Tahlequah Restoration Monitoring Report
Pre-restoration baseline 2020-2021

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Vashon Nature Center

Summary:

From May 2020 to June 2021 Vashon Nature Center staff and volunteers collected the first season of monitoring data for the Tahlequah shoreline restoration project. This restoration project involves replacing an old concrete and creosote bulkhead with natural shoreline armoring that is designed to improve habitat for salmon. The restoration is being conducted by Washington State Ferries.

Data was collected at three beach sites including: the restoration site (pre-restoration); an adjacent armored site; and a nearby natural shoreline. Representative photos were taken at each site. In addition, the following surveys were conducted: forage fish spawning, juvenile salmon use, beach profile, beach wrack cover, logs, insects, and vegetation cover and type. This report provides the results of the above surveys. These data can be used as a pre-restoration baseline. Data collected after restoration occurs can be compared to these initial surveys to track changes that happen due to the restoration.

Forage fish spawning numbers were low at all sites all year long (May 2020-May 2021). No spawning was detected at the natural site for the duration of the study. The pre-restoration and armored sites had surf smelt spawning events (defined as 2 or more eggs detected) in February 2021 and May 2021. In contrast, snorkel surveys detected the most juvenile salmon use of the shoreline at the natural site.

The natural site had the highest beach wrack cover, number of logs, percent cover of overhanging vegetation, and proportion of plant species that were native indicating that the natural site provides more habitat for beach life, including salmonids, then the armored and pre-restoration sites. Therefore, data from the natural site could be used as a reference to set goals for what the pre-restoration site could look like in the future. Future surveys that compare the restoration site to the armored site and the natural site will allow for tracking whether the restoration site begins to resemble the natural site in terms of higher habitat values over time. The pre-restoration and armored sites looked similar in all data categories collected indicating that the armored site can act as a control to compare what the restoration site would have looked like through time without restoration.

In addition to data collection, this survey effort involved 18 volunteers from the local community, including 4 students pursuing studies in environmental science, for a total of 198 volunteer hours of field work. Involving community members in research increased awareness of the project in the local community and created a core group of stewards that are supportive of the restoration intent and invested in following the progress of the restoration.

Acknowledgements:

Vashon Nature Center would like to thank the **Washington State Ferries** for giving the local island community the opportunity to participate in monitoring the results of this restoration project and for taking a leadership role as a transportation organization that cares about the health of the marine environment.

Thank you very much to the **landowners** who have generously allowed us access to the beach for surveys. Thank you to the **community volunteers** and students that have helped us with monitoring: Steve Fogard, Paulina and Pearl Barry, Adrian Swain, Laura Camner, Tabitha Gray, Kristen Miller, Rusty Knowler, Logan Sinner, James and Nick Hyde, Jason and Quinn Williams, Abel Eckhardt, Adria Magrath, Bob Lane, Heidi Skyrzpeck, and Randy Tonkin.

Thanks to **Jason Toft and lab staff at University of Washington** for lab analysis of terrestrial invertebrates, creation of survey protocols, and general guidance and support. Thanks to **CREOi and View into the Blue** for supporting the marine camera installation and to **The Russell Family Foundation** for supporting our work with students on the site.

Thank you to the **marine life** that brightened our days when we were out in the field!

This report was written by Vashon Nature Center. The content herein does not constitute an endorsement by any of our partner organizations or supporters.

Contents

Introduction

Despite numerous protected designations and recovery plans, Salish Sea chinook salmon populations have declined by more than 60% since 1984 from 1.2 million fish to about 450,000 in 2018 (Pacific Salmon Commission 2019). The number of chinook salmon that are caught by humans has similarly declined (Pacific Salmon Commission 2019). In addition, declining salmon have impacted Southern Resident Orca whale populations leading them to be listed as federally endangered (in 2005), partly due to this decreasing food source (chinook salmon are the whale's primary food; NOAA 2014).

The declining trends in many salmon populations around the Puget Sound have prompted calls for increased restoration efforts with the goal of improving the habitat of the Puget Sound for wildlife of all species as well as human quality of life (PSVS 2020). Shoreline health is an integral part of ecosystem health in Puget Sound. Natural shorelines connect land with sea providing a rich transfer of nutrients, structural habitat components, and sediments that are utilized by a variety of terrestrial and marine invertebrates as well as fish (Dethier et al. 2016).

Currently, 58% of the shoreline in King County and 49% of the shoreline on Vashon Island is armored (CGS 2004). Shoreline armoring, while necessary in some cases to protect human homes and other structures, can impact shoreline health by cutting off connections between terrestrial and marine environments (Morley et al. 2012). To restore some shoreline functionality and to improve fish habitat and beach ecology, many different organizations are undertaking shoreline restoration efforts throughout the Puget Sound region. These efforts include both removing shoreline armoring completely when possible or experimenting with novel ways of protecting shorelines with softshore armoring methods that continue to provide fish habitat. Current information shows that shoreline armoring removal significantly benefits a variety of marine species including salmon (Lee et al. 2018). However, less research has been done on softshore armoring methods to see what benefits these may bring to fish and other intertidal inhabitants.

Washington State Ferries is in the process of restoring a long stretch of bulkheaded beach adjacent to the Tahlequah ferry dock at the south end of Vashon Island, WA. During this restoration process they will be experimenting with removing the existing concrete and creosote piling bulkhead and replacing it with a more natural bulkhead design. The goal is to protect the adjacent road while increasing overall shoreline health and fish habitat.

In 2020, Vashon Nature Center was contracted by Washington State Ferries to monitor this restoration project over time to see if shoreline habitat improves. Vashon Nature Center is a local nonprofit organization that conducts citizen science projects and nature education on Vashon-Maury Island (vashonnaturecenter.org). Vashon Nature Center involves community members and students in these monitoring projects. This provides the community an opportunity to learn alongside scientists about how local restoration projects on the island progress and to be involved in helping managers meet the goals of the project.

This report summarizes the first year of data collection at the Tahlequah site. All data was collected before restoration began. This provides a vital baseline picture of what the restoration site looked like before restoration happened. Vashon Nature Center scientists and community members, along with cooperation from local landowners, collected baseline data at the restoration site and two comparison sites—an armored site that will remain armored for the duration of the study, and a natural site that has had no armoring. Restoration was started in the summer of 2021. After restoration occurs, repeating the data collection at these sites in subsequent years will allow for comparison to baseline conditions to see if restoration improves beach habitat and how long it takes to occur.

The Tahlequah restoration project is a ground-breaking project for a number of reasons: it is being instigated voluntarily by a transportation department; it is testing new techniques in natural shoreline protection; and it is actively involving the community as a partner in the learning process. Because of this, the Tahlequah restoration project is a potential model for restoration practices of the future. What is learned from this project will help organizations all over the Puget Sound and beyond think more creatively about how to restore ecological function to shorelines while integrating and benefitting human communities. We humbly thank all the staff at VNC, WSDOT, as well as partner organizations, volunteers, landowners and other community members involved in this effort. We are excited to learn alongside everyone as this project develops.

Methods

Study Area

Tahlequah is located on the south end of Vashon Island, Washington, central Puget Sound, King County, Watershed Resource Inventory Area 9. The restoration site is on land owned by the Washington State ferry system, Washington Department of Transportation. It is adjacent to, and to the west of, the ferry dock (Figure 1). The restoration site is southwest facing. From the southeast, drift cells carry sediment from Neill Point westward across the restoration site to the small cove formed by Tahlequah creek (WADOE 2014). Another drift cell starts on the southwestern point of Vashon and runs east to a deposition point at Tahlequah creek cove (WADOE 2014). Much of the shoreline along these drift cells is armored so there is potential that increased sediment due to armoring removal and shoreline restoration on the restoration site will have an appreciable benefit in feeding the shoreline from the restoration site to Tahlequah creek.

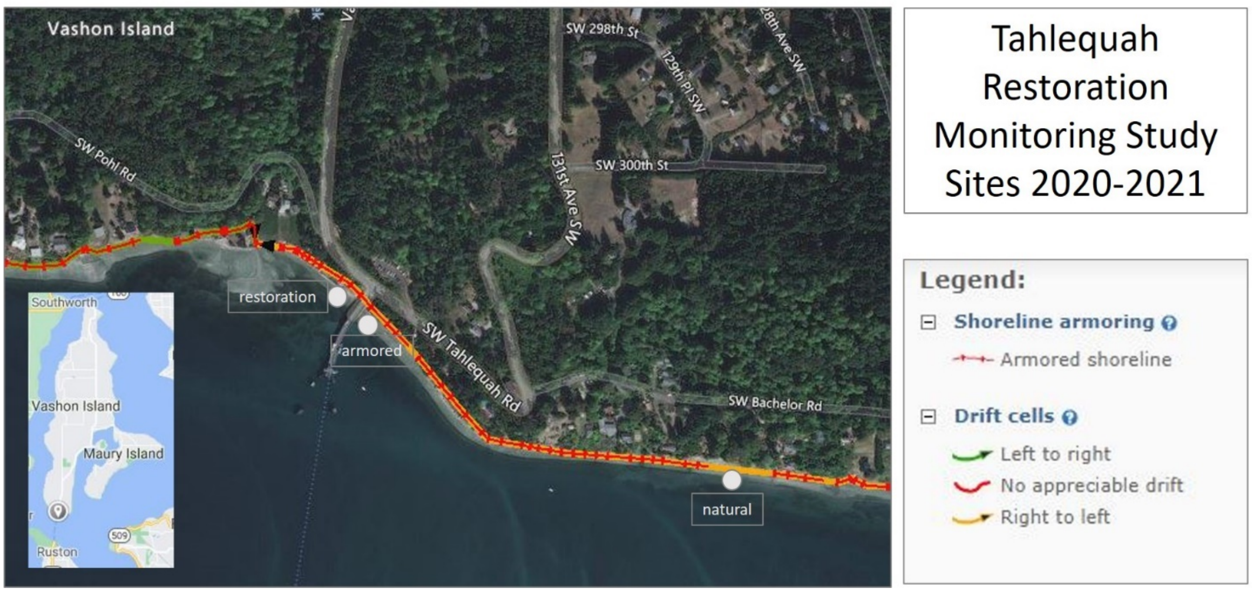

Figure 1. Location of study sites for the Tahlequah restoration project long-term monitoring study. Tahlequah is located on the south end of Vashon Island, WA. Most of the shoreline along the south end of the island is armored except for a few parcels. Drift cells carry sediment from the SW tip of Vashon eastward and from Neill Point on the SE tip of Vashon westward. Drift cells converge at Tahlequah creek outlet near the restoration site. Sediment from the restoration site has a westward drift. Map by: Vashon Nature Center using WA Coastal Atlas data.

Comparison sites were picked as close to the restoration site as possible. Both comparison sites are on private land and researchers were granted permission from landowners for access. The armored site is adjacent to the ferry dock and to the restoration site. It is located immediately to the east and is extremely comparable in slope, aspect (SW), beach type and armoring type to the restoration site. The natural site is located about ¾ of a mile to the east and is the only natural shoreline of appreciable length existing on the south end of the island. Aspect for the natural site is due south which differs slightly compared to the armored and restoration sites which are facing marginally more to the southwest. However, all sites are predominantly south-facing and within a short distance of each other making them comparable.

Study Design and Data Collection Methods

Similar to other long-term shoreline restoration monitoring studies, a paired design was used (Critchley and Bishop 2019). Three sub-sites were monitored: the restoration site (pre-restoration); a natural site (not armored); and an armored site (that will remain armored throughout the duration of the monitoring study) (Figure 1). All three sites were monitored before restoration took place from May 2020-June 2021. Restoration started end of June 28, 2021. Subsequent monitoring will take place on all three sites after restoration has taken place. This will provide a three-way comparison of changes due to restoration overtime.

A suite of habitat variables was selected for monitoring to give a comprehensive picture of how habitat may change due to restoration and what implications this may have for fish use. Habitat variables were selected from the Shoreline Monitoring Toolbox using a decision tree for study design (SMT 2020). These habitat variables represent habitat features that are important to forage fish populations and juvenile salmon, but they also may benefit a suite of other intertidal species (Dethier et al. 2016). Standardized measurement protocols were followed for each variable. These protocols are provided in the Shoreline Monitoring toolbox and are also attached in Appendix A.

The following habitat variables were monitored annually at all three sub-sites in the study area: photo points, beach profile, vegetation cover and type, beach wrack, logs, and terrestrial invertebrates (Table 1). Long-term photo points were set up to record qualitatively what each beach sub-site in the study area looks like through time. Photos were taken at a slight angle to the site and locations were recorded and described so that they can be returned to annually.

Beach profiles measured beach slope and topography. Vegetation cover measured the amount of overhanging vegetation that shades the beach and the composition and cover of trees, shrubs, and groundcovers on land adjacent to the beach. Beach wrack is the buildup of seaweed and other flotsam and jetsam at the high tide line. Beach wrack cover, depth, and width were measured to assess the biomass available at the base of the food web on beaches. Log counts quantify the number of logs that wash up and anchor on the beach providing buffering against erosion during storms, habitat for invertebrates, and hiding and foraging places for fish at high tides. Terrestrial arthropod fall out from beachside vegetation was measured using fall out traps (bins with soapy water). These invertebrates were analyzed for quantity of invertebrates in families that are known to be preferred by juvenile salmonids (SMT 2020; Appendix A).

Fish use of shorelines during high tide was monitored using snorkel surveys once in summer of 2020 at all sites and monthly from February-July 2021 at the restoration site and the adjacent armored site. The natural site is harder to access during high tide requiring a long swim so annual snorkel surveys were done at the natural site rather than monthly. Snorkel survey monitoring protocols from the shoreline toolbox were used (SMT 2020; Appendix A).

Monthly surveys for forage fish spawning were conducted for one full year before restoration starting in May 2020 running through May 2021. Standard forage fish survey protocols and datasheets from the Washington Department of Fish and Wildlife were used to conduct these surveys (WDFW 2011; Appendix A). Bulk beach sediment samples collected during these surveys were then winnowed using the blue bowl method (WDFW 2015). Winnowed samples were looked at under the microscope and forage fish eggs of surf smelt, sand lance, and rock sole were counted if present (Moulton and Petilla 2006).

Table 1. *Field variables that were monitored and frequency of measurement for the pre-restoration baseline survey.*

Sub-site	***Beach profile***	***Vegetation cover and type***	***Beach Wrack***	***Log count***	***Terrestrial invertebrate fall out***	***Forage fish***	***Fish use snorkel survey***	***Photo points***
Pre-restoration	Annual	Annual	Annual	Annual	Annual	Monthly	Monthly Feb-June	Annual; 24-hr marine camera
Natural	Annual	Annual	Annual	Annual	Annual	Monthly	Annual	Annual
Armored	Annual	Annual	Annual	Annual	Annual	Monthly	Monthly Feb-June	Annual

Results

Long-term photo points

Long-term photo points were taken at each subsite and are presented below.

Figure 2. Long-term monitoring photo point for restoration site exists at the 3rd piling down on the ferry dock facing towards the site at 1.5 meter height.

Figure 3. Long-term photo point for armored site is located at the 5th piling of the ferry dock at 1.5 meter height pointing towards the site.

Figure 4. Long-term photo point for the natural site is located at a significant boulder that is in line with poplar trees on shore and is taken at 1.5 meter height pointing towards the site.

In addition to the long-term photo points several voucher photos were taken along the study transects including photos of sediment changes and slope changes during the beach profile; photos of vegetation; photos of significant habitat features or species of interest; and one representative photo of the start, middle and end of each transect line. Photos of sediments (taken from waist height) and of each cardinal direction were also taken at each forage fish survey. These are stored in a google folder and the link was shared with WSDOT scientists.

Beach profile

Beach profiles revealed some key differences between natural and armored sites. Most notable was the fact that the natural site had 21 feet of back beach habitat. This is the length of beach that exists above the mean high waterline. Both the pre-restoration site and the armored site had bulkhead locations that were below the mean high waterline meaning there is no back beach habitat available and high tides would inundate these areas without the bulkhead. Placing shoreline protection back farther on the beach at the restoration site may allow some back beach habitat to form. This habitat is essential for allowing logs to anchor and overhanging vegetation to form adjacent to the tideline. Vegetation that overhangs the water provides more food for fish in the form of terrestrial invertebrates that occupy the vegetation and occasionally drop into the water. Beach width (the length of beach existing above mean low water, MLW) was also greatest on the natural beach allowing for more space for different habitat zones to occur.

Figure 5. Volunteer Steve Fogard demonstrates the incredible amount of sediment movement through the natural site. The central rebar marker was regularly covered and then uncovered to a depth of up to 5 inches as sediments accumulated and then moved off the site feeding beaches to the west.

Beach slope was slightly steeper on the armored and pre-restoration sites compared to the natural site. This is to be expected but the difference was very minimal (possibly because the natural site is in a highly active drift cell that moves sediment away from it and towards the west). Usually, armored beaches have steeper slopes than natural beaches because more scouring takes place. Slope can influence sediment size (steeper slopes=less sand) and placement of habitat zones like eelgrass bands. We would expect that the slope of the pre-restoration site will get gentler overtime once restoration has occurred, and this could lead to a shift in the bands of sediments and perhaps creation of wider habitat zones for eelgrass.

Table 2. *Physical characteristics of the beach at each sub-site. Beach width is defined as the length of beach existing above MLW. Back beach is the length of beach existing above MHHW. Beach slope is the slope of the beach from the bulkhead base or bluff base to the MLW line.*

Sub-site	**Beach width (ft)**	**Back beach (ft)**	**Beach slope**
Pre-restoration	83	0	-0.093
Armored	69	0	-0.11
Natural	112	21	-0.092

Habitat zones (for example eelgrass or ulva zones) and changes in sediments were recorded on the beach profiles. This will enable tracking of any changes in the sediment bands and habitat zones on the restoration site overtime.

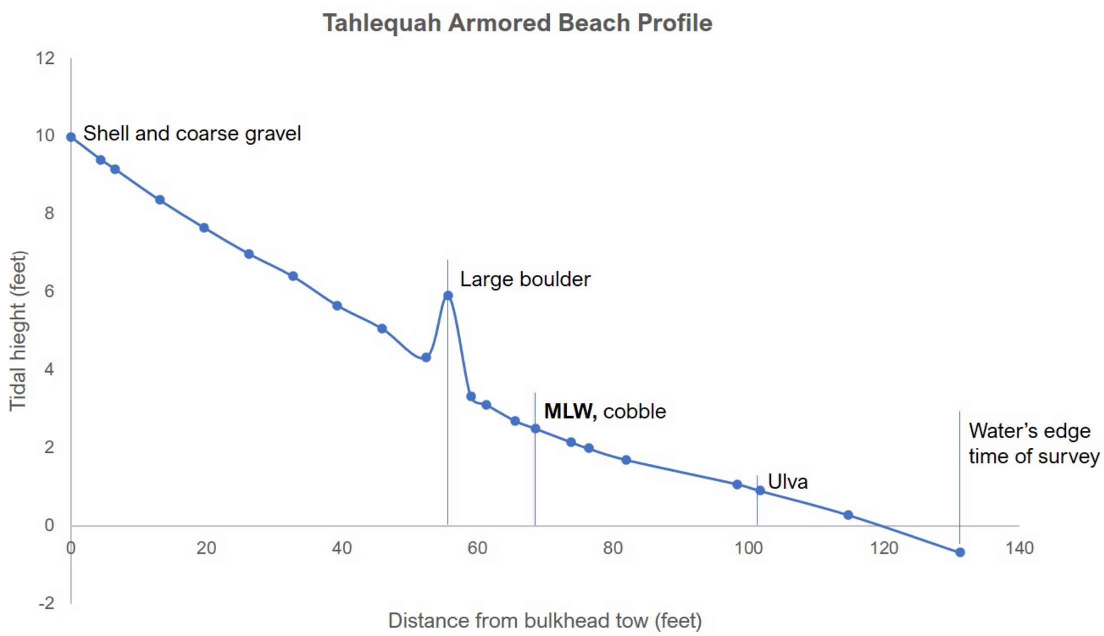

Figure 6. Beach profile, armored site. May 26, 2020. Start at bulkhead, end at waterline. Data: NOAA tide charts for the Tacoma tide station were used to calibrate to actual observed tidal elevations and for MLW and MHHW datums. MHHW was behind the bulkhead so it is not recorded in this beach profile. There was also no appreciable beach wrack line to record.

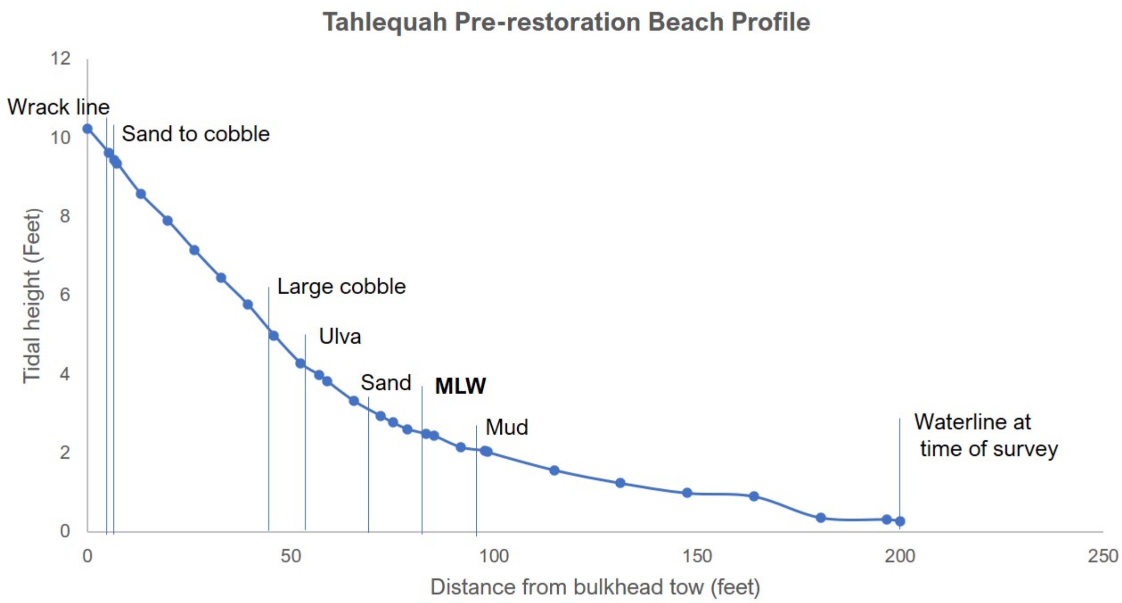

Figure 7. Beach profile for pre-restoration site. Measured May 26, 2020 starting at the bulkhead and going to waterline. Data from NOAA tide charts for the Tacoma tide station were used to calibrate to actual observed tidal elevations and for MLW and MHHW datums. MHHW was behind the bulkhead so it is not recorded in this beach profile.

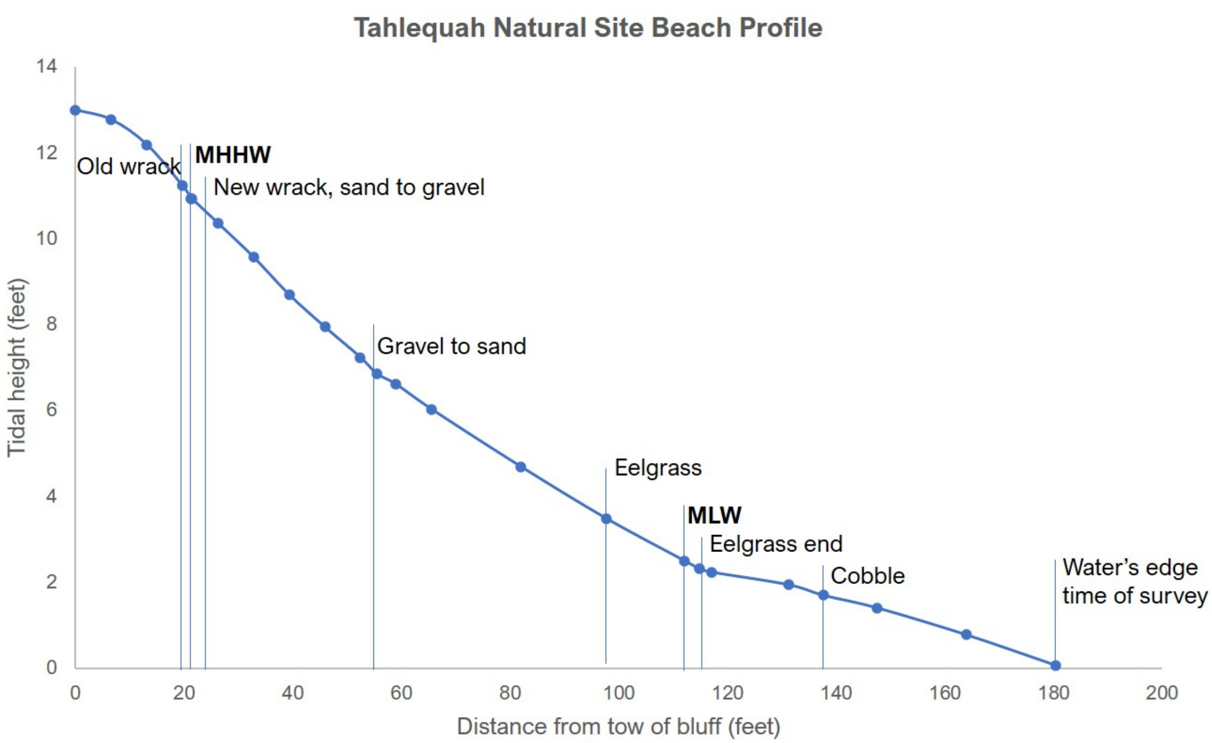

Figure 8. Beach profile, natural site. Measured May 26, 2020 starting at the bluff base and going to waterline. Data: NOAA tide charts for the Tacoma tide station were used to calibrate to actual observed tidal elevations and for MLW and MHHW. Eelgrass bed mapped was a mix of Zostera marina (native) with Zostera japonica (non-native) dominating the higher tidal elevations.

Beach Wrack cover

Figure 9. A photo of the beach wrack line at the natural site.

Beach wrack cover and depth was greater on the natural site compared to the pre-restoration and armored sites indicating more biomass available for nutrient cycling and the marine food web on the natural beach. There was no significant difference between the pre-restoration site and the armored site.

Figure 10. Average percent cover of beach wrack on the pre-restoration and armored sites were similar. There was much higher percent cover of beach wrack on the natural site. Average wrack cover: natural=19.4%; armored=1.5%; pre-restoration=2.3%. Error bars represent to standard errors from the mean.

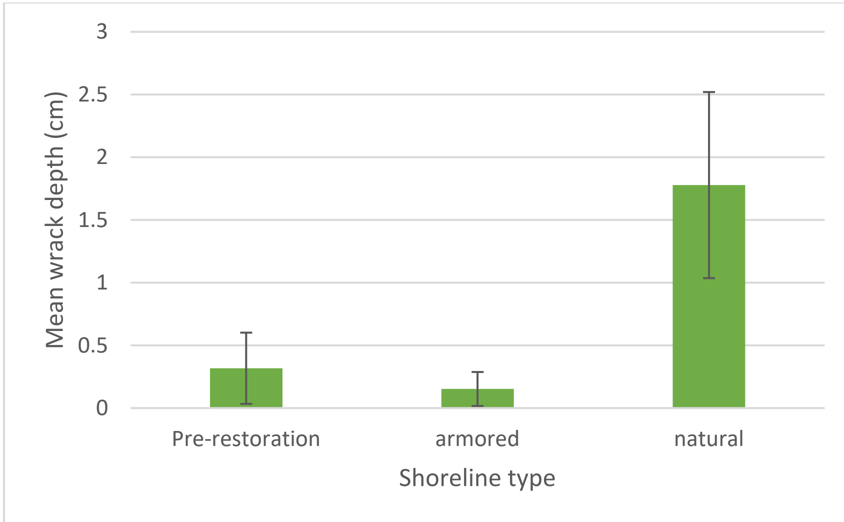

Figure 11. Beach wrack was thicker on the natural site compared to pre-restoration and armored sites. Average wrack depth natural=1.8 cm; armored=.15 cm; pre-restoration=.3 cm. Error bars represent two standard errors from the mean.

Logs

Figure 12 a,b. A comparison of the start of the pre-restoration site (a) above and the natural site (b) below to demonstrate the difference in log accumulation. Logs provide habitat for invertebrates which provide food for fish. They also provide places to hide for juvenile salmon who forage these shorelines at high tide.

Log counts were also higher on the natural site compared to the pre-restoration and armored sites. The average log count for the natural site was 11.4 logs per transect point. The pre-restoration site had no logs detected and the armored site had an average of .4 logs detected per transect point. Logs provide habitat for terrestrial and marine invertebrates as well as foraging and hiding places for juvenile salmon at high tides. In addition, logs create a permeable buffer against wave action that allows for a back beach to form above the high tide line. On bulkheaded sites, rather than being able to anchor on the back beach, logs hit the bulkhead and bounce back into the water floating away from the site.

Figure 13. The natural site had a much higher average count of logs per transect point than armored and pre-restoration sites. Error bars represent two standard errors from the mean.

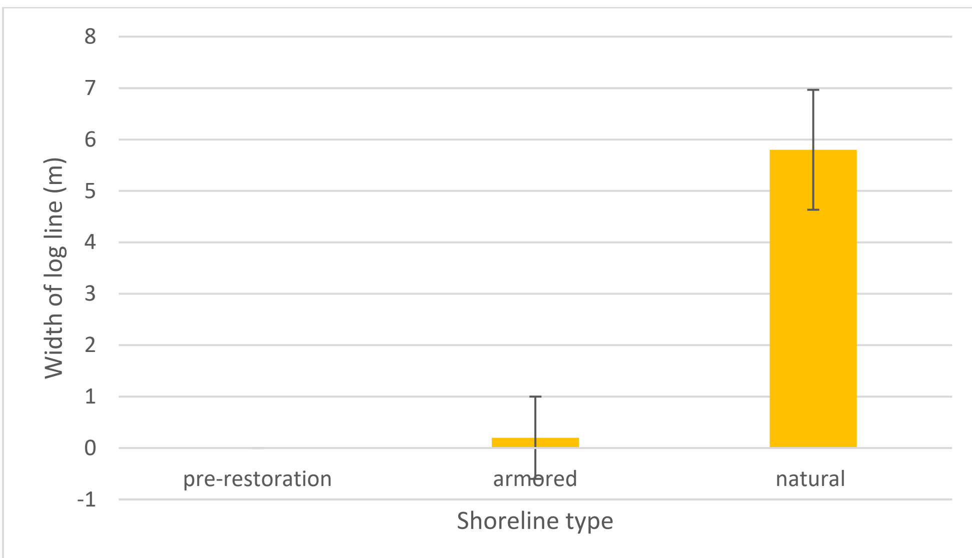

Figure 14. The average width of the log line on the natural site was 5.8 meters indicating a large zone of invertebrate and fish habitat that exists on the natural site but is absent on pre-restoration and armored sites. Error bars represent two standard errors from the mean.

The average width of the log line on the natural site was 5.8 meters. Because of the absence of logs on the other two sites, the log line was negligible. The establishment of a log line creates a significant zone of habitat on natural sites that is not present on armored sites. It will be interesting to see whether a log line establishes on the pre-restoration site after restoration is complete.

Vegetation cover

The natural site had higher tree cover and more cover of vegetation overhanging the shoreline. The pre-restoration site notably had no overhanging vegetation cover. The armored site had overhanging vegetation cover that shaded the beach for 40% of the length of the bulkhead. Overhanging vegetation provides shade which cools the beach. For forage fish, that spawn on the beach, this shade helps keep eggs cool. Overhanging vegetation is also a significant source of terrestrial arthropods that can fall into the water and become food for fish. Juvenile salmon depend on this terrestrial source of food when they forage along marine shorelines.

Habitat at the pre-restoration site could be significantly improved by planting native vegetation, especially trees that eventually overhang the shoreline. Of all the habitat variables measured, vegetation cover leaves the most room for improvement through restoration on the restoration site. The pre-restoration values for vegetation cover were lower even compared to the adjacent armored site.

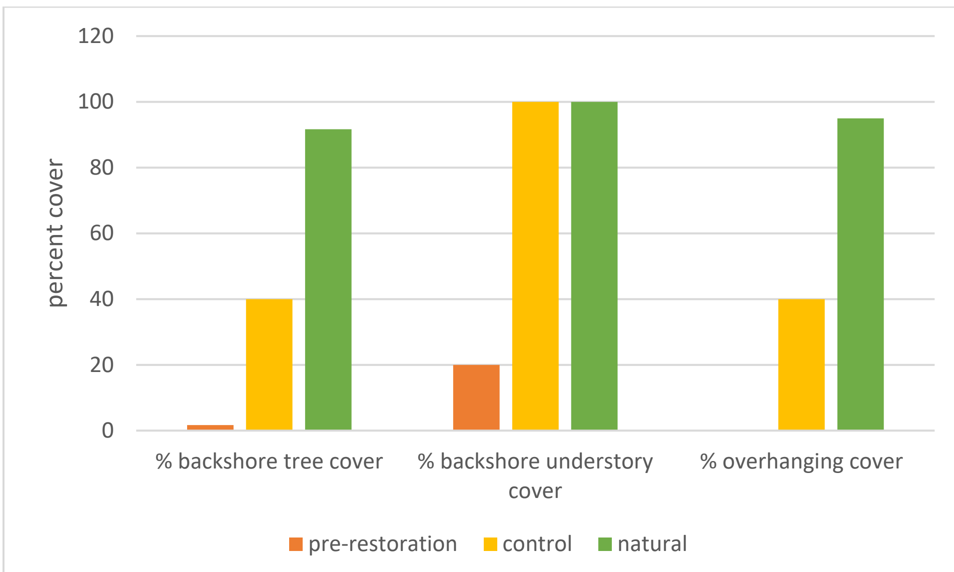

Figure 15. Pre-restoration site has much less vegetation cover than the other two sites. The natural site had the highest overhanging vegetation cover.

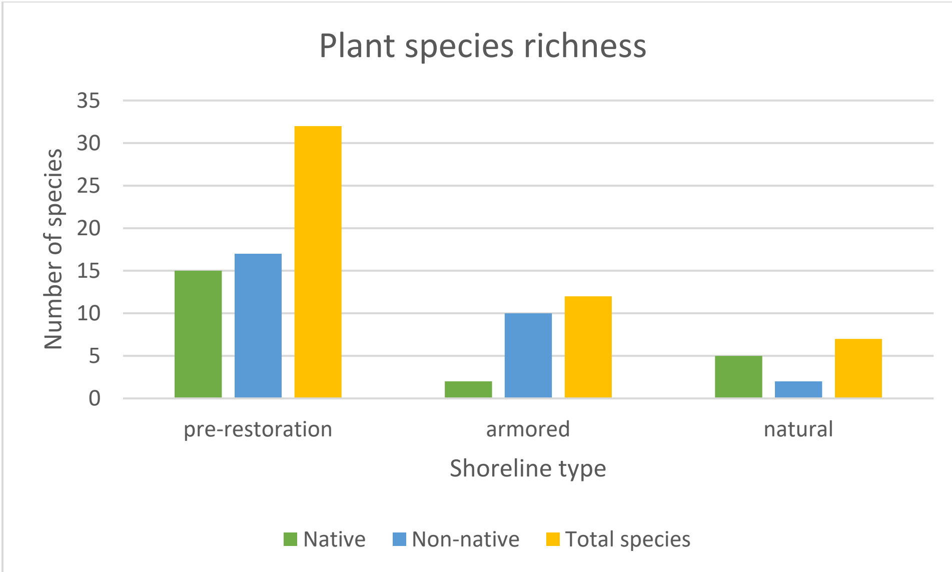

Figure 16. Plant species richness was lowest on the natural site. However, most plants on the natural site were native as opposed to the other two sites where non-native species dominated.

Plant species richness, or the total amount of different species present, was highest on the pre-restoration site. There were two reasons for this. The pre-restoration site has a small saltmarsh habitat behind the bulkhead that hosts a variety of salt tolerant species like pickleweed (*Salicornia virginica*) and Pacific gumweed (*Grindelia integrifolia*) that do not occur on the other sites. If it is possible through the restoration process to maintain some of this saltmarsh habitat it would be beneficial in terms of habitat complexity and species richness. The pre-restoration site also had a high proportion of non-native species which elevated the species richness value. It is highly recommended that non-native species, in particular the flag iris (*Iris pseudacorus*) are removed so that they do not spread to neighboring properties.

The natural site had the least species richness but the highest proportion of native species. In planning native plantings on the restoration site, it may be useful to consult the species lists to see what native plants are growing naturally on all sites as this would indicate plants that are well adapted to this south-facing, marine riparian environment. In the table below we recommend some plants based on what we found growing at these sites. Although it was not present on any site, dunegrass (*Leymus mollis*) may be a good candidate for planting on the restoration site. It has become established on two other restoration sites on Vashon after armoring removal and provides important supratidal habitat amid the log zone.

Table 3. *Recommended plants that have been found growing naturally in this area and may be good low-maintenance natives to include in a restoration planting palette.*

Species name	Common Name	Form	Habitat zone
Salicornia virginica	Pickleweed	Groundcover	Salt spray zone; supratidal
Grindelia integrifolia	Pacific gumweed	Groundcover	Salt spray zone; supratidal

Acer macrophylla	Big-leaf maple	Tree	Marine riparian; back beach
Lonicera ciliosa	honeysuckle	Vine	Marine riparian; back beach
Arbutus menziesii	Pacific madrone	Tree	Marine riparian; back beach
Gaultheria shallon	salal	Shrub	Marine riparian; back beach
Distichlis spicata	saltgrass	Grass	Salt spray zone; supratidal
Salix sp.	Willow (Scouler's or Pacific)	Shrub/tree	Marine riparian; back beach
Atriplex sp.	Orache	Shrub	Salt spray zone; supratidal
Leymus mollis	dunegrass	Grass	supratidal

Full plant species list is available in Appendix B.

Insects

Terrestrial arthropods, in particular Diptera (flies and midges), provide important food sources for juvenile salmon. Quantification of arthropods that fell off nearby vegetation and into fall out traps over the course of 24-hours revealed that the natural site had more than double the density of arthropods compared to the other two sites. This provides a good reference baseline target for goals in terms of arthropod diversity and density that the pre-restoration site should approach overtime. Full taxa list available in Appendix B.

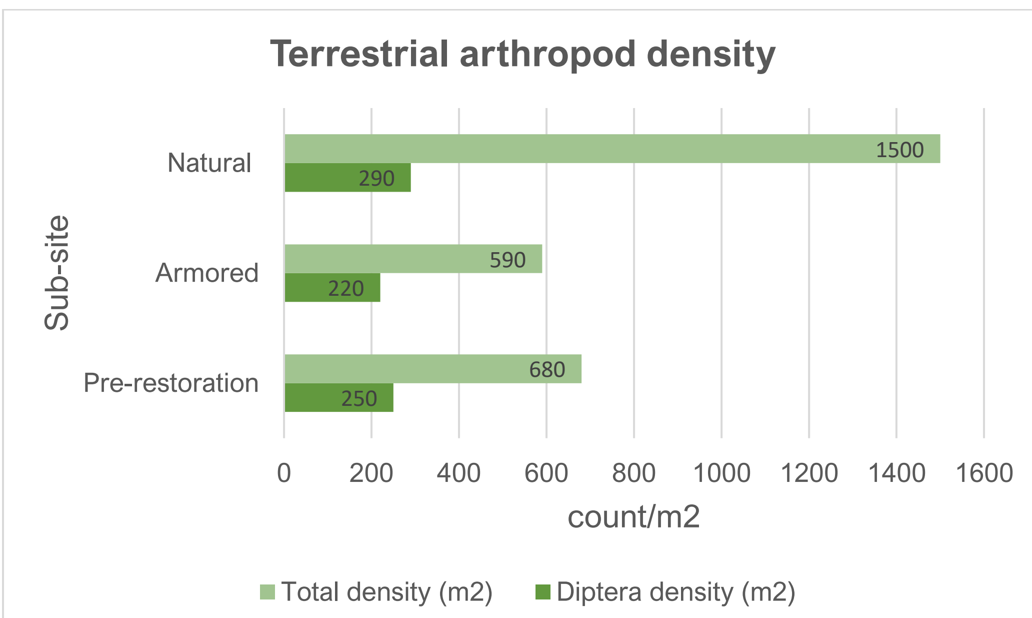

Figure 17. The density in m2 of terrestrial arthropods falling from overhanging vegetation in a 24-hr period at all three sub-sites. We separated out insects of the order Diptera as they are a preferred food of salmon. All sites had Diptera but the natural site had the highest density. This could provide a target of arthropod density to reach on the restoration site as restoration progresses.

Forage Fish

Figure 18. Volunteer Steve Fogard collecting sediment to look for forage fish eggs. Surf smelt, sand lance, and rock sole spawn on island beaches. These surveys were conducted monthly for one-year.

Surprisingly, there were incredibly low instances of forage fish spawning on all three sites. We detected no forage fish eggs on the natural site for all months surveyed despite this site having potentially good habitat for forage fish spawning including gravel sediments underlain with sand and overhanging vegetation. We did detect an appreciable amount of sediment movement on this beach. Our transect marker, a rebar pole that stuck up 5 inches above the ground surface was regularly buried and re-excavated, sometimes within the span of a month, from sediment movement. This may mean this beach is too active in terms of sediment shift to support spawning habitat. However, it also indicates that this one remaining natural shoreline portion on the south end is likely contributing much needed sediments to beaches down drift all the way to the pre-restoration site and Tahlequah creek cove. This potentially supports the spawning habitat in that area.

Spawning was not only low it was also detected later in the year than other island beaches where Vashon Nature Center has conducted spawning surveys. Beaches to the north in Quartermaster harbor and on Maury Island, peak with spawning events between November and January. This could indicate that a separate population of surf smelt are using these south end beaches to spawn. They may be helped by restoration that increases sandy sediments and fine gravels, preferred spawning substrates.

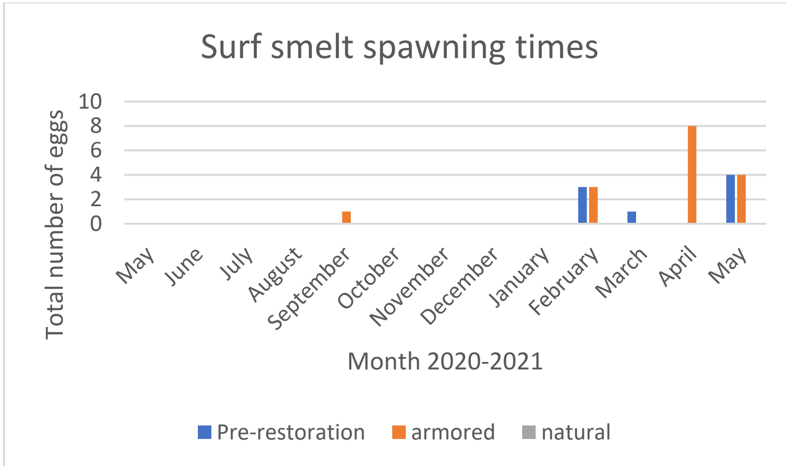

Figure 19. No spawning on the natural site. Spawning was detected in low numbers in February, April and May. September and March only uncovered one egg which is below the threshold for defining a spawning event.

In addition to finding surf smelt eggs, a few Pacific herring eggs were found. The numbers were low (1-2 for 2 months) and the eggs were not attached to eelgrass. This likely means these were not from spawning events on the local beach but may have floated in from elsewhere. Large masses of small eggs with filamentous attachments were found consistently for 3 months. The small diameter of these eggs (less than 1 mm) may indicate that they are a marine invertebrate of some kind but despite widespread sharing of photos and specimens with forage fish experts and marine experts throughout the Puget Sound we have yet to identify these eggs!

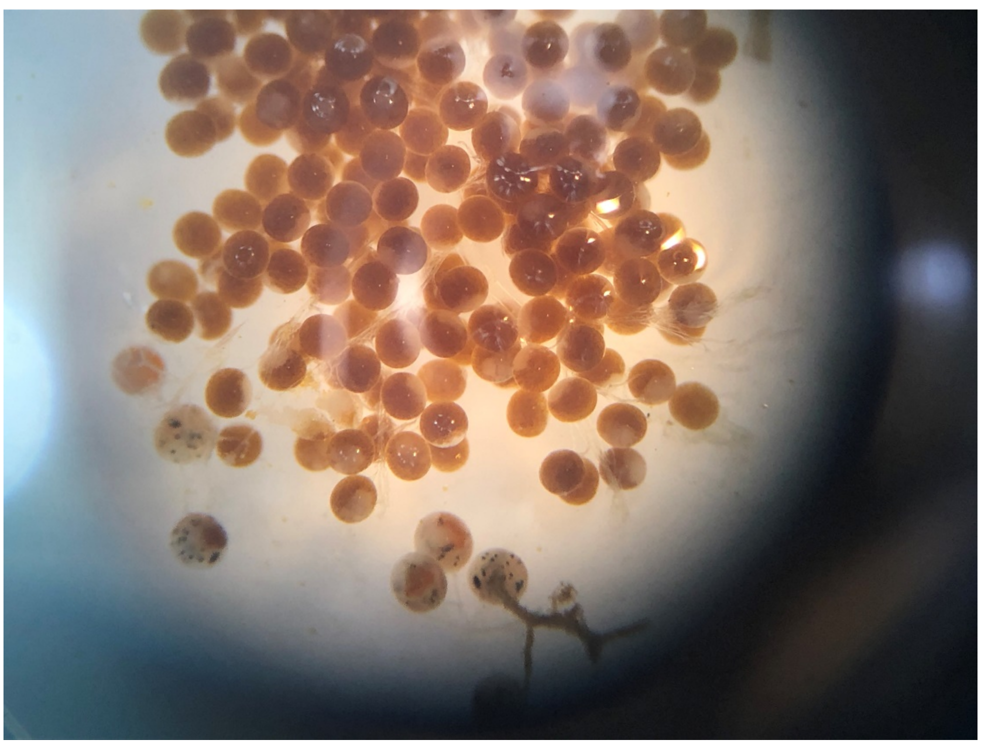

Figure 20. Mystery eggs found on the pre-restoration site. Diameter is less than 1 mm making them too small to be forage fish eggs (at first it was thought they might be topsmelt but they are too small). Eggs are connected with a filament. We are still in the process of trying to identify what these eggs are!

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Fish use

Snorkel surveys detected very low numbers of fish using both the pre-restoration site and the armored site throughout the monthly surveys. One yearly survey was conducted at the natural site which revealed a large school of juvenile salmon using the site in the shallows at high tide. Sand lance and sculpin were seen on the pre-restoration site, surf smelt on the armored site, and juvenile salmon (a mixed school of chum and unidentified salmon), shiner perch and sculpin were seen on the natural site. As overhanging vegetation is increased on the restoration site, we would expect to see juvenile salmon using that site as it is close to the natural site that they are using already.

A marine camera is in the process of being installed at the restoration site. This should give us a better idea of fish use in deeper areas of the restoration site to see how deep the effects of restoration may go. As of this report, the camera has not been successfully uploaded for video sharing to take place.

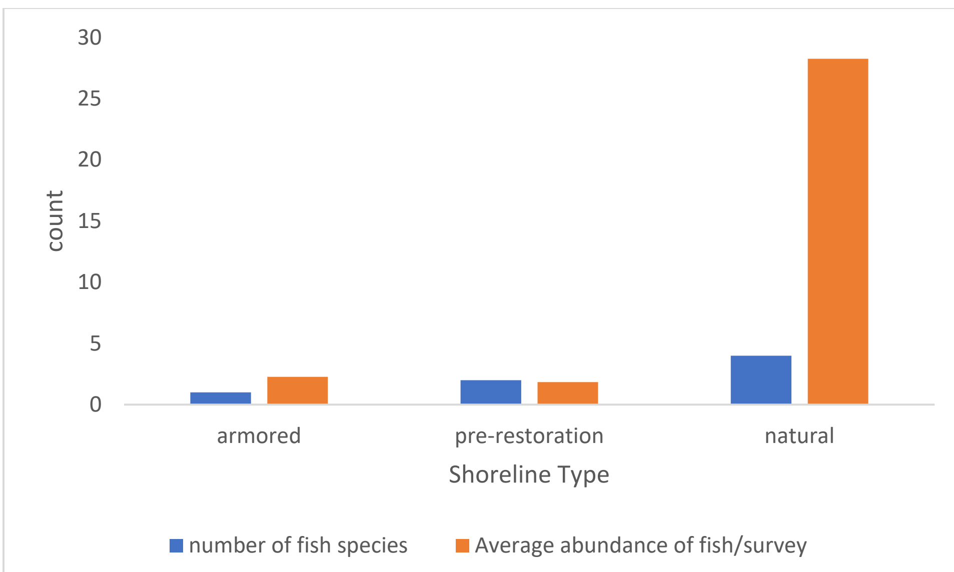

Figure 21. Total fish counts for each sub-site. Armored and pre-restoration sites had one snorkel survey in 2020 and monthly snorkels in 2021 from February-June. The natural site had one snorkel survey in 2020 and none in 2021. No salmon were found using the pre-restoration and armored sites, but they were found at the natural site.

Volunteers

Figure 22. We love our volunteers! Thank you for braving a pandemic with us to continue this baseline data collection!

A total of 18 volunteers participated in various aspects of data collection during this baseline study. Volunteer age range fell between 16 and 70. These volunteers provided 198 hours of volunteer time from the community to the progress of this restoration project so far.

Much of the research conducted happened during the COVID-19 pandemic and so we doubly appreciate the efforts it took volunteers to mask up and practice strict safety protocols for most of the time research happened. Four volunteers were students or recent graduates in environmental science who gained important field experience and lessons in survey techniques that will help them as they further their careers. This project was particularly important for 2 of the volunteers who were forced to come home from college during the pandemic. This project gave them a chance to continue hands-on learning and get field work experience locally when other opportunities closed down.

Conclusion

This report provides a suite of baseline data that documents initial conditions at the restoration site pre-restoration, along with two companion sites. This data can be compared using a repeat study once restoration has been completed to track changes due to restoration.

The use of comparison sites gives a reference point for what a natural site looks like and how it functions ecologically in this local area. This can be used to create goals for what the restoration site could approach in terms of fish use, vegetation cover, logs, wrack accumulation, and terrestrial arthropod density and richness. The use of the comparison armored site provides a control in which to determine what changes over time are due to restoration and what changes are due to other factors in the environment.

Some changes due to restoration, like overhanging vegetation and fish use, are hypothesized to take longer than others (beach wrack and log accumulation). For this reason, we recommend re-visiting this study and collecting data shortly after restoration has been completed and again several years after restoration has occurred to see what changes occur in the long-term.

This project has the potential to be a model for future restoration projects in terms of community involvement, and restoration technique and approach. We look forward to learning more as restoration progresses!

Figure 23. May the restoration proceed well! And may many more fish be in all our futures!

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APPENDIX A: SURVEY PROTOCOLS

1. **Photo points**
2. **Beach Profile**
3. **Beach wrack**
4. **Insects**
5. **Logs**
6. **Vegetation**
7. **Fish (Snorkel Surveys)**
8. **Forage Fish spawning field**
9. **Forage Fish spawning: winnowing and lab**

Photo points

Taking photographs during sampling can be useful to document habitat conditions that may change over time. Habitat conditions include natural (sediments/vegetation) and constructed parameters (bulkheads/docks). They may change depending on planned activities such as plantings of vegetation and construction of shoreline armoring, and unplanned activities such as sediment and log movement due to winter storms and landslides.

Materials

- Digital camera, and tripod if possible
- Compass (or smartphone version) and transect tape
- GPS is useful for establishing locations
- Scalable reference (e.g., stadia rod, transect, or quadrat)
- Copy of previous photos, if applicable

Sampling Summary

- Annual photo points at exact locations and compass bearings
- Panorama photos of the entire site
- Photos related to other protocols, such as transect and quadrat locations, or cobble cam techniques for sediment sizes
- Photos useful for plant, algae, and invertebrate identifications

Scale of Effort

$$ Cost – medium, depending on materials, smartphones can substitute for other gear

$ People – low, 2-3 people can take photos

$ Fieldwork time – low, 1 day, once a year or during other sampling

$$ Processing time – medium, downloading and labeling photos

$ Technical expertise – low, use of digital camera and compass

Additional Resources

Reports that have used this method: Toft et al. 2012 (e.g., Figs 27-28)

Also see Ch. 8 in the Marine Shoreline Design Guidelines for more guidance on photo points

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant.
Website: wsg.washington.edu/toolbox

Methods

Establish exact locations for photo points where key habitat conditions are visible and record the compass bearing of photo direction, camera height, and zoom or other photo details to allow future re-establishment. Document locations by relating to stable features, recording Lat/Long with GPS, or using a compass and transect tape to triangulate bearing and distance to stable features. Many smartphones have compass/GPS capabilities that can be used in place of other gear. Try to document habitat conditions such as vegetation, driftwood, beach topography, and shoreline armoring if present. Place a scalable reference in the area if it will help make qualitative measurements, such as a stadia rod, a known length of transect or size of quadrat. Take photos annually on a similar date. Daytime low tides in May-August allow documentation of the exposed intertidal beach. More frequent photos allow better documentation of episodic events such as winter storms and movement of logs. A panorama photo can be useful to capture general features of the entire site. Photos should be taken during other protocol sampling, such as at (1) transects looking from beginning to end and vice versa, also looking away from the transect to document adjacent conditions, (2) quadrats from above, (3) characteristics during invertebrate sampling (e.g., vegetation surrounding insect fallout traps). Photos can also be very useful to verify identifications of plants, algae, invertebrates, and other taxa of question.

Data to record in the field

Date, time, site name, location, compass bearing, and any other details pertaining to the photo.

Processing

Download and label each photo by using a standard labeling convention, such as: Site_Date_Habitat_photo#.jpg (e.g., Seahurst_6-11-14_dunegrass_4.jpg). Include in the label any other unique descriptors, such as transect elevation or quadrat number. Create a spreadsheet that includes the photo label and related information, such as location and compass bearing. Make a back-up and store where others can access. Photo points over time can generate qualitative metrics of parameters such as vegetative growth, log movement, general sediment and algae types, and presence and type of shoreline armoring or landscaping.

Beach profile

Characterizing the beach profile provides valuable information on the physical structure of the beach. This may change depending on winter storms, restoration activities, and shoreline armoring. The variability in beach topography and slope is indicative of physical forces acting on the beach and can affect associated algae and invertebrates.

Materials

- 100 m transect tape and wired flags
- Laser level
- 14' Stadia rod

Sampling Summary

- 100 m transect perpendicular to shore, from top of the berm or toe of bluff/armoring down to MLLW
- Take an elevation measurement every 2 meters and at key features
- Record elevation at the water line and note the time, adjust profile elevations based on the nearest NOAA station measurements, or alternatively adjust elevations to that of a benchmark

Scale of Effort

$$ Cost – medium, supply costs are moderate, data are all field-based

$ People – low, 2-3 people can establish transects and record profile data

$ Fieldwork time – low, 1 day, once or twice a year (summer daytime low tides allow sampling to MLLW)

$ Processing time – low, entering field data into computer format

$$ Technical expertise – medium, knowledge of laser level techniques

Additional Resources

Reports that have used this method: Heerhartz et al. 2014, and Toft et al. 2013

Other methods that require more technical expertise: RTK-DGPS

See the Beach Watchers procedures for methods that are less costly and technical (profile poles and line)

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant.
Website: wsg.washington.edu/toolbox

Methods

Establish a transect perpendicular to shore, starting from above MHHW at the top of the berm or toe of the bluff at natural beaches, or at the base of armoring if there is bulkhead or riprap. Extend the transect down to MLLW. Mark any key elevation or transition areas with wired flags such as at the wrack line, an obvious change in beach profile or sediment grain size, or where you may be collecting other data. Take elevation measurements using the laser level and stadia rod at all flagged areas and every 2 meters along the transect, more frequently if the topography greatly varies, and less frequently if there is an extensive low tide terrace with not much change in gradient. A 100 m transect should be long enough; some beaches may require moving the transect tape if they extend far from shore. The 'head' of the laser level must be higher than the highest point to be surveyed (e.g., the base of the bluff). For most sites you will need a 14 foot stadia rod, or will need to survey high and low sections separately. Record the elevation at the water line and note the time so that data can be corrected to actual elevations measured at NOAA stations (Note: uncertainty increases with distance from the tide station). It may also be possible to measure the vertical distance from the start of the transect to a benchmark with a known elevation. Laser levels are commonly used in surveying work – search for detailed instructions online if you are unfamiliar with their use. Summer daytime low tides allow sampling down to MLLW.

Data to record in the field

Date, time, site name, transect measurement, elevation data. It is advisable to take a digital photo of the transect for documentation.

Processing

Enter field data into computer spreadsheets. Correct the data based on the actual elevation at the water line or a benchmark. Calculate the beach width (distance from MHHW to MLLW) and the beach slope. Plot the elevations along the transect length to note any key features in the topography, which will allow visualization of changes over time.

Beach Wrack

Characterizing beach wrack provides valuable information on the habitat of the upper beach and marine-terrestrial connectivity. This may change depending on shoreline armoring, source material alterations, and winter storms. Beach wrack provides food and shelter for many invertebrates, and foraging habitat for shorebirds.

Materials

- 50 m transect tape
- 32 x 32 cm pvc quadrat, subdivided with string into 25 6 x 6 cm small squares

Sampling Summary

- 50 m transect parallel to shore
- 0.1 m^2 quadrat (32 x 32 cm)
- N=10 random quadrats per transect
- Transects at most recent wrack line and higher elevation older wrack line
- Measure % cover of algae, eelgrass, terrestrial plants, and trash

Scale of Effort

$ Cost – low, simple materials and data are all field-based

$ People – low, 2-3 people can establish transects and record quadrat data

$ Fieldwork time – low, 1 day, once a year in September when wrack lines are exposed

$ Processing time – low, entering field data into computer format

$ Technical expertise – low, identification of major wrack types

Additional Resources

Reports that have used this method:
Dethier et al. 2016
Heerhartz et al. 2014
Sobocinski et al. 2010

Other methods that require a larger scale of effort and more technical expertise: methods in Heerhartz et al. 2014 that measure biomass of wrack

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant.
Website: wsg.washington.edu/toolbox

Methods

At ten random points along a 50 m transect parallel to shore, place a 0.1 m^2 quadrat on the beach surface and conduct a visual estimate of the percent composition of algae, eelgrass, terrestrial plant material, and trash. Divide the quadrat with string into 25 6 x 6 cm small squares to facilitate these estimates – each square equals 4%. If possible, specify the algae type (e.g., red, green, brown, or species). Establish two transects: (1) at the most recent high tide line that has fresh wrack deposition, and (2) just above MHHW in older wrack. The most recent high tide line will target mobile wrack, whereas the higher elevation sample will target the more stable wrack layer. If there is a bluff or shoreline armoring, sample the elevation at the base. Sample in September as it is typically a period of high wrack accumulation, and on an ebbing tide when the upper beach +6’ MLLW and above is exposed.

Data to record in the field

Date, time, site name, transect elevation, sample number, beach wrack data. It is advisable to take a digital photo of the transect and of some example quadrats for documentation.

Processing

Enter the field data into computer spreadsheets. The percentages for each wrack type can be analyzed separately, or combined for a percentage of total wrack cover. The different wrack types give information on the source material available (e.g., riparian vegetation for terrestrial sources), and the amounts that deposit on the beach.

Insects

Terrestrial insects are a good indicator of shoreline conditions and an important prey component for juvenile salmon. Using passive fallout traps to characterize the insect community simulates insects that could fall on the surface of the water and be available as fish prey. Insect communities may vary depending on the amount of riparian vegetation, shoreline armoring, and other habitat features.

Materials

- Plastic storage bins 40 x 25 cm (0.1 m^2), 10 cm high
- Natural dishwashing soap (biodegradable, odorless)
- 0.106 mm sieve
- Water sprayer, two buckets for collecting and sieving water
- Jars and labels, 70% isopropyl alcohol
- Microscope

Sampling Summary

- 50 m transect parallel to shore above tidal inundation
- Place bins with a few drops of soap and ~5 cm of sieved water
- N=5 random bins per transect
- Leave for 24 hours, preserve in 70% isopropyl alcohol
- SAFETY: isopropyl alcohol is flammable, store carefully and avoid skin contact

Scale of Effort

$$$ Cost – high, field and laboratory supplies can be expensive (e.g., alcohol, microscopes)

$ People – low, 2-3 people can deploy and collect bins

$$ Fieldwork time – medium, once a month June and July, two days in a row for deployment and collection

$$$ Processing time – high, analyzing insect samples in the laboratory

$$ Technical expertise – medium, depending on insect ID level

Additional Resources

Reports that have used this method:
[Toft et al. 2013]
[Sobocinski et al. 2010]

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant.
Website: wsg.washington.edu/toolbox

Methods

Use plastic storage bins (preferably 40 x 25 cm) filled with 5 cm of soapy water as fallout traps. Make sure to measure the surface area of the bins to standardize counts. Place five replicate bins randomly along a 50 m transect parallel to shore. Pour a few drops of natural odorless dishwashing soap in the bottom, and fill with about 5 cm of sieved water. The dishwashing soap relieves surface tension so that insects will remain trapped, and sieving the water ensures that there are no invertebrates that could contaminate your sample. Leave the bins in place for 24 hours. To collect the insects, drain each bin through a 106 micron mesh sieve, and spray the insects into a sample jar (fill a spray bottle or weed sprayer with sieved water for this). Fix the sample in 70% isopropyl alcohol and label the jar. Sample in June-July when juvenile Chinook salmon are feeding along the shoreline, and vegetation and insect communities are developed.

Data to record in the field

Date, site name, time of deployment and collection, sample number (also include these on the jar label). It is advisable to take a digital photo of the transect for documentation.

Processing

Microscope identification of insects requires some skill and time. Chironomidae flies and aphids are two key juvenile salmon prey items that should be identified at the Family taxonomic level. Other insects such as Hymenoptera and Lepidoptera can be identified at the Order level if taxonomic expertise is limited. Processing at a consistent taxonomic level allows calculation of diversity measurements (e.g., taxa richness, the number of different taxa in the sample). Convert counts to density (#/m^2) based on the surface area of the bin.

Logs and riparian vegetation

Characterizing logs and riparian vegetation provides valuable information on the habitat of the upper beach and marine-terrestrial connectivity. Logs provide shelter for many invertebrates such as beach-hopper amphipods, and foraging habitat for shorebirds. Riparian vegetation provides habitat for terrestrial insects that are prey resources for juvenile salmon.

Materials

- Two 50 m measuring tapes, one for the transect and one for width of the log line

Sampling Summary

- 50 m transect parallel to shore
- N=5 random samples per transect
- Width of log line, and number of large and small logs (<> 2 m length)
- Total percent and type of riparian vegetation along the transect
- Total count of fallen trees along the transect

Scale of Effort

$ Cost – low, simple materials and data are all field-based

$ People – low, 2-3 people can establish transects and record quadrat data

$ Fieldwork time – low, 1 day, once a year in September when driftwood is exposed

$ Processing time – low, entering field data into computer format

$ Technical expertise – low, identification of major vegetation types

Additional Resources

Reports that have used this method:
Dethier et al. 2016
Heerhartz et al. 2014

Also see Brennan 2007 for further information on riparian vegetation in Puget Sound

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant.
Website: wsg.washington.edu/toolbox

Methods

At five random points along a 50 m transect parallel to shore, measure the width of the log line perpendicular to the transect as the distance from the seaward-most edge of logs to the landward-most edge of logs. Count the number of large and small logs (longer or shorter than 2 m) intersecting the perpendicular line, and categorize as "natural" log recruits or human-altered (e.g., cut poles, dock material). Note any other defining characteristics of the logs, such as if they have marine or terrestrial growth (e.g., barnacles, moss). Estimate total percent cover along the 50 m transect of vegetation overhanging the upper beach. Also estimate the percent of supratidal vegetation categories (e.g., dunegrass, blackberries) and backshore vegetation categories (e.g., trees, shrubs, lawn). Make a total count of fallen trees along the 50 m transect. Sample in September at the end of the vegetation growing season, on an ebbing tide when the upper beach +6' MLLW and above is exposed.

Data to record in the field

Date, time, site name, sample number, log and vegetation data. It is advisable to take a digital photo of the transect for documentation.

Processing

Enter the field data into computer spreadsheets. Calculate averages of width of the log line and number of logs. Log and vegetation data can be used as causal factors for other data types such as insects, beach wrack, and shorebirds.

Vegetation

Characterizing shoreline vegetation such as dunegrass and willows can give valuable information on the habitat of the upper beach and marine-terrestrial connectivity. This may change depending on shoreline armoring, development in the uplands, and new plantings of vegetation at restoration sites. Vegetation stabilizes the shoreline and provides habitat for terrestrial insects that are prey resources for juvenile salmon.

Materials

- Two 50 m measuring tapes, one for the transect and one for vegetation measurements
- 0.25 m^2 pvc quadrat (0.5 x 0.5 m)

Sampling Summary

- Generate a plant species list
- Percent cover of over and understory vegetation
- Canopy diameter of trees
- Health ratings of vegetation
- Dunegrass: 50 m transect parallel to shore. N=5 measurements for patch width and 0.25 m^2 quadrats for shoot density and percent cover

Scale of Effort

$ Cost – low, simple materials and data are all field-based

$ People – low, 2-3 people can establish transects and record vegetation data

$ Fieldwork time – low, 1 day, once a year in July when vegetation is lush

$ Processing time – low, entering field data into computer format

$ Technical expertise – medium, identification of plant species

Additional Resources

Reports that have used this method: Toft et al. 2012

Also see Chappell 2006 for species information of vegetation in the Puget Sound region

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant.
Website: wsg.washington.edu/toolbox

Methods

Start by generating a plant species list for the site, noting native and introduced species. Estimate the percent cover of over (trees) and understory (e.g., dunegrass, salal) vegetation in increments of 5% at different areas; this is best done in ~5 x 5 m patches, choose a subset depending on the size of the site and location of key vegetation features. Measure the canopy diameter of trees at their widest point by using a transect tape. Give each vegetation area a health rating between 1 (dead) and 5 (vigorous growth), noting specific plants/trees that are characteristic of the rating. At patches of dunegrass establish a transect parallel to shore along its length, or for 50 m if the patch is very long. At five random points along the transect measure the width of the dunegrass patch, and use a 0.25 m^2 quadrat to estimate shoot density and percent cover in increments of 1%. Sample in a summer month such as July when vegetation is lush.

Data to record in the field

Date, time, site name, sample numbers, vegetation data. It is advisable to take a digital photo of the transect and specific vegetation types for documentation.

Processing

Enter the field data into computer spreadsheets. Monitoring over time can generate growth parameters for different vegetation types and detail any changes in over and understory structure. Vegetation data can be used as causal factors for other data types such as insects and shorebirds.

Fish

Improving habitat for out-migrating juvenile salmon is often a goal of nearshore restoration efforts. Direct observation of fish use of a site is desirable to assess function of the site. Surface snorkel surveys are recommended as an observational method that can generate data without handling fish. Observations are focused on juvenile salmon abundance, feeding behaviors, and records of other nearshore fishes.

Materials

- Snorkel gear – drysuit or wetsuit, mask, snorkel, fins, ankle weights
- 50 m or longer transect tape
- Underwater writing tablet, or clipboard with datasheet printed on waterproof paper

Sampling Summary

- 75 m transect parallel to shore
- 3 m and 10 m from shore for deep sites, 1.5 m water depth if shallow
- Need at least 2.5 m water visibility
- SAFETY: Highly advised to be a skilled swimmer and have snorkel or SCUBA dive experience. Always stay at the surface, be aware of any boat traffic or hazards, and have a shore-based observer

Scale of Effort

$$$ Cost – high, snorkel gear is expensive, SCUBA divers may already have gear which would greatly reduce costs

$ People – low, 2 snorkelers and 1 shore observer can establish transects and record data

$$$ Fieldwork time – high, base effort 2x/month at high tides May-July

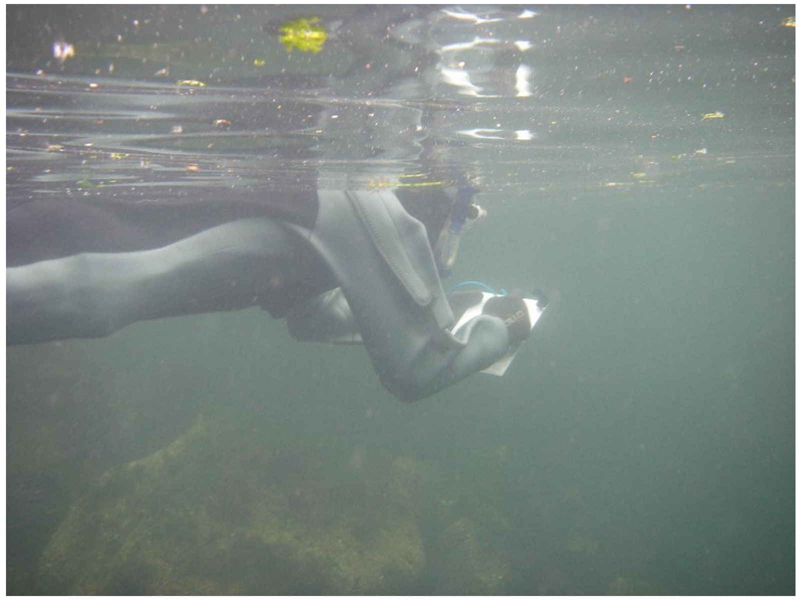
$$ Processing time – medium, entering field data into computer format, possible verification of fish ids

$$$ Technical expertise – high, snorkel surveys and fish identifications both require background knowledge

Additional Resources

Reports that have used this method:
Toft et al. 2007, 2013

Suggested citation: Shoreline Monitoring Toolbox. Washington Sea Grant.
Website: wsg.washington.edu/toolbox



Methods

Conduct surface snorkel surveys parallel to shore along a 75 m transect at high tide. Have two snorkelers in the water and a shore-based observer. The water depth and distance from shore may vary with the site – for deep sites target 3 m and 10 m from shore, for shallower sites target 1.5 m water depth. These are good ranges for juvenile Chinook salmon. Smaller juvenile chum and pink salmon may be in shallower water. Record observations of fish species, number (approximate if over 20), length range (2.5 cm increments), water column position (surface, mid-water, bottom), and feeding behavior. Swim slowly and consistently, scanning the water column with a focus near the water's surface where juvenile salmon are likely to be (tilt your head sideways for this). Pause to record data as appropriate. Data can be written on either an underwater writing tablet or clipboard with datasheet printed on waterproof paper. Use the transect tape to measure the transect length, water depth, and underwater visibility (horizontal distance that you can see the writing tablet underwater – needs to be at least 2.5 m). May is a good month to target the peak outmigration of juvenile chum and pink salmon, June and July are good peak months for Chinook.

Data to record in the field

Date, time, site name, transect length, water depth, distance from shore, underwater visibility, fish data. An underwater digital camera can help document fish presence.

Processing

Enter the field data into computer spreadsheets. Fish counts are standardized by numbers/m^2 as: fish number/(transect length x underwater visibility).

WDFW Intertidal Forage Fish Spawning Habitat Survey Protocols

Procedures for obtaining bulk beach substrate samples

Field materials needed:

Measuring tape (100+ feet)
16-ounce plastic jar or large scoop
8 inch x 24 inch polyethylene bag (or large, sturdy ziplock)
Handheld GPS device
Tide table
Digital camera (optional)
Hypsometer (if available)
Data sheet (preprint on Write-in-the-Rain paper if possible)

Note: Sampling should occur on the lowest tide practicable. Prior to sampling any site consult tide tables to ensure you will be able to access the +7-9 (surf smelt) and +5-8 (sandlance) tidal height. It may also be necessary to obtain **permission to access the beach** from private or corporate landowners.

Procedure:

1. Upon arriving on the beach, fill out the header information on the attached data sheet. *Do not* fill in "Reviewed by." Before conducting the first sample, describe the character of the upland and beach environment using the codes provided on the back of the data sheet. For additional details on sample codes see Moulton and Penttila (2001)*.

2. Identify a landmark from which you will measure the distance to the bulk substrate sample tidal elevation. Typical landmarks include the upland toe of the beach, the last high tide mark or wrack line, and the edge of the water.

3. Measure the distance from the landmark to the tidal elevation to be surveyed. Note that linear measurements along the beach face serve as an index of tidal height but do not directly quantify *vertical* tidal height. If available, a hypsometer can be used to measure vertical sampling height.

4. Stretch a measuring tape at least 100 feet along the selected tidal height. Note that beach contours may cause the landmark to be 'wavy' and that the tape should remain a consistent distance from the landmark.

5. Standing at one end of the measuring tape, record a GPS fix on the data sheet.

6. Using a 16-ounce sample jar or large scoop remove the top 5-10 cm (2-4 in) of sediment from the location recorded in Step 6 above. Place the sediment in an 8 inch x 24 inch polyethylene bag or large, sturdy ziplock. You may need to take two scoops to get sufficient sediment, depending on the coarseness of the beach.

7. Walk ten paces (single steps) along the measuring tape, repeat the sediment scooping action, and place the sediment in the bag. Move an additional ten paces and repeat. Move an additional ten paces, approximately to the end of the tape, and repeat. The bag should now have sediment from four locations along the tape and be at least ½ to ⅔ full.

8. If additional transects, representing various tidal heights, along the beach are to be surveyed, place the sample bag in a cool, shady place and repeat the above procedures at these additional locations. If no additional samples will be taken, move on to wet sieving and winnowing the sample as described in the companion protocol "Procedures for recovering "winnowed light fractions" subsamples of forage fish egg-sized material from bulk beach substrate samples."

9. If you have a camera, take several photos of the survey area showing sampling locations. Be sure to take photos from several perspectives (i.e., both up and down, as well as along, the beach). For each photo, record the cardinal direction you are facing on the data sheet in the comments field.

* Moulton, L.L., and Penttila, D.E. 2001. Field manual for sampling forage fish spawn in intertidal shore regions. Field Manual, MJM Research and Washington Department of Fish and Wildlife, Lopez Island, WA. PDF available on request from Dayv Lowry at WDFW (dayv.lowry@dfw.wa.gov).

Original protocol by Dan Penttila, WDFW. Reformatted by Dayv Lowry, WDFW.

Forage Fish Spawning Surveys

Page ____ of _____

Reviewed by_________________

Last high tide

Time (24-hr) Elevation

Location Day Month Year

SEE CODES ON BACK OF DATA SHEET

Beach Number	Sample Number	Time (24-hr)	Latitude (decimal degrees)	Longitude (decimal degrees)	Beach	Uplands	Landmark	Sample zone	Tidal elevation	Smelt	Sand lance	Rock sole	Herring	Width	Length	Shading	Comments

Samplers:____

Field Observation Sampling Codes

Beach: Sediment character of the upper beach (particle size range in inches)
0 = mud (<0.0025)
1 = pure sand (0.0025-0.079)
2 = pea gravel (0.079-0.31, “fine gravel”) with sand base
3 = medium gravel (0.31-0.63) with sand base
4 = coarse gravel (0.63-2.5) with sand base
5 = cobble (2.5-10.1) with sand base
7 = boulder (>10.1) with sand base
8 = gravel to boulders without sand base
9 = rock, no habitat

Uplands: Character of the uplands (up to 1,000 ft from high water mark)
1 = natural, 0% impacted (no bulkhead, rip-rap, housing, etc.)
2 = 25% impacted
3 = 50% impacted
4 = 75% impacted
5 = 100% impacted

Landmark: landmark for determining sample zone where collection occurs
1 = down beach from last high tide mark
2 = up beach from last high tide mark
3 = down beach from second to last high tide mark
4 = down beach from upland toe
5 = up beach from waterline at the time noted

Sample Zone: Distance of sample zone transect parallel to the landmark, in feet to the nearest ½ foot. Used to determine the tidal elevation of the spawn deposit.

Tidal Elevation: Determined in the office using location and time data provided.

Smelt, Sand Lance, Rock Sole, Herring: subjective field assessment of spawn intensity apparent to the naked eye:
0 = no eggs visible
1 = very light, sparse
2 = light, but apparent
3 = light medium, visible
4 = medium, readily visible
5 = medium heavy, abundant
6 = heavy, broadly abundant
7 = very heavy, widespread
8 = eggs observed in the winnow

Width: Width of the potential spawning substrate band to the nearest foot. Judged by character of sediment and presence of spawn, when possible.

Length: Length of the beach up to 1,000 feet (500 feet on either side of the station). The value “C” may be assigned if surveyed beach is continuous with other potential sample sites.

Shading: Shading of spawning substrate zone, averaged over the 1,000 foot station and best interpretation for the entire day and season
1 = fully exposed
2 = 25% shaded
3 = 50% shaded
4 = 75% shaded
5 = 100% shaded

Vortex method for separation of forage fish eggs from beach sediment

Addendum to the 2006 revision of
Field Manual for Sampling Forage Fish Spawn in Intertidal Shore Regions

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Washington Department of FISH and WILDLIFE

FPT 18-06

Introduction

Washington Department of Fish and Wildlife (WDFW) biologists have assessed marine shorelines for evidence of forage fish spawning (presence of eggs) since the 1970's. During this time, the biologists have continued to develop effective and efficient protocols for collecting and identifying forage fish eggs from beaches. The purpose of this document is to describe an alternative method for extracting forage fish eggs from beach sediment samples that increases lab efficiency and egg count accuracy.

The sampling protocols developed prior to 2015 are documented in Moulton and Penttila (2006 revision; https://wdfw.wa.gov/publications/01209/wdfw01209.pdf), which described the process from beach site selection and sediment sample collection through condensing bulk sediment samples to laboratory analysis. As described on pages 24 and 25 of the 2006 field manual, the first step in treating the bulk sample is to sieve the sample through progressively finer sieves (4 mm, 2 mm, and 0.5 mm mesh). Only the material collected in the 0.5 mm sieve is retained for further processing. During the *winnowing* process, the condensed sample material is transferred to a square washbasin where it is covered with a thin layer of water and agitated to suspend and concentrate the lighter material, including eggs above the heavier material. This top layer of lighter material is collected and retained for laboratory analysis (examination of material by microscope) to identify and count the eggs.

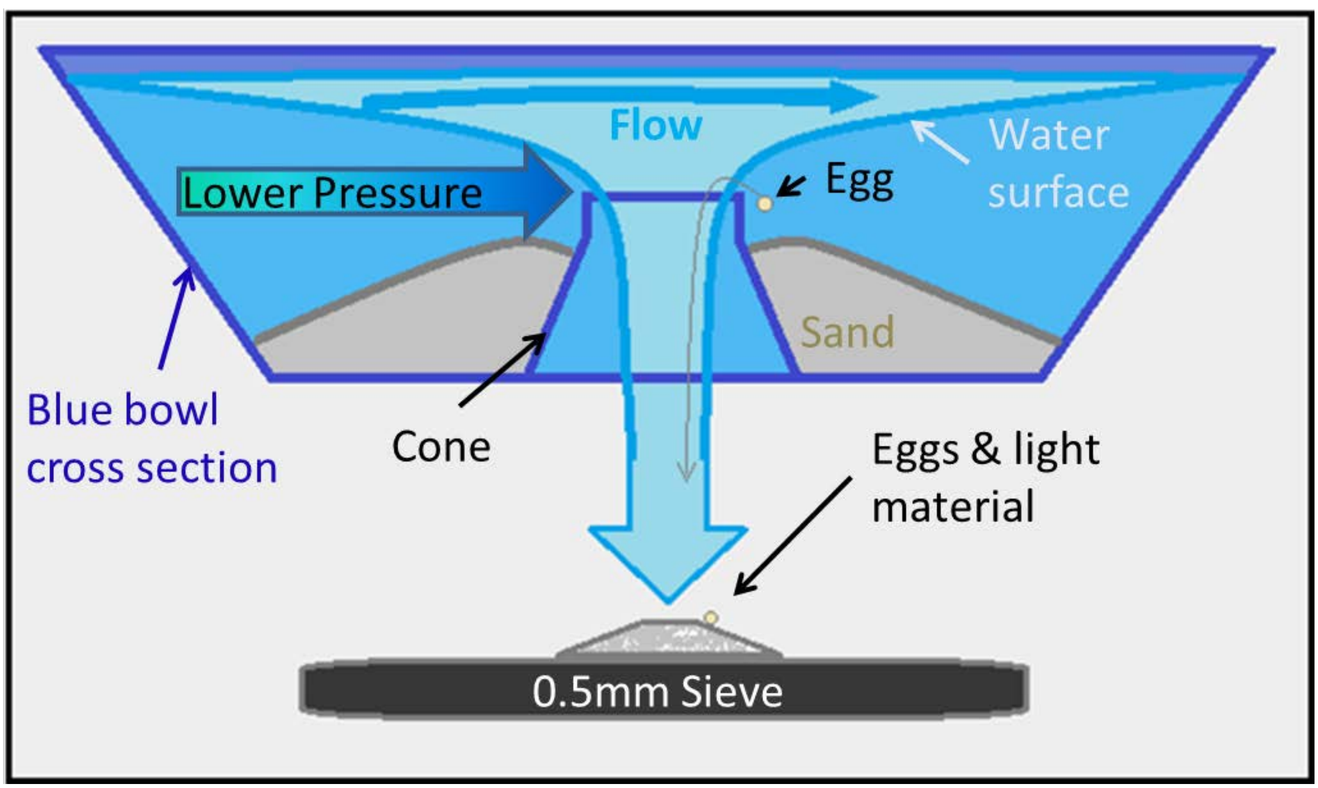
An alternative to the *winnow* method, the *vortex* method, was developed for condensing bulk samples to concentrate eggs. The *vortex* method, like *winnowing*, also follows sieving. The condensed material collected in the 0.5 mm sieve is added to a hydrocyclone device consisting of a circular bowl and a recirculating electric water pump to create a vortex that concentrates the light material. Thus, this step replaces the agitation process described in the 2006 field manual. The *vortex* method resulted in less material to be sorted through in the lab for egg identification. We intend the *vortex* method to be used in place of the *winnowing* method.

We compared the two condensing methods, *winnow* and *vortex*, and found the *vortex* method has a higher egg recovery rate than the winnow method (average smelt egg recovery rates, *winnow* method: 59%, *vortex* method: 90%) and results in a smaller volume of material to process in the lab. In light of these improvements in efficiency, we recommend the *vortex* method for condensing bulk samples after sieving. However, before any modifications are made to your sampling program, be advised that careful consideration should be given to potential impacts to results and whether results from the two methods are directly comparable. Please consult with WDFW staff if you would like to discuss compatibility with WDFW data standards.

This document contains a description of the process and system that we have designed and tested. Modifications to the process or system we describe below may alter the efficiency of the system and consequently lead to results that are not comparable with our results. Those who intend to utilize the *vortex* method should obtain training prior to implementation. Biologists using these methods for regulatory surveys must complete the WDFW training. Additional information and resources for training are provided on page 11 of this document.

How it works

- The movement of the water through the bowl creates a vortex resulting in a pressure gradient.
- The material in the water moves from higher pressure at the edge to lower pressure in the middle of the bowl.
- Less dense materials, such as eggs, move towards the center faster than more dense materials.
- The raised cone in the middle of the bowl reduces the amount of sand and other dense material that leaves the bowl.
- The water leaving the blue bowl passes through a 0.5 mm sieve before being returned to the water reservoir.
- The sieve collects only the material that is egg size or greater.



Materials

For more detail, a list of URLs for parts is included on page 12 of this document.

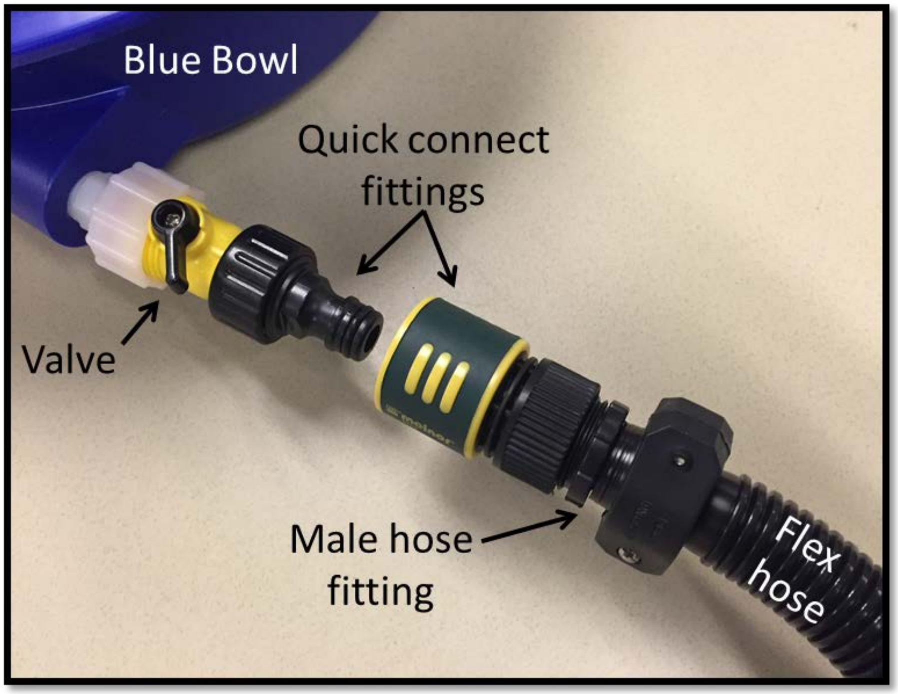
One 18 gallon tote with lid
One blue bowl gold concentrator
One 750 to 1000 gph submersible electric water pump
One, two foot length of ¾” flex hose
One, ¾” hose clamp
One, ¾” male thread hose end kit
One adjustable hose valve
One quick connect hose fittings kit with female thread
One, 0.5 mm sieve (this can be the same sieve used to sieve the bulk sample)
Three shims
One, 250 to 1000 ml wash bottle
One rubber spatula
One plastic spoon
One large pipette or turkey baster
Sample jars

Tools for assembly:
Screw driver
Metric ruler
Permanent marker
Box cutter

Optional: The unit can be configured with a bilge pump and 12 volt battery to allow for use at locations where electricity is not available.

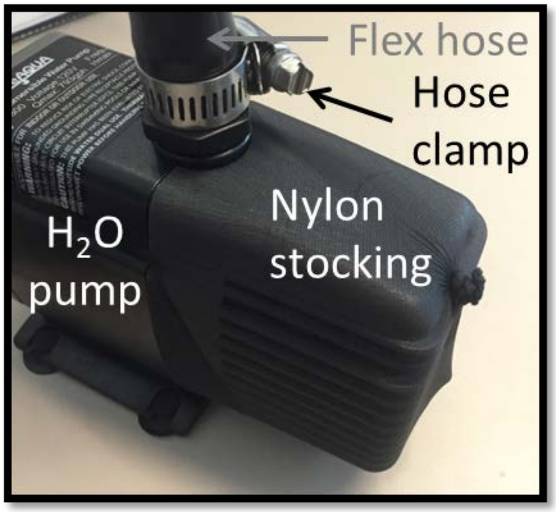
Assembly

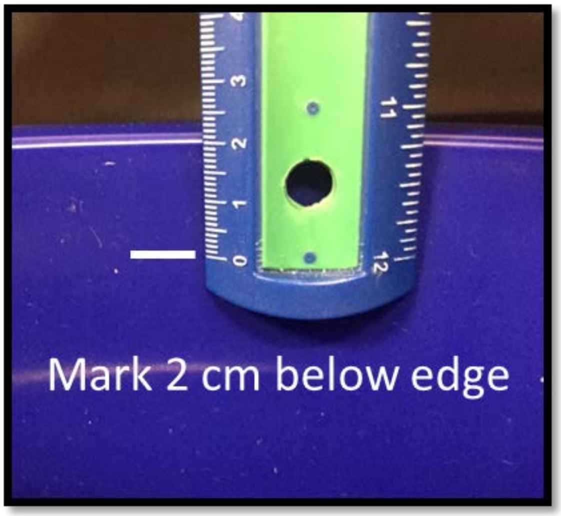
1. First assemble the pump with the flex hose, hose clamp, male hose end, adjustable valve and one side of the quick connect hose fitting. Attach the other side of the quick connect hose fitting to the blue bowl.



2. Use a nylon stocking or pantyhose to stretch over the water intake of the pump to act as a filter and ensure that any eggs that may inadvertently fall into the water reservoir are not passed though the pump to other samples.

3. Use a ruler and a permanent marker to make a mark 2 cm below the inner edge of the blue bowl at several locations around the bowl.

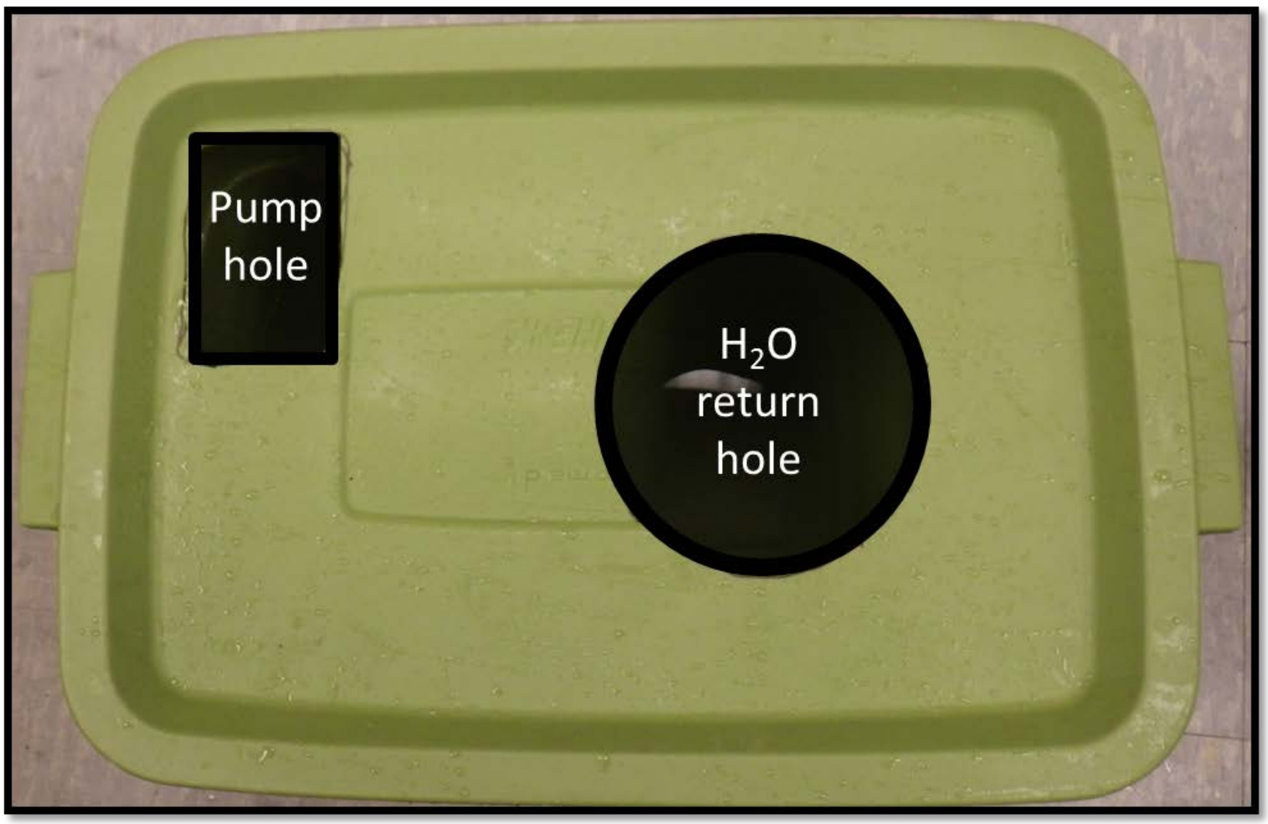




Assembly

4. Next, modify the tote lid by cutting two holes; one for the pump and one for water to return after passing through the blue bowl and the sieve.

> The pump hole should be large enough for the pump to pass through and should be located so that the flex hose can be easily connected to the blue bowl without kinking.
>
> The water return hole should be smaller than the outer diameter of your sieve so that the sieve can rest on the lid without falling through the hole. Sieves are generally 8” to 12” in diameter.



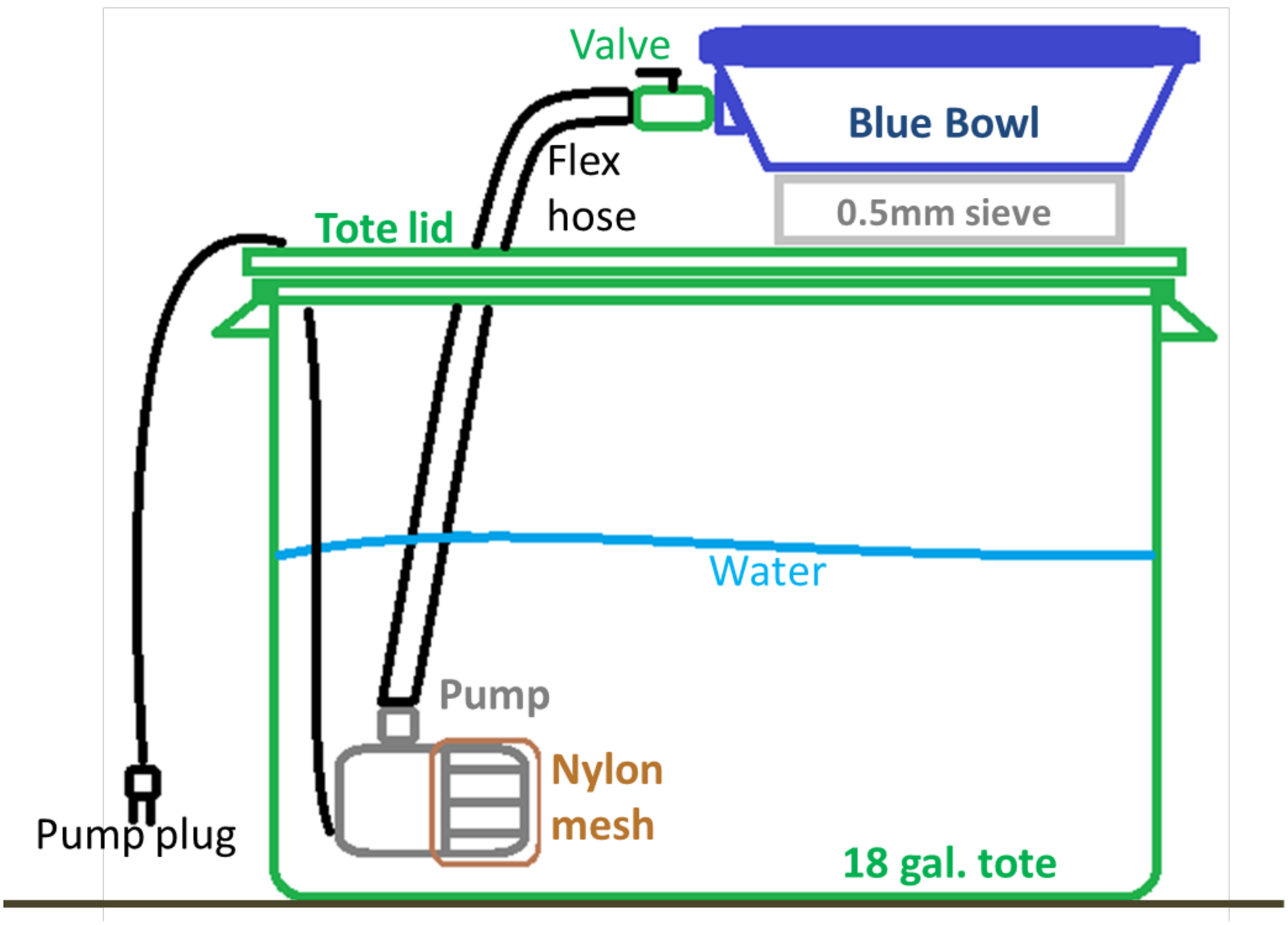
Set up

1. Remove any equipment stored within the tote and place the tote on a relatively level surface.

2. Add enough water to the tote so that the pump will be covered by several inches of water when connected.

3. Attach the tote lid, place the 0.5 mm sieve over the water return hole, place the blue bowl on top of the sieve, and connect the pump to the bowl.

4. Add water to the bowl to aid in determining if it is near level. Use the shims to level the bowl if needed by placing them under the edge of the sieve.



Sample processing

Note: Before each sample is processed, the blue bowl and sieve should be rinsed and the pump should be run briefly with the valve open while disconnected from the blue bowl to avoid any possible cross contamination between samples.

Once your vortex unit is setup and the bulk sample has been sieved to retain the sediment in the 0.5 mm sieve, you are ready to run the sample through the vortex.

1. Open the valve about ½ way and turn on the power to the pump.

    The pump should not be left on with the valve closed as the hose may rupture.

2. Use the valve to adjust the flow as needed to ensure that water is not overflowing the outer edge of the blue bowl. A vortex will form draining through the center of the bowl.

3. Add up to about 60 oz. of the sieved sediment to the bowl. The rubber spatula and wash bottle may be used to help add the sediment to the bowl.

    If you have more sediment you may need to divide the sample and repeat the process.

4. Once the sediment has been added, open the valve all the way, or until the water is about 1 to 2 cm from the edge of the bowl. You should aim to keep the water level within about 2 cm of the edge of the bowl for steps 5 and 6 of the sampling process.

    It is common for the water level to drop after you add sediment due to the decreased water velocity caused by the rough surface of the sediment, so be prepared to adjust the valve.

Sample processing

5. Using a sturdy plastic spoon or the spatula, stir the sediment from the middle to the edge of the bowl by sliding the spoon down the edge of the cone, across the bottom of the bowl, then up the side.

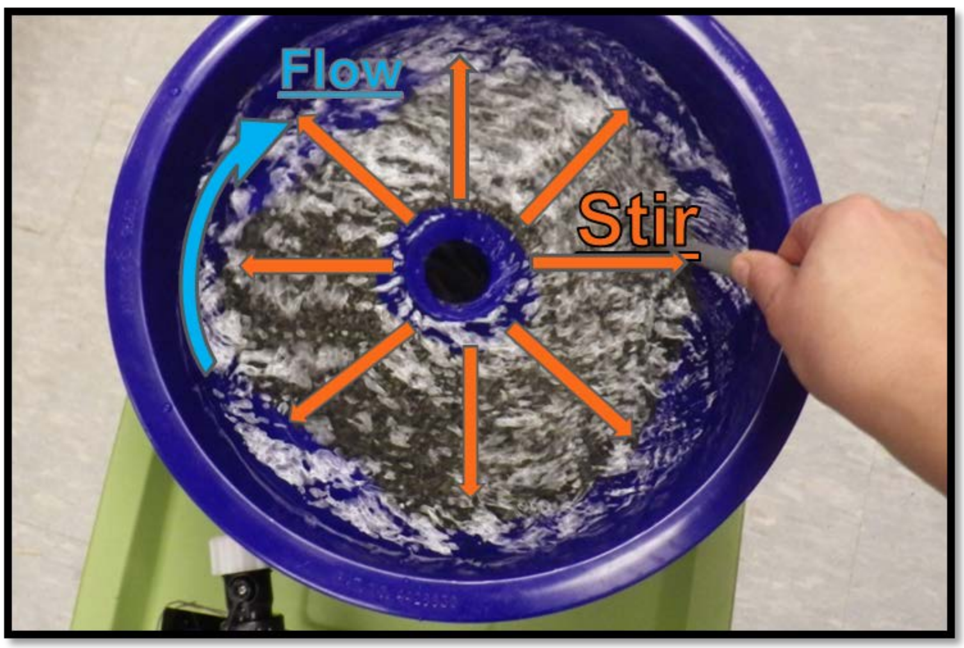
    A plastics spoon is preferred over metal because it will not scratch the surface of the bowl. Scratches may affect the flow of water and may create areas where sediment or eggs could be trapped.

    Move around the perimeter of the bowl as you stir while paying special attention to areas where the sediment has piled up or accumulated around the cone. This will help suspend eggs and ensure that they aren't being buried under the sand.

6. Stir for 1 to 3 minutes, and then allow the bowl to run undisturbed for about 10 seconds before turning off the pump and closing the valve.

    It is important to close the valve quickly after turning off the pump to avoid material being sucked back into the hose.

7. Once the water has settled, examine the sediment in the area immediately around the cone for eggs. If eggs are observed, skim them off with a spoon, or suck them up with a pipette or turkey baster and add them to the sample jar.



Sample processing

8. Remove the blue bowl from the sieve and with the aid of a wash bottle, rinse the material captured by the sieve into a sample jar.

9. Once the material from the sieve is in the sample jar, strain off as much water as possible (being careful not to lose eggs), cover the sample material with preservative and insert the appropriate sample label before securing the lid to the sample jar.

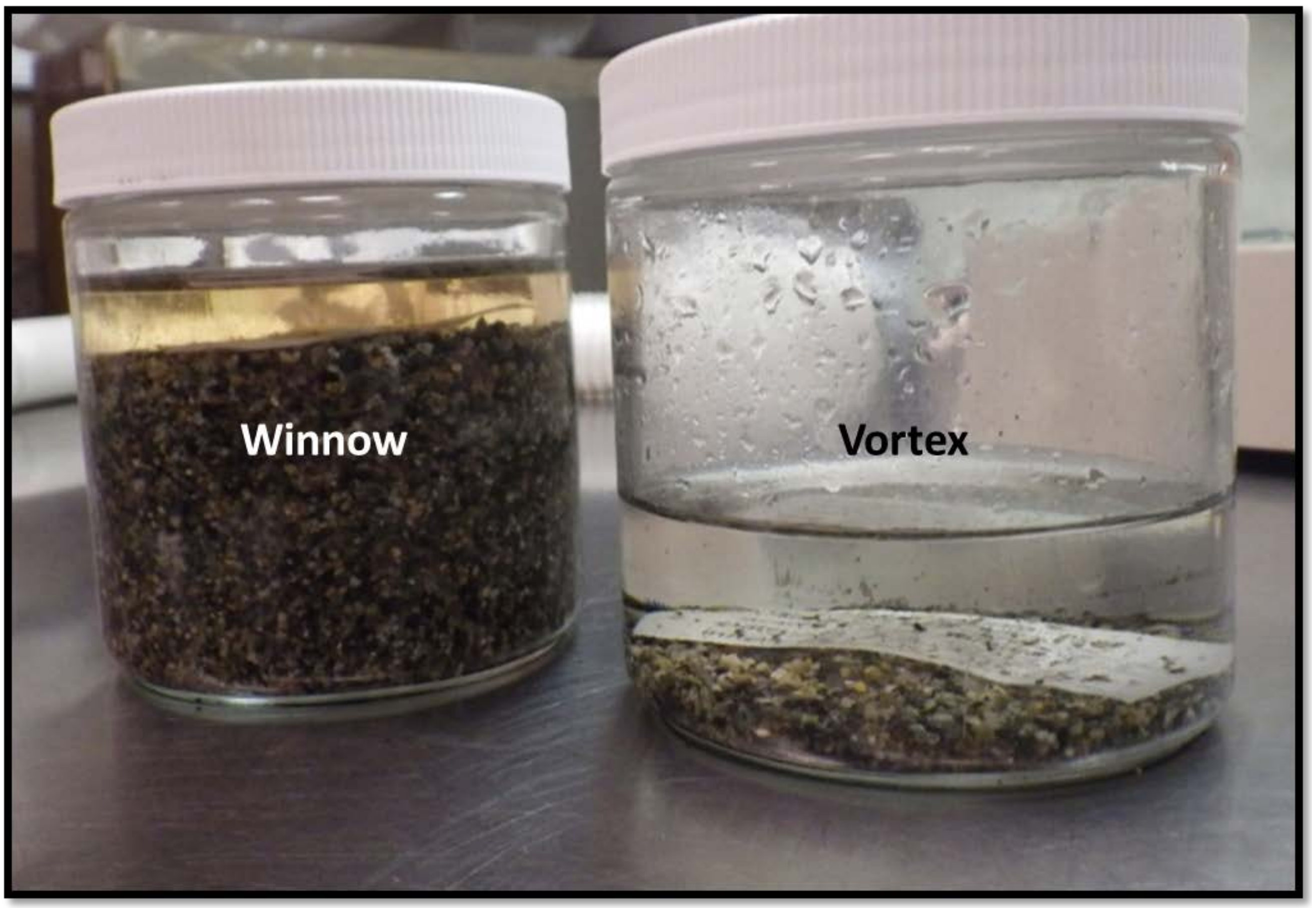
   The sample is now ready for lab processing.

Notes for lab processing

The laboratory procedures described in the field manual by Moulton and Penttila (2006) describe the process of further winnowing and reducing the sample prior to analysis with a dissecting microscope.

We have found that the volume of material retained after processing with the vortex method is typically so small that no additional winnowing or reduction is necessary. Instead, the entire preserved sample can generally be inspected for eggs in a standard 10 cm petri dish in just two or three batches.

For samples with a high volume of material in the condensed sample, it may be appropriate to apply the additional condensing process described in the field manual laboratory procedures.



Additional Resources

For training, consultation, or more information about WDFW forage fish studies, please contact Phillip Dionne at: *Phillip.Dionne@dfw.wa.gov; 360-902-2641*

Sampling protocols, identification guides, maps and other materials are available online at: *wdfw.wa.gov/conservation/research/projects/marine_beach_spawning/*

Field Manual: (https://wdfw.wa.gov/publications/01209/wdfw01209.pdf)
Moulton, L., and D. E. Penttila. "San Juan County forage fish assessment project: Field Manual for sampling forage fish spawn in intertidal shore regions"; First Edition; March 2001 (revised 2006) *San Juan County Marine Resource Committee and Northwest Straits Commission, La Conner, WA.* (2006).

Acknowledgments: Special thanks Ned Pittman for assembling the first prototype for the vortex method, to Kira Kranzler for photos and organizing methods testing, and to Dan Penttila, Shannon Miller, and the numerous Washington Conservation Corps interns for participating in the methods testing.

Parts vendors

The use of product brand names, images, vendor names and web addresses for the sources or descriptions of materials are included for convenience to aid in the identification of the materials used by WDFW in the development of these methods and do not represent an endorsement of the vendor or the product by the WDFW or its staff. Alternate products and/or vendors are likely available. We apologize for out of date or inactive links.

18 gallon tote: https://www.homedepot.com/p/18-Gal-Roughneck-Tote-RMRT180001/302148847

Blue bowl (includes hose valve): http://www.blackcatmining.com/mining-equipment/blue-bowl.cfm

750 – 1000 gph water pump: http://www.ebay.com/itm/Active-Aqua-Submersible-Water-Pumps-Aquarium-Reservoir-Fountain-Pond-Hydroponics-/111476699981

¾” flex hose: http://www.blackcatmining.com/mining-equipment/flex-hose.cfm

¾” quick–connect hose connection (with or without valve): http://www.amazon.com/Gilmour-2939Q-Premium-Complete-Quick-Connect/dp/B000E1AHVW

¾" male thread hose repair kit: http://www.tacomascrew.com/Products/Couplers-Connectors/Gilmour-01M-Garden-Hose-Repair-Ends?CAWELAID=120168600000024660&CAGPSPN=pla&catargetid=120168600000026509&cadevice=c&gclid=CKD8kczP6sYCFZJgfgod9PMKiw

0.5 mm sieve: https://www.fishersci.com/shop/products/fisherbrand-u-s-standard-stainless-steel-sieves-8-in-dia-2-in-d/0488110q
A 1/50 inch fine mesh sieve is an alternative: http://www.goldfeverprospecting.com/keclsc.html

Shims: http://www.homedepot.com/p/Unbranded-8-in-Composite-Shim-Bundle-of-12-SHM1-12-TW/202807695

Rubber spatula: http://www.amazon.com/Farberware-Color-Silicone-Spoon-Spatula/dp/B005GT01KE

APPENDIX B: SPECIES LISTS

1. **Plant species**
2. **Terrestrial invertebrates**

Plant Species recorded in 2020 surveys at Tahlequah

Species	Common	Native	Nonnative	Pre-restoration	Armored	Natural
Grindelia integrifolia	Pacific gumweed	1	0	1		
Salicornia virginica	Pickleweed	1	0	1		
Rubus armeniacus	Himalayan blackberry	0	1	1	1	1
Taraxacum officianale	common dandelion	0	1	1		
Danthonia californica	oatgrass	1	0	1		
Rumex occidentalis (aquaticus)	Western dock	1	0	1		
Cytisus scoparius	scotch broom		1	1		
Tanacetum vulgare	Common tansy		1	1		
Bromus carinatus	California brome	1	0	1		
Prunus sp.	Prunus domestic		1	1		
Vicia americana	American vetch	1	0	1		1
Vicia sp.	Vetch 2			1		
Hypochaeris radicata	Cat's ear		1	1		
Trifolium pretense	red clover		1	1		
Hedera helix	Ivy		1	1	1	
VInca minor	Vinca		1	1		
Plantago lanceolata	narrow-leaved plantain		1	1		
Atriplex prostata	Saltbush orache	1		1		
Salix scouleriana	Scouler's willow	1		1		1
Sonchus asper	sow thistle		1	1		
Geranium sp.	Geranium sp			1		
Distichlis spicata	Saltgrass	1		1		
Toxicodendron diversilobum	poison oak	1		1		
Gaultheria shallon	salal	1		1		
Arbutus menziesii	madrone	1		1	1	1
Lonicera ciliosa	honeysuckle	1		1		
Equisetum arvensis	horsetail	1		1		1
Holcus lanatus	velvetgrass	0	1	1		
Iris pseudacorus	Flag iris		1	1		
Buddleja davidii	Butterfly bush		1	1		
Oenanthe sarmentosa	water parsley	1		1		
Chenopodium album	lamb's ear		1	1		
Cypressia	Cypress sp		1		1	
Ficus sp.	Fig		1		1	
Camellia sp.	Cameillia		1		1	
Cortaderia selloana	pampas grass		1		1	
Rosa sp.	Rose		1		1	
Laurus nobilis	Bay laurel		1		1	
Pseudotsuga menziesii	Douglas fir	1			1	
Allium schoenoprasum	chives		1		1	
Sedum sp.	sedum		1		1	
Acer macrophylla	bigleaf maple	1				1
Populus sp.	Popular		1			1

Terrestrial invertebrate taxa list for 2020 surveys

Strata	Taxa	Family	Order	Density/m2
armored	Sciaridae	Sciaridae	Diptera	10
armored	Thripidae	Thripidae	Thysanoptera	20
armored	Isotomidae	Isotomidae	Collembola	10
armored	Aphididae (winged)	Aphididae	Hemiptera	10
armored	Chironomidae	Chironomidae	Diptera	30
armored	Cecidomyiidae	Cecidomyiidae	Diptera	10
armored	Platygastridae	Platygastridae	Hymenoptera	10
armored	Coccoidea	Coccoidea	Hemiptera	10
armored	Cecidomyiidae	Cecidomyiidae	Diptera	10
armored	Ceratopogonidae	Ceratopogonidae	Diptera	10
armored	Araneae	Araneae	Araneae	10
armored	Sciaridae	Sciaridae	Diptera	20
armored	Thripidae	Thripidae	Thysanoptera	20
armored	Phoridae	Phoridae	Diptera	20
armored	Ptilidae	Ptilidae	Coleoptera	10
armored	Entomobryiidae	Entomobryiidae	Collembola	10
armored	Acari	Acari	Acari	40
armored	Hemiptera	Hemiptera	Hemiptera	10
armored	Mymaridae	Mymaridae	Hymenoptera	10
armored	Platygastridae	Platygastridae	Hymenoptera	10
armored	Phoridae	Phoridae	Diptera	10
armored	Chironomidae	Chironomidae	Diptera	10
armored	Thripidae	Thripidae	Thysanoptera	10
armored	Psocoptera (wingless)	Psocoptera (wingless)	Psocoptera	10
armored	Brachycera	Brachycera	Diptera	50
armored	Cecidomyiidae	Cecidomyiidae	Diptera	10
armored	Isotomidae	Isotomidae	Collembola	10
armored	Araneae	Araneae	Araneae	10
armored	Thripidae (winged)	Thripidae	Thysanoptera	20
armored	Formicidae	Formicidae	Hymenoptera	10
armored	Sminthuridae	Sminthuridae	Collembola	10
armored	Acari	Acari	Acari	40
armored	Chironomidae	Chironomidae	Diptera	10
armored	Psocoptera (wingless)	Psocoptera (wingless)	Psocoptera	10
armored	Entomobryiidae	Entomobryiidae	Collembola	10
armored	Aphididae (wingless)	Aphididae	Hemiptera	30
armored	Psocoptera	Psocoptera	Psocoptera	10
armored	Aphididae (winged)	Aphididae	Hemiptera	10
armored	Sciaridae	Sciaridae	Diptera	10
armored	Ceratopogonidae	Ceratopogonidae	Diptera	10
natural	Entomobryiidae	Entomobryiidae	Collembola	140
natural	Sciaridae	Sciaridae	Diptera	40
natural	Cecidomyiidae	Cecidomyiidae	Diptera	20
natural	Aphididae (wingless)	Aphididae	Hemiptera	10
natural	Brachycera	Brachycera	Diptera	10

natural	Ptilidae	Ptilidae	Coleoptera	10
natural	Araneae	Araneae	Araneae	20
natural	Acari	Acari	Acari	110
natural	Ceraphronidae	Ceraphronidae	Hymenoptera	10
natural	Thysanoptera	Thysanoptera	Thysanoptera	10
natural	Entomobryiidae	Entomobryiidae	Collembola	150
natural	Sminthuridae	Sminthuridae	Collembola	20
natural	Sciaridae	Sciaridae	Diptera	20
natural	Psocomorpha (winged)	Psocomorpha	Psocomorpha	10
natural	Cecidomyiidae	Cecidomyiidae	Diptera	30
natural	Araneae	Araneae	Araneae	10
natural	Acari	Acari	Acari	60
natural	Aphididae (winged)	Aphididae	Hemiptera	10
natural	Braconidae	Braconidae	Hymenoptera	10
natural	Psocoptera (wingless)	Psocoptera (wingless)	Psocoptera	10
natural	Megalorchestia sp	Talitridae	Amphipoda	30
natural	Cecidomyiidae	Cecidomyiidae	Diptera	70
natural	Chironomidae	Chironomidae	Diptera	40
natural	Entomobryiidae	Entomobryiidae	Collembola	70
natural	Acari	Acari	Acari	180
natural	Traskorchestia sp	Talitridae	Amphipoda	40
natural	Sciaridae	Sciaridae	Diptera	20
natural	Araneae	Araneae	Araneae	10
natural	Latridiidae	Latridiidae	Coleoptera	10
natural	Isotomidae	Isotomidae	Collembola	20
natural	Cecidomyiidae	Cecidomyiidae	Diptera	10
natural	Aphididae (winged)	Aphididae	Hemiptera	10
natural	Ceraphronidae	Ceraphronidae	Hymenoptera	10
natural	Cicadellidae	Cicadellidae	Hemiptera	10
natural	Oniscidea	Oniscidea	Isopoda	10
natural	Baeus sp	Platygastridae	Hymenoptera	10
natural	Thripidae (winged)	Thripidae	Thysanoptera	10
natural	Mymaridae	Mymaridae	Hymenoptera	10
natural	Phoridae	Phoridae	Diptera	30
natural	Entomobryiidae	Entomobryiidae	Collembola	30
natural	Hypogastruridae	Hypogastruridae	Collembola	20
natural	Phlaeothripidae	Phlaeothripidae	Thysanoptera	20
natural	Acari	Acari	Acari	30
natural	Isotomidae	Isotomidae	Collembola	30
natural	Formicidae	Formicidae	Hymenoptera	10
natural	Amphipoda	Amphipoda	Amphipoda	10
natural	Acari	Acari	Acari	20
natural	Sminthuridae	Sminthuridae	Collembola	10
natural	Coccoidea (wingless)	Coccoidea (wingless)	Hemiptera	10
pre-restoration	Acari	Acari	Acari	70
pre-restoration	Chironomidae	Chironomidae	Diptera	30
pre-restoration	Isotomidae	Isotomidae	Collembola	10
pre-restoration	Aphididae (winged)	Aphididae	Hemiptera	10

pre-restoration	Araneae	Araneae	Araneae	10
pre-restoration	Ichneumonidae	Ichneumonidae	Hymenoptera	30
pre-restoration	Thripidae (winged)	Thripidae	Thysanoptera	40
pre-restoration	Thysanoptera	Thysanoptera	Thysanoptera	10
pre-restoration	Aphididae (winged)	Aphididae	Hemiptera	10
pre-restoration	Cicadellidae	Cicadellidae	Hemiptera	20
pre-restoration	acari	Acari	Acari	10
pre-restoration	Chironomidae	Chironomidae	Diptera	10
pre-restoration	Psocoptera	Psocoptera	Psocoptera	10
pre-restoration	Phoridae	Phoridae	Diptera	10
pre-restoration	Thripidae	Thripidae	Thysanoptera	20
pre-restoration	Phoridae	Phoridae	Diptera	50
pre-restoration	Hemiptera	Hemiptera	Hemiptera	10
pre-restoration	Thripidae	Thripidae	Thysanoptera	20
pre-restoration	Thripidae	Thripidae	Thysanoptera	10
pre-restoration	Isotomidae	Isotomidae	Collembola	10
pre-restoration	Cecidomyiidae	Cecidomyiidae	Diptera	10
pre-restoration	Mymaridae	Mymaridae	Hymenoptera	10
pre-restoration	Aphididae (winged)	Aphididae	Hemiptera	10
pre-restoration	Sciaridae	Sciaridae	Diptera	20
pre-restoration	Entomobryiidae	Entomobryiidae	Collembola	10
pre-restoration	Phoridae	Phoridae	Diptera	20
pre-restoration	Chironomidae	Chironomidae	Diptera	20
pre-restoration	Cecidomyiidae	Cecidomyiidae	Diptera	30
pre-restoration	Thripidae (winged)	Thripidae	Thysanoptera	40
pre-restoration	Braconidae	Braconidae	Hymenoptera	20
pre-restoration	Phoridae	Phoridae	Diptera	30
pre-restoration	Aphididae (winged)	Aphididae	Hemiptera	10
pre-restoration	Chironomidae	Chironomidae	Diptera	10
pre-restoration	Thripidae	Thripidae	Thysanoptera	10
pre-restoration	Entomobryiidae	Entomobryiidae	Collembola	10
pre-restoration	Sphaeroceridae	Sphaeroceridae	Diptera	10
pre-restoration	Hydrophilidae	Hydrophilidae	Coleoptera	10