Community-based Freshwater Mussel Surveys

EMSWCD Partners in Conservation Grant #209-7000

Final Project Report from the Xerces Society

Young volunteer surveying at Johnson Creek

Margaritifera falcata, *upper Johnson Creek*

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Abstract

The Xerces Society for Invertebrate Conservation collaborated with Johnson Creek Watershed Council and Friends of Crystal Springs on a pilot project to document freshwater mussel populations in the Johnson Creek watershed in the summer and fall of 2010. JCWC & FoCS recruited volunteers and students to conduct presence/absence mussel surveys in reaches of Johnson Creek and Crystal Springs Creek. Participants documented two native taxa, western pearlshell (*Margaritifera falcata)* and floaters (*Anodonta* sp.), as well as the invasive Asian clam (*Corbicula fluminea*). *Margaritifera falcata* was relatively abundant on upstream reaches of Johnson Creek mainstem but absent from lower Johnson Creek. *Anodonta* were present but sparse in the mid-reaches of Crystal Springs Creek but were absent from the lower reaches to the confluence with Johnson Creek. Few to no juvenile mussels were observed, raising concerns about the status of these populations. Asian clams were present in both streams, with highest densities seen in the mid to lower reaches of Crystal Springs. This project successfully engaged volunteer participants in simple, cost-effective surveys that generated baseline data on mussel species and distribution in the watershed, increased awareness of these threatened species among local residents and stakeholders, and provided resources to enable watershed organizations to begin considering mussel conservation needs in stream management decisions.

Project Background & Summary

Freshwater mussels (superfamily Unionoidea) are the most at-risk group of all animals and plants in the United States. The Nature Conservancy considers 68% of U.S. unionid species at risk, compared to 17% for mammals and 15% for birds (Biggins & Butler 2000). This group is also extremely understudied; the National Strategy for the Conservation of Native Freshwater Mussels (National Native Mussel Conservation Committee 1998) stated that the basic life history, reproductive biology, ecology, and habitat requirements of most mussels are unknown and that this information is critical for successful conservation of freshwater mussels. Freshwater mussel declines have been better studied in eastern North America but have received very little attention in the Pacific Northwest.

Eight species of native freshwater mussel are recognized in western North America, in the genera *Margaritifera*, *Gonidea*, and *Anodonta* (Turgeon *et al*. 1998). The first two genera each contain a single species in the Northwest, *Margaritifera falcata* (western pearlshell) and *Gonidea angulata* (western ridgeshell). Six species of *Anodonta* (floaters) were recognized previously in the Northwest, but recent genetic analysis has revealed taxonomic uncertainties within this group (Mock *et al*. 2004, Chong *et al*. 2008). Pending resolution of species, *Anodonta* are currently divided into clades: clade 1 = *A. californiensis* (California floater) and *A. nuttalliana* (winged floater); clade 2 = *A. oregonensis* (Oregon floater) and *A. kenneryli* (western floater); and clade 3 = *A. beringiana* (Yukon floater). Native Northwest mussels are experiencing population declines due to habitat alteration and destruction, loss of host fish species, and the effects of invasive non-native aquatic species. However, systematic surveys for most species have not been conducted, and more information about mussel distribution and abundance is needed to inform conservation efforts.

Although frequently overlooked, freshwater mussels are vital to the ecology of a healthy stream. The ability of mussels to form dense beds may allow them to dominate the benthic biomass, and they are key players in many ecosystem functions. They provide food for wildlife such as raccoons, muskrats, and river otters, and they help improve habitat conditions for native fish. Mussel filter-feeding activities can reduce turbidity, which favors greater light penetration and makes it easier for fish to locate prey. Mussel burrowing mixes sediments, thereby influencing its physical and chemical properties (McCall *et* *al*. 1986). They also enhance habitat conditions for aquatic macroinvertebrates, which are a vital prey item for fish. Mussel beds form a substrate that can be used as habitat by a variety of macroinvertebrate species, and mussel feeding activities help mobilize nutrients for use by macroinvertebrates. The density of aquatic macroinvertebrates is greater in and around mussel beds, as mussel shells provide a physical habitat for invertebrates and a substrate for growth of the periphyton on which many aquatic invertebrates graze (Vaughn & Spooner 2006, Vaughn *et al*. 2008). Mussel beds also stabilize streambed sediments, which may help protect invertebrates using the beds as habitat during periods of high flow (Strayer *et al*. 2004). Mussels can be excellent biological indicators of stream condition, as they are long-lived (10-100 years, depending on species), relatively stationary, and sensitive to changes in water quality. Long-term changes in resident mussel populations can reflect changes in streams and watersheds.

The health of native mussel and native fish populations is inextricably linked. Mussel larvae (glochidia) have an obligate requirement to attach to fish hosts to develop successfully into juvenile mussels. The movement of fish hosts enables juveniles to re-colonize areas devoid of mussels, extending the distribution of individual species and populating new areas of favorable habitat. Some studies have shown that large populations of mussels improve conditions for salmon reproduction by improving water quality. Decreases in the native fish populations with which native mussels evolved is thought to be one of the causes of freshwater mussel decline; streams where natives have declined or been extirpated may retain relict adult mussel populations, but no juvenile replacements can enter the system. The protection and restoration of native fish and freshwater mussel species is interdependent, and the conservation of either will benefit both.

Freshwater mussels have declined in Multnomah County as in other urbanized areas, and limited surveys have shown that mussel species are lacking from some streams where they likely occurred in the past. However, other surveys have indicated that some mussel species may be able to survive in urbanized streams, which could be an important refuge for these threatened organisms, especially in urban streams undergoing restoration activities. Currently, mussel management efforts are hampered by a lack of understanding of mussel distribution, ecology and behavior. This project worked to address a serious lack of awareness among both the general public as well as area watershed organizations regarding mussel presence in Portland-area streams and to provide monitoring and educational resources and baseline survey data on mussel distribution.

In the course of this project, Xerces worked with The Johnson Creek Watershed Council (JCWC), Friends of Crystal Springs (FoCS), Freshwater Trust, and Clackamas Web Academy to conduct outreach and education about freshwater mussels and to perform visual presence/absence surveys in reaches of Johnson Creek and Crystal Springs Creek. The resources and data generated through this study laid the groundwork to enable watershed organizations to monitor populations of both native and invasive mussel species and to better consider the conservation needs of freshwater mussels in future stream management decisions. All the objectives of this project were met successfully, including:

- Development and implementation of effective outreach materials and a mussel monitoring protocol for volunteer-based freshwater mussel surveys
- Implementation of five mussel outreach and monitoring events with significant positive feedback from volunteer participants
- Increased awareness among local residents and watershed organizations regarding the presence and importance of freshwater mussels in area streams

- Baseline data on the presence, species, abundance, and age classes of native freshwater mussels in reaches of Johnson Creek and Crystal Springs Creek
- Baseline data on the presence and abundance of the non-native invasive Asian clam (*Corbicula fluminea*)
- Increased engagement in freshwater mussel conservation and management among area watershed organizations

Methods

<u>Participant Recruitment</u>
JCWC and FoCS contacted prospective volunteers via phone, e-mail, and letters. Each survey event was directed primarily at adult volunteers but was also accessible to children. Two volunteer-based mussel monitoring events were held with JCWC volunteers, and three events were held with FoCS volunteers. Each event lasted 4-5 hours each and included a presentation on freshwater mussel life history, non-native mussel species, and mussel survey techniques. Volunteers then divided into teams to survey transects in designated stream reaches.

Although outreach to area schools was not planned as part of this project, both Wolftree and Freshwater Trust received information about the surveys through JCWC and contacted Xerces to request educational presentations and guidance during field trips to Johnson Creek. In-class teaching presentations on freshwater mussels were done for two different sections of the Marshall High School BizTech Campus Environmental Education class (via Wolftree). Xerces staff did not accompany these students on subsequent field trips, and the importance of not handling or collecting live mussels in the absence of a Scientific Take Permit was stressed to the teachers and students. Xerces staff also conducted an on-site teaching presentation for a Clackamas Web Academy field trip to Johnson Creek (via Freshwater Trust) and helped guide subsequent informal visual mussel surveys.

<u>Identification of Survey Reaches</u>
JCWC and FoCS identified survey reaches based on the accessibility for volunteers and the ability to obtain site manager and/or landowner permission for access. JCWC also prioritized areas in proximity to reaches where standard aquatic macroinvertebrate monitoring was done in 2009.

<u>Mussel Survey Events</u>
Mussel surveys were conducted in Gresham along two reaches of Johnson Creek and one small perennial tributary (July 31 & August 7, 2010), and in Portland along six reaches of Crystal Spring Creek (September 9, 10, & 17, 2010). Survey reaches were about 0.1 miles each; see Appendix A for transect coordinates and map. Each stream reach was divided into transects, which were flagged, numbered, and the coordinates recorded using a Garmin Dakota 10 GPS unit (NAD83 datum). Surveys were timed to allow monitors to enter the streams at a time when native fish were not breeding or laying eggs to avoid disrupting fish redds. The suitability of survey dates was confirmed by the ODFW North Willamette Watershed District Fish Biologist (Todd Alsbury).

Because current ODFW regulations prohibit handling live mussels without a permit, Xerces staff obtained an Oregon Scientific Taking Permit for Fish and Marine and Freshwater Invertebrates (permit #15404) for this project. All participants were trained in the proper techniques for handling and replacing live mussels unharmed in the stream substrate and operated under the guidance and supervision of the Xerces staff permit holder. Mussel surveys were conducted using standard qualitative (shoreline surveys) and semi-quantitative (visual surveys) methods (Miller & Payne 1993, Strayer & Smith 2003). Presence of freshwater mussels was first assessed by shoreline surveys for middens, piles of empty shells left by predators or by low water events that may indicate the presence of a nearby mussel bed in deeper water. Visual surveys were conducted in-stream to locate mussel beds; these included tactile (hand) searches of the benthos and observation below the surface of the water using a clear-bottomed AquaScope (Figure 1).

Figure 1. *M. falcata* observed through AquaScope viewing device

Photo courtesy of Johnson Creek Watershed Council

Materials and methodology for community-based freshwater mussel surveys were developed by Xerces and tested in this study. Xerces staff spent the morning of each sampling day educating volunteers about freshwater mussels and training them in sampling and identification techniques. Information on invasive species such as zebra mussels, quagga mussels, and Asian clams was also presented.

Participants worked in teams of two to four people. At each transect, multiple aspects of landscape use and stream characteristics were recorded (see Appendix B for data sheet). Participants slowly walked 2-m wide, cross-channel transects placed at 10-20 m intervals along the reach, using AquaScopes to aid visibility. When mussel beds were found in the substrate (Figure 2), they were identified to genus (Nedeau *et al*. 2009), and shell dimensions (length, width, and height) were measured.

In accordance with current ODFW regulations, and because of the threatened status of freshwater mussels in general and the unknown status of mussels in these streams, no live mussels were harmed or taken from the stream. Each mussel was held out of the water only for the duration of measuring and, in some cases, photographing, and then carefully replaced in the proper orientation in the substrate. Shell length was used later to assess age-class distributions (see Results & Discussion). If the non-native invasive Asian clam was present (*Corbicula fluminea*; Figure 3), the number of individuals in the transect was recorded and shell dimensions were also measured.
At the end of each survey event, participants were given a Volunteer Motivation & Knowledge Survey

(Appendix C). This survey was designed to assess participants' level of knowledge about native and invasive freshwater mussels prior to the event and to solicit feedback regarding training and methodology.

Figure 2. *M. falcata* bed in Johnson Creek. Note open position of valves (shells) to allow filter feeding

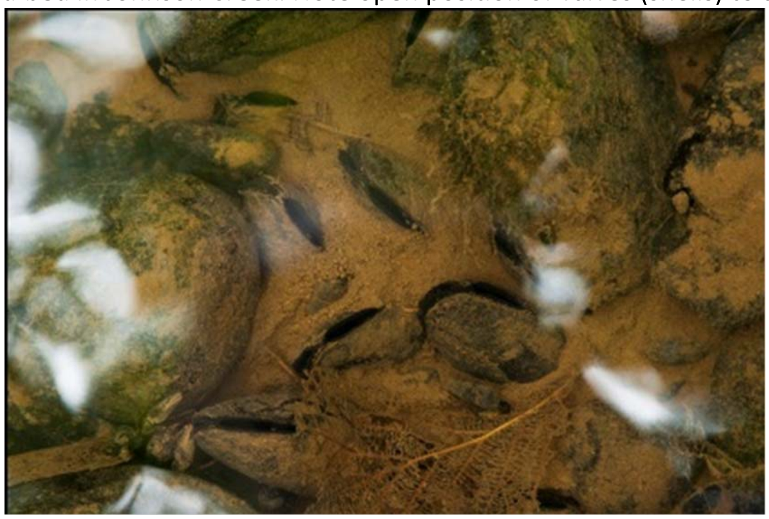


Photo courtesy of Johnson Creek Watershed Council

Figure 3. *Corbicula fluminea*, a non-native invasive freshwater bivalve

Photo by Celeste Mazzacano, Xerces Society

Results

<u>Volunteer Engagement</u>

The level of volunteer engagement exceeded expectations, with 52 adult volunteers and 35 students participating overall. One adult survey event on Johnson Creek also included three children, aged ~8-12 years old, who remained interested and active throughout the event. This suggests that the outreach and training materials developed for this project are effective for adults as well as for children. Many watershed stewardship events are held on weekends when families can participate together, and the accessibility of these surveys to children thus renders them more valuable and appealing as both an outreach and monitoring tool for watershed organizations.

The results of the Volunteer Interest & Motivation Surveys given at the end of each event indicated that the overwhelming majority of participants were completely unaware that native freshwater mussels existed in our streams. The most commonly heard comment at the training sessions was some variation of "I had no idea we even had native mussels." In addition, while most people were familiar with the threat posed to native ecosystems by zebra mussels, they were largely unaware of the presence and impacts of Asian clams in Portland streams. Participants exhibited a remarkably high level of interest, enthusiasm, and engagement in the surveys, and comments regarding the information received, and the understandability, ease, and degree of enjoyment of the surveys were consistently strongly positive.

Mussel Surveys

Johnson Creek

Western pearlshell (*M. falcata*) were abundant at the survey sites in upper Johnson Creek, although absent from the one small tributary surveyed. *M. falcata* were found at five of the six transects surveyed at the reach of Johnson Creek located furthest upstream (SE Bluff Rd.), with a total of 91 live and 25 dead mussels (see Appendix A for maps, transect coordinates and mussel counts). The number of live mussels per bed in each transect ranged from 4 to 29. A single Asian clam was also found in this reach. This reach of the creek was substantially impacted by livestock, as cows appeared to graze in the unfenced riparian zone, cow feces were observed on the stream bank, and a trampled muddy area with visible hoof prints spanned the stream adjacent to one survey transect.

A total of 153 *M. falcata* were found further downstream at the SE Telford site, consisting of 126 live and 27 dead mussels. No Asian clams were seen in this reach. Distribution was patchier in this reach; no mussels were found in four of the 14 transects surveyed, and bed size ranged from one to 57 individuals in transects where *M. falcata* were present. Most of the empty valves (shells) found were scattered intermittently along the shoreline, with the exception of a single small shell midden found at the edge of a small sandbar by the stream bank and surrounded by raccoon footprints. No mussels were found in the small tributary feeding into Johnson Creek at this site.

Staff from JCWC, who helped guide Marshall High School field trips, reported that no *M. falcata* were observed in lower Johnson Creek, but that *Anodonta* were present.

Crystal Springs Creek

Small patches of *Anodonta* were found scattered along Crystal Springs Creek. Reaches from the source to the mouth of the creek were surveyed; survey areas can be roughly grouped into Reed College, Crystal Springs Rhododendron Garden, Crystal Springs golf course, Union Manor, Westmoreland Park, and Johnson Creek Park. Asian clams were widely distributed along Crystal Springs, at densities that increased from the mid-reaches (Westmoreland Park) downstream to the confluence with Johnson Creek.

A single live *Anodonta* was found at Reed College, just upstream of restoration work to convert existing culverts into a bridge (SE 28th Ave.). Multiple discarded shells were found upstream around the edges of Reed Canyon Lake, but no live mussels were found during limited dip-netting around the edges of the lake. Steep banks, thick vegetation, soft sediment, and deep water levels made it impossible to conduct tactile searches in the water. Three *Anodonta* were found in the golf course reach, although this is likely an underestimation, as sampling here was difficult due to the presence of thick floating mats of vegetation. The *Anodonta* here were found at the interface between the bottom edge of the vegetation mat and the water.

Anodonta abundance increased further downstream at Union Manor, where >42 mussels were found. The majority were seen in a deep channel that passes under SE Bybee Road. Many dead *Anodonta* and scattered damaged shells were also observed at this site, suggesting that high flow events may increase water velocity in this area and scour out some mussels.

Four *Anodonta* were found at Westmoreland Park, all in a transect at the north end of the park just before the stream flows into a large constructed pond. The mussels here were not visible on the surface but were found by digging down several inches into the soft substrate at the edge of the channel. No live *Anodonta* were found at downstream transects in the park, although a few remnant valves were seen, but several Asian clams were noted at each transect. Asian clam density was highest at Johnson Creek Park, where Crystal Springs enters Johnson Creek. Asian clams covered the substrate at this site; indeed, their shells appeared to comprise a large proportion of the stream substrate. The only sign of *Anodonta* was a portion of shell found on a rocky sandbar between the two creeks.

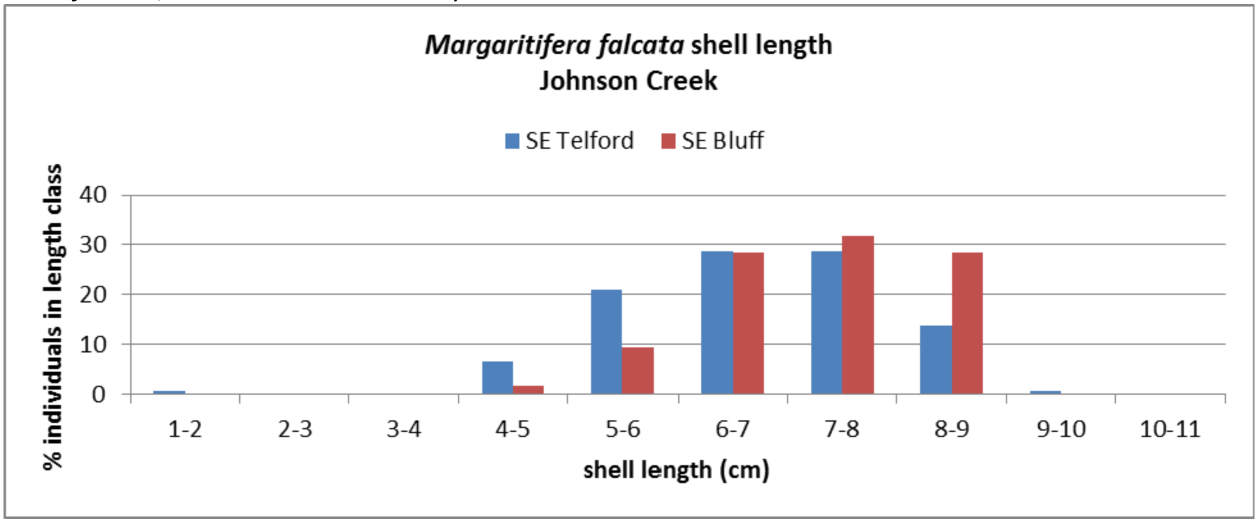
Age Class Distributions

Accurate aging of freshwater mussels requires mounting thin pieces of shell and counting annual growth rings under a microscope (Schöne *et al*. 2004, Black *et al*. 2010). However, an estimation of age class distributions (juvenile vs. mature mussels) can be done based on shell length measurements. The age structure of existing mussel populations provides insight into whether a population is receiving reproductive replacements as opposed to being only a surviving remnant with no juveniles entering the system.

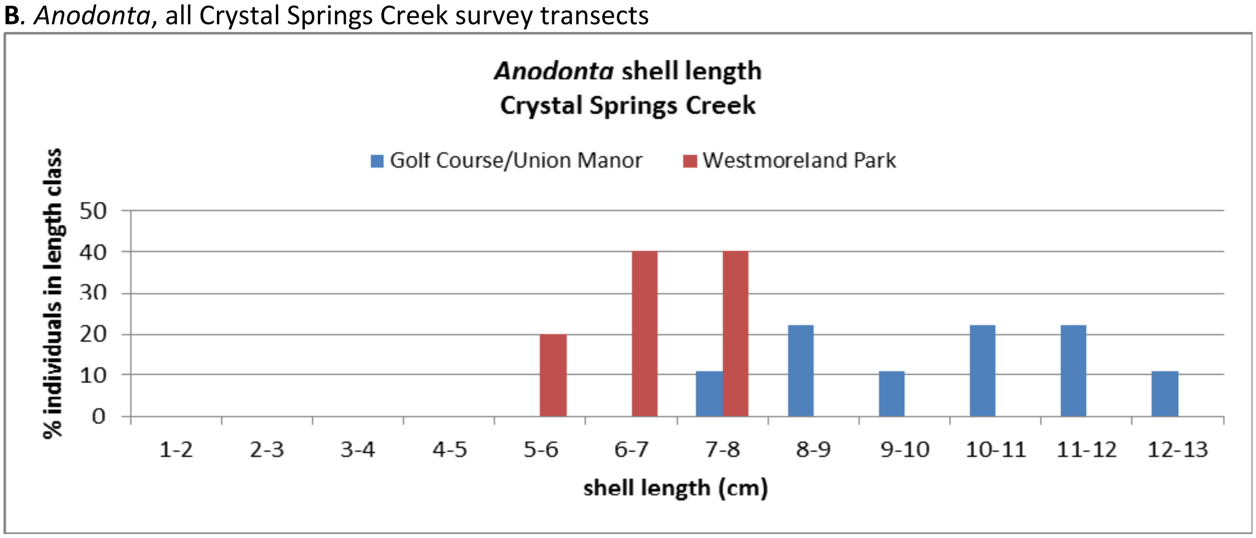
Shell length class distribution was similar among *M. falcata* at sites surveyed on Johnson Creek, with few to no individuals in lowest age classes (Figure 4), indicating that these populations are dominated by mature individuals. In contrast, a more bimodal shell length distribution was observed for *Anodonta* collected in Crystal Springs Creek. The lower shell length classes predominated for *Anodonta* at Westmoreland Park; these length classes were absent at sites further upstream, where larger/older individuals predominated.

Figure 4. Mussel shell length class distributions

A. *M. falcata*, all Johnson Creek survey transects



B. *Anodonta*, all Crystal Springs Creek survey transects



Discussion

The presence of freshwater mussels in at least some portions of the Johnson Creek watershed highlights the potential conservation significance of urbanized waterways for these imperiled and declining natives. Johnson Creek has undergone multiple restoration projects in recent years, but the effects of restoration activities on aquatic invertebrates, especially freshwater mussels, are largely unknown. In addition, the majority of local stakeholders and watershed organizations are unaware of the presence or status of freshwater mussels in area streams, the roles these animals play in stream ecology, and ways to address their conservation needs.

Volunteer Engagement

An educated and motivated public is an important component of watershed protection. Watershed organizations often rely on a volunteer base to assist with stream restoration projects and help with different aspects of chemical or biological monitoring. In turn, these volunteers become more aware of watershed-related issues, are made more educated voters and land managers, and increase the outreach effect by sharing their knowledge with friends and neighbors. Aquatic macroinvertebrate monitoring may be conducted by watershed organization staff and volunteers, but protocols for volunteer-based freshwater mussel sampling have not been developed. This project enabled Xerces to develop and implement a volunteer-based mussel survey protocol and solicit user feedback.

Our results show that a one-hour training session is sufficient to provide volunteers with background information on native and invasive freshwater bivalves and to clearly convey the survey and data-gathering techniques. Volunteer teams worked successfully in the field, with support from Xerces staff to help clarify aspects of the datasheet and confirm mussel identification. Several adult volunteers brought their children (~ 8-12 years old), and the monitoring event proved to be accessible to these younger volunteers, and both children and adults remained engaged in the entire process. Feedback from surveys administered after monitoring was completed was overwhelmingly positive, both regarding their interest and enjoyment in the survey day and the ease of use of the monitoring protocol. In fact, a number of volunteers have enthusiastically inquired as to when they can next help survey for freshwater mussels.

It is encouraging to note that although the majority of volunteers associated with watershed organizations (and the broader public) are completely unaware that freshwater mussels exist in our streams, they have a high level of interest in learning more about these organisms. Several volunteers also indicated that prior to the survey event they were either unaware of the presence of invasive Asian clams in Portland streams or had assumed these were part of the native fauna. Volunteer-based mussel surveys thus serve valuable functions in filling a knowledge gap about an important component of stream fauna, increasing awareness of threats posed by non-native species, generating data that can be used in future management plans, and helping watershed organizations retain and recruit volunteers.

Mussel Surveys: Species & Age Classes

These surveys showed that different species of native freshwater mussels are currently present in Johnson Creek versus Crystal Springs. *Margaritifera falcata* (western pearlshell) were relatively abundant in two upstream reaches of the Johnson Creek mainstem but was absent from all reaches surveyed in Crystal Springs Creek. Small numbers of *Anodonta* (floaters) were present in the mid to lower reaches of Crystal Springs and in the lower reaches of Johnson Creek. The invasive non-native bivalve *Corbicula fluminea* (Asian clam) was found in both streams but was much more abundant in Crystal Springs Creek, especially in the lower reaches where clam shells formed a substantial layer of the substrate.

These results suggest that a mixture of younger and older *M. falcata* are present at the more undisturbed site surveyed along Johnson Creek (SE Telford), although only a very small proportion (0.7%) of the individuals measured were in a length class consistent with juvenile mussels. A site more heavily impacted by human use about two miles upstream (SE Bluff) contains a larger proportion of larger/older individuals and may lack replacement juvenile mussels. A similar situation was seen with *Anodonta* in Crystal Springs, where no mussels in length classes corresponding to small juvenile mussels were found. The mussel population seen at Westmoreland Park appeared to be larger/older than that further upstream at Crystal Springs golf course, but no small juveniles were found in either area. Also, native mussels were lacking overall at the downstream portion of Crystal Springs where invasive Asian clam populations were densest.

The absence of juvenile mussels seen in this project may have multiple causes. One possibility includes under-sampling due to the visual survey techniques used in this project. Very young mussels are buried in the substrate for the first two to four years of life, using their foot to absorb nutrients via pedal-feeding from the sediment rather than being exposed at the surface. Juvenile mussels are thus more likely to be found using a double sampling technique (Smith *et al*. 2001) in which a large number of transects are surveyed using visual counts, and a subset are resurveyed by excavating the substrate to determine the proportion of mussels found at the surface vs. buried. Excavation was not used in the survey methodology in this study, as we wished to avoid negative impacts on the stream substrate, but this also means that surveys were more biased against finding the smallest individuals.

However, native freshwater mussels have a complex life history, several aspects of which may also explain the absence of juvenile mussels at study sites. Fertilized embryos develop in a specialized chamber within the female mussel, and the larval mussels (glochidia) are then expelled into the water. Glochidia can survive in the water for hours to weeks depending on the species and water temperature (Zimmerman & Neves 2001, Ingersoll *et al*. 2006, Akiyama & Iwakuma 2007), but they must attach to a host fish in order to develop further into juvenile mussels (Rogers-Lowery & Dimock 2006, Barnhart *et al*. 2008). Glochidia attach to the gills and fins of host fish and can thus be carried into new regions of a stream or watershed. This is an important dispersal mechanism for an organism whose adult stage is largely sessile. After a period of days to weeks on the host fish, glochidia complete development to juvenile mussels, drop off the host, and settle into the sediment, where they feed and grow rapidly to avoid predation and the crushing and erosive forces of flowing water. It should be noted that while technically parasites, glochidia have not been documented to harm their host fish unless it is carrying excessive numbers of glochidia (i.e. hundreds), which is very rarely observed in nature (Kaiser 2005, Howerth & Keller 2006, Kneeland & Rhymer 2008).

A complete list of host fish has yet to be delineated for our native mussels. *Margaritifera falcata* is thought to use salmon and trout species as hosts, including cutthroat trout, rainbow trout, sockeye salmon, and steelhead, while *Anodonta* may use trout, specked dace, prickly sculpin, and threespine stickleback (Nedeau *et al*. 2010). Glochidia are vulnerable and subject to high mortality; a study on an eastern *Margaritifera* species (*M. margaritifera*) estimated that only one in every million shed glochidia survives to the juvenile stage (Young & Williams 1984). Native fish populations have declined in Johnson Creek as in other parts of the U.S., and the loss of native fish hosts is thought to be a contributing factor to native mussel declines. Johnson Creek watershed may lack good fish host species for native mussels, or the fish hosts may be present but unable to access different reaches successfully due to stream alterations.

Differential sensitivity of glochidia, juvenile mussels, and adult mussels to environmental stressors and contaminants has been demonstrated (Cope *et al*. 2008); this has important implications, as stream conditions may be such that adult mussels can survive while glochidia perish or are unable to establish as juvenile mussels. Temperature plays an important role in the timing of mussel fertilization, glochidia development and expulsion, and attachment and release from host fish. Thermal stress has been shown to cause abortion in some unionid species (Aldridge & McIvor 2003), and increased temperatures may decrease glochidia viability (Zimmerman & Neves 2002). *Margaritifera falcata* is considered one of our most sensitive species of native mussel, unable to tolerate decreased flows, higher water temperatures, increased siltation, and chemical pollution. Johnson Creek is known to be affected by thermal and chemical pollution, and the current and past water quality conditions may be affecting development and survival of glochidia and larval mussels. Crystal Springs Creek has similar stressors, which may be exacerbated as it runs through highly developed regions of Portland and is greatly affected by thermal and chemical pollution due to large pools created at the Rhododendron Garden and Westmoreland Park, which experience tremendous waterfowl visitation. *Anodonta* are considered to be more tolerant of increased siltation and slower flows, but current conditions in Crystal Springs may be preventing establishment of larval mussels.

The presence of the invasive species *Corbicula fluminea* could also have a negative impact on native mussel populations. The Asian clam was introduced into North America in the early 1900s; the first collection from the Columbia River occurred in 1938, and since then it has spread to lakes and streams throughout much of the U. S. (Foster *et al*. 2011). Asian clams have a higher filtration rate than native mussels, are more tolerant of low flows and fine sediments (Vaughn & Spooner 1996), and lack a parasitic glochidial stage of development. These factors allow *Corbicula* populations to grow rapidly to the point where they may dominate the benthic biomass (Hakenkamp & Palmer 1999).

Impacts of Asian clams on native mussels include competing for food, nutrients, and habitat (Neves & Widlak 1987, Leff *et al*. 1990); ingesting sperm, glochidia, and juveniles of native mussels (Strayer 1999, Yeager *et al*. 2000); disturbing sediments and displacing newly settled juvenile mussels (Fuller & Richardson, 1977, Strayer 1999, Yeager et al. 2000); and reducing phytoplankton biomass (Strayer 2010), which affects water chemistry and clarity. Asian clam beds are also subject to sudden die-offs at low stream flows, and the production of ammonia as their bodies decompose may raise concentrations above the tolerance level of native juvenile mussels (Cherry *et al*. 2005). Interestingly, some studies have shown that abundance of native mussels is negatively correlated with Asian clam abundance at small spatial scales (Vaughn & Spooner 2006), and that Asian clams appear to preferentially invade areas where native mussels are declining due to anthropogenic stressors (Strayer 1999). This suggests that watershed management activities that sustain dense native mussel populations may help limit the spread of Asian clam. This could be particularly important for the fate of native mussels in upper Johnson Creek, where Asian clams are present but at much lower densities than was seen in Crystal Springs.

<u>Dissemination & Use of Data</u>

Results of this project were disseminated as a poster at the annual conference of the Urban Ecosystem Research Consortium (January 24, 2011: "Freshwater mussel surveys in Johnson Creek—Volunteer Biological Monitoring") and have been shared with the Johnson Creek Interjurisdictional Council (IJC). The 2002 report *Johnson Creek Restoration Action Plan: An Adaptive Approach* identified knowledge gaps related to fish and macroinvertebrates. Johnson Creek Watershed Council is keenly interested in incorporating data from mussel surveys into their management and restoration plans, and data from this and potential subsequent mussel monitoring projects will be incorporated into their 2012 *State of the Watershed Biota Report*. The IJC has begun to implement monitoring programs for fish and aquatic insects and they recognize that native mussels represent a major gap, which they are eager to address, especially given the strong links between native mussels and native fish and the ongoing efforts to improve stream conditions for native fish. Mussel monitoring is a straightforward, cost-effective activity that can provide information about stream biological health, and JCWC believes there is good potential for these activities to become a valuable addition to area monitoring programs.

JCWC will also make immediate use of mussel distribution data in restoration planning and construction. Stream restoration activities may include periods of dewatering or physical disturbance of the substrate. These activities can result in high morbidity and mortality of native mussels occupying targeted stream reaches. However, with increased knowledge of mussel distribution, mussels can be salvaged and relocated to a different reach of the same stream (Luzier & Miller 2009) prior to initiating restoration activities using.

Conclusions & Next Steps

This project showed that volunteer-based monitoring can be a successful tool for investigating the status and distribution of native and invasive freshwater mussels in urban waterways. Volunteer-based surveys for native freshwater mussels present an excellent opportunity for education and outreach about these important but little-known species and the clues they provide about overall watershed health.

Data generated through such monitoring provides valuable information for watershed organizations. It has been suggested that that watershed-wide surveys to assess populations and consider basin-scale management practices and impacts may be the most efficient approach for positive mussel management (Brown *et al*. 2010). Recommended strategies for *Margaritifera* conservation in Europe include mapping distribution, understanding population demographics and juvenile recruitment rates, assessing local impacts on populations, and determining the impacts of existing management plans (Geist 2010). Using large numbers of volunteers in concentrated survey activities enables watershed organizations to survey more sites and longer reaches than could be accomplished by agency staff alone.

Systematic surveys for native mussels will provide the information about distribution and abundance needed to inform conservation efforts. Locating and characterizing extant mussel populations and obtaining data on their abundance, distribution, and age structure will allow watershed groups and local government agencies to prioritize restoration projects for the benefit of mussels. This will in turn benefit other aquatic macroinvertebrates and the organisms that depend upon them, such as native fish. Area watershed organizations are eager to expand upon the success of this pilot project, and funding is being pursued to address identified next steps, including:

- Expand the project to conduct extensive mussel surveys throughout the Johnson Creek watershed in 2011 and 2012. Mussel distribution is frequently patchy, and additional studies are needed to more thoroughly investigate mussel distribution along Johnson Creek and its tributaries, as well as population age structure at each site.
- Examine mussel distribution in conjunction with planned and implemented restoration projects and in the context of surrounding land uses.
- Work with anadromous fish surveys to examine fish gills for larval mussels (glochidia) as an indication of whether juvenile mussels are entering existing populations.
- Determine whether mussels in the basin are reproductively active, or whether existing populations are relicts of a healthier ecosystem consisting only of aging adults; if so, identify and address factors that may be impacting mussel reproduction and establishment.
- Identify invasive mussel species and document their distribution.

- Link basic habitat information to presence and abundance of native and invasive mussel species.
- Build capacity of JCWC, IJC, and partner organizations so that freshwater mussels are considered in restoration planning and construction.

Literature Cited

Akiyama, Y., and T. Iwakuma. 2007. Survival of glochidial larvae of the freshwater pearl mussel, *Margaritifera laevis* (Bivalvia: Unionoida), at different temperatures: a comparison between two populations with and without recruitment. Zoological Science 24: 890–893.

Aldridge, D.C., and A.L. McIvor. 2003. Gill evacuation and release of glochidia by *Unio pictorum* and *Unio tumidus* (Bivalvia: Unionidae) under thermal and hypoxic stress. Journal of Molluscan Studies 69: 55–59.

Barnhart, M. C., W. R. Haag, and W. N. Roston. 2008. Adaptations to host infection and larval parasitism in Unionoida. Journal of the North American Benthological Society 27: 370-394.

Biggins, R. G. & R. S. Butler, 2000. Bringing mussels back in the southeast. Endangered Species Technical Bulletin 25: 24–27.

Black, B. A., J. B. Dunham, B. W. Blundon, M. F. Raggon, and D. Zima. 2010. Spatial variability in growth-increment chronologies of long-lived freshwater mussels: Implications for climate impacts and reconstructions. Ecoscience 17(3): 240-250.

Brown, K. M., G. George, and W. Daniel. 2010. Urbanization and a threatened freshwater mussel: evidence from landscape scale studies. Hydrobiologia 655: 189-196.

Cherry, D. S., J. L. Scheller, N. L. Cooper & J. R. Bidwell. 2005. Potential effects of Asian clam (*Corbicula fluminea*) die-offs on native freshwater mussels (Unionidae) I: Watercolumn ammonia levels and ammonia toxicity. Journal of the North American Benthological Society 24: 369–380.

Chong J. P., J. C. Brim Box, J. K. Howard, D. Wolf, T. L. Myers, and K. E. Mock. 2008. Three deeply divided lineages of the freshwater mussel genus *Anodonta* in western North America. Conservation Genetics 9(5): 1303-1309.

Cope W. G., R. B. Bringolf, D. B. Buchwalter, T. J. Newton, C. G. Ingersoll, N. Wang, T. Augspurger, F. J. Dwyer, M. C. Barnhart, R. J. Neves, and E. Hammer. 2008. Differential exposure, duration, and sensitivity of unionoidean bivalve life stages to environmental contaminants. Journal of the North American Benthological Society 27(2): 451-462.

A. M. Foster, P. Fuller , A. Benson, S. Constant, and D. Raikow. 2011. *Corbicula fluminea,* USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Available at: http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=92.

Fuller, S. L. H. and J. W. Richardson, 1977. Amensalistic competition between *Corbicula manilensis* (Philippi), the Asiatic clam (Corbiculidae), and freshwater mussels (Unionidae) in the Savannah River of Georgia and South Carolina (Mollusca: Bivalvia). Bulletin of the Association of Southeastern Biologists 24: 52.

Geist, J. 2010. Strategies for the conservation of endangered freshwater pearl mussels (*Margaritifera margaritifera* L.): a synthesis of conservation genetics and ecology. Hydrobiologia 644: 69-88

Hakenkamp C. C. and M. A. Palmer. 1999. Introduced bivalves in freshwater ecosystems: the impact of *Corbicula* on organic matter dynamics in a sandy stream. Oecologia 119(3): 445-451

Howerth, E. W., and A. E. Keller. 2006. Experimentally induced glochidiosis in smallmouth bass (*Micropterus dolomieu*). Veterinary Pathology 43: 1004–1007.

Ingersoll, C. G., N. J. Kernaghan, T. S. Gross, C. D. Bishop, N. Wang, and A. Roberts. 2006. Laboratory toxicity testing with freshwater mussels. *In*: J. L. Farris and J. H. van Hassel (eds.), Freshwater bivalve ecotoxicology. Society of Environmental Toxicology and Chemistry, Pensacola, Florida, pp. 95–134.

Kaiser, B. E. 2005. The effects of glochidiosis on fish respiration. MSc Thesis, Missouri State University, Springfield, Missouri.

Kneeland, S. C., and J. M. Rhymer. 2008. Determination of fish host use by wild populations of rare freshwater mussels using a molecular identification key to identify glochidia. Journal of the North American Benthological Society 27: 150–160.

Leff, L. G., J. L. Burch, and J. V. McArthur. 1990. Spatial distribution, seston removal, and potential competitive interactions of the bivalves *Corbicula fluminea* and *Elliptio complanata*, in a coastal plain stream. Freshwater Biology 24: 409-416.

Luzier, C. and S. Miller. 2009. Freshwater mussel relocation guidelines. Pacific Northwest Freshwater Mussel Workgroup, 7 pp.

McCall, P. L., G. Matisoff, and M. J. S. Tevesz. 1986. The effects of a unionid bivalve on the physical, chemical, and microbial properties of cohesive sediments from Lake Erie. American Journal of Science 286: 127–159.

Miller, A. C. & Payne, B.S. 1993. Qualitative versus quantitative sampling to evaluate population and community characteristics at a large-river mussel bed. American Midland Naturalist, 130(1): 133-45.

Mock, K.E., J.C. Brim-Box, M.P. Miller, M.E. Downing, and W.R. Hoeh. 2004. Genetic diversity and divergence among freshwater mussel (Anodonta) populations in the Bonneville Basin of Utah. Molecular Ecology 13: 1085–1098.

National Native Mussel Conservation Committee. 1998. Journal of Shellfish Research 17(5): 1419-1428.

Nedeau, E., Smith, A. K., & Stone, J., and Jepson, S., 2009. Freshwater mussels of the Pacific Northwest, 2nd ed. Pacific Northwest Native Freshwater Mussel Group, Vancouver WA, 51 pp.

Neves, R. J. and J. C. Widlak. 1987. Habitat ecology of juvenile freshwater mussels (Bivalvia: Unionidae) in a headwater stream in Virginia. American Malacological Union Bulletin 5(1): 1-7.

Parmalee, P. W. and A. E. Bogan. 1998. The freshwater mussels of Tennessee. University of Tennessee Press, Knoxville, Tennessee.

Rogers-Lowery, C. L., and R. V. Dimock. 2006. Encapsulation of attached ectoparasitic glochidia larvae of freshwater mussels by epithelial tissue on fins of naive and resistant host fish. Biological Bulletin 210: 51–63.

Schöne, B. R., E. Dunca, H. Mutvei & U. Norlund. 2004. A 217-year record of summer air temperature reconstructed from freshwater pearl mussels (*M. margaritifera*, Sweden). Quaternary Science Reviews, 23: 1803–1816.

Smith, D. R., R. F. Villella, D. P. Lemarie, and S. Von Oettingen. 2001. How much excavation is needed to monitor freshwater mussels? *In*: P. D. Johnson & R. S. Butler (eds.) Proceedings of the first symposium of the Freshwater Mollusk Conservation Society. Ohio Biological Survey, Columbus OH.

Spooner, D. E., and C. C. Vaughn. 2006. Context-dependent effects of freshwater mussels on the benthic community. Freshwater Biology 51: 1016–1024, corrigendum 1188.

Strayer, D. L., 1999. Effects of alien species on freshwater mollusks in North America. Journal of the North American Benthological Society 18: 74–98.

Strayer, D. L. & Smith, D. R. 2003. A guide to sampling freshwater mussel populations. American Fisheries Society Monograph 8: 1-103.

Strayer, D. L., J. A. Downing, W. R. Haag, T. L. King, J. B. Layzer, T. J. Newton, and S. Nichols. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. BioScience 54: 429–439.

Strayer D. L. 2010. Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. Freshwater Biology 55 (Suppl. 1): 152–174.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks. Second Edition. American Fisheries Society Special Publication 26, Bethesda, Maryland. 526 pages.

Vaughn, C. C., S. J. Nichols, and D. E. Spooner. 2008. Community and foodweb ecology of freshwater mussels. Journal of the North American Benthological Society 27: 409–423.

Vaughn, C. C., and D. E. Spooner. 2006. Unionid mussels influence macroinvertebrate assemblage structure in streams. Journal of the North American Benthological Society 25: 691–700.

Vaughn, C. C., and D. E. Spooner. 2006. Scale-dependent associations between native freshwater mussels and invasive *Corbicula*. Hydrobiologia 568: 331-339.

Yeager, M. M., D. S. Cherry & R. J. Neves, 2000. Competitive interactions between early life stages of *Villosa iris* (Bivalvia: Unionidae) and adult Asian clams (*Corbicula fluminea*). *In*: Tankersley, R. A., D. I.

Warmolts, G. T. Watters, B. J. Armitage, P. D. Johnson & R. S. Butler (eds.), Freshwater Mollusk Symposium Proceedings. Ohio Biological Survey, Columbus, Ohio: 274.

Young, M. R. and J. E. Williams. 1984. The reproductive biology of the freshwater pearl mussel *Margaritifera margaritifera* (Linn.) in Scotland. II. Laboratory studies. Archiv fur Hydrobiologie 100: 29-43.

Zimmerman, L. L., and R. J. Neves. 2002. Effects of temperature on longevity and viability of glochidia of freshwater mussels (Bivalvia: Unionidae). American Malacological Bulletin 17(1/2): 31–35.

Acknowledgements

This project was made possible by generous funding from the East Multnomah Soil & Water Conservation District. Thanks to project partners Johnson Creek Watershed Council and Friends of Crystal Springs and to project collaborators Wolftree, the Freshwater Trust, Marshall High School-Biz Tech Academy (Amy Lindahl's Advanced Biology class), and Clackamas Web Academy (Terri Gibson's Environmental Science class).

Appendix A. Mussel survey sites

I. Site Coordinates and Mussel Counts

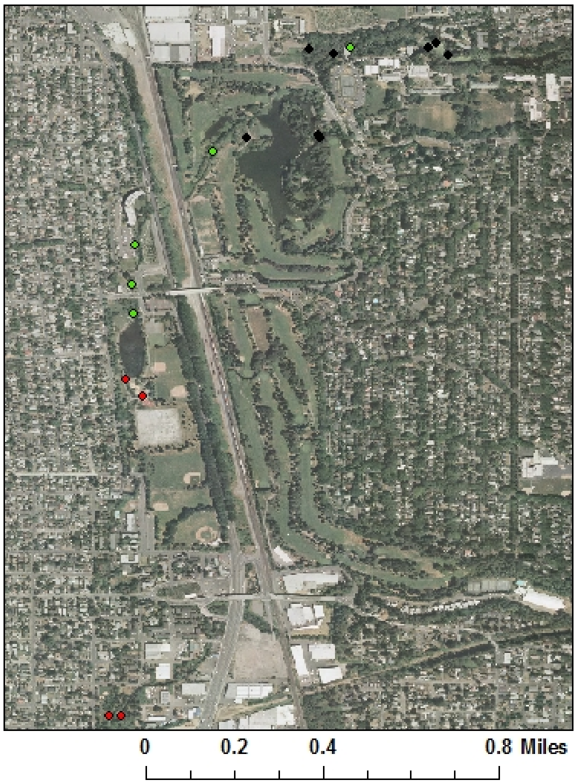
Stream name	Latitude	Longitude	Site	Mussel sp., # live
Johnson Creek	45.46238°	-122.33935°	SE Bluff & SE Pleasant Home Rd., Gresham	M. falcata, 21
Johnson Creek	45.46244°	-122.33958°	SE Bluff & SE Pleasant Home Rd., Gresham	0 mussels
Johnson Creek	45.46262°	-122.33967°	SE Bluff & SE Pleasant Home Rd., Gresham	M. falcata, 10
Johnson Creek	45.46263°	-122.33979°	SE Bluff & SE Pleasant Home Rd., Gresham	M. falcata, 4
Johnson Creek	45.46243°	-122.34004°	SE Bluff & SE Pleasant Home Rd., Gresham	M. falcata, 29
Johnson Creek	45.46229°	-122.34042°	SE Bluff & SE Pleasant Home Rd., Gresham	M. falcata, 27 C. fluminea, 1
Johnson Creek	45.466737°	-122.396241°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 11
Johnson Creek	45.46663°	-122.39625°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 6
Johnson Creek	45.46655°	-122.39626°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 15
Johnson Creek	45.46647°	-122.39639°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 20
Johnson Creek	45.46643°	-122.39637°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 1
Johnson Creek	45.46635°	-122.39653°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 6
Johnson Creek	45.46629°	-122.39641°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 3
Johnson Creek	45.46622°	-122.39686°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 6
Johnson Creek	45.46614°	-122.39675°	SE Telford Rd. & SE 262nd, Gresham	0
Johnson Creek	45.46595°	-122.39626°	SE Telford Rd. & SE 262nd, Gresham	0
Johnson Creek	45.46580°	-122.39603°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 1
Johnson Creek	45.46548°	-122.39568°	SE Telford Rd. & SE 262nd, Gresham	M. falcata, 57
Johnson Cr., small tributary	45.46540°	-122.39558°	SE Telford Rd. & SE 262nd, Gresham	0
Johnson Cr., small tributary	45.46549°	-122.39541°	SE Telford Rd. & SE 262nd, Gresham	0
Crystal Springs Creek	45.48197°	-122.63144°	Reed College	0

Crystal Springs	45.48235°	-122.63186°	Reed College	0
Crystal Springs	45.48221°	-122.63211°	Reed College	0
Crystal Springs	45.482213°	-122.63463°	Reed College	Anodonta, 1
Crystal Springs	45.48204°	-122.63519°	Reed College	0
Crystal Springs	45.48215°	-122.63599°	Reed College	0
Crystal Springs	45.479318°	-122.635682°	Rhododendron Garden	0
Crystal Springs	45.479371°	-122.635701°	Rhododendron Garden	0
Crystal Springs	45.479250°	-122.638090°	Crystal Springs golf course	0
Crystal Springs	45.47881°	-122.63916°	Crystal Springs golf course	Anodonta, 3
Crystal Springs	45.47577°	-122.641697°	Union Manor	Anodonta, 6
Crystal Springs	45.47447°	-122.64179°	Union Manor	Anodonta, 36
Crystal Springs	45.47351°	-122.64175°	Westmoreland Park	Anodonta, 4
Crystal Springs	45.47136°	-122.64199°	Westmoreland Park	C. fluminea, 3
Crystal Springs	45.47085°	-122.64146°	Westmoreland Park	C. fluminea, 3
Crystal Springs	45.46041°	-122.64215°	Johnson Creek Park	C. fluminea, 15
Crystal Springs	45.46038°	-122.64253°	Johnson Creek Park, confluence of Johnson & Crystal Springs Creeks	C. fluminea, 14

II. Site maps

Freshwater Mussel Surveys
Johnson Creek & Crystal Springs Creek, Portland OR

Crystal Springs, source to mouth

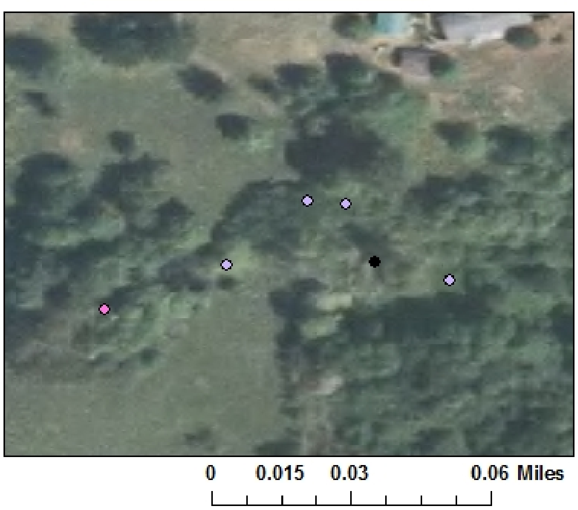


Each point shows a single survey transect. Colors indicate whether native species (Anodonta or M. falcata) were found in the presence (Y) or absence (N) of the invasive Asian clam, if neither native or invasive species were found (none, N), and if Asian clams but no native species were found (none, Y).

Mussel surveys
Native species, invasive species

- Anodonta, N
- M. falcata, N
- M. falcata, Y
- none, N
- none, Y

Johnson Creek, SE Bluff Rd.



Johnson Creek, SE Telford Rd.

Appendix B. Mussel Survey Data Sheet

Date:	Transect #:	Time begin:
Waterbody:	Lat: N	Time end:
Location:	Long: W	# surveyors:

Instream Features	Water Quality
Specify units of measurement % canopy cover: ________ wetted width: _________ water depth (at thalweg):________	Water Temp: _____ ^{o}C Air temp: ______ ^{o}C pH: ______ heavy rain in last 7 days?: Y N

Substrate composition (% estimated, 100% total)	Water Clarity (check one)
bedrock (contin.):______ gravel (0.6-2.5 in.):_____ boulder (>12 in.): ______ sand (<0.6 in.): ______ cobble (2.5-12 in.):______ silt/clay/muck:______ large woody debris:______ other:______	clear ______ turbid ______ slightly turbid _____ opaque _____ Comments:

Riparian Features	Fish presence:
right buffer width (ft): left buffer width (ft): ____ 10-25 ____ 10-25 ____ 25-75 ____ 25-75 ____ 75-150 ____ 75-150 ____ 150+ ____ 150+	____ absent ____ common ____ rare ____ abundant Fish passage blocked? Y N

Land use: 100 ft to each side of stream	Non-point source pollution potential:
(looking downstream) Right bank Left bank % natural forest % silviculture % pasture % residential % agricultural % pasture % commercial % industrial	____ none evident ____ slight potential ____ moderate potential ____ obvious sources ____ livestock access Describe:

Additional wildlife observed (include fish species, if known)	Comments:

Mussel Measurement Data Sheet

Date: Page ____ of ____

Transect #: Survey type: Shoreline or in-stream

Genus code:

Mf = *Margaritifera falcata* (western pearlshell)

An = *Anodonta spp*. (floater)

Ga = *Gonidea angulata* (western ridge shell)

Cf = *Corbicula fluminea* (Asian clam)

All measurements should be made in mm

Genus code	length	width	height	comments

Appendix C. Volunteer Motivation and Knowledge Survey

Please answer the questions below and turn in the form at the end of the survey day. Responses are confidential, and will be used to inform planning and implementation of future volunteer mussel survey events. Thank you for your input!

1. How did you hear about today's mussel sampling event?

Please rate your response to each statement according to the following scale:

	1 strongly disagree	**2** disagree	**3** no opinion/ N.A.	**4** agree	**5** strongly agree
2. I enjoy the social interactions involved in volunteer work.					
3. I enjoy learning new skills.					
4. I like contributing data to research and management studies.					
5. I am concerned about the health of Johnson Creek.					
6. I gained experience that may help my current work or future employment opportunities.					
7. Engaging in community service is important to me.					
8. I frequently recreate in or along Johnson Creek.					
9. I am familiar with Northwest native freshwater mussel species.					
10. I am aware of the threats facing Northwest native mussels.					
11. I am familiar with invasive mussel species in the Northwest.					
12. I am familiar with techniques to help stop transport and spread of non-native mussel species.					

13. What is your age range?

___ 18-25 ___ 26-35 ___ 36-45 ___ 46-55 ___ 56-65 ___ 66 or older

14. What is your gender?

15. Did you feel you gained a good working knowledge of mussel sampling techniques after today's presentations and your hands-on experience?

16. Did you feel physically comfortable with the sampling technique?
If 'no', please give a brief explanation:

17. Would you be likely to participate in a similar mussel sampling event again?

18. Do you have any other comments or suggestions that you would like to share with us?