Freshwater Mussel Surveys to Assess Extinction Debt in the South Umpqua Basin, Oregon

Field Report of Summer 2018 Findings

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Abstract: Native freshwater mussels are a persistently overlooked component of freshwater systems in North America despite the valuable ecosystem services they provide. This trend is especially prevalent in the Pacific Northwest, where species distribution maps are still being established and baseline population data is scarce to non-existent in most watersheds. Preliminary inquiries into native mussel population dynamics have found some beds lacking juveniles, indicative of impending extinction debt phenomenon. In the summer of 2018, I resurveyed 8 sites in the South Umpqua Basin, Oregon, where western pearlshell (*Margaritifera falcata*) mussel presence was documented within the past 30 years. Western pearlshell were present at each site, but the density and spatial variability of animals differed dramatically -- from as few as 4 animals in a 0.85 km stretch of river to a mussel bed with greater than 85,000 animals in a 950 m^2 area. In total, 2 western pearlshell beds and 1 floater mussel bed (*Anodonta sp.*) were sampled to determine whether reproduction was occurring and to document baseline population structures. These beds were located in either the upper S. Umpqua River near Tiller, OR, or in Cow Creek near Riddle, OR. No western pearlshell beds meeting the definition of this project were found in the lower S. Umpqua River sites; native mussels at these sites were few and far between. Instead, high densities of invasive Asian clams (*Corbicula fluminea*) were omnipresent and likely out-competing native mussels. The relationship between invasive and native bivalves merits further research in Pacific Northwest streams, especially as warming waters expand the fundamental niche of Asian clams into historically cold-water streams and rivers.

Background:

Native freshwater mussel species provide valuable ecosystem services through their role as filter feeders: mussels improve water quality by removing excess sediment and nutrients from the water column and enhancing aquatic food webs.[1] North America is a hotspot of freshwater mussel diversity, and yet mussels have been historically relegated to the sidelines of ecological inquiry and conservation efforts. Attention to native mussel species has increased alongside the growing awareness that this faunal group is one of the most threatened in the world.[2] Declining mussel populations have been linked to drivers such as land-use change, increased sedimentation, altered hydrologic flow regimes, and declines in host-fish species.[3,4] In the Pacific Northwest, the western ridged mussel (*Gonidea angulata)* is Vulnerable to extinction and the western pearlshell mussel (*Margaritifera falcata*) is Near Threatened per the International Union for Conservation of Nature's Red List.[2] Urgent research priorities have been identified in the Pacific Northwest, and include investigating mussel abundance and distribution on multiple spatial scales.[4]

Mussels are long-lived: most species found in the Pacific Northwest have a lifespan of 20-40 years, and the western pearlshell can live to 100 years.[1] A lack of juvenile mussels in some Oregon mussel beds suggests an "extinction debt" in which their populations will inevitably decline without intervention.[5,6] Extinction debts are a phenomenon impacting long-lived species wherein past habitat degradation or disturbance negatively affects a population's ability to reproduce. Impacted populations do not go extinct until sometime in the future when relic individuals eventually die. Surveying known mussel populations to determine baseline population parameters and whether reproduction is occurring will provide evidence of impending extinction debt phenomena and has been identified as a top priority with high conservation benefit by the Pacific Northwest Native Freshwater Mussel Working Group.[4] In absentia of baseline population data, land managers and researchers do not know how populations are changing over time and cannot develop appropriate management or conservation plans.

Introduction to Project:

The Western Freshwater Mussel Database is a compilation of all records of native freshwater mussel occurrence in the western region and includes a host of information per record including date (ranging from 1834 to present), location, species, observer, and count information. This database is compiled and maintained jointly by the Xerces Society for Invertebrate Conservation and the Confederated Tribes of the Umatilla Indian Reservation. Within the South Umpqua Basin, there are 50 occurrence records documenting the location of native freshwater mussels between the years of 1841 to 2017.[7] Of these records, 36 were recorded in the year 1990 or after. Records made prior to 1990 were generally attributed vaguely to water bodies or municipalities, and therefore of little use for re-locating and monitoring the status of populations over time. None of these records includes population level information regarding mussel density or reproductive status, even though population-level parameters are required for effective management of populations. The primary goals of this project were twofold. The first goal was to resurvey locations where mussels were reported between 1990 - 2017 in the South Umpqua basin by resurveying sites identified in the Western Freshwater Mussel Database.[7] The second goal was to provide baseline population data and

relevant mussel-associated habitat information for key mussel populations located during resurvey efforts.

Potential sites were selected using the following criteria: records must be from the year 1990 or more recent, records must be attributed to either the South Umpqua River or Cow Creek, records must be located within 15 km from a functioning USGS stream gauge, and records must fall within the Klamath Mountains Geomorphic Region. Nine potential sites were identified; all records of mussels in the database meeting these criteria pertained to western pearlshell, a native mussel species with a broad distribution in the Pacific Northwest. Four sites were located in the lower South Umpqua River near the USGS Brockway gauge, three sites were located in the upper South Umpqua River near the USGS Tiller gauge, and two sites were located in lower Cow Creek near the USGS Riddle gauge (Figure 1). Site clusters around each of the three USGS stream gauges were used to delineate three different zones within the basin; each zone is subject to a unique set of hydrologic and land use drivers.

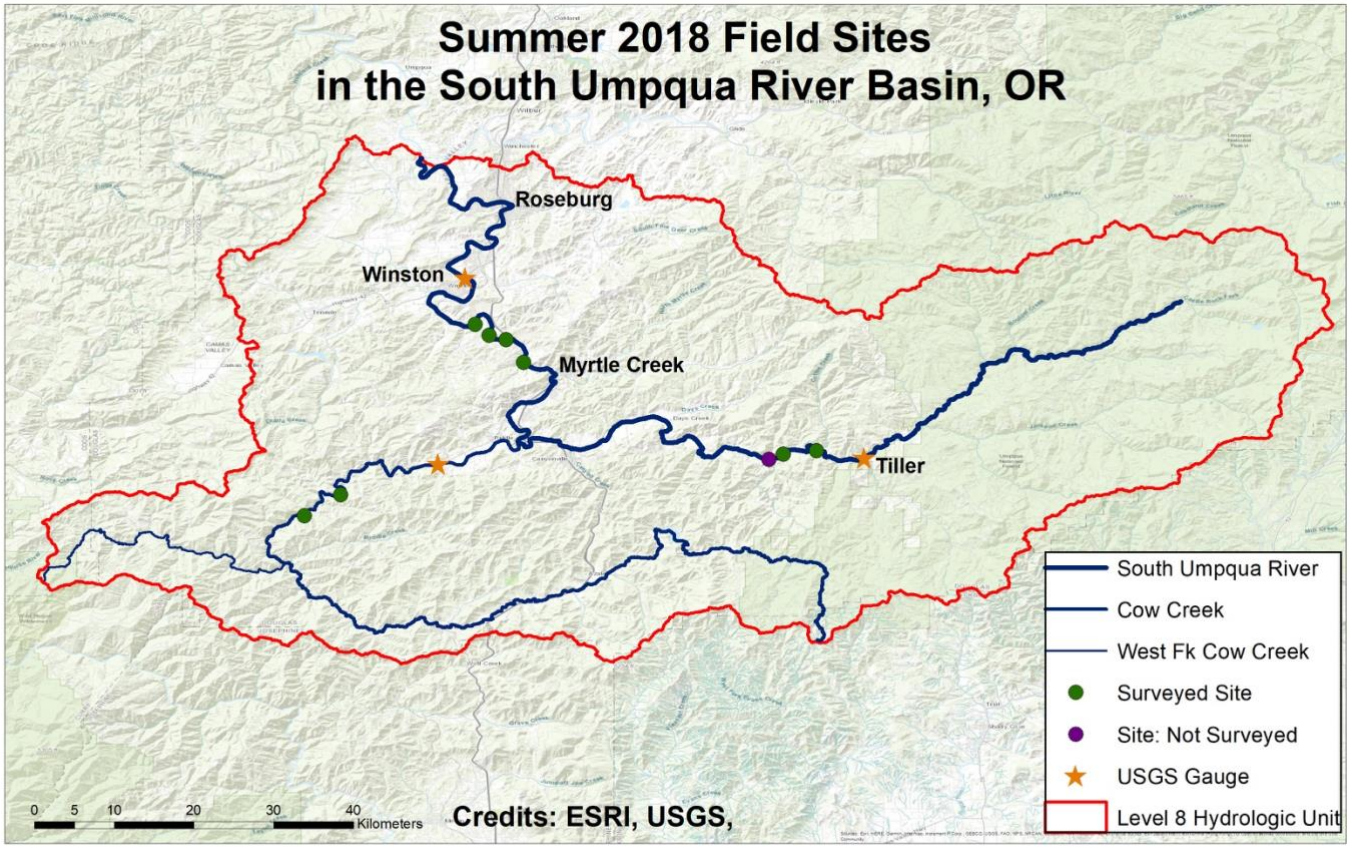

Figure 1: Site map showing the nine site locations for re-survey that were selected from the Western Freshwater Mussel Database. Site locations were chosen based on their location within the basin and their proximity to active USGS stream gauges.

This project was completed as part of my master's thesis research with the ultimate goal of comparing the spatial distribution and reproductive status of mussel beds to hydrologic and land use variables predicted to be important drivers constraining mussel populations.

Investigating mussel records in waterbodies of a comparable size and within the Klamath Mountains Geomorphic Region was a way to hold certain environmental variables as 'constant'.

Methods:

Mussel site locations were visited in June and September of 2018; 22 days were spent in the field assessing sites or sampling mussel beds. Out of 9 potential sites, 8 were visited and site assessment surveys completed (Table 1). The goal was to visit sites where western pearlshell mussels had been documented within the previous 30 years and attempt to re-find extant mussel populations. However, the GPS points associated with each site were not specific to exact mussel locations and more commonly documented the access point to the river (for example, a cobble bar with road access). Prior to visiting field sites, a protocol was developed to systematize the process of assessing site locations for mussels and for documenting mussels when they were found.

At each site, snorkel survey methodologies paired with timed search efforts were used to search for mussels. A minimum of 2 surveyors navigated to the GPS point associated with each site record and made a preliminary plan for how to search the river at that location. Ideally, surveyors began surveying at some point approximately 250 – 500 m downstream of the GPS point and continued surveying upstream of the point by 250 – 500 m to fully

Site:	Length Surveyed (km):
BROCKWAY01	0.36
BROCKWAY02	0.85
BROCKWAY03	0.64
BROCKWAY04	0.48
TILLER01	0.00
TILLER02	0.35
TILLER03	0.18
RIDDLE01	0.70
RIDDLE02	0.31

Table 1: Sites visited during summer 2018 and length (km) of stream surveyed at each location. Site names reference the nearest USGS gauge location; Brockway and Tiller sites were in the South Umpqua River whereas Riddle sites were in Cow Creek. Site TILLER01 was not visited due to time constraints and sickness.

encompass habitat around the point. However, land owner denials at some sites resulted in truncated search efforts that did not fully encompass the point. A minimum of 5 person hours were spent at each site. For the purposes of this study, a mussel aggregation was defined as one or more mussels found at the substrate surface within close physical proximity to one another. Mussels separated by more than 10 m or within substantially different habitat zones were considered separate aggregations.

When a mussel was found, surveyors recorded a GPS location to mark the aggregation and intensified their search effort in the proximal stream bed. The approximate stream area (in m^2) encompassing the aggregation was recorded in addition to any observations regarding substrate, habitat, or demography. Mussel beds were defined as being any mussel aggregation containing 15 or more individuals. If a mussel bed was located at a site, surveyors returned to the location of the bed to complete a mussel bed assessment. The purpose of the bed

assessments was to determine the physical extent of the mussel bed for use in the design of a sampling methodology and to document habitat features of interest. To complete a bed assessment survey, a surveyor would spend 30 minutes re-snorkeling the bed and counting all mussels seen at the substrate surface to provide an initial estimate of density. Bed areas were defined using animals available at the substrate surface; each bed area was likely an underrepresentation of the true bed size as some mussels at the bed margins were either buried or too cryptic to locate.

Bed sampling designs involved counting animals at the substrate surface within 0.25 m^2 quadrats (Photo 1).[8] Sampling strategies varied dependent on bed size: a complete census of substrate was conducted in beds with an area of 50 m^2 or less, and a systematic sampling design was utilized for beds with an area of greater than 50 m^2. Regardless of the sampling methodology used, double sampling of a minimum number of 0.25 m^2 quadrats occurred after the surface count had been conducted by excavating the substrate to a depth of 13 cm and sieving it through a 3.5 mm mesh screen to count any buried mussels.[8] Including excavation within a sampling plan is necessary to answer questions about burial rates and the presence or absence of juvenile mussels.

Photo 1: A snorkeler samples mussels available at the substrate surface within a 0.25 m^2 quadrat along a transect in the TILLER02 floater mussel bed.

Mussel bed demographic information was obtained by measuring all mussels within sampling units. Animals found at the substrate surface or in excavated substrate were collected, counted, identified to species (or genus in the case of *Anodonta sp.*), and shell length measured in centimeters using calipers. Length was defined as the maximum anterior to posterior extent of the shell. Freshwater mussel length is commonly used as a proxy for age because mussels grow by adding annual rings; therefore, length is positively correlated with age.[9,10,11] Therefore, western pearlshell and floater mussel juveniles are those animals in the smallest size classes. Mussels are considered adults at the onset of sexual maturity; this transition is dependent not only on species but also on abiotic environmental factors affecting growth. The oldest adult western pearlshell mussels can live over 100 years and reach lengths of 12-15 cm, whereas floater mussels typically reach maximum lengths of between 10-13 cm and live between 10-15 years.[1]

Results of Site Assessments:

Western pearlshell aggregations were found at every site. However, the number of aggregations found at each site, the number of mussels within each aggregation, and the stream area encompassing the aggregation varied substantially. For example, at the RIDDLE02 site in Cow Creek, one mussel aggregation containing two mussels was found in the entire 0.31 km surveyed. At the BROCKWAY03 site in the lower South Umpqua River, four aggregations were documented in 0.36 km. These aggregations ranged from two mussels in a 30 m^2 area to twelve mussels in a 210 m^2 area. Floater mussels (*Anodonta sp.*) were the only other live native mussel encountered during site assessments. One floater mussel aggregation containing one

mussel was found in Cow Creek (RIDDLE01), and one bed was found in the upper S. Umpqua River (TILLER02) with 112 mussels counted in a 45 m^2 bed area.

Two western pearlshell beds were found during site assessment surveys: one in the upper South Umpqua (TILLER03) and another in Cow Creek (RIDDLE01). None of the sites in the lower South Umpqua River near the Brockway gauge had enough animals visible at the substrate surface to qualify as a bed as defined by this project. In order to have population level and reproduction information for one western pearlshell population in each of the three zones within the basin, the Brockway site containing the aggregation with the highest surface count within the smallest stream area was selected for further sampling (BROCKWAY01).

Results & Discussion of Mussel Bed Assessments:

The floater mussel bed at TILLER02 and the western pearlshell bed at RIDDLE01 were sampled using a complete bed census method, whereas the western pearlshell beds at sites TILLER03 and BROCKWAY01 were systematically sampled. Burial rates and density rates varied between the four beds and amongst the two species. The burial factor for all the western pearlshell beds were at or near 1 (Table 2), indicating that the majority of animals in these beds were available at the substrate surface. The burial factor was highest in the floater mussel bed at TILLER02, with 4 mussels being buried for every 1 available at the surface. In addition, 100% of the juvenile mussels in this bed were buried and only discovered during excavation. Differing bed substrate was likely the primary driver of the disparate burial rates. The floater mussel bed was dominated by sand and silt substrate that is easier to bury into, whereas all western pearlshell beds were located in substrate dominated by gravel and cobble.

Bed density was highest in the upper South Umpqua River sties and lowest in the lower South Umpqua River site (Table 2). The western pearlshell bed at TILLER03 is of special note as it had an overall density of over 90 mussels/m^2 and an estimated count of nearly 87,000 mussels within an approximately 950 m^2 area. The highest density documented while sampling this bed was 113 mussels within a 0.25 m^2 quadrat! In comparison, the highest density sampling unit in the floater mussel bed at TILLER02 was 9 mussels/ quadrat, 8 mussels/ quadrat at the RIDDLE01 bed, and 1 mussel/ quadrat at the BROCKWAY01 bed.

Site	Species	Bed Size (m^2)	Survey Method	Bed Density (mussels/m^2)	Burial Factor	Sample Count	Estimated Count
BROCKWAY01	western pearlshell	135	systematic	0.3	1	8	40
RIDDLE01	western pearlshell	45	census	1.2	1.167	97	112
TILLER02	floater	45	census	6.9	4	112	364
TILLER03	western pearlshell	952	systematic	93.4	1.023	1151	86,978

Table 2: Summary of bed specific density and count information. Bed density is calculated from the total number of mussels found in sample units/ total area sampled. The burial factor describes the relationship between the real number of mussels within a quadrat to the number visible at the substrate surface. The sample count is the number of mussels physically counted within all quadrats during the sampling process, whereas the estimated count incorporates the burial factor and density to provide an estimate of mussels within the entire bed area.

Initial visualizations of population structure for the three western pearlshell beds reveal interesting variations. The population in Cow Creek at RIDDLE01 was the youngest (mean shell length of 4.9 cm) and had very few mussels larger than 7 cm in length. Although this population was the youngest, there was an absence of juvenile mussels in the smallest size classes from 0 – 2 cm (Figure 2). The population in the upper South Umpqua River at TILLER03 was the oldest (mean shell length of 8.1 cm), but contained mussels within every size class including the smallest and largest known for this species (Figure 2). The lengths/ages of the animals in the BROCKWAY01 bed were relatively evenly spread within size classes (Figure 2), but because only 8 mussels were sampled this may not be indicative of the true age structure of the bed. The sampling protocol developed for this research called for a minimum of 50 animals to be sampled from every bed to ensure a representative sample was collected, but this minimum requirement was not met at the BROCKWAY01 bed. The BROCKWAY01 bed also did not satisfy the definition of a mussel bed as defined by this project.

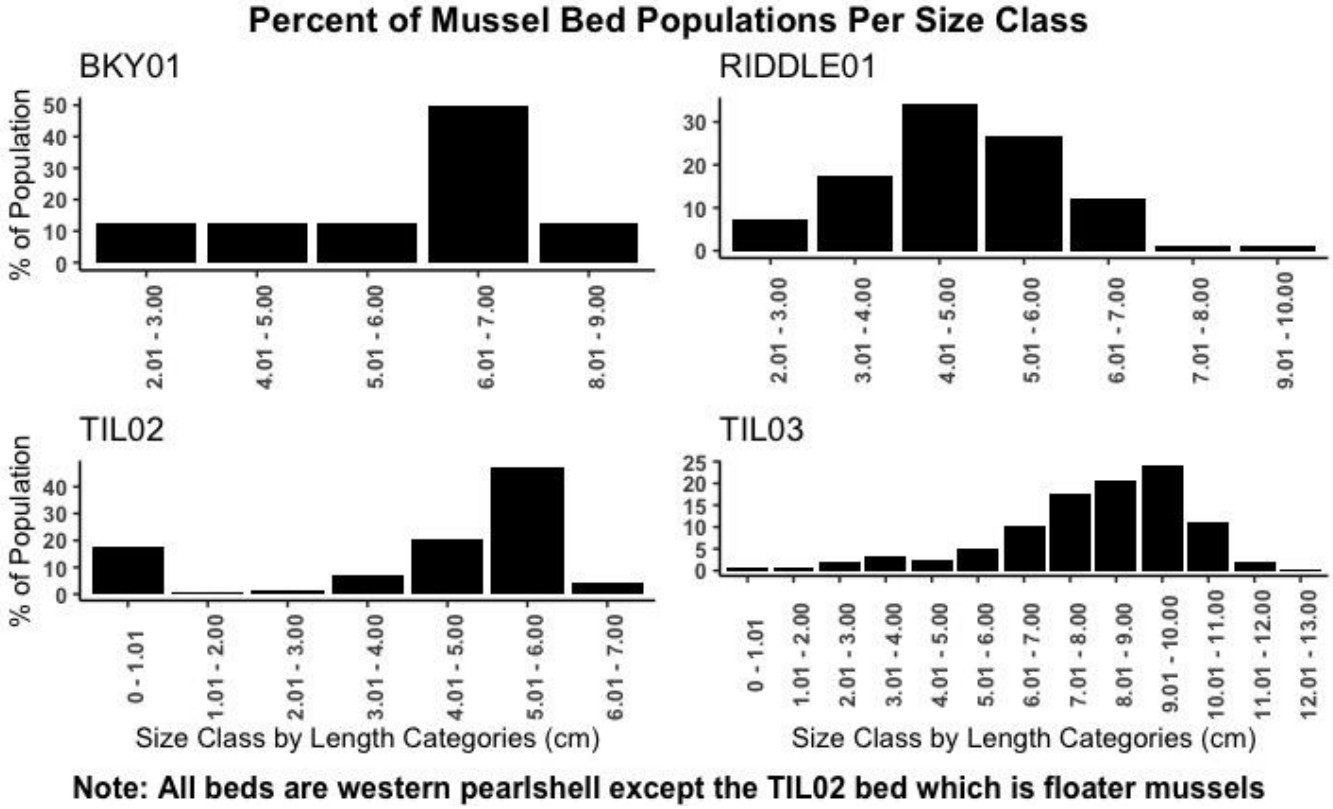

Figure 2: Size class distributions by length categories for each mussel bed sampled in the summer of 2018. The BROCKWAY (BKY) site was located in the lower South Umpqua River near Myrtle Creek, OR, the TILLER (TIL) sites were located in the upper S. Umpqua R. near Tiller, OR, and the RIDDLE site was in Cow Cr. near Riddle, OR. The number of mussels sampled at each site varied and is listed as the 'Sample Count' in Table 2.

The floater mussel bed at TILLER02 had a population that was dominated by either very young mussels less than 1 cm in length or by more middle aged mussels between 4-6 cm in length (Figure 2). Almost 20% of this population was juveniles less than 1 cm in length, but mussels in the next two size classes (1-2 cm & 2-3 cm) comprised a very small percentage of the

total population. Less than 10% of the population was greater than 6 cm in length, and no mussels were larger than 7 cm. Floater mussel species typically reach a maximum length of 10-13 cm and live only 10-15 years, so this population likely established in this location within the past decade.

Invasive species may be an important factor leading to lower densities of native freshwater mussels in the lower South Umpqua River. The Brockway sites were the only areas where the invasive Asian clam (*Corbicula fluminea*) was visibly present; these sites also consistently harbored the lowest densities of native mussels. Although western pearlshell mussels were found at each Brockway site during site assessments, aggregations were spatially distant and mussels were not seen at the surface in high numbers. The BROCKWAY01 sampling site was also the only location where no buried mussels were discovered in excavation units. Instead, at the Brockway sites, hundreds to thousands of Asian clams were present in virtually all areas of the substrate. In-stream deposition zones were littered with empty Asian clam shells (Photo 2), while living clams were either buried in the substrate or simply sitting on the substrate surface. In an attempt to quantify the number of live Asian clams present at the BROCKWAY01 site, seven evenly spaced excavation units were selected and all live Asian clams within the units were counted. On average, each excavated unit contained 157 live Asian clams, with the highest count within a single 0.25 m^2 quadrat being 310 animals (Photo 3). Asian clams compete with native mussels for space and food resources, and seem to be out-competing native mussels where they co-exist. This relationship merits further research and inquiry, especially as warming waters expand the fundamental niche of this species in historically cold-water streams and rivers.

Photo 2: A deposition zone in the lower South Umpqua River BROCKWAY03 site appears to be an Asian clam graveyard, but thousands more living clams lie buried in the sandy substrate. This photo was taken at the location of a historic western pearlshell bed (landowner account).

Photo 3: A portion of excavated substrate from the BROCKWAY01 bed boasts a high concentration of living and dead Asian clams. On average, each excavation unit at this site contained 157 live Asian clams.

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