and taxa richness at armored shoreline sampling sites compared to soft shorelines. However, as previously noted, fallout traps at the T-105 riprap site were placed directly beneath trees, shrubs and other dense vegetation to be above the high tide line, which may explain the high densities observed at this site. The densities from three of five samples at T-105 taken on 5/31 are significantly higher than the other six samples from T-105. The high counts of talitridae found at the T-105 vegetated riprap site reflect that this site may be less representative of a typical armored shoreline, given the overhead plant cover and soil/sand at the top of the riprap. Talitridae (i.e., sand hoppers/fleas) have been found to be a relatively small percentage of juvenile Chinook salmon diets in Puget Sound (Brennan et al. 2004); the sample from the T-105 vegetated riprap site with the highest density was comprised of 80% talitridae. Talitridae were generally not present in the barge samples, presumably due to their life history. At T-108, the soft shoreline samples contained higher average densities of invertebrates and taxa richness than the vegetated riprap reference site or the barge.

Plant density on the barges was low compared to the relatively dense vegetation that characterized the soft shoreline sites. Both vegetated riprap sites had overhanging vegetation that may also have provided more insect habitat than the marsh plants on the barges. Interestingly, we did not observe a trend in invertebrate density over the duration of the monitoring season as plants on the barges grew. The *Plant*

Monitoring section provides more detail on plant growth throughout the season, and Appendix D includes pictures that show the plant density on the BioBarges.

In addition to using fallout traps to sample terrestrial invertebrates at the barges, we sampled the substrate of the barges and “pucks” for marine invertebrates. These samples have not been systematically analyzed. However, anecdotally the pucks contained high densities of marine amphipods, as well as several large “kelp” isopods. These invertebrates appeared to be living within the mycoboard and woodstraw. Future research could investigate marine invertebrates at the BioBarges as an aspect of novel habitat created by the structures.

4.4. Water Quality Monitoring

4.4.1. Introduction

The Wetland Biofilters were created with layers of materials designed to support plant growth and flotation. Mushroom Mycoboard, wood straw, Biofoam, and willow branches are the primary layers of the biofilter (see 3. Floating Wetlands Structural Design, Figure 3b). Plant plugs were then inserted into the Mycoboard that served as the planting substrate of the structure. The Wetland Biofilters were placed in the Duwamish River with the goal to provide additional salmon habitat to the area, and so the water quality parameters we measured focused on those that affect juvenile salmon. The juvenile salmon have certain conditions that they look for when searching for a habitat. Salmon react to light levels, temperatures, and dissolved oxygen levels to select suitable habitat. Salmon have been shown to prefer a filtered light level and avoid areas with too much shade (Cordell et al, 2017). Sauter et al. (2001) have shown that subyearling and juvenile salmon have an ideal temperature range between 12^{0}C and 14^{0}C. As the temperature gets further away from that range, the percent of salmon outmigrating is less. If the level reaches about 25^{0}C, then the temperature has hit lethal levels for salmon (Sauter et al., 2012). Finally, dissolved oxygen must be found in the water in order for salmon to survive. According to Kidd (2011), salmon prefer to have the optical dissolved oxygen (ODO) levels above 11 mg/L. If the ODO levels drop below 6 mg/L, then the conditions become lethal for salmon (Kidd, 2011).

Because of ecological and human health risks posed by sediment contaminants, the Duwamish River was previously designated as a Superfund site in 2001 by the United States Environmental Protection Agency (US EPA). The river runs through Seattle's main industrial corridor and has toxins that were generated from "stormwater runoff, wastewater, and industrial practices" (US EPA). The United States Geological Survey (USGS) has continued to monitor water quality 16.7 river kilometers upstream at USGS streamgage 12113390; Duwamish River at Golf Course at Tukwila, WA. On this site, metals were testing in unfiltered water showing presence of arsenic (As), barium (Ba), chromium (Cr), copper (Cu), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), zinc (Zn), and carbon (C). As floating wetlands were being added to the river, the research team needed to understand if they were adding more toxins to the water, helping reduce toxins through phytoremediation processes, or not having an impact on river water quality.

Research Questions for Water Quality

- Do the floating wetlands improve water quality conditions and microhabitat related to the salmon? (light, dissolved oxygen, and temperature)
- Do other water quality measures change as a result of the floating wetlands? How do the measurements compare between testing locations? What does this tell us about the microhabitats of the floating wetlands in terms of chlorophyll levels (algae levels for salmon habitat), turbidity (suspended matter in water for salmon), conductance (information on the tide levels), salinity (salt water influence on plant health), dissolved oxygen (oxygen levels for salmon health), and temperature (ranges for plant and salmon health)?

- Do the floating wetlands contribute to reducing the following river contaminants: arsenic (As), barium (Ba), chromium (Cr), copper (Cu), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), zinc (Zn), and carbon (C)?

4.4.2. Methods

To determine the habitat qualities that were created for the salmon, measurements of light, dissolved oxygen levels, and temperature were recorded. Light was measured through using a Hobo Pendant mx 2202 meter™, which measured luminosity (lum/ft²) and temperature. Three Hobo meters were placed on each BioBarge – one at the side of a Wetland Biofilter at water level, one underneath the water near the bottom of the floating wetland, and one above the water in open air as a control measure. See Figure 15. These 24-hr loggers measured light and temperature at 10 minute intervals during the entire monitoring period. In this case, the monitoring period for BioBarge D (at T-105) began May 10th and ended July 26th. BioBarges A, B, and C began the monitoring period on June 14th and ended July 26th. (See TABLE 12 for full monitoring schedule.)

TABLE 12: Water quality monitoring schedule

Monitoring Day	**YSI EXO2 Sonde:** **chlorophyll, conductance, turbidity, salinity, dissolved oxygen, and temperature**	**Dissolved Oxygen check samples for sonde Titration**	**Hobo Pendant mx 2202™:** **light, temperature**	**miniDOT usb Oxygen Logger:** **Dissolved oxygen and temperature**
4/26/2019	Dissolved Oxygen only: BioBarge A, B, C, D	Grab #1		
5/10/2019			Deployed BioBarge D	
5/17/2019				Deployed BioBarge C,D
5/24/2019	BioBarge C,D			
5/31/2019	BioBarge C,D			
6/7/2019	BioBarge D		Deployed BioBarge A, B, C	
6/14/2019	BioBarge A, B, C, D			Data checked
6/21/2019	BioBarge A, B, C, D			
6/28/2019	BioBarge A, B, C, D		Deployed temp controls: BioBarge B, C	

7/3/2019	BioBarge A, B, C, D			
7/10/2019	BioBarge A, B, C, D			
7/15/2019	All: BioBarge D All expect ODO: BioBarge A, B, C	Grab #2		
7/26/2019			Retrieved	Retrieved

The dissolved oxygen levels were measured using a miniDOT usb Oxygen Logger which also measured temperature in10 minute intervals. Two miniDOTs were installed in the Duwamish River to record data 24-hrs a day. One miniDot was installed at T-105 on BioBarge D and the other was installed at T-108 on BioBarge C. The monitoring period for these miniDots was May 10th to July 26th. See Figure 15 for more information on the Hobo Pendant™ and miniDOT™ locations within each BioBarge.

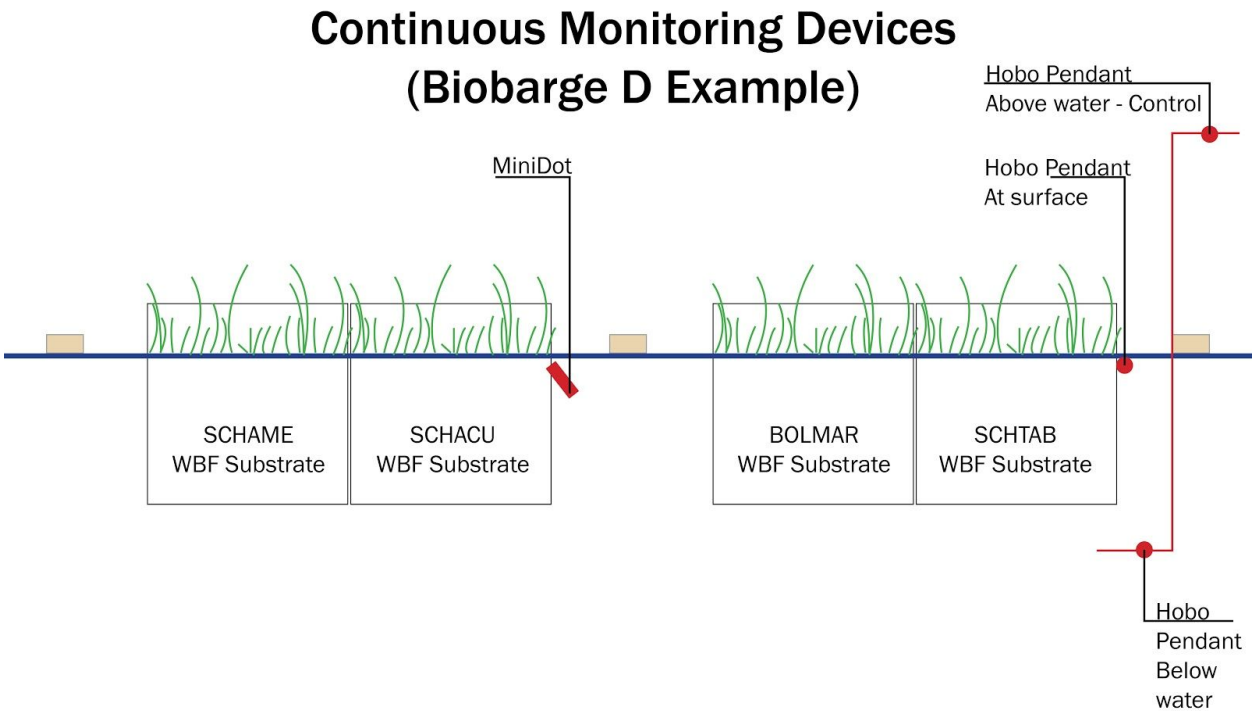


FIGURE 15. Location of continuous monitoring devices

Additional water quality measures were conducted using a spot analysis with a YSI EXO2 datasonde to understand other water quality aspects. The datasonde was used to measure chlorophyll levels, conductance, turbidity, salinity, dissolved oxygen, and temperature. In each BioBarge, three locations (one at each end of the BioBarge and one in the middle) were measured with each location being at different depths of 0.3m, 0.6m, and 1.0m. See Appendix C for more details on measurement locations. At each depth, the sonde was given time to settle to the new depth, then 5 measurements were taken

with 10 seconds between. A mean value was used as the average for each depth. These measurements were used to compare the location of the points and find out more about the micro ecosystems being created by the Wetland Biofilters. All measures were not correlated with the tide levels and therefore cannot be compared from week to week by value because they were taken at different times of the day. They can, however, be compared based on same day measurement trends. The DO concentrations were compared based on depth levels, location (T-105 vs. T-108), control vs. BioBarge, and the middle to edge of the BioBarge. The sonde dissolved oxygen levels were dissolved oxygen analyzed by titration in grab samples collected concurrently calibrate the sonde measurements (twice during the monitoring period). A multiplier of the grab sample result was applied to the sonde readings to give more accurate data for dissolved oxygen levels (new sonde level = original sonde value * 1.0582 - 1.0279).

Lastly, planting medium and plant samples were collected and analyzed to determine if the Wetland Biofilters were releasing or absorbing metals, carbon, and nitrogen to the water. The method used smaller version (1' x 1') "pucks" that were created with the same layers and process as the larger Wetland Biofilters (3' x 3') that were described in the structural design section. Both the pucks and the full biobarges were 3' deep. The smaller version was immersed in the Duwamish for 133 days (early April to August 16th). Pucks were disassembled and grouped for sampling and analyses based on material and puck (location in the Duwamish). Two pucks with living plant material were taken from T-105, and two pucks with living plant material were selected from T-108. Additionally, control pucks were collected one week after the pucks had been in the Duwamish River and allowed to dry on the Green Futures Balcony over the summer. These controls provided data about the metals, carbon, and nitrogen contained within the materials used to construct the Wetland Biofilters. The control was compared with the pucks that were collected at the end of the monitoring season to evaluate the potential positive and negative impacts of Wetland Biofilters in the Duwamish River.

TABLE 13. Water quality methods and parameters measured

Equipment	**Research Question**	**Parameter**
Hobo Pendant mx 2202™	How do the light levels present at the floating wetlands compare to desired salmon habitat?	Light levels, temperature
MiniDOT usb Oxygen Logger™	How do continuous oxygen and temperature levels in the floating wetlands compare to desired salmon habitat levels?	ODO, temperature
YSI EXO2 sonde™	How do various water quality parameters change based on depth level, location (T-105 vs. T-108), control vs. BioBarge, and middle to edge of BioBarge?	Chlorophyll, turbidity, conductance, salinity, dissolved oxygen, temperature
Pucks analyzed in UW Soil	What metals and nutrients	Metals (Al, As, B, Ba, Ca, Cd, Cr,

Analytics Lab	change from control to biofilter and help remove contaminants from the Duwamish River?	Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Zn, Si, Ag), Carbon, Nitrogen

4.4.3. Findings

All tested water quality measures showed a consistent variation with tide levels based on a preliminary 2-day datasonde deployment that collected data every hour. The change in water quality measures was more drastic than anticipated in some measures. The water quality parameters (chlorophyll, turbidity, salinity, dissolved oxygen, and temperature) responded to tides suggesting the influence of salt water over the freshwater. There was more influence from Eliott Bay than first expected.

Water within the top meter of water column had temperature levels during the study period that ranged between 12.5 and 17°C. Ideal temperature levels for juvenile salmon migration are between 12 and 14°C. Lethal levels for juvenile salmon are above 25°C. The water temperature did not exceed 25°C in the Hobo Pendants™ (Figure 19) and sonde points, shown in Figure 16. There was one spike in the miniDOT data shown in Figure 17, but it is speculated that the data at that point were taken as the miniDOT was being checked at a midway point in the monitoring period. Earlier in the monitoring period, the temperatures appeared to be closer to desired levels of 12 to 14°C. As the monitoring season progressed, the air temperature increased and the cold snow runoff from the mountains decreased creating higher water temperatures, but never in jeopardy of reaching the lethal level.

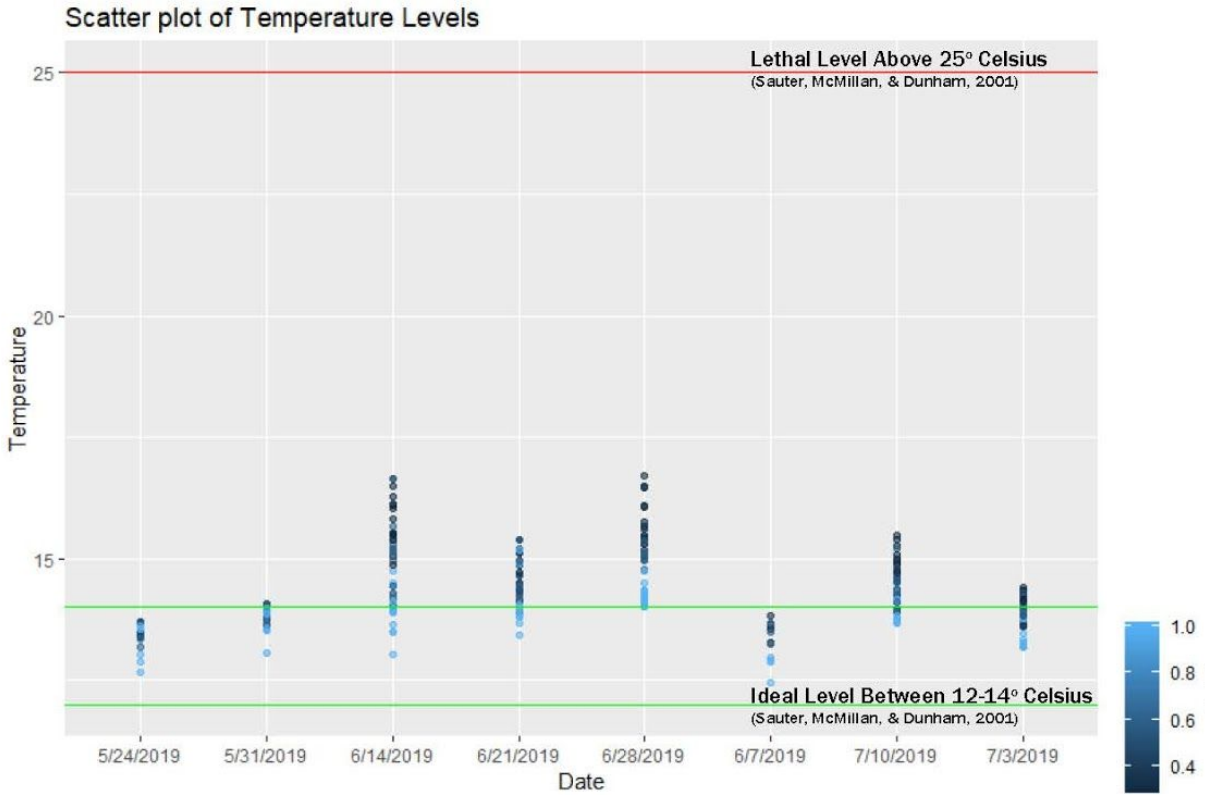
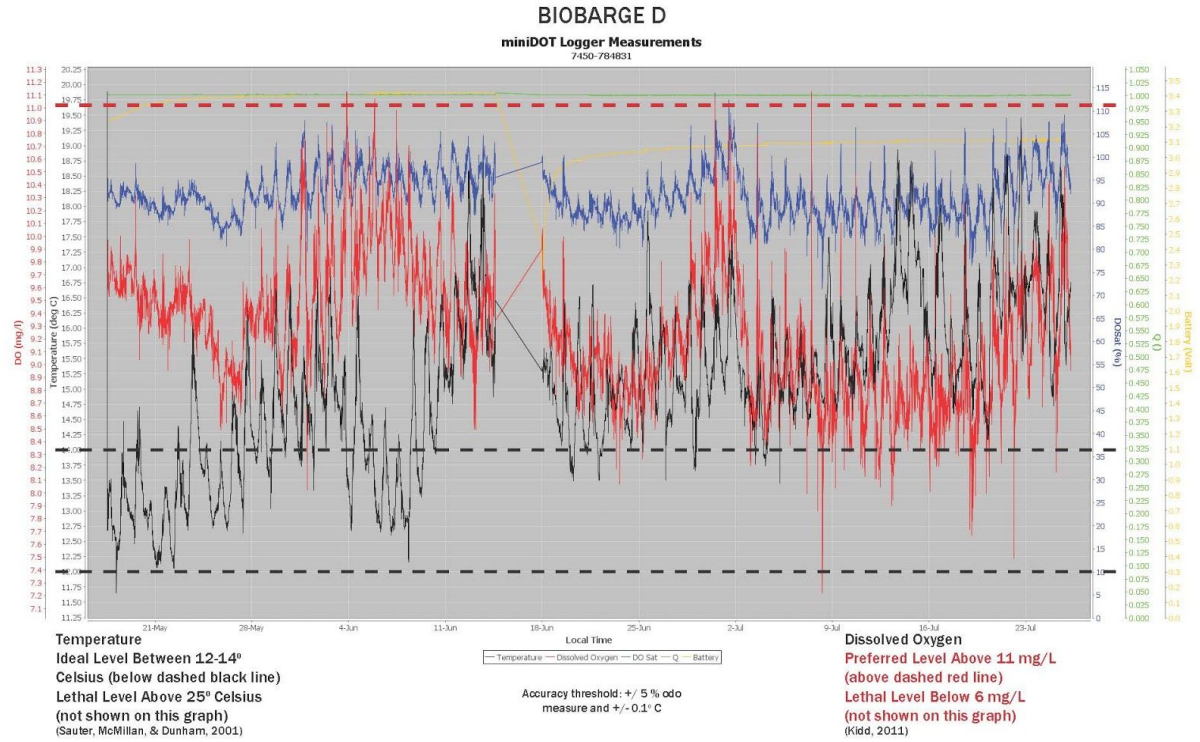


FIGURE 16. Sonde temperature readings with ideal salmon levels in green, lethal salmon levels in red, and the sonde depth (meters) in blue.

Dissolved oxygen levels are preferably above 11 mg/L; salmon can survive in dissolved oxygen conditions that are lower, but less than 6 mg/L can be lethal to juvenile salmon. In the miniDOT readings, the DO levels spiked above the 11 mg/L mark three times (June 4, 8, and July 8) and did not fall below the 6 mg/L mark, seen in Figure 17. Sonde DO levels ndid not exceed 11 mg/L or fall below 6 mg/L. See Figure 18. The YSI dissolved oxygen measurements exhibited no clear patterns over depth and were similar between T-105 and T-108 biobarges. There was no difference between the BioBarge and the control site at each location. Lastly, the dissolved oxygen patterns measured in the middle of the BioBarge were similar to those measured at the edge of the BioBarge.



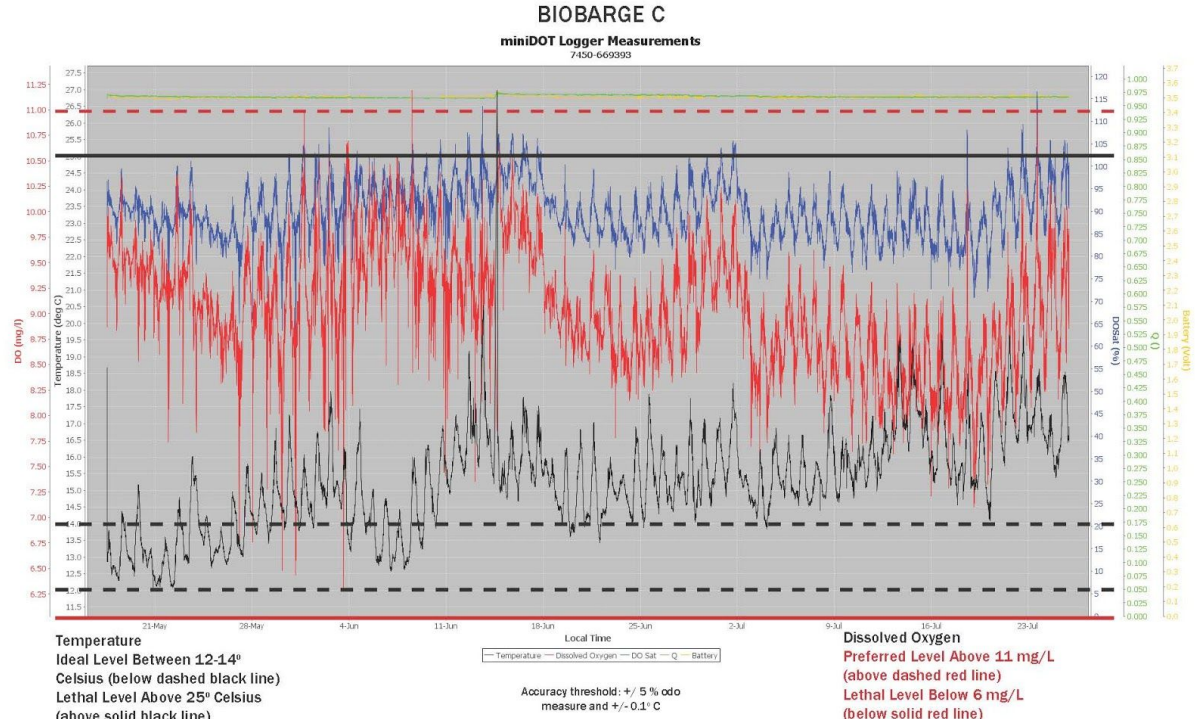


FIGURE 17 Temperature and Dissolved Oxygen Levels from miniDOT Logger, BioBarge C (top) and D (bottom)

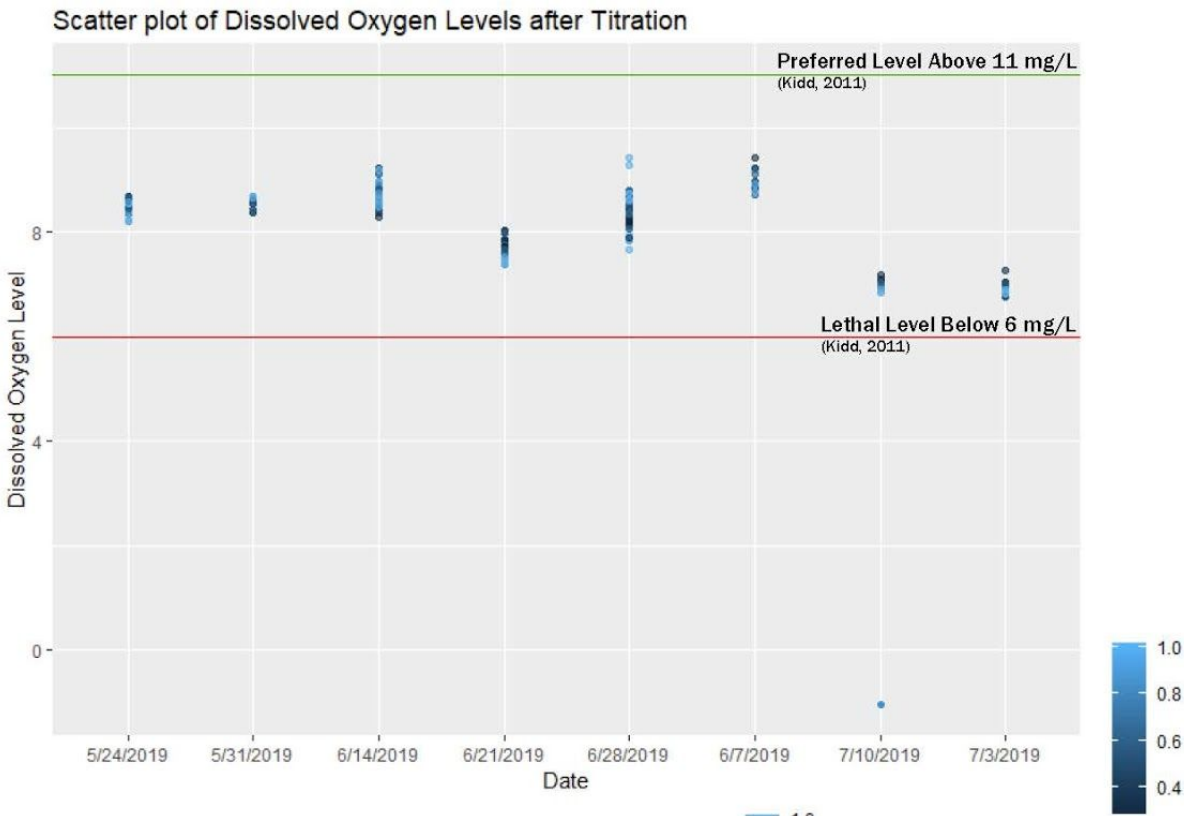
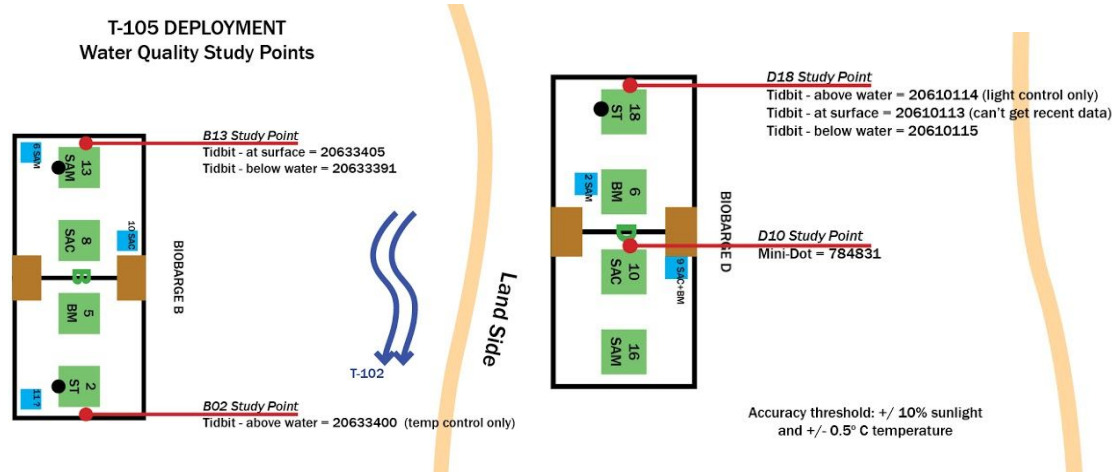
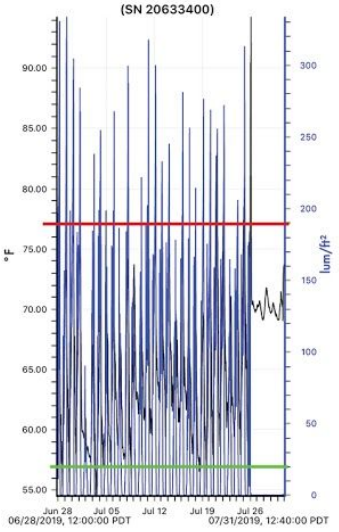


FIGURE 18. Sonde dissolved oxygen readings with preferred levels below green, lethal level below red, and sonde depth (meters) in blue. For Titration information see Appendix C.

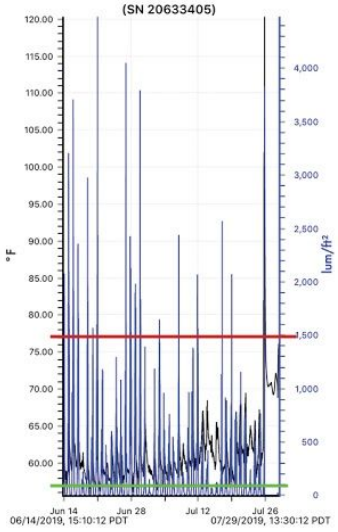
Juvenile salmon prefer to feed in areas with dappled light, as opposed to dark areas. Piers and overhead structures create shaded or dark areas that juvenile salmon have been observed to avoid (Ono and Simenstad, 2014). The light levels were measured at the surface and 2 - 3 feet below the surface to determine how light levels would compare to the control (above water sensor). Light levels were lower at the surface and "below surface" depths than in the control sensor, but there were light levels between 100 lum/ft2 and 3,000 lum/ft2 seen at the surface and below the surface. The light levels show that while some shading is occurring, light is still being emitted in the sensor location which is positive for the salmon. Light levels can be seen in Figure 19.



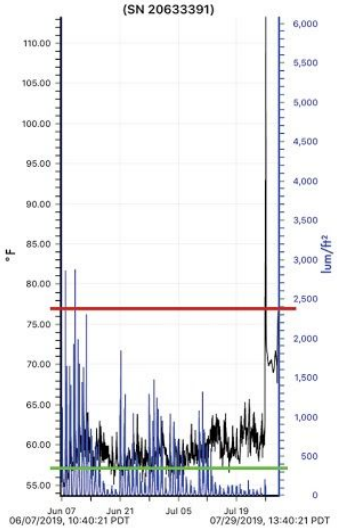
Biobarge B - above water
(temp control only)



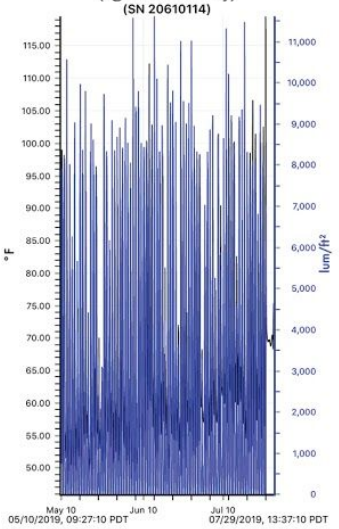
Biobarge B - at Surface



Biobarge B - below Surface



Biobarge D - above water
(light control only)

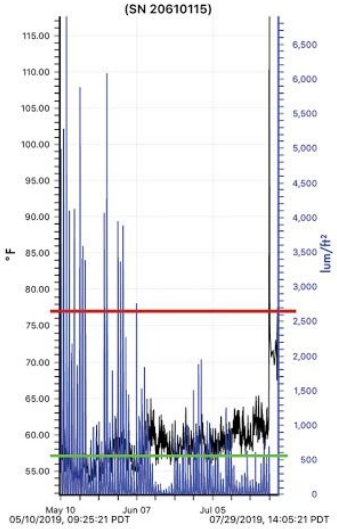


Biobarge D - at Surface

Sensor Malfunctioned in
Final Pickup

Temperature
Ideal Level Between 12-14° Celsius
(below green line)
Lethal Level Above 25° Celsius
(above red line)
(Sauter, McMillan, & Dunham, 2001)

Biobarge D - below Surface



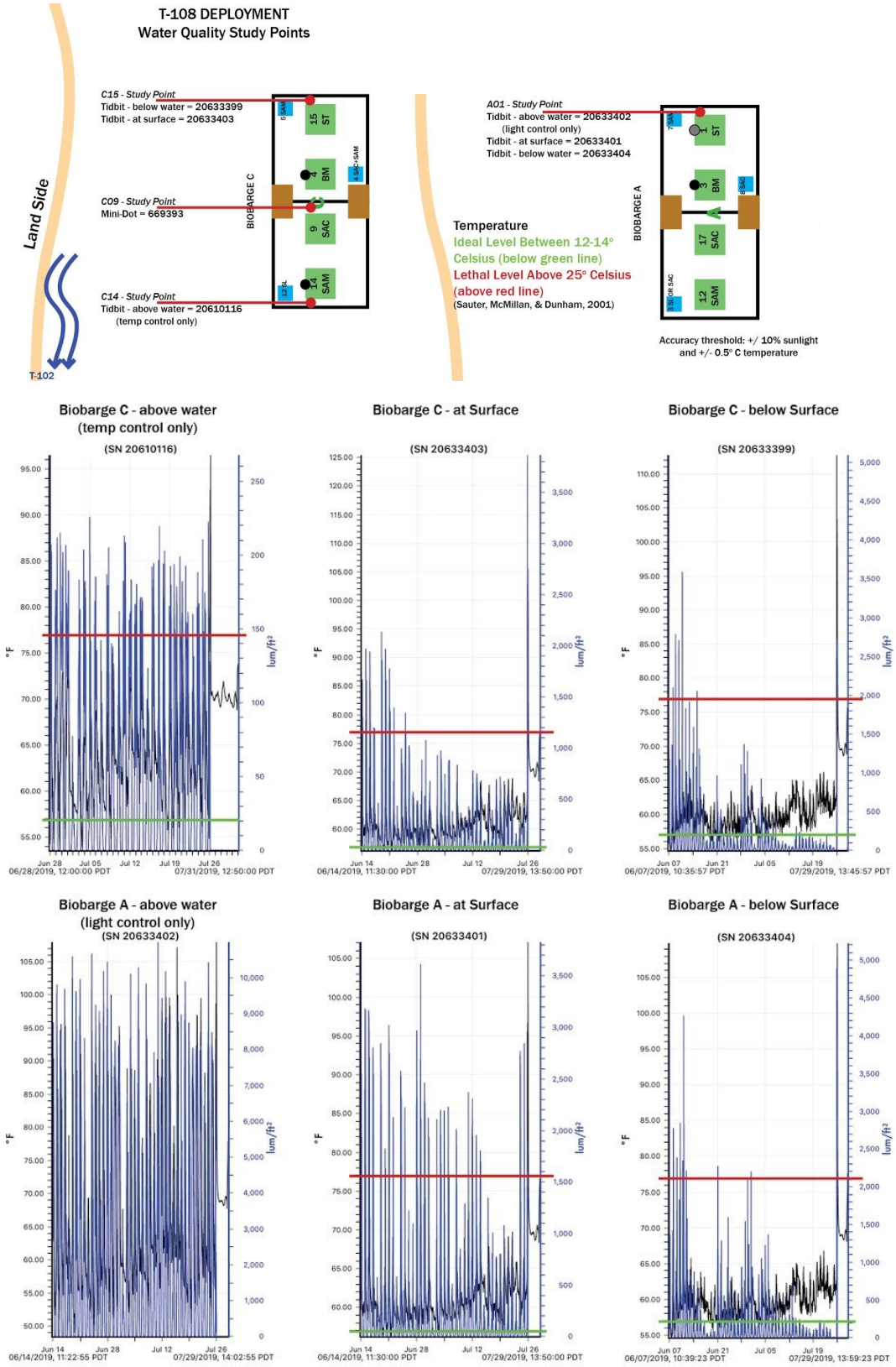


FIGURE 19. Light and Temperature Levels from Hobo Pendants™ (p 48 and 49)

Using the sonde in spot locations, salinity and temperature levels varied over measurement depth below the surface. As the depth increased, the temperature levels mostly decreased and salinity increased. There was slight inconsistency with the temperature levels decreasing with depth of measurement decreasing, but that was the overall trend throughout the monitoring period. No other changes in temperature readings were apparent from the results. Salinity levels were similar between T-105 and T-108 locations. Additionally, the BioBarge and control for each location did not show any difference in the salinity results. Lastly, the middle of the BioBarge and edge of the BioBarge showed similar results for salinity.

Turbidity levels did not show a difference across measurement depth, control vs. BioBarge, or BioBarge middle vs. edge. It did show turbidity levels to generally be lower at T-105 than T-108. Overall, turbidity levels had a mean of 1.1 NTU. Chlorophyll did not show consistency or difference in any of the categories and had a mean value of 1.02 ug/L. Chlorophyll readings were based on sonde readings and not verified with water samples analyzed by a laboratory.

Summary Sonde Data	As depth increases…	T-105 vs. T-108	Biobarge vs Control	Middle vs. Edge (of Biobarge)
Salinity	Salinity increases	No difference	No difference	No difference
Dissolved Oxygen	Not consistent	Not consistent/ No difference	No difference	Not consistent
Turbidity	No difference	105 is lower	No difference	No difference
Chlorophyll	Not consistent	Not consistent	No difference	No difference
Temperature	Not consistent (Mostly temperature decrease)	Not consistent	No difference	No difference

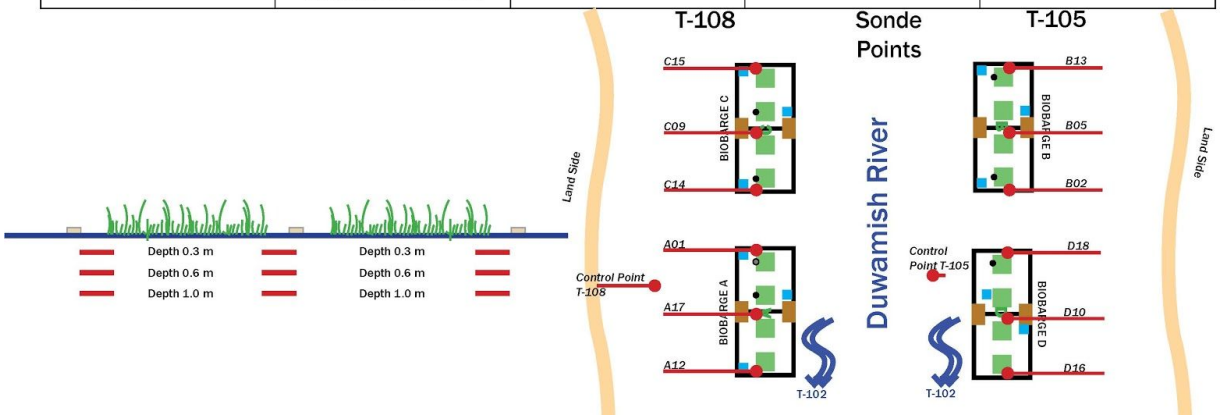


FIGURE. 20 YSI datasonde summary with measurement comparison point diagrams

The puck analysis involved evaluating constituent concentrations in the planting medium before and after deployment of the biobarges. The results indicated relatively greater uptake (average percent increase over control) of certain metals than others. The metals initially identified by USGS that were tested include arsenic (As), barium (Ba), chromium (Cr), copper (Cu), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), and zinc (Zn) (Conn et al., 2018). The pucks showed accumulation of Cu, Mn, Ni, Pb, and Zn. Additionally, Ba and Si increased and decreased depending on the material tested. Metals

including B, Ca, Fe, K, Mg, Na, P, and S showed an uptake increase in the pucks. For other metals tested, in general (but not always) the pucks exhibited greater uptake in the willow and wood chip layers than in the other layers. The willow is known to be a good phytoremediation species for metals. The plant and mycoboard layers showed some increase in metal intake, but not as high as the wood-based layers. See the metals table in Appendix C for more detailed results and percent increases. Further investigation to where the increase in additional metals occurs and where the carbon releases is needed to understand the positive or negative effects of the carbon release. Additionally, baseline USGS metals samples are collected approximately 16 kilometers upstream from the floating wetlands test sites. Metal concentrations in the water at the test sites may be different from the tested location. Carbon concentrations were higher in the controls than in the pucks. Additional research is needed to understand where released carbon is going and what is producing the additional carbon in the control.

Cd, Cu, Pb, and Zn are the tested metals of highest concern to salmon health. Cd was not detected in the USGS testing (Conn et al., 2018) nor in the pucks study. Cu, Pb, and Zn were absorbed by the floating wetlands. Each Wetland Biofilter was estimated to absorb 0.5 g of Cu, 1.3 g of Pb, and 1.1 gram of Zn over the 133 day deployments. (Note – small amounts of Wetland Biofilters were tested, and the inflation factor from the tested sample size to the full BioBarge is significant. Actual metal intake volumes may differ in the larger wetland BioBarge. Additionally, four Wetland Biofilters made up one BioBarge, and there were four BioBarges in the study.)

See Appendix C for additional results charts and diagrams.

4.5. Plant Monitoring

4.5.1. Introduction

As the BioBarges were constructed, extra efforts were taken to consider which plants should be placed in the BioBarges. Chosen species needed to work well in an estuary environment and be able to tolerate fluctuating freshwater and saltwater salinity levels. According to Hutchinson (1988), four species proven to grow in both environments include: *Bolboschoenus maritimus* (BOLMAR - saltmarsh bulrush), *Schoenoplectus acutus* (SCHACU - hardstem bulrush), *Schoenoplectus americanus* (SCHAME - sweetgrass, three square), and *Schoenoplectus tabernaemontani* (SCHTAB - softstem bulrush). Within each BioBarge, there were four Wetland Biofilters planted with these species, with one species planted per Biofilter. Each Biofilter was located within the BioBarge in the same order for consistency in comparison (See Figure 21).

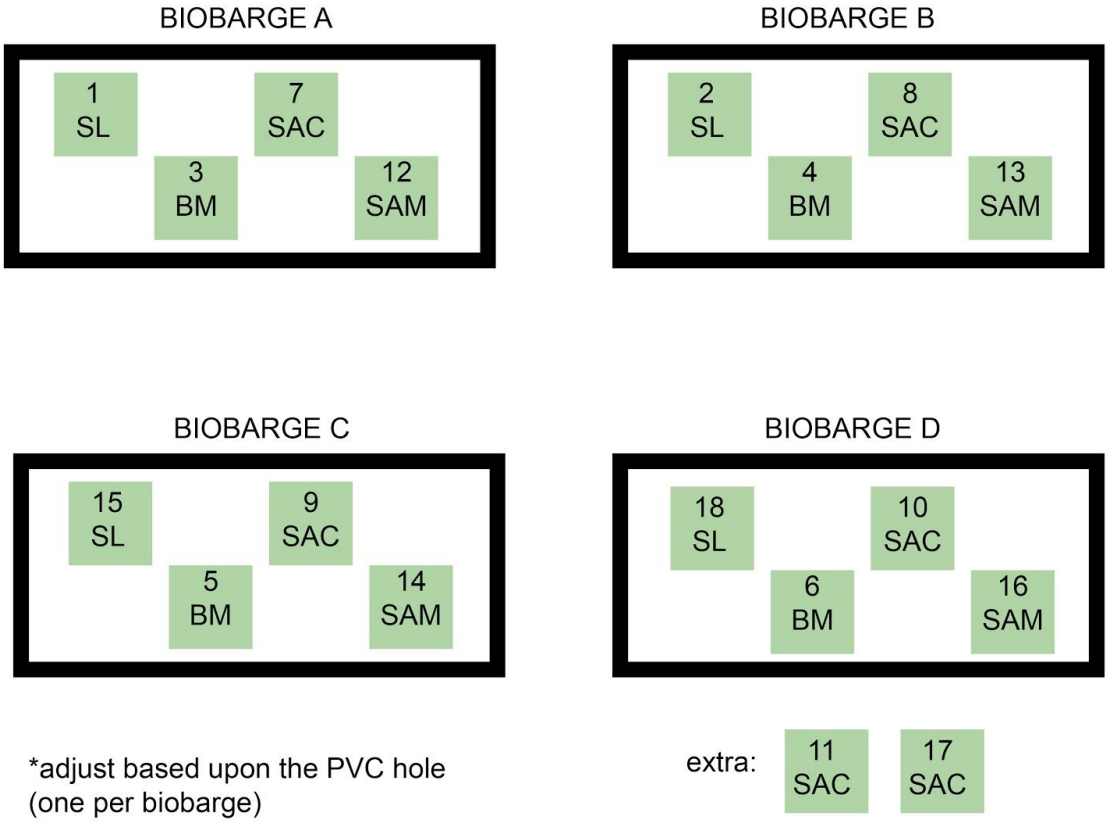


FIGURE 21. Planting scheme (Note SL is the same species as SCHTAB)

The ideal plant temperatures for these species to help maximize their plant health are between 3 degrees Celsius and 31 degrees Celsius. The maximum salinity levels for each plant are as follows: SCHACU at 15 ppt, SCHTAB and BOLMAR at 17 ppt, and SCHAME at 20 ppt (Hutchinson, 1988).

Research Questions for Plant Monitoring

- Are the floating wetland plants healthy and growing as intended?
- How have the species performed in terms of density, visual cover, and plant height?
- How does the plant health change from BioBarge to BioBarge and from one location to another (T-108 to T-105)?

4.5.2. Methods

To address these questions, plants were measured weekly for height, percent visual cover, density measurement, and a flower count in each Wetland Biofilter. The plant height of the tallest stem in each Wetland Biofilter was measured in inches using a tape measure. Percent visual cover was estimated across the full square based on visual comparison to charts (figure 22), then grouped into percentages of 5% (0 to .05), 10% (.06-.10), 25% (.11-.25), 50% (.26-.50), 75% (.51-.75), and 100% (.76-1.00). The Mycoboard substrate has specific holes created as a place to insert each plant plug, allowing researchers to study the number of plants in each Wetland Biofilter. Plant density was measured by counting the number of drilled holes in the Mycoboard with plants growing in them and comparing that to the original number of drilled holes in each substrate. Only living plants were counted for plant density. Lastly, in late May and early June flowers started to form on the rushes, indicating future growth and health of the plant. The number of flowers in each Wetland Biofilter was counted and tracked. In addition to these quantitative methods, pictures of each Wetland Biofilter were taken to visually record plant growth throughout the study.

Data collected weekly from each Wetland Biofilter told us if the plants were healthy and continued to show growth. The plant species can be compared to determine whether or not each species developed well within the floating wetlands. Additionally, the data can be compared between BioBarges to learn if there was a particular location that seemed to do better than others. Lastly, as the data collection unfolded, the plant health was compared to the salinity levels found from the water quality observations that were being reported in the field. Therefore, comparing salinity measurements from water quality helped to determine and predict plant health and understand how growth is connected to salinity.

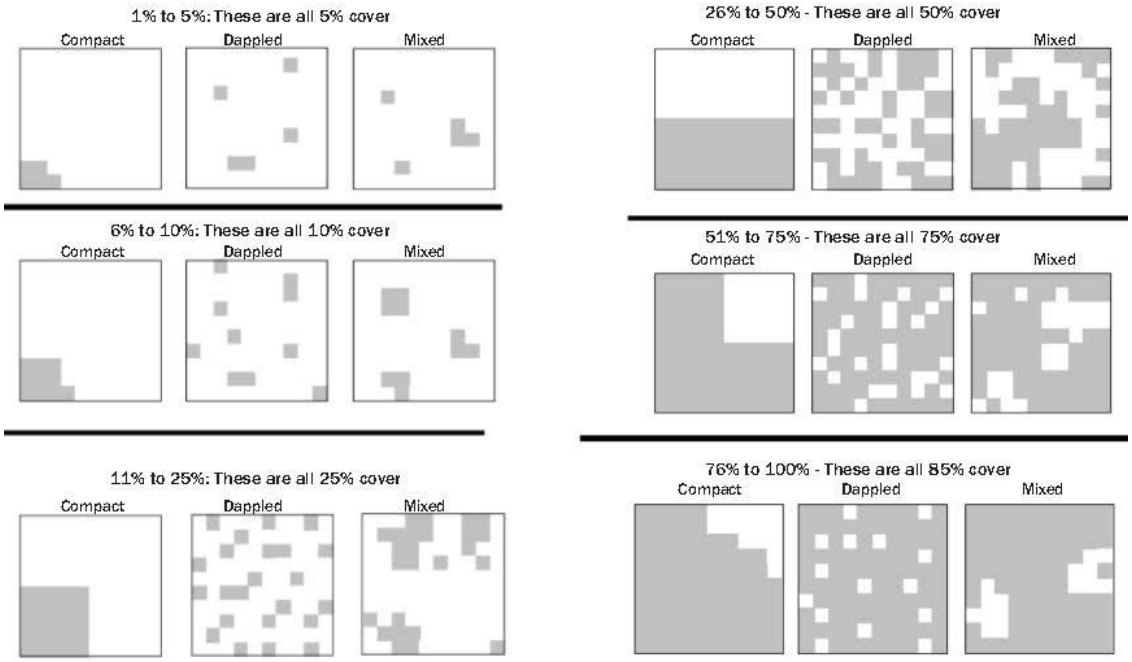


FIGURE 22. In-field percent cover guide.

4.5.3. Findings

Initially, the plants overall showed weekly growth in height and quantity which gave hope to the plant health rising. The freshwater lens is higher in the spring. The saltwater layers of water come from the connection of the Duwamish River and estuary area to Elliot Bay and the Puget Sound. Plant health seemed to plateau or decline as the study progressed, salinity levels increased, and warmer summer temperatures were in full force. Salinity levels naturally increase during summer months due to less freshwater runoff from the snow melt in the mountains. The freshwater lens comes from the mountains and runoff into the Green River, which turns into the Duwamish River. Salinity levels were additionally shown to be dependent on the tide levels and were higher during high tides, as shown in Figure 23. When more salt water comes in from Puget Sound, salinity is increased.

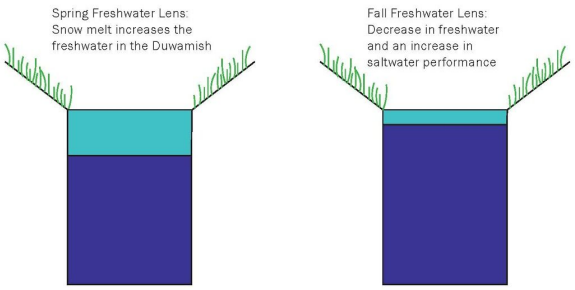


FIGURE 23. Freshwater Lens Diagram

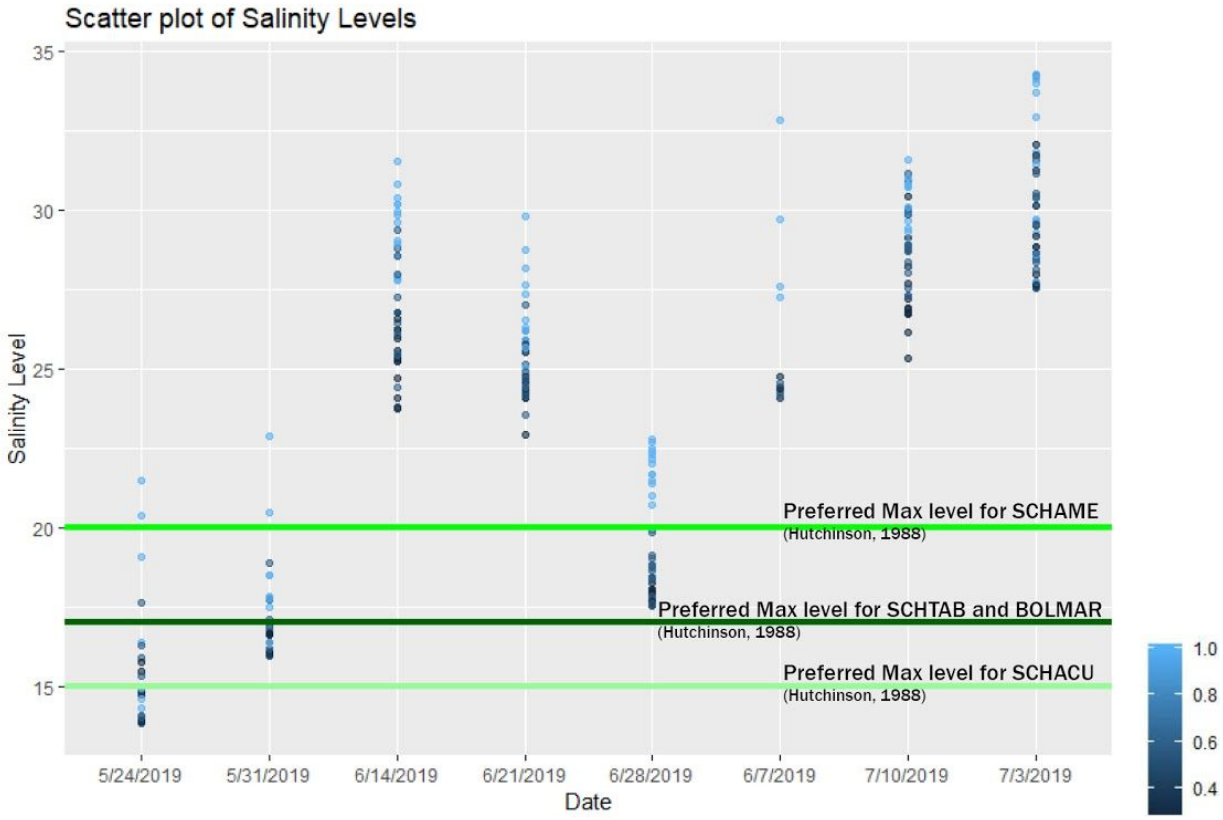


FIGURE 23.Sonde Salinity Levels

In general, plant growth between T-105 and T-108 was similar. As the growing season progressed, the plant density and visual cover initially increased, then plateaued, and finally decreased, shown in figure 24 and 25. In all species except SCHAME, there was a strong decrease in plant density from T-105 compared to T-108. SCHAME saw the opposite effect in that the stronger decline was in T-108 than T-105. There were no differences in salinity levels between T-105 and T-108, the BioBarges and the control, and the middle and ends of the BioBarge. There was, however, a change in depth of the salinity levels. Consistently, as the depth increases in the water, the salinity levels also increase. This ties back to the freshwater lens coming above the saltwater levels from Puget Sound. Salinity levels did not change throughout the comparisons and would not be the reason for change in plant health. The most likely case is as the freshwater lens got smaller, the saltwater lens increased. This showed a greater increase in

a range of salinity levels with the tide changes that creates a harsher environment for the plants. That shows the decrease in plant health towards the end of the research period. Air and water temperature levels were consistently in the desired range for all species and did not seem to be a factor in the plant health.

Each species had slightly different reactions to the biofilters and floating wetlands. BOLMAR was the last plant to begin its growth. There was some concern early on that it wasn't going to take, but the plant took off late and eventually showed the best overall plant health among the four species. They recorded overall positive results with salinity levels with the least amount of die off at the end of the monitoring season. The plant density was consistent across all four BioBarges. Percent visual coverage was stronger in BioBarges D and A than in BioBarges B and C. This indicates that it was not related to the BioBarge location in the differing results. Overall, the plant height reached between 25" - 30" in all the BioBarges, slightly under the national average of 36" – 72" (LBJ Wildflower Center). Additionally, the flower count in the BOLMAR Wetland Biofilters averaged second highest compared to other species.

SCHACU initially had a good take in the plant growth. The species began to reveal the most wear and die out of any of the species. The plant density showed a downward curve across the BioBarges with results on the decline at the end of the monitoring season. The percent visual cover showed inconsistent results to when the peaks occurred. The BioBarges trended around 25% for percent visual cover but spiked to 50% a couple of times. Additionally, the SCHACU Wetland Biofilters had the highest number of flowers on average. The average height of the plants was around 30" tall, which is less than the average 36" – 72" typically seen in this plant (LBJ Wildlife Center). In personal field experience, this species tends to be closer to the 72" height when it is doing well and healthy. The plant never quite took off to those heights but got close to the 36" mark that is on the low side of the average.

SCHAME demonstrated some growth over the monitoring period. The plants never got very tall to look overgrown or full, but the plant density was consistently on the higher end throughout the monitoring period. Plant density also declined on each BioBarge, showing a downward turn in growth at the end of the monitoring period. The plants tended to reach an average height of 20" by the end of the growing period. The average height for these plants is 48" (New Moon Nursery).

Lastly, the SCHTAB showed a lackluster performance overall. There was a consistently poor performance in percent visual coverage – most often at 5% for all the BioBarges. The plant density of each BioBarge was often between 50 and 100%. Despite there being a live plant in the plug holes, the plants did not take off and grow well, which is why the percent visual cover is lower. There was only one BioBarge that showed the SCHTAB above 20". The average height for this plant is 36" – 72" (LBJ Wildlife Center). There was a rare plant that reached the heights average shown, but most plants stayed low. Again, this is seen in the low percent visual cover numbers.

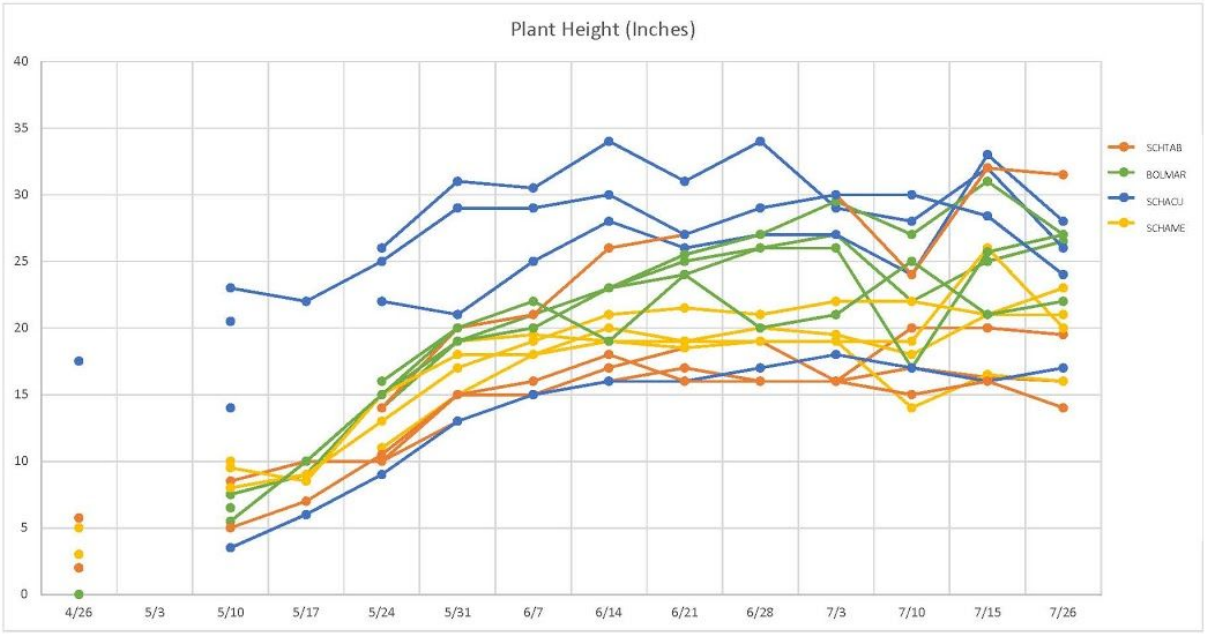


FIGURE 24. Comparison between species plant height

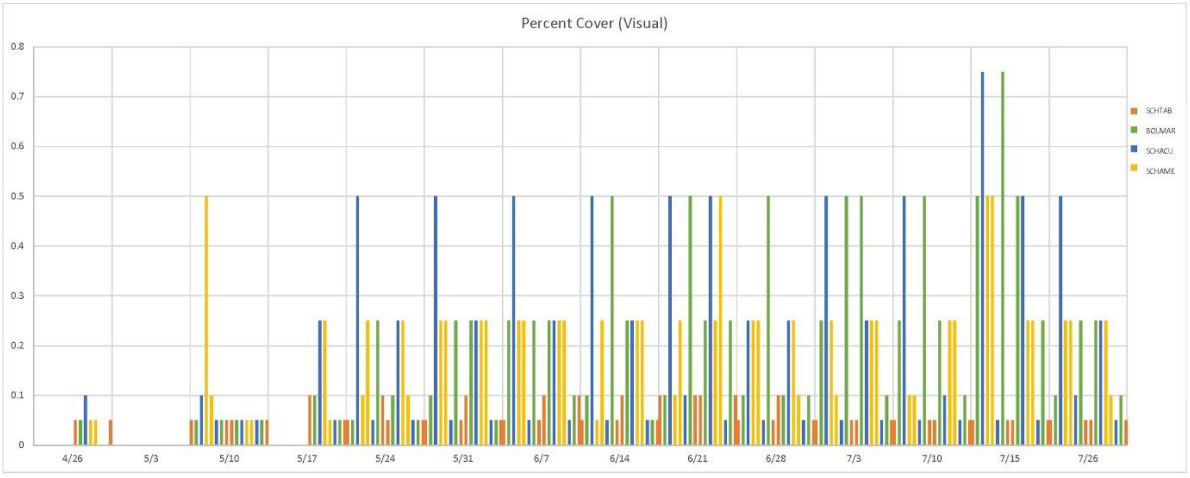
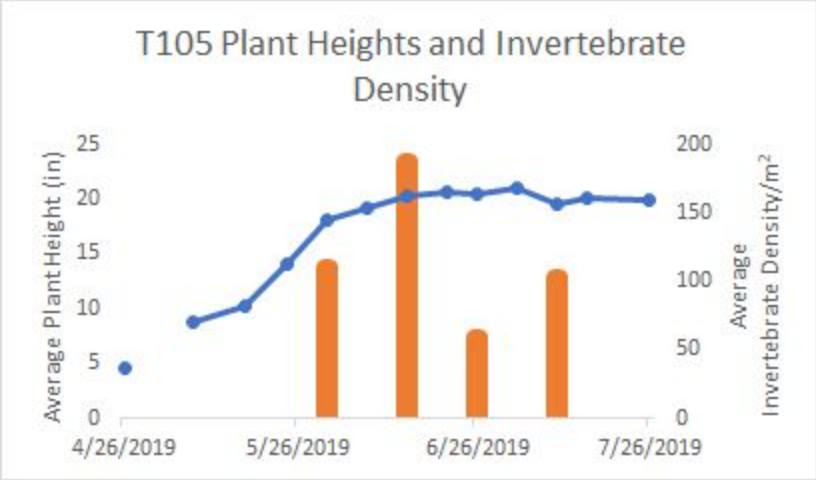


FIGURE 25. Comparison between plant species percent visual cover

See the charts and image growth of each Wetland Biofilter in Appendix D

In addition to assessing plant growth, we examined any high-level relationships between plant growth and invertebrate density. Figure 26 shows the average plant growth at T-105 and T-108, and average invertebrate density per square meter at the barges. With the exception of a high initial density of invertebrates, invertebrate densities at T-108 increase as average plant height increases. The relationship at T-105 is more variable. This comparison is very rough, averaging plant heights across species may not be representative.



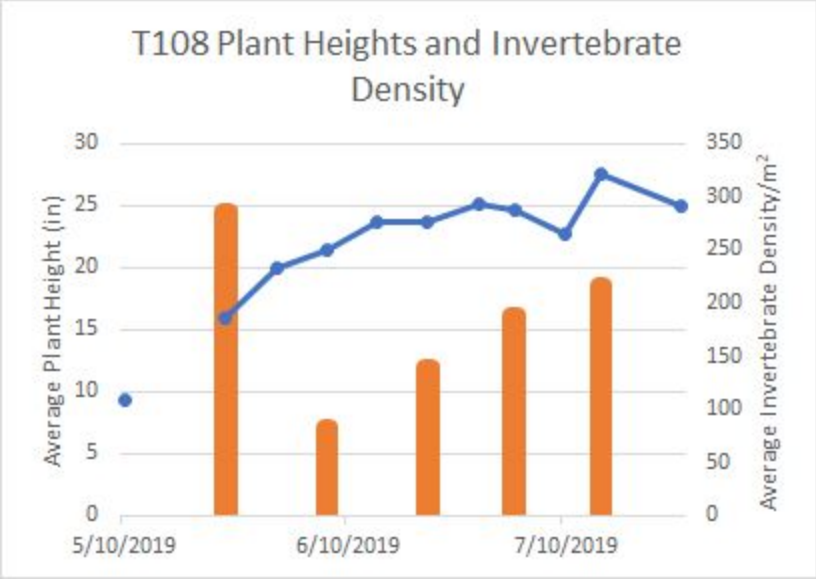


FIGURE 26. Plant heights compared to invertebrate density at T-105 (top) and T-108 (bottom)

5. Design and Monitoring Recommendations

Table 15 below provides a summary of the recommendations for each component of the floating wetlands monitoring program. The following sections provide more detail on each recommendation. Some crosscutting recommendations (e.g., location of study sites) are relevant to more than one area.

Table 15. Overview of Design and Monitoring Recommendations

Design and Construction	● **BioBarge location and anchoring:** Improve stability of the BioBarges ● **Puck design:** Use stronger materials to construct pucks ● **Biofilter design for monitoring:** Ensure that design allows for monitoring within biofilters

	● **Substrate monitoring:** Improve substrate monitoring approach
Fish Use and Response	● **Timing of monitoring:** Align timing of monitoring with peak fish migration ● **Data collection:** Consider changes to data collection methodology ● **Design and placement for fish:** Consider design modifications to allow for easier access by fish ● **Location of study sites:** Consider locating barges further upriver and consider different comparison (e.g., bulkhead with FWL versus bulkhead without FWL) to learn more about potential fish use of FWLs
Invertebrate Production	● **Location of study sites:** Identify appropriate reference sites (e.g., bulkheads with/without FWL, see above) to better understand invertebrate production of FWLs compared to unvegetated shore ● **Fallout trap methodology:** Refine trap placement methods ● **Sampling frequency and processing:** Reduce the frequency of sampling and prioritize sample count consistency
Water Quality	● **Location of study sites:** Strong marine influence in the lower estuary, monitoring further upstream could be informative ● **Designing and measuring shade/light:** Change floating wetland design to create more dappled light and determine method for monitoring light below the biofilters ● **Site comparison**: More differentiation between study sites could help understand if floating wetlands affect water quality under some conditions ● **Puck design and analysis:** Improve construction of pucks and consider comparing puck analysis with water grab samples ● **Measuring river flow:** Discontinue monitoring with stream flow meter and consider other approach if information on water movement is relevant
Plant Growth	● **Salinity considerations**: Ensure salinity levels are appropriate for wetland plant growth ● **Monitoring methods:** Reduce opportunities for observation error due to different interpretations of plant cover/density measurement ● **Root depth:** Ensure that biofilter design allows for root penetration and develop approach for assessing root growth ● **Species selection**. Plant the biofilters with most successful species (e.g., BOLMAR and SCHACU) ● **Location of study sites**: Consider locating project further upriver in a lower salinity zone

5.1. Reflections and Recommendations on Design and Construction

Finding locations that have less wave action or are more protected would be helpful in having the Wetland Biofilters stay together, not flip, and be easier to walk on and monitor. Additionally, T-108 had

some connection to the piling for support, but had one corner anchored with a free-standing anchor. This allowed for a lot more free movement of the BioBarges and less stability of the structures.

In the pucks, using stronger materials (especially stronger gabion on the exterior to hold everything together) and stronger attachments (more than just two carabiners) would be helpful. Creating more of a checkered pattern with the pucks and having pieces that stretch across multiple pucks may help create some stability and create more dappled light for the salmon.

As the Wetland Biofilters were being constructed, a hole and ABS pipe was placed in the center of some of the substrate zones with plans to monitor the water quality in the center of the wetland biofilters. Unfortunately, that hole didn't continue through the biofoam that was added later in the construction process and therefore could not be used for monitoring. Additionally, there was evidence of geese browsing on the plants early on in the monitoring. Goose fencing was placed over each Wetland Biofilter covering each circle that was initially built through the substrate.

As the substrate was being studied, it was often difficult to determine if it was substrate degrading or if the Wetland Biofilter was just under water. Additionally, as different people did the substrate observations each week, there was more room for human error.

5.2. Recommendations and Considerations for Monitoring Fish Use

Timing of monitoring: Due to unanticipated logistical issues and challenges deploying the floating wetlands in the river, we began regular fish monitoring later than would be ideal. Peak Chinook smolt outmigration in the Duwamish/Green River is typically March to May; we started regular monitoring in May and continued throughout the summer. Future studies ideally would begin monitoring in March/April, and consider ending in May/June to better align with peak migration and learn more about the potential for floating wetlands to provide juvenile salmon habitat. An additional reason for the delay in our monitoring season was that interest in aligning fish monitoring with when the wetland plants were growing and potentially providing benefits to salmon. Plants were just beginning to grow in the BioBarges in May, and continued growing throughout June. This mismatch in plant growth and migration timing should be considered for future studies and analyses.

Data collection:

Visual overwater observation is a challenging methodology to accurately identify and quantify fish use of the sites. Future studies should clarify in advance of monitoring how to delineate observations of "barge use" (e.g., one meter from barge) rather than going back through the data to assess this. In addition, it would be helpful to standardize data collection roles (e.g., consistent number of observers and scribes, consistent position on BioBarges, etc.). If possible, any team members involved in fish monitoring should practice together and should frequently discuss implementation of the protocol to ensure consistency.

Formalizing species identification training would be beneficial, so that all team members are looking for the same indicators and making similar decisions. However, there is a difference in memorizing photos of species versus being able to identify them in the water while they are swimming and moving quickly. The team could consider snorkeling sites once per month to confirm species identification and observe

fish use at closer proximity. Snorkeling and/or reviewing Gopro footage earlier in the season to confirm species identification would also be helpful.

Developing and implementing protocols for GoPro monitoring also presented a challenge. Future studies could simplify this component by prioritizing either a timer-based approach (i.e., using blink timers on cameras to record intervals of video throughout a period of time) or continuous recording. Managing both types of recording across many cameras presented a challenge and resulted in some technological failures (e.g., cameras not programmed to record, batteries dying, etc.). The team could consider using a Gopro (e.g., mounted on a pole) to try to record fish sightings, to immediately review and use to ground truth species identifications and counts instead of mounting continuously recording Gopros to the barge during visual overwater observation. Fixed recordings can be helpful for validating overwater observation, but there is always the possibility that observed fish are not in the field of view of a fixed camera. Recorded GoPro footage should be reviewed and species noted and shared with the team bi-weekly, if possible, to assist visual observers with species identification. ROV monitoring and considerations are described in section 4.2.3. above.

Floating wetland design and placement for fish: Early on in the monitoring season, we moved the BioBarges about ten feet closer to shore and decided to monitor only at low tide, noting that juvenile salmon travel along and utilize the shoreline rather than the middle of the channel. We also removed the plastic floats on the upriver and downriver ends of the BioBarge structure, due to the concern that fish would be deterred by this hard edge, which has been observed at piers and docks. These modifications and others should be considered for future studies. Major trash accumulation within the BioBarges was not observed, despite removing the up and down river floats. Floating wetlands are constructed to balance several intended functions (e.g., provide fish habitat, provide plant substrate, allow for monitoring) and must be durable to withstand wakes and current.

Future studies could consider redesigning elements of the floating wetlands to create more optimal conditions for fish habitat. A key feature of other shoreline restoration projects is creation of shallow-water habitat (e.g., habitat benches at the Seattle seawall). Future studies could consider a tiered wetland structure (e.g., a shelf beneath the emergent layer) that would create shallow habitat and potentially allow for easier monitoring. One of the underlying hypotheses of this study was that the roots of floating wetland plants would grow down into the water beyond the bottom of the cages and that fish could access these spaces for shelter. We did not observe root growth beneath the cages.

In addition, fish needed to actively swim under a physical barrier attached to the barge frame in order to access the biofilters themselves. The team could consider a new design, where the Wetland Biofilters are attached on the outside of the frame/flotation structure, so that fish traveling downriver first encounter the BioFilter rather than the frame. This access to Biofilters should be a key consideration for design changes, and durability and stability of the Biofilters should also be taken into account.

Study sites and BioBarge location: One potential application of this study is to understand if floating wetlands could be used as a restoration strategy in areas where shorelines are heavily armored (e.g., bulkheads) and infrastructure cannot be removed and replaced with soft shoreline. To further examine this question, the team could install redesigned floating wetlands on bulkheads further upriver in the transition zone (e.g. River Mile 3-5) in more brackish sections of the river, and compare fish use of

vertical bulkheads with attached wetlands to adjacent bulkhead sections without any built/attached wetlands. Juvenile salmon likely spend more time feeding further upriver of where the study sites were located in 2019, which could have contributed to the low number of salmon utilizing the BioBarges. Visibility was often a challenge; muddy and wave exposed shorelines are very turbid, and some sections of the river are more shaded than others. These factors can affect visibility and feasibility of observing fish. Potential future site locations should be assessed for visibility by visiting the site in advance, ideally on a cloudy day, and assessing conditions visually and with a secchi disc (note that secchi discs may be visible at much greater depths than fish).

5.3. Recommendations and Considerations for Invertebrate Monitoring

Study design: A long-term question that further study may aim to address is the potential viability of using floating wetlands as a restoration strategy to add habitat in reaches of the Duwamish where shoreline restoration projects may be less feasible. To address this question, invertebrate sampling could include shoreline reference sites with less overhead vegetation, such as bulkheads, to assess invertebrate production at floating wetlands compared to unvegetated armored shorelines.

Fallout trap methodology: Placing the fallout traps above the high tide line on riprap walls presented some challenges, and samples were frequently lost due to tipping over. Other studies (e.g., Cordell et al. 1998) have used fallout traps that can rise and fall with the tide; this could be a potential solution to this issue, though this would add a level of complexity that may not be worthwhile. In addition, there may have been some instances of barge fallout traps being swamped by waves; marine species were identified in at least two barge samples. We did one trial day to try to assess if water in the fallout traps would be displaced by wave action moving the barges, but future studies could investigate this further by conducting more tests and attaching the bins higher on the cages. Additionally, sample jars were not always clearly labelled (1-5) in the field. This caused some complexity during analysis because sample numbers recorded on data sheets were not always consistent between team members.

Sampling frequency and processing: Weekly sampling was challenging to manage from a logistical standpoint; future studies could sample fewer days (e.g., 3 days per site, which could correspond to once per month during peak migration). This would allow the team to focus on getting a consistent number of samples (e.g., 5) for sample days representing the beginning, middle, and end of the spring/summer monitoring season. The sampling could either be timed to peak juvenile Chinook outmigration (March, April, May), or during plant growth (May, June, July); the mismatch in plant growth and salmon migration timing is discussed elsewhere and could merit further thought in designing invertebrate sampling protocols. In addition, it was determined towards the end of the season that the team should sample marine amphipods that were visible on the barge substrate. Substrate was scooped into jars and preserved, and substrate was also sampled from the pucks. Prior to analysis, the puck substrate was observed to contain many marine amphipods and a few large isopods. Substrate from the biobarges could be sampled for invertebrates at the beginning and end of the season.

Identifying samples to the family level and counting individuals in each sample takes considerable time (up to two hours per sample for beginners), so sampling more strategically could be advantageous, and samples could be more efficiently processed by more experienced entomologists.

Sample analysis: No statistical analysis was conducted on the results presented in the current report. In the future, conducting some basic statistical tests could allow for a more meaningful comparison between sites.

5.4. Water Quality Reflections and Recommendations

Location. The amount of correlation between the tide levels and the sonde water quality parameters (salinity, dissolved oxygen, chlorophyll, temperature, and turbidity) was a surprise. With a much stronger connection to the Sound than to the Duwamish River, the results showed sonde readings closer to what would be seen in the saltwater than in a freshwater environment. Trying another location upstream may be beneficial to determine if the water quality conditions would change.

Designing and Measuring the Floating Wetlands for Light. Compared to what juvenile salmon prefer, the high luminosity levels were a surprise. Finding ways to create more dappled light for the salmon on the edges is needed to support the salmon to linger around the Wetland Biofilters and not just pass by. The results showed high light levels surrounding the BioBarge, but little salmon use of the BioBarges. Measuring specific shade amounts produced by the edges of the BioBarge would be beneficial to determine if that is a limitation to the salmon. Additionally, finding a way to better measure light levels underneath the Wetland Biofilters is important. In future years, more research with better comparison numbers is needed to determine how much more light is needed at the edges to reduce the shade line.

Comparison Water Quality Levels. In reviewing the comparison numbers, many sources were related to freshwater salmon. With being in the estuary, the transition from freshwater to saltwater, the numbers could relate to the environments the salmon are coming from. Based on the research in the field and the strong influence of the Puget Sound conditions, further research in comparable values for saltwater conditions of chlorophyll, turbidity, dissolved oxygen, and temperature is needed.

Site Selection. Because there was no difference between the T-105 and T-108 location for most water quality elements, more significant differentiation between the two locations would be helpful in future studies. Additionally, there were no differences seen between the control and the BioBarges, beyond luminosity readings. The microhabitat created by the wetlands was not found to change the water quality levels or create habitats that were lethal to the fish. The same was true for the difference in numbers between the middle and edge of the BioBarges. They were not showing a difference that would be harmful to the salmon.

Puck Design. The puck analysis was a constraint in having limited pucks to choose from due to the natural deconstruction of the pucks in the water. Pucks were much more likely to tip in the water, lose substrate, and not contain growing plant material. Only three and a half pucks out of twelve had living material within them by the end of the monitoring period. Could the pucks be redesigned to have a stronger gabion metal around them to encourage a stronger outside mold to hold everything together? Additionally, finding ways to better secure the pucks and make them a part of a larger design could help stabilize the pucks and be useful for a longer monitoring period. The pucks should also be added to the plant condition calculations to understand how they are growing in comparison to the Wetland Biofilters and how much of a duplication they are showing (see Section 4.5 Plant Monitoring). The pucks should also be planted consistently as the planting phase of the pucks was not systematic this first year. Having

one species in each puck would help mimic the biofilters better and help with the analysis phase to make sure the species can be understood when doing a metals comparison.

Puck Analysis. Further research on where the metals found in the pucks are coming from could be done by comparing the pucks to a grab sample of water at that location. This minimizes the changes from upstream conditions to your site conditions. Additional considerations about carbon testing and understanding of where the carbon is going should be integrated into future research designs. Monitoring of specific conductance could be measured on the wetlands through a conductivity sensor to gain direct understanding of tide levels at the floating wetlands.

Flow Meter. Finally, we had initially intended to measure the current speed within and outside the BioBarge structures to assess any calming or slowing effect of the BioBarges. While we were able to visually observe that the BioBarges dampened waves and in some cases slowed water, we could not measure this using a flowmeter, possibly because we were often monitoring near slack tide. The flow meter read near zero at several depths, locations, and on several days. To our knowledge, the flowmeter is designed for in stream use, where the bottom of the pole can rest on the bottom and the propeller is positioned mid-water column against the direction of a consistent flow that is more characteristic of a river. If the current speed is a priority for future study, the team could look into other equipment designed for deep, tidally-influenced systems.

Additional Equipment and Methods. Pucks were used to test how the floating wetlands were helping to remove toxins such as PCBs, cPAHs, and heavy metals from the Duwamish River. Testing for intake of PCBs or cPAHs could provide additional reasons that the floating wetlands are beneficial. Streamlining the number of sonde collection points could improve time management and data collection. Based on this year's results, if sonde measurements were taken in the middle of the BioBarge, beneath the BioBarge, and at a control site, you should be able to still see changes if microhabitats are being created. A conductivity sensor was recommended for future research to provide continuous measurement instead of limited sonde point readings. Lastly, starting the monitoring time earlier could enhance our understanding of the conditions for early season out-migrating salmon. Weekly monitoring of water quality was useful for understanding changes across the season.

5.5. Reflections and Recommendations for Plant Monitoring

Salinity Considerations. Overall, the plants started well and then we saw a decrease in the plant growth. It is speculated that the continuous change in salinity levels through the monitoring period might have caused the downturn in plant health that was seen at the end of the monitoring period. The plants are known to have grown in both freshwater and saltwater zones, but the high fluctuation in conditions found in the floating wetlands is a different experience for the plants. The Duwamish River has some of these same plants along the edges in restored zones. While the restored stationary shorelines see modest change in the tide and salinity levels, they are less exposed due to being out of the water zone at low tide. Floating wetlands function differently since they are constantly in the water.

Monitoring Methods. When comparing results from week to week, it should be noted that the consistency in visual coverage and plant density was tougher to achieve. Despite having visual guides for percent cover to maintain consistency over time, how people interpreted the weekly data varied,

especially when different people did the monitoring each week. The plant density counting was difficult to keep track of what had already been counted. Additionally, the SCHACU species was hard to see the original plant plugs to know how many plugs didn't have live plants in them. In both of these monitoring areas, there was room for human error and inconsistency.

Root Depth. Root depth had been an original goal for measurement to determine plant growth. The initial method for studying root depth using a remotely operated vehicle (ROV) from the Port of Seattle was not possible due to repairs of the equipment. As a result, the root depth was initially examined under the Wetland Biofilters using a GoPro camera, but no roots were visible. At the end of the monitoring season, a ROV was used to understand what was happening under the BioBarges and roots were still not visible. The biofouling at the bottom of the BioBarge was also more prominent and made deciphering roots from algae build up challenging. Furthermore, in the construction of the Wetland Biofilters, the biofoam had a layer without any breaks to allow the roots to grow through the layer. One unexpected way the root growth was visible was in the pucks, smaller Wetland Biofilters that were used for water quality and invertebrate testing. In deconstructing the pucks for the water quality testing, root growth was seen in some plants and continued through the wood chip layer of the pucks. There were two pucks that had roots deeply connected and entwined to the wood chips to create a hold on the material. Other pucks showed very linear roots that didn't attach as much. The pucks did not show the roots going below the woodchip layer.

Species Selection. The BOLMAR species surprisingly worked out well. The species was very late to come out of dormancy. In initial construction, it was questioned whether the entire Wetland Biofilter needed replanting. It turned out that the species was just a late blooming plant. If there is an opportunity to replant the Wetland Biofilters, BOLMAR and SCHACU are both suitable options for further study. SCHAME had more mixed results, and SCHTAB had low plant health results. Consider replacing the SCHAME and the SCHTAB with other species with different rushes, sedges, or forbs.

Location. For future research, it may be recommended to try conditions that are further upstream and have lower salinity levels. Additionally, it may be beneficial to have the two locations (e.g. T-105 and T-108) in locations that are further apart to determine if there is a difference between the BioBarge results. T-105 and T-108 were fairly close together and resulted in very similar results of salinity to determine if that was a factor in plant growth. Lastly, if there is an opportunity to replant the Wetland Biofilters, BOLMAR and SCHACU are both suitable options for further study. SCHAME had more mixed results, and SCHTAB had low plant health results. Consider replacing the SCHAME and the SCHTAB with other species with different rushes, sedges, or forbs.

6. Community Science and Outreach

6.1. Summary of the Community Science Program

The main role of the community science lead was to foster movement, motivation, and alignment of project agenda and community scientist interest. The community science branch of the Duwamish Floating Wetland Project brought together ecological design, scientific research, and community participants including the Rose Foundation, the Port of Seattle, King County, Duwamish River Cleanup Coalition, UW Doris Duke Conservation Scholars Program, Pacific Science Center, University of Washington undergraduate interns, and a collective of community scientists from across the Puget Sound Region.

FIGURE 27. Photos by Floating Wetland Team Left: Doris Duke Conservation Scholars (DDCSP) and project team, Right: Observations of fish from armored shoreline

Fostering pathways for community-led science, community participants helped evaluate how floating wetlands may affect localized water quality and provide habitat for salmon smolts in the Puget Sound, while inspiring community stewardship and education. With support from the team, the Community Science Lead crafted research specific participatory positions for interested community members and University of Washington undergraduate capstone students. Before its launch, outreach to organizations working in the Duwamish community was done to ensure the project was working in tandem with efforts already on the ground and help spread the word about opportunities for community science in order to prioritize participation of historically-underrepresented communities in the environmental field. Projects developed by undergraduate capstone students established research questions around scientific aspects of the project as well as investigating what makes for successful advancement of environmental justice in participatory projects.

FIGURE 28. Photos by Floating Wetland Team Left: Public Advisory, common signage along the Duwamish River Right: Land acknowledgement and project description by the floating wetlands project. The signage, written in english, displayed pictures of area specific biodiversity as well as the project description.

Several cross cutting themes emerged from the series of meetings and formed the goals of the community science program.

Goals of the Community Science and Outreach:

- Infuse equity and access at the forefront of the research and monitoring engagement
- Remain mindful of project capacity and realistic commitments
- Record data with intent to be delivered both to trained scientists and to community scientists and the public
- Hold diversity (such as age, gender identity, gender expression, race, ethnicity, physical ability, sexual orientation, income, culture, religion, and education) as the core strength of the community science and outreach

5.1.2 Approach to Participant Engagement

While the protocol for fish monitoring, invertebrate collection, and water quality developed, a variety of steps were established after consideration for important factors the community science design had to take into account. Roles for community scientists were determined based off of what was required for the methods of fish monitoring, water quality, and invertebrate collection. In addition to defining roles on the project, a framework was offered to navigate the role of the community science lead. The framework can be shared in 10 steps which represent critical “must-haves” for engaging community participation on the project.

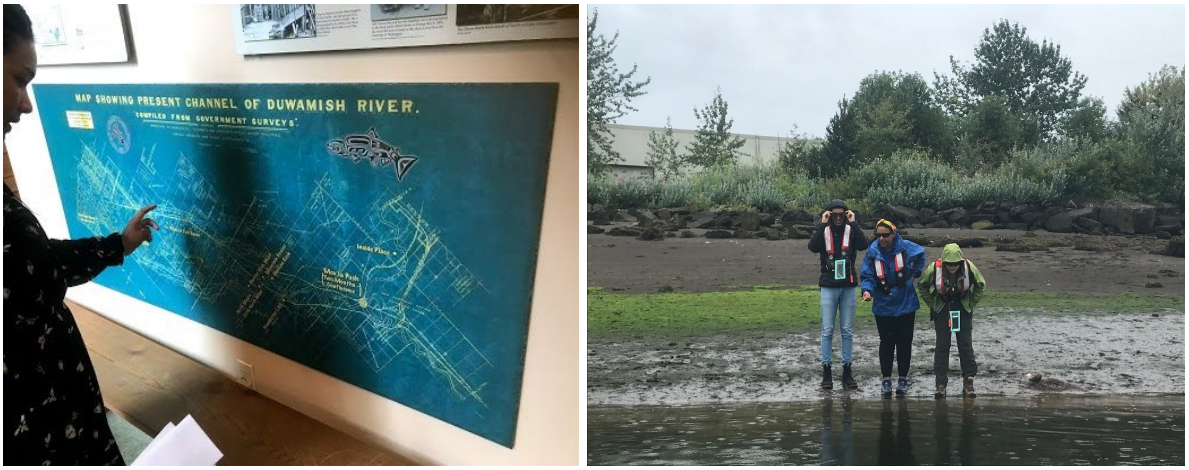


FIGURE 29. Photos by Floating Wetland Team Left: Reviewing a map of the Duwamish River at the Duwamish Longhouse and Cultural Center Right: Fish observations from the shoreline

The following steps represent the necessary actions project leads will need to address in future projects:

- Be present
- Prepare a holistic vision and mission statement for the community science program, including considerations in regard to what will be asked of the participant such as time commitment, accessibility of methods, and determine the "how" in order to accomplish your set goal(s)
- Make no assumptions and always use tools and alternative ways of communicating to accommodate the needs and comfort styles of others.
- Share this vision with individuals who live and/or work in the surrounding project area, refine to remain accountable to the suggestion(s) offered, questions asked, or address gasps in project details in a meaningful way. In this way, the vision should be reflective of community values.
- Design an accessible word document which illustrates the entire ask of the call to participate on the project for Facebook, Instagram, and email channels as a means to market the opportunity.
- Establish a platform to collect names, email or phone, and brief explanation of interest for the project. The form should be welcoming and paired with the various marketing tools to act as a sign up sheet which the community science lead and team can refer to at any time.
- Strategically distribute materials with project capacity in mind, plan to follow up by phone or in person in order for individuals to get a sense of who they are working with and directly explain what participation on the project would ask of the individuals (comfort around water, safety concerns, monthly time commitment, and other important information).
- Respond to interest after a fixed internal team schedule is established. If an individual cannot participate physically, sharing project information is always an option.
- Establish a scheduling platform for days the project team plans to visit the site then schedule community scientist accordingly. Be sure to offer an alternative method of participation if community scientist is unavailable.
- Once scheduled, follow up with the individual with a friendly confirmation message that includes the phone numbers of everyone arriving that day, directions by preferred means of travel, and paperwork (this should include a liability wavier and form for compensation).

- In the field, you will want to make sure the individual signs the paperwork and also receives a copy of the forms for personal records.
- Have a great time in the field! Make sure an acknowledgement for place, recognition of environmental injustices and the advancement of environmental justice occurs before starting the day -- brief overview of the Duwamish geography can go a long way.

5.1.3 Results of the Approach

A total of 37 individuals responded to the call to sign up to participate in the project between April and July 2019. Of the 37 individuals who responded, 13 individuals participated directly in monitoring, research, and outreach efforts of the project. The ages of community science participants ranged from 12 to 75 years of age. Community scientists represented environmental justice advocates, educators, environmental group board members, undergraduate scholars, dedicated community volunteers, community leaders, individuals in-between employment, and graduate students.

FIGURE 30. Photos by Floating Wetland Team: Invertebrate collection with Community Science Lead and DDCSP Scholars Right: Amy, Port of Seattle Intern, read water quality measurements with a community scientist

Community scientists received compensation, $70 a day, for their four hour commitment, one day a week to participate in the project. Two community scientists joined the research team in the boat monitoring for almost every day during the monitoring season with the field team. On average, each community scientist participated twice on the project for a total of 8 hours.

The following channels represent the various opportunities to participate on the project or share out project information:

1. **Field Research and Analysis:** With a project team lead, community participants joined efforts to a) record fish observations and behavior from shore and the barges, take water quality

measurements from the barge, set and collect invertebrate traps and b) make environmental observations from land.

2. **Outreach and Education:** Efforts to engage a broader audience on the projected included events such as a) distributing signage in site areas as an invitation for environmental observations from land, the b) community science kick off training event, organized c) boat tour of for visiting scholars, and d) environmental education with youth groups from the Pacific Science Center.
3. **Presentations and Community Events:** The project was presented at the a) Duwamish River Festival, August 17th 2019, hosted by the Duwamish River Cleanup Coalition (DRCC); b) Salish Sea Environmental Justice Panel on November 15, 2019; c) Sustainability in Prisons Project at Washington Corrections Center for Women in Gig Harbor on July 8, 2018; and d) UW Floating Wetlands Seminar Spring quarter 2018
4. **Independent Projects for Early Careers:** Two Program on the Environment Capstone students went through a short hiring process and then interned on the project for the summer quarter.

After a short survey was sent out after the field season, one community scientist commented, saying "I think this is such a worthwhile project, I loved the flexibility of it so participation could be adjusted to the volunteer's availability."

FIGURE 31. Photos by Floating Wetland Team Left: Demonstrating of pilot flow meter testing Right: Demonstrating of environmental observations from land at Terminal 105 Park, 98106

Field Research Season

A. The majority of community scientists participated on all aspects of the scientific monitoring after completing their 8 hours of participation. In this way, even if an individual indicated that they were interested in water quality monitoring, that individual most likely was also open to making fish observations as well.

B. While interest was high, factors such as boat size, research protocol, and staff capacity influenced how many community scientists secured a role in the project. Due to the nature of the BioBarge interaction on open water, opportunities for community science participation occurred both on the Duwamish River and on land at various locations such as Terminal 105 Park. In this way, the project worked to be more inclusive in its outlets for access to the project in the face of transportation, administrative, staff, and time constraints. The methods to participate from land failed due to vandalism of signage and field note recording box.

Outreach and Engagement

Several opportunities allowed project participants to dive deeper into the landscape of the Duwamish Valley at the intersection of current public affairs. These singular events are important for individuals who may have high interest in the project, yet are limited in the amount of time that they can spend participating during the weekday with the field crew.

A. Each project site on the river was located near a Port of Seattle established park. In this way, a postage box was put out at each site and was filled with environmental observation sheets. In this way, any individual in the park could read the sign and then feel compelled to fill out a form which the project team would collect later.

B. In hopes of exposing the viewing access points to the BioBarges, a "community science kick off training" was held to gather additional community scientists who would be interested in checking on the bio barges from land. This event was created to allow participants to observe the BioBarges from land, make environmental observations through drawing, description and other forms of naturalist notes, and to ask the field team questions about the pilot project.

C. Later on in the season, the floating wetlands project team facilitated the boat tour to community scientists and the Doris Duke Conservation Scholars Program (DDCSP). Leadership of the Duwamish River Cleanup Coalition was invited to give a boat tour of the Duwamish River to further understand the large scale clean-up process and restoration efforts. In addition, this leadership was brought in to acknowledge the natural relationship of the Duwamish River to the long standing Duwamish people, Georgetown and South Park neighborhoods. Because DDCSP's summer course curriculum closely aligned with the work of the project, scholars had the opportunity to be completely immersed in practicum.

D. The Pacific Science Center at Mercer Slough summer camps reached out earlier in the field season in hopes to bring youth on as community scientists, yet project capacity and accessibility did not allow for multiple youth participation on an official project monitoring day. Therefore, towards the end of the season, the project team facilitated a "Build your Own Floating Wetland" activity day for two Pacific Science summer camps for students living in King County. The activity days took place at T-105 Park, students also had the chance to observe fish and use project technology from the research dock. After a feedback survey sent to this group, one summer camp student wrote:

"I also gained more insight into the role of environmental re-engineering, especially with the BioBarges, on the last day. I learned that sometimes, in order to restore the damage people do to the environment, people need to intervene to accelerate how quickly it can recover. And because nature can't accelerate its own recovery, scientists have an important responsibility in finding ways to make that happen. This encouraged me more to pursue a career in an environmental, and less technical, science."

FIGURE 32. Photos by Floating Wetland Team Left: Demonstrating of invertebrates collection with Pacfic Science Center camp and Siyao, Career Career capstone research assistant Right: Build your own BioBarge agenda activity.

Participation in Community Events

A. Showing up in the community for moments to educate the public on innovative use of green infrastructure was an additional project priority.
B. The project facilitated a table at the Duwamish River Festival, about 190 individuals participated in the event, representing a cross cultural body of people. The Festival is organized by the Duwamish River Cleanup Coalition, which represents community, neighborhood, environmental, tribal, and small business organizations that came together to serve as EPA's Community Advisory Group for the Duwamish River Superfund Site. The floating wetlands project table was joined by a wide range of organizations in the Greater Seattle Area such as the Puget Soundkeeper Alliance, Department of Ecology, Front and Centered, Social Justice Fund, ECOSS, and the Seattle Aquarium. The project team brought examples of floating wetland prototypes, native bulrush plants, an invertebrate collection, and additional handouts and project information for an interactive, educational experience.
C. Accepted proposal to speak and share a personal reflection on decision making and designing of equitable processes for participatory science project at the Salish Sea Equity and Justice Symposium --- Sustainability in Prisons Project at Washington Corrections Center for Women in Gig Harbor on July 8, 2018---UW Floating Wetlands Seminar Spring quarter 2018

Independent Projects for Early Careers

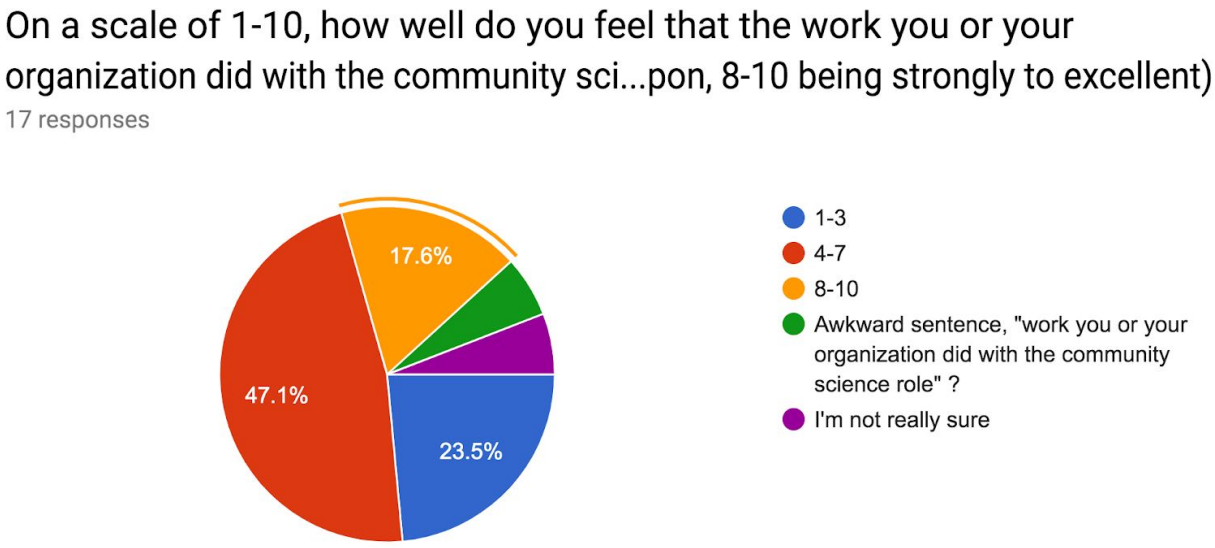
The Program on the Environment requires graduating students to participate in a quarter long internship and through the internship, develop a research project using a mix of qualitative and quantitative methods. The project was delighted to host 2 capstone students who would support field research and developed their own independent projects based on the various aspects of the floating wetlands. The two research questions were developed around the advancement of environmental justice and distribution of collected invertebrates. The outcomes of the independent project on translated facts of the Duwamish River and work with invertebrates was incorporated into the invertebrate data, section 4.2.3, while the results of the survey used to investigate aspects which make for the successful advancement of environmental justice were incorporated into the recommendations section, section 5.2., of the community science chapter of this report.

Example Translation:

- The development of Seattle into a densely populated urban center resulted in the loss of 98% of Duwamish River estuarine wetlands and replaced them with over 2,100 ha of developed shorelines and floodplain.The Duwamish watershed has also been reduced significantly by permanent diversion of two of three major tributaries, resulting in loss of 70–75% of the historic freshwater inflow to the estuary. (Jeffery R. Cordell, Jason Toft 2012)
- 西雅圖的城市化發展導致了杜瓦米什(Duwamish)河98%的河口濕地損失，取而代之的是超過2100公頃的沖擊平原。杜瓦米什流域也被永久性地分化成了兩條主要支流， 導致了70-75%的河口淡水流入損失。(Jeffery R. Cordell, Jason Toft 2012)

Example Survey Question:

The survey asked the question “On a scale of 1-10, how well do you feel that the work you or your organization did with the community science role helped or helps the advancement of environmental justice? (1-3 being not at all to a small amount, 4-7 being some but not enough to a good amount but could be improved upon, 8-10 being strongly to excellent)” Survey participants responded in the following ways:



Overall, capstone students had access to variable professional development opportunities and have gained unique skills which can be added to their personal resumes.

FIGURE 33. Photos by Floating Wetland Team Left: Demonstrating plant identification, transect count, and growth height.

6.2. Further Discussion for Community Science

Overall, the community science branch of the floating wetlands project was successful in identifying the BioBarge as an access point to the Duwamish River. Participation in the research process of the pilot project made it accessible for individuals to address the environmental issues related to the Duwamish River in a new and creative way. In this way, the floating wetlands project served as a point of

accessibility for individuals in the area to visit the River and potentially increase a personal sense of environmental stewardship and/or share knowledge for conservation and restoration practices.

FIGURE 34. Photos by Floating Wetland Team Left and Right: Demonstrating how to stand on the BioBarge structure. In addition to choosing whether to stand or walk on the structure, an individual could also move around on all fours.

Recommendations for Future Programming:

Short Term Recommendations

- Hire additional support for community science work
- Disseminate information on project design, implementation, teachings, and opportunities through “lunch and learns” or presentations at various community centers
- Keep community science participants up to date on opportunities for professional development such as workshops, or trainings outside of field work
- Ask specifically for photo permissions from community scientist in written from
- Introduce open access data platforms to record naturalist notes and digital photos with a plan to incorporate findings into the research question, analysis and results
- Establish a platform for internal and external scheduling for community participants, project team, and site visits such as google calendar, asana, or Microsoft teams
- Compensation was handed to community scientist participants in cash form, the community science lead went to the ATM for a cash withdrawal each time. If the ATM trips can be reduced, this would be beneficial to the community science lead

Long Term Recommendations

- Involve past and incoming community science participants in the community science design, research question forming, or program implementation
- Community scientists are more like friends than individuals the project can host for one day, in this way the project can build in opportunities for follow up and capacity building for community participant retention and tracking
- Consider power dynamics in the project and when it may or may not be appropriate to engage various groups. For example, future outreach to tribes will need to be carryout in a meaningful way in order to show full honor to individuals under the power structures of the UW and Port.
- The project may consider partnering with an event or other organization that have close relationships with tribal communities
- Invite early career individuals such as UW Capstone students on to the project
- Maintain steady communication stream to community science participants, including project updates, participation sign up, photos or video, and thank you notes
- Remember: projects & people can always do more therefore remain mindful of project resources and partnerships
- Remain mindful or project capacity (how many people can fit on the boat?) and accessibility
- Compensation should factor out, by the hour, to be no lower than minimum wage and no higher than wage of the project. Future community engagement may also consider reimbursement for gas mileage, day-care, and food such as snacks or water.

Even in its limited capacity as a pilot, the project has worked to infuse diversity, equity, and inclusion in all aspects of community science from transportation and accessibility to activities, speakers, and data dissemination. The Duwamish Floating Wetlands pilot project joins the collective efforts in long term river restoration, and also explores techniques for community science for the future advancement of a successful environmental justice movement in a meaningful way.

With research methods tested and established, we hope to continue monitoring and expand our community science involvement for at least another year of deploying floating wetland BioBarges in the limiting habitat conditions of the Duwamish River.

7. Conclusions

This project explored the implementation of floating wetlands in the Duwamish River as an innovative use of green infrastructure in a habitat-limited estuary and as an opportunity to engage community scientists in on-water and shore-based research.

The project team designed, built, and installed four floating wetlands, locating them at two sites in the Duwamish River Estuary near Harbor Island. The team monitored the BioBarge structures and Wetland Biofilters throughout the spring and summer, observing some degradation of substrate layers due to wakes and current. At T-108, the Wetland Biofilters occasionally broke the riggings, indicating a need for stronger reinforcement or a modified design.

Monitoring fish use of the floating wetlands compared to adjacent reference shorelines was one of the core research questions. The team observed only a few instances of schools of outmigrating juvenile

salmon utilizing the floating wetlands. Fish most commonly showed no response to the BioBarges, with fewer schools entering the BioBarge or avoiding the structure entirely. By contrast, the team observed heavy use of the floating wetlands by other species of fish, including perch and three-spine stickleback. Challenges and limitations of fish monitoring are described above, as well as recommendations for future studies. More information would be necessary to understand if floating wetlands provide habitat for outmigrating juvenile salmon. Future studies could examine fish use of floating wetlands along bulkheads or other armored shorelines further up the river.

We sampled terrestrial invertebrates using fallout traps at the floating wetlands and at adjacent vegetated riprap and soft shorelines. We identified chironomids and other dipteran flies at the floating wetlands, which are a known component of juvenile salmon diets in the Duwamish River. In general, invertebrate densities and taxa richness were lower at the barges than at the shoreline sites. This could be related to the relatively low plant densities found at the floating wetlands compared to the shoreline sites, though there was not a clear relationship between plant growth and invertebrate density at the barges over time. Analyzing additional samples and/or conducting statistical analysis of the results could provide more information regarding the differences between invertebrate inputs into the system at each site.

In addition to monitoring fish use and sampling invertebrates, we also measured water quality parameters at the BioBarges and at control sites nearby. At the BioBarges, we observed levels of salinity, dissolved oxygen, and temperature within ranges that are tolerable for salmon. In comparing the conditions at the BioBarges to control points, we did not observe notable differences in water quality. High light levels observed at the BioBarges suggest that future designs could consider creating more dappled light conditions.

Plant growth on the floating wetlands varied by species and over the course of the season. In general, plant heights, density, and visual cover initially increased, then plateaued, and in some cases began to decrease. In general, the cosmopolitan (or alkali or saltmarsh) bulrush had the highest overall plant success among the four species. Results from plant monitoring suggest that the biofilters, as designed, are able to support the growth of native bulrush species. However, high salinity levels and a lack of holes punched through all layers of substrate may have limited plant growth in the floating wetlands compared to average heights of these species growing on land.

With few observations of juvenile salmon utilizing the floating wetlands, it was difficult to assess significant direct contributions of the floating wetlands to salmon habitat in the Duwamish River Estuary, though juvenile salmon were observed within the BioBarges in some instances. Results from year one, proof-of-concept monitoring found that wetlands can support plant growth, and that invertebrates that are important to salmon diets are produced by the floating wetland systems. We did not observe potential negative water quality conditions created by the floating wetlands; no microhabitat signal was detected based on the data collected this year. The sections above provide further detail on limitations and recommendations for further study to better understand these questions.

One interesting finding from this year is the potential role of floating wetlands as novel ecosystems. Novel ecosystems are “a unique assemblage of biota and environmental conditions” that is the result of alteration by humans (Morse et al. 2014). While there were certainly some aspects of a novel system

observed at the floating wetlands, novel ecosystems must also be self-sustaining; here, we are using the term generally to discuss observations. As previously mentioned, brown algae grew on the gabion cages and rigging, and the structure aggregating material included kelp holding fish eggs, which later hatched. We observed otters utilizing the structure, including swimming around it and leaving dead flounder (heads and whole fish) on the bird exclusion netting and on the substrate. Three-spine stickleback and perch (mostly shiner perch, other species possible) appeared to utilize the floating wetland more consistently than the adjacent shoreline at T-105. Spiderwebs formed on the corners of the structures, and the Mycoboard substrate was full of marine amphipods. While we did not directly measure most of these observations, it is important to consider these effects when discussing floating wetlands and designing future studies.

The Duwamish River Floating Wetlands Community Science Program ran in parallel and was inextricably linked to the research and monitoring project. The program lead conducted outreach with organizations in the Duwamish community in order to engage community members and worked to ensure that the project elevated equity and access, shared data, prioritized diversity within the project as a strength, and that commitments were realistic. Community scientists and members of the public contributed directly to the research by joining the research team on the water to collect and record data on most research days. The team undertook additional community engagement through hosting field trips and participating in the Duwamish River Festival, among other activities. Limitations of the pilot year and recommendations for continuing the program are described above. A key takeaway from the Program was that access to the Duwamish River in South Park and Georgetown is limited, and this project provided a unique access opportunity, both physically and through the information shared.

Designing, conducting, and implementing a novel research and community science program for floating wetlands in the Duwamish River involved many challenges and required an iterative process. The research team navigated these challenges and adapted methods, protocols, and approaches in response to the evolving needs of the project. This report documents a proof-of-concept and recommendations that can be built upon for future study.

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APPENDICES

Appendix A. Fish Monitoring

Appendix B. Invertebrate Monitoring

Appendix C -1. Water Quality Monitoring

Appendix C-2. Water Quality - Raw sonde data excel file

Appendix D. Plant Monitoring

Appendix E. Puget Sound Hatchery Release Protocols

Appendix A: Fish Monitoring

This appendix includes sample data sheets, Google sheets database layouts, and monitoring protocols developed for the 2018-2019 monitoring season. The protocol is described in greater detail below. At a high level, the "fish monitoring" steps included the following: 1) 30 minutes of overwater observation by 2 observers stationed one on each barge at the first site (e.g., T-105). Scribe or observer records fish observations on the field data collection sheet. 2) 30 minutes of observation at the shoreline reference site with roughly the same observer configuration. 3) Perform other tasks (e.g., collect invert traps). 4) Conduct barge and shore monitoring at the second site (e.g., T-108). 5) At the end of the day, one person collects field data sheets and later inputs them into a Google sheets database stored in a shared drive.

Example Field Data Collection Sheet

Below is the field data sheet used for recording fish observations during the spring/summer 2019 monitoring season. This sheet should be modified to reflect any revisions to the monitoring protocol and researcher preferences.

Site + Date + Start time + Collection Window					CK, CM, CO, SH		*if multi, make note						
#	observer	**barge ID**	**side of barge (inshore OR offshore)**	time first observed. Linger (mark if Y)	**species**	**initial response to barge**	**location w/in barge frame**	behavior 1 + 2 (circle 1, underline 2)	# fish recorded	**Range**	fish depth	distance (m)	notes
1						No Response Avoid Edge, Enter	under, open area, edge filter, under filter, multi*	swimming, feeding, darting, hiding, resting		1 - 10, 10 - <25 25 - <50, 50 - <75 75 - <100, >100-200			
2						No Response Avoid Edge, Enter	under, open area, edge filter, under filter, multi*	swimming, feeding, darting, hiding, resting		1 - 10, 10 - <25 25 - <50, 50 - <75 75 - <100, >100-200			
3						No Response Avoid Edge, Enter	under, open area, edge filter, under filter, multi*	swimming, feeding, darting, hiding, resting		1 - 10, 10 - <25 25 - <50, 50 - <75 75 - <100, >100-200			
4						No Response Avoid Edge, Enter	under, open area, edge filter, under filter, multi*	swimming, feeding, darting, hiding, resting		1 - 10, 10 - <25 25 - <50, 50 - <75 75 - <100, >100-200			

Example Online Database

Below is an example of the online database used for compiling data from the field data sheets. This format should also be adapted as needed. Header terms included in the sheet are defined below.

T105																								
*see definitions below																								
date	**site**	**location**	**start time**	**observer**	**collection window**	**time first observed**	**linger (Y/N)**	**barge ID (B + D)**	**side of barge**	**initial response**	**location within frame**	**behavior 1**	**behavior 2**	**salmon? 1 = yes, salmon**	**species**	number fish recorded	**<10**	**10 - <25**	**25 - <50**	**50 - <75**	**75 - <100**	**100 - 200**	fish depth	distance (m)	notes
4/25/19	T105	barge		CC	30	NA	0	NA	offshore	edge	NA	swimming	feeding	1	CM	15	0	1	0	0	0	0	NA	NA	4/25/19 first monitoring/scoping visit; swimming
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	darting	NA	1	CM	30	0	0	1	0	0	0	surface	NA	
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	feeding	NA	1	CM	30	0	0	1	0	0	0	NA	NA	
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	swimming	NA	1	CM	50	0	0	1	0	0	0	deeper	NA	going out, 1-2 feet deep
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	swimming	darting	1	CM	80	0	0	0	0	1	0	NA	NA	back and forth
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	swimming	darting	1	CM	90	0	0	0	0	1	0	NA	NA	going back and forth
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	swimming	NA	1	CM	90	0	0	0	0	1	0	NA	NA	going in
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	swimming	NA	1	CM	15	0	1	0	0	0	0	NA	NA	going in
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	swimming	darting	1	CM	30	0	0	1	0	0	0	surface	NA	back and forth
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	NA	NA	1	CM	10	0	1	0	0	0	0	mid	NA	
4/25/19	T105	shore		CC	30	NA	0	NA	NA	NA	NA	NA	NA	1	CM	14	0	1	0	0	0	0	surface	NA	
5/9/19	T105	barge	2:24 PM	NA	15	NA	NA	NA	NA	NA	NA	NA	NA	**none**	**none**	0	0	0	0	0	0	0	NA	NA	None observed at barge

Definitions of Data Sheet Header Terms

Start time: of fish observation

Collection window: amount of time of fish observation, usually 30 minutes

Linger Y/N: Yes if at the location for >1 min

Barge ID, side of barge: Describe location in relation to the barge

Initial response: edge, enter, avoid, no response

Location within frame: record if the school enters

Behavior 1: primary behavior

Behavior 2: secondary behavior

Salmon?: Record a 1 for salmon, 0 for other, None for no fish
Species: Chinook (CK), Chum (CM), Coho (CO), Steelhead (SH), SM (unknown salmon)
Number of fish: Record a count if possible
Ranges: Record a 1 for which range the school fell into, 0 for others
Fish depth: approximate depth of the fish: surface (0-4 in), mid (5-12 in), or deeper (>12 in). This is helpful for species ID because juvenile salmon tend to be surface-oriented
Distance: approximate distance from barge or shore
Notes: Description of fish behavior, etc.

Visual Fish Observation – Monitoring Protocol

Floating Wetlands Fish Research Questions and Methods
Initially drafted April 15, 2019 – Minor updates October 2019

"How might floating wetlands (FWLs) support or influence out-migrating juvenile salmon in the Lower Duwamish River?"
Questions and Methods are separated into a Fish section and an Invertebrates section.

Methods Overview
Visual observations of fish from above the water will be the primary means of data collection. In addition, GoPros will be used to collect information that can be used as a qualitative comparison (described below). The primary method of Visual Overwater Observations is discussed in more detail in relation to specific research questions, below.

Visual Overwater Observation Methods
2 observers, 1 per barge, + 1 scribe. 30 minutes.
Note: There are two Barges in close proximity to one another at each site.

- one observer per Barge => two simultaneous observers at a given site
- each observer sits on the "Viewing Platform" on the edge of Barge, over the middle beam
- observers should face opposite directions from one another - one east, one west, and set up platforms accordingly
- observer may sit directly on the platform (ideally, to be closer to the water), or on a chair, facing inward *(***note that during the 2019 season, observers ended up looking in and around the barge for fish, not just facing inward, and occasionally standing, depending on visibility. This is something that could be standardized going forward.)*
- additionally, one scribe will sit on a third platform on either one of the Barges
- time will first be recorded upon settling on the Barge-- once everyone is settled in place and the water is no longer disturbed by movement
- each time a school of fish is observed, start and end time will be marked
- total observation window is 30 minutes per Barge.

Research question 1: How are juvenile salmon responding to and utilize floating wetlands?

1.1 What is the <u>initial response</u> of a school of fish to the FWL structure?

*A school is defined as a group of fish swimming together: response and behavior are observed on a school by school basis.

Initial response will be categorized as one of the below:

- **No response** = the school is observed up river and does not respond to the FWL as it swims by; it simply continues swimming past the barge
- **Avoid** = swims toward/approaches and then darts away or leaves slowly
    - [record specific behavior] - darts away at shadow, darts away at Barge edge
- **Edge** = the school approaches the FWL and swims along the edge of the structure without engering.
- **Enter** = the school approaches the FWL and enters.

1.2 What is the <u>behavior and location</u> of juvenile fish <u>utilizing*</u> the FWL structure?

*For those fish that Utilize (enter) the Barge frame, what specific behavior(s) do they exhibit:

- Resting
- Feeding
- Darting/avoidance
- Swimming
- Other:_____?

and where:

- Plants, i.e. BioFilters - edges or below
- open area
- both

1.3 How many and what species of fish are observed?

- total number of schools per observation period (30 min. per Barge)
- approximate number of fish per school, i.e. school size
  - # in school: <20 get count (no designation or XXS?), 20 - 50 (XS), 50-75(S), 75-100(M), 100-200(L), >200 (XL) – see data sheet
- species may include: Chum, Chinook, Coho, or others: stickleback, flounder, perch?

Note: As discussed above, response and behavior will be designated **per school of fish** observed. A school will be a unit of analysis, and the size of the school is an additional unit of analysis... e.g., how do behaviors differ amongst schools of the same size?

Research question 2: How does observed juvenile fish response and behavior at FWLs differ from response and behavior at a) armored shorelines and b) soft/vegetated shorelines?

- Repeat observations specified in questions 1.1, 1.2, and 1.3 at shoreline reference site

Control Site Methods:

- Observe a total area equal to that of the two barges (~ 60 feet long, out to ~ 10 feet from waterline at time of observation
- Stand on the shoreline facing the water
- Two observers positioned at same distance from one another as on the Barges
- Scribe stands between the observers

Supplies:

- 1 metal case clipboard for the scribe
- 1 Write in Rain notebook for each observer
- 1 laminated data sheet template for each observer
- 3 waterproof wrist watches
- 3 pairs polarized sunglasses
- 3 lifejackets
- 10 Data Sheets per day - in clipboard case

GoPro Fish Observations – Monitoring Protocol

Drafted April 2019, updated October 2019.

Methods Overview

This is a description of the methodology that was used for observing fish using GoPros. Please note that the methodology evolved over the course of the monitoring season. We started the season with one GoPro and one timer, and eventually added five more cameras and 1 more timer to the protocol. There is a lot of room for improvement in how the GoPros could be utilized to assess fish use and verify overwater observations.

GoPro Methods Phase 1: Interval Recordings at one barge

- **Preparation:** Fully charge GoPro and program the Blink timer in advance of going into the field. We generally programmed the Blink timer to record 1 minute of video, every half an hour, during daylight hours. Note that we started with 20-30 second videos but had battery life to increase to one minute. Using this setup, the GoPro battery would last for at least 1-2 days (~24 min of video). The Blink timer powers on the camera to record and then powers it off, which conserves battery.
- **Supplies:** 1 GoPro, 1 Camdo Blink Timer, 1 GoPro pole (pvc pole with GoPro mount cemented to the end).
- **Recording protocol:** When you arrive at the barge, attach the camera to the end of the GoPro pole. Climb onto the barge platform, sink the pole into the water (making sure to hold on tightly!!!!) until you are able to feed the pole up through the pvc mount on the barge and thread the keeper through the punched hole. Make sure the GoPro is angled so that it is level and angled looking under the biofilter (see Cam 1 in the diagram below).
- **Retrieval protocol:** Go back to the barge ~24 hrs later (or as available) and pick up the camera.
- **Upload protocol:** Remove the SD card from the camera or use the USB port to connect camera to computer and upload the recorded videos to the drive. Into a dated folder. Add the filenames and recording times to the Google sheets database for review. Make sure to check that the camera recording times match the actual recording times. It seems like these are off by 7 hours; couldn't figure out how to correct that.
- **Footage review protocol:** see below.

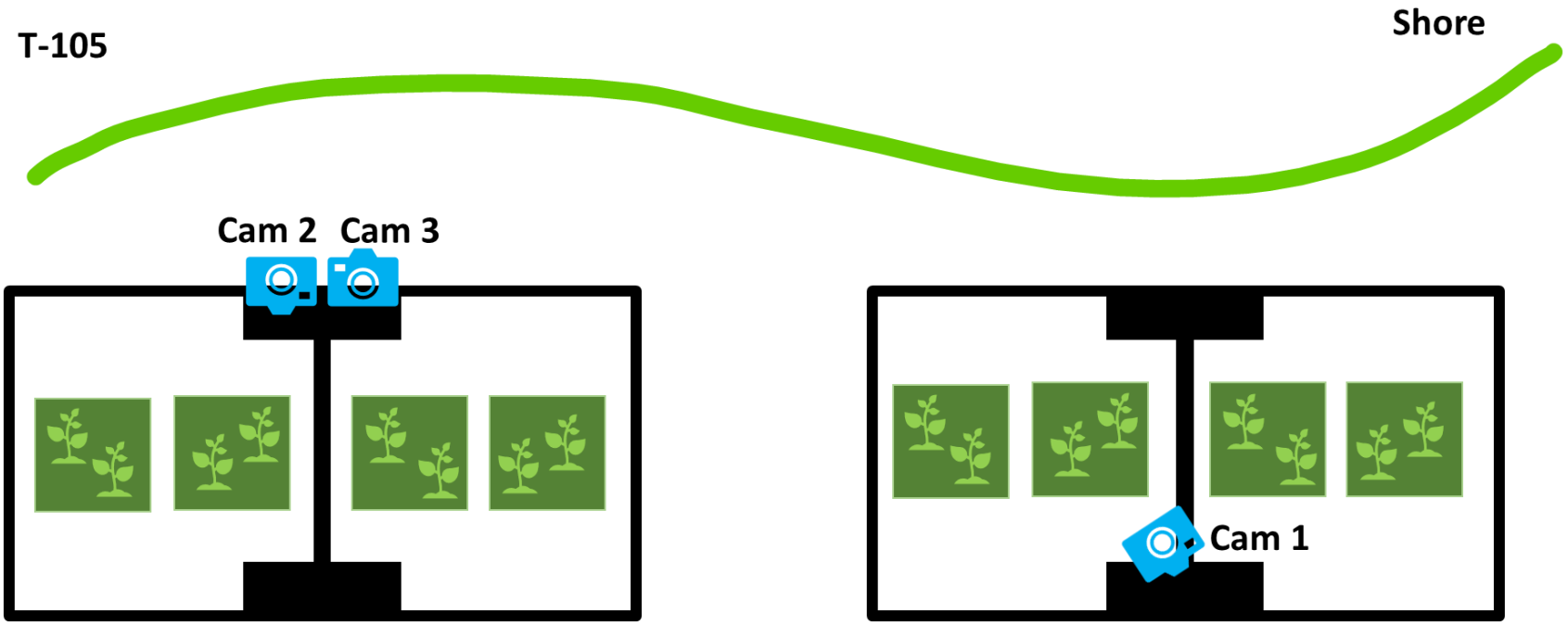
GoPro Methods Phase 2: Interval Recordings at both barges, continuous recordings at both barges

On about June 20th, we switched over from using one GoPro to using 6 GoPros (3 at each site. 2 taking timed interval video, 4 taking continuous video). The goal of this increase was to capture more underwater observations, capture clips at both T-105 and T-108, and take continuous video, during overwater observations of both the space beneath the BioBarges as well as facing away from the barges into open water for purposes of comparison. However, this added considerable complexity to the GoPro methodology, and there were several days when one or more camera did not successfully record, were not programmed correctly, were not charged, etc. In addition, the team did not have capacity to review all of the additional video, particularly the continuous video recordings. Additionally, though few of the "open water" facing videos were reviewed, initial review suggests that it's difficult to orient for a reviewer without any objects in view and limited visibility.

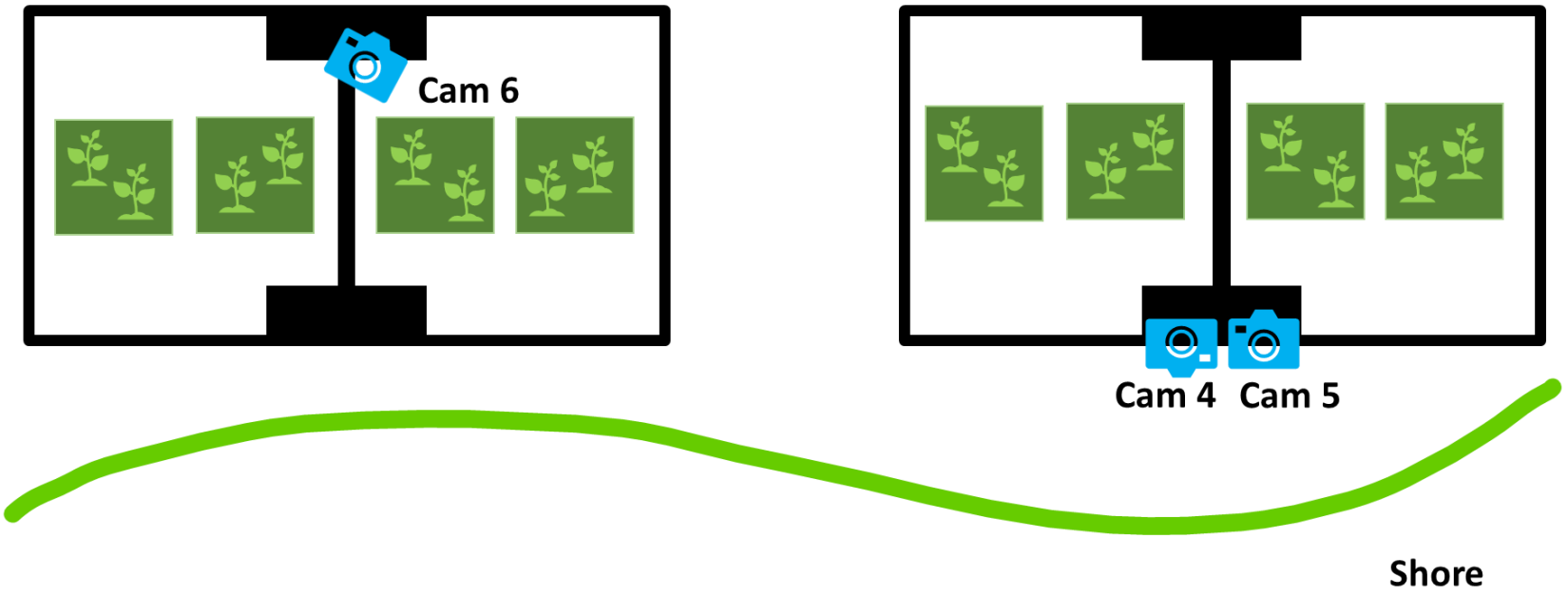
- **Preparation:** Fully charge all 6 GoPros and program both Blink timers in advance of going into the field. Blink timers programmed for 1 minute of video every 30 minutes during daylight hours. 2 cameras operated with Blink timers, 4 cameras operated without Blink timers. Ensure that all cameras have full battery and clean SD cards.
- **Supplies:** 6 GoPros, 2 Blink timers, 6 GoPro poles and caps with mounts cemented on.
- **Placement:** Gopro 1 goes on barge D, looking under the filters at an angle towards shore (this is the one we've been doing for a while). Gopros 2 and 3 go on barge B, one looking straight towards shore, and one looking straight out under the biobarge (180 degrees different). Gopro 4 and 5 go on barge A, same orientation as 2 & 3. Gopro 6 goes on barge C, same placement and orientation as Gopro 1.

- **Recording protocol:** Gopros 1 and 6 (with the blink timers) can just be placed anytime early on during the monitoring day and left in place to be picked up the next day. You don't need to turn them on – just put them in the water. Gopros 2-5 are intended to run while you do the fish monitoring, so ideally turn them on and put them in the water as you are getting onto the barges. They have about 1.5 hours of battery life, so I think it would be best to pull them and bring them back to GFL when you leave for the day (record in 17-minute chunks).
- **Retrieval protocol:** Bring GoPros 2-5 (continuous recorders) back at the end of the day. Leave GoPros 1 and 6 for at least 24 hours before retrieving.
- **Upload protocol:** Remove the SD card from the camera or use the USB port to connect camera to computer and upload the recorded videos to the drive. Into a dated folder. Add the filenames and recording times to the Google sheets database for review. Make sure to check that the camera recording times match the actual recording times. It seems like these are off by 7 hours; couldn't figure out how to correct that.
- **Footage review protocol:** see below

The diagrams below show the configuration of cameras at T-105,



T-108



Footage review protocol:

Below is a screenshot of the Google sheets database we used to review GoPro footage and store data. From left to right, the column fields are:

1) **Folder** where the clips are stored, this is the date that the video was recorded
2) **Filename** of the recording; we did not rename the files until we had all 6 cameras going.
3) **Date** that the clip was recorded, could be different than the folder if the camera was left out for two days
4) **Time recorded** = actual time, not the time noted in the file details
5) **Barge –** A, B, C, or D
6) **Site –** T-105 or T-108
7) **View –** what was the camera looking at? Biofilters at an angle, straight under the biofilters, towards shore?
8) **Fish Y/N –** Does the clip have fish in it?
9) **Time fish spotted –** We added this field later, more important for longer clips, but also helpful if people are verifying species ID
10) **#** of fish sightings
11) **Species** if possible
12) **Location** of fish in the video
13) **Behavior** – e.g., swimming, feeding, resting

14) **Notes**
15) **Type –** clip or continuous
16) **Recording time –** Total length of the recording
17) **Reviewer initials**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**Folder**	**File Name**	**Date**	**Time Recorded**	**Barge**	**Site**	**View**	**Fish Y/N**	**Time Fish Spotted**	**#**	**Species**	**Location**	**Behavior**	**Notes**	**Type (clip/continuous)**	**Recording time (minutes)**	**Reviewer initials**
10	_051619	GOPR2692	5/16/19	1:00 PM	D	T105	biofilters, a	N							Clip	0.17	CD
11	_051619	GOPR2693	5/16/19	1:30 PM	D	T105	biofilters, a	Y				Below filter	Swimming		Clip	0.17	
12	_051619	GOPR2694	5/16/19	2:00 PM	D	T105	biofilters, a	N							Clip	0.17	CD
13	_051619	GOPR2695	5/16/19	2:30 PM	D	T105	biofilters, a	N							Clip	0.17	CD
14	_051619	GOPR2696	5/16/19	3:00 PM	D	T105	biofilters, a	N							Clip	0.17	CD
15	_051619	GOPR2697	5/16/19	3:30 PM	D	T105	biofilters, a	N							Clip	0.17	CD
16	_051619	GOPR2698	5/16/19	4:00 PM	D	T105	biofilters, a	N							Clip	0.17	CD
17	_051619	GOPR2699	5/16/19	4:30 PM	D	T105	biofilters, a	N							Clip	0.17	CD
18	_051619	GOPR2700	5/16/19	5:00 PM	D	T105	biofilters, a	N							Clip	0.17	CD
19	_051619	GOPR2701	5/16/19	5:30 PM	D	T105	biofilters, a	N							Clip	0.17	CD
20	_051619	GOPR2702	5/16/19	6:00 PM	D	T105	biofilters, a	N							Clip	0.17	CD
21	_051619	GOPR2703	5/16/19	6:30 PM	D	T105	biofilters, a	N							Clip	0.17	CD
22	_051619	GOPR2704	5/16/19	7:00 PM	D	T105	biofilters, a	N							Clip	0.17	CD
23	_051619	GOPR2705	5/16/19	7:30 PM	D	T105	biofilters, a	Y				Next to filter	Swimming		Clip	0.17	
24	_051619	GOPR2706	5/16/19	8:00 PM	D	T105	biofilters, a	N							Clip	0.17	CD
25	_051619	GOPR2707	5/16/19	8:30 PM	D	T105	biofilters, a	N							Clip	0.17	CD
26	051619	GOPR2708	5/16/19	9:00 PM	D	T105	biofilters, a	NA						Too dark	Clip	0.17	CD

Fish Monitoring Photos

1 and 2: barge monitoring, 3: shoreline reference site monitoring. 4: Barge, with the PVC GoPro mount visible on the right edge of the BioBarge FWL sign.

Additional Observations

We experimented with several other data and approaches for collecting general environmental information. It could be helpful to have a data sheet for general observations (e.g., date, time, weather, tasks completed, "naturalist notes") etc. We lacked a consistent, standardized approach for collecting these data. We had initially developed data sheets for this type of information as well as for flow and turbidity (secchi disc depth), but we stopped measuring flow and were inconsistent about measuring secchi depth because the disc was on the port boat and we occasionally monitored with the small dinghy only.

Example Field Workflow

Field Equipment and Workflow - FWLs Spring 2019 (WQ and plant methods not described)

This document was developed during spring 2019, minor revisions November 2019

Equipment Checklist

General:

- X PFDs - in deck box at T102
- 2 clipboards (metal container)
- 4 small rite-in-rain notebooks
- 4 Pencils + sharpener

Plants:

- Tape measure
- Other tbd

Abiotic factors/ water quality

- 1 secchi disc
- 1 flowmeter
- OTHER TBD

Fish:

- 3 polarized sunglasses
- stack of data sheets in clipboard
- Binder/case for completed data sheets
- 3 watches
- Rubber boots for going ashore* helpful

Invertebrates:

-Setting out traps:

- 15 fallout traps (plastic bins)
  - 5 at the barges, 5 at the vegetated riprap shoreline, 5 at the soft shoreline
- Bungee cords (barges only; 2 per trap)
- Odorless biodegradable dish soap
- Bucket and seive

-Collecting traps:

- 15 labelled jars
- 1 bucket
- 1 sieve
- 1 sprayer
- Isopropyl alcohol

Bob (the small paddle boat)*
*3 people MAX with minimal extra room

- plastic jug (bailer) + pump (in blue bag)

Workflow in the field

1. ***Preparation for monitoring*** **(20 min)**
   - Meet at T-102 or other specified location
   - Introductions/ice breaker with comm. science, discussion of comfort levels + roles

- Double check supplies
- Load Port boat; put Bob in water and tie off to Port boat (alongside stern)
- Drive boat to a location near first observation site (alternates per week/as determined and by tides) and record preliminary observations (weather, start time, etc.)

*NOTE: If 4 observers are available, it's possible to do the barges and the shore sites simultaneously by having a paddler drop people at the barges or on shore as determined.

2*. T-105 monitoring (Barges B & D)

- Tie Port boat to nearest piling (~20 feet from barges)
- Observers load Bob with supplies and paddle to biobarge
- Drop 1 observer at first biobarge, paddle to second biobarge, 1 -2 other observers get on
- Tie-off Bob and push away from barge into current, ideally on the shoreward side of the barge
- Wait ~3 minutes after getting settled, begin overwater fish count for 30 minutes
- Measure flow within biobarge at surface (first red hash) and 1 meter; time for 1 min and record min and max *(flow discontinued during monitoring season)*
- Set or collect fallout trap and gopro *(or after doing fish monitoring at shoreline reference site)*
- Paddle Bob towards space between biobarges, measure flow *(flow monitoring discontinued)*
- Paddle Bob to next biobarge; measure flow at front of "upstream" barge *(flow monitoring discontinued)*

3. Shoreline reference site monitoring @T105

- Location: along the adjacent shoreline, starting north of the mouth of the channel and extending south, see map in report.
- Observers space out evenly within the 60 ft. space, 30 min. data collection
- Set/collect fallout traps on soft/vegetated riprap sites

4*. T-108 monitoring

- Tie Port boat to nearest piling (~100 feet south of barges)
- Observers load Bob with supplies and paddle to biobarge
- Drop 1 observer at first biobarge, paddle to second biobarge, 1 -2 other observers get on
- Tie-off Bob and push away from barge into current
- Wait ~3 minutes after getting settled, begin overwater fish count for 30 minutes
- Measure flow within biobarge at surface (first red hash) and 1 meter; time for 1 min and record min and max *(flow measurements discontinued)*
- Set or collect fallout trap and gopro *(or after shoreline monitoring)*

5. Shoreline reference site monitoring @T108

- Location: along the shoreline parallel to the barges, see map in report.
- Observers space out evenly within the 60 ft. space, 30 min. data collection
- Set/collect fallout traps on soft and vegetated riprap sites

6. Back on land

- Photograph data sheets
- Identify point people for uploading data and photos
- Return to meeting place and return supplies TBD

Appendix B: Invertebrate Monitoring

This appendix includes a description of the invertebrate monitoring protocol, example data recording sheets, and photos of the fallout trap placement and sampling approach. At a high level, invertebrate monitoring steps included the following: 1) Attaching 5 traps randomly to the gabion cages of the biobarges, placing 5 traps on an adjacent vegetated riprap shoreline, and 5 traps at an adjacent soft shoreline. Traps are filled with ~3 inches of sieved sea water mixed with a few drops of biodegradable, unscented dish soap. 2) Leave traps in place for 24 hours. 3) Return to the site and process the samples by straining each fallout trap bin and rinsing the invertebrates into a sample jar and fixing with 70% isopropyl alcohol. 4) Transporting samples back to the lab for analysis. 5) Analyzing the contents of each sample by identifying invertebrates and counting them. We alternated sampling at T-105 and T-108 by week.

Invertebrate Sampling Protocol

Initially drafted April 2019, Updated November 2019.

Methods Overview

Fallout traps will be used to sample invertebrates from floating wetlands, armored/vegetated riprap, and soft/restored shorelines. Fallout traps will be placed at floating wetlands and reference sites 24 hours prior to collection. Methods for placing traps and collecting samples are described below.

Research question 1: How do invertebrate densities and species richness at floating wetlands compare to a) armored shorelines and b) soft/vegetated shorelines?

Invertebrate Sampling Methods

2 people place fallout traps 24 hrs prior to collecting; 2 people process samples

Fallout trap deployment at biobarges:

- Attach 5 fallout trap bins to the sides of the FWL cage using bungee cords; bins should be positioned above the water surface on the cages. Randomly attach bins (e.g., use a random number generator to specify which sides of the gabion cages to use).
- Pour a few drops of natural odorless dishwashing soap in the bottom, and fill with about 5 cm of sieved water.
- Leave in place for 24 hrs.

Fallout trap deployment at armored and soft/vegetated shorelines:

- Approximate a 60 foot transect along the shoreline (same transect throughout sampling season), at vegetated riprap site and soft shoreline site.
- Randomly select positions for 5 fallout traps per site along the transect (5 at armored/vegetated rip rap site, 5 at soft shoreline)
- Set fallout traps along shoreline above high tide line.
- Pour a few drops of natural odorless dishwashing soap in the bottom, and fill with about 5 cm of sieved water.
- Leave in place for 24 hrs.

Invertebrate collection:

- Make sure that collection jars are prelabeled, see below.

- Collect fallout trap from biobarge/shoreline. Note - fallout traps should be collected from biobarges after fish surveys are completed.
- Drain trap contents through a 106 micron mesh sieve into a bucket, and spray the insects into labeled sample jars (fill a spray bottle or weed sprayer with sieved water for this).
- Fix the sample in 70% isopropyl alcohol.
- Transport samples back to UW for later analysis
- Record how many samples were collected from each location

Timing: Fallout traps placed at FWLs, armored, and soft/vegetated shorelines weekly (alternating sites by week), 24 hrs before field days, traps collected weekly during field day

Survey Locations: FWL barges (5 barge collections total), armored shoreline (5 per site), soft shoreline (5 per site) = 15 total weekly collections

Materials:
- Plastic storage bins
- Natural dishwashing soap (biodegradable, odorless)
- 0.106 mm sieve
- Water sprayer, two buckets for collecting and sieving water
- Labeled jars (date, site, #)
- 70% isopropyl alcohol

Initial Analysis:
- Invertebrates will be counted and classified to the family or order level in the lab following collection.

Example sample jar label:

DWFL
Barge/Site:
Date:
Sample #:

Invertebrate Sampling Photos

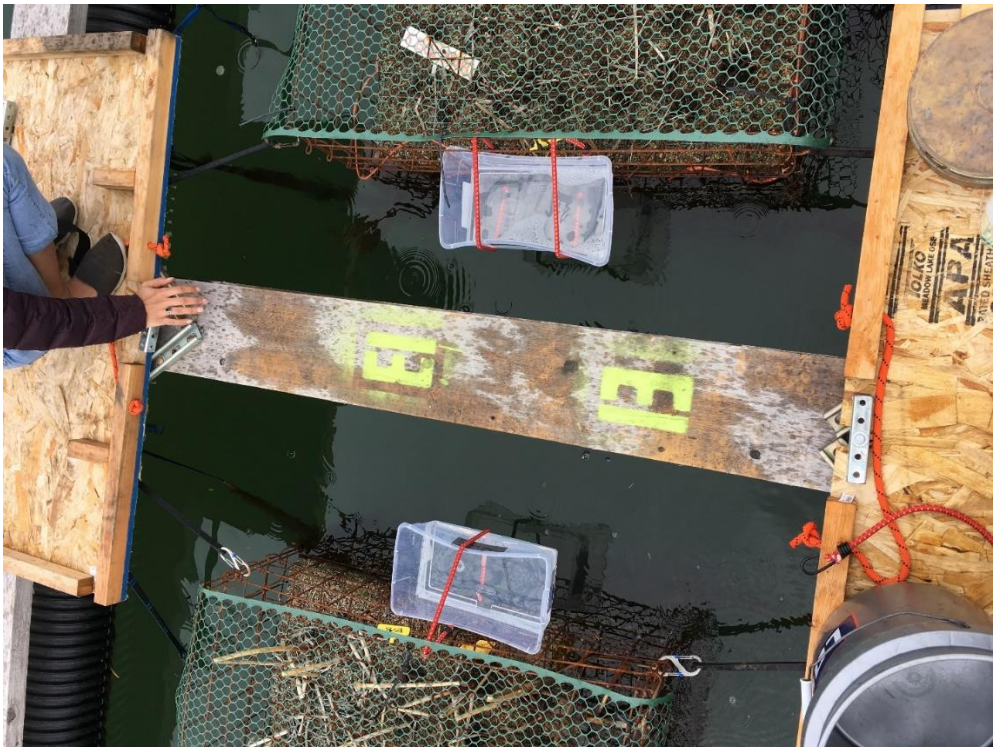


Figure 1. Barge placement

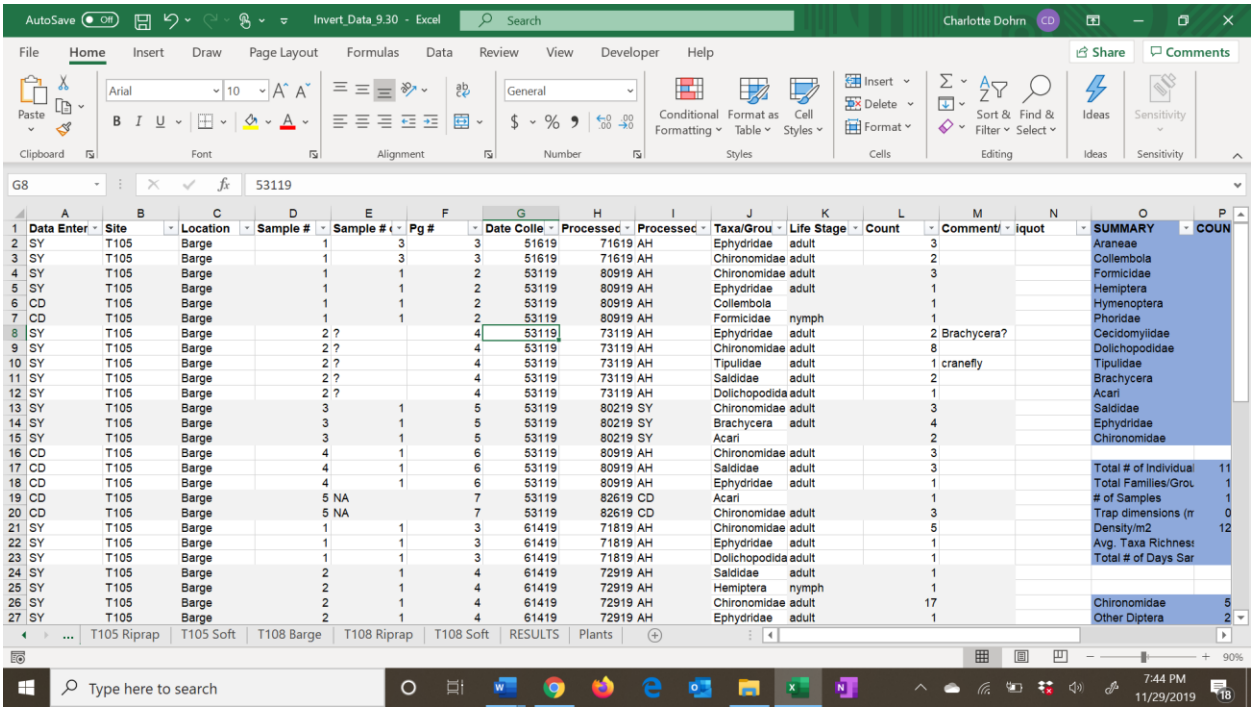
Figure 2, Soft shoreline placement at T-108

Figure 3. Vegetated Riprap placement at T-105. Note the overhanging bushes; at times, traps were placed even higher up under the bushes.

Figure 4. Soft shoreline placement at T-105.

Figure 5. Vegetated riprap shoreline placement at T-108.

Figure 6. Processing invertebrates on the biobarges.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Data Enter	Site	Location	Sample #	Sample # (	Pg #	Date Colle	Processed	Processed	Taxa/Grou	Life Stage	Count	Comment/	iquot	SUMMARY	COUN
2	SY	T105	Barge	1	3	3	51619	71619	AH	Ephydridae	adult	3			Araneae	
3	SY	T105	Barge	1	3	3	51619	71619	AH	Chironomidae	adult	2			Collembola	
4	SY	T105	Barge	1	1	2	53119	80919	AH	Chironomidae	adult	3			Formicidae	
5	SY	T105	Barge	1	1	2	53119	80919	AH	Ephydridae	adult	1			Hemiptera	
6	CD	T105	Barge	1	1	2	53119	80919	AH	Collembola		1			Hymenoptera	
7	CD	T105	Barge	1	1	2	53119	80919	AH	Formicidae	nymph	1			Phoridae	
8	SY	T105	Barge	2 ?		4	53119	73119	AH	Ephydridae	adult	2	Brachycera?		Cecidomyiidae	
9	SY	T105	Barge	2 ?		4	53119	73119	AH	Chironomidae	adult	8			Dolichopodidae	
10	SY	T105	Barge	2 ?		4	53119	73119	AH	Tipulidae	adult	1	cranefly		Tipulidae	
11	SY	T105	Barge	2 ?		4	53119	73119	AH	Saldidae	adult	2			Brachycera	
12	SY	T105	Barge	2 ?		4	53119	73119	AH	Dolichopodida	adult	1			Acari	
13	SY	T105	Barge	3	1	5	53119	80219	SY	Chironomidae	adult	3			Saldidae	
14	SY	T105	Barge	3	1	5	53119	80219	SY	Brachycera	adult	4			Ephydridae	
15	SY	T105	Barge	3	1	5	53119	80219	SY	Acari		2			Chironomidae	
16	CD	T105	Barge	4	1	6	53119	80919	AH	Chironomidae	adult	3				
17	CD	T105	Barge	4	1	6	53119	80919	AH	Saldidae	adult	3			Total # of Individual	11
18	CD	T105	Barge	4	1	6	53119	80919	AH	Ephydridae	adult	1			Total Families/Grou	1
19	CD	T105	Barge	5	NA	7	53119	82619	CD	Acari		1			# of Samples	1
20	CD	T105	Barge	5	NA	7	53119	82619	CD	Chironomidae	adult	3			Trap dimensions (m	0
21	SY	T105	Barge	1	1	3	61419	71819	AH	Chironomidae	adult	5			Density/m2	12
22	SY	T105	Barge	1	1	3	61419	71819	AH	Ephydridae	adult	1			Avg. Taxa Richnes	
23	SY	T105	Barge	1	1	3	61419	71819	AH	Dolichopodida	adult	1			Total # of Days Sar	
24	SY	T105	Barge	2	1	4	61419	72919	AH	Saldidae	adult	1				
25	SY	T105	Barge	2	1	4	61419	72919	AH	Hemiptera	nymph	1				
26	SY	T105	Barge	2	1	4	61419	72919	AH	Chironomidae	adult	17			Chironomidae	5
27	SY	T105	Barge	2	1	4	61419	72919	AH	Ephydridae	adult	1			Other Diptera	2

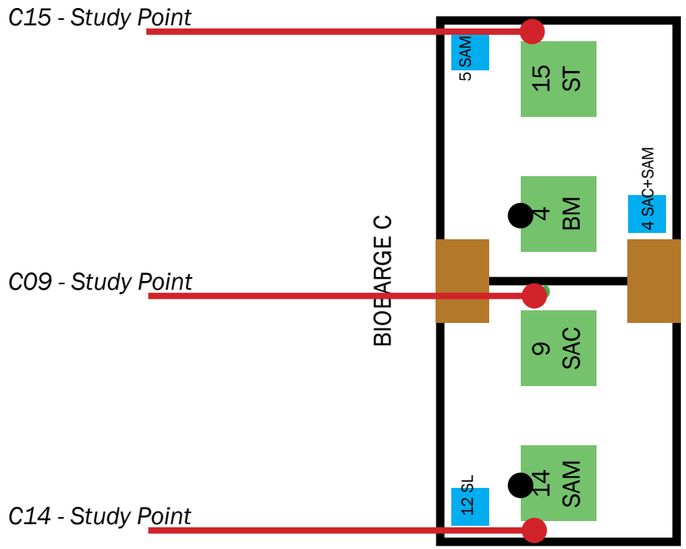
Figure 7. Screenshot of the Excel database used for invertebrate sample analysis

Appendix C

Water Quality Monitoring

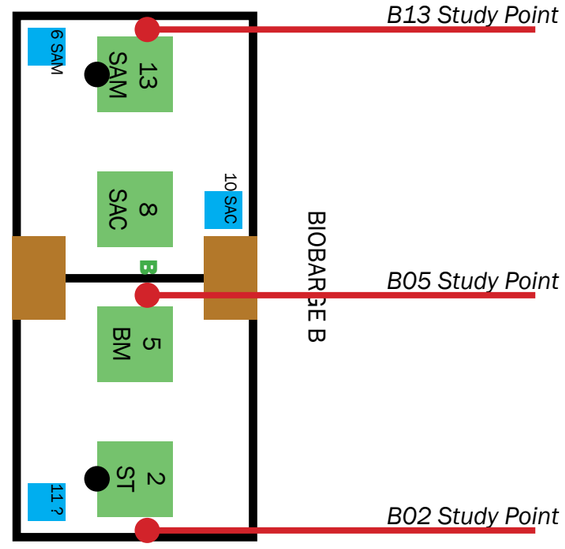
What we did

T-108 DEPLOYMENT
Water Quality Study Points



Sonde Points

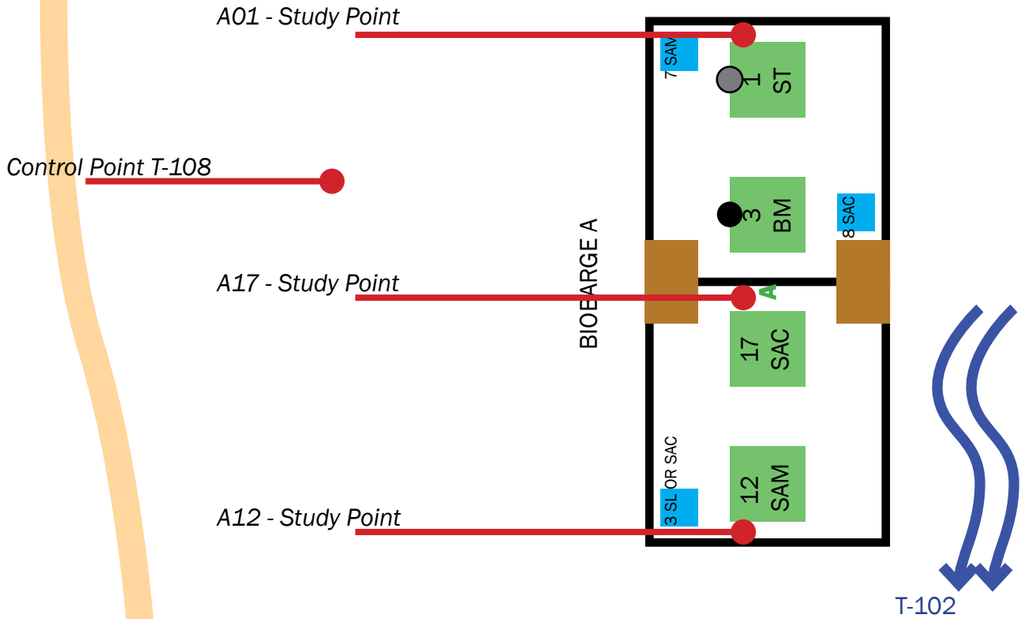
T-105 DEPLOYMENT
Water Quality Study Points



Land Side

Land Side

Duwamish River



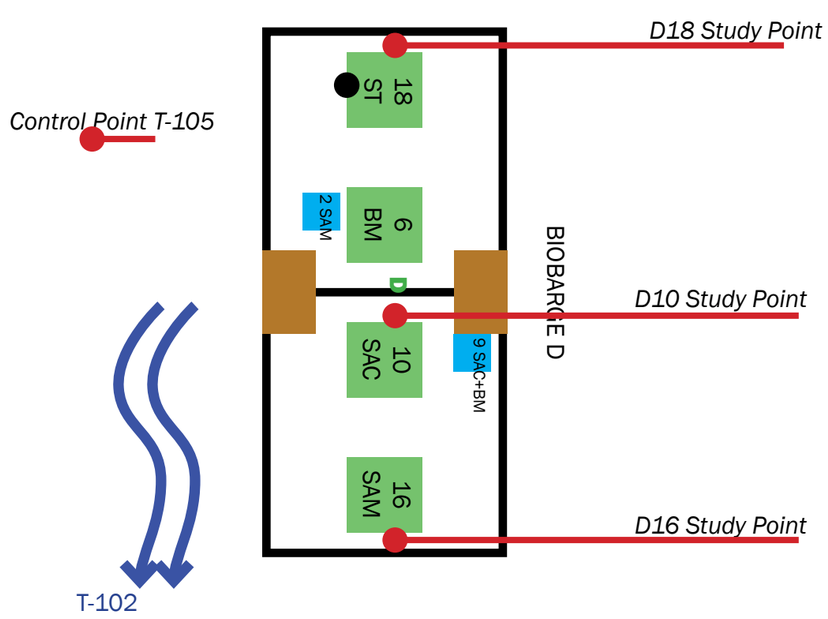
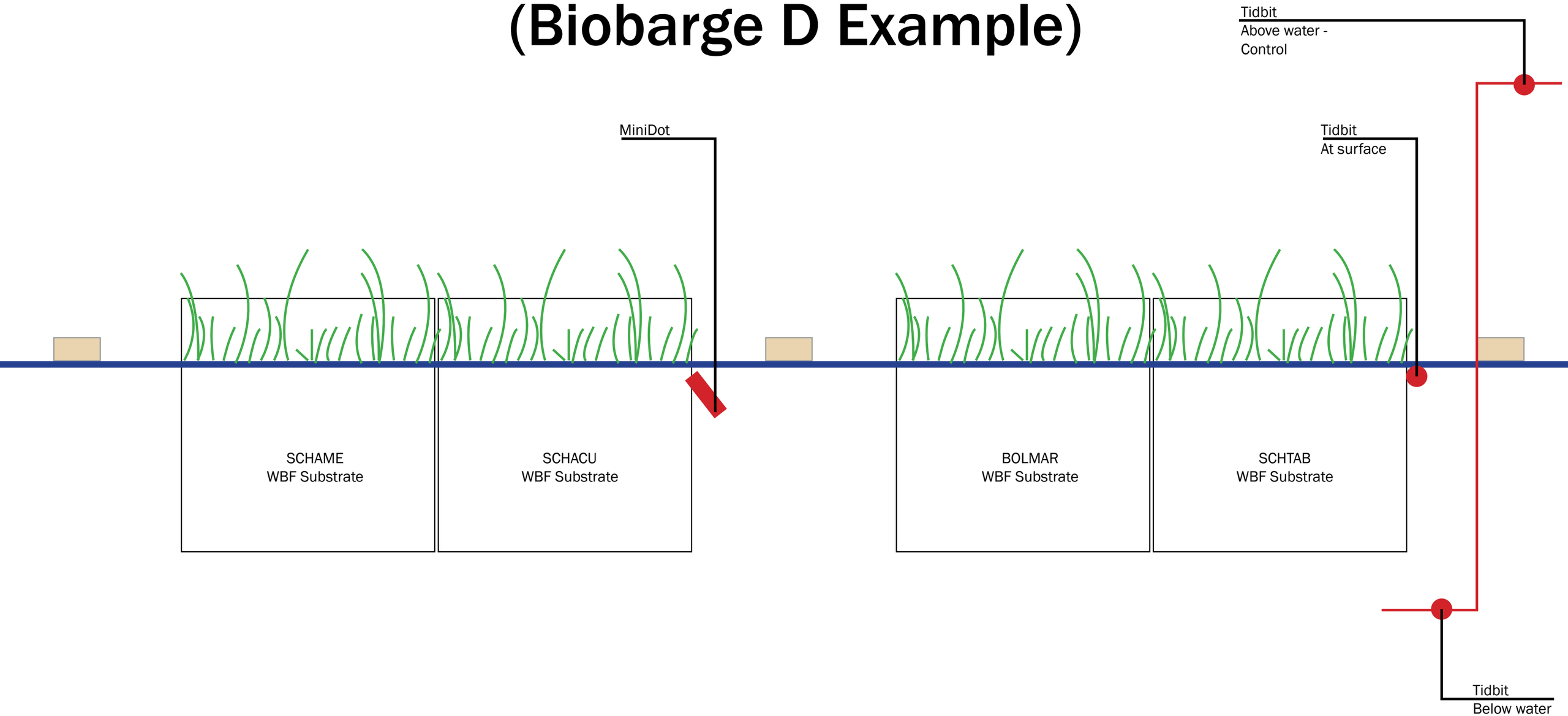
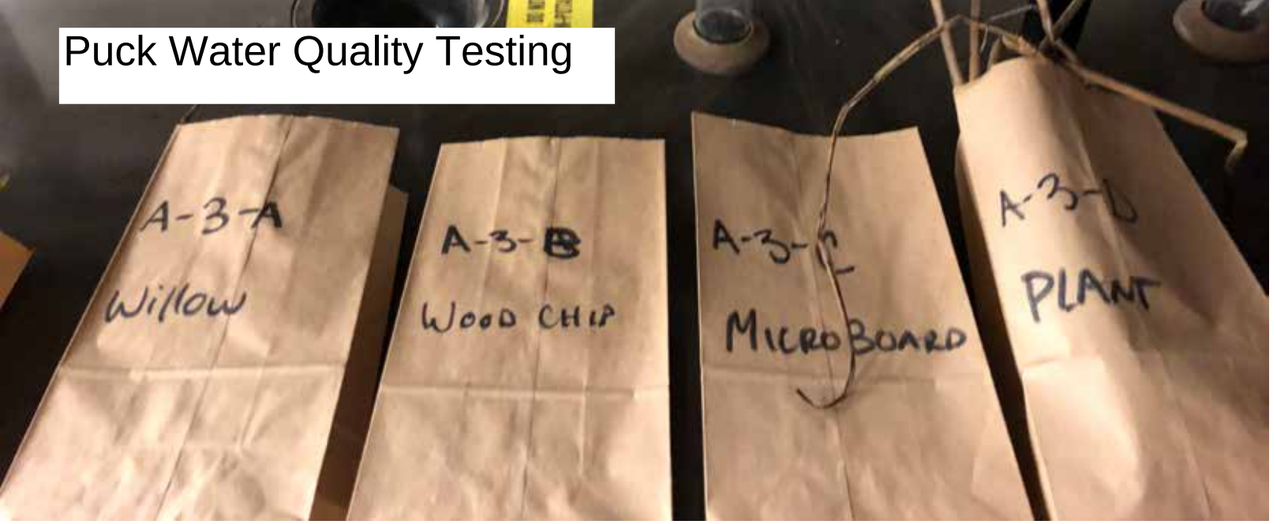


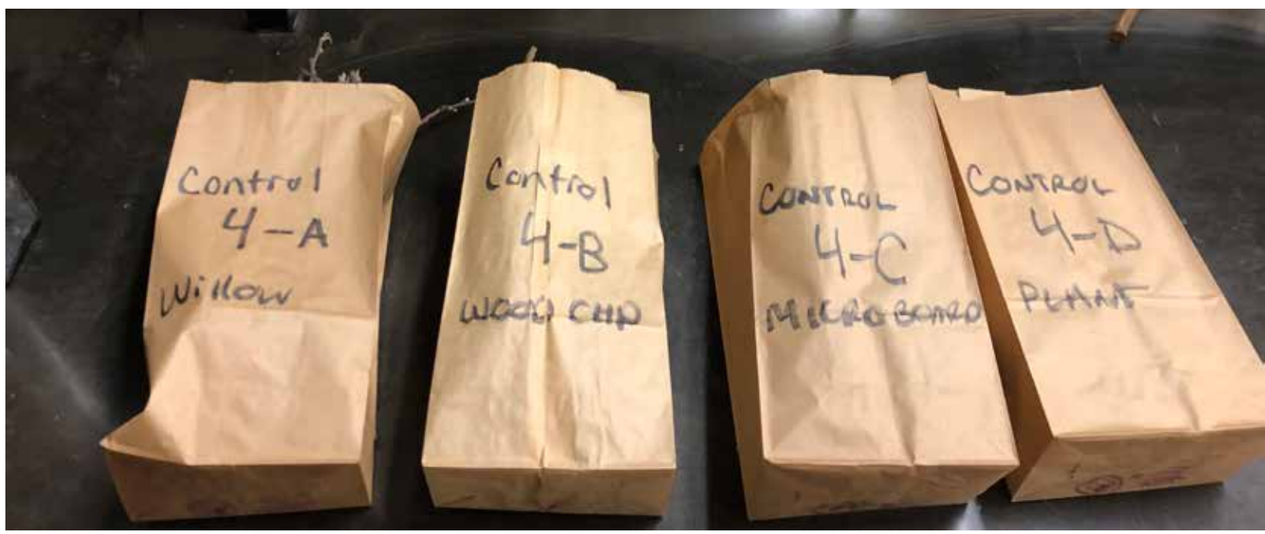
Image from
07/03/2019
Field Day

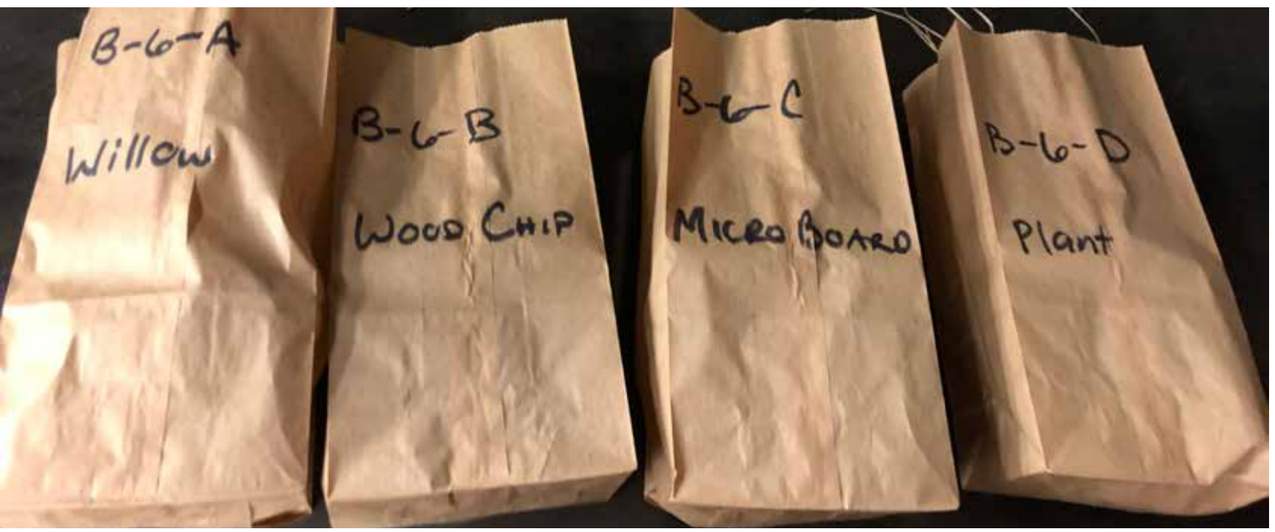
Continuous Monitoring Devices (Biobarge D Example)

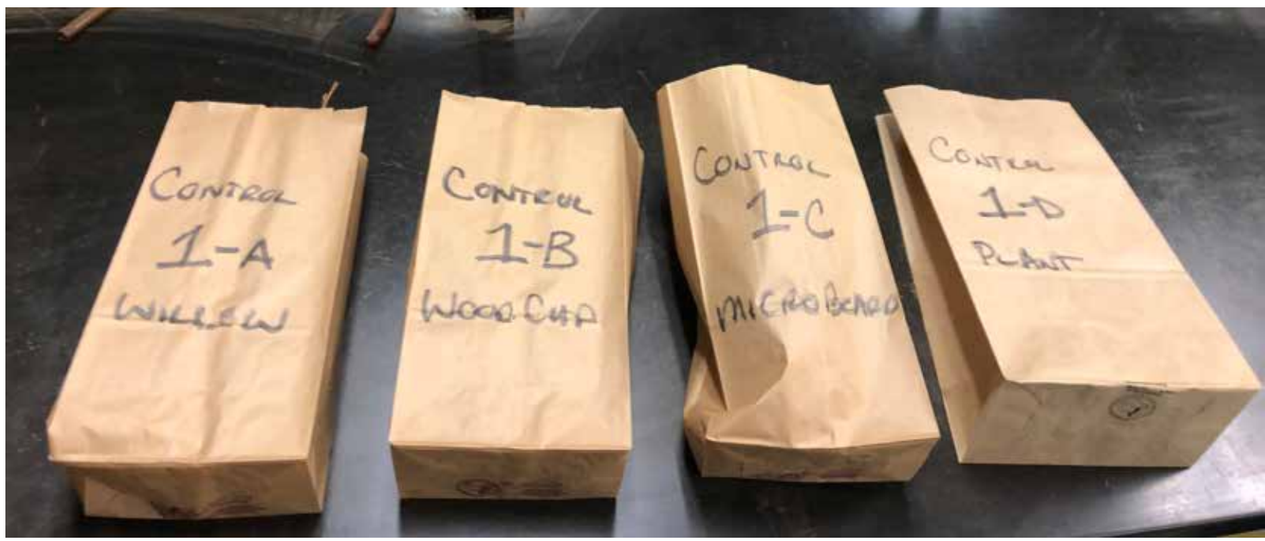


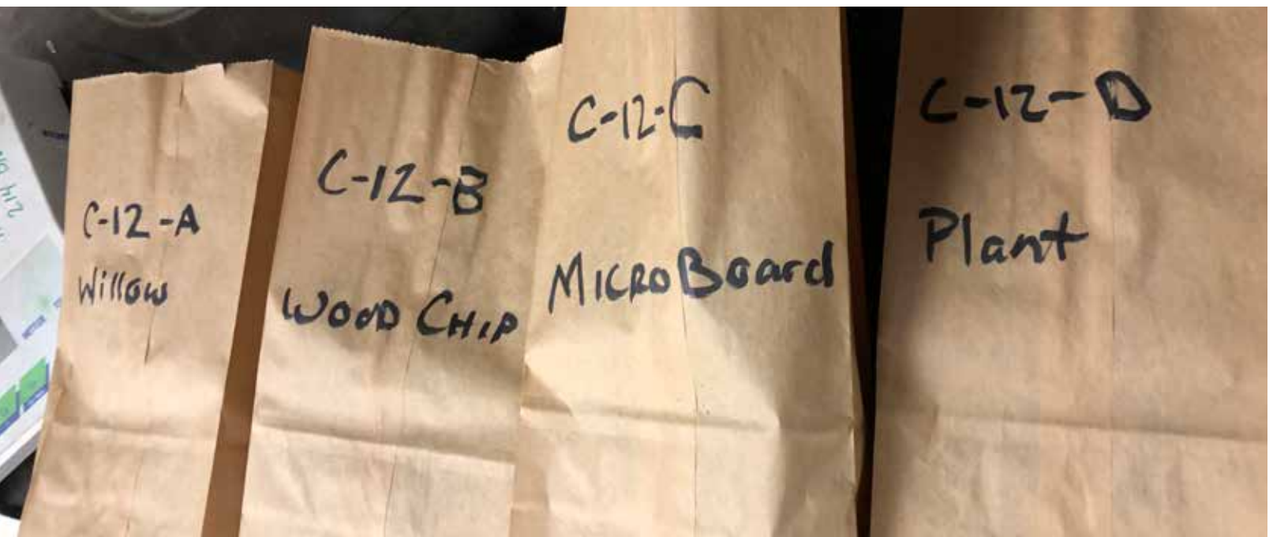
Puck Water Quality Testing

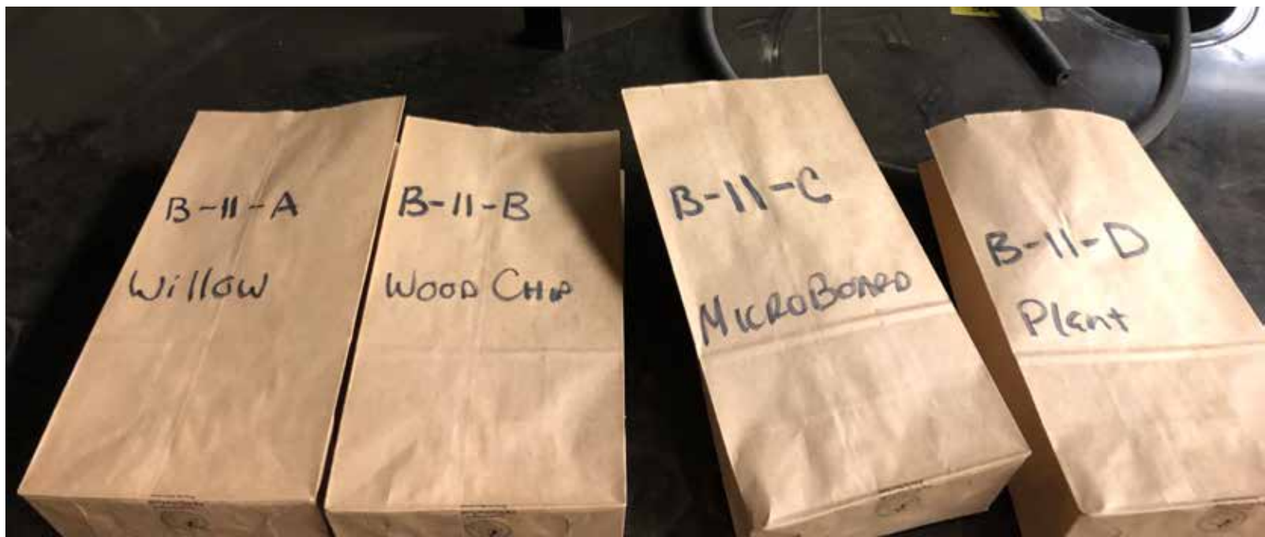












Findings

T-108 DEPLOYMENT
Water Quality Study Points

May 24th, 2019
Dissolved Oxygen Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1mg/L

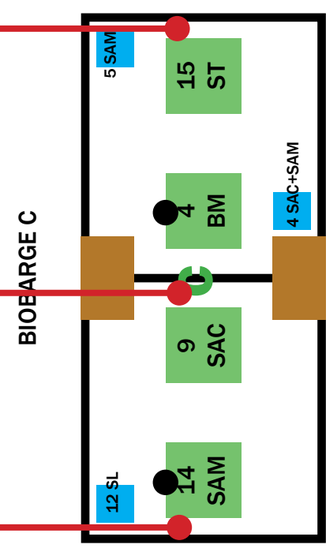
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.5
ODO mg/L (1.0) = 8.2

C09 - Study Point
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.4

C14 - Study Point
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.2

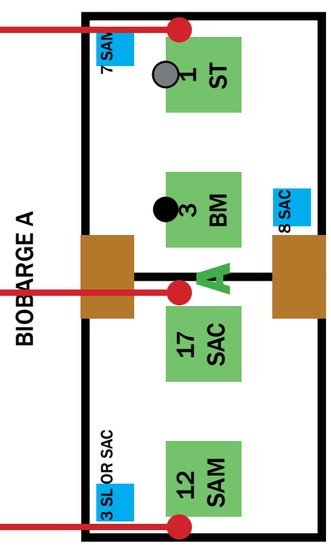


A01 - Study Point

Control Point T-108
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.2

A17 - Study Point

A12 - Study Point

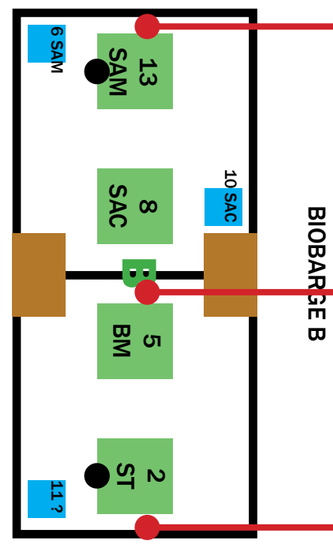


T-102

Duwamish River

Numbers modified based on grab samples and titration

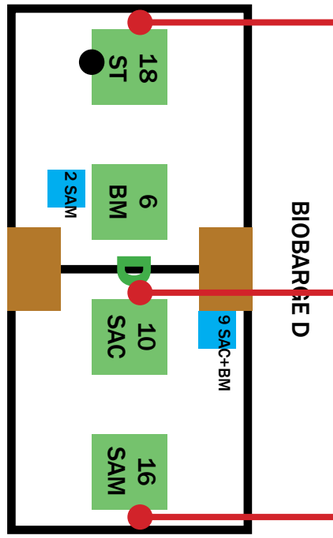
Control Point T-105
ODO mg/L (0.3) = 8.7
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 8.5



B13 Study Point

B05 Study Point

B02 Study Point



D18 Study Point
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 8.6

D10 Study Point
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 8.6

D16 Study Point
ODO mg/L (0.3) = 8.7
ODO mg/L (0.6) = 8.7
ODO mg/L (1.0) = 8.6

T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

May 31st, 2019
Dissolved Oxygen Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1mg/L

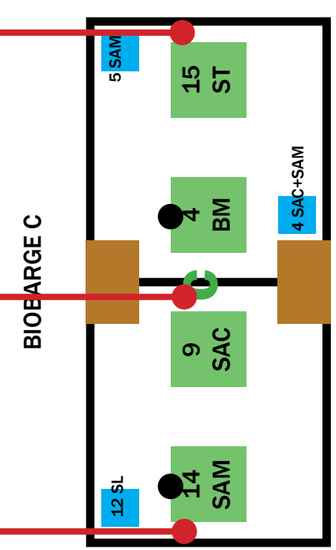
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
ODO mg/L (0.3) = 8.4
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.6

C09 - Study Point
ODO mg/L (0.3) = 8.4
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.4

C14 - Study Point
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.4

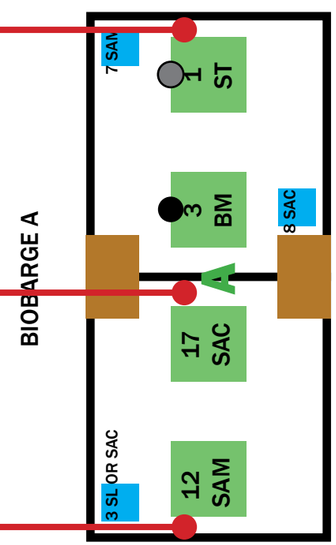


A01 - Study Point

Control Point T-108
ODO mg/L (0.3) = 8.4
ODO mg/L (0.6) = 8.5
ODO mg/L (1.0) = 8.4

A17 - Study Point

A12 - Study Point



T-102

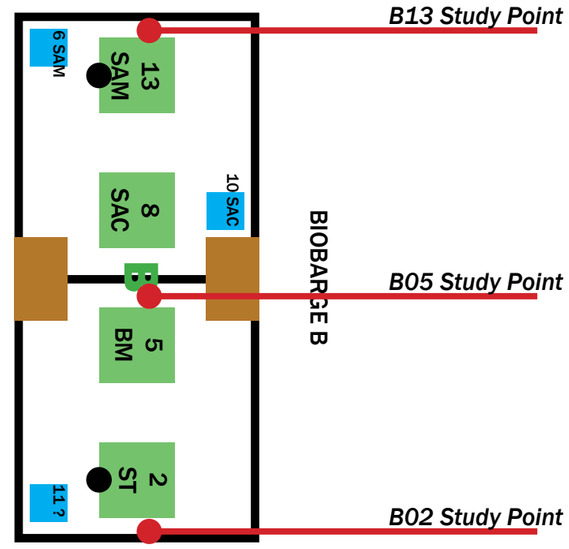
Duwamish River

Numbers modified based on grab samples and titration

B13 Study Point

B05 Study Point

B02 Study Point

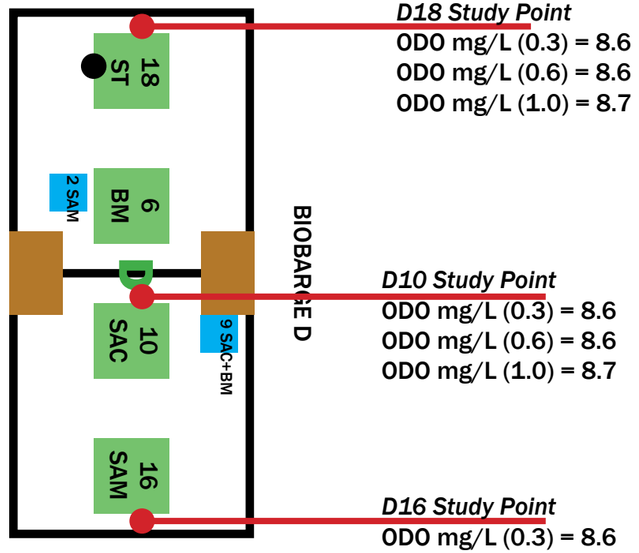


Control Point T-105
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.7
ODO mg/L (1.0) = 8.7

D18 Study Point
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 8.7

D10 Study Point
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 8.7

D16 Study Point
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 8.7



T-102

Land Side

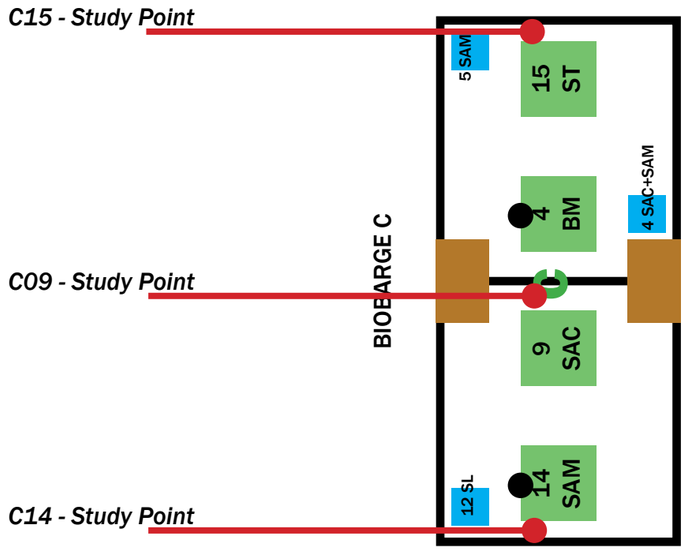
T-108 DEPLOYMENT
Water Quality Study Points

June 7th, 2019
Dissolved Oxygen Data

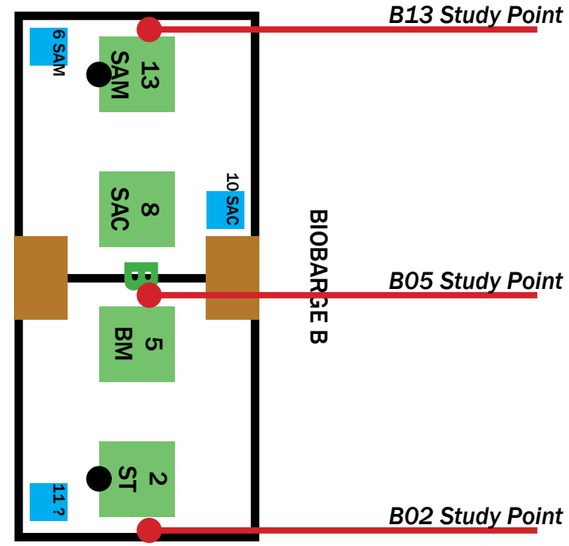
Accuracy threshold: +/- 1.0 % of the reading or 0.1mg/L

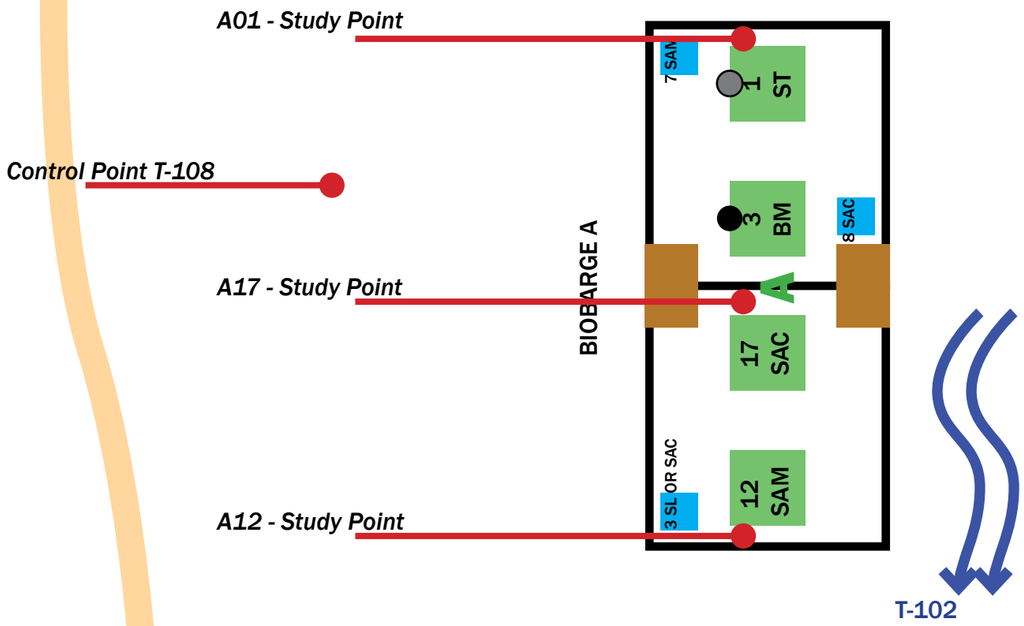
T-105 DEPLOYMENT
Water Quality Study Points

Land Side



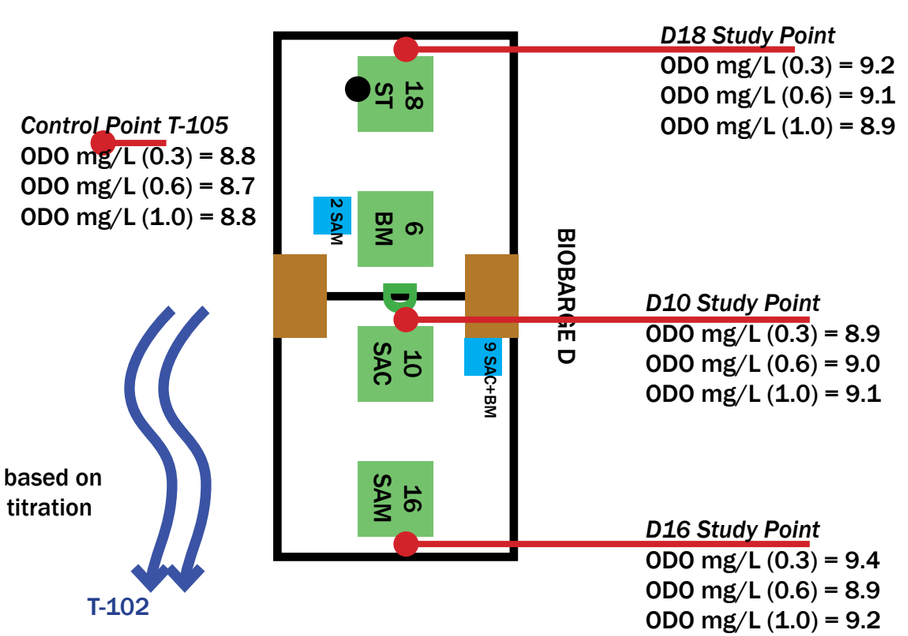
Duwamish River





T-102

Numbers modified based on grab samples and titration



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 14th, 2019
Dissolved Oxygen Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1mg/L

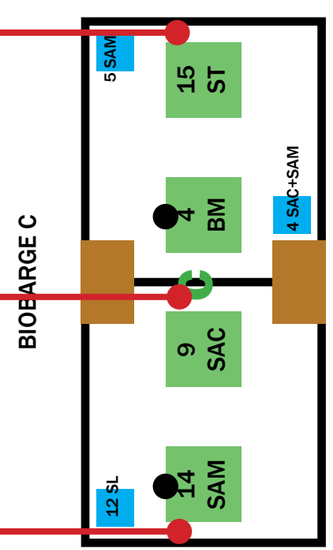
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
ODO mg/L (0.3) = 8.9
ODO mg/L (0.6) = 8.9
ODO mg/L (1.0) = 8.9

C09 - Study Point
ODO mg/L (0.3) = 8.9
ODO mg/L (0.6) = 8.9
ODO mg/L (1.0) = 8.9

C14 - Study Point
ODO mg/L (0.3) = 8.7
ODO mg/L (0.6) = 8.8
ODO mg/L (1.0) = 8.8

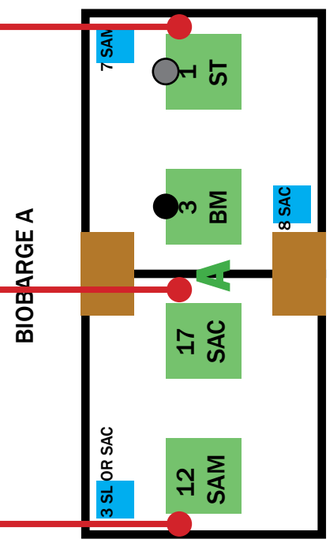


A01 - Study Point
ODO mg/L (0.3) = 8.8
ODO mg/L (0.6) = 8.9
ODO mg/L (1.0) = 9.1

Control Point T-108
ODO mg/L (0.3) = 8.8
ODO mg/L (0.6) = 8.9
ODO mg/L (1.0) = 9.0

A17 - Study Point
ODO mg/L (0.3) = 9.2
ODO mg/L (0.6) = 9.1
ODO mg/L (1.0) = 8.9

A12 - Study Point
ODO mg/L (0.3) = 8.7
ODO mg/L (0.6) = 8.8
ODO mg/L (1.0) = 9.2



T-102

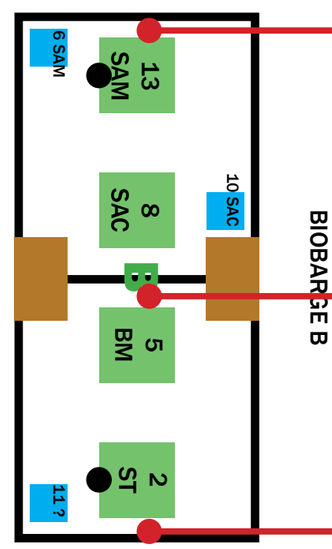
Duwamish River

Numbers modified based on grab samples and titration

B13 Study Point
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.5
ODO mg/L (1.0) = 8.6

B05 Study Point
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.8

B02 Study Point
ODO mg/L (0.3) = 8.4
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 8.7

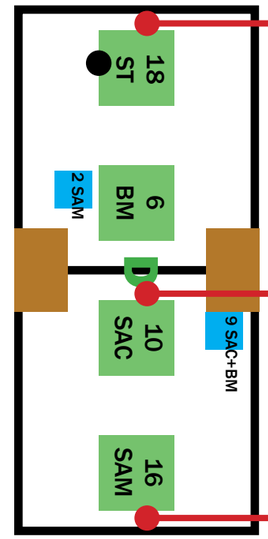


Control Point T-105
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 8.6

D18 Study Point
ODO mg/L (0.3) = 8.8
ODO mg/L (0.6) = 8.8
ODO mg/L (1.0) = 8.7

D10 Study Point
ODO mg/L (0.3) = 8.3
ODO mg/L (0.6) = 8.5
ODO mg/L (1.0) = 8.5

D16 Study Point
ODO mg/L (0.3) = 8.4
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.5



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 21st, 2019
Dissolved Oxygen Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1mg/L

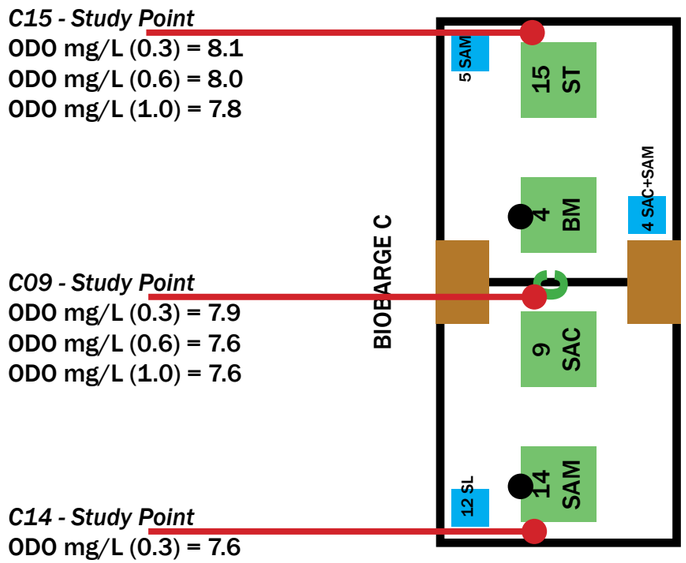
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
ODO mg/L (0.3) = 8.1
ODO mg/L (0.6) = 8.0
ODO mg/L (1.0) = 7.8

C09 - Study Point
ODO mg/L (0.3) = 7.9
ODO mg/L (0.6) = 7.6
ODO mg/L (1.0) = 7.6

C14 - Study Point
ODO mg/L (0.3) = 7.6
ODO mg/L (0.6) = 7.6
ODO mg/L (1.0) = 7.6

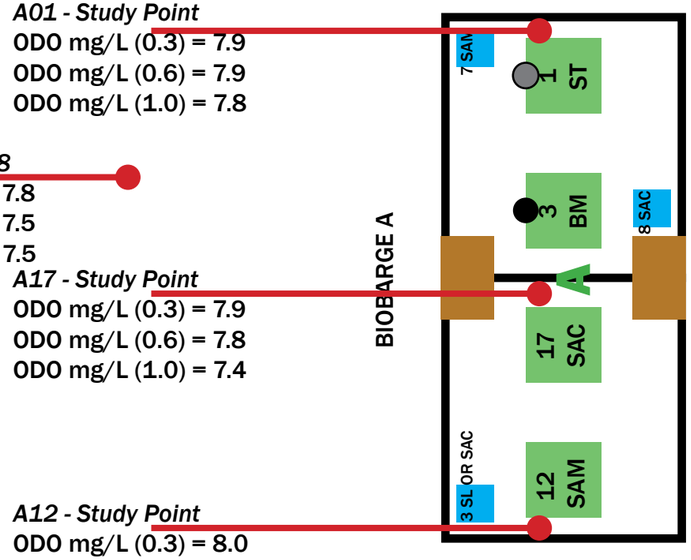


A01 - Study Point
ODO mg/L (0.3) = 7.9
ODO mg/L (0.6) = 7.9
ODO mg/L (1.0) = 7.8

Control Point T-108
ODO mg/L (0.3) = 7.8
ODO mg/L (0.6) = 7.5
ODO mg/L (1.0) = 7.5

A17 - Study Point
ODO mg/L (0.3) = 7.9
ODO mg/L (0.6) = 7.8
ODO mg/L (1.0) = 7.4

A12 - Study Point
ODO mg/L (0.3) = 8.0
ODO mg/L (0.6) = 7.6
ODO mg/L (1.0) = 7.5



T-102

Duwamish River

Numbers modified based on grab samples and titration

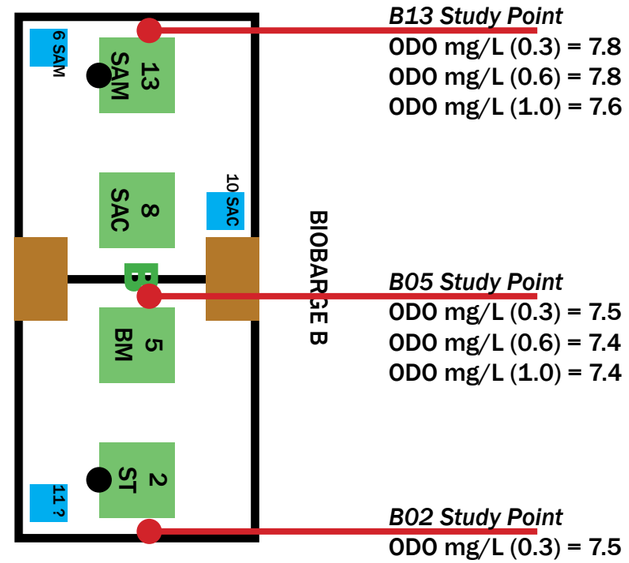
Control Point T-105
ODO mg/L (0.3) = 7.8
ODO mg/L (0.6) = 7.5
ODO mg/L (1.0) = 7.4

T-102

B13 Study Point
ODO mg/L (0.3) = 7.8
ODO mg/L (0.6) = 7.8
ODO mg/L (1.0) = 7.6

B05 Study Point
ODO mg/L (0.3) = 7.5
ODO mg/L (0.6) = 7.4
ODO mg/L (1.0) = 7.4

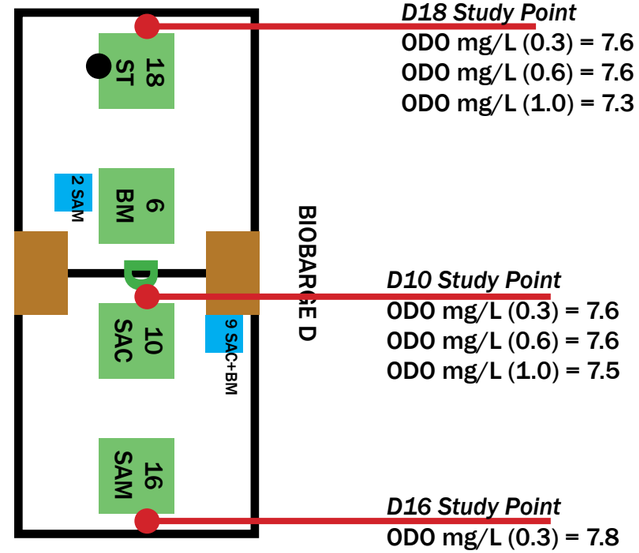
B02 Study Point
ODO mg/L (0.3) = 7.5
ODO mg/L (0.6) = 7.4
ODO mg/L (1.0) = 7.4



D18 Study Point
ODO mg/L (0.3) = 7.6
ODO mg/L (0.6) = 7.6
ODO mg/L (1.0) = 7.3

D10 Study Point
ODO mg/L (0.3) = 7.6
ODO mg/L (0.6) = 7.6
ODO mg/L (1.0) = 7.5

D16 Study Point
ODO mg/L (0.3) = 7.8
ODO mg/L (0.6) = 7.6
ODO mg/L (1.0) = 7.4



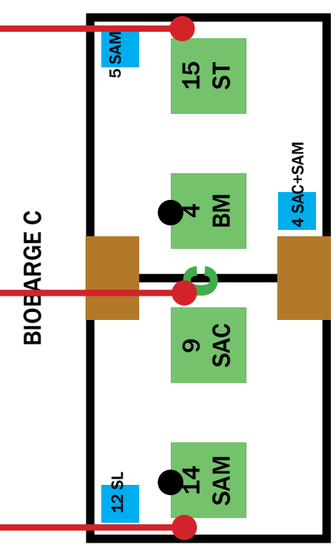
Land Side

T-108 DEPLOYMENT
Water Quality Study Points

C15 - Study Point
ODO mg/L (0.3) = 8.8
ODO mg/L (0.6) = 8.2
ODO mg/L (1.0) = 7.9

C09 - Study Point
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.5
ODO mg/L (1.0) = 8.1

C14 - Study Point
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.6
ODO mg/L (1.0) = 7.6

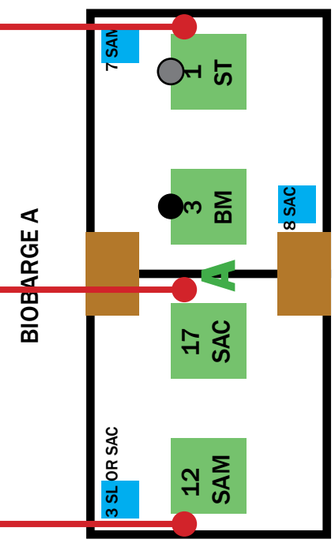


A01 - Study Point
ODO mg/L (0.3) = 8.4
ODO mg/L (0.6) = 8.3
ODO mg/L (1.0) = 7.9

Control Point T-108
ODO mg/L (0.3) = 8.5
ODO mg/L (0.6) = 8.2
ODO mg/L (1.0) = 8.0

A17 - Study Point
ODO mg/L (0.3) = 8.4
ODO mg/L (0.6) = 8.5
ODO mg/L (1.0) = 7.9

A12 - Study Point
ODO mg/L (0.3) = 8.6
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.3



T-102

Land Side

June 28th, 2019
Dissolved Oxygen Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1mg/L

Duwamish River

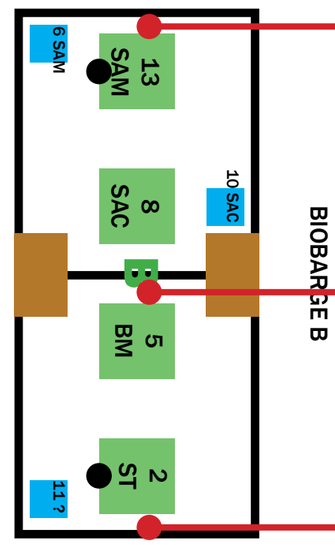
Numbers modified based on grab samples and titration

T-105 DEPLOYMENT
Water Quality Study Points

B13 Study Point
ODO mg/L (0.3) = 8.2
ODO mg/L (0.6) = 8.3
ODO mg/L (1.0) = 8.7

B05 Study Point
ODO mg/L (0.3) = 8.2
ODO mg/L (0.6) = 8.8
ODO mg/L (1.0) = 9.3

B02 Study Point
ODO mg/L (0.3) = 8.3
ODO mg/L (0.6) = 8.2
ODO mg/L (1.0) = 8.2

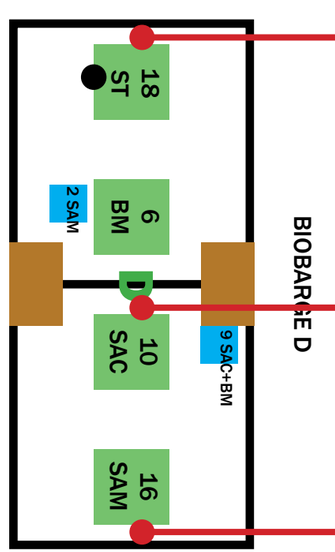


Control Point T-105
ODO mg/L (0.3) = 7.9
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 9.4

D18 Study Point
ODO mg/L (0.3) = 8.2
ODO mg/L (0.6) = 8.1
ODO mg/L (1.0) = 8.6

D10 Study Point
ODO mg/L (0.3) = 8.3
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.7

D16 Study Point
ODO mg/L (0.3) = 8.3
ODO mg/L (0.6) = 8.4
ODO mg/L (1.0) = 8.6



T-102

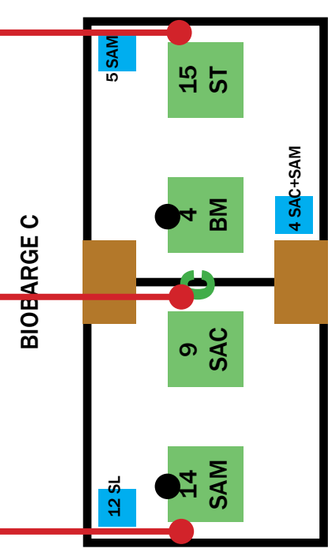
Land Side

T-108 DEPLOYMENT
Water Quality Study Points

C15 - Study Point
ODO mg/L (0.3) = 6.8
ODO mg/L (0.6) = 6.8
ODO mg/L (1.0) = 6.8

C09 - Study Point
ODO mg/L (0.3) = 6.8
ODO mg/L (0.6) = 6.8
ODO mg/L (1.0) = 6.8

C14 - Study Point
ODO mg/L (0.3) = 6.8
ODO mg/L (0.6) = 6.8
ODO mg/L (1.0) = 6.8

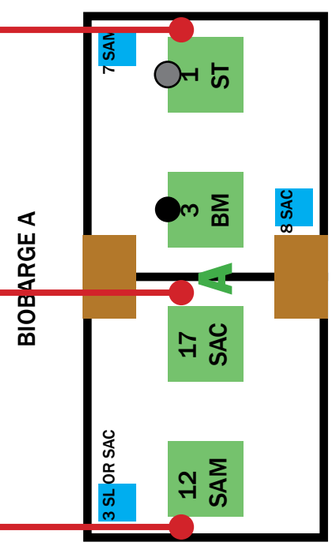


A01 - Study Point
ODO mg/L (0.3) = 6.8
ODO mg/L (0.6) = 6.8
ODO mg/L (1.0) = 6.8

Control Point T-108
ODO mg/L (0.3) = 6.8
ODO mg/L (0.6) = 6.8
ODO mg/L (1.0) = 6.8

A17 - Study Point
ODO mg/L (0.3) = 6.9
ODO mg/L (0.6) = 6.8
ODO mg/L (1.0) = 6.8

A12 - Study Point
ODO mg/L (0.3) = 6.8
ODO mg/L (0.6) = 6.8
ODO mg/L (1.0) = 6.8



T-102

July 3rd, 2019
Dissolved Oxygen Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1mg/L

Duwamish River

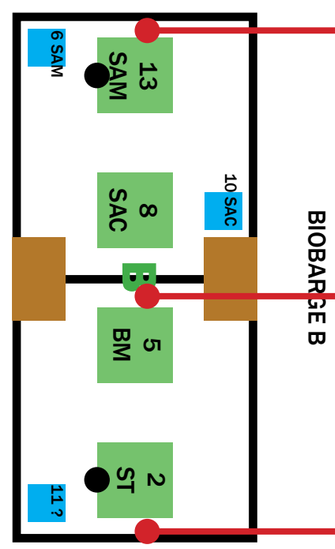
Numbers modified based on grab samples and titration

T-105 DEPLOYMENT
Water Quality Study Points

B13 Study Point
ODO mg/L (0.3) = 7.0
ODO mg/L (0.6) = 7.0
ODO mg/L (1.0) = 6.9

B05 Study Point
ODO mg/L (0.3) = 7.0
ODO mg/L (0.6) = 7.0
ODO mg/L (1.0) = 6.9

B02 Study Point
ODO mg/L (0.3) = 7.0
ODO mg/L (0.6) = 7.0
ODO mg/L (1.0) = 6.9

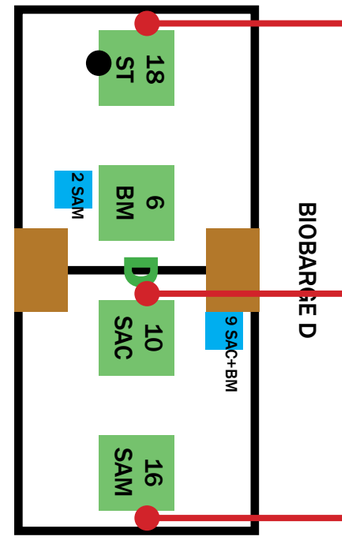


Control Point T-105
ODO mg/L (0.3) = 6.9
ODO mg/L (0.6) = 6.9
ODO mg/L (1.0) = 6.9

D18 Study Point
ODO mg/L (0.3) = 7.0
ODO mg/L (0.6) = 7.0
ODO mg/L (1.0) = 6.9

D10 Study Point
ODO mg/L (0.3) = 7.0
ODO mg/L (0.6) = 7.0
ODO mg/L (1.0) = 6.9

D16 Study Point
ODO mg/L (0.3) = 7.2
ODO mg/L (0.6) = 7.0
ODO mg/L (1.0) = 6.8



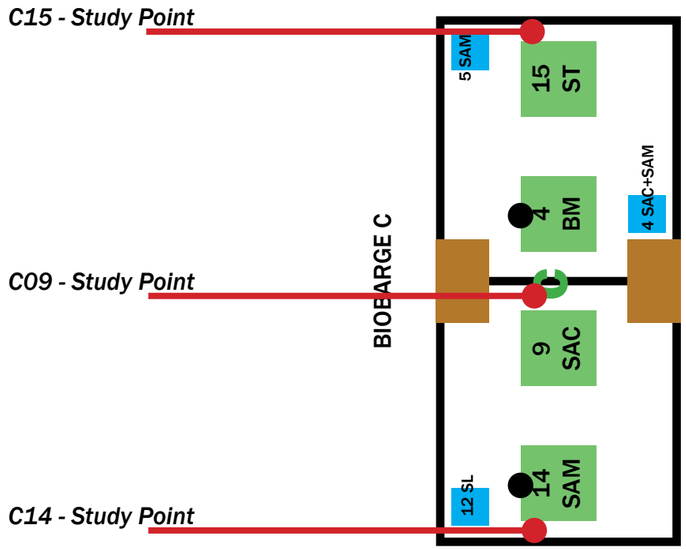
T-102

Land Side

Land Side

Land Side

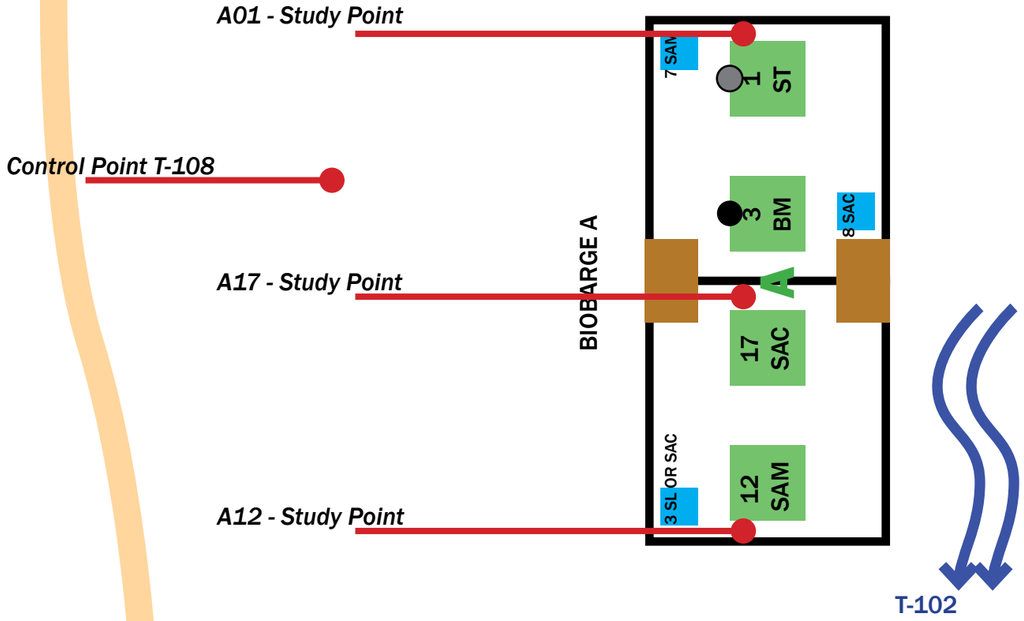
T-108 DEPLOYMENT
Water Quality Study Points



July 10th, 2019
Dissolved Oxygen Data

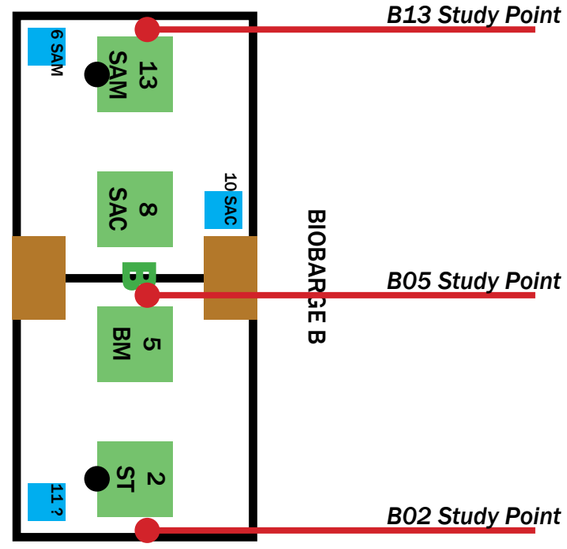
Accuracy threshold: +/- 1.0 % of the reading or 0.1mg/L

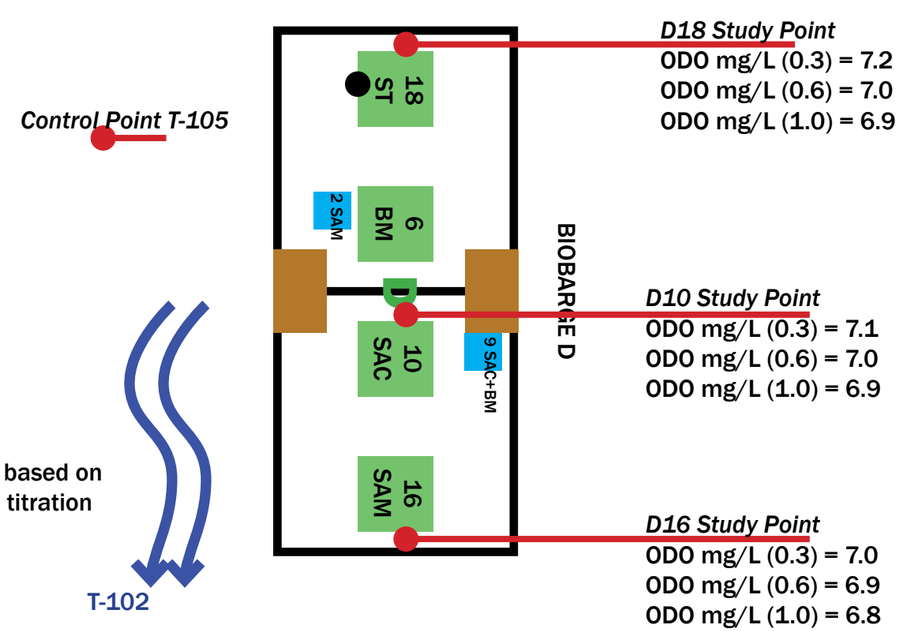
Duwamish River



Numbers modified based on grab samples and titration

T-105 DEPLOYMENT
Water Quality Study Points





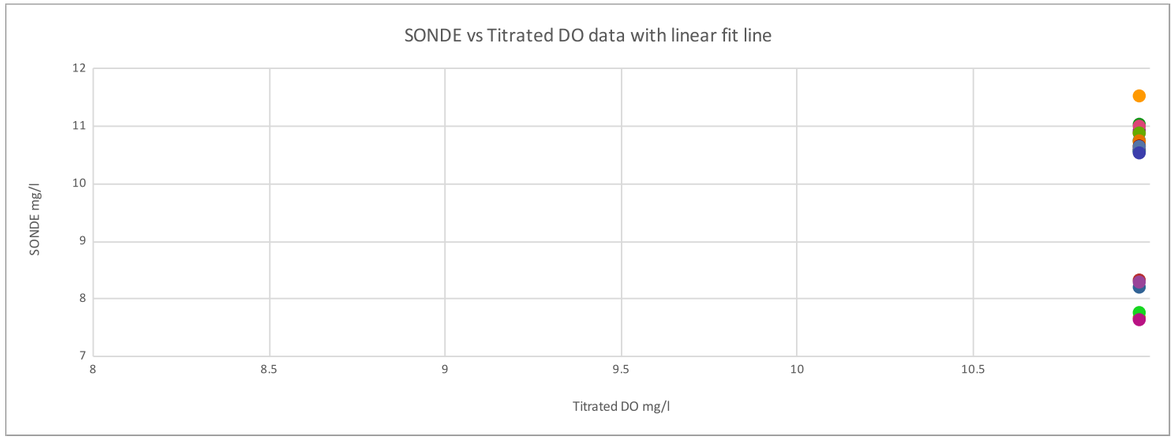
D18 Study Point
ODO mg/L (0.3) = 7.2
ODO mg/L (0.6) = 7.0
ODO mg/L (1.0) = 6.9

D10 Study Point
ODO mg/L (0.3) = 7.1
ODO mg/L (0.6) = 7.0
ODO mg/L (1.0) = 6.9

D16 Study Point
ODO mg/L (0.3) = 7.0
ODO mg/L (0.6) = 6.9
ODO mg/L (1.0) = 6.8

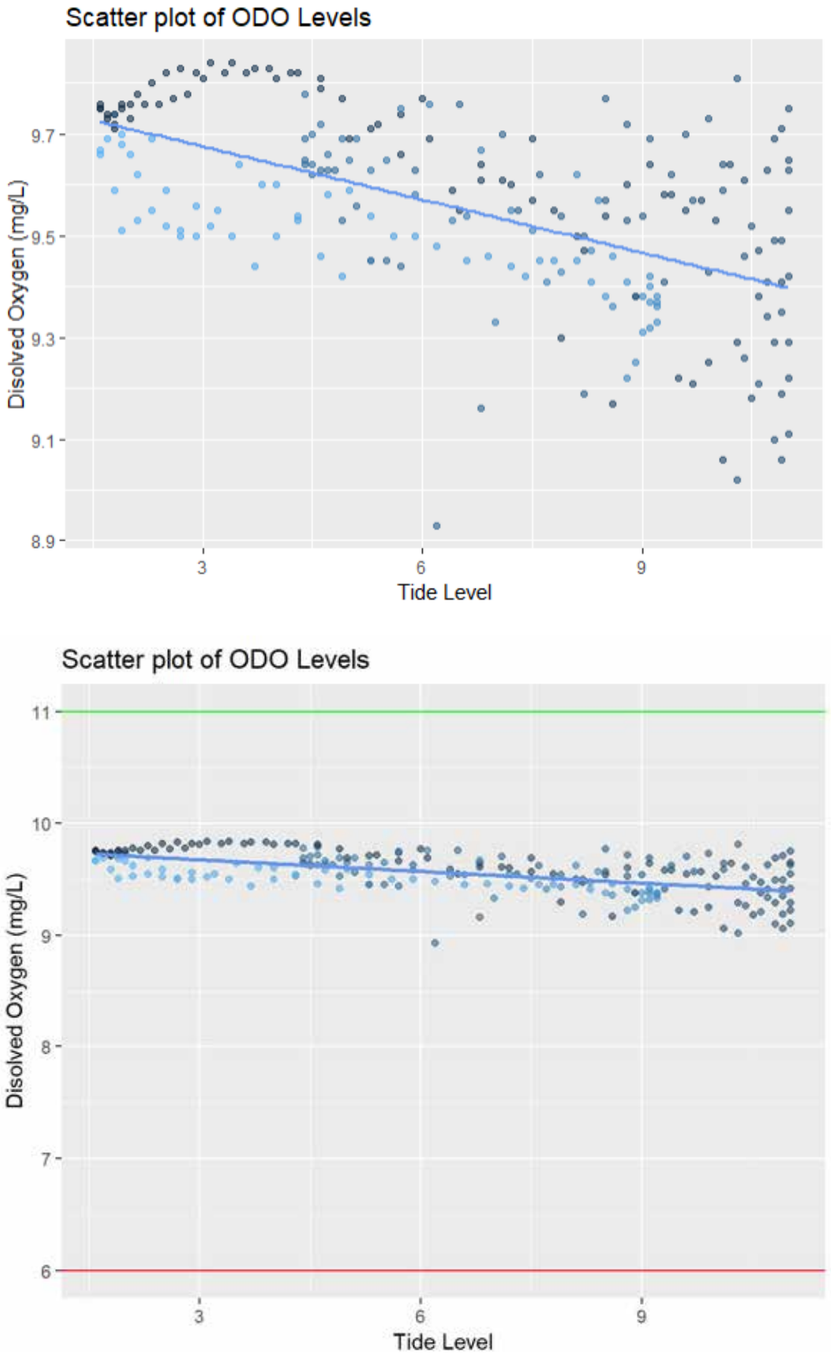
Land Side

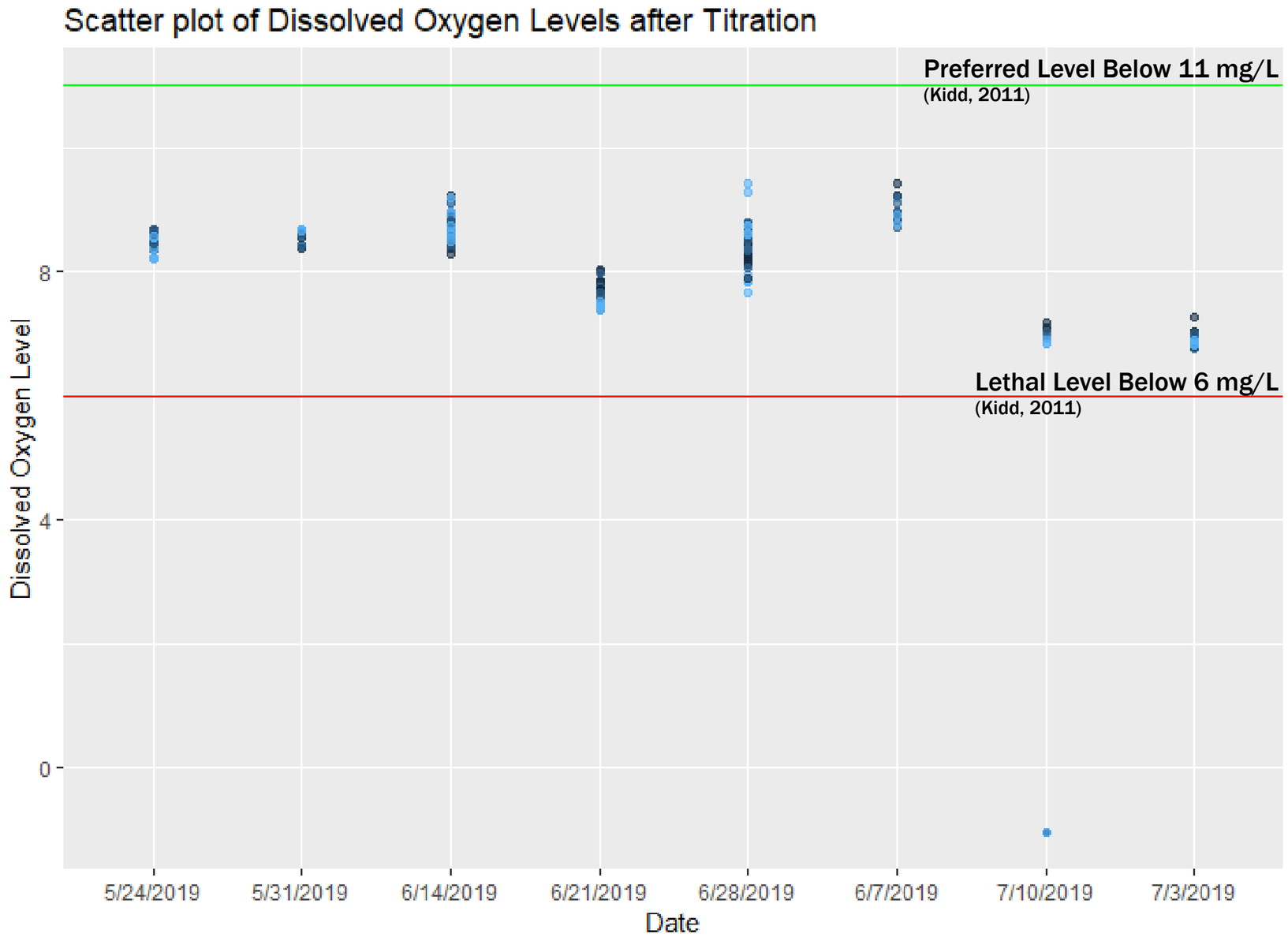
Barge	location	Depth (m)	O2 Bottle No.	O2Bottle Volume (ml)	Buret Reading (ml) - R	Standard (ml) - Rstd	Correction Factor (ml) - Rblk	DO (ml/l)	DO (mg/l)	SONDE	calibrated sonde
D	sp 4	0.3	25	133.23	0.682	0.481	0.002	6.15790079			
B	sp3	0.3	26A	140.44	0.898	0.481	0.002	7.684617124	10.97116748	10.58	10.167856
C	sp 12	0.3	27A	144.68	0.931	0.481	0.002	7.727205189	11.03196957	10.73	10.326586
D	sp 5	0.3	31	131.38	0.77	0.481	0.002	7.055952781			
D	sp2	0.3	32A	138.32	0.877	0.481	0.002	7.623108949	10.88335355	10.58	10.167856
C	sp 11	0.3	33	129.77	0.87	0.481	0.002	8.07692442	11.53125642	10.75	10.34775
C	sp 10	0.3	39	130.55	0.838	0.481	0.002	7.73114369	11.03759249	10.66	10.252512
B	sp 1	0.3	38	145.4	0.927	0.481	0.002	7.654708441	10.92846748	10.61	10.199602
D	sp 6	0.3	37	147.3	0.925	0.481	0.002	7.536760083	10.76007507	10.56	10.146692
C	cp 2	0.3	45	133.67	0.856	0.481	0.002	7.707321524	11.00358208	10.65	10.24193
	cp 3	0.3	44	132.72	0.842	0.481	0.002	7.636998627			
D	cp 1	0.3	43	132.92	0.842	0.481	0.002	7.625134833	10.88624586	10.54	10.125528



Barge	Locaton	Depth (m)	O2 Bottle No.	O2 Bottle Colume (ml)	Buret Reading (ml) - R	Standard (ml) - Rstd	Corection Factor (ml) - Rblk	DO (ml/l)	DO (mg/l)	SONDE	calibrated sonde
A	Acontrol	0.3	34A	142.79	0.747	0.492	0.005	6.150124529	8.780404431		
A	A3 mid	0.3	40	130.76	0.643	0.492	0.005	5.790397295	8.266829367		
A	A1 start	0.3	46	132.06	0.693	0.492	0.005	6.180749446	8.824126986		
A	A12 down	0.3	27A	144.68	0.754	0.492	0.005	6.124676376	8.744072635		
C	C9 mid	0.3	33	129.77	0.703	0.492	0.005	6.384856758	9.115526735		
C	C14 down	0.3	39	129.77	0.676	0.492	0.005	6.137878058	8.7629204		
C	C15 start	0.3	26A	140.44	0.723	0.492	0.005	6.053780537	8.642856124		
B	Bcontrol	0.3	32A	138.32	0.681	0.492	0.005	5.789690131	8.265819764		
B	B05	0.3	38	138.61	0.725	0.492	0.005	6.153238314	8.784849917		
B	B13 start	0.3	44	132.72	0.669	0.492	0.005	5.934530796	8.472605759		
B	B2 downstrea	0.3	25	133.23	0.652	0.492	0.005	5.759752913	8.223079022		
D	D10	0.3	31	131.38	0.651	0.492	0.005	5.834443063	8.329712591	7.674	7.0927268
D	D18	0.3	37	147.3	0.721	0.492	0.005	5.747705245	8.205878818	7.764	7.1879648
D	D16	0.3	43	132.92	0.656	0.492	0.005	5.809308927	8.29382911	7.64	7.056748
										9.9	9.44828

Dissolved Oxygen Data 5/24/2019	As depth increases... ODO has slight decrease	T-105 vs. T-108 105 is slightly higher	Biobarge vs Control No difference	Middle vs. Edge (of Biobarge) No difference
5/31/2019	Not consistent	105 is slightly higher	No difference	No difference
6/07/2019	Not consistent	NA	Biobarge slight increase	Not consistent
6/14/2019	Not consistent	108 is slightly higher	No difference	Not consistent
6/21/2019	ODO has slight decrease	No difference	No difference	No difference
6/28/2019	Not consistent	No difference	No difference	No difference
7/03/2019	No difference	105 is slightly higher	No difference	Not consistent
7/10/2019	ODO has slight decrease	NA	NA	NA
Consensus	**Not consistent**	**Not consistent/ No difference**	**No difference**	**Not consistent**


Scatter plot of ODO Levels
Disolved Oxygen (mg/L)
9.7
9.5
9.3
9.1
8.9
3
6
9
Tide Level
Scatter plot of ODO Levels
Disolved Oxygen (mg/L)
11
10
9
8
7
6
3
6
9
Tide Level


Scatter plot of Dissolved Oxygen Levels after Titration
Preferred Level Below 11 mg/L
(Kidd, 2011)
Lethal Level Below 6 mg/L
(Kidd, 2011)
Dissolved Oxygen Level
8
4
0
5/24/2019
5/31/2019
6/14/2019
6/21/2019
6/28/2019
6/7/2019
7/10/2019
7/3/2019
Date
1.0
0.8
0.6
0.4
Depth of Sonde measurement

T-108 DEPLOYMENT
Water Quality Study Points

June 14th, 2019
Turbidity Data

Accuracy threshold: +/- 2.0 % of the reading or 0.3 FNU

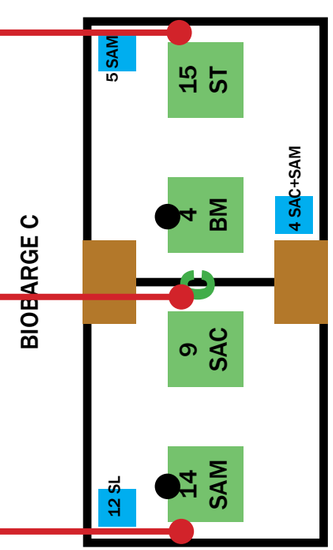
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Turbidity FNU (0.3) = 1.4
Turbidity FNU (0.6) = 1.4
Turbidity FNU (1.0) = 1.1

C09 - Study Point
Turbidity FNU (0.3) = 1.1
Turbidity FNU (0.6) = 1.5
Turbidity FNU (1.0) = 1.3

C14 - Study Point
Turbidity FNU (0.3) = 1.1
Turbidity FNU (0.6) = 0.9
Turbidity FNU (1.0) = 1.0

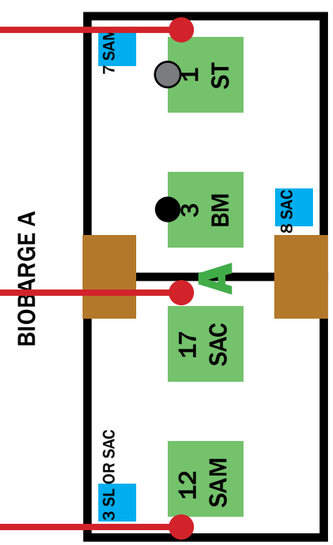


A01 - Study Point
Turbidity FNU (0.3) = 1.4
Turbidity FNU (0.6) = 1.4
Turbidity FNU (1.0) = 1.3

Control Point T-108
Turbidity FNU (0.3) = 1.5
Turbidity FNU (0.6) = 1.3
Turbidity FNU (1.0) = 1.3

A17 - Study Point
Turbidity FNU (0.3) = 1.6
Turbidity FNU (0.6) = 1.5
Turbidity FNU (1.0) = 1.3

A12 - Study Point
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.5
Turbidity FNU (1.0) = 1.5



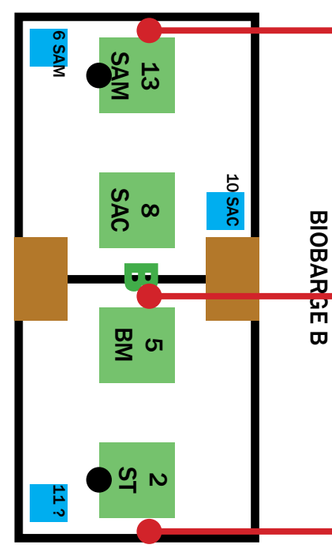
T-102

Duwamish River

B13 Study Point
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 0.9

B05 Study Point
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 1.2

B02 Study Point
Turbidity FNU (0.3) = 1.1
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 1.1

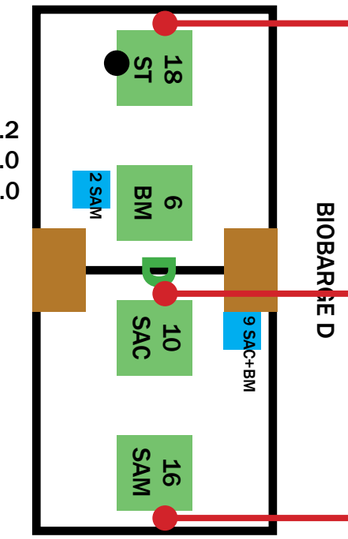


Control Point T-105
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.0

D18 Study Point
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.3
Turbidity FNU (1.0) = 1.3

D10 Study Point
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.4
Turbidity FNU (1.0) = 1.1

D16 Study Point
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.4
Turbidity FNU (1.0) = 1.3



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 21st, 2019
Turbidity Data

Accuracy threshold: +/- 2.0 % of the reading or 0.3 FNU

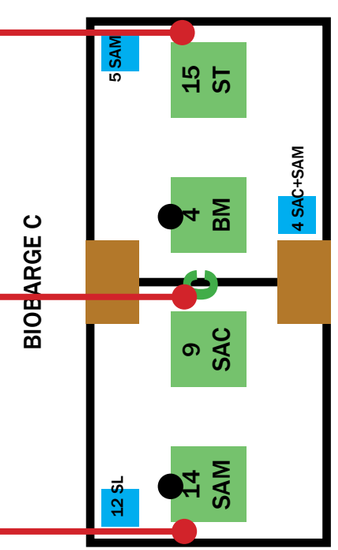
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Turbidity FNU (0.3) = 1.5
Turbidity FNU (0.6) = 1.6
Turbidity FNU (1.0) = 1.9

C09 - Study Point
Turbidity FNU (0.3) = 1.6
Turbidity FNU (0.6) = 1.7
Turbidity FNU (1.0) = 1.7

C14 - Study Point
Turbidity FNU (0.3) = 1.6
Turbidity FNU (0.6) = 1.6
Turbidity FNU (1.0) = 1.7

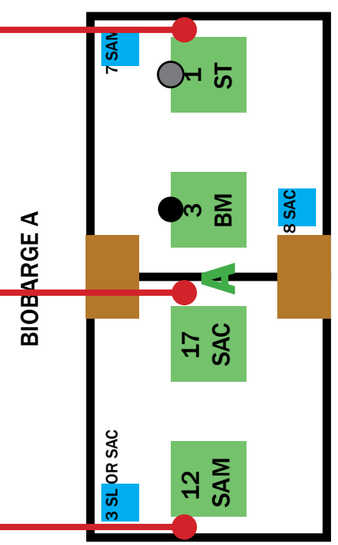


A01 - Study Point
Turbidity FNU (0.3) = 1.4
Turbidity FNU (0.6) = 1.6
Turbidity FNU (1.0) = 1.5

Control Point T-108
Turbidity FNU (0.3) = 1.6
Turbidity FNU (0.6) = 1.2
Turbidity FNU (1.0) = 1.4

A17 - Study Point
Turbidity FNU (0.3) = 1.8
Turbidity FNU (0.6) = 1.5
Turbidity FNU (1.0) = 1.3

A12 - Study Point
Turbidity FNU (0.3) = 2.0
Turbidity FNU (0.6) = 1.6
Turbidity FNU (1.0) = 1.3



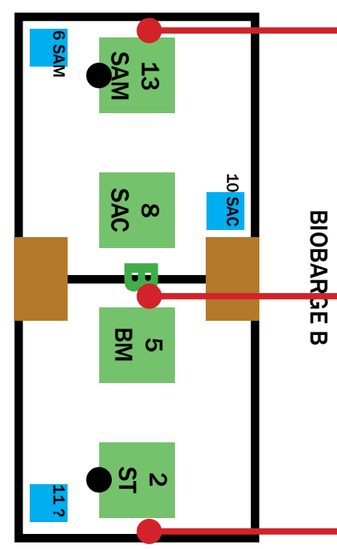
T-102

Duwamish River

B13 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 0.9

B05 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.0

B02 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.0

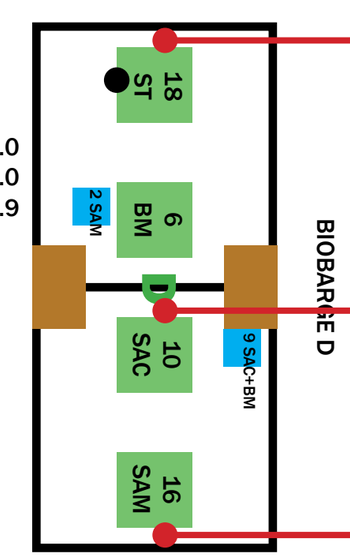


Control Point T-105
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 0.9

D18 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.0

D10 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 1.0

D16 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.0



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 28th, 2019
Turbidity Data

Accuracy threshold: +/- 2.0 % of the reading or 0.3 FNU

T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Turbidity FNU (0.3) = 1.6
Turbidity FNU (0.6) = 1.3
Turbidity FNU (1.0) = 1.2

C09 - Study Point
Turbidity FNU (0.3) = 1.1
Turbidity FNU (0.6) = 1.3
Turbidity FNU (1.0) = 1.2

C14 - Study Point
Turbidity FNU (0.3) = 2.5
Turbidity FNU (0.6) = 1.6
Turbidity FNU (1.0) = 1.1

BIOBARGE C

5 SAM
15 ST
4 BM
4 SAC+SAM
9 SAC
12 SL
14 SAM

B13 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 1.1

B05 Study Point
Turbidity FNU (0.3) = 0.9
Turbidity FNU (0.6) = 1.2
Turbidity FNU (1.0) = 1.3

B02 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 1.1

BIOBARGE B

6 SAM
13 SAM
8 SAC
10 SAC
5 BM
2 ST
11 ?

Land Side

Duwamish River

A01 - Study Point
Turbidity FNU (0.3) = 1.4
Turbidity FNU (0.6) = 1.4
Turbidity FNU (1.0) = 1.1

Control Point T-108
Turbidity FNU (0.3) = 1.7
Turbidity FNU (0.6) = 1.2
Turbidity FNU (1.0) = 1.3

A17 - Study Point
Turbidity FNU (0.3) = 1.3
Turbidity FNU (0.6) = 1.5
Turbidity FNU (1.0) = 1.1

A12 - Study Point
Turbidity FNU (0.3) = 1.8
Turbidity FNU (0.6) = 1.5
Turbidity FNU (1.0) = 1.2

BIOBARGE A

7 SAM
1 ST
3 BM
8 SAC
17 SAC
3 SL OR SAC
12 SAM

T-102

Control Point T-105
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 1.2

D18 Study Point
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.1

D10 Study Point
Turbidity FNU (0.3) = 1.3
Turbidity FNU (0.6) = 1.3
Turbidity FNU (1.0) = 1.1

D16 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 1.2

BIOBARGE D

18 ST
2 SAM
6 BM
10 SAC
9 SAC+BM
16 SAM

T-102

T-108 DEPLOYMENT
Water Quality Study Points

July 3rd, 2019
Turbidity Data

Accuracy threshold: +/- 2.0 % of the reading or 0.3 FNU

T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Turbidity FNU (0.3) = 3.1
Turbidity FNU (0.6) = 3.2
Turbidity FNU (1.0) = 2.7

C09 - Study Point
Turbidity FNU (0.3) = 4.1
Turbidity FNU (0.6) = 3.4
Turbidity FNU (1.0) = 3.1

C14 - Study Point
Turbidity FNU (0.3) = 3.3
Turbidity FNU (0.6) = 2.9
Turbidity FNU (1.0) = 2.8

BIOBARGE C

5 SAM
15 ST
4 BM
4 SAC+SAM
9 SAC
12 SL
14 SAM

A01 - Study Point
Turbidity FNU (0.3) = 4.1
Turbidity FNU (0.6) = 2.7
Turbidity FNU (1.0) = 3.0

Control Point T-108
Turbidity FNU (0.3) = 3.0
Turbidity FNU (0.6) = 3.4
Turbidity FNU (1.0) = 2.7

A17 - Study Point
Turbidity FNU (0.3) = 3.2
Turbidity FNU (0.6) = 3.5
Turbidity FNU (1.0) = 3.3

A12 - Study Point
Turbidity FNU (0.3) = 4.9
Turbidity FNU (0.6) = 3.6
Turbidity FNU (1.0) = 2.2

BIOBARGE A

7 SAM
1 ST
3 BM
8 SAC
17 SAC
3 SL OR SAC
12 SAM

T-102

Duwamish River

B13 Study Point
Turbidity FNU (0.3) = 1.1
Turbidity FNU (0.6) = 1.2
Turbidity FNU (1.0) = 1.2

B05 Study Point
Turbidity FNU (0.3) = 1.1
Turbidity FNU (0.6) = 1.3
Turbidity FNU (1.0) = 1.2

B02 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.1
Turbidity FNU (1.0) = 0.9

BIOBARGE B

6 SAM
13 SAM
8 SAC
10 SAC
5 BM
2 ST
11 ?

Control Point T-105
Turbidity FNU (0.3) = 1.1
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.0

D18 Study Point
Turbidity FNU (0.3) = 0.9
Turbidity FNU (0.6) = 1.7
Turbidity FNU (1.0) = 0.8

D10 Study Point
Turbidity FNU (0.3) = 0.9
Turbidity FNU (0.6) = 0.9
Turbidity FNU (1.0) = 0.8

D16 Study Point
Turbidity FNU (0.3) = 0.9
Turbidity FNU (0.6) = 0.9
Turbidity FNU (1.0) = 0.6

BIOBARGE D

18 ST
2 SAM
6 BM
10 SAC
9 SAC+BM
16 SAM

T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

July 10th, 2019
Turbidity Data

Accuracy threshold: +/- 2.0 % of the reading or 0.3 FNU

T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Turbidity FNU (0.3) = 1.6
Turbidity FNU (0.6) = 1.4
Turbidity FNU (1.0) = 1.5

C09 - Study Point
Turbidity FNU (0.3) = 1.2
Turbidity FNU (0.6) = 1.5
Turbidity FNU (1.0) = 1.6

C14 - Study Point
Turbidity FNU (0.3) = 1.9
Turbidity FNU (0.6) = 1.8
Turbidity FNU (1.0) = 1.5

BIOBARGE C

5 SAM
15 ST
4 BM
4 SAC+SAM
9 SAC
12 SL
14 SAM

B13 Study Point
Turbidity FNU (0.3) = 0.9
Turbidity FNU (0.6) = 0.9
Turbidity FNU (1.0) = 1.0

B05 Study Point
Turbidity FNU (0.3) = 0.9
Turbidity FNU (0.6) = 0.9
Turbidity FNU (1.0) = 1.0

B02 Study Point
Turbidity FNU (0.3) = 0.9
Turbidity FNU (0.6) = 0.8
Turbidity FNU (1.0) = 0.8

BIOBARGE B

6 SAM
13 SAM
8 SAC
10 SAC
5 BM
2 ST
11 ?

Land Side

Duwamish River

A01 - Study Point
Turbidity FNU (0.3) = 1.5
Turbidity FNU (0.6) = 1.2
Turbidity FNU (1.0) = 1.0

Control Point T-108
Turbidity FNU (0.3) = 1.9
Turbidity FNU (0.6) = 1.6
Turbidity FNU (1.0) = 1.8

A17 - Study Point
Turbidity FNU (0.3) = 1.4
Turbidity FNU (0.6) = 1.4
Turbidity FNU (1.0) = 1.3

A12 - Study Point
Turbidity FNU (0.3) = 1.3
Turbidity FNU (0.6) = 1.6
Turbidity FNU (1.0) = 1.5

BIOBARGE A

7 SAM
1 ST
3 BM
8 SAC
17 SAC
3 SL OR SAC
12 SAM

T-102

Control Point T-105
Turbidity FNU (0.3) = 0.8
Turbidity FNU (0.6) = 0.9
Turbidity FNU (1.0) = 0.9

D18 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 0.9

D10 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.0

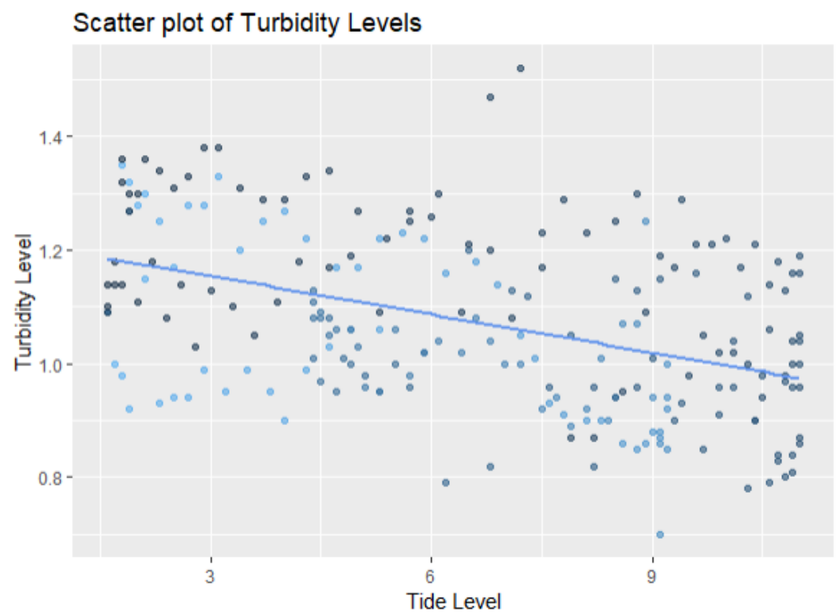
D16 Study Point
Turbidity FNU (0.3) = 1.0
Turbidity FNU (0.6) = 1.0
Turbidity FNU (1.0) = 1.0

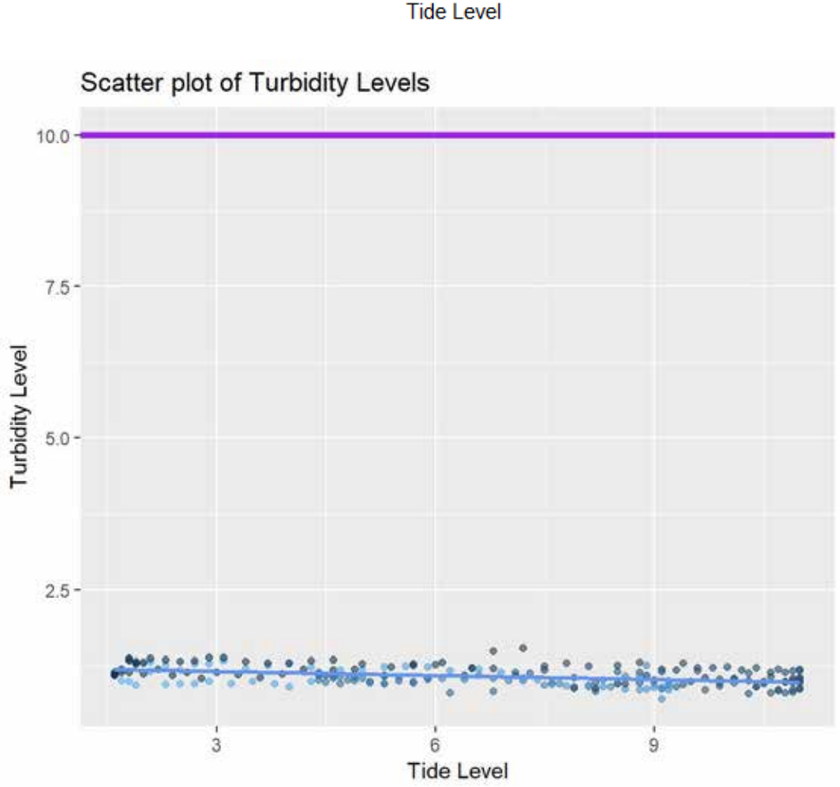
BIOBARGE D

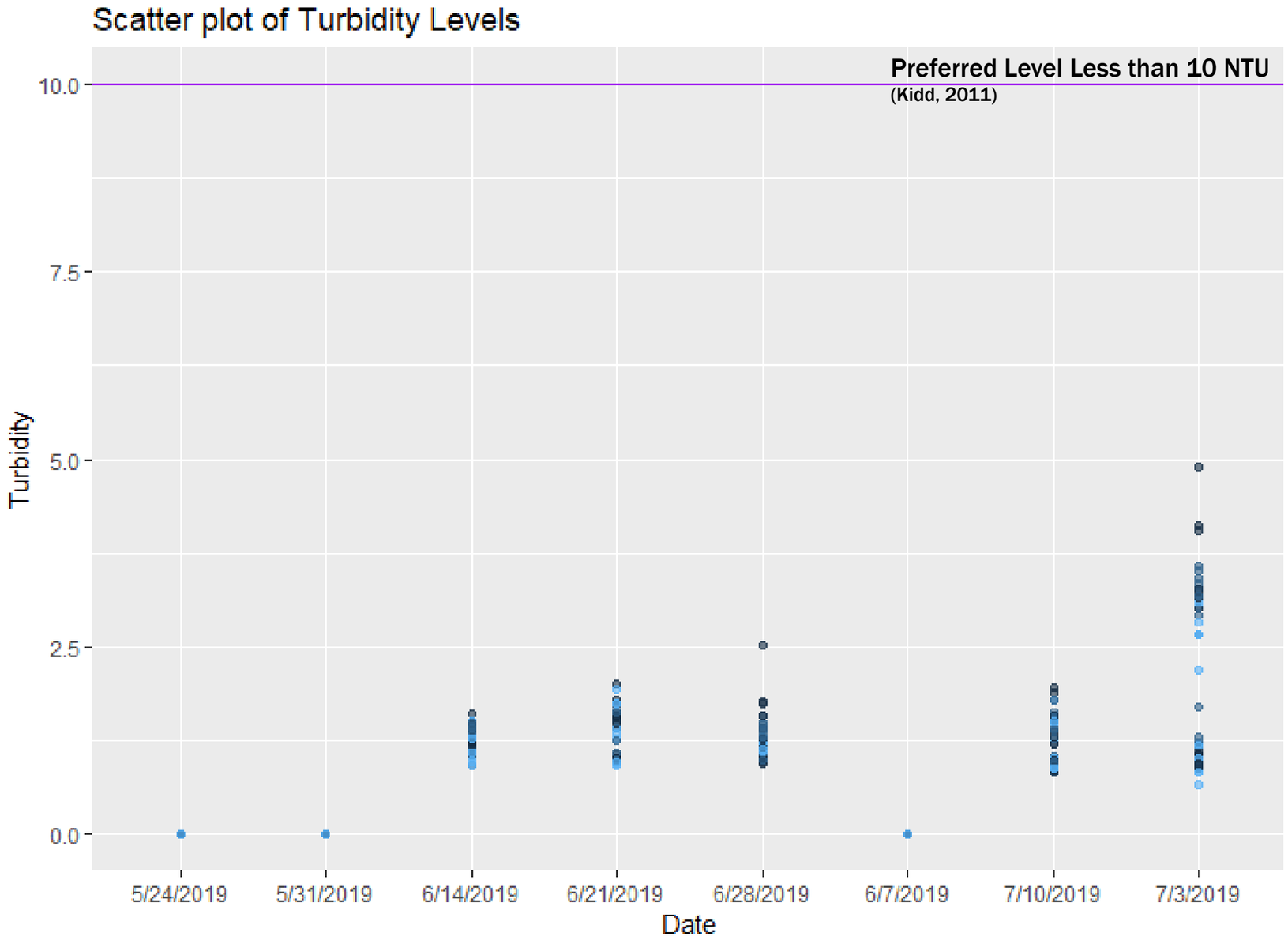
18 ST
2 SAM
6 BM
10 SAC
9 SAC+BM
16 SAM

T-102

Turbidity Data 5/24/2019	As depth increases…	T-105 vs. T-108	Biobarge vs Control	Middle vs. Edge (of Biobarge)
5/31/2019				
6/07/2019				
6/14/2019	No difference	Not consistent	No difference	No difference
6/21/2019	No difference	105 is lower	No difference	No difference
6/28/2019	Not consistent	Not consistent	No difference	No difference
7/03/2019	Not consistent	105 is lower	No difference	Not consistent
7/10/2019	No difference	105 is lower	No difference	Not consistent
Consensus	**No difference**	**105 is lower**	**No difference**	**No difference**


Scatter plot of Turbidity Levels
Turbidity Level
1.4
1.2
1.0
0.8
3
6
9
Tide Level


Scatter plot of Turbidity Levels
Turbidity Level
10.0
7.5
5.0
2.5
3
6
9
Tide Level


Scatter plot of Turbidity Levels
Preferred Level Less than 10 NTU
(Kidd, 2011)
Turbidity
10.0
7.5
5.0
2.5
0.0
5/24/2019
5/31/2019
6/14/2019
6/21/2019
6/28/2019
6/7/2019
7/10/2019
7/3/2019
Date
1.0
0.8
0.6
0.4
Depth of Sonde measurement

T-108 DEPLOYMENT
Water Quality Study Points

May 24th, 2019
Chlorophyll Data

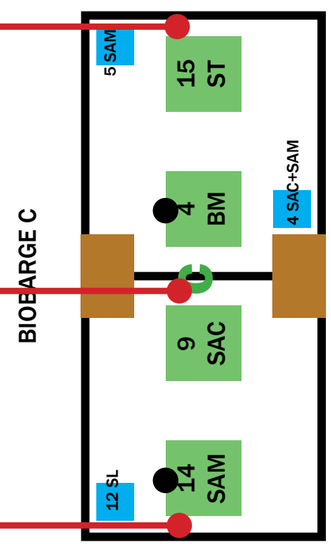
T-105 DEPLOYMENT
Water Quality Study Points

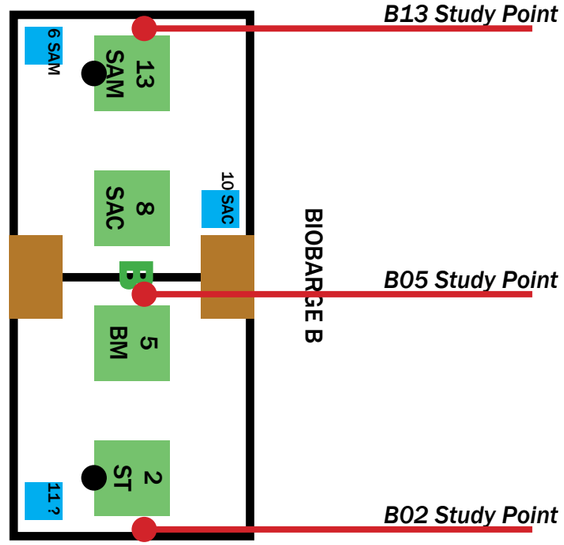
Land Side

C15 - Study Point
Chlorophyll (0.3) = 0.11
Chlorophyll (0.6) = 0.21
Chlorophyll (1.0) = 0.75

C09 - Study Point
Chlorophyll (0.3) = -0.07
Chlorophyll (0.6) = 0.11
Chlorophyll (1.0) = 0.14

C14 - Study Point
Chlorophyll (0.3) = 0.08
Chlorophyll (0.6) = 0.03
Chlorophyll (1.0) = 0.56

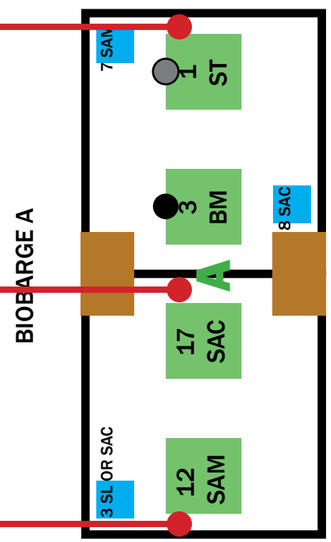




B13 Study Point
B05 Study Point
B02 Study Point

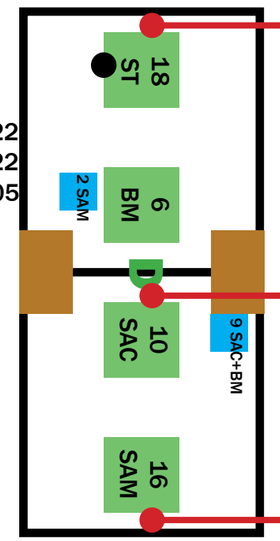
Duwamish River

A01 - Study Point
Control Point T-108
Chlorophyll (0.3) = 0.18
Chlorophyll (0.6) = 0.36
Chlorophyll (1.0) = 0.75
A17 - Study Point
A12 - Study Point



T-102

Control Point T-105
Chlorophyll (0.3) = -0.22
Chlorophyll (0.6) = -0.22
Chlorophyll (1.0) = -0.05



T-102

D18 Study Point
Chlorophyll (0.3) = -0.13
Chlorophyll (0.6) = -0.20
Chlorophyll (1.0) = -0.14

D10 Study Point
Chlorophyll (0.3) = -0.19
Chlorophyll (0.6) = -0.24
Chlorophyll (1.0) = 0.03

D16 Study Point
Chlorophyll (0.3) = -0.24
Chlorophyll (0.6) = -0.23
Chlorophyll (1.0) = -0.17

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

May 31st, 2019
Chlorophyll Data

T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Chlorophyll (0.3) = 0.46
Chlorophyll (0.6) = 0.81
Chlorophyll (1.0) = 3.00

C09 - Study Point
Chlorophyll (0.3) = 0.60
Chlorophyll (0.6) = 0.48
Chlorophyll (1.0) = 1.78

C14 - Study Point
Chlorophyll (0.3) = 0.22
Chlorophyll (0.6) = 0.41
Chlorophyll (1.0) = 0.92

BIOBARGE C
5 SAM
15 ST
4 BM
4 SAC+SAM
9 SAC
12 SL
14 SAM

A01 - Study Point

Control Point T-108
Chlorophyll (0.3) = 0.19
Chlorophyll (0.6) = 0.53
Chlorophyll (1.0) = 1.35

A17 - Study Point

A12 - Study Point

BIOBARGE A
7 SAM
1 ST
3 BM
8 SAC
17 SAC
3 SL OR SAC
12 SAM

T-102

Duwamish River

B13 Study Point

B05 Study Point

B02 Study Point

BIOBARGE B
6 SAM
13 SAM
8 SAC
10 SAC
5 BM
2 ST
11 ?

Control Point T-105
Chlorophyll (0.3) = 0.17
Chlorophyll (0.6) = 1.07
Chlorophyll (1.0) = 1.66

D18 Study Point
Chlorophyll (0.3) = 0.70
Chlorophyll (0.6) = 0.21
Chlorophyll (1.0) = 0.44

D10 Study Point
Chlorophyll (0.3) = 0.19
Chlorophyll (0.6) = 0.07
Chlorophyll (1.0) = 1.06

D16 Study Point
Chlorophyll (0.3) = 0.52
Chlorophyll (0.6) = 0.54
Chlorophyll (1.0) = 1.05

BIOBARGE D
18 ST
2 SAM
6 BM
10 SAC
9 SAC+BM
16 SAM

T-102

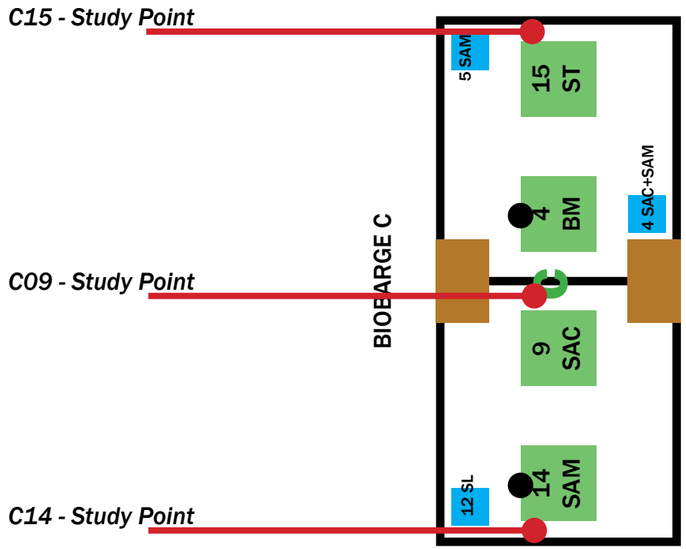
Land Side

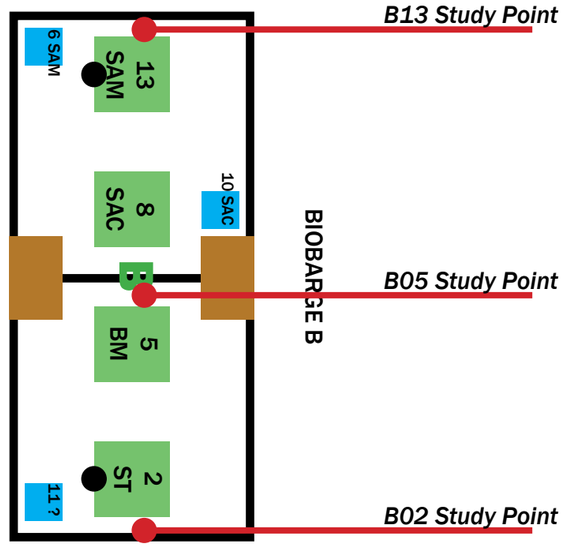
T-108 DEPLOYMENT
Water Quality Study Points

June 7th, 2019
Chlorophyll Data

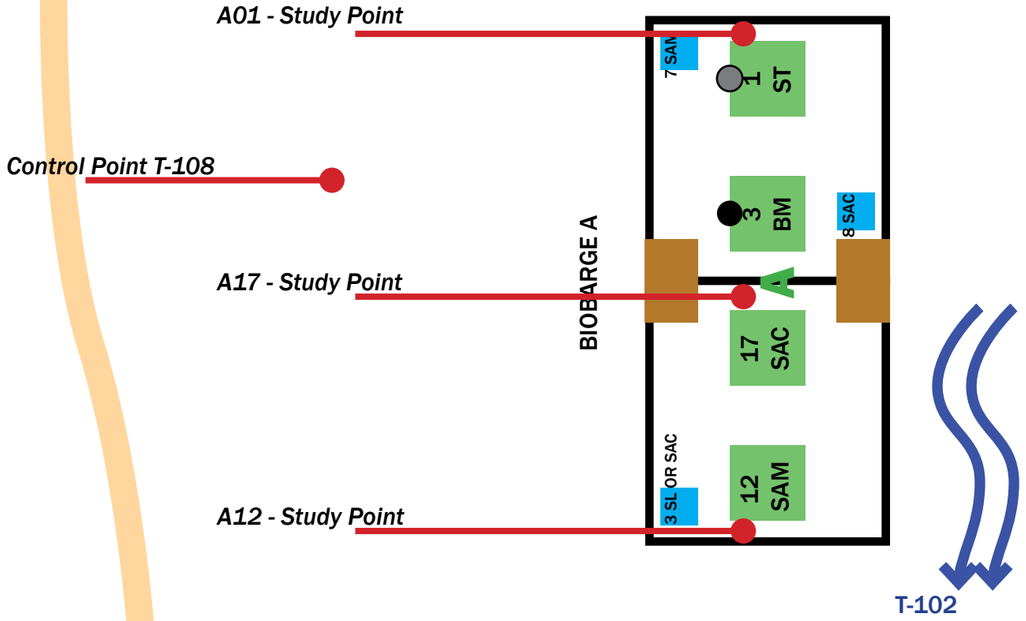
T-105 DEPLOYMENT
Water Quality Study Points

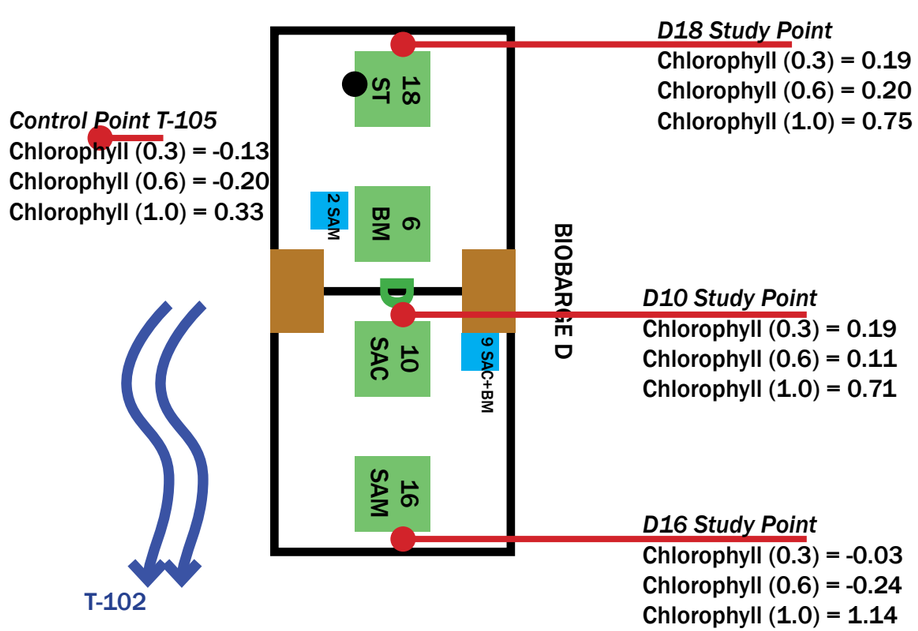
Land Side





Duwamish River





D18 Study Point
Chlorophyll (0.3) = 0.19
Chlorophyll (0.6) = 0.20
Chlorophyll (1.0) = 0.75

D10 Study Point
Chlorophyll (0.3) = 0.19
Chlorophyll (0.6) = 0.11
Chlorophyll (1.0) = 0.71

D16 Study Point
Chlorophyll (0.3) = -0.03
Chlorophyll (0.6) = -0.24
Chlorophyll (1.0) = 1.14

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 14th, 2019
Chlorophyll Data

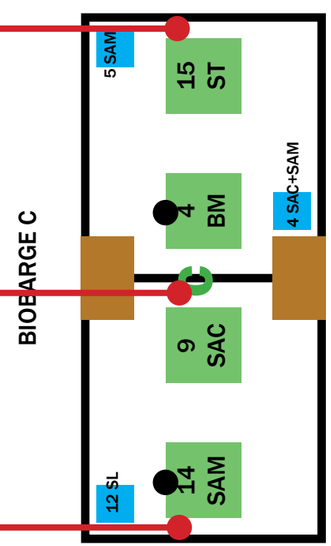
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Chlorophyll (0.3) = 0.08
Chlorophyll (0.6) = 0.53
Chlorophyll (1.0) = 3.32

C09 - Study Point
Chlorophyll (0.3) = 0.26
Chlorophyll (0.6) = 0.49
Chlorophyll (1.0) = 4.24

C14 - Study Point
Chlorophyll (0.3) = 0.14
Chlorophyll (0.6) = 0.34
Chlorophyll (1.0) = 1.26

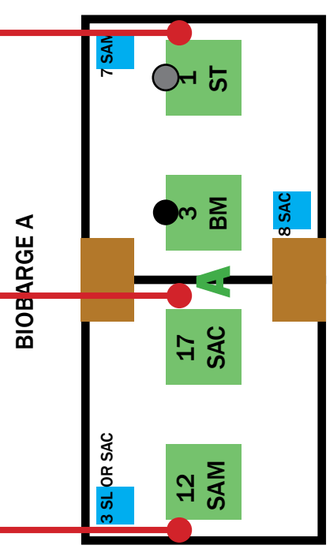


A01 - Study Point
Chlorophyll (0.3) = 1.57
Chlorophyll (0.6) = 2.42
Chlorophyll (1.0) = 6.61

Control Point T-108
Chlorophyll (0.3) = 0.83
Chlorophyll (0.6) = 2.20
Chlorophyll (1.0) = 7.63

A17 - Study Point
Chlorophyll (0.3) = 5.21
Chlorophyll (0.6) = 12.64
Chlorophyll (1.0) = 7.60

A12 - Study Point
Chlorophyll (0.3) = 0.13
Chlorophyll (0.6) = 1.82
Chlorophyll (1.0) = 12.76



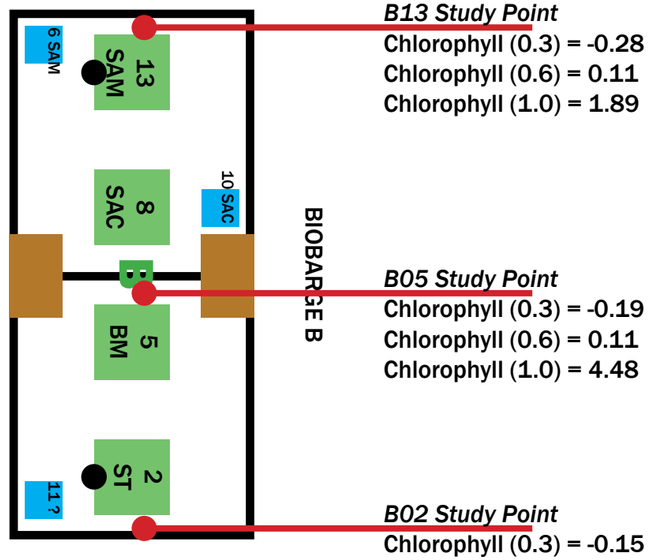
T-102

Duwamish River

B13 Study Point
Chlorophyll (0.3) = -0.28
Chlorophyll (0.6) = 0.11
Chlorophyll (1.0) = 1.89

B05 Study Point
Chlorophyll (0.3) = -0.19
Chlorophyll (0.6) = 0.11
Chlorophyll (1.0) = 4.48

B02 Study Point
Chlorophyll (0.3) = -0.15
Chlorophyll (0.6) = 0.84
Chlorophyll (1.0) = 3.25

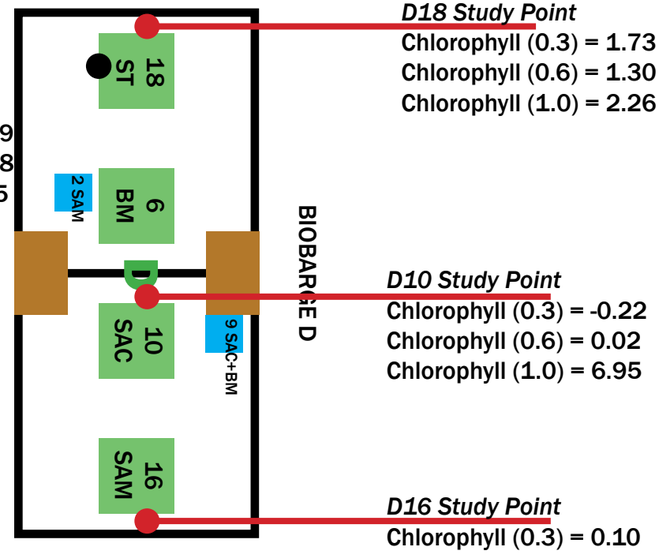


Control Point T-105
Chlorophyll (0.3) = -0.19
Chlorophyll (0.6) = -0.18
Chlorophyll (1.0) = 0.25

D18 Study Point
Chlorophyll (0.3) = 1.73
Chlorophyll (0.6) = 1.30
Chlorophyll (1.0) = 2.26

D10 Study Point
Chlorophyll (0.3) = -0.22
Chlorophyll (0.6) = 0.02
Chlorophyll (1.0) = 6.95

D16 Study Point
Chlorophyll (0.3) = 0.10
Chlorophyll (0.6) = 0.04
Chlorophyll (1.0) = 2.57



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 21st, 2019
Chlorophyll Data

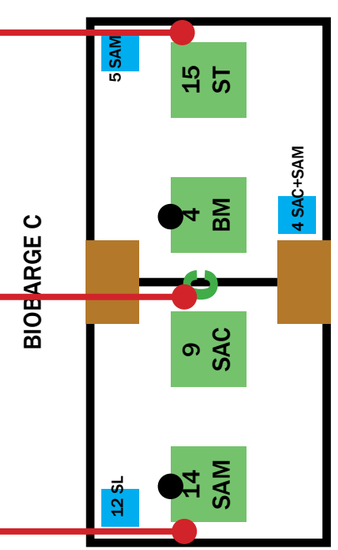
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Chlorophyll (0.3) = -0.30
Chlorophyll (0.6) = -0.19
Chlorophyll (1.0) = -0.16

C09 - Study Point
Chlorophyll (0.3) = -0.23
Chlorophyll (0.6) = -0.26
Chlorophyll (1.0) = -0.22

C14 - Study Point
Chlorophyll (0.3) = -0.31
Chlorophyll (0.6) = -0.35
Chlorophyll (1.0) = -0.28

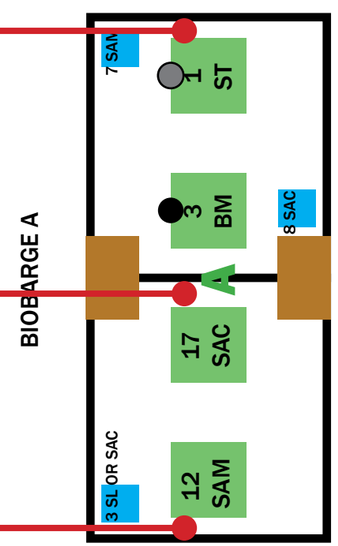


A01 - Study Point
Chlorophyll (0.3) = -0.17
Chlorophyll (0.6) = -0.26
Chlorophyll (1.0) = -0.36

Control Point T-108
Chlorophyll (0.3) = -0.26
Chlorophyll (0.6) = -0.25
Chlorophyll (1.0) = -0.29

A17 - Study Point
Chlorophyll (0.3) = -0.23
Chlorophyll (0.6) = -0.24
Chlorophyll (1.0) = -0.26

A12 - Study Point
Chlorophyll (0.3) = -0.10
Chlorophyll (0.6) = -0.31
Chlorophyll (1.0) = -0.31



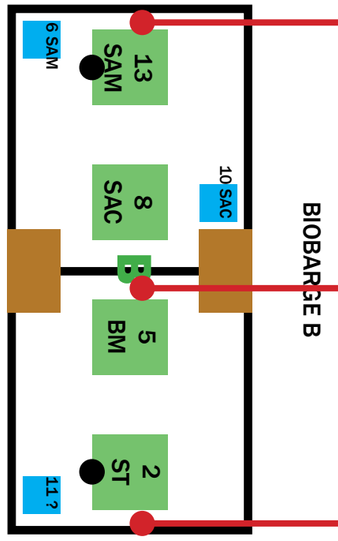
T-102

Duwamish River

B13 Study Point
Chlorophyll (0.3) = -0.36
Chlorophyll (0.6) = -0.37
Chlorophyll (1.0) = -0.28

B05 Study Point
Chlorophyll (0.3) = -0.32
Chlorophyll (0.6) = -0.38
Chlorophyll (1.0) = -0.31

B02 Study Point
Chlorophyll (0.3) = -0.22
Chlorophyll (0.6) = -0.29
Chlorophyll (1.0) = -0.28

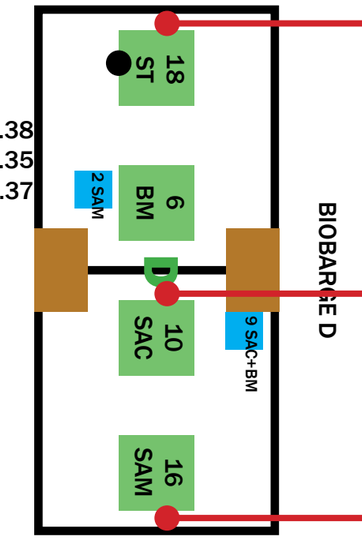


Control Point T-105
Chlorophyll (0.3) = -0.38
Chlorophyll (0.6) = -0.35
Chlorophyll (1.0) = -0.37

D18 Study Point
Chlorophyll (0.3) = -0.34
Chlorophyll (0.6) = -0.35
Chlorophyll (1.0) = -0.33

D10 Study Point
Chlorophyll (0.3) = -0.32
Chlorophyll (0.6) = -0.27
Chlorophyll (1.0) = -0.26

D16 Study Point
Chlorophyll (0.3) = -0.36
Chlorophyll (0.6) = -0.33
Chlorophyll (1.0) = -0.31



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 28th, 2019
Chlorophyll Data

T-105 DEPLOYMENT
Water Quality Study Points

Land Side

Land Side

Duwamish River

C15 - Study Point
Chlorophyll (0.3) = 0.12
Chlorophyll (0.6) = 0.34
Chlorophyll (1.0) = 0.68

C09 - Study Point
Chlorophyll (0.3) = 0.51
Chlorophyll (0.6) = 0.73
Chlorophyll (1.0) = 0.81

C14 - Study Point
Chlorophyll (0.3) = 0.65
Chlorophyll (0.6) = 0.47
Chlorophyll (1.0) = 0.57

BIOBARGE C
5 SAM
15 ST
4 BM
4 SAC+SAM
9 SAC
12 SL
14 SAM

A01 - Study Point
Chlorophyll (0.3) = 0.26
Chlorophyll (0.6) = 0.37
Chlorophyll (1.0) = 0.36

Control Point T-108
Chlorophyll (0.3) = 0.27
Chlorophyll (0.6) = 0.39
Chlorophyll (1.0) = 0.69

A17 - Study Point
Chlorophyll (0.3) = 0.32
Chlorophyll (0.6) = 0.73
Chlorophyll (1.0) = 0.46

A12 - Study Point
Chlorophyll (0.3) = 0.17
Chlorophyll (0.6) = 0.24
Chlorophyll (1.0) = 0.92

BIOBARGE A
7 SAM
1 ST
3 BM
8 SAC
17 SAC
3 SL OR SAC
12 SAM

T-102

B13 Study Point
Chlorophyll (0.3) = 0.05
Chlorophyll (0.6) = 0.17
Chlorophyll (1.0) = 0.98

B05 Study Point
Chlorophyll (0.3) = 0.12
Chlorophyll (0.6) = 0.18
Chlorophyll (1.0) = 0.60

B02 Study Point
Chlorophyll (0.3) = 0.11
Chlorophyll (0.6) = 0.04
Chlorophyll (1.0) = 0.52

BIOBARGE B
6 SAM
13 SAM
8 SAC
10 SAC
5 BM
2 ST
11 ?

Control Point T-105
Chlorophyll (0.3) = -0.13
Chlorophyll (0.6) = 0.00
Chlorophyll (1.0) = 0.65

D18 Study Point
Chlorophyll (0.3) = 0.12
Chlorophyll (0.6) = 0.15
Chlorophyll (1.0) = 0.72

D10 Study Point
Chlorophyll (0.3) = 0.17
Chlorophyll (0.6) = 0.26
Chlorophyll (1.0) = 1.02

D16 Study Point
Chlorophyll (0.3) = 0.11
Chlorophyll (0.6) = 0.23
Chlorophyll (1.0) = 0.70

BIOBARGE D
18 ST
2 SAM
6 BM
10 SAC
9 SAC+BM
16 SAM

T-102

T-108 DEPLOYMENT
Water Quality Study Points

July 3rd, 2019
Chlorophyll Data

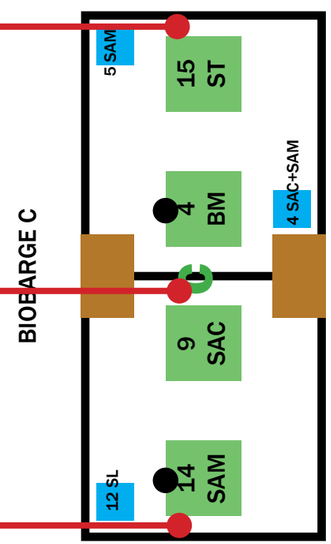
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Chlorophyll (0.3) = 1.87
Chlorophyll (0.6) = 2.38
Chlorophyll (1.0) = 2.51

C09 - Study Point
Chlorophyll (0.3) = 1.89
Chlorophyll (0.6) = 1.85
Chlorophyll (1.0) = 2.03

C14 - Study Point
Chlorophyll (0.3) = 1.81
Chlorophyll (0.6) = 1.78
Chlorophyll (1.0) = 2.14

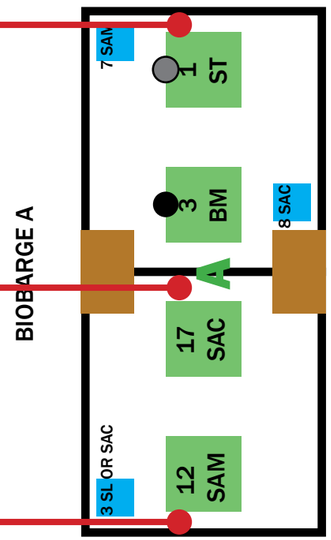


A01 - Study Point
Chlorophyll (0.3) = 2.19
Chlorophyll (0.6) = 1.74
Chlorophyll (1.0) = 1.90

Control Point T-108
Chlorophyll (0.3) = 1.58
Chlorophyll (0.6) = 2.06
Chlorophyll (1.0) = 2.32

A17 - Study Point
Chlorophyll (0.3) = 2.29
Chlorophyll (0.6) = 1.96
Chlorophyll (1.0) = 1.95

A12 - Study Point
Chlorophyll (0.3) = 2.39
Chlorophyll (0.6) = 2.60
Chlorophyll (1.0) = 2.25



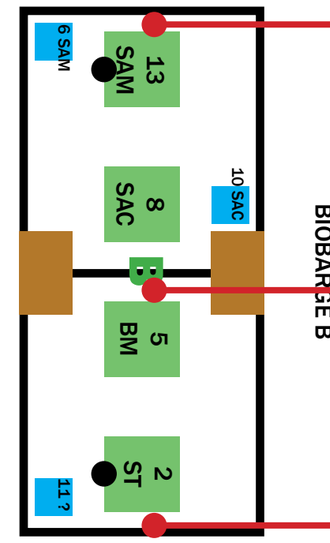
T-102

Duwamish River

B13 Study Point
Chlorophyll (0.3) = 1.66
Chlorophyll (0.6) = 1.73
Chlorophyll (1.0) = 1.63

B05 Study Point
Chlorophyll (0.3) = 1.55
Chlorophyll (0.6) = 1.81
Chlorophyll (1.0) = 1.79

B02 Study Point
Chlorophyll (0.3) = 1.52
Chlorophyll (0.6) = 1.49
Chlorophyll (1.0) = 1.64

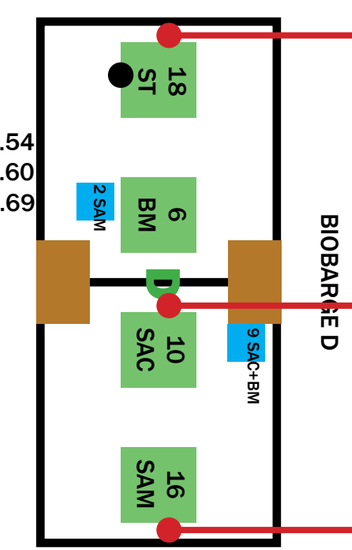


Control Point T-105
Chlorophyll (0.3) = 1.54
Chlorophyll (0.6) = 1.60
Chlorophyll (1.0) = 1.69

D18 Study Point
Chlorophyll (0.3) = 1.60
Chlorophyll (0.6) = 1.75
Chlorophyll (1.0) = 1.84

D10 Study Point
Chlorophyll (0.3) = 1.56
Chlorophyll (0.6) = 1.88
Chlorophyll (1.0) = 1.47

D16 Study Point
Chlorophyll (0.3) = 1.76
Chlorophyll (0.6) = 1.71
Chlorophyll (1.0) = 1.52



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

July 10th, 2019
Chlorophyll Data

T-105 DEPLOYMENT
Water Quality Study Points

Land Side

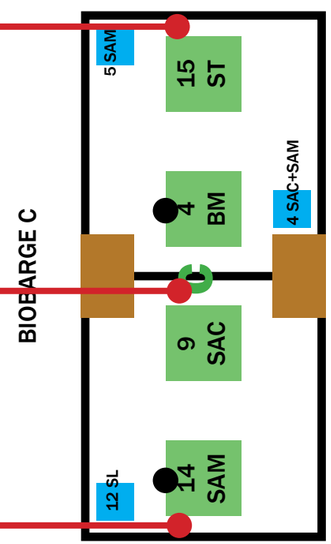
Land Side

Duwamish River

C15 - Study Point
Chlorophyll (0.3) = 2.86
Chlorophyll (0.6) = 2.59
Chlorophyll (1.0) = 1.98

C09 - Study Point
Chlorophyll (0.3) = 1.57
Chlorophyll (0.6) = 1.70
Chlorophyll (1.0) = 1.77

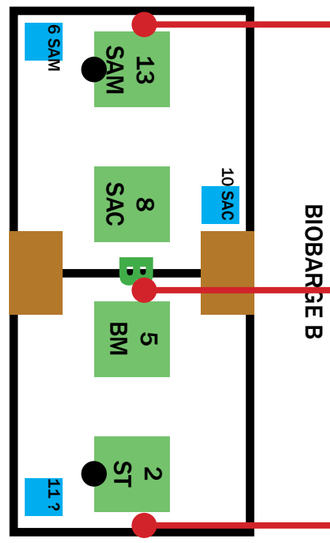
C14 - Study Point
Chlorophyll (0.3) = 1.97
Chlorophyll (0.6) = 1.70
Chlorophyll (1.0) = 1.76



B13 Study Point
Chlorophyll (0.3) = 1.51
Chlorophyll (0.6) = 1.57
Chlorophyll (1.0) = 1.84

B05 Study Point
Chlorophyll (0.3) = 1.45
Chlorophyll (0.6) = 1.67
Chlorophyll (1.0) = 1.96

B02 Study Point
Chlorophyll (0.3) = 1.30
Chlorophyll (0.6) = 1.22
Chlorophyll (1.0) = 1.44

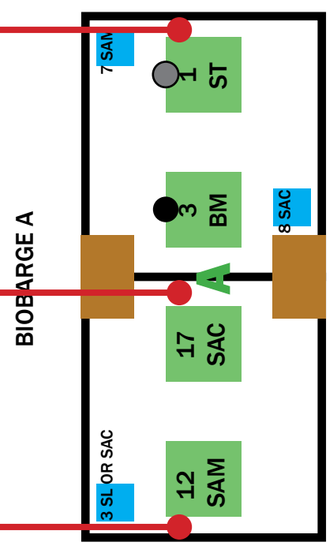


A01 - Study Point
Chlorophyll (0.3) = 1.67
Chlorophyll (0.6) = 1.69
Chlorophyll (1.0) = 1.74

Control Point T-108
Chlorophyll (0.3) = 2.25
Chlorophyll (0.6) = 1.88
Chlorophyll (1.0) = 2.15

A17 - Study Point
Chlorophyll (0.3) = 1.35
Chlorophyll (0.6) = 1.45
Chlorophyll (1.0) = 1.73

A12 - Study Point
Chlorophyll (0.3) = 1.58
Chlorophyll (0.6) = 1.85
Chlorophyll (1.0) = 1.69



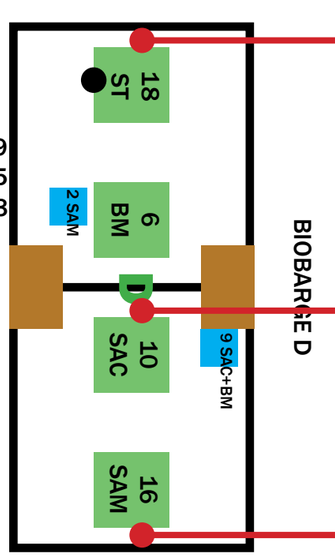
T-102

Control Point T-105
Chlorophyll (0.3) = 1.69
Chlorophyll (0.6) = 1.65
Chlorophyll (1.0) = 1.53

D18 Study Point
Chlorophyll (0.3) = 1.38
Chlorophyll (0.6) = 1.45
Chlorophyll (1.0) = 1.78

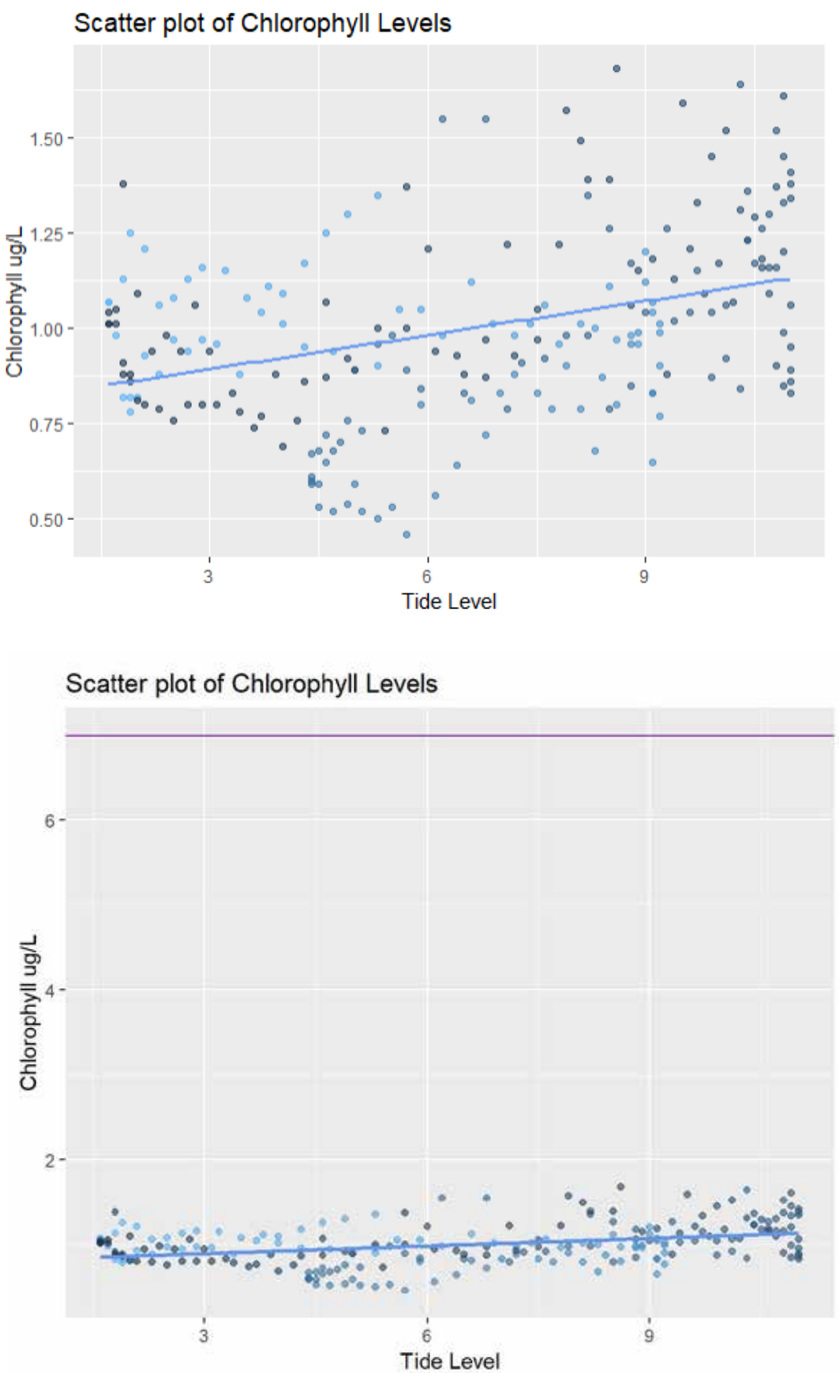
D10 Study Point
Chlorophyll (0.3) = 1.49
Chlorophyll (0.6) = 1.55
Chlorophyll (1.0) = 2.02

D16 Study Point
Chlorophyll (0.3) = 1.66
Chlorophyll (0.6) = 2.00
Chlorophyll (1.0) = 2.36

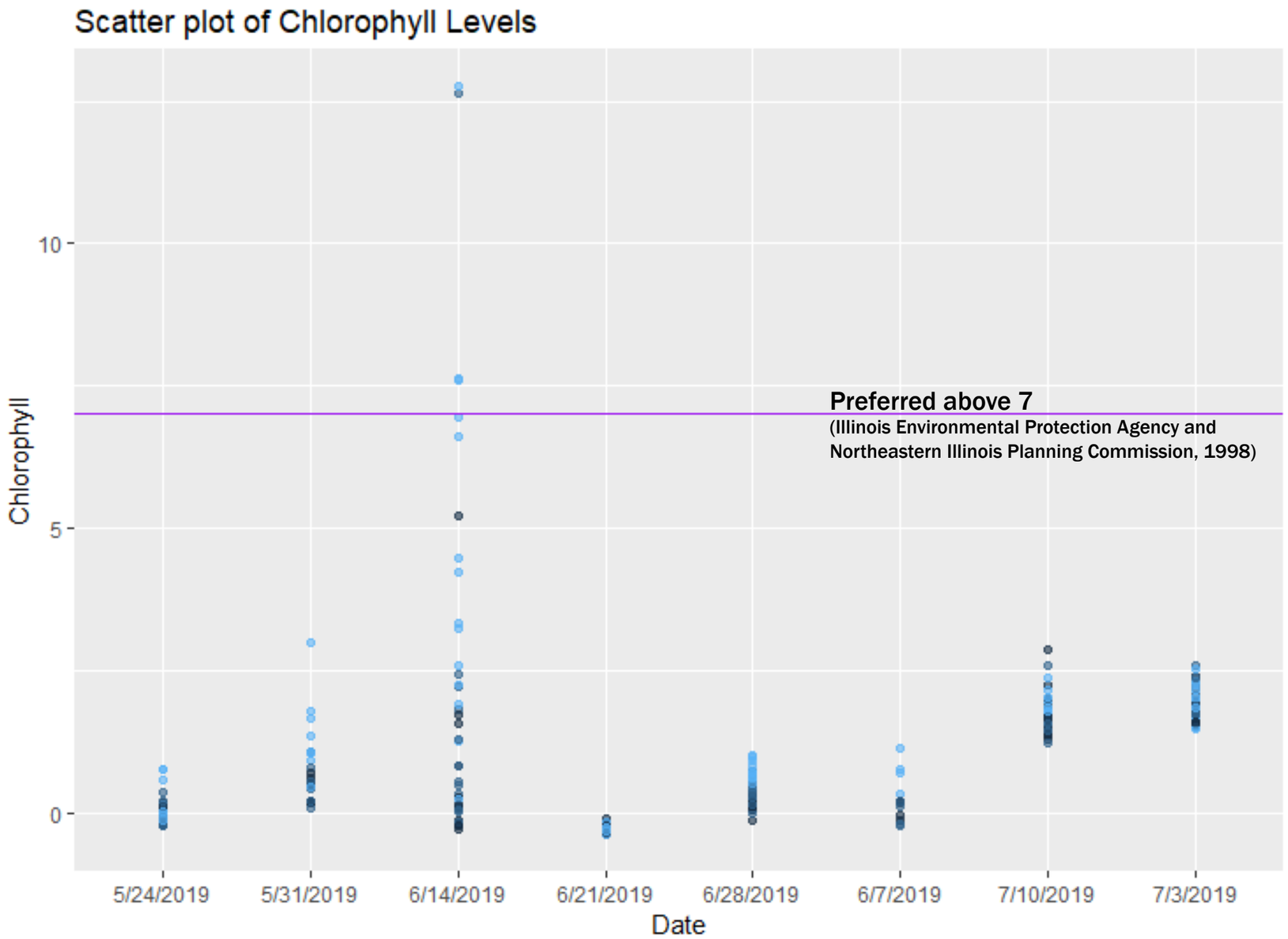


T-102

Chlorophyll Data	As depth increases…	T-105 vs. T-108	Biobarge vs Control	Middle vs. Edge (of Biobarge)
5/24/2019	Not consistent	105 is lower	No difference	No difference
5/31/2019	Not consistent	No difference	No difference	No difference
6/07/2019	Not consistent	NA	No difference	No difference
6/14/2019	Not consistent	No difference	No difference	No difference
6/21/2019	Not consistent	No difference	No difference	No difference
6/28/2019	Not consistent	Not consistent	No difference	No difference
7/03/2019	No difference	Not consistent	No difference	No difference
7/10/2019	No difference	Not consistent	No difference	No difference
Consensus	**Not consistent**	**Not consistent**	**No difference**	**No difference**


Scatter plot of Chlorophyll Levels
Chlorophyll ug/L
1.50
1.25
1.00
0.75
0.50
3
6
9
Tide Level

Scatter plot of Chlorophyll Levels
Chlorophyll ug/L
6
4
2
3
6
9
Tide Level


Scatter plot of Chlorophyll Levels
Chlorophyll
10
5
0
5/24/2019
5/31/2019
6/14/2019
6/21/2019
6/28/2019
6/7/2019
7/10/2019
7/3/2019
Date
Preferred above 7
(Illinois Environmental Protection Agency and Northeastern Illinois Planning Commission, 1998)
1.0
0.8
0.6
0.4
Depth of Sonde measurement

T-108 DEPLOYMENT
Water Quality Study Points

May 24th, 2019
Temperature Data

Accuracy threshold: +/- 0.01°C[2]

T-105 DEPLOYMENT
Water Quality Study Points

Land Side

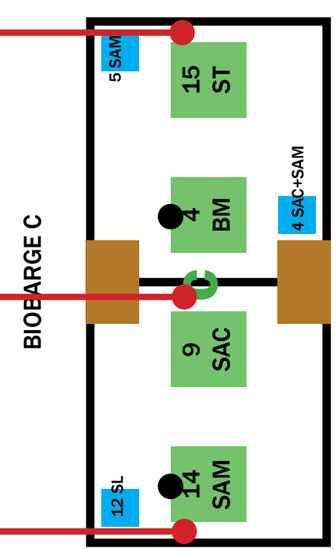
Land Side

Duwamish River

C15 - Study Point
Temperature °C (0.3) = 13.398
Temperature °C (0.6) = 13.364
Temperature °C (1.0) = 12.887

C09 - Study Point
Temperature °C (0.3) = 13.491
Temperature °C (0.6) = 13.446
Temperature °C (1.0) = 13.332

C14 - Study Point
Temperature °C (0.3) = 13.456
Temperature °C (0.6) = 13.403
Temperature °C (1.0) = 13.028

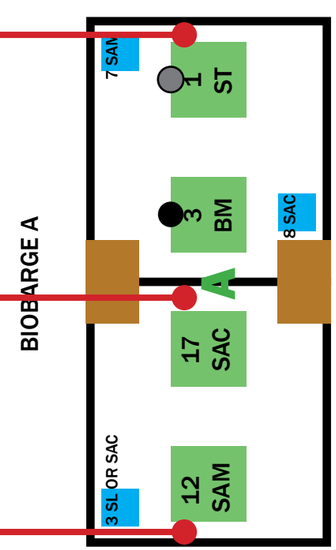


A01 - Study Point

Control Point T-108
Temperature °C (0.3) = 13.450
Temperature °C (0.6) = 13.195
Temperature °C (1.0) = 12.681

A17 - Study Point

A12 - Study Point

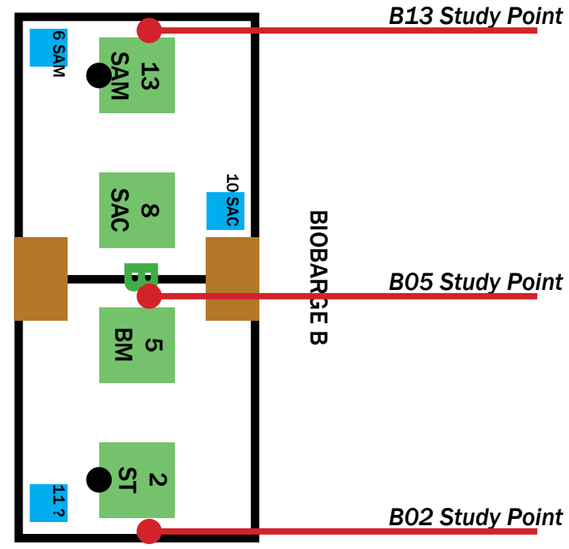


T-102

B13 Study Point

B05 Study Point

B02 Study Point

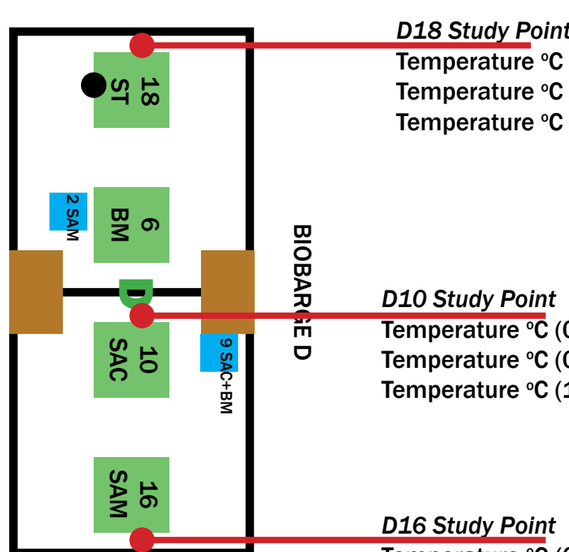


Control Point T-105
Temperature °C (0.3) = 13.679
Temperature °C (0.6) = 13.669
Temperature °C (1.0) = 13.564

D18 Study Point
Temperature °C (0.3) = 13.695
Temperature °C (0.6) = 13.698
Temperature °C (1.0) = 13.613

D10 Study Point
Temperature °C (0.3) = 13.704
Temperature °C (0.6) = 13.695
Temperature °C (1.0) = 13.551

D16 Study Point
Temperature °C (0.3) = 13.695
Temperature °C (0.6) = 13.704
Temperature °C (1.0) = 13.662



T-102

T-108 DEPLOYMENT
Water Quality Study Points

May 31st, 2019
Temperature Data

Accuracy threshold: +/- 0.01°C[2]

T-105 DEPLOYMENT
Water Quality Study Points

Land Side

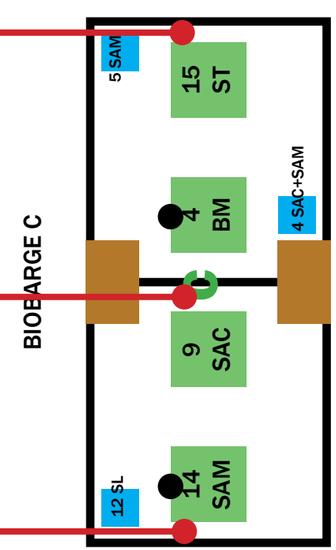
Land Side

Duwamish River

C15 - Study Point
Temperature °C (0.3) = 13.890
Temperature °C (0.6) = 13.650
Temperature °C (1.0) = 13.076

C09 - Study Point
Temperature °C (0.3) = 13.860
Temperature °C (0.6) = 13.825
Temperature °C (1.0) = 13.554

C14 - Study Point
Temperature °C (0.3) = 13.839
Temperature °C (0.6) = 13.783
Temperature °C (1.0) = 13.648

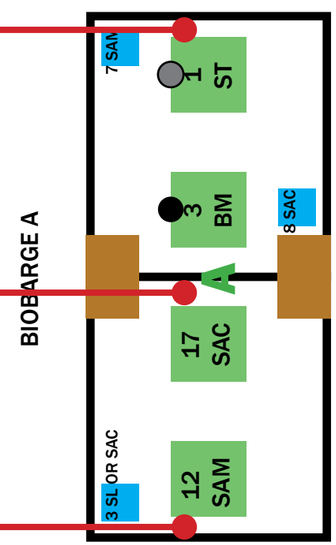


A01 - Study Point

Control Point T-108
Temperature °C (0.3) = 13.915
Temperature °C (0.6) = 13.861
Temperature °C (1.0) = 13.534

A17 - Study Point

A12 - Study Point

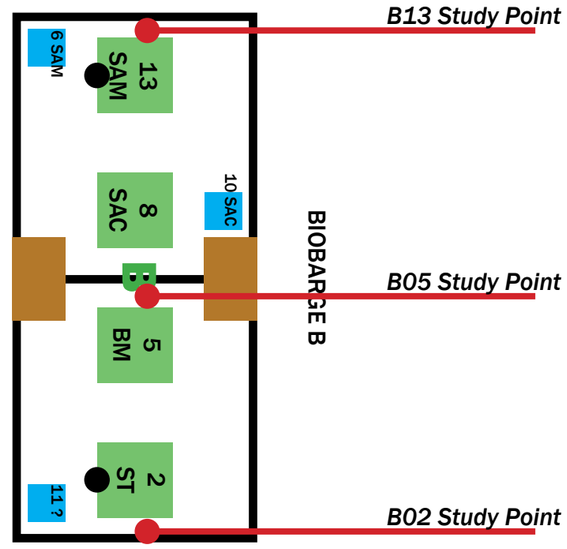


T-102

B13 Study Point

B05 Study Point

B02 Study Point

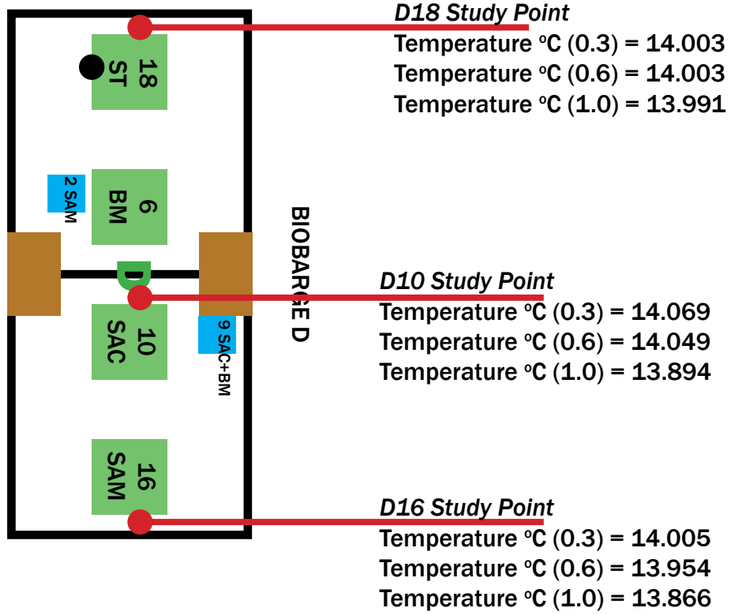


Control Point T-105
Temperature °C (0.3) = 14.020
Temperature °C (0.6) = 13.749
Temperature °C (1.0) = 13.564

D18 Study Point
Temperature °C (0.3) = 14.003
Temperature °C (0.6) = 14.003
Temperature °C (1.0) = 13.991

D10 Study Point
Temperature °C (0.3) = 14.069
Temperature °C (0.6) = 14.049
Temperature °C (1.0) = 13.894

D16 Study Point
Temperature °C (0.3) = 14.005
Temperature °C (0.6) = 13.954
Temperature °C (1.0) = 13.866



T-102

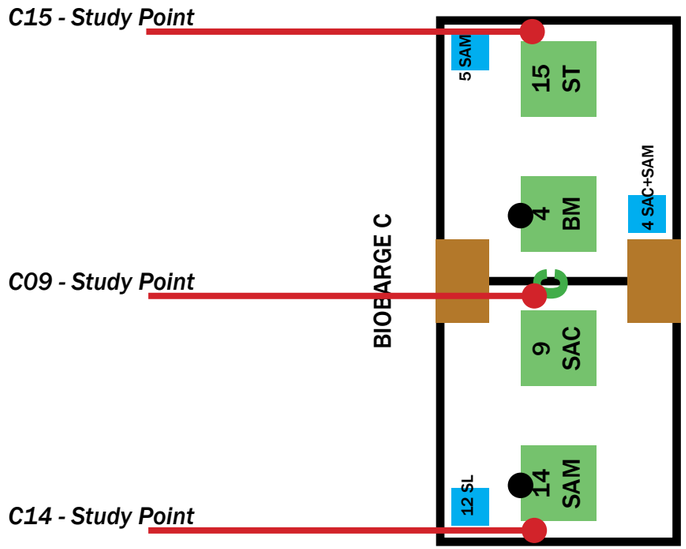
T-108 DEPLOYMENT
Water Quality Study Points

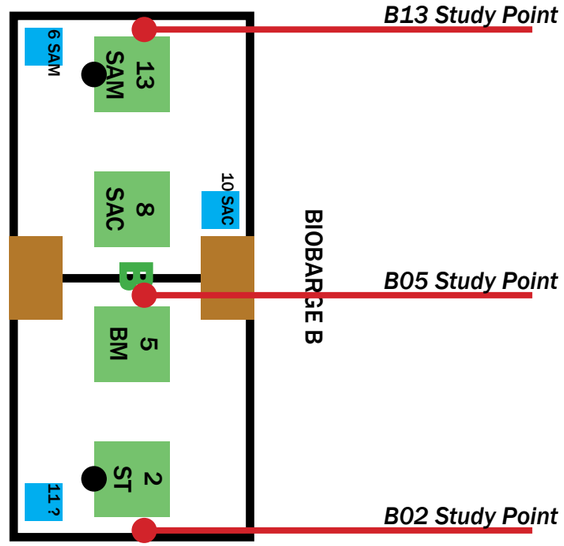
June 7th, 2019
Temperature Data

Accuracy threshold: +/- 0.01°C[2]

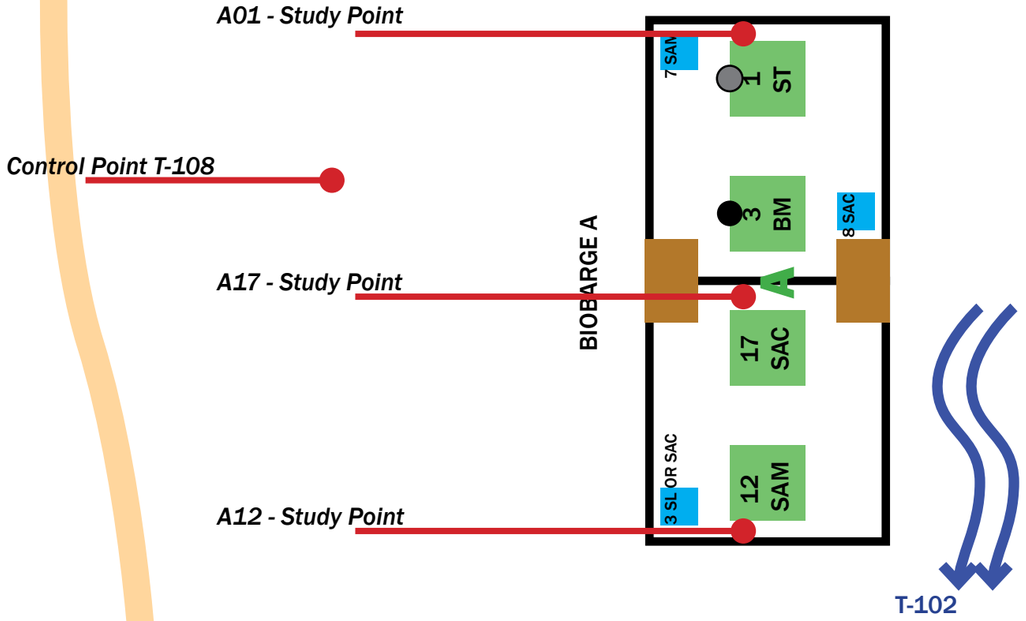
T-105 DEPLOYMENT
Water Quality Study Points

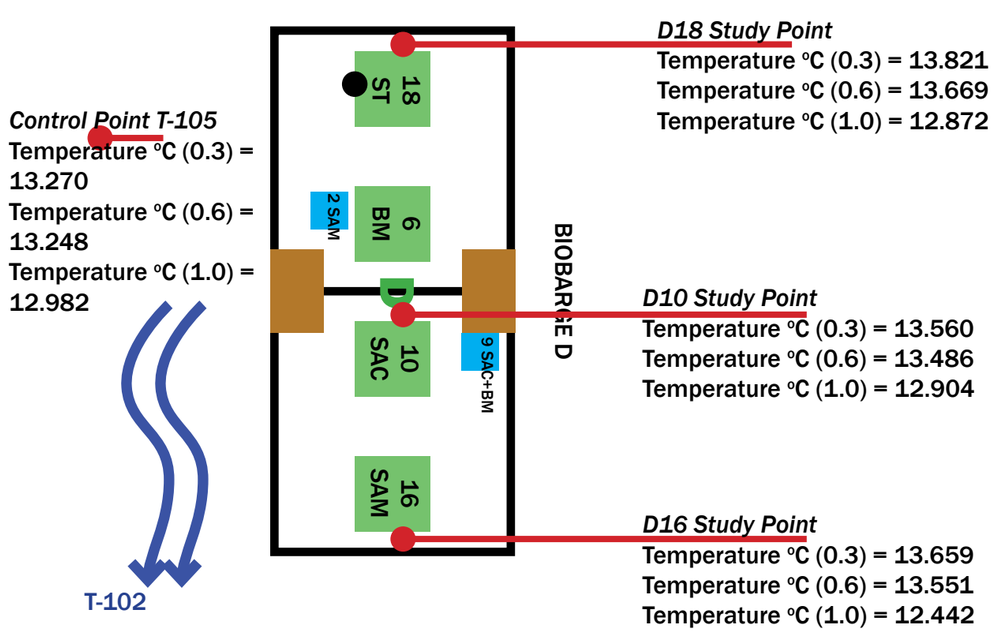
Land Side





Duwamish River





D18 Study Point
Temperature °C (0.3) = 13.821
Temperature °C (0.6) = 13.669
Temperature °C (1.0) = 12.872

D10 Study Point
Temperature °C (0.3) = 13.560
Temperature °C (0.6) = 13.486
Temperature °C (1.0) = 12.904

D16 Study Point
Temperature °C (0.3) = 13.659
Temperature °C (0.6) = 13.551
Temperature °C (1.0) = 12.442

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 14th, 2019
Temperature Data

Accuracy threshold: +/- 0.01°C[2]

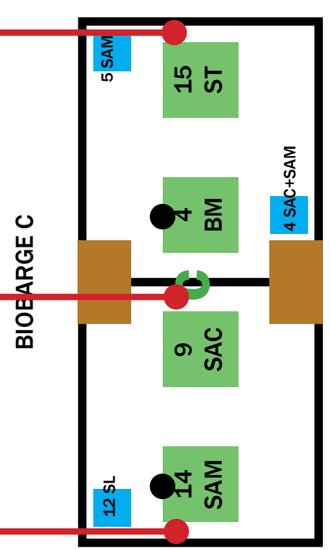
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Temperature °C (0.3) = 16.488
Temperature °C (0.6) = 16.636
Temperature °C (1.0) = 13.908

C09 - Study Point
Temperature °C (0.3) = 16.289
Temperature °C (0.6) = 15.659
Temperature °C (1.0) = 13.949

C14 - Study Point
Temperature °C (0.3) = 16.038
Temperature °C (0.6) = 15.195
Temperature °C (1.0) = 14.512

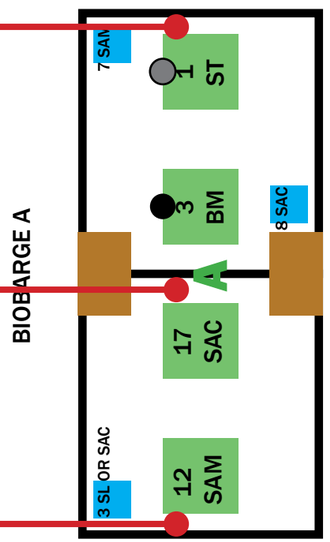


A01 - Study Point
Temperature °C (0.3) = 16.099
Temperature °C (0.6) = 15.543
Temperature °C (1.0) = 14.735

Control Point T-108
Temperature °C (0.3) = 16.139
Temperature °C (0.6) = 15.297
Temperature °C (1.0) = 14.281

A17 - Study Point
Temperature °C (0.3) = 15.506
Temperature °C (0.6) = 14.043
Temperature °C (1.0) = 13.925

A12 - Study Point
Temperature °C (0.3) = 16.654
Temperature °C (0.6) = 15.403
Temperature °C (1.0) = 14.439



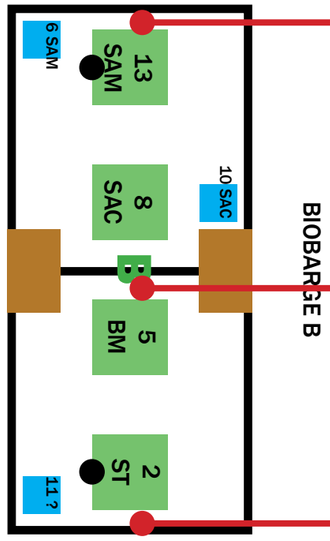
T-102

Duwamish River

B13 Study Point
Temperature °C (0.3) = 15.806
Temperature °C (0.6) = 14.192
Temperature °C (1.0) = 13.498

B05 Study Point
Temperature °C (0.3) = 15.490
Temperature °C (0.6) = 14.450
Temperature °C (1.0) = 13.651

B02 Study Point
Temperature °C (0.3) = 15.388
Temperature °C (0.6) = 14.019
Temperature °C (1.0) = 13.487

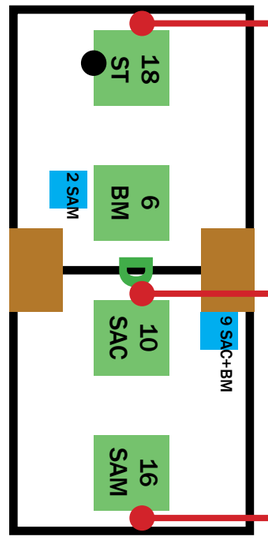


Control Point T-105
Temperature °C (0.3) = 15.063
Temperature °C (0.6) = 15.161
Temperature °C (1.0) = 13.905

D18 Study Point
Temperature °C (0.3) = 14.866
Temperature °C (0.6) = 14.284
Temperature °C (1.0) = 13.974

D10 Study Point
Temperature °C (0.3) = 15.503
Temperature °C (0.6) = 14.958
Temperature °C (1.0) = 13.042

D16 Study Point
Temperature °C (0.3) = 15.524
Temperature °C (0.6) = 15.174
Temperature °C (1.0) = 14.105



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 21st, 2019
Temperature Data

Accuracy threshold: +/- 0.01°C[2]

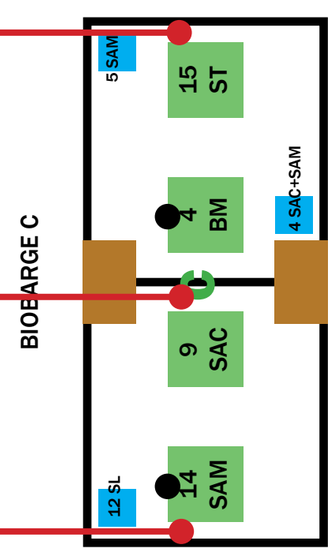
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Temperature °C (0.3) = 15.404
Temperature °C (0.6) = 15.394
Temperature °C (1.0) = 15.182

C09 - Study Point
Temperature °C (0.3) = 15.383
Temperature °C (0.6) = 14.976
Temperature °C (1.0) = 14.710

C14 - Study Point
Temperature °C (0.3) = 15.135
Temperature °C (0.6) = 15.197
Temperature °C (1.0) = 14.888

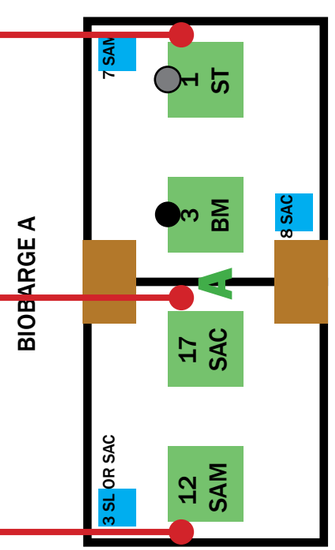


A01 - Study Point
Temperature °C (0.3) = 14.886
Temperature °C (0.6) = 14.891
Temperature °C (1.0) = 14.359

Control Point T-108
Temperature °C (0.3) = 15.106
Temperature °C (0.6) = 14.654
Temperature °C (1.0) = 14.454

A17 - Study Point
Temperature °C (0.3) = 14.951
Temperature °C (0.6) = 14.301
Temperature °C (1.0) = 13.801

A12 - Study Point
Temperature °C (0.3) = 14.916
Temperature °C (0.6) = 14.459
Temperature °C (1.0) = 14.324



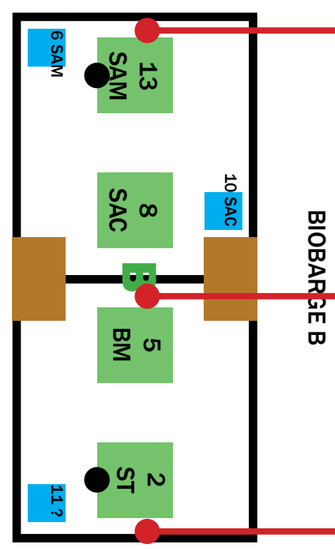
T-102

Duwamish River

B13 Study Point
Temperature °C (0.3) = 14.657
Temperature °C (0.6) = 14.644
Temperature °C (1.0) = 13.418

B05 Study Point
Temperature °C (0.3) = 14.309
Temperature °C (0.6) = 14.249
Temperature °C (1.0) = 14.047

B02 Study Point
Temperature °C (0.3) = 14.132
Temperature °C (0.6) = 13.917
Temperature °C (1.0) = 13.838

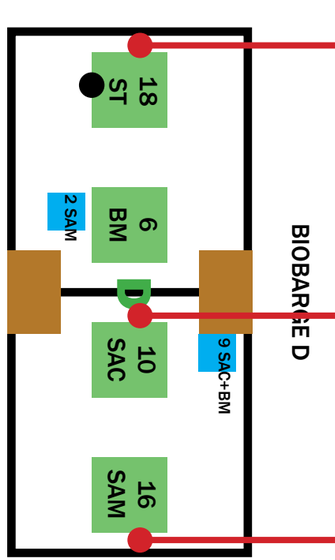


Control Point T-105
Temperature °C (0.3) = 14.720
Temperature °C (0.6) = 14.308
Temperature °C (1.0) = 13.681

D18 Study Point
Temperature °C (0.3) = 14.504
Temperature °C (0.6) = 14.457
Temperature °C (1.0) = 13.833

D10 Study Point
Temperature °C (0.3) = 14.340
Temperature °C (0.6) = 14.286
Temperature °C (1.0) = 14.032

D16 Study Point
Temperature °C (0.3) = 14.307
Temperature °C (0.6) = 14.220
Temperature °C (1.0) = 13.958



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 28th, 2019
Temperature Data

Accuracy threshold: +/- 0.01°C[2]

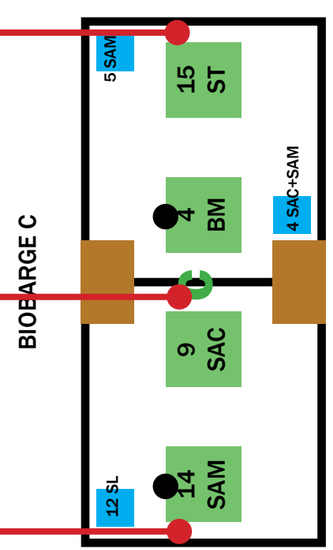
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Temperature °C (0.3) = 16.703
Temperature °C (0.6) = 15.004
Temperature °C (1.0) = 14.154

C09 - Study Point
Temperature °C (0.3) = 16.094
Temperature °C (0.6) = 15.646
Temperature °C (1.0) = 14.502

C14 - Study Point
Temperature °C (0.3) = 16.472
Temperature °C (0.6) = 15.431
Temperature °C (1.0) = 14.009

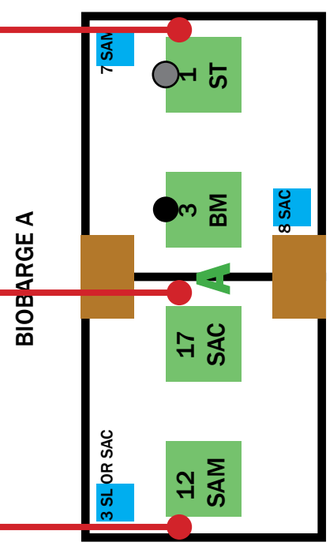


A01 - Study Point
Temperature °C (0.3) = 15.756
Temperature °C (0.6) = 15.312
Temperature °C (1.0) = 14.365

Control Point T-108
Temperature °C (0.3) = 16.495
Temperature °C (0.6) = 14.949
Temperature °C (1.0) = 14.110

A17 - Study Point
Temperature °C (0.3) = 15.602
Temperature °C (0.6) = 14.980
Temperature °C (1.0) = 14.331

A12 - Study Point
Temperature °C (0.3) = 16.070
Temperature °C (0.6) = 15.482
Temperature °C (1.0) = 14.231



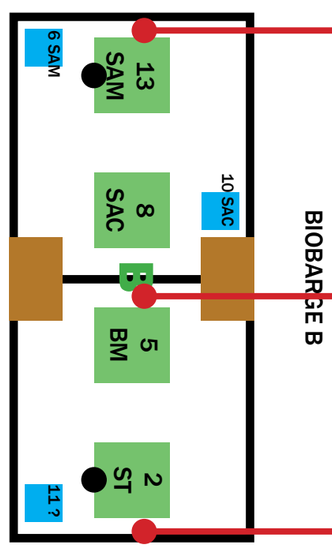
T-102

Duwamish River

B13 Study Point
Temperature °C (0.3) = 15.655
Temperature °C (0.6) = 15.107
Temperature °C (1.0) = 14.018

B05 Study Point
Temperature °C (0.3) = 15.478
Temperature °C (0.6) = 15.104
Temperature °C (1.0) = 14.749

B02 Study Point
Temperature °C (0.3) = 15.067
Temperature °C (0.6) = 14.793
Temperature °C (1.0) = 14.150

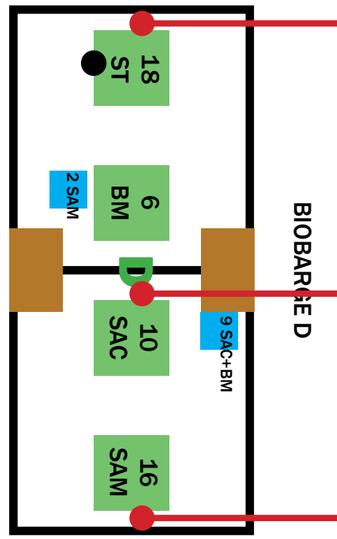


Control Point T-105
Temperature °C (0.3) = 15.422
Temperature °C (0.6) = 15.047
Temperature °C (1.0) = 14.188

D18 Study Point
Temperature °C (0.3) = 15.351
Temperature °C (0.6) = 15.371
Temperature °C (1.0) = 14.346

D10 Study Point
Temperature °C (0.3) = 15.296
Temperature °C (0.6) = 15.131
Temperature °C (1.0) = 14.033

D16 Study Point
Temperature °C (0.3) = 15.175
Temperature °C (0.6) = 15.107
Temperature °C (1.0) = 14.242



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

July 3rd, 2019
Temperature Data

Accuracy threshold: +/- 0.01°C[2]

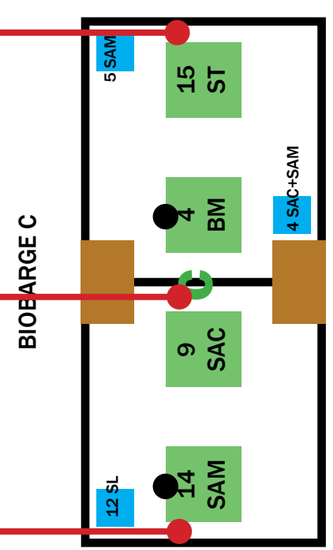
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Temperature °C (0.3) = 14.247
Temperature °C (0.6) = 14.043
Temperature °C (1.0) = 13.836

C09 - Study Point
Temperature °C (0.3) = 14.224
Temperature °C (0.6) = 14.251
Temperature °C (1.0) = 14.214

C14 - Study Point
Temperature °C (0.3) = 14.246
Temperature °C (0.6) = 14.298
Temperature °C (1.0) = 13.912

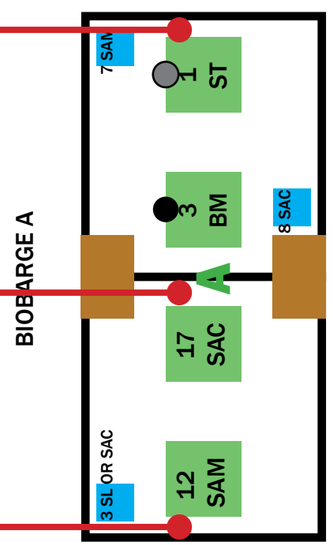


A01 - Study Point
Temperature °C (0.3) = 14.347
Temperature °C (0.6) = 14.321
Temperature °C (1.0) = 14.516

Control Point T-108
Temperature °C (0.3) = 14.316
Temperature °C (0.6) = 14.157
Temperature °C (1.0) = 13.988

A17 - Study Point
Temperature °C (0.3) = 14.206
Temperature °C (0.6) = 14.295
Temperature °C (1.0) = 14.265

A12 - Study Point
Temperature °C (0.3) = 14.424
Temperature °C (0.6) = 14.136
Temperature °C (1.0) = 13.943



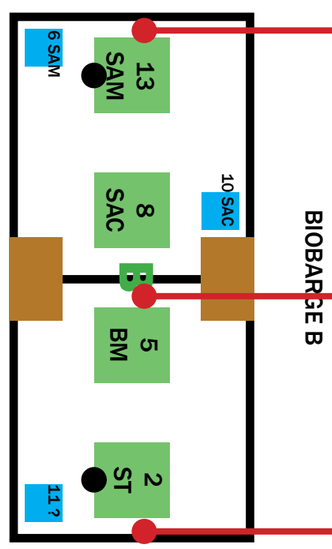
T-102

Duwamish River

B13 Study Point
Temperature °C (0.3) = 13.656
Temperature °C (0.6) = 13.741
Temperature °C (1.0) = 13.755

B05 Study Point
Temperature °C (0.3) = 13.999
Temperature °C (0.6) = 14.081
Temperature °C (1.0) = 13.583

B02 Study Point
Temperature °C (0.3) = 14.090
Temperature °C (0.6) = 13.945
Temperature °C (1.0) = 13.476

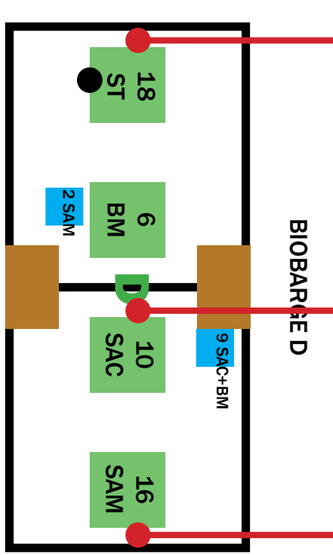


Control Point T-105
Temperature °C (0.3) = 13.612
Temperature °C (0.6) = 13.178
Temperature °C (1.0) = 13.197

D18 Study Point
Temperature °C (0.3) = 14.143
Temperature °C (0.6) = 13.933
Temperature °C (1.0) = 13.264

D10 Study Point
Temperature °C (0.3) = 13.820
Temperature °C (0.6) = 13.824
Temperature °C (1.0) = 13.328

D16 Study Point
Temperature °C (0.3) = 14.177
Temperature °C (0.6) = 13.947
Temperature °C (1.0) = 13.245



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

July 10th, 2019
Temperature Data

Accuracy threshold: +/- 0.01°C[2]

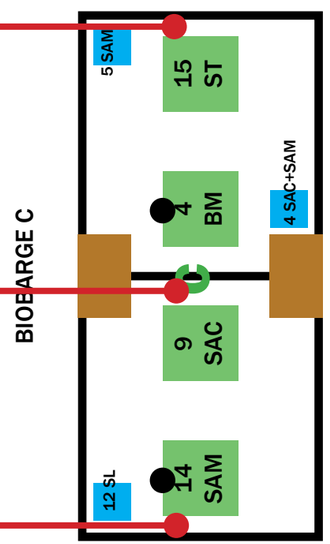
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Temperature °C (0.3) = 13.912
Temperature °C (0.6) = 13.730
Temperature °C (1.0) = 14.107

C09 - Study Point
Temperature °C (0.3) = 15.382
Temperature °C (0.6) = 15.196
Temperature °C (1.0) = 14.259

C14 - Study Point
Temperature °C (0.3) = 15.273
Temperature °C (0.6) = 14.658
Temperature °C (1.0) = 14.304

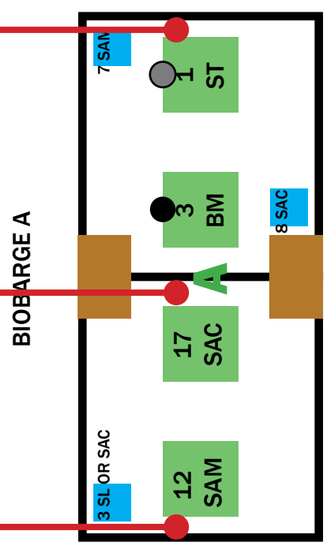


A01 - Study Point
Temperature °C (0.3) = 14.516
Temperature °C (0.6) = 13.940
Temperature °C (1.0) = 13.712

Control Point T-108
Temperature °C (0.3) = 14.907
Temperature °C (0.6) = 14.376
Temperature °C (1.0) = 14.159

A17 - Study Point
Temperature °C (0.3) = 15.003
Temperature °C (0.6) = 14.707
Temperature °C (1.0) = 13.932

A12 - Study Point
Temperature °C (0.3) = 15.497
Temperature °C (0.6) = 14.870
Temperature °C (1.0) = 14.505



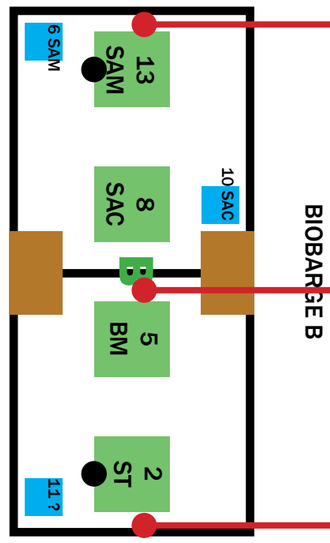
T-102

Duwamish River

B13 Study Point
Temperature °C (0.3) = 15.080
Temperature °C (0.6) = 14.610
Temperature °C (1.0) = 14.100

B05 Study Point
Temperature °C (0.3) = 14.594
Temperature °C (0.6) = 14.337
Temperature °C (1.0) = 13.781

B02 Study Point
Temperature °C (0.3) = 14.257
Temperature °C (0.6) = 13.943
Temperature °C (1.0) = 13.686

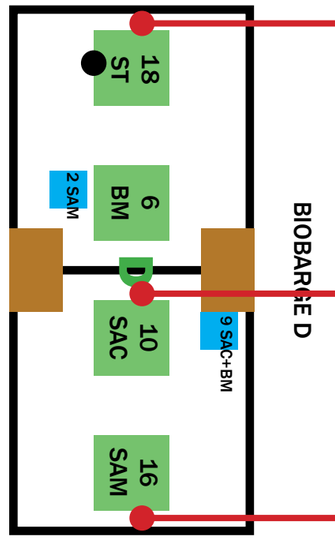


Control Point T-105
Temperature °C (0.3) = 14.776
Temperature °C (0.6) = 14.248
Temperature °C (1.0) = 14.164

D18 Study Point
Temperature °C (0.3) = 14.95
Temperature °C (0.6) = 14.528
Temperature °C (1.0) = 13.672

D10 Study Point
Temperature °C (0.3) = 14.539
Temperature °C (0.6) = 14.113
Temperature °C (1.0) = 13.840

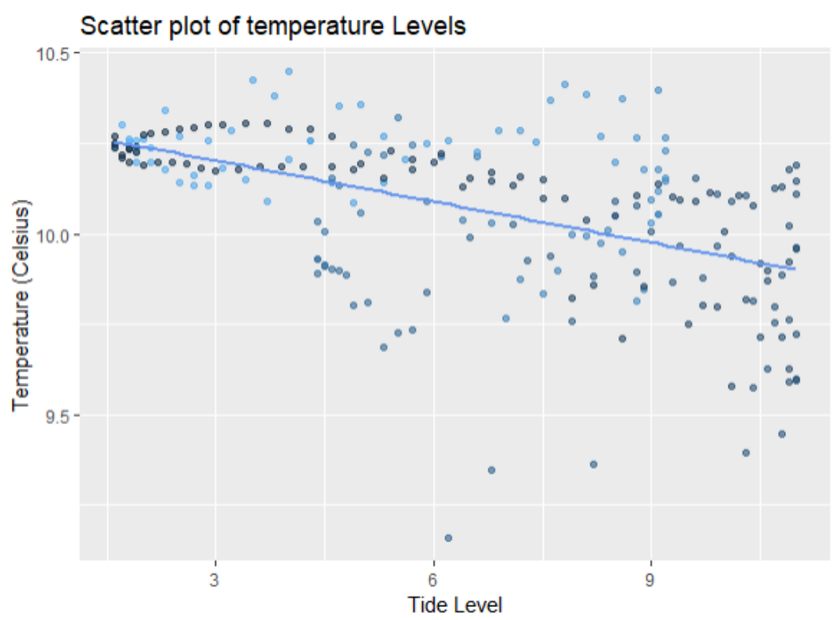
D16 Study Point
Temperature °C (0.3) = 14.722
Temperature °C (0.6) = 13.915
Temperature °C (1.0) = 13.730

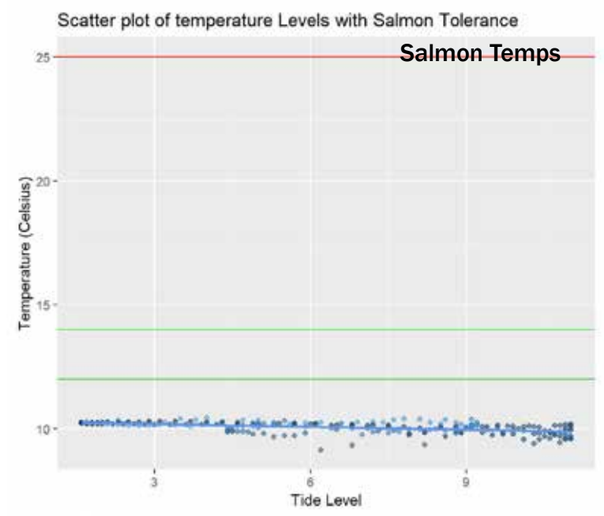


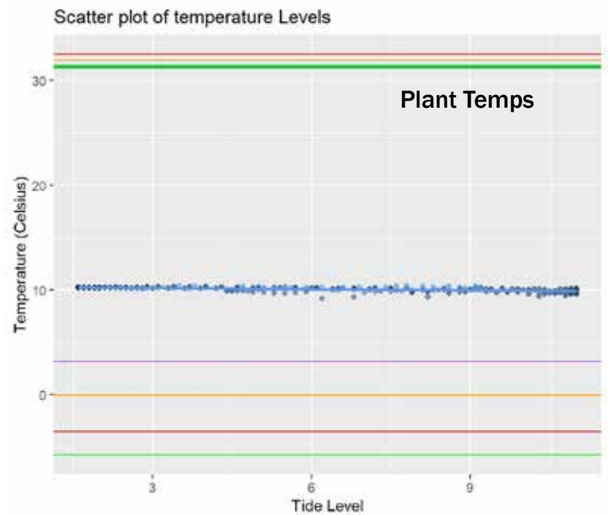
T-102

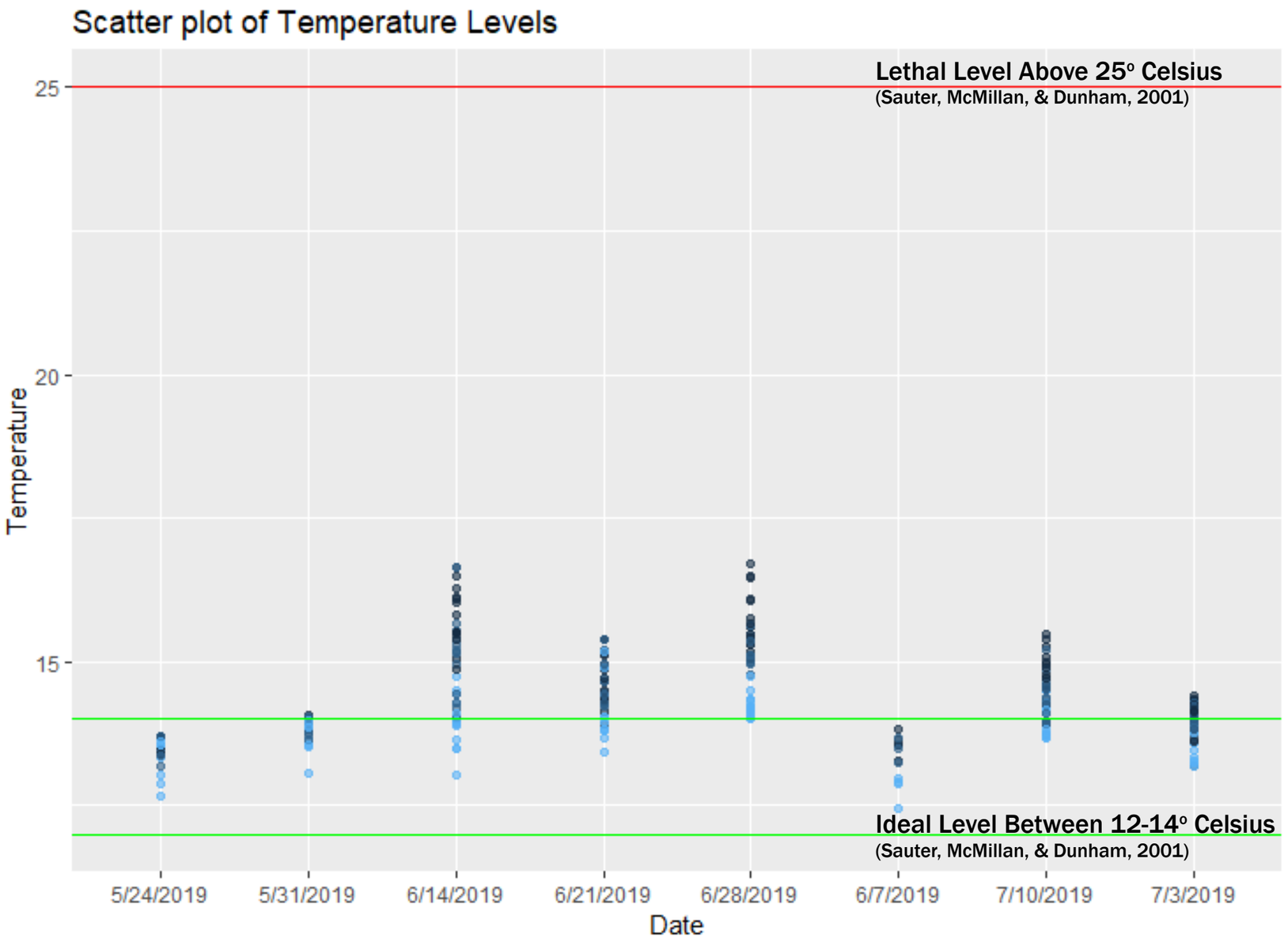
Land Side

Temperature Data	As depth increases...	T-105 vs. T-108	Biobarge vs Control	Middle vs. Edge (of Biobarge)
5/24/2019	Not consistent (Mostly temperature decrease)	No difference	No difference	No difference
5/31/2019	Temperature decreases	105 is warmer	No difference	No difference
6/07/2019	Temperature decreases	NA	No difference	No difference
6/14/2019	Not consistent (Mostly temperature decrease)	108 is warmer	No difference	No difference
6/21/2019	Not consistent	Not consistent (Mostly 108 is warmer)	No difference	No difference
6/28/2019	Not consistent (Mostly temperature decrease)	Not consistent	No difference	No difference
7/03/2019	Not consistent	108 is warmer	Not consistent	No difference
7/10/2019	Not consistent (Mostly temperature decrease)	Not consistent	No difference	No difference
Consensus	**Not consistent (Mostly temperature decrease)**	**Not consistent**	**No difference**	**No difference**

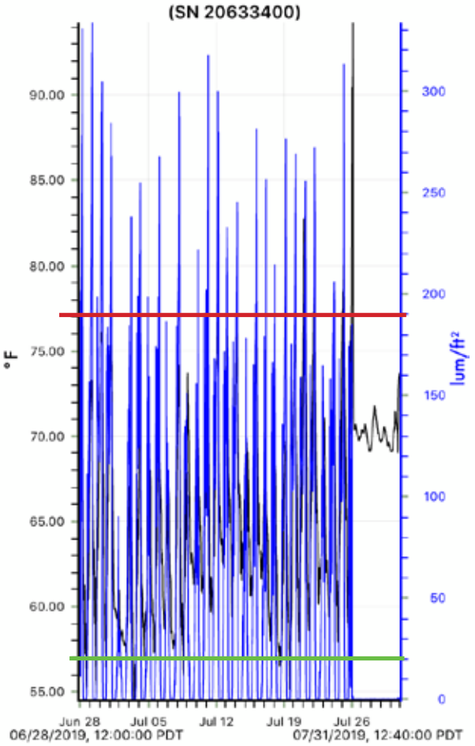

Scatter plot of temperature Levels
Temperature (Celsius)
10.5
10.0
9.5
3
6
9
Tide Level


Scatter plot of temperature Levels with Salmon Tolerance
Salmon Temps
Temperature (Celsius)
25
20
15
10
3
6
9
Tide Level

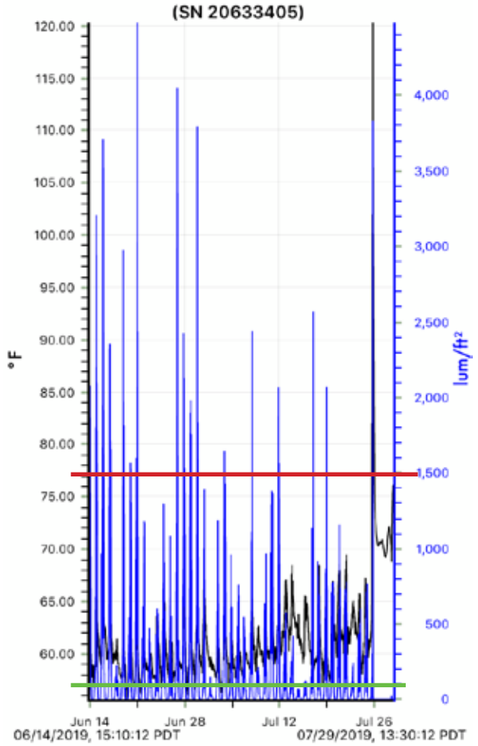

Scatter plot of temperature Levels
Plant Temps
Temperature (Celsius)
30
20
10
0
3
6
9
Tide Level


Scatter plot of Temperature Levels
Lethal Level Above 25° Celsius
(Sauter, McMillan, & Dunham, 2001)
Temperature
25
20
15
Ideal Level Between 12-14° Celsius
(Sauter, McMillan, & Dunham, 2001)
5/24/2019
5/31/2019
6/14/2019
6/21/2019
6/28/2019
6/7/2019
7/10/2019
7/3/2019
Date
1.0
0.8
0.6
0.4
Depth of Sonde measurement

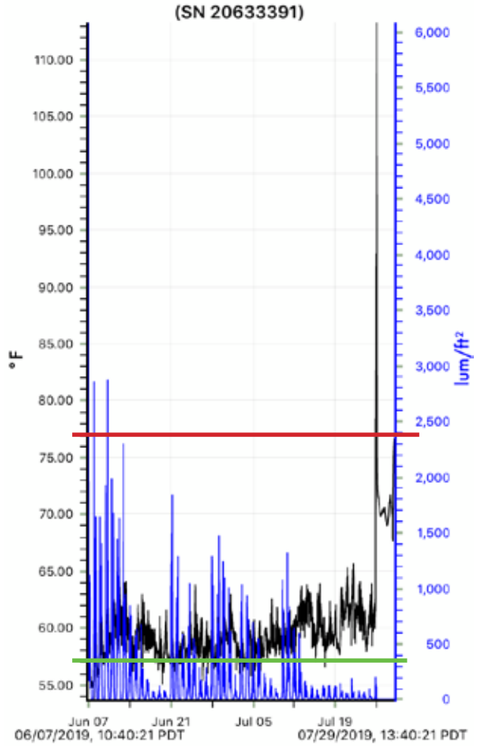
Biobarge B - above water
(temp control only)



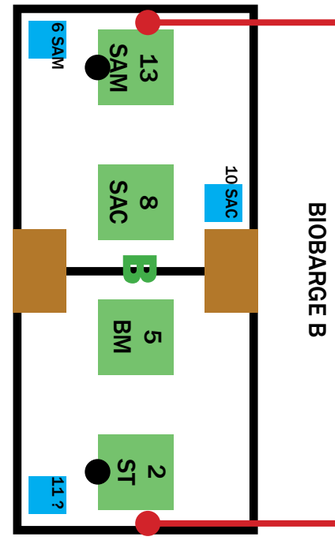
Biobarge B - at Surface



Biobarge B - below Surface



T-105 DEPLOYMENT
Water Quality Study Points

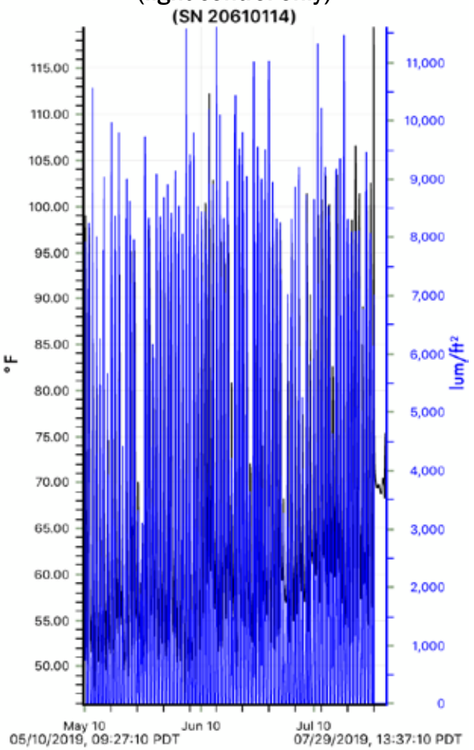


B13 Study Point
Tidbit - at surface = 20633405
Tidbit - below water = 20633391

B02 Study Point
Tidbit - above water = 20633400 (temp control only)

Land Side

Biobarge D - above water
(light control only)

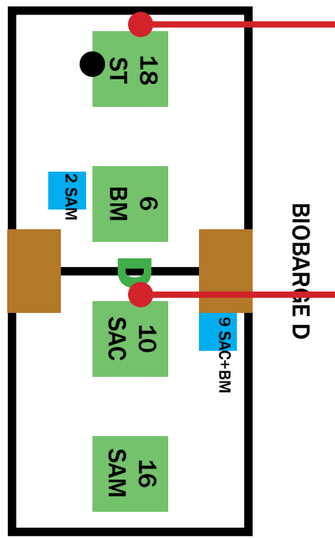


Biobarge D - at Surface

Sensor Malfunctioned in
Final Pickup

Biobarge D - below Surface

Temperature
Ideal Level Between 12-14° Celsius
(below green line)
Lethal Level Above 25° Celsius
(above red line)
(Sauter, McMillan, & Dunham, 2001)



D18 Study Point
Tidbit - above water = 20610114 (light control only)
Tidbit - at surface = 20610113 (can't get recent data)
Tidbit - below water = 20610115

D10 Study Point
Mini-Dot = 784831

Accuracy threshold: +/ 10% sunlight
and +/- 0.5° C temperature

T-108 DEPLOYMENT
Water Quality Study Points

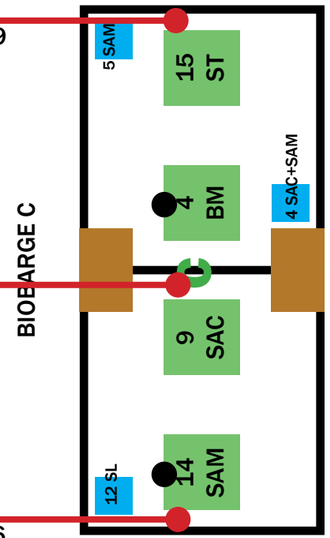
Land Side

T-102

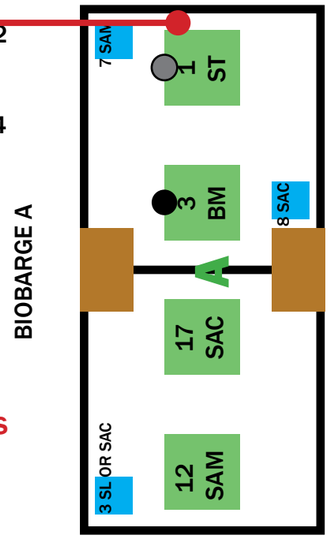
C15 - Study Point
Tidbit - below water = 20633399
Tidbit - at surface = 20633403

C09 - Study Point
Mini-Dot = 669393

C14 - Study Point
Tidbit - above water = 20610116
(temp control only)



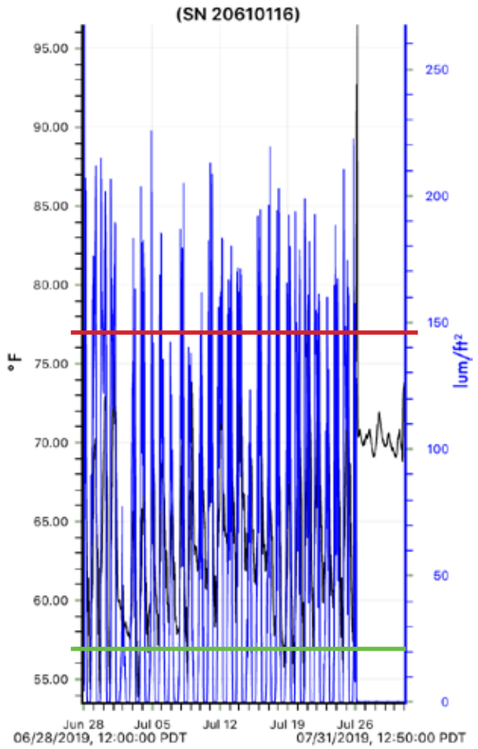
A01 - Study Point
Tidbit - above water = 20633402
(light control only)
Tidbit - at surface = 20633401
Tidbit - below water = 20633404



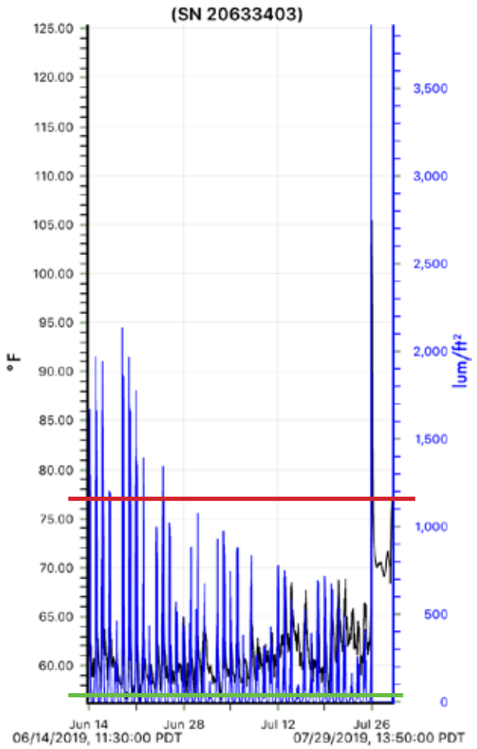
Temperature
Ideal Level Between 12-14° Celsius (below green line)
Lethal Level Above 25° Celsius (above red line)
(Sauter, McMillan, & Dunham, 2001)

Accuracy threshold: +/ 10% sunlight and +/- 0.5° C temperature

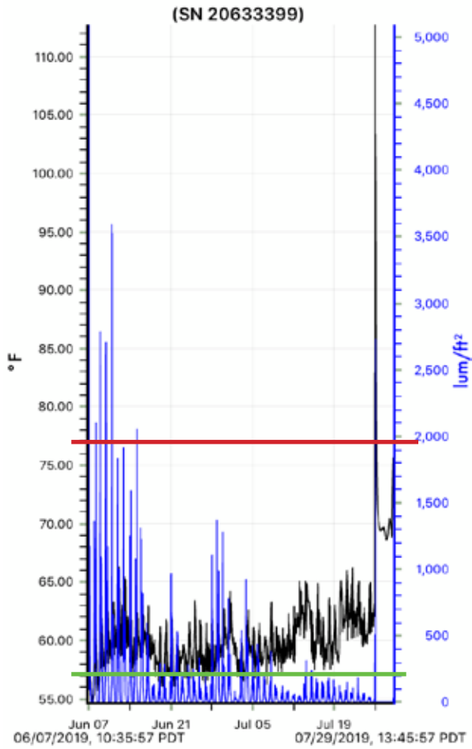
Biobarge C - above water (temp control only)



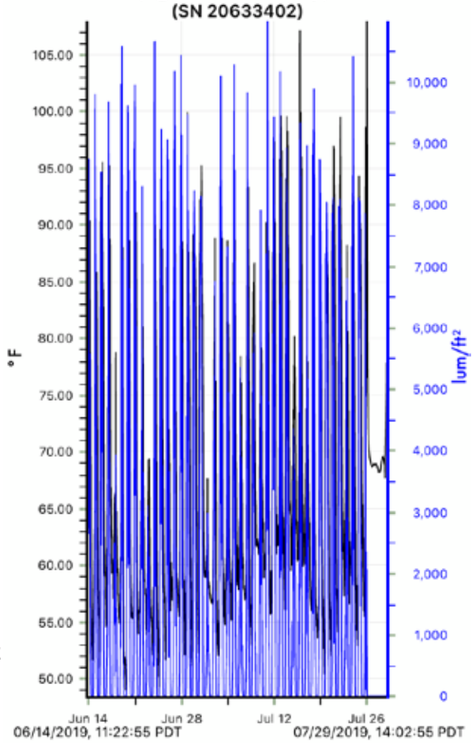
Biobarge C - at Surface



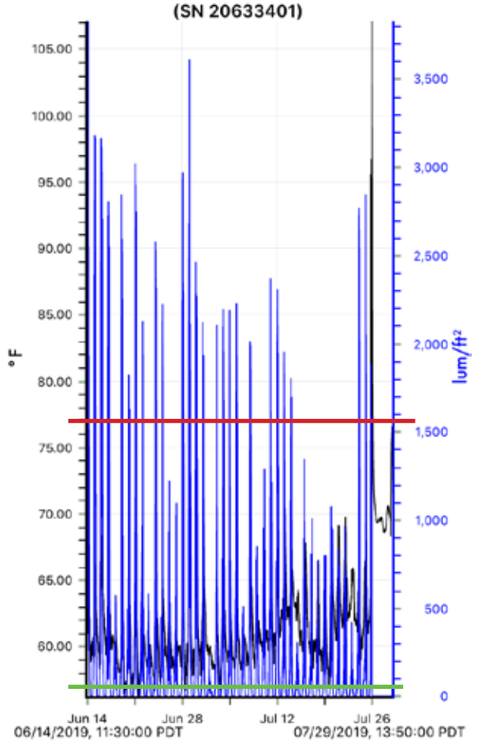
Biobarge C - below Surface



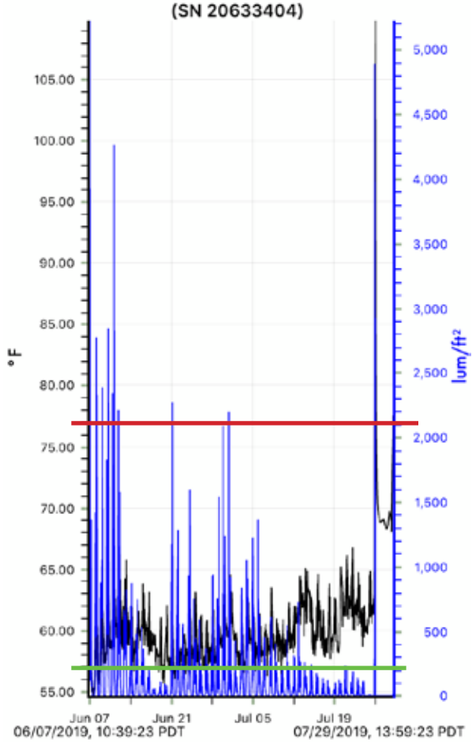
Biobarge A - above water (light control only)



Biobarge A - at Surface



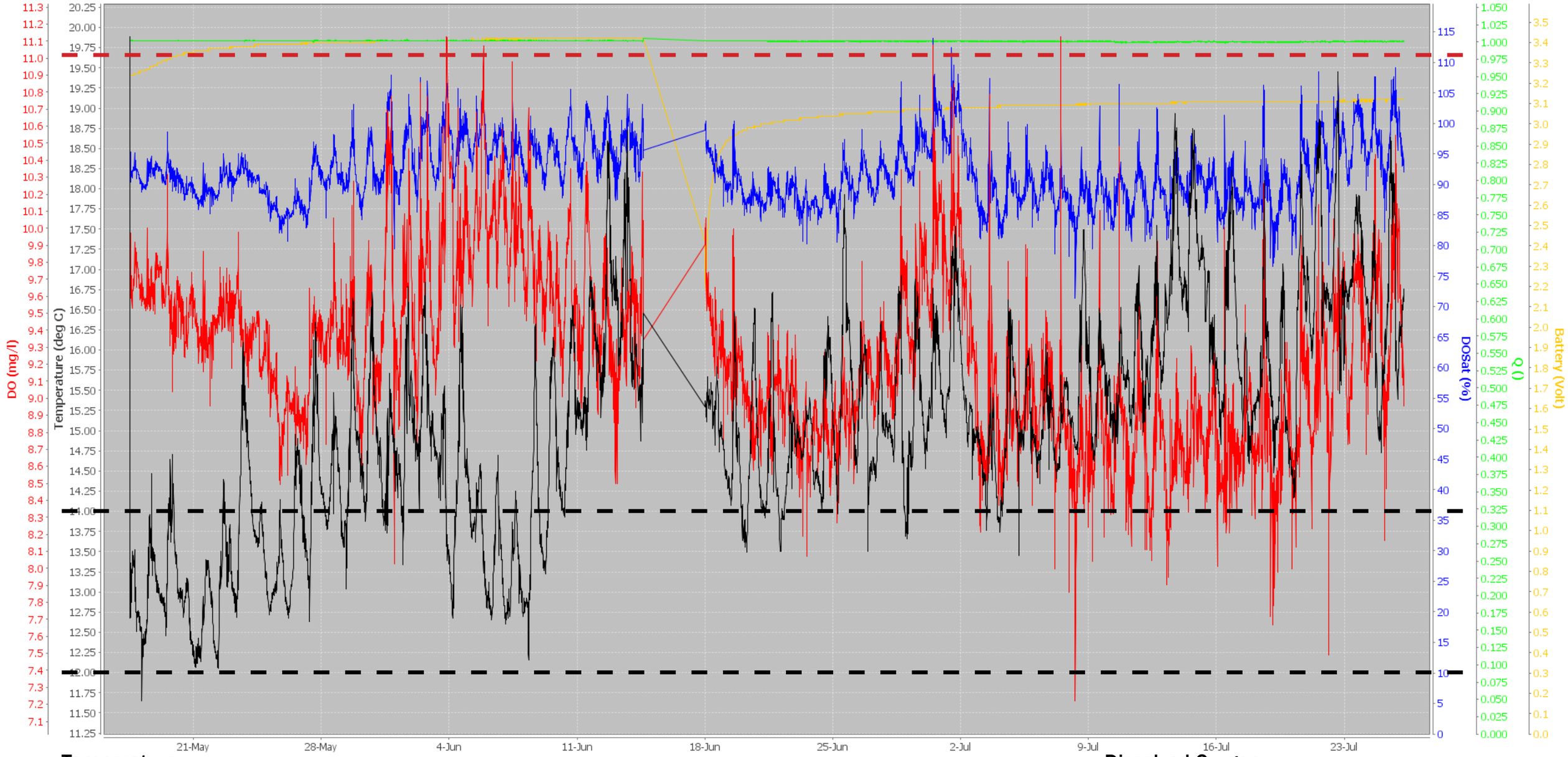
Biobarge A - below Surface



BIOBARGE D

miniDOT Logger Measurements

7450-784831



Temperature
Ideal Level Between 12-14° Celsius (below dashed black line)
Lethal Level Above 25° Celsius (not shown on this graph)
(Sauter, McMillan, & Dunham, 2001)

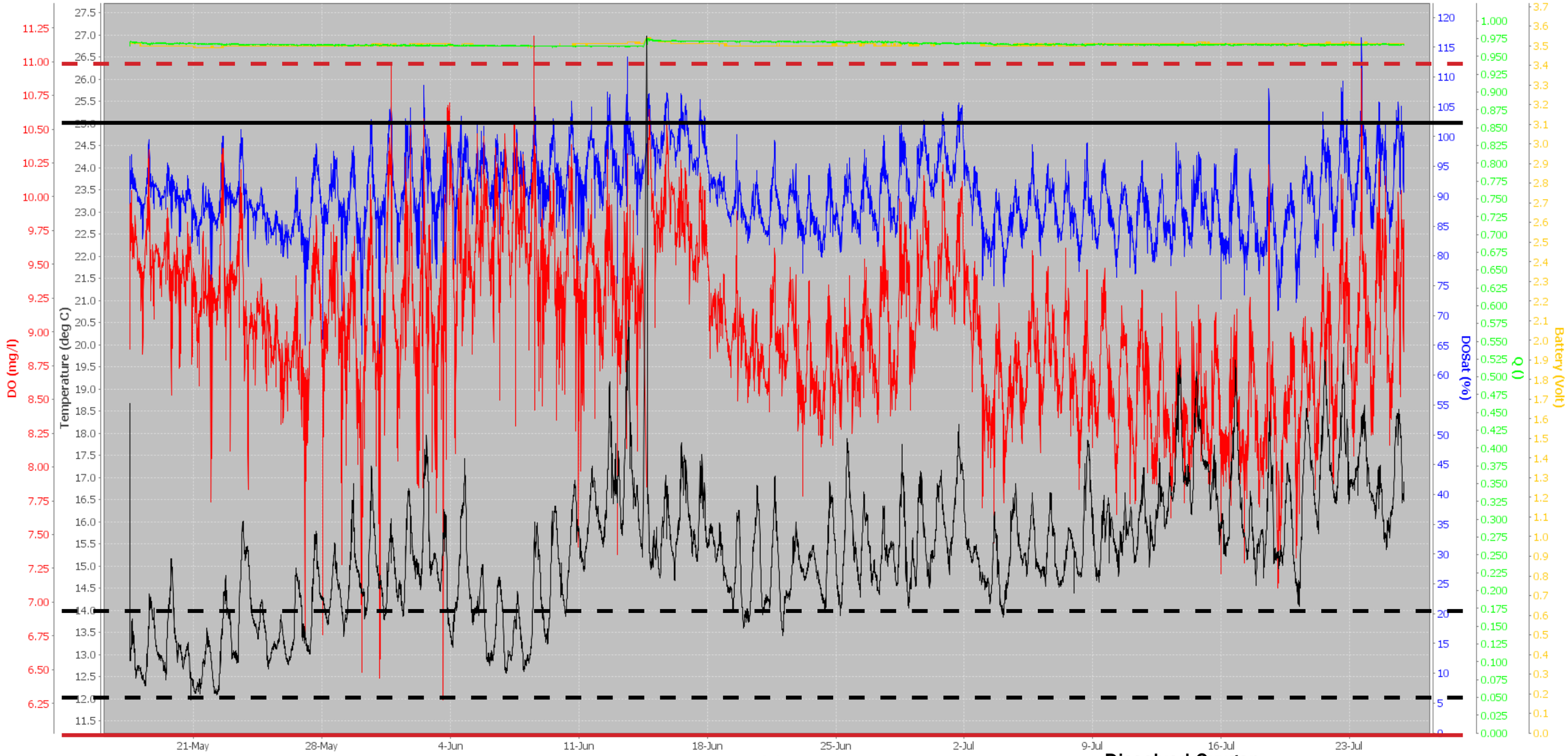
Accuracy threshold: +/ 5 % odo measure and +/- 0.1° C

Dissolved Oxygen
Preferred Level Below 11 mg/L (below dashed red line)
Lethal Level Below 6 mg/L (not shown on this graph)
(Kidd, 2011)

BIOBARGE C

miniDOT Logger Measurements

7450-669393



Temperature
Ideal Level Between 12-14° Celsius (below dashed black line)
Lethal Level Above 25° Celsius (above solid black line)
(Sauter, McMillan, & Dunham, 2001)

Accuracy threshold: +/ 5 % odo measure and +/- 0.1° C

Dissolved Oxygen
Preferred Level Below 11 mg/L (below dashed red line)
Lethal Level Below 6 mg/L (below solid red line)
(Kidd, 2011)

Initial Metals, Carbon, and Nitrogen results - raw data

9/18/2019

	Initial Results	µg/g Al	µg/g As	µg/g B	µg/g Ba	µg/g Ca	µg/g Cd	µg/g Cr	µg/g Cu	µg/g Fe	µg/g K	µg/g Mg	µg/g Mn	µg/g Mo	µg/g Na	µg/g Ni	µg/g P	µg/g Pb	µg/g S	µg/g Se	µg/g Zn	µg/g Si	µg/g Ag	% C	% N
4-A	Jenn-4-A willov	101.2	0.02	16.14	18.67	5533	0.046	0.042	7.34	522.1	1195	1013	142.2	0.018	2799	4.597	561.6	0.233	611	0.49	141.7	0.092	0.005	46.1	0.682
4-B	4-D control wood chi	199.7	0.067	8.73	2.264	539.7	0.046	0.042	6.21	782.5	433	835.2	94.28	0.018	4837	3.263	223.9	0.233	641.7	0.49	16.7	23.27	0.005	44.19	0.223
4-C	4-C control mycoboarc	565.7	0.02	9.721	13.92	1560	0.046	0.14	8.094	1125	454.8	1342	44.98	0.018	4936	4.954	455.2	0.233	1176	0.49	40.63	431.8	0.005	41.24	0.538
4-D	4-D control plan	2309	0.067	34.9	24.81	2691	0.046	0.14	33.86	6658	1496	2454	250.2	0.06	7152	12.44	959.4	32.61	1756	60.42	97.85	324.9	0.005	28.42	0.867
1-A	1-A control willo	99.3	0.02	16.69	16.29	4822	0.046	0.042	7.98	654	997.9	1049	147.6	0.018	3355	5.063	676.4	0.233	666.7	0.49	193.1	0.092	0.005	46.2	0.735
1-B	1-B control mycoboarc	129.8	0.02	7.085	2.006	322.5	0.046	0.042	0.063	540.2	216.6	666.3	42.97	0.018	3667	2.062	137.9	0.07	656.4	0.147	10.38	0.092	0.005	44.93	0.156
1-C	1-C mycoboard	457.8	0.067	8.124	14.14	1448	0.046	0.14	5.503	693	664.8	1109	19.74	0.018	4762	3.691	260.5	0.07	998.2	0.49	34.69	85.23	0.005	49.66	0.714
1-D	1-D plant	3004	0.067	24.75	50.04	2272	0.046	0.14	30.76	5988	2532	2138	179.2	5.779	5645	12.17	1142	33.08	1825	63.85	159.9	299.2	0.005	30.08	0.881
A-3-A	A-3-A willov	457.8	0.02	75.67	6.947	9416	0.046	0.14	18.63	2471	1076	2499	389.6	0.06	14497	6.705	813.1	19.01	2855	0.49	171.7	90.42	0.005	39.99	0.911
A-3-B	A-3-B woodchi	643	0.02	32.85	5.614	2921	0.046	0.14	27.66	3450	1544	2570	719	0.06	15840	7.704	674.9	20.55	1986	36.52	46.07	117	0.005	36.96	0.806
A-3-C	A-3-C mycoboard	675.1	0.067	27.23	6.081	1802	0.046	0.14	10.21	1678	1303	2978	88.35	0.06	18616	6.093	492.4	21.61	2365	0.49	31.54	81.96	0.005	39.87	0.811
A-3-D	A-3-D plant	774.1	0.02	45.35	9.761	2557	0.046	0.14	31.32	3644	2982	3129	1298	0.06	17856	9.479	1061	26.3	2413	42.35	59.23	144.1	0.005	38.85	0.372
B-11-A	B-11-A willov	358	0.02	74.01	12.38	8514	0.046	0.14	17.46	2116	1124	2687	387.8	0.06	17158	7.191	840.9	20.45	2395	0.49	211.5	85.98	0.005	39.51	0.875
B-11-B	B-11-B Willo	296.9	0.02	44.07	8.117	2930	0.046	0.14	23.67	2416	1700	3538	477.6	0.06	25236	8.58	672.3	31.17	2408	0.49	126.7	30.7	0.005	39.23	0.497
B-11-C	B-11-C mycoboard	417.8	0.02	60.11	11.61	2187	0.046	0.14	15.21	2040	2670	7142	143	4.797	382724	11.87	501.7	36.77	4394	41.92	115.2	56.37	0.005	44.86	0.769
B-11-D	B-11-D plant	3695	0.02	77.92	27.94	4438	0.046	12.48	37.44	6174	3083	9030	164.4	12.14	315460	17.44	800.9	50.05	6262	88.9	83.27	238.7	0.005	10.65	0.382
B-6-A	B-6-A willov	365.3	0.067	77.22	9.714	17019	0.046	0.14	16.73	1722	1217	2756	298.4	0.06	16365	6.227	642.1	18.69	2715	0.49	148.4	62.68	0.005	39.15	0.877
B-6-B	B-6-B wood chi	246.8	0.02	39.38	2.899	2295	0.046	0.14	21.8	4884	1247	2700	538.8	0.06	17399	8.572	710.7	24.94	2159	42.91	59.53	63.71	0.005	41.74	0.468
B-6-C	B-6-C mycoboard	497.9	9.942	34.66	5.521	1685	0.046	0.14	9.374	1670	1702	4415	70.28	0.06	30143	7.315	386.1	21.53	3280	0.49	30.21	119.4	0.005	36.42	0.627
B-6-B	B-6D plant	1629	0.02	126	11.09	4698	0.046	0.14	22.45	7372	4884	6388	369.8	8.339	37343	13.75	914.2	36.4	5744	72.14	62.11	216.4	0.005	31.79	0.768
C-12-A	C-12-A willov	263.2	0.02	84.41	8.913	6551	0.046	0.14	14.97	1589	1631	3121	314.3	0.06	19504	6.93	716	19.34	2772	0.49	181.8	50.17	0.005	36.54	0.771
C-12-B	C-12-B woodchi	590.3	0.067	31.25	5.101	1771	0.046	0.042	15.88	1957	2461	2951	392.3	4.123	20318	5.826	592.1	0.233	2464	0.49	26.34	86.54	0.017	38.68	0.561
C-12-C	C-12-C micoboarc	1232	0.02	49.85	32.79	1933	0.046	17.02	9.222	1725	2391	7208	42.3	6.245	33277	13.16	554.2	29.66	4414	44.49	31.57	195.8	0.005	36.08	0.855
C-12-D	C-12-D plant	6301	0.067	90.07	36.47	4023	0.046	15.44	28.43	11388	2324	4969	244.8	16.47	16575	21.59	1142	53.64	7130	119.4	101.9	249.2	0.005	26.32	0.69
C-12-D	C-12-D plant dup	6228	9.928	90.29	36.64	4073	0.046	15.3	27.68	11288	2331	4874	229.1	17.35	16618	21.42	1092	51.6	7294	118.4	104	273.1	0.005	26.25	0.701
	QC rur	24.7	4.576	4.921	4.936	24.89	4.957	4.938	4.957	4.966	49.7	4.929	4.951	4.988	9.87016	4.963	10.78	5.004	4.919	4.898	4.962	5.014	4.884	71.32	10.38
	QC true	25.0	5.000	5.000	5.000	25.00	5.000	5.000	5.000	5.000	50.0	5.000	5.00	5.00	10.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00	71.2	10.36
	QC relative differenc	0.012	0.085	0.016	0.013	0.004	0.009	0.012	0.009	0.007	0.005	0.014	0.010	0.002	0.013	0.007	-0.078	-0.001	0.016	0.020	0.008	-0.003	0.023	-0.002	-0.002

QUANT LIM ->	0.130	0.067	0.030	0.020	0.187	0.153	0.140	0.063	0.063	1.317	0.363	0.010	0.060	0.34	0.027	0.283	0.233	0.250	0.490	0.097	0.307	0.017		
DET LIM ->	0.039	0.020	0.009	0.006	0.056	0.046	0.042	0.019	0.019	0.395	0.109	0.003	0.018	0.10	0.008	0.085	0.070	0.075	0.147	0.029	0.092	0.005	0.005	0.005

Found in USGS testing

Trace or No detection in USGS testing

Of concern to salmon health

Trace (TR)

Not detected (ND)

Percent Increase - seen in each puck sample with an overall analysis at the bottom

QUANT LIM ->	0.130	0.067	0.030	0.020	0.187	0.153	0.140	0.063	0.063	1.317	0.363	0.010	0.060	0.34	0.027	0.283	0.233	0.250	0.490	0.097	0.307	0.017		
DET LIM ->	0.039	0.020	0.009	0.006	0.056	0.046	0.042	0.019	0.019	0.395	0.109	0.003	0.018	0.10	0.008	0.085	0.070	0.075	0.147	0.029	0.092	0.005	0.005	0.005

Trace (TR)
Not detected (ND)

	Percent Increase between means	µg/g Al	µg/g As	µg/g B	µg/g Ba	µg/g Ca	µg/g Cd	µg/g Cr	µg/g Cu	µg/g Fe	µg/g K	µg/g Mg	µg/g Mn	µg/g Mo	µg/g Na	µg/g Ni	µg/g P	µg/g Pb	µg/g S	µg/g Se	µg/g Zn	µg/g Si	µg/g Ag	% C	% N
Material A	Control willow (mea	100.2	0.02	16.41	17.48	5177	0.046	0.14	7.66	588.1	1097	1031	144.9	0.018	3077.3	4.83	619	0.233	638.8	0.49	167.4	0.001	0.005	46.15	0.7085
Material B	Control woodchip (mear	164.8	0.067	7.907	2.135	431.1	0.046	0.14	3.105	661.4	324.8	750.7	68.62	0.06	4252.2	2.662	180.9	0.233	649.1	0.49	13.54	11.63	0.005	44.56	0.1895
Material C	Control mycoboard (mean	511.8	0.067	8.923	14.03	1504	0.046	0.042	6.798	909.2	559.8	1225	32.36	0.06	4849.03	4.323	357.8	0.233	1087	0.49	37.66	258.5	0.005	45.45	0.626
Material D	Control plant (mear	2656	0.067	29.82	37.42	2481	0.046	0.042	32.31	6323	2014	2296	214.7	2.889	6398.53	12.3	1051	32.84	1790	62.13	128.9	312.1	0.005	29.25	0.874
Material A	Willow (mean	361.1		77.83	9.488	10375			16.95	1975	1262	2766	347.5		16880.9	6.763	753	19.37	2684		178.4	72.31		38.798	0.8585
Material B	Woodchip (mean	444.3		36.89	5.433	2479			22.25	3177	1738	2940	531.9		19698.4	7.671	662.5	19.22	2254		64.65	74.49		39.153	0.583
Material C	mycoboard (mean)	705.8		42.96	14	1902			11	1778	2016	5436	85.98		116190	9.611	483.6	27.39	3613		52.14	113.4		39.308	0.7655
Material D	Plant (mean)	3100		84.83	21.32	3929			29.91	7144	3318	5879	519.1		96808.7	15.56	979.6	41.6	5387	80.69	76.63	212.1		26.903	0.553
Material A	Willow Percent Increas	2.602		3.742	-0.457	1.004			1.212	2.358	0.151	1.684	1.399		4.48561	0.4	0.217	82.14	3.202		0.065	72311		-0.159	0.2117
Material B	Woodchip Percent Increas	1.697		3.665	1.544	4.751			6.167	3.803	4.351	2.916	6.751		3.63253	1.881	2.662	108.7	2.473		3.776	5.404		-0.121	2.0765
Material C	mycoboard Percent Increase	0.379		3.815		0.265			0.619	0.956	2.602	3.436	1.657		22.9615	1.223	0.352	116.6	2.324		0.384	-0.561		-0.135	0.2228
Material D	Plant Percent Increase	0.167		1.844	-0.43	0.584			-0.074	0.13	0.648	1.56	1.418		14.1298	0.265	-0.068	0.267	2.009	0.299	-0.405	-0.32		-0.08	-0.367

willow	I		I	D	I			I	I	I	I	I		I	I	I	I	I		I/Same	I		D	I
wood chip	I		I	I	I			I	I	I	I	I		I	I	I	I	I		I	I		D	I
mycoboard	I		I	Same	I			I	I	I	I	I		I	I	I	I	I		I	D		D	I
plant	I		I	D	I			D	I	I	I	I		I	I	D	I	I	I	D	D		D	D

I = Increase
D= Decrease
Same = No change in value

Overall Intake by Wetland Biofilter

QUANT LIM ->	0.130	0.067	0.030	0.020	0.187	0.153	0.140	0.063	0.063	1.317	0.363	0.010	0.060	0.34	0.027	0.283	0.233	0.250	0.490	0.097	0.307	0.017		
DET LIM ->	0.039	0.020	0.009	0.006	0.056	0.046	0.042	0.019	0.019	0.395	0.109	0.003	0.018	0.10	0.008	0.085	0.070	0.075	0.147	0.029	0.092	0.005	0.005	0.005

Trace (TR)
Not detected (ND)

	Percent Increase between means	µg/g Al	µg/g As	µg/g B	µg/g Ba	µg/g Ca	µg/g Cd	µg/g Cr	µg/g Cu	µg/g Fe	µg/g K	µg/g Mg	µg/g Mn	µg/g Mo	µg/g Na	µg/g Ni	µg/g P	µg/g Pb	µg/g S	µg/g Se	µg/g Zn	µg/g Si	µg/g Ag	% C	% N
Material A	Control willow (mea	100.2	0.02	16.41	17.48	5177	0.046	0.14	7.66	588.1	1097	1031	144.9	0.018	3077.3	4.83	619	0.233	638.8	0.49	167.4	0.001	0.005	46.15	0.7085
Material B	Control woodchip (mear	164.8	0.067	7.907	2.135	431.1	0.046	0.14	3.105	661.4	324.8	750.7	68.62	0.06	4252.2	2.662	180.9	0.233	649.1	0.49	13.54	11.63	0.005	44.56	0.1895
Material C	Control mycoboard (mean	511.8	0.067	8.923	14.03	1504	0.046	0.042	6.798	909.2	559.8	1225	32.36	0.06	4849.03	4.323	357.8	0.233	1087	0.49	37.66	258.5	0.005	45.45	0.626
Material D	Control plant (mear	2656	0.067	29.82	37.42	2481	0.046	0.042	32.31	6323	2014	2296	214.7	2.889	6398.53	12.3	1051	32.84	1790	62.13	128.9	312.1	0.005	29.25	0.874
Material A	Willow (mean	361.1		77.83	9.488	10375			16.95	1975	1262	2766	347.5		16880.9	6.763	753	19.37	2684		178.4	72.31		38.798	0.8585
Material B	Woodchip (mean	444.3		36.89	5.433	2479			22.25	3177	1738	2940	531.9		19698.4	7.671	662.5	19.22	2254		64.65	74.49		39.153	0.583
Material C	mycoboard (mean)	705.8		42.96	14	1902			11	1778	2016	5436	85.98		116190	9.611	483.6	27.39	3613		52.14	113.4		39.308	0.7655
Material D	Plant (mean)	3100		84.83	21.32	3929			29.91	7144	3318	5879	519.1		96808.7	15.56	979.6	41.6	5387	80.69	76.63	212.1		26.903	0.553
Material A	Willow Percent Increas	2.602		3.742	-0.457	1.004			1.212	2.358	0.151	1.684	1.399		4.48561	0.4	0.217	82.14	3.202		0.065	72311		-0.159	0.2117
Material B	Woodchip Percent Increas	1.697		3.665	1.544	4.751			6.167	3.803	4.351	2.916	6.751		3.63253	1.881	2.662	108.7	2.473		3.776	5.404		-0.121	2.0765
Material C	mycoboard Percent Increase	0.379		3.815		0.265			0.619	0.956	2.602	3.436	1.657		22.9615	1.223	0.352	116.6	2.324		0.384	-0.561		-0.135	0.2228
Material D	Plant Percent Increase	0.167		1.844	-0.43	0.584			-0.074	0.13	0.648	1.56	1.418		14.1298	0.265	-0.068	0.267	2.009	0.299	-0.405	-0.32		-0.08	-0.367

willow	I		I	D	I			I	I	I	I	I		I	I	I	I	I		I/Same	I		D	I
wood chip	I		I	I	I			I	I	I	I	I		I	I	I	I	I		I	I		D	I
mycoboard	I		I	Same	I			I	I	I	I	I		I	I	I	I	I		I	D		D	I
plant	I		I	D	I			D	I	I	I	I		I	I	D	I	I	I	D	D		D	D

I = Increase
D= Decrease
Same = No change in value

	Over uptake by wetland biofilter	g Al	g As	g B	g Ba	g Ca	g Cd	g Cr	g Cu	g Fe	g K	g Mg	g Mn	g Mo	g Na	g Ni	g P	g Pb	g S	g Se	g Zn	g Si	g Ag	% C	% N
Material A	Willov	6.202		1.46	-0.19	123.6			0.221	32.97	3.936	41.26	4.819		328.224	0.046	3.187	0.455	48.64		0.26	1.719		-1748	35.667
Material B	Woodchip	3.048		0.316	0.036	22.34			0.209	27.43	15.41	23.87	5.053		168.457	0.055	5.252	0.207	17.51		0.557	0.686		-589.7	42.915
Material C	Mycoboard	4.646		0.815		9.533			0.101	20.81	34.87	100.8	1.284		2665.51	0.127	3.011	0.65	60.47		0.347	-3.474		-1471	33.396
Material D	Plant	0.277		0.034	-0.01	0.904			-0.001	0.513	0.814	2.236	0.19		56.4227	0.002	-0.045	0.005	2.245	0.012	-0.033	-0.062		-14.65	-2.003
	wetland biofilter tot	14.17		2.626	-0.164	156.4			0.529	81.72	55.03	168.2	11.35		3218.61	0.229	11.41	1.318	128.9	0.012	1.132	-1.131		-3823	109.98

	Grams Tested	Volume of material tested	Volume of material in biobarge	Scale (Inflation factor)	Grams per biobarge	
	(g)	(cubic inches)	(cubic inches)		(g)	
Material A	174.3	144	15552	136.4211	23778.18947	Willov
Material B	277.7	198	7776	39.27273	10906.03636	Woodchip
Material C	624.1	118.25	4536	38.35941	23940.10655	Mycoboard
Material D	15.7	1 plant*	39.75 plant average	39.75	624.075	Plant

* tested material came from control not contaminated puck due to lack o
living plant material in contaminate pucks

Appendix D

Plant Monitoring

What we did

Date: **Measurer:** **Recorder:**

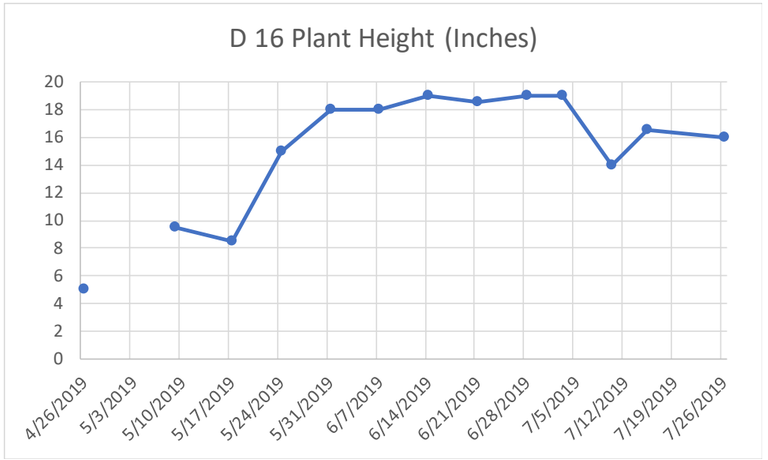
Station #	BioBarge	WBF	Species	Total # of Plants (# of planted holes)	Plant Height	Root Height	Percent Cover (Visual)	Plant Density (# of stems in WBF)	WBF Intact Structure	WBF Structure Failing	WBF Substrate Degrading	Notes:
T-105	B	2	SCHLAC	41								
T-105	B	5	BOLMAR	46								
T-105	B	8	SCHACU	34								
T-105	B	13	SCHAME	39								
T-105	D	16	SCHAME	42								
T-105	D	10	SCHACU	47								
T-105	D	6	BOLMAR	46								
T-105	D	18	SCHLAC	41								

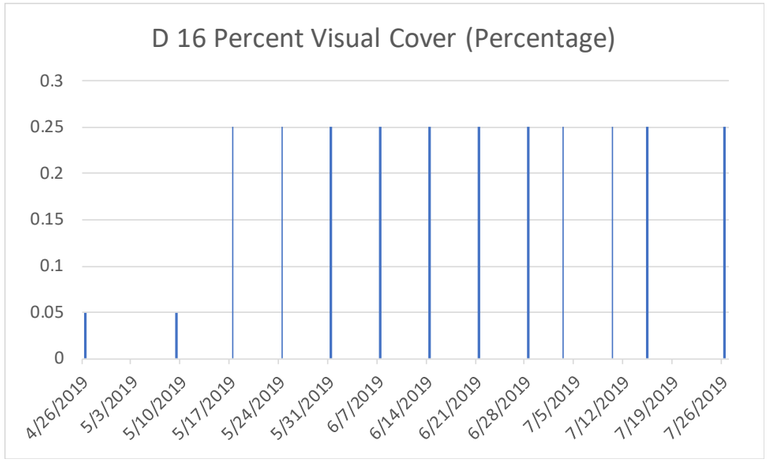
Findings

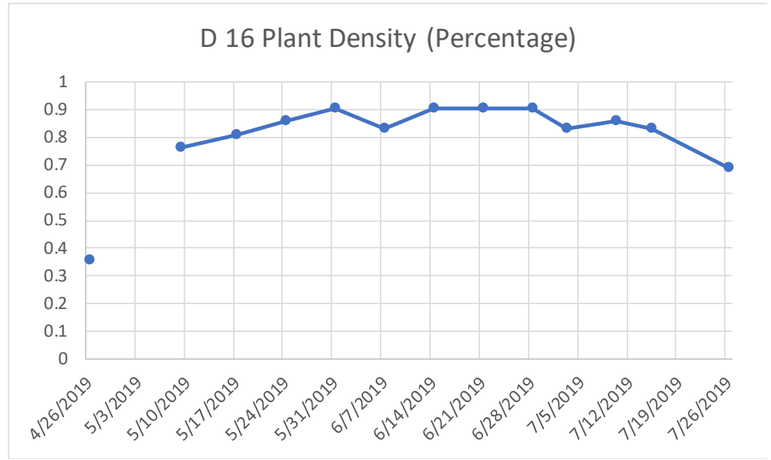
Plant Records

Biobarge D

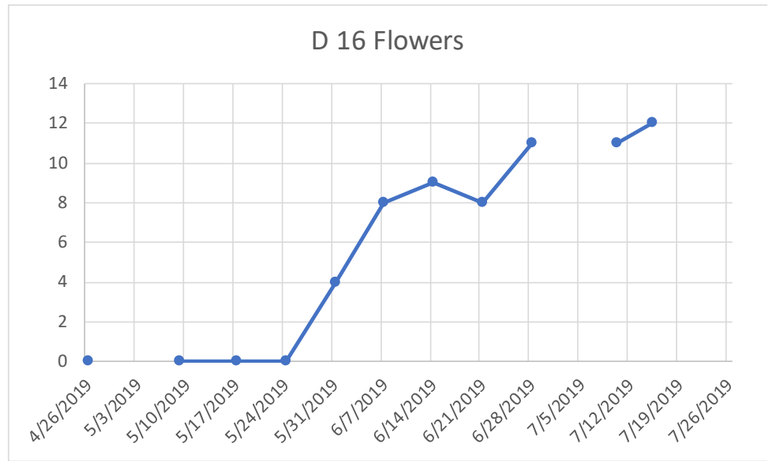
Biobarge D 16 change in plants each week - SCHAME

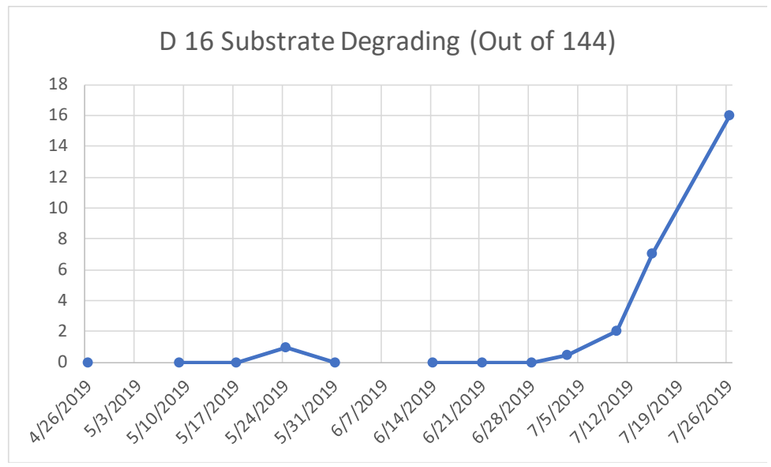

D 16 Plant Height (Inches)
20
18
16
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


D 16 Percent Visual Cover (Percentage)
0.3
0.25
0.2
0.15
0.1
0.05
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

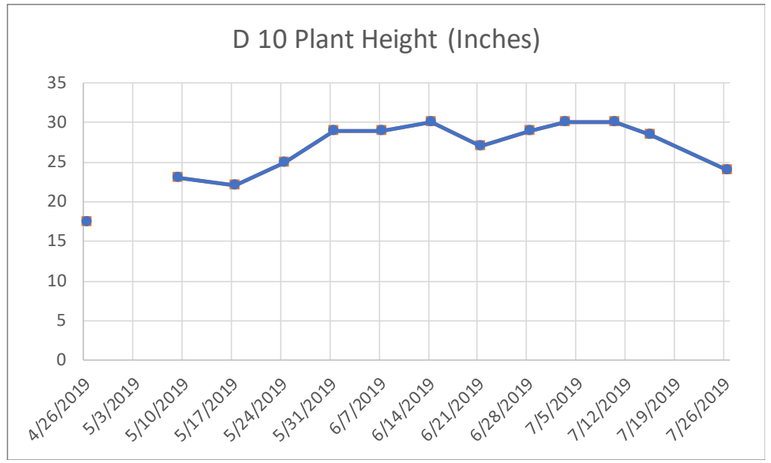

D 16 Plant Density (Percentage)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

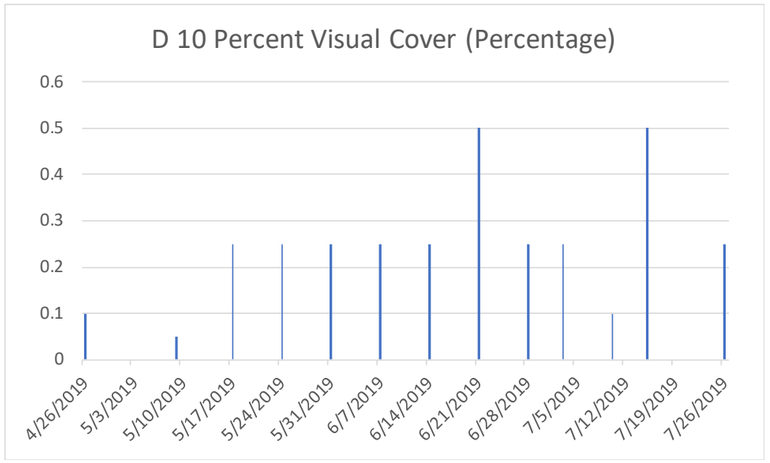

SAM
07/26/2019

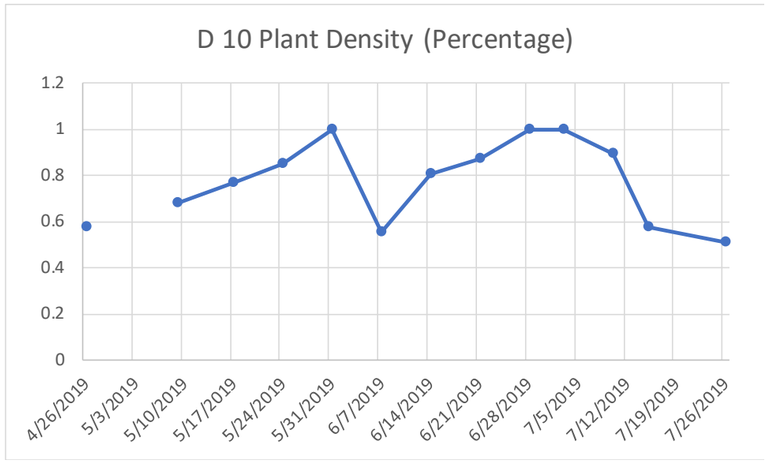

D 16 Flowers
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


D 16 Substrate Degrading (Out of 144)
18
16
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

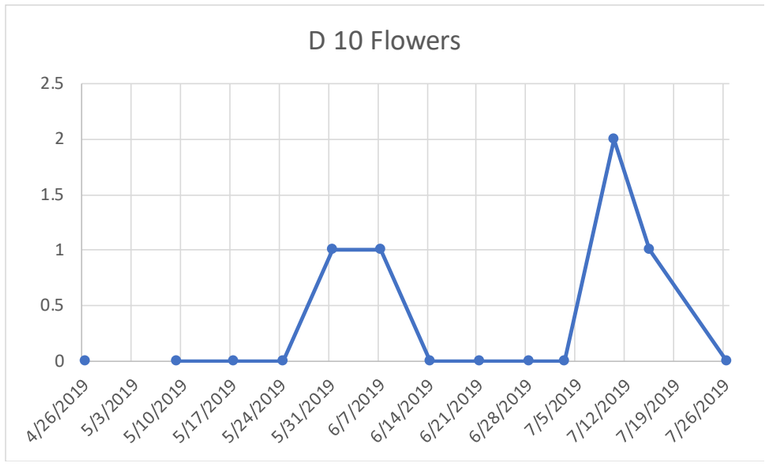
Biobarge D 10 change in plants each week - SCHACU

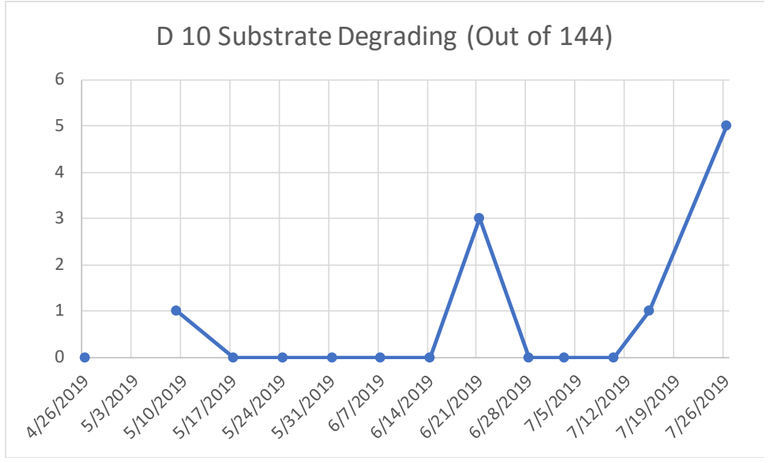

D 10 Plant Height (Inches)
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


D 10 Percent Visual Cover (Percentage)
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

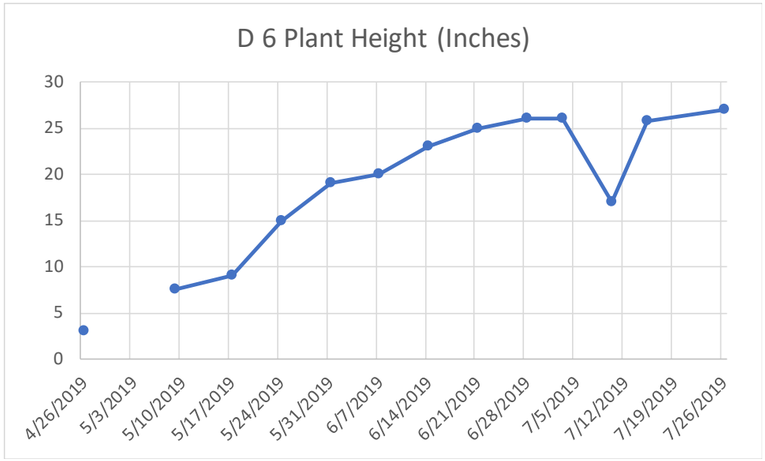

D 10 Plant Density (Percentage)
1.2
1
0.8
0.6
0.4
0.2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

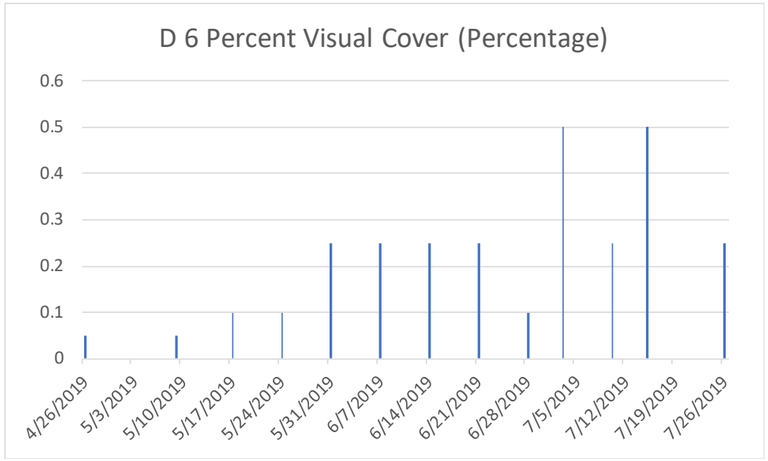

07/26/2019

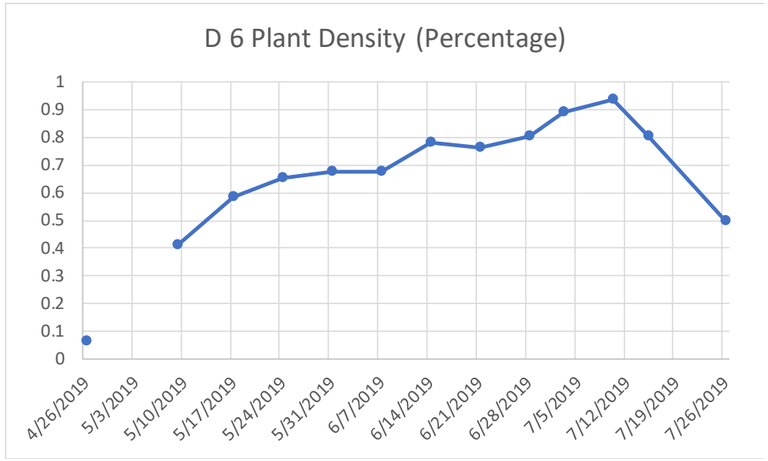

D 10 Flowers
2.5
2
1.5
1
0.5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


D 10 Substrate Degrading (Out of 144)
6
5
4
3
2
1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

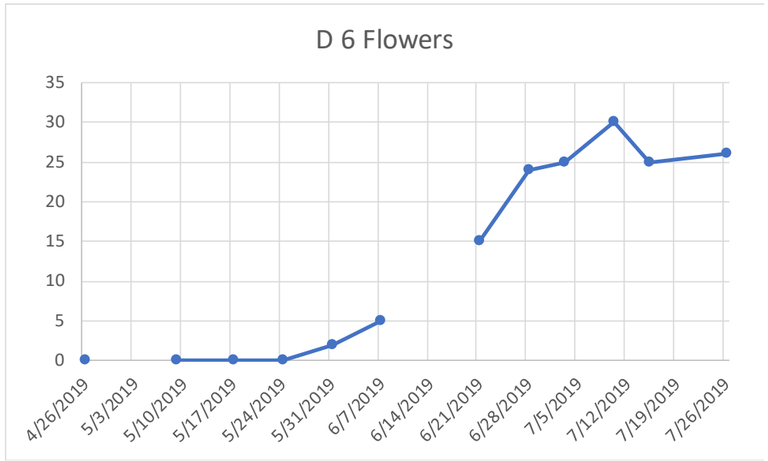
Biobarge D 6 change in plants each week - BOLMAR

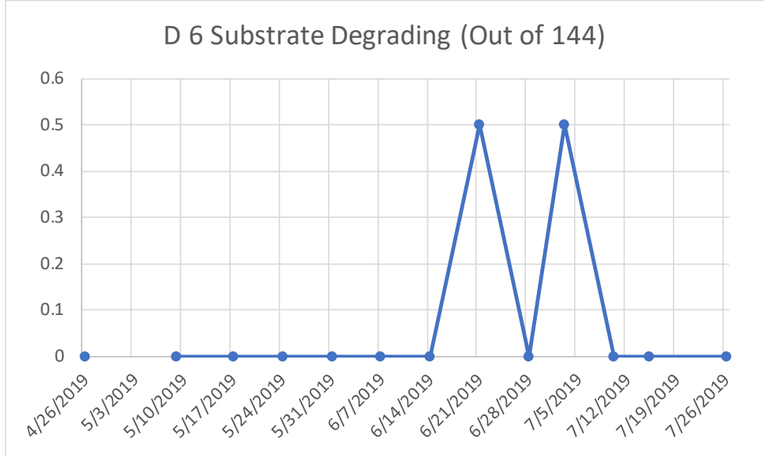

D 6 Plant Height (Inches)
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


D 6 Percent Visual Cover (Percentage)
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

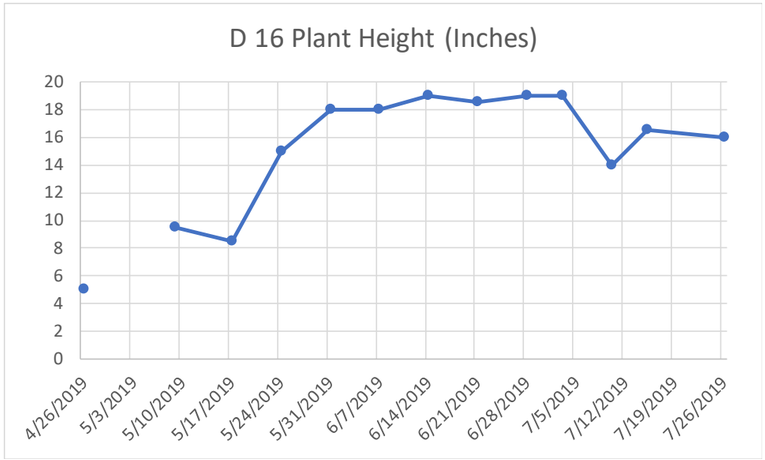

D 6 Plant Density (Percentage)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

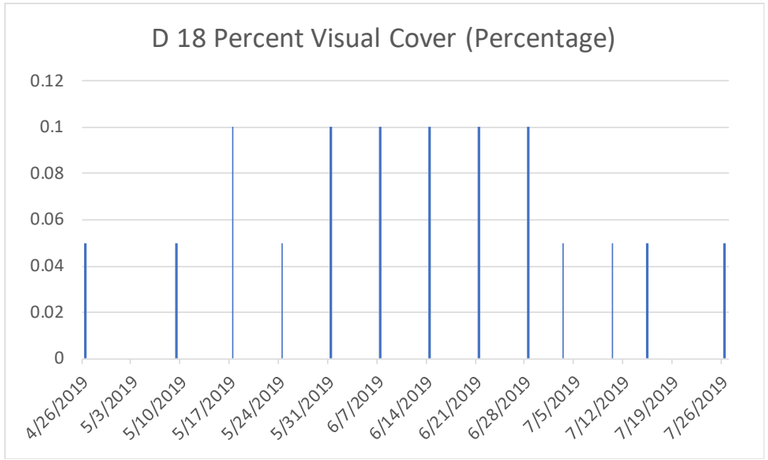

D7
D6
07/26/2019

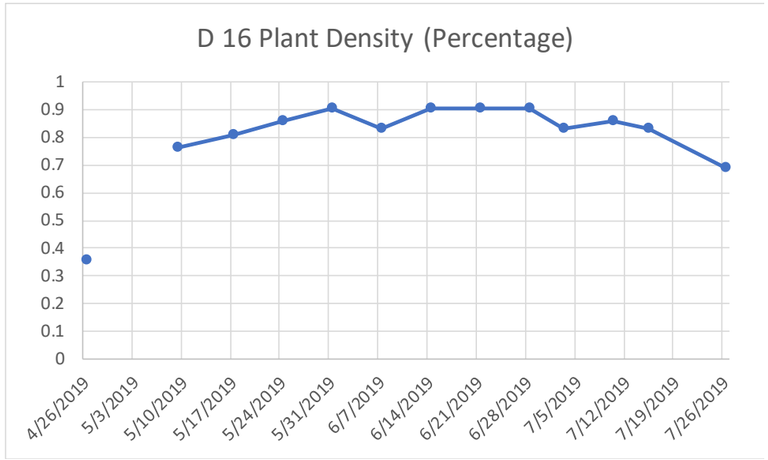

D 6 Flowers
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


D 6 Substrate Degrading (Out of 144)
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

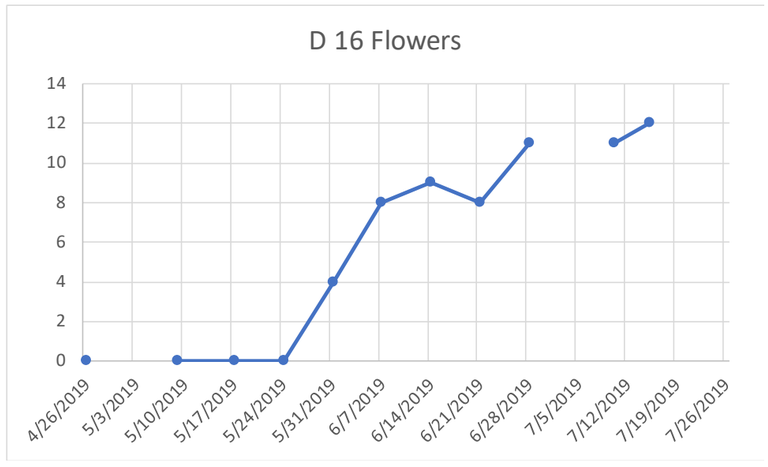
Biobarge D 18 change in plants each week - SCHTAB

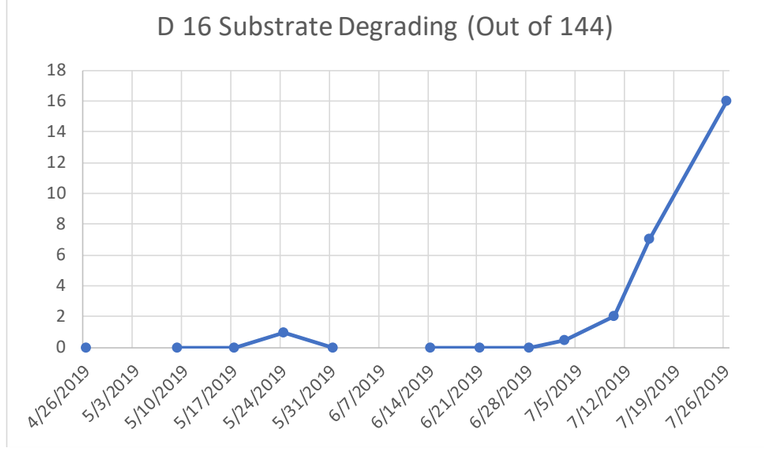

D 16 Plant Height (Inches)
20
18
16
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


D 18 Percent Visual Cover (Percentage)
0.12
0.1
0.08
0.06
0.04
0.02
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


D 16 Plant Density (Percentage)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


07/26/2019

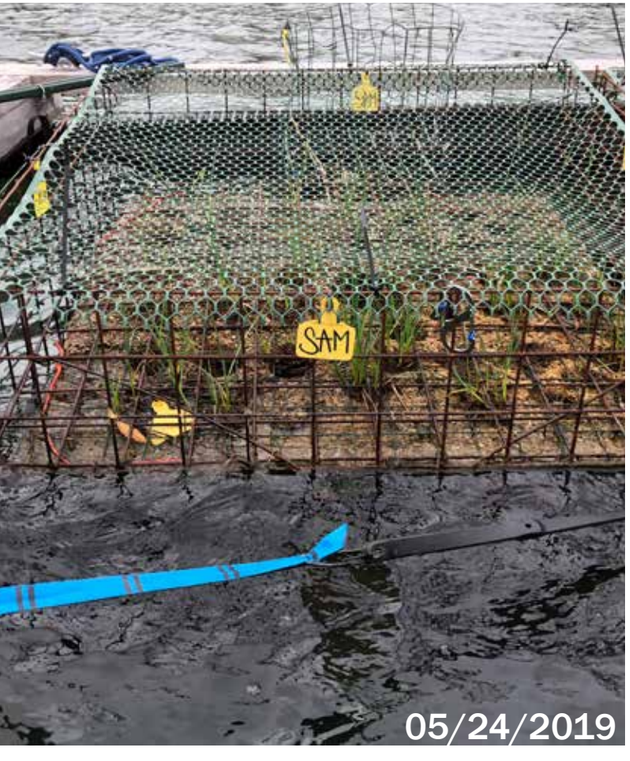

D 16 Flowers
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

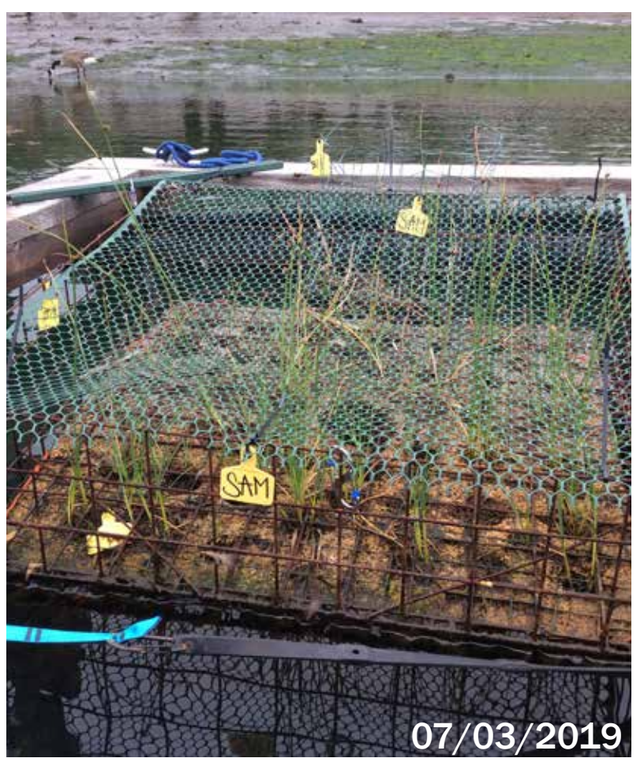

D 16 Substrate Degrading (Out of 144)
18
16
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

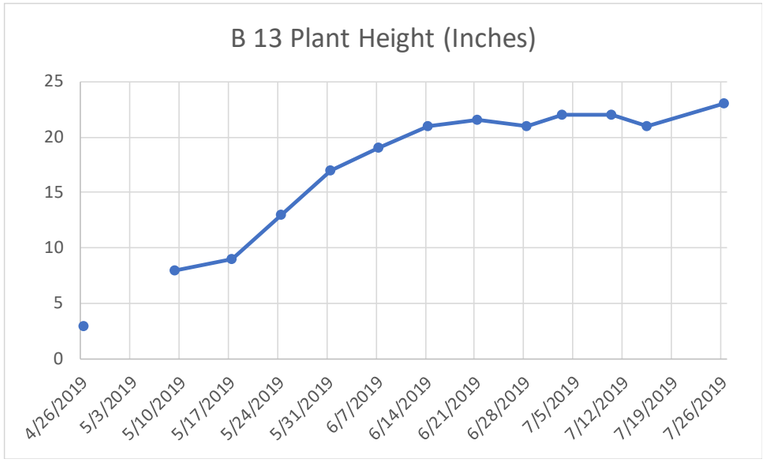
Plant Records

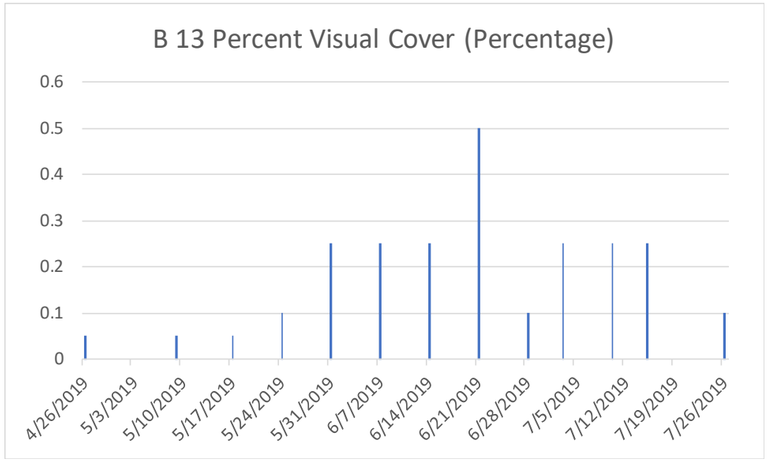
Biobarge B

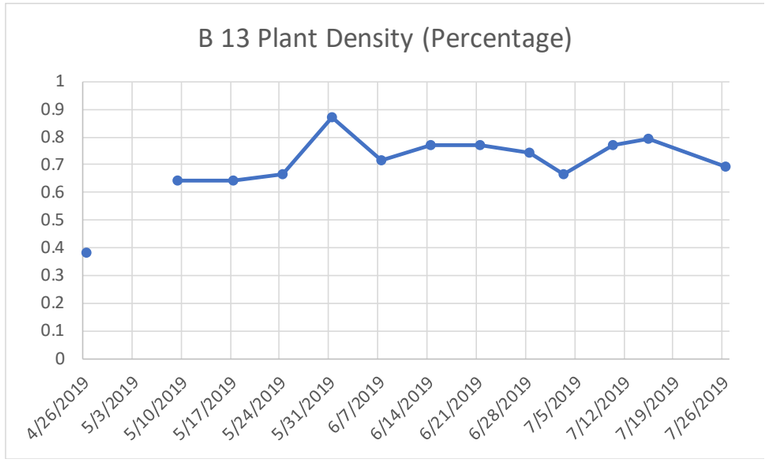
Biobarge B 13 change in plants each week - SCHAME






B 13 Plant Height (Inches)
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


B 13 Percent Visual Cover (Percentage)
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


B 13 Plant Density (Percentage)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019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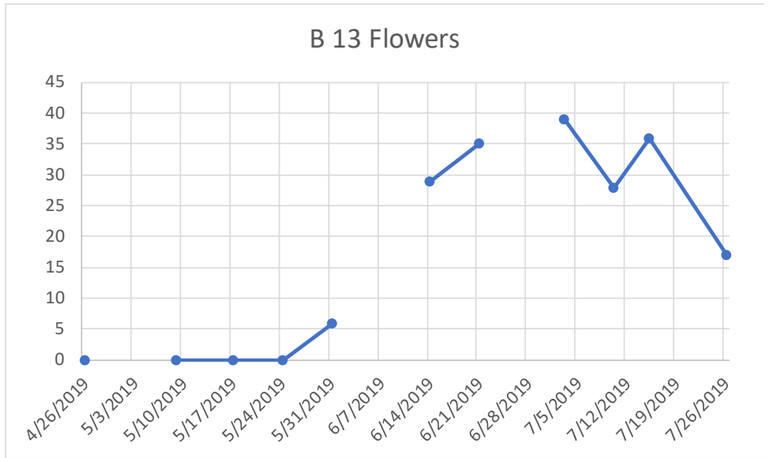
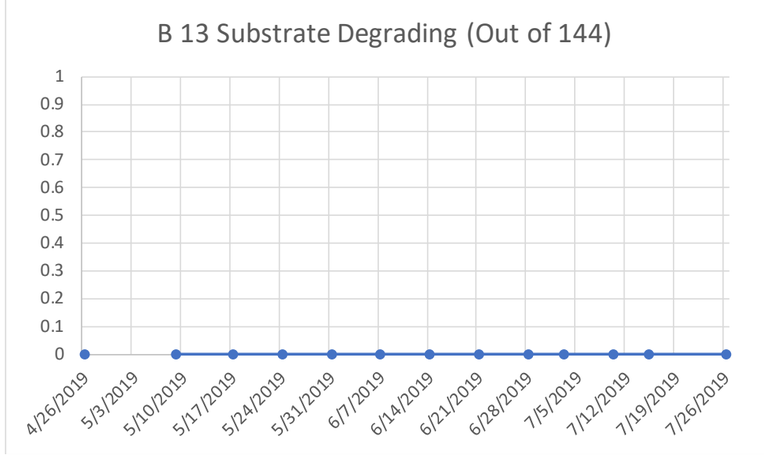
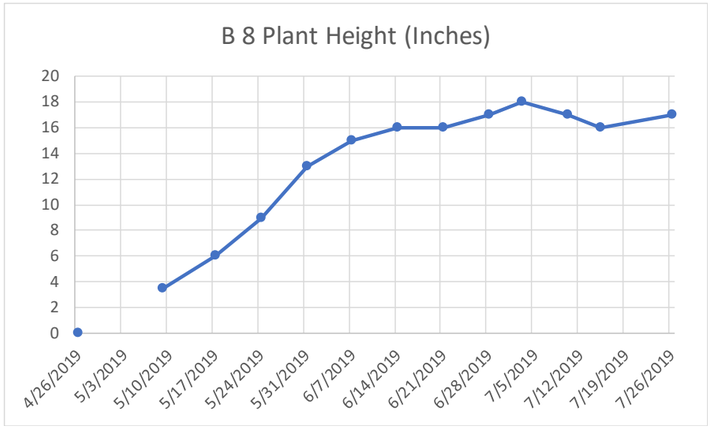
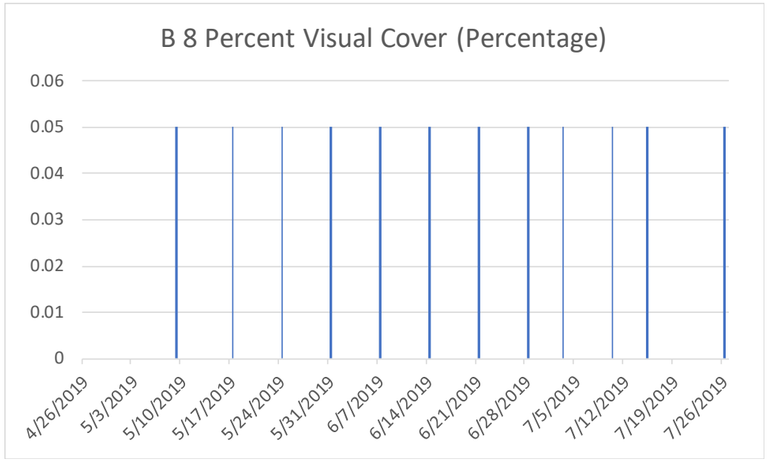
BIOBARGE FLOATI
07/26/2019

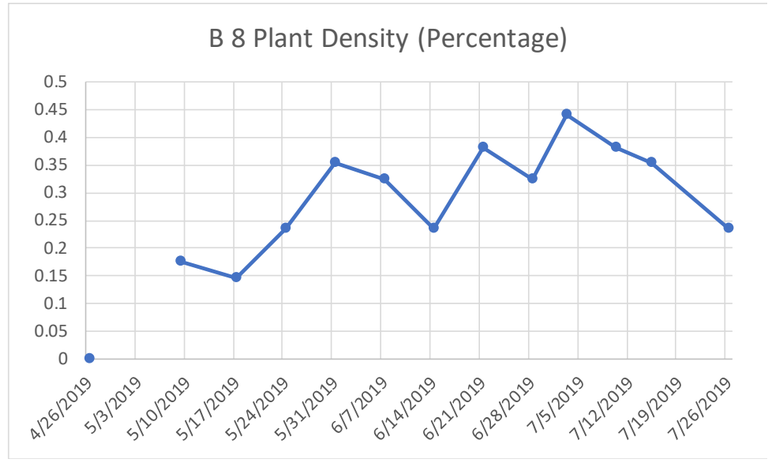

B 13 Flowers
45
40
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


B 13 Substrate Degrading (Out of 144)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

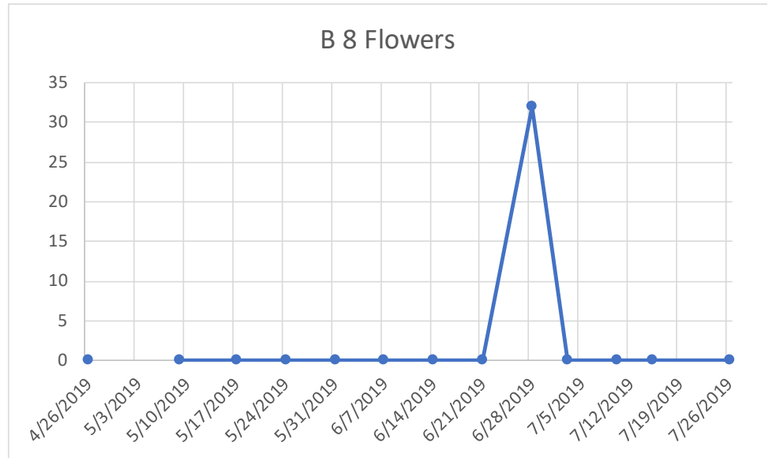
Biobarge B 8 change in plants each week - SCHACU

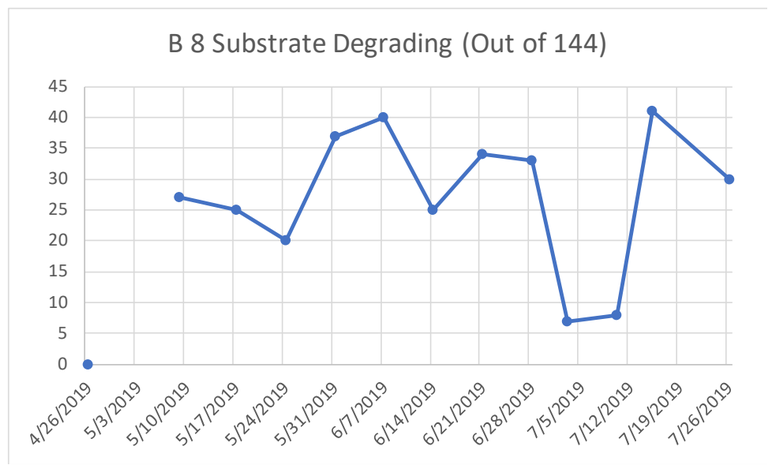

B 8 Plant Height (Inches)
20
18
16
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


B 8 Percent Visual Cover (Percentage)
0.06
0.05
0.04
0.03
0.02
0.01
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

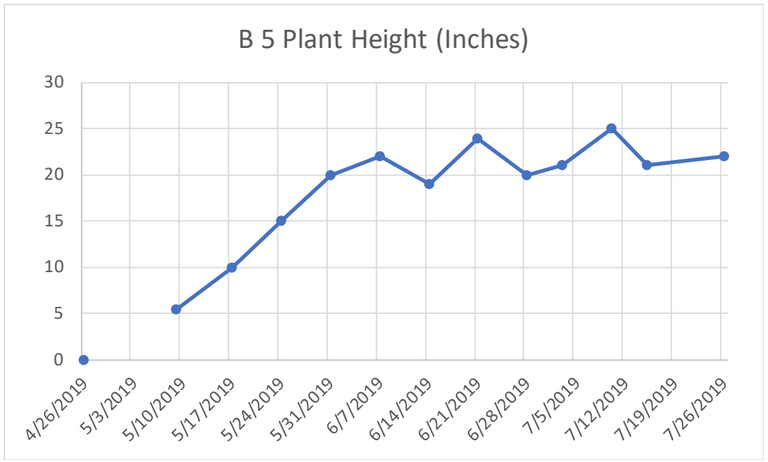

B 8 Plant Density (Percentage)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

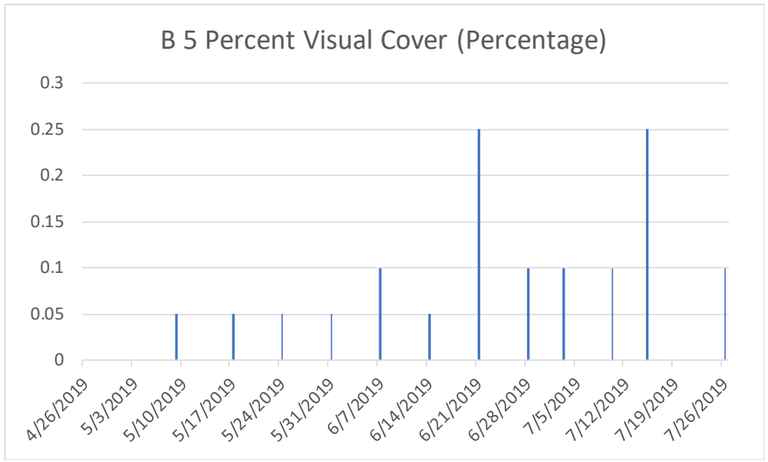

07/26/2019

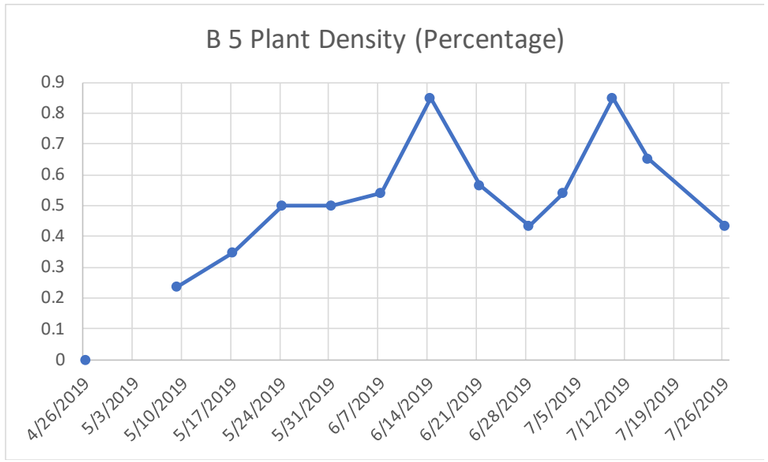

B 8 Flowers
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


B 8 Substrate Degrading (Out of 144)
45
40
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

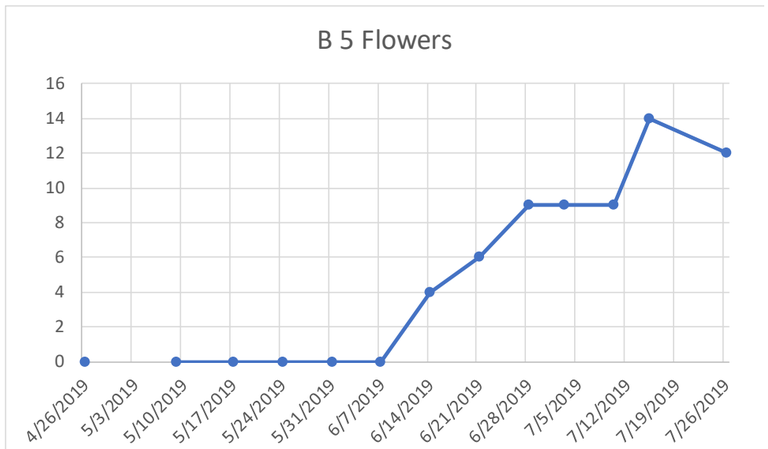
Biobarge B 5 change in plants each week - BOLMAR

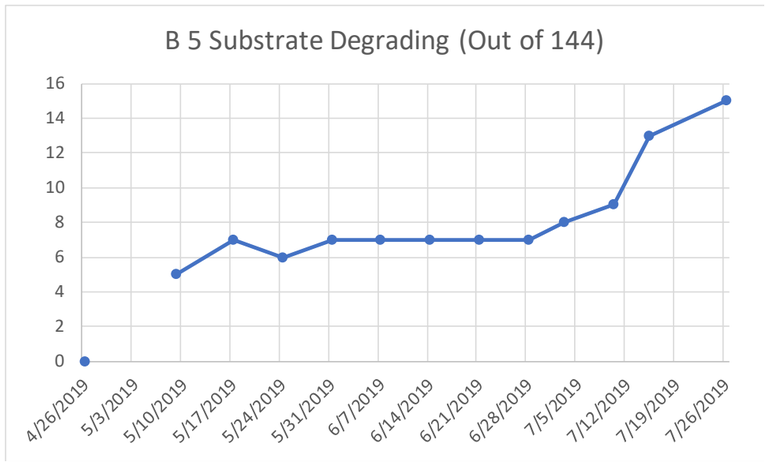

B 5 Plant Height (Inches)
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


B 5 Percent Visual Cover (Percentage)
0.3
0.25
0.2
0.15
0.1
0.05
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

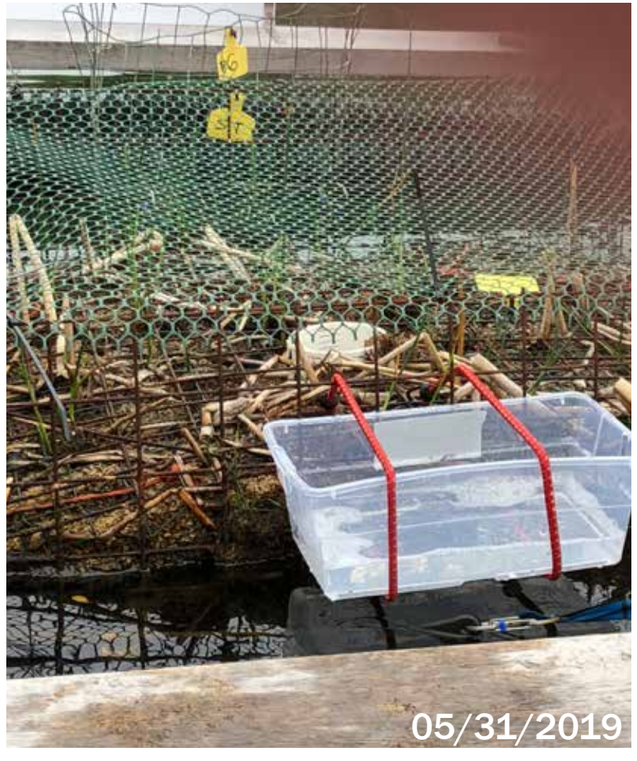

B 5 Plant Density (Percentage)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

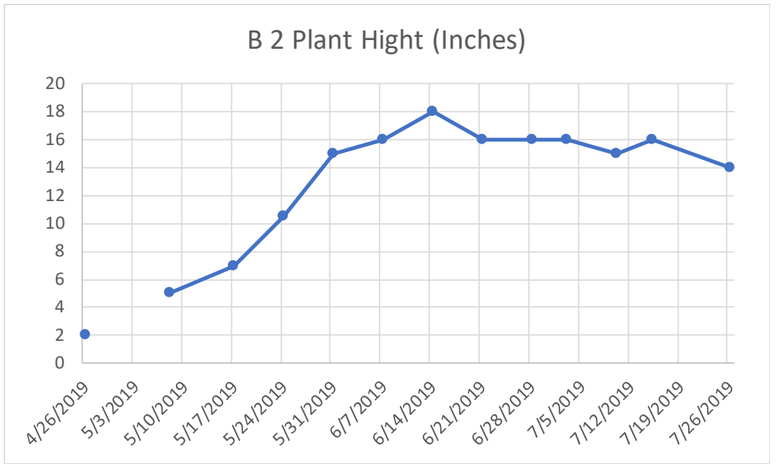

07/26/2019

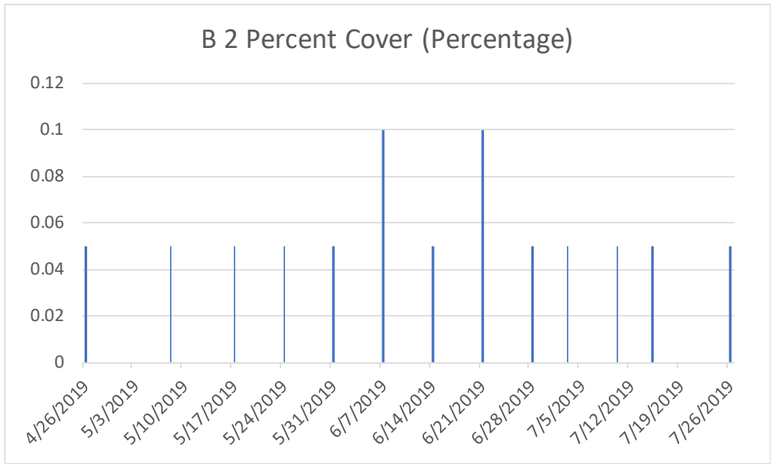

B 5 Flowers
16
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

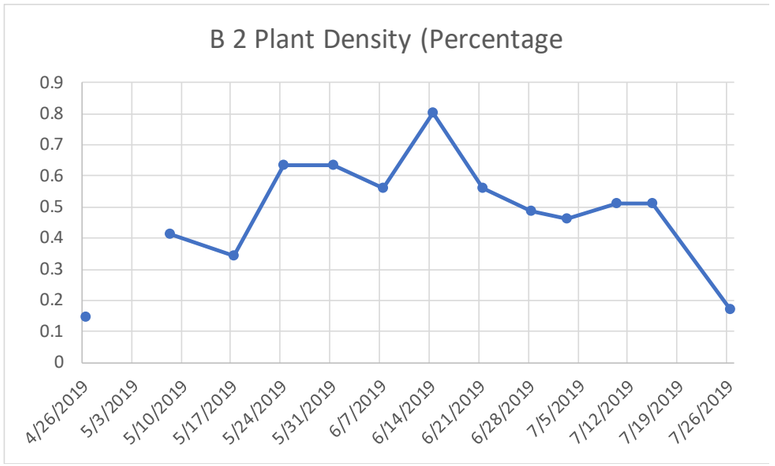

B 5 Substrate Degrading (Out of 144)
16
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

Biobarge B 2 change in plants each week - SCHTAB

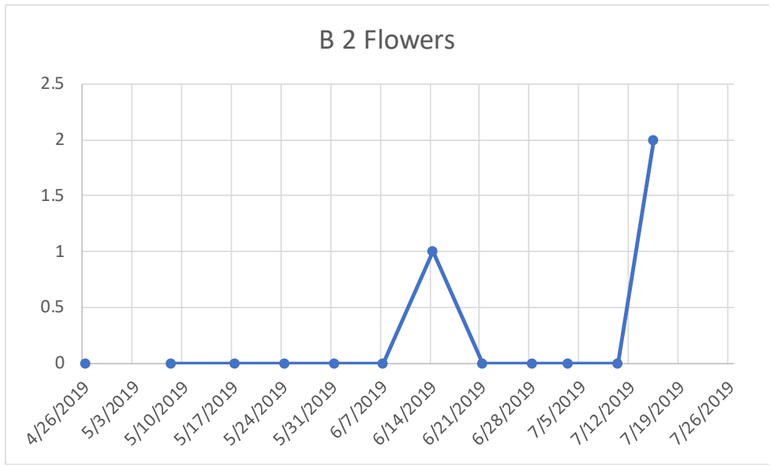


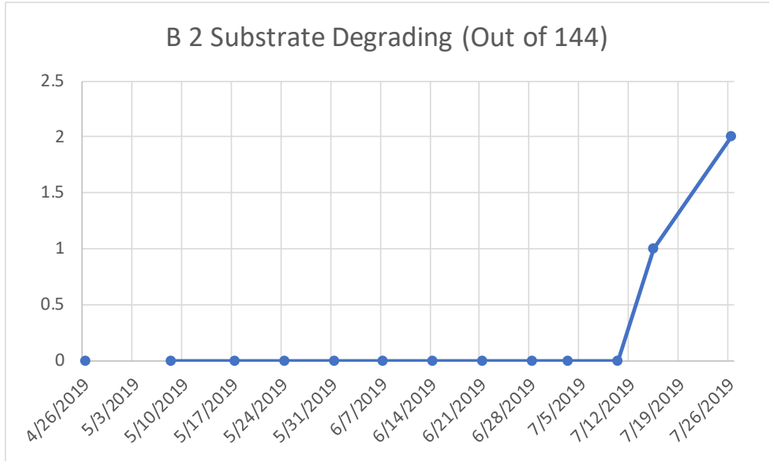

B 2 Plant Hight (Inches)
20
18
16
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


B 2 Percent Cover (Percentage)
0.12
0.1
0.08
0.06
0.04
0.02
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


B 2 Plant Density (Percentage
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


07/26/2019

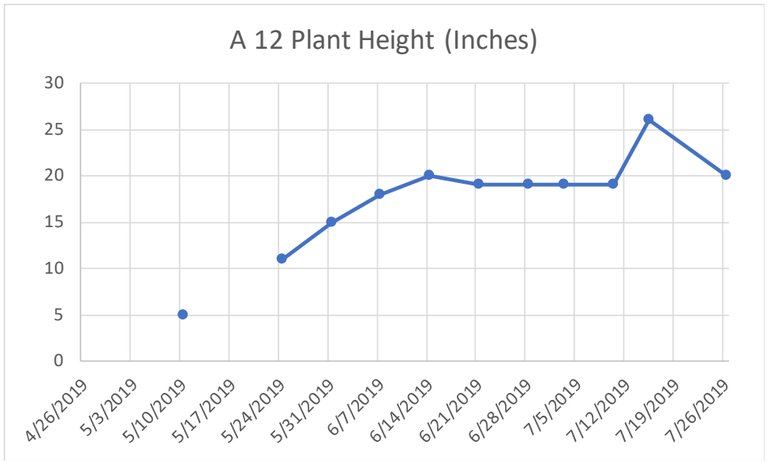

B 2 Flowers
2.5
2
1.5
1
0.5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

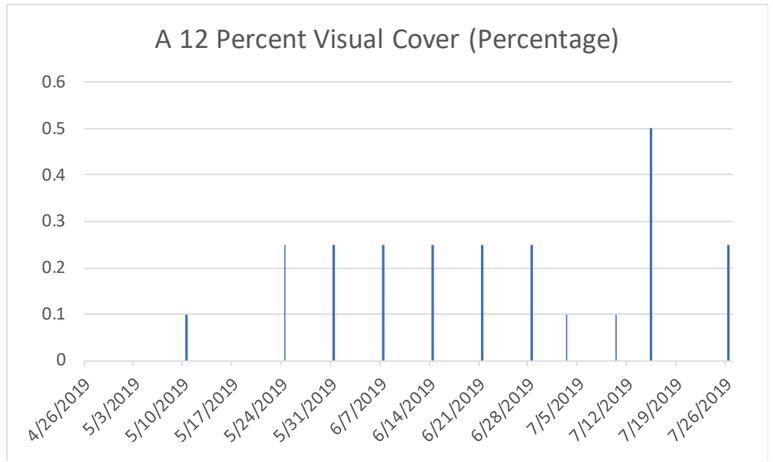

B 2 Substrate Degrading (Out of 144)
2.5
2
1.5
1
0.5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

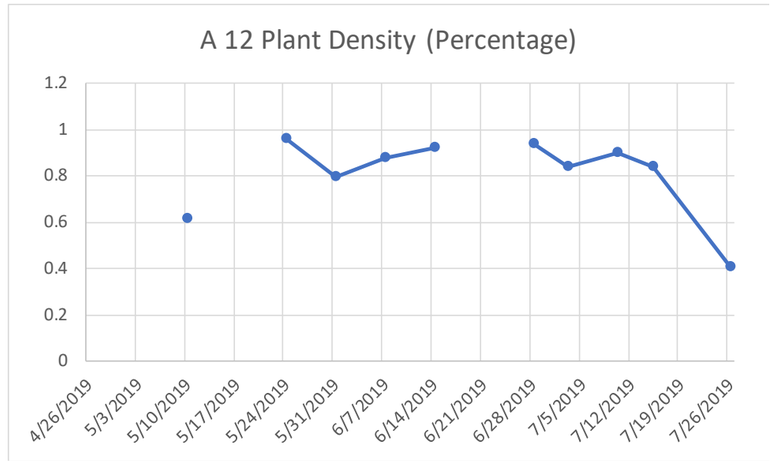
Plant Records

Biobarge A

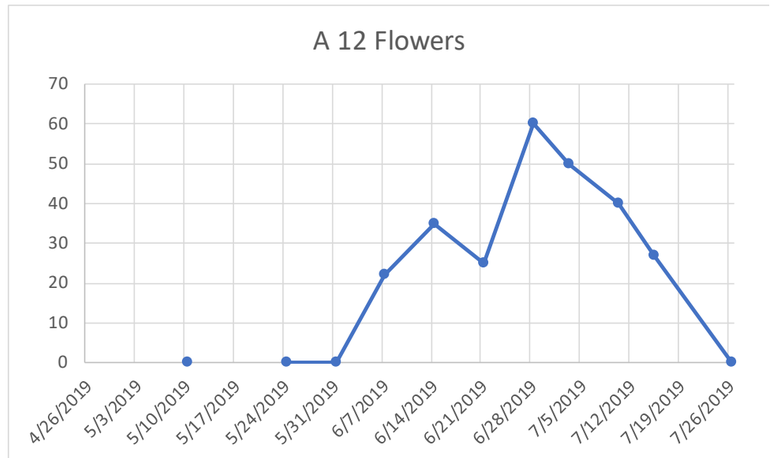
Biobarge A 12 change in plants each week - SCHAME

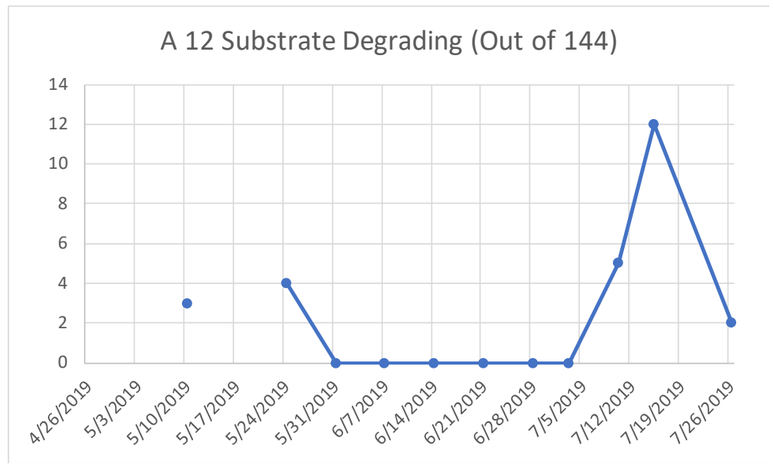

A 12 Plant Height (Inches)
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A 12 Percent Visual Cover (Percentage)
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

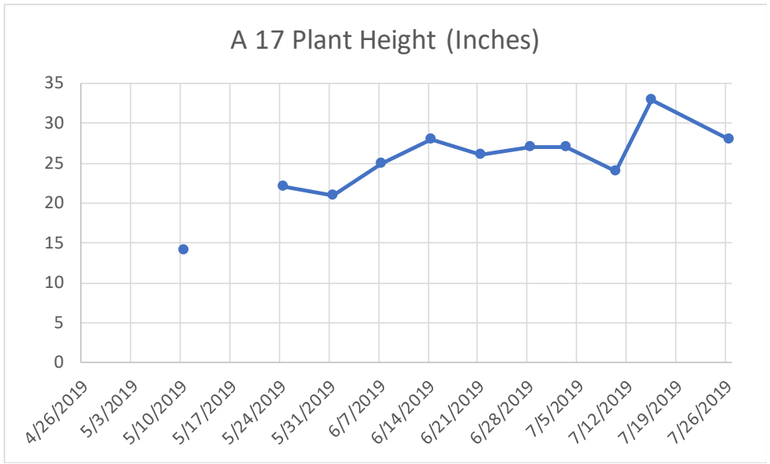

A 12 Plant Density (Percentage)
1.2
1
0.8
0.6
0.4
0.2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

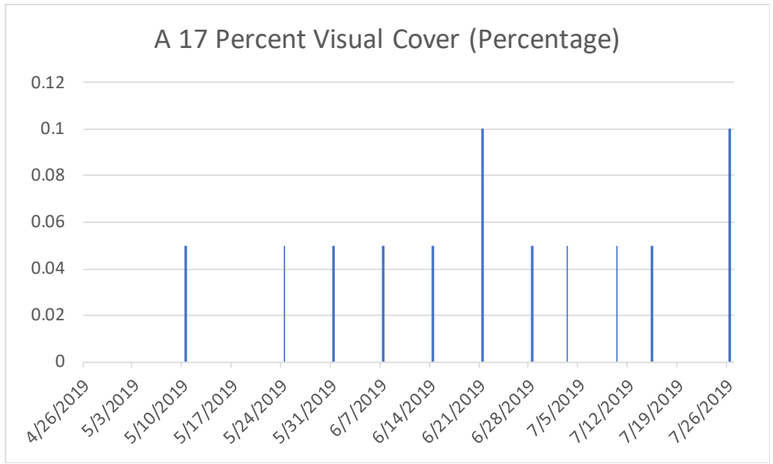

A12
07/15/2019

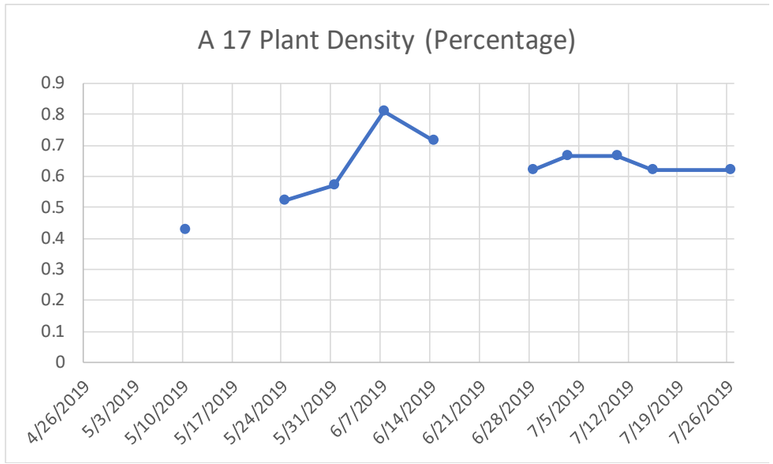

A 12 Flowers
70
60
50
40
30
20
10
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A 12 Substrate Degrading (Out of 144)
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

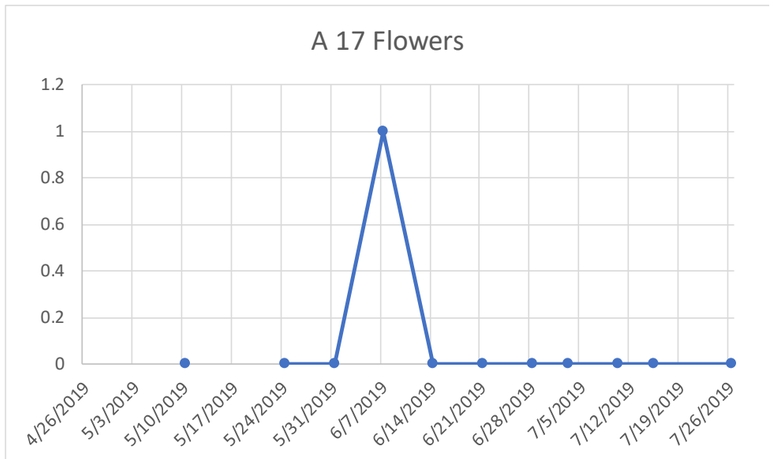
Biobarge A 17 change in plants each week - SCHACU

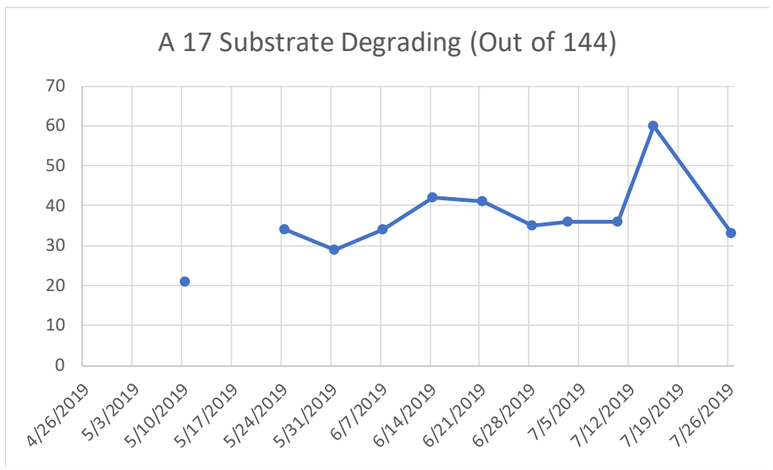

A 17 Plant Height (Inches)
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A 17 Percent Visual Cover (Percentage)
0.12
0.1
0.08
0.06
0.04
0.02
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

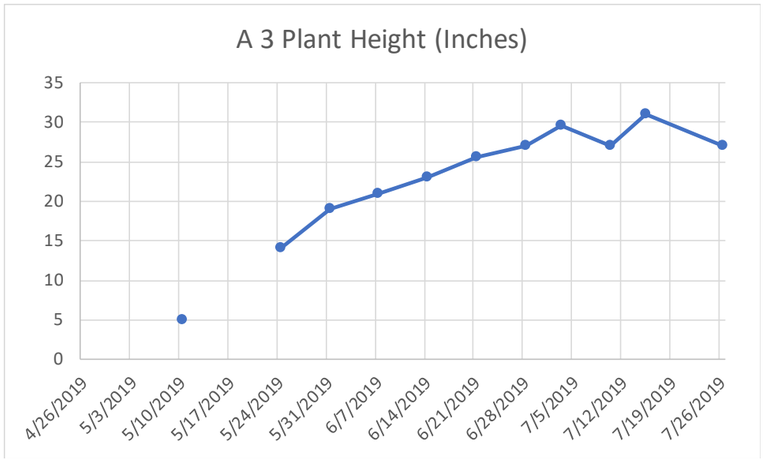

A 17 Plant Density (Percentage)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

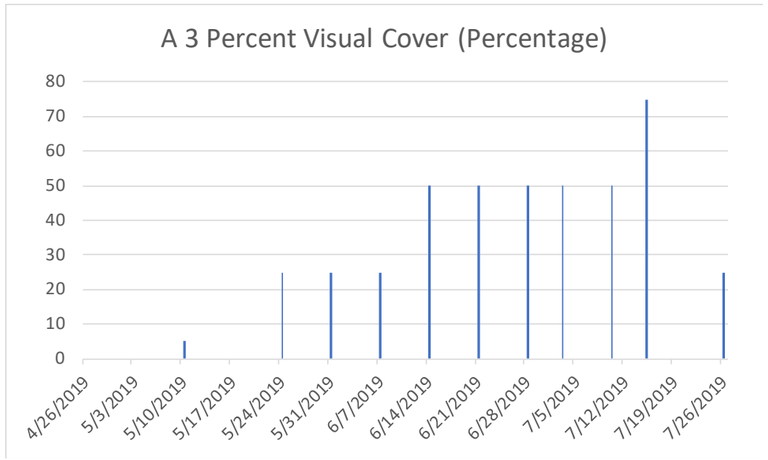

SCAC
07/15/2019

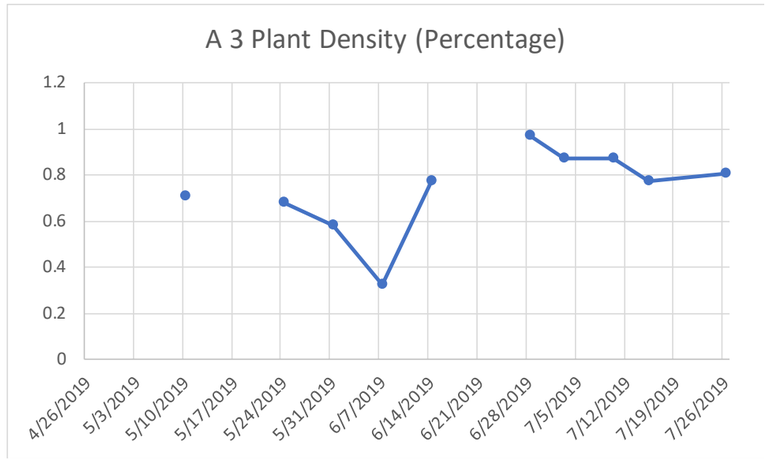

A 17 Flowers
1.2
1
0.8
0.6
0.4
0.2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A 17 Substrate Degrading (Out of 144)
70
60
50
40
30
20
10
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

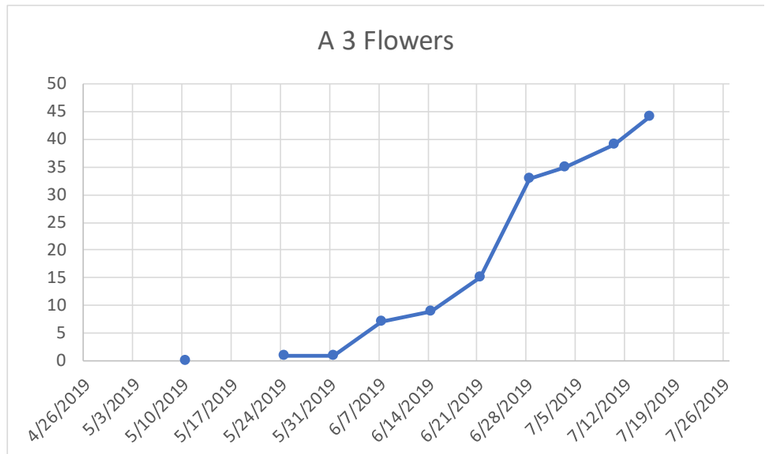
Biobarge A 3 change in plants each week - BOLMAR

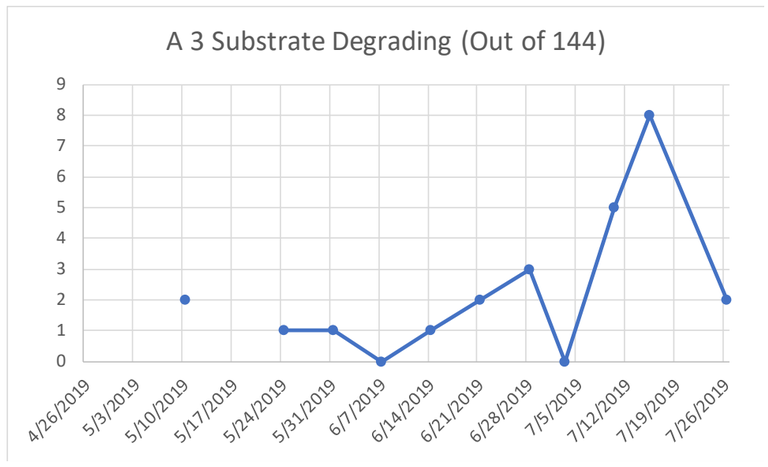

A 3 Plant Height (Inches)
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A 3 Percent Visual Cover (Percentage)
80
70
60
50
40
30
20
10
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

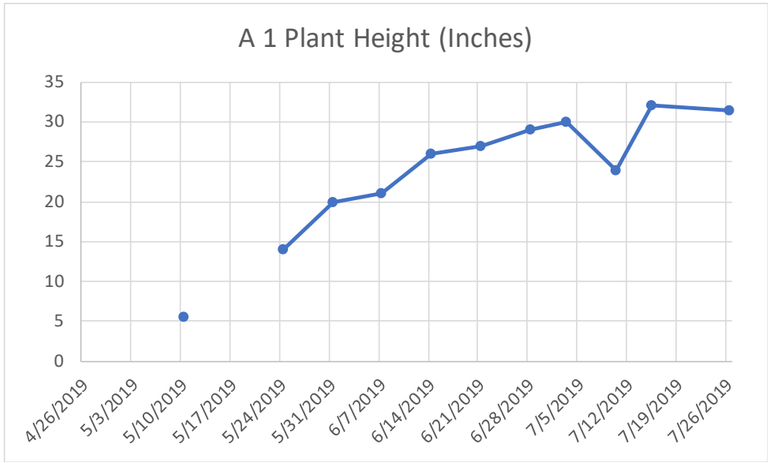

A 3 Plant Density (Percentage)
1.2
1
0.8
0.6
0.4
0.2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

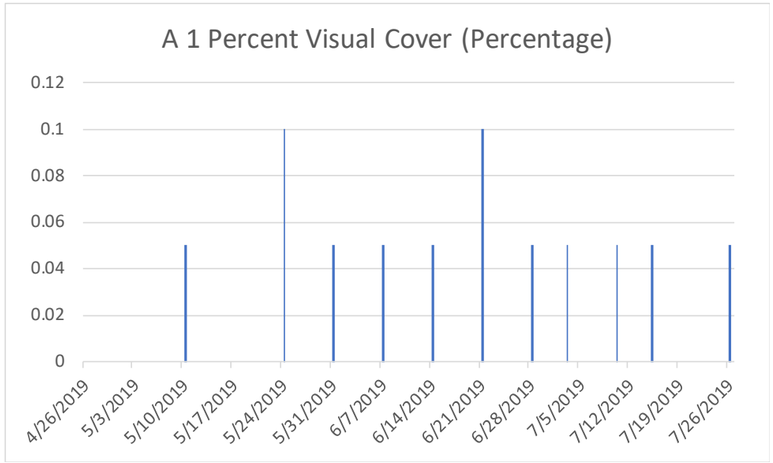

07/15/2019

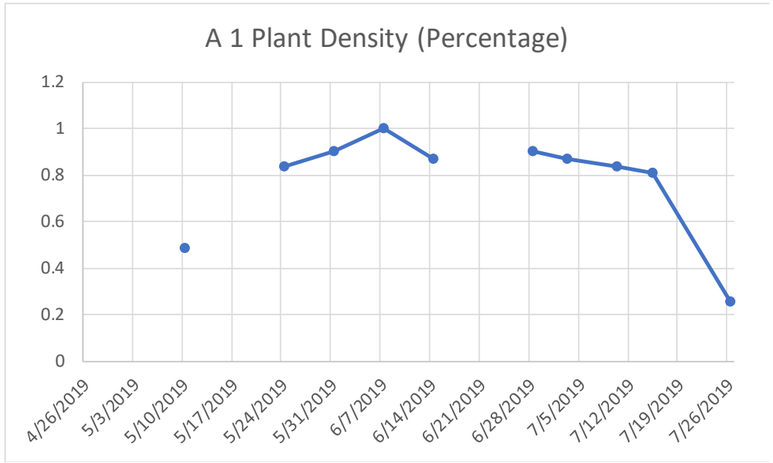

A 3 Flowers
50
45
40
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A 3 Substrate Degrading (Out of 144)
9
8
7
6
5
4
3
2
1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

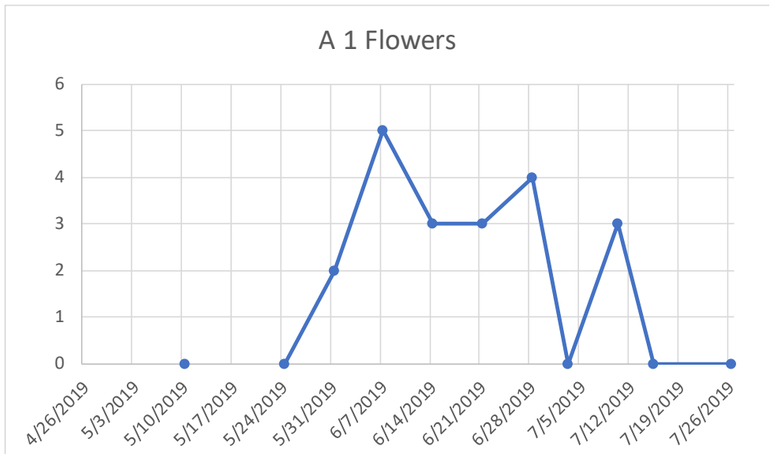
Biobarge A 1 change in plants each week - SCHTAB

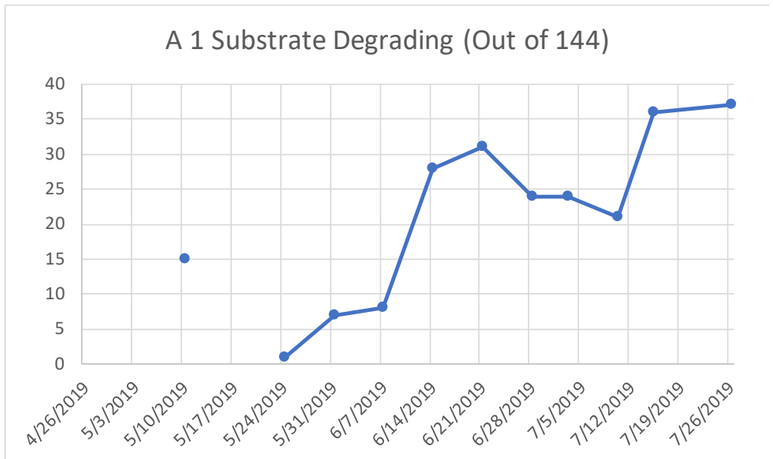

A 1 Plant Height (Inches)
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A 1 Percent Visual Cover (Percentage)
0.12
0.1
0.08
0.06
0.04
0.02
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A 1 Plant Density (Percentage)
1.2
1
0.8
0.6
0.4
0.2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


A1
07/15/2019

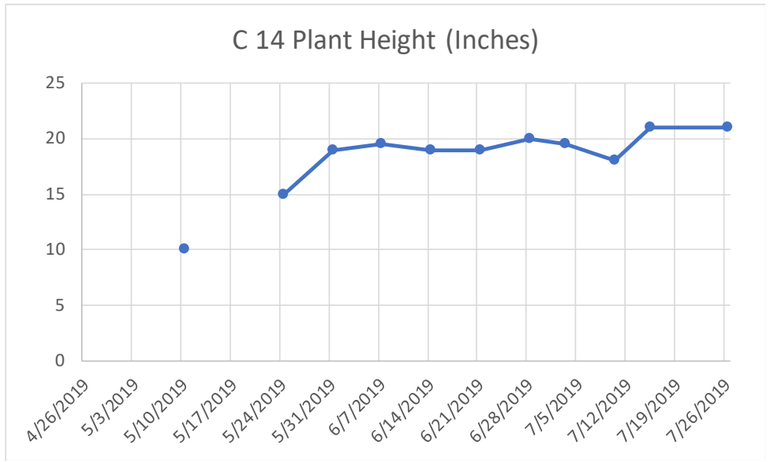

A 1 Flowers
6
5
4
3
2
1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

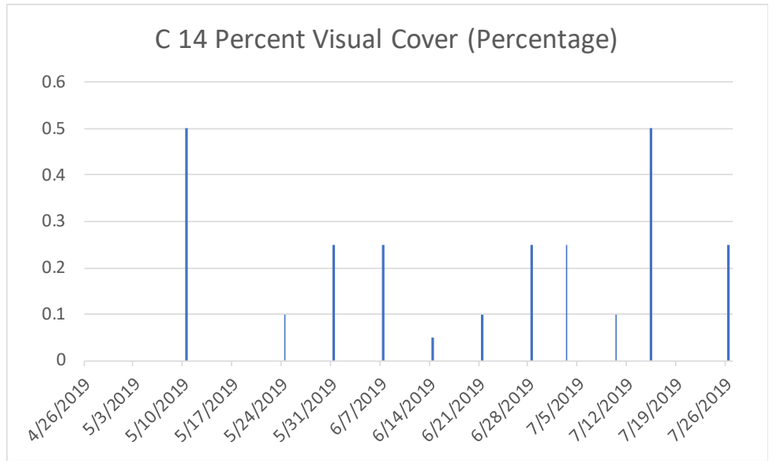

A 1 Substrate Degrading (Out of 144)
40
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

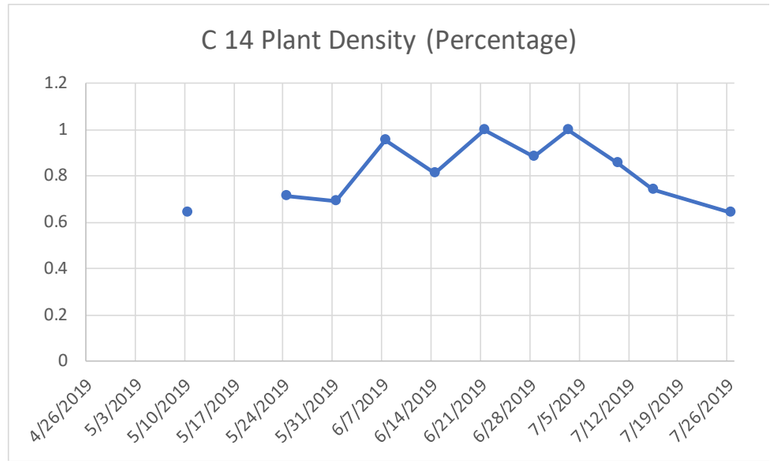
Plant Records

Biobarge C

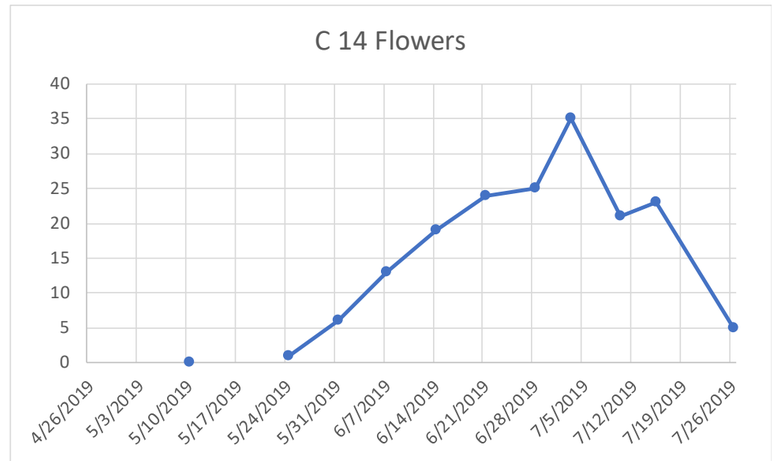
Biobarge C 14 change in plants each week - SCHAME

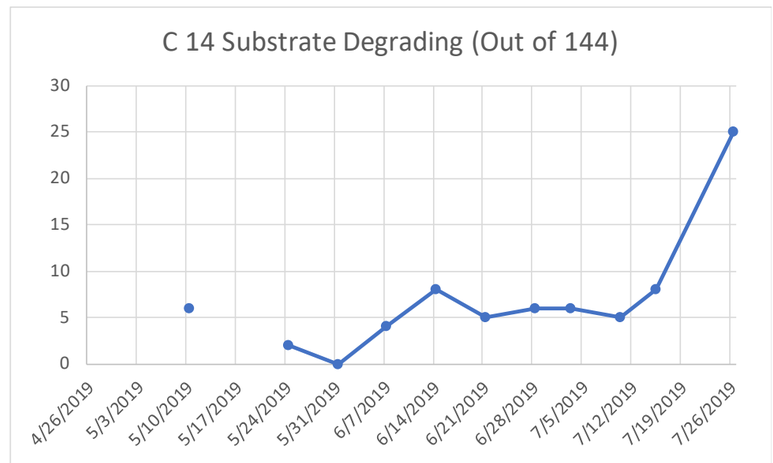

C 14 Plant Height (Inches)
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


C 14 Percent Visual Cover (Percentage)
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

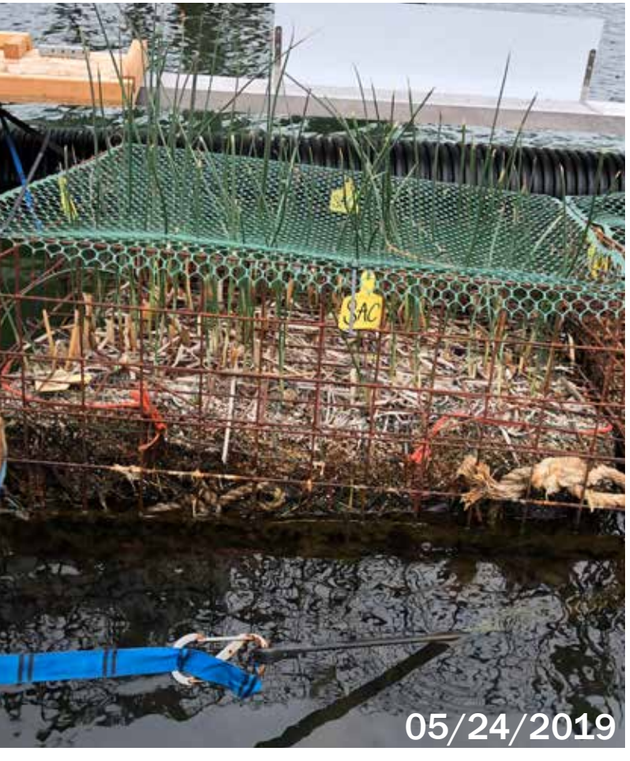

C 14 Plant Density (Percentage)
1.2
1
0.8
0.6
0.4
0.2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

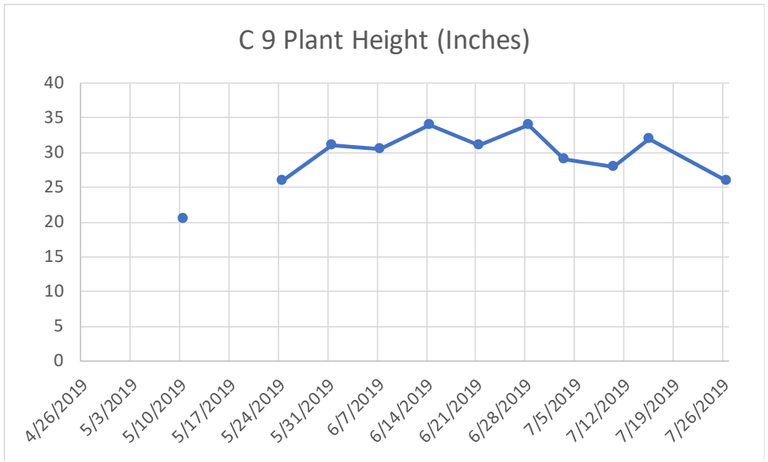

C14
07/15/2019

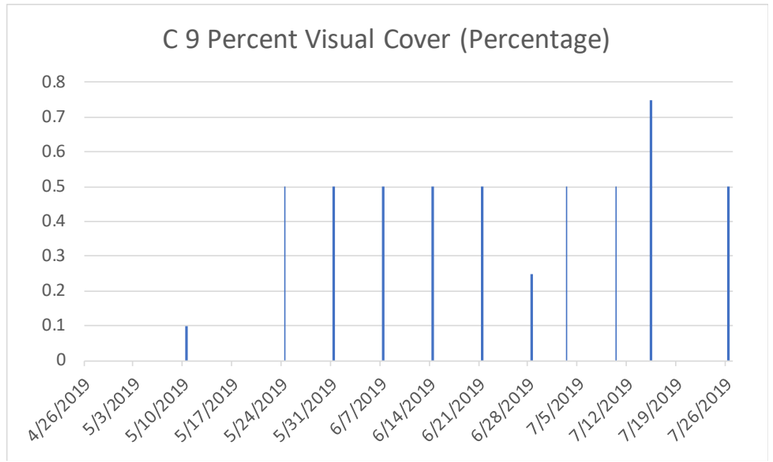

C 14 Flowers
40
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

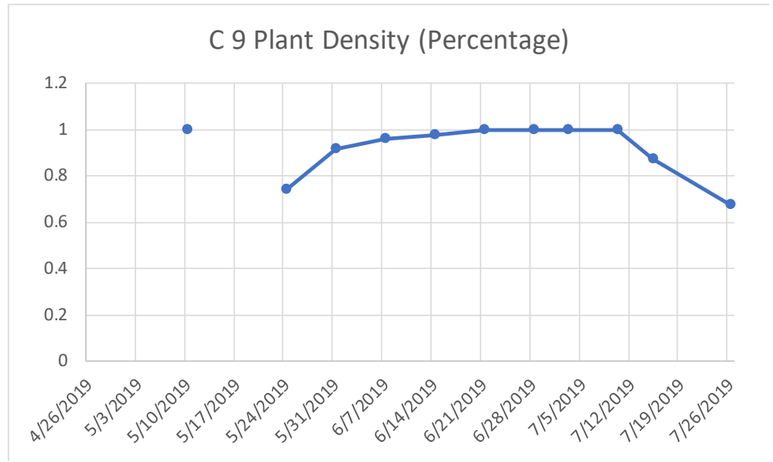

C 14 Substrate Degrading (Out of 144)
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

Biobarge C 9 change in plants each week - SCHACU

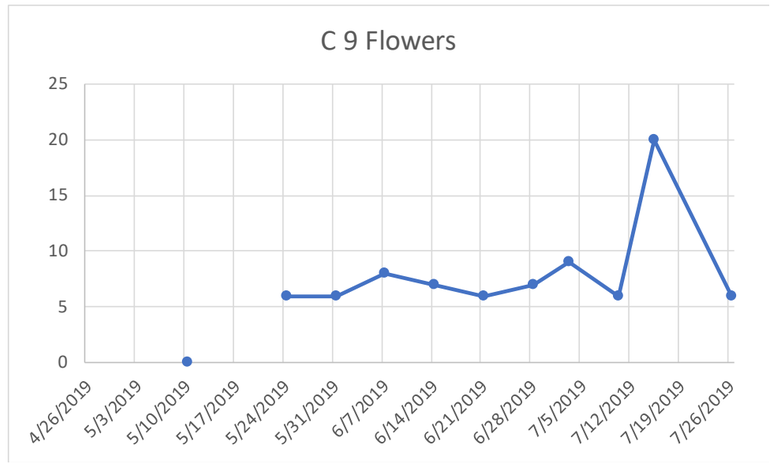


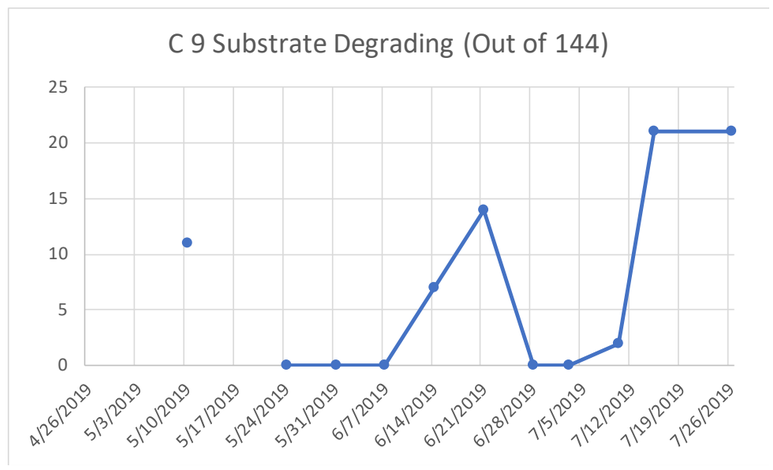

C 9 Plant Height (Inches)
40
35
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


C 9 Percent Visual Cover (Percentage)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

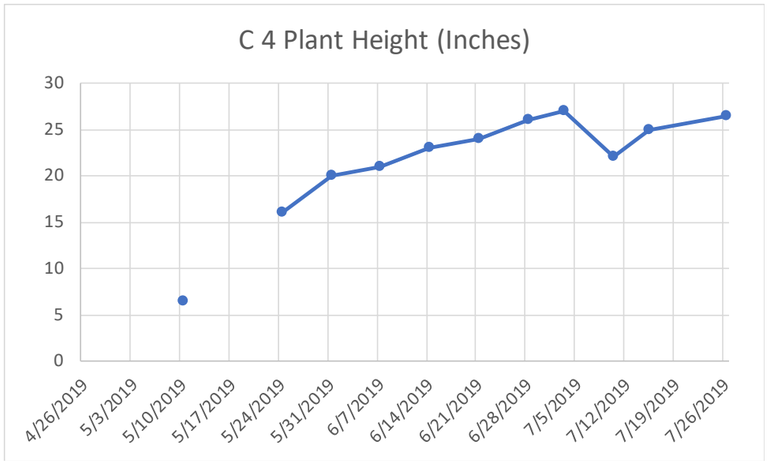

C 9 Plant Density (Percentage)
1.2
1
0.8
0.6
0.4
0.2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

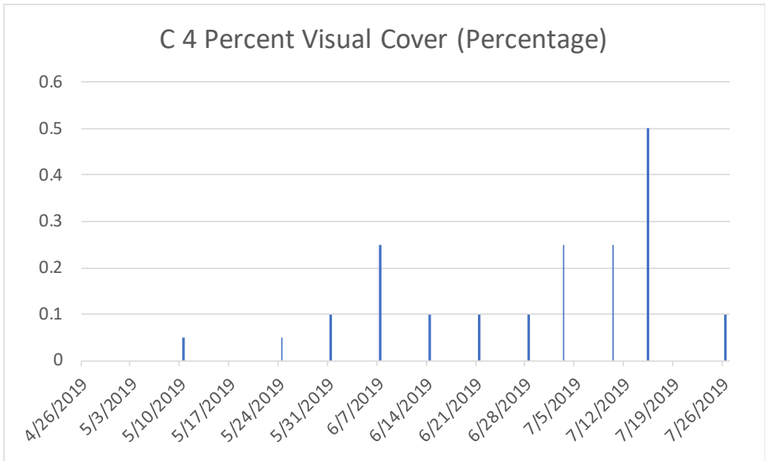

SAC
07/15/2019

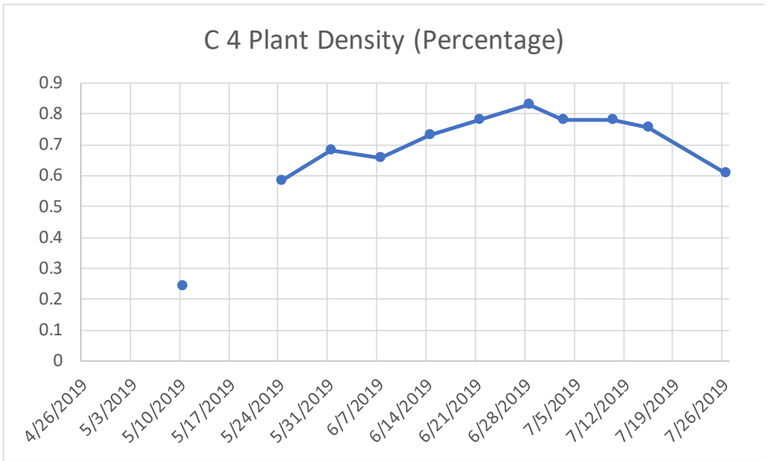

C 9 Flowers
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


C 9 Substrate Degrading (Out of 144)
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

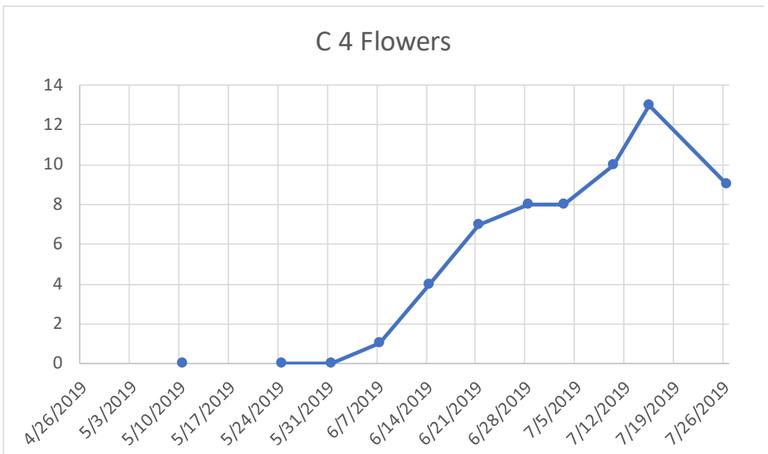
Biobarge C 4 change in plants each week - BOLMAR

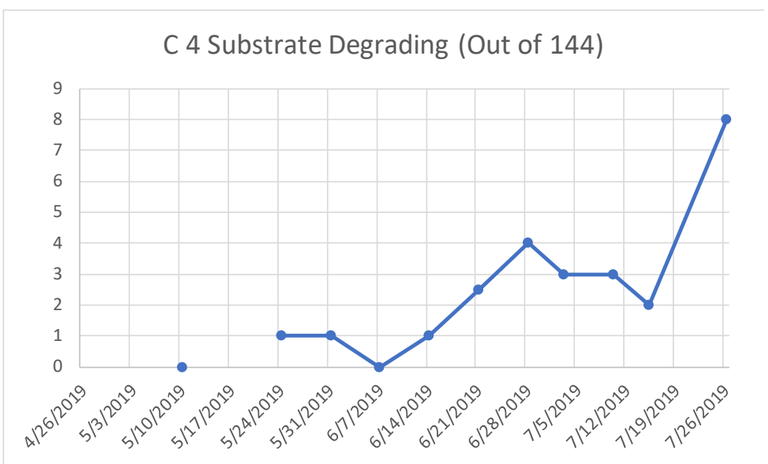

C 4 Plant Height (Inches)
30
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


C 4 Percent Visual Cover (Percentage)
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

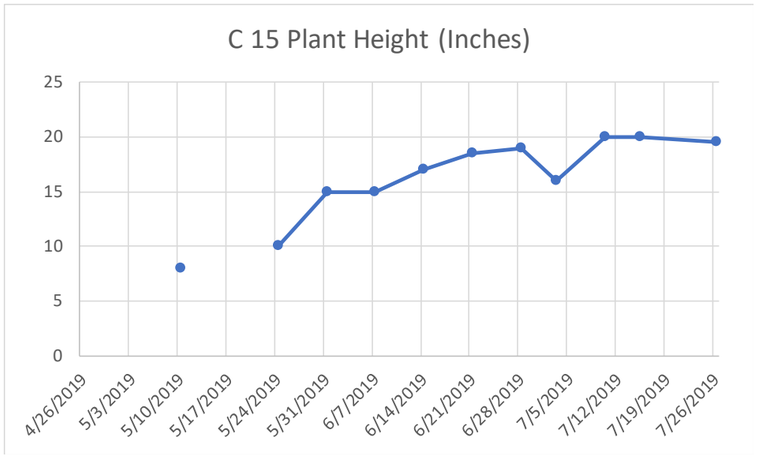

C 4 Plant Density (Percentage)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

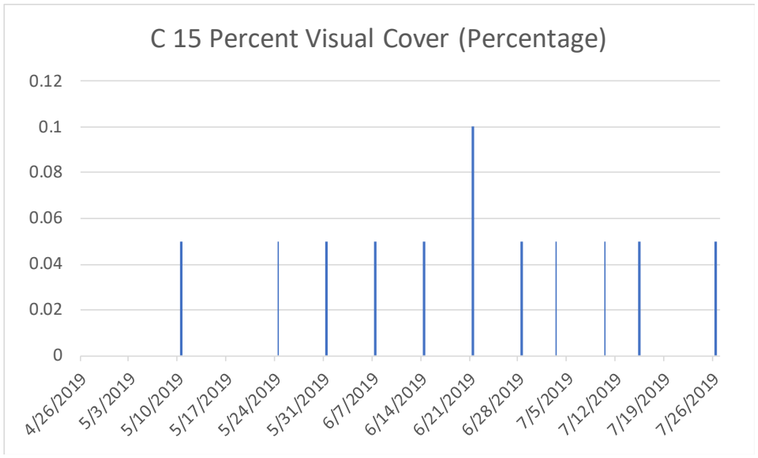

BM
07/15/2019

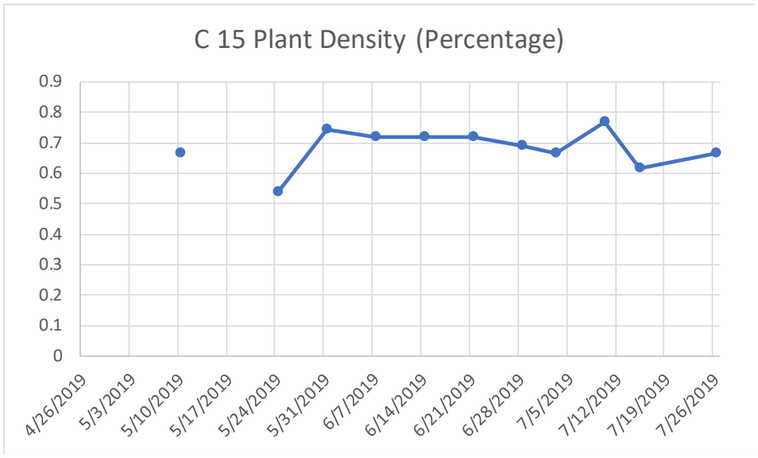

C 4 Flowers
14
12
10
8
6
4
2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


C 4 Substrate Degrading (Out of 144)
9
8
7
6
5
4
3
2
1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

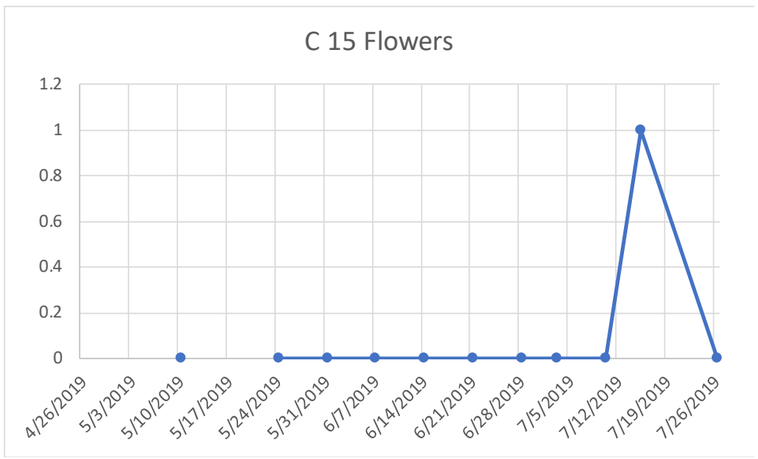
Biobarge C 15 change in plants each week - SCHTAB

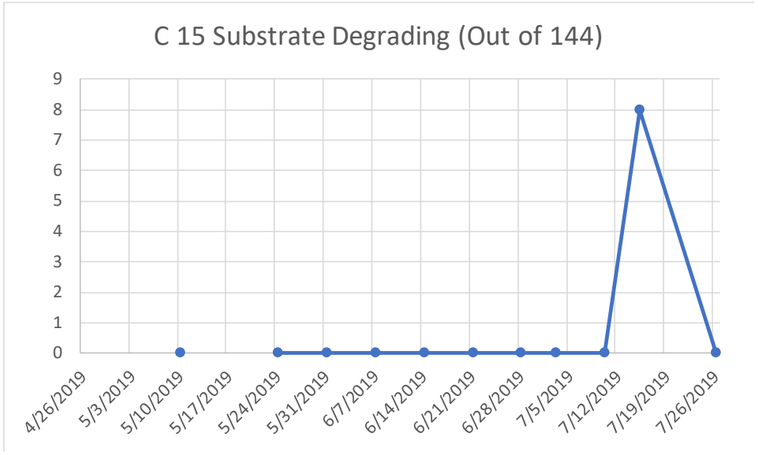

C 15 Plant Height (Inches)
25
20
15
10
5
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

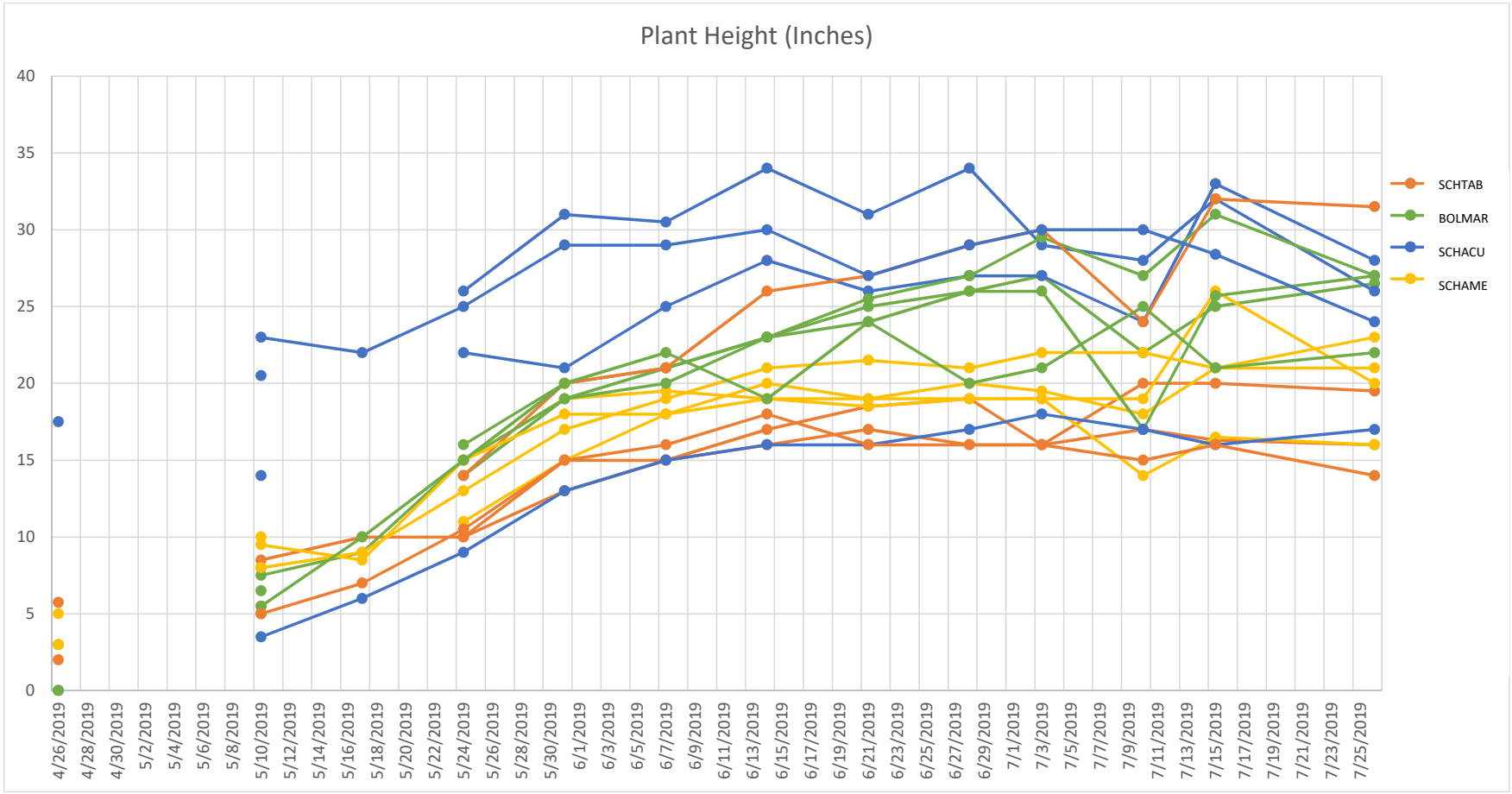

C 15 Percent Visual Cover (Percentage)
0.12
0.1
0.08
0.06
0.04
0.02
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019

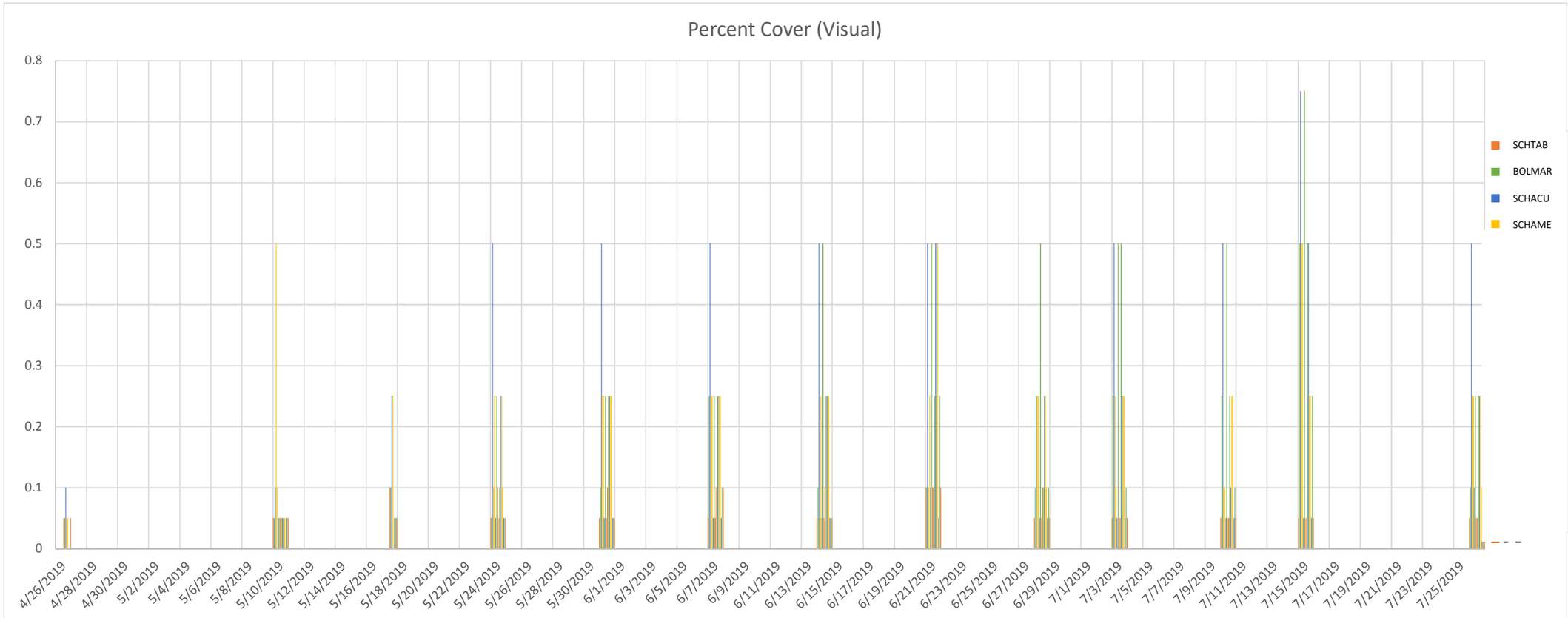

C 15 Plant Density (Percentage)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


C15
07/15/2019


C 15 Flowers
1.2
1
0.8
0.6
0.4
0.2
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


C 15 Substrate Degrading (Out of 144)
9
8
7
6
5
4
3
2
1
0
4/26/2019
5/3/2019
5/10/2019
5/17/2019
5/24/2019
5/31/2019
6/7/2019
6/14/2019
6/21/2019
6/28/2019
7/5/2019
7/12/2019
7/19/2019
7/26/2019


Plant Height (Inches)
40
35
30
25
20
15
10
5
0
4/26/2019
4/28/2019
4/30/2019
5/2/2019
5/4/2019
5/6/2019
5/8/2019
5/10/2019
5/12/2019
5/14/2019
5/16/2019
5/18/2019
5/20/2019
5/22/2019
5/24/2019
5/26/2019
5/28/2019
5/30/2019
6/1/2019
6/3/2019
6/5/2019
6/7/2019
6/9/2019
6/11/2019
6/13/2019
6/15/2019
6/17/2019
6/19/2019
6/21/2019
6/23/2019
6/25/2019
6/27/2019
6/29/2019
7/1/2019
7/3/2019
7/5/2019
7/7/2019
7/9/2019
7/11/2019
7/13/2019
7/15/2019
7/17/2019
7/19/2019
7/21/2019
7/23/2019
7/25/2019
SCHTAB
BOLMAR
SCHACU
SCHAME


Percent Cover (Visual)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/26/2019
4/28/2019
4/30/2019
5/2/2019
5/4/2019
5/6/2019
5/8/2019
5/10/2019
5/12/2019
5/14/2019
5/16/2019
5/18/2019
5/20/2019
5/22/2019
5/24/2019
5/26/2019
5/28/2019
5/30/2019
6/1/2019
6/3/2019
6/5/2019
6/7/2019
6/9/2019
6/11/2019
6/13/2019
6/15/2019
6/17/2019
6/19/2019
6/21/2019
6/23/2019
6/25/2019
6/27/2019
6/29/2019
7/1/2019
7/3/2019
7/5/2019
7/7/2019
7/9/2019
7/11/2019
7/13/2019
7/15/2019
7/17/2019
7/19/2019
7/21/2019
7/23/2019
7/25/2019
SCHTAB
BOLMAR
SCHACU
SCHAME

T-108 DEPLOYMENT
Water Quality Study Points

May 24th, 2019
Salinity Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1 ppt

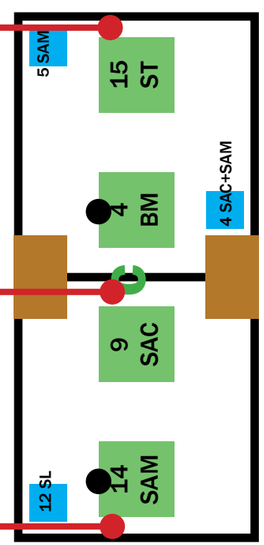
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Salinity (0.3) = 15.8
Salinity (0.6) = 16.3
Salinity (1.0) = 20.4

C09 - Study Point
Salinity (0.3) = 14.7
Salinity (0.6) = 15.3
Salinity (1.0) = 16.4

C14 - Study Point
Salinity (0.3) = 14.8
Salinity (0.6) = 15.9
Salinity (1.0) = 19.1

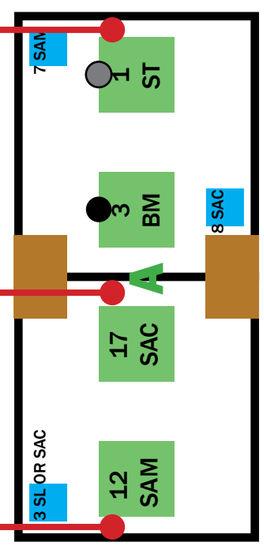


A01 - Study Point

Control Point T-108
Salinity (0.3) = 15.5
Salinity (0.6) = 17.6
Salinity (1.0) = 21.5

A17 - Study Point

A12 - Study Point



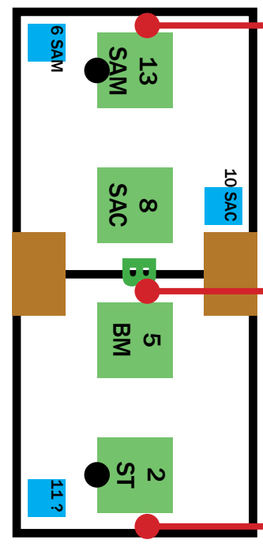
T-102

Duwamish River

B13 Study Point

B05 Study Point

B02 Study Point

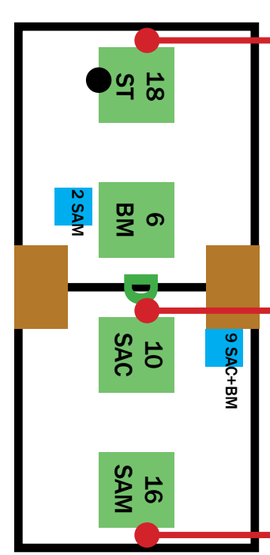


Control Point T-105
Salinity (0.3) = 13.9
Salinity (0.6) = 14.1
Salinity (1.0) = 14.9

D18 Study Point
Salinity (0.3) = 13.9
Salinity (0.6) = 14.0
Salinity (1.0) = 14.6

D10 Study Point
Salinity (0.3) = 13.9
Salinity (0.6) = 13.9
Salinity (1.0) = 15.0

D16 Study Point
Salinity (0.3) = 13.9
Salinity (0.6) = 13.8
Salinity (1.0) = 14.3



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

May 31st, 2019
Salinity Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1 ppt

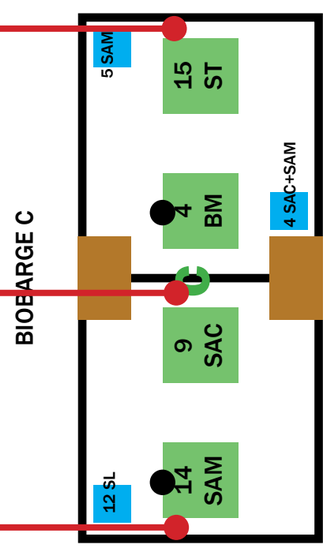
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Salinity (0.3) = 16.7
Salinity (0.6) = 17.7
Salinity (1.0) = 22.9

C09 - Study Point
Salinity (0.3) = 16.6
Salinity (0.6) = 16.8
Salinity (1.0) = 18.5

C14 - Study Point
Salinity (0.3) = 16.6
Salinity (0.6) = 16.9
Salinity (1.0) = 17.8

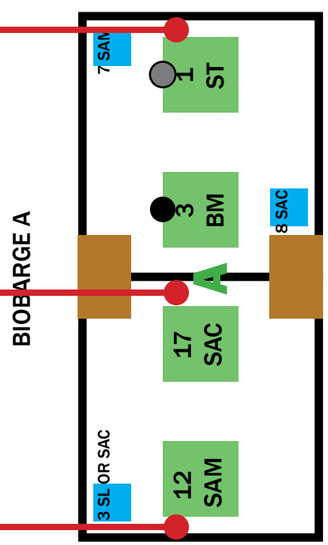


A01 - Study Point

Control Point T-108
Salinity (0.3) = 16.4
Salinity (0.6) = 16.7
Salinity (1.0) = 18.5

A17 - Study Point

A12 - Study Point



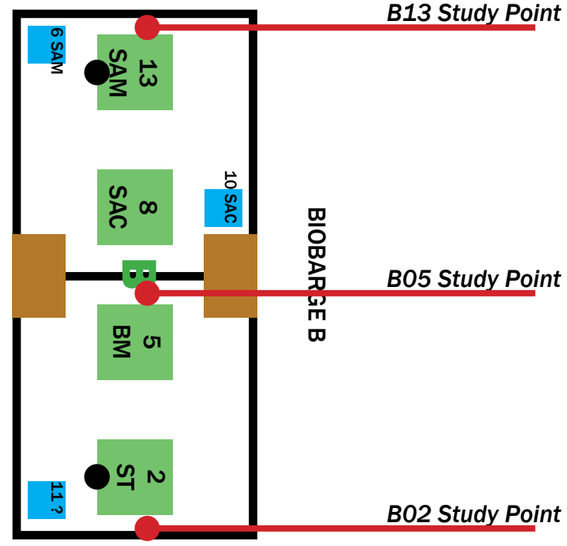
T-102

Duwamish River

B13 Study Point

B05 Study Point

B02 Study Point

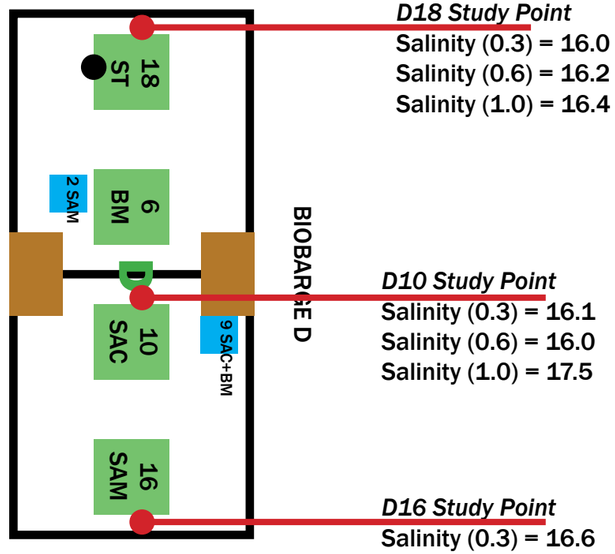


Control Point T-105
Salinity (0.3) = 16.1
Salinity (0.6) = 18.9
Salinity (1.0) = 20.5

D18 Study Point
Salinity (0.3) = 16.0
Salinity (0.6) = 16.2
Salinity (1.0) = 16.4

D10 Study Point
Salinity (0.3) = 16.1
Salinity (0.6) = 16.0
Salinity (1.0) = 17.5

D16 Study Point
Salinity (0.3) = 16.6
Salinity (0.6) = 17.1
Salinity (1.0) = 17.8



T-102

Land Side

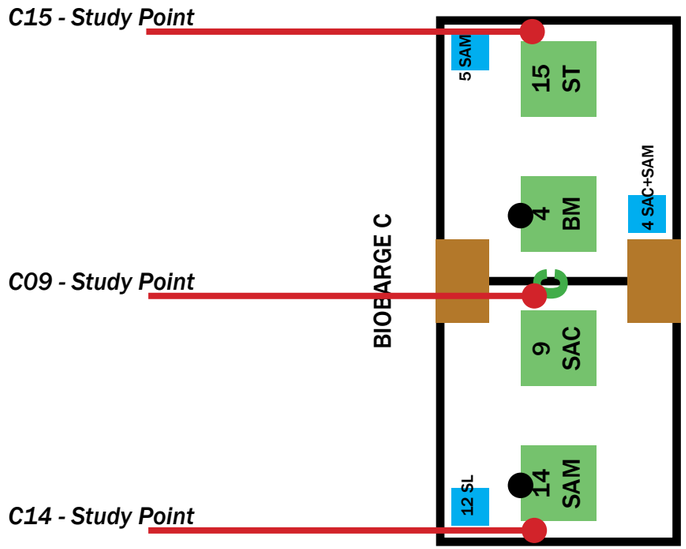
T-108 DEPLOYMENT
Water Quality Study Points

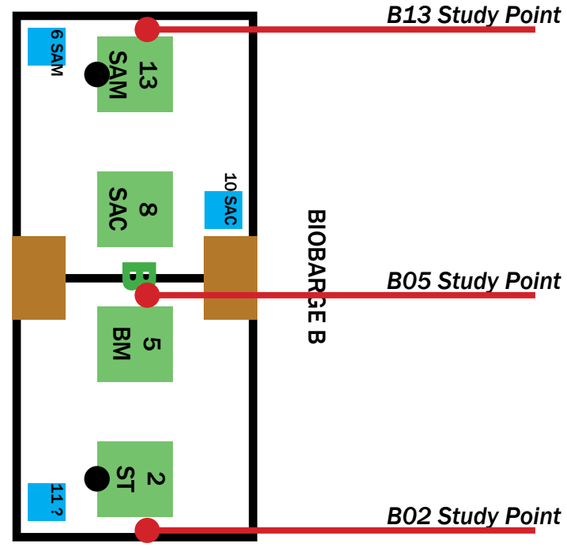
June 7th, 2019
Salinity Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1 ppt

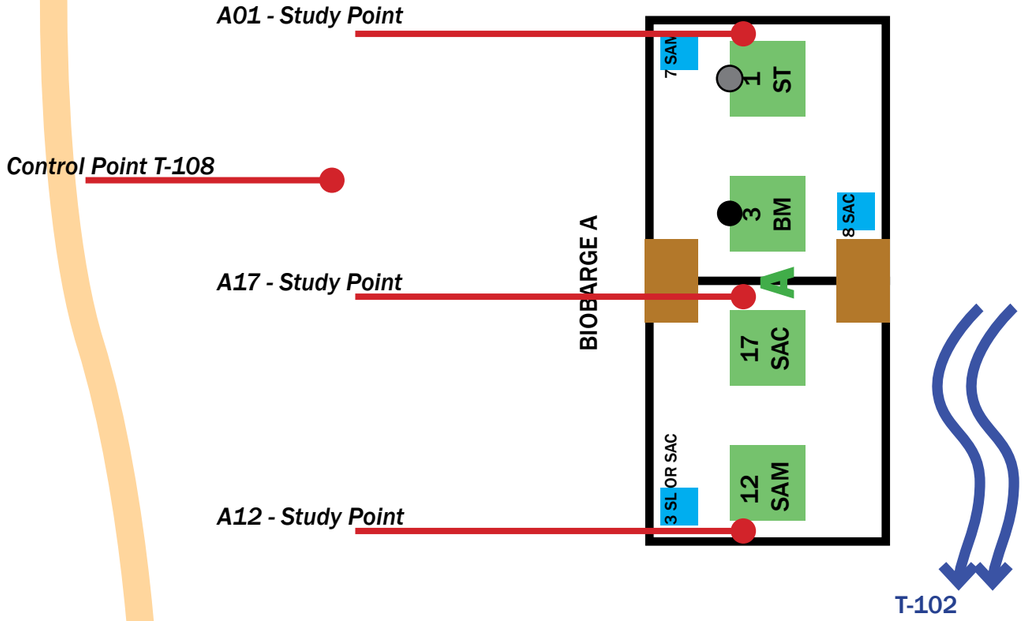
T-105 DEPLOYMENT
Water Quality Study Points

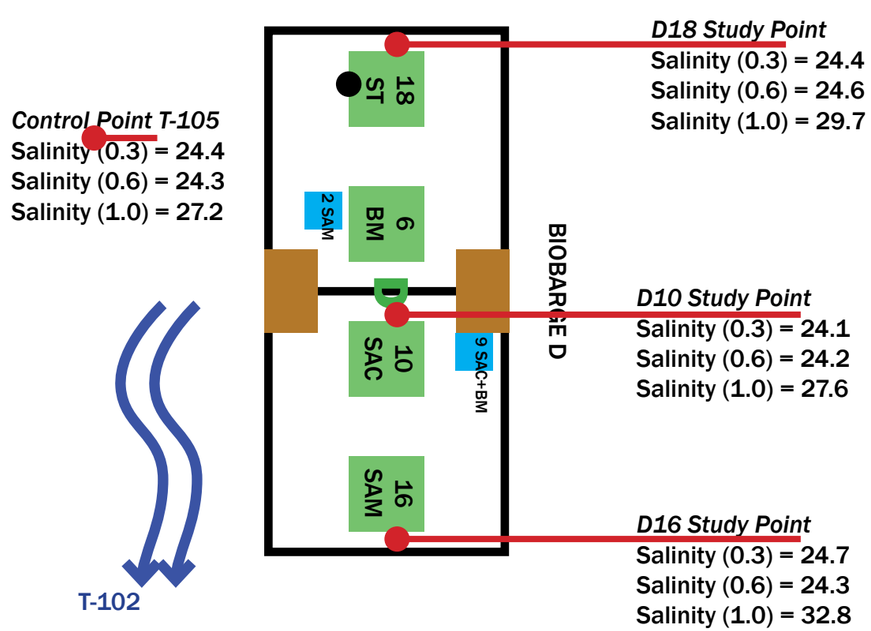
Land Side





Duwamish River





D18 Study Point
Salinity (0.3) = 24.4
Salinity (0.6) = 24.6
Salinity (1.0) = 29.7

D10 Study Point
Salinity (0.3) = 24.1
Salinity (0.6) = 24.2
Salinity (1.0) = 27.6

D16 Study Point
Salinity (0.3) = 24.7
Salinity (0.6) = 24.3
Salinity (1.0) = 32.8

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 14th, 2019
Salinity Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1 ppt

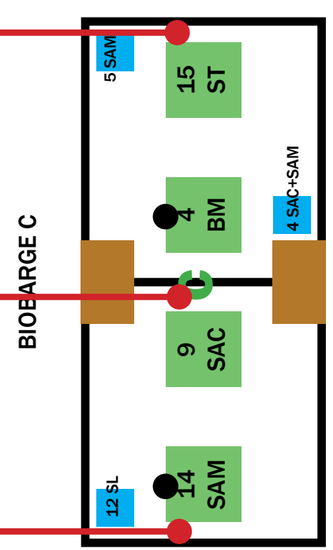
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Salinity (0.3) = 25.4
Salinity (0.6) = 25.5
Salinity (1.0) = 30.4

C09 - Study Point
Salinity (0.3) = 25.3
Salinity (0.6) = 26.4
Salinity (1.0) = 30.2

C14 - Study Point
Salinity (0.3) = 25.6
Salinity (0.6) = 26.8
Salinity (1.0) = 28.5

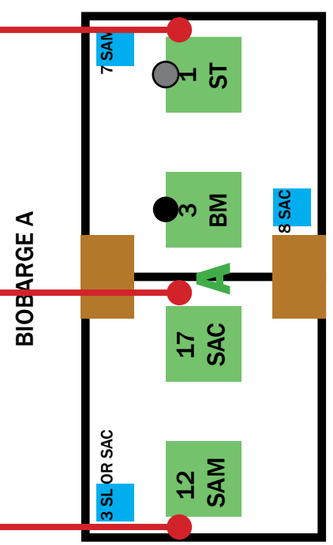


A01 - Study Point
Salinity (0.3) = 25.2
Salinity (0.6) = 26.2
Salinity (1.0) = 27.8

Control Point T-108
Salinity (0.3) = 25.2
Salinity (0.6) = 26.8
Salinity (1.0) = 29.0

A17 - Study Point
Salinity (0.3) = 26.2
Salinity (0.6) = 29.4
Salinity (1.0) = 29.6

A12 - Study Point
Salinity (0.3) = 24.1
Salinity (0.6) = 26.0
Salinity (1.0) = 27.9



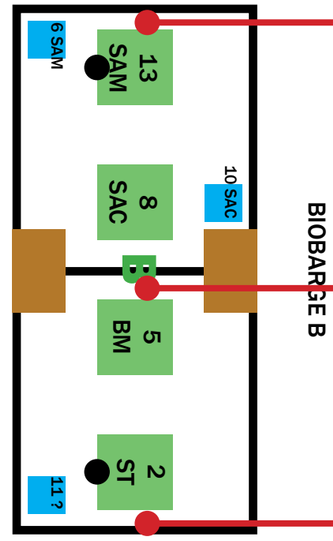
T-102

Duwamish River

B13 Study Point
Salinity (0.3) = 25.4
Salinity (0.6) = 28.6
Salinity (1.0) = 30.8

B05 Study Point
Salinity (0.3) = 26.0
Salinity (0.6) = 27.3
Salinity (1.0) = 29.9

B02 Study Point
Salinity (0.3) = 24.7
Salinity (0.6) = 28.8
Salinity (1.0) = 30.2

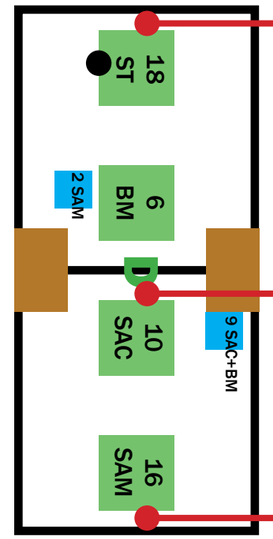


Control Point T-105
Salinity (0.3) = 26.7
Salinity (0.6) = 26.8
Salinity (1.0) = 29.8

D18 Study Point
Salinity (0.3) = 26.6
Salinity (0.6) = 28.0
Salinity (1.0) = 28.9

D10 Study Point
Salinity (0.3) = 23.7
Salinity (0.6) = 25.4
Salinity (1.0) = 31.5

D16 Study Point
Salinity (0.3) = 23.8
Salinity (0.6) = 24.4
Salinity (1.0) = 27.8



T-102

Land Side

T-108 DEPLOYMENT
Water Quality Study Points

June 21st, 2019
Salinity Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1 ppt

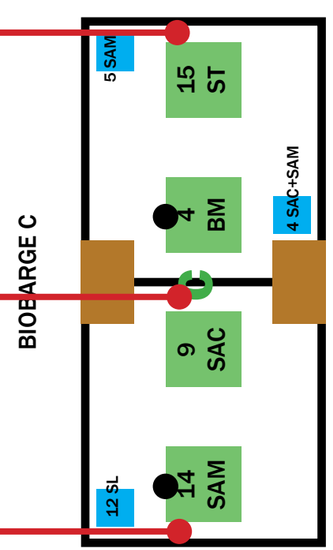
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Salinity (0.3) = 22.9
Salinity (0.6) = 23.5
Salinity (1.0) = 24.7

C09 - Study Point
Salinity (0.3) = 24.1
Salinity (0.6) = 24.9
Salinity (1.0) = 25.6

C14 - Study Point
Salinity (0.3) = 24.6
Salinity (0.6) = 24.4
Salinity (1.0) = 25.0

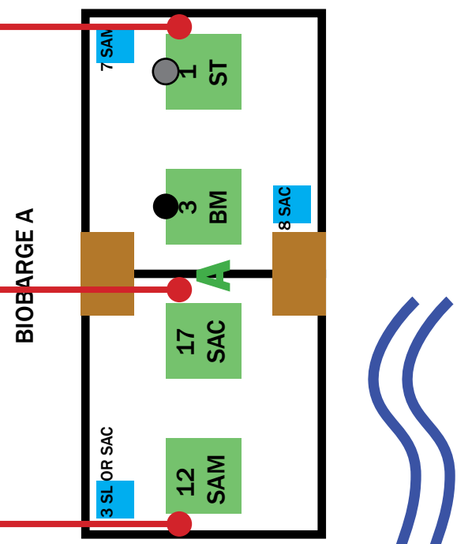


A01 - Study Point
Salinity (0.3) = 24.2
Salinity (0.6) = 24.3
Salinity (1.0) = 25.9

Control Point T-108
Salinity (0.3) = 24.6
Salinity (0.6) = 25.2
Salinity (1.0) = 25.9

A17 - Study Point
Salinity (0.3) = 24.4
Salinity (0.6) = 26.2
Salinity (1.0) = 28.2

A12 - Study Point
Salinity (0.3) = 24.6
Salinity (0.6) = 25.9
Salinity (1.0) = 26.3

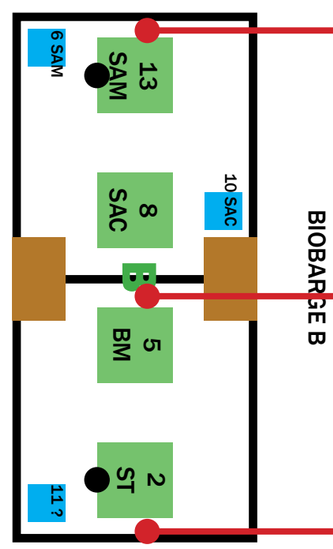


Duwamish River

B13 Study Point
Salinity (0.3) = 24.7
Salinity (0.6) = 24.7
Salinity (1.0) = 29.8

B05 Study Point
Salinity (0.3) = 25.5
Salinity (0.6) = 25.7
Salinity (1.0) = 26.5

B02 Study Point
Salinity (0.3) = 25.8
Salinity (0.6) = 27.0
Salinity (1.0) = 27.6

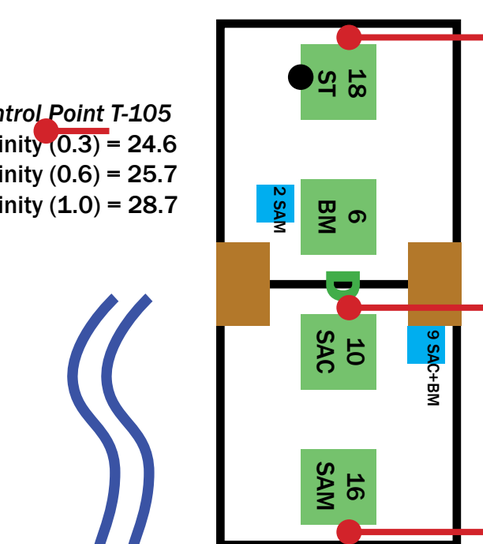


Control Point T-105
Salinity (0.3) = 24.6
Salinity (0.6) = 25.7
Salinity (1.0) = 28.7

D18 Study Point
Salinity (0.3) = 24.1
Salinity (0.6) = 24.1
Salinity (1.0) = 27.4

D10 Study Point
Salinity (0.3) = 24.1
Salinity (0.6) = 24.7
Salinity (1.0) = 25.7

D16 Study Point
Salinity (0.3) = 24.1
Salinity (0.6) = 24.4
Salinity (1.0) = 26.2



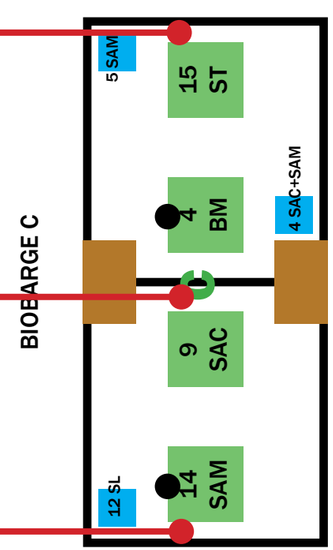
Land Side

T-108 DEPLOYMENT
Water Quality Study Points

C15 - Study Point
Salinity (0.3) = 17.6
Salinity (0.6) = 19.8
Salinity (1.0) = 22.2

C09 - Study Point
Salinity (0.3) = 17.9
Salinity (0.6) = 18.8
Salinity (1.0) = 21.4

C14 - Study Point
Salinity (0.3) = 17.6
Salinity (0.6) = 19.0
Salinity (1.0) = 22.8

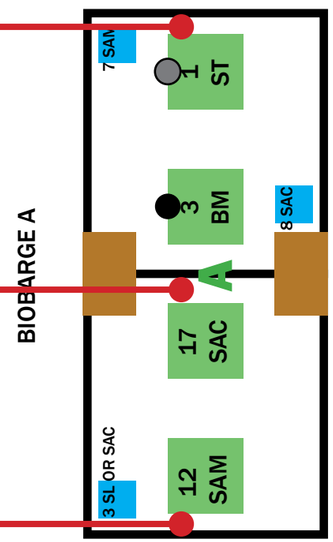


A01 - Study Point
Salinity (0.3) = 18.1
Salinity (0.6) = 18.7
Salinity (1.0) = 21.5

Control Point T-108
Salinity (0.3) = 18.0
Salinity (0.6) = 20.0
Salinity (1.0) = 22.7

A17 - Study Point
Salinity (0.3) = 18.3
Salinity (0.6) = 19.9
Salinity (1.0) = 21.6

A12 - Study Point
Salinity (0.3) = 17.6
Salinity (0.6) = 18.4
Salinity (1.0) = 22.3



T-102

June 28th, 2019
Salinity Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1 ppt

Land Side

Duwamish River

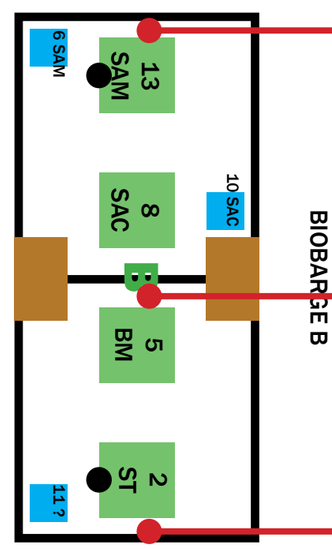
Land Side

T-105 DEPLOYMENT
Water Quality Study Points

B13 Study Point
Salinity (0.3) = 17.8
Salinity (0.6) = 18.3
Salinity (1.0) = 22.5

B05 Study Point
Salinity (0.3) = 17.9
Salinity (0.6) = 19.1
Salinity (1.0) = 20.0

B02 Study Point
Salinity (0.3) = 18.4
Salinity (0.6) = 18.8
Salinity (1.0) = 21.7

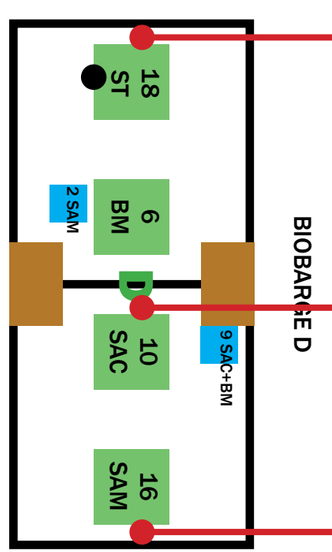


Control Point T-105
Salinity (0.3) = 18.0
Salinity (0.6) = 18.8
Salinity (1.0) = 22.0

D18 Study Point
Salinity (0.3) = 17.6
Salinity (0.6) = 17.6
Salinity (1.0) = 20.7

D10 Study Point
Salinity (0.3) = 17.7
Salinity (0.6) = 18.5
Salinity (1.0) = 22.4

D16 Study Point
Salinity (0.3) = 17.6
Salinity (0.6) = 17.8
Salinity (1.0) = 21.0



T-102

T-108 DEPLOYMENT
Water Quality Study Points

July 3rd, 2019
Salinity Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1 ppt

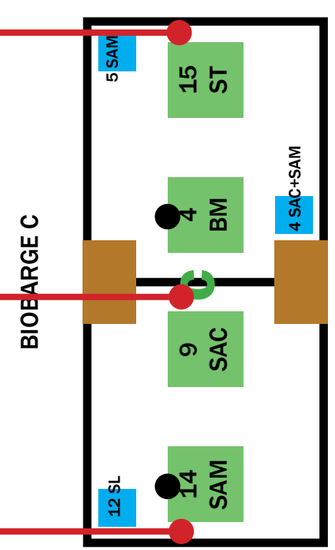
T-105 DEPLOYMENT
Water Quality Study Points

Land Side

C15 - Study Point
Salinity (0.3) = 27.6
Salinity (0.6) = 28.8
Salinity (1.0) = 30.1

C09 - Study Point
Salinity (0.3) = 27.5
Salinity (0.6) = 27.5
Salinity (1.0) = 27.7

C14 - Study Point
Salinity (0.3) = 27.7
Salinity (0.6) = 27.6
Salinity (1.0) = 29.6

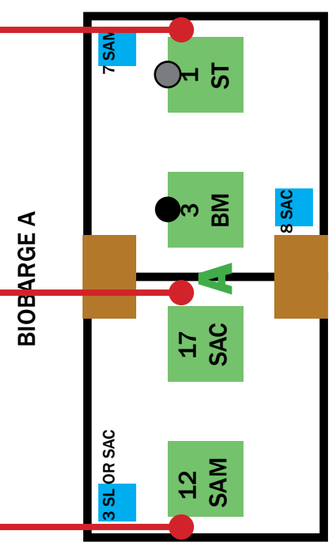


A01 - Study Point
Salinity (0.3) = 28.0
Salinity (0.6) = 28.1
Salinity (1.0) = 28.5

Control Point T-108
Salinity (0.3) = 27.6
Salinity (0.6) = 28.4
Salinity (1.0) = 29.3

A17 - Study Point
Salinity (0.3) = 28.6
Salinity (0.6) = 28.4
Salinity (1.0) = 28.6

A12 - Study Point
Salinity (0.3) = 27.6
Salinity (0.6) = 28.7
Salinity (1.0) = 29.7



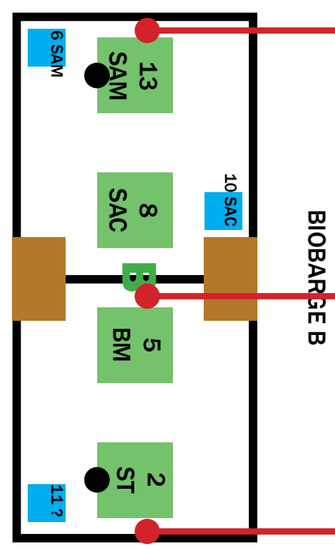
T-102

Duwamish River

B13 Study Point
Salinity (0.3) = 31.7
Salinity (0.6) = 31.6
Salinity (1.0) = 31.4

B05 Study Point
Salinity (0.3) = 30.1
Salinity (0.6) = 29.6
Salinity (1.0) = 31.8

B02 Study Point
Salinity (0.3) = 29.5
Salinity (0.6) = 30.4
Salinity (1.0) = 32.9

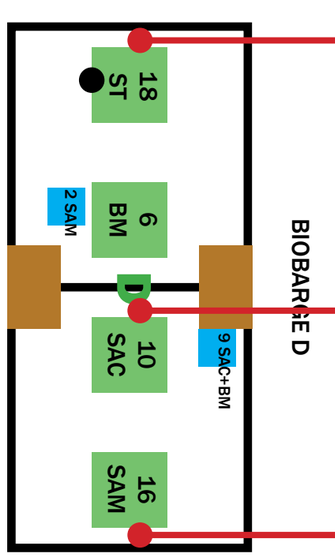


Control Point T-105
Salinity (0.3) = 32.1
Salinity (0.6) = 34.2
Salinity (1.0) = 34.2

D18 Study Point
Salinity (0.3) = 29.2
Salinity (0.6) = 30.5
Salinity (1.0) = 34.0

D10 Study Point
Salinity (0.3) = 31.3
Salinity (0.6) = 31.1
Salinity (1.0) = 33.7

D16 Study Point
Salinity (0.3) = 28.9
Salinity (0.6) = 30.4
Salinity (1.0) = 34.1



T-102

Land Side

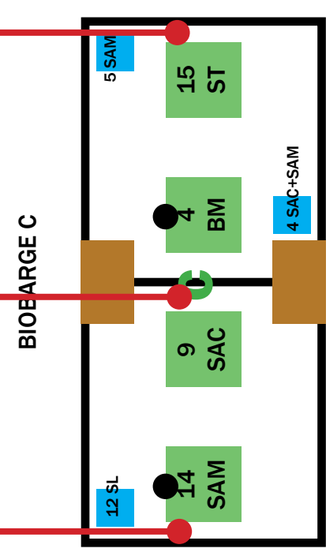
Land Side

T-108 DEPLOYMENT
Water Quality Study Points

C15 - Study Point
Salinity (0.3) = 30.4
Salinity (0.6) = 31.1
Salinity (1.0) = 29.9

C09 - Study Point
Salinity (0.3) = 26.8
Salinity (0.6) = 27.3
Salinity (1.0) = 29.7

C14 - Study Point
Salinity (0.3) = 26.7
Salinity (0.6) = 28.3
Salinity (1.0) = 29.4

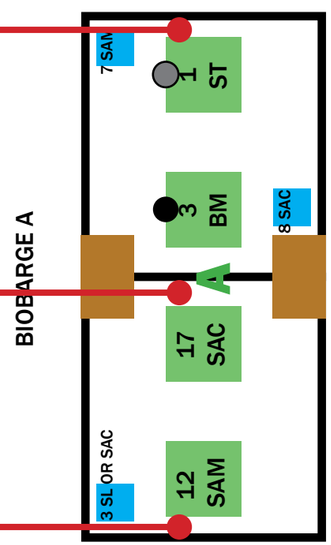


A01 - Study Point
Salinity (0.3) = 29.1
Salinity (0.6) = 30.9
Salinity (1.0) = 31.5

Control Point T-108
Salinity (0.3) = 28.7
Salinity (0.6) = 30.0
Salinity (1.0) = 30.8

A17 - Study Point
Salinity (0.3) = 28.2
Salinity (0.6) = 28.7
Salinity (1.0) = 30.7

A12 - Study Point
Salinity (0.3) = 26.7
Salinity (0.6) = 28.0
Salinity (1.0) = 28.9



T-102

July 10th, 2019
Salinity Data

Accuracy threshold: +/- 1.0 % of the reading or 0.1 ppt

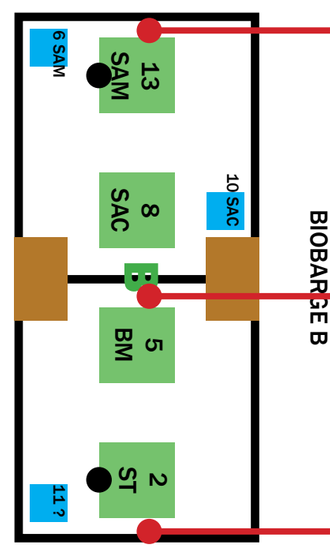
Duwamish River

T-105 DEPLOYMENT
Water Quality Study Points

B13 Study Point
Salinity (0.3) = 26.9
Salinity (0.6) = 27.5
Salinity (1.0) = 29.8

B05 Study Point
Salinity (0.3) = 27.7
Salinity (0.6) = 28.9
Salinity (1.0) = 30.8

B02 Study Point
Salinity (0.3) = 28.9
Salinity (0.6) = 30.0
Salinity (1.0) = 31.0

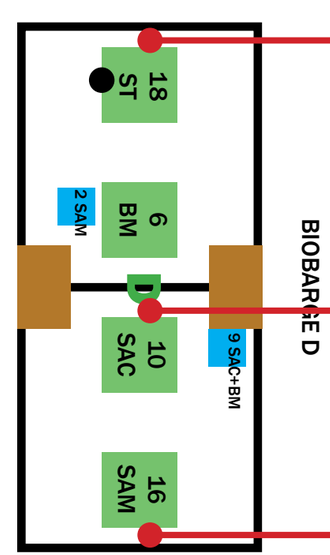


Control Point T-105
Salinity (0.3) = 27.2
Salinity (0.6) = 28.8
Salinity (1.0) = 29.3

D18 Study Point
Salinity (0.3) = 25.3
Salinity (0.6) = 27.3
Salinity (1.0) = 30.8

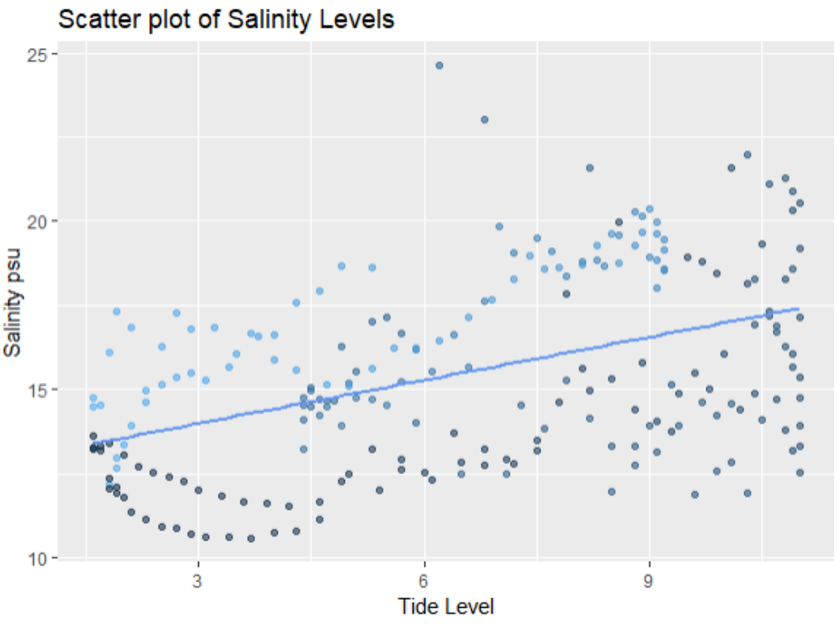
D10 Study Point
Salinity (0.3) = 26.9
Salinity (0.6) = 28.7
Salinity (1.0) = 30.1

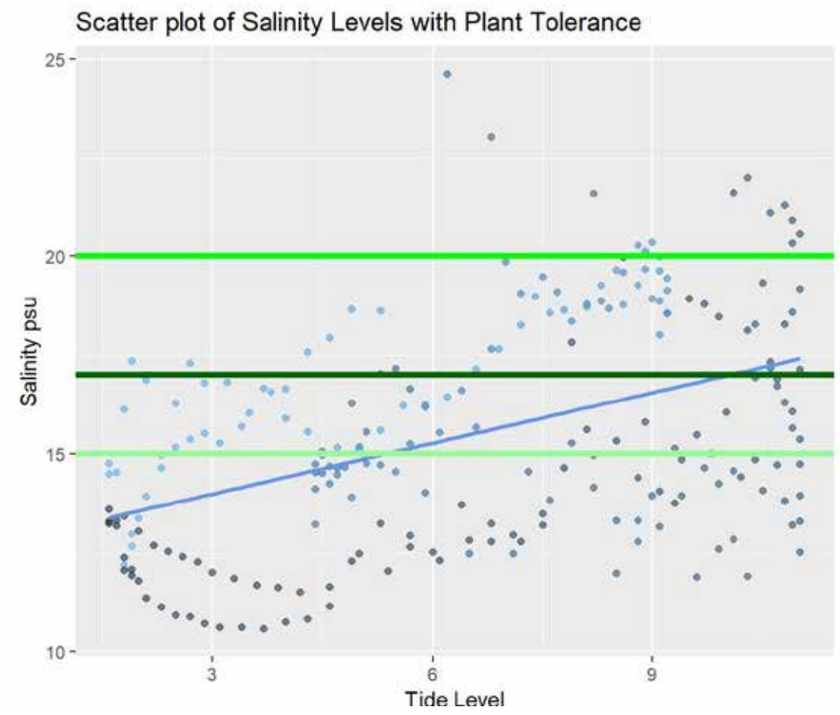
D16 Study Point
Salinity (0.3) = 26.1
Salinity (0.6) = 29.8
Salinity (1.0) = 30.7

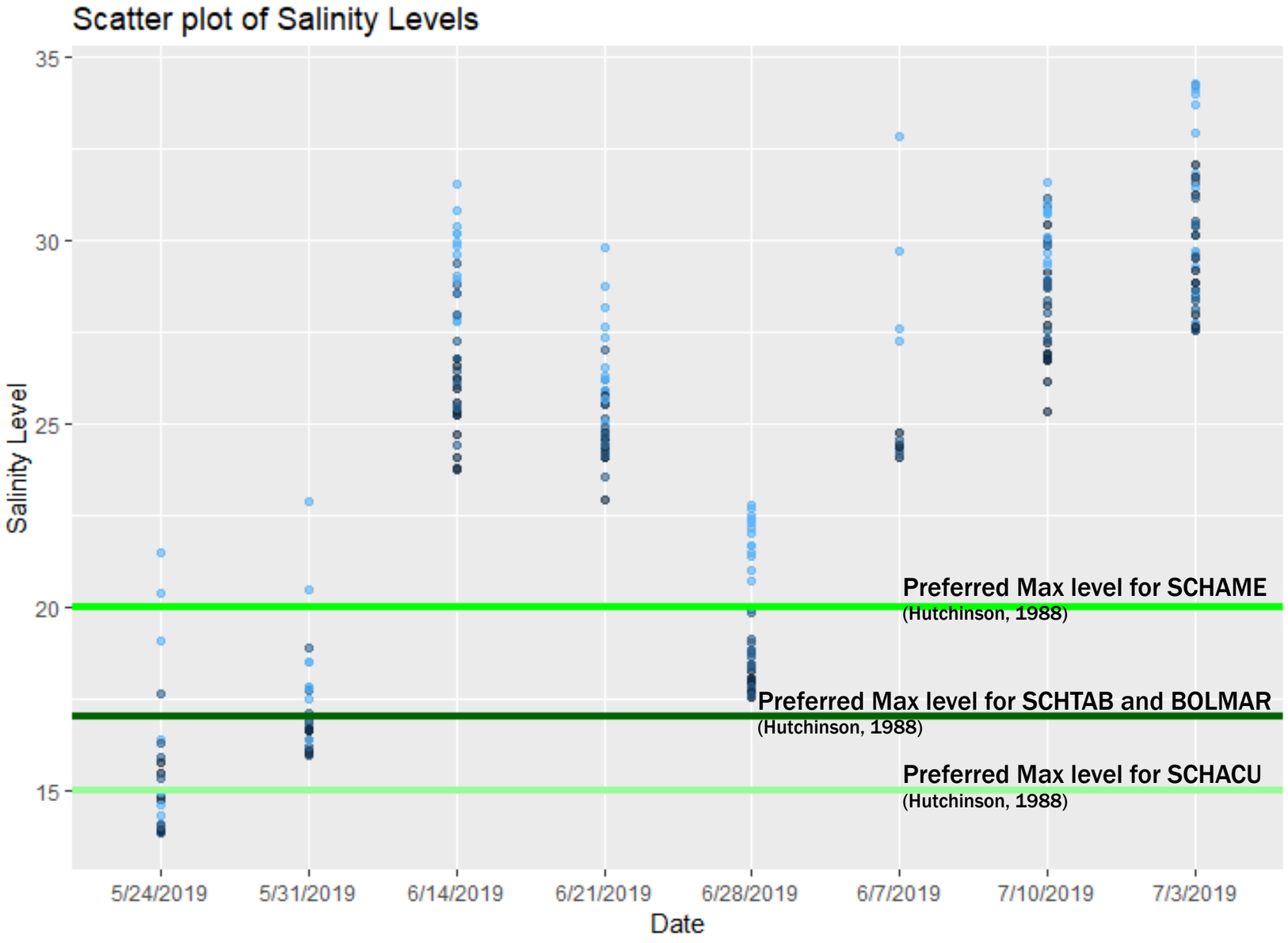


T-102

Land Side


Scatter plot of Salinity Levels
Salinity psu
25
20
15
10
3
6
9
Tide Level


Scatter plot of Salinity Levels with Plant Tolerance
Salinity psu
25
20
15
10
3
6
9
Tide Level


Scatter plot of Salinity Levels
Salinity Level
35
30
25
20
15
Preferred Max level for SCHAME
(Hutchinson, 1988)
Preferred Max level for SCHTAB and BOLMAR
(Hutchinson, 1988)
Preferred Max level for SCHACU
(Hutchinson, 1988)
5/24/2019
5/31/2019
6/14/2019
6/21/2019
6/28/2019
6/7/2019
7/10/2019
7/3/2019
Date
1.0
0.8
0.6
0.4
Depth of Sonde measurement

Salinity Data	As depth increases…	T-105 vs. T-108	Biobarge vs Control	Middle vs. Edge (of Biobarge)
5/24/2019	Salinity increases	108 is slightly higher	No difference	No difference
5/31/2019	Salinity increases	No difference	No difference	No difference
6/07/2019	Salinity increases	NA	No difference	No difference
6/14/2019	Salinity increases	No difference	No difference	No difference
6/21/2019	Salinity increases	No difference	No difference	No difference
6/28/2019	Salinity increases	No difference	No difference	Not consistent
7/03/2019	Not consistent	No difference	No difference	No difference
7/10/2019	Salinity increases	No difference	No difference	No difference
Consensus	**Salinity increases**	**No difference**	**No difference**	**No difference**

Appendix E: Hatchery Release protocols

Table 5. Proposed annual release protocols for each program. AD = adipose fin clip; CWT = coded-wire tag; BWT = blank-wire tag; SCH = Soos Creek Hatchery, IC = Icy Creek Rearing Ponds, FGP = Flaming Geyser Ponds, KCC = Keta Creek Complex, MCH = Miller Creek Hatchery, MTC = Marine Technology Center, FRF = Fish Restoration Facility, HHD = Howard Hanson Dam.

Program	Number, life stage, and size (fpp)	Marking and Tagging	Egg incubation and rearing Location	Release Location	Volitional Release?	Release Time
Soos Creek Fall Chinook	3,200,000 subyearling; 80	88% ad; 6% ad and CWT; 6% CWT only	SCH	SCH[2]	No	Early-May to June
	1,000,000 subyearling; 80	100% BWT	SCH	SCH	No	
	2,000,000 subyearling; 45	100% ad	SCH, FRF[3]	Palmer Ponds, SCH, FRF, IC[3]	Yes	June to July 4
	300,000 yearling; 10	100% ad	SCH	IC	Yes	April
FRF Fall Chinook[1]	600,000 subyearling; 65	100% ad; 10% CWT	FRF	FRF, Palmer Ponds	Yes	June
FRF Coho[1]	600,000 yearling; 14	100% ad; 10% CWT	FRF	FRF	Yes	April to May 15
KCC Coho	1,000,000 yearling; 14	100% ad; 10% ad and CWT	KCC	KCC	Yes	April to May 10
	1,000,000 yearling; 9	100% ad; 13% ad and CWT	KCC	Elliott Bay netpens	Yes	June
	50,000 yearling; 14	None	KCC	FRF site	Yes	April to May 15
Soos Creek Coho	600,000 yearling; 17	85% ad; 7.5% ad and CWT; 7.5% CWT	SCH	SCH	Yes	April to May 10
	30,000 yearling; 15	100% ad	SCH	Des Moines Ponds	No	June
	120,000 fed fry; 1500	None	MCH	Miller, Walker and Des Moines Creeks	No	January
KCC Fall Chum	5,000,000 fry; 450-150	None	KCC	KCC	Yes	March 1 to May 15
MTC Coho	10,000 yearling; 11	100% ad	MTC	MTC	No	April
FRF steelhead[1]	250,000 yearling; 5-10	100% ad; 10% CWT	FRF	FRF	No	Mid-April to June 30
Green River Native Winter Steelhead	23,000 yearling; 8	100% BWT	SCH	IC	Yes	May
	15,000 yearling; 8	100% BWT	SCH	FGP	Yes	
	17,000 yearling; 8	100% BWT	SCH	Palmer Ponds	Yes	
Green River Summer Steelhead	100,000 yearling; 5	100% ad	SCH	SCH, IC[4]	Yes[5]	Mid-April to May

Taken from: Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and MagnusonStevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation

https://www.westcoast.fisheries.noaa.gov/publications/hatchery/duwamish-green/green-duwamish_hatchery_opinion_041519.pdf