Assessing the Status of Freshwater Mussels within Longwood Gardens

A publication of:

Partnership for the Delaware Estuary; a National Estuary Program

November 18th, 2015

PDE Report No 15-07
Established in 1996, the Partnership for the Delaware Estuary is a non-profit organization based in Wilmington, Delaware. The Partnership manages the Delaware Estuary Program, one of 28 estuaries recognized by the U.S. Congress for its national significance under the Clean Water Act. PDE is the only tri-state, multi-agency National Estuary Program in the country. In collaboration with a broad spectrum of governmental agencies, non-profit corporations, businesses, and citizens, the Partnership works to implement the Delaware Estuary’s Comprehensive Conservation Management Plan to restore and protect the natural and economic resources of the Delaware Estuary and its tributaries.

November 18th, 2015
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Acknowledgements
The authors would like to acknowledge the generous funding provided by Longwood Gardens. The authors would also like to acknowledge Ryan Kelleher and Allison Ostertag for their support in the field and Bill Haldeman of Longwood Gardens for the opportunity to pursue this research.

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Introduction

Importance of Freshwater Mussels

In North America, over 70% of the 297 native species of freshwater mussel species are endangered, threatened, or of special concern (Williams et al. 1993) making them the most imperiled group of aquatic animals nationally (Nobles and Zhang 2011). Freshwater mussels are also considered to be the most imperiled animal locally in the Delaware River basin (PDE 2012a, 2012b). Accordingly, the 12 species of freshwater mussels native to the basin are declining in species richness, population abundance, and geographic range. Despite their decline, there are emerging data suggesting that freshwater mussels are important for water quality and ecological integrity depending on abundance, similar to other filter feeding bivalves (e.g. clams, mussels, and oysters). Due to their imperiled status and potential importance in ecosystem functioning and water quality, there has been a rise in national interest in protecting and understanding these animals.

This expanded interest is reflected by the greater diversity of state and federal agencies that are now attentive to freshwater mussel status and trends. In the past, the main groups that focused on mussel conservation and restoration were state heritage programs and a few federal agencies (e.g. United States Fish and Wildlife Service and United States Geological Survey), which focused on biodiversity preservation and the protection of listed species. Now, many other agencies (e.g., United States Environmental Protection Agency) and water supply companies (e.g., Philadelphia Water Department and United Water) are focused on the water and habitat benefits that are furnished by healthy mussel beds in streams, rivers and lakes.

As a National Estuary Program, the Partnership for the Delaware Estuary (PDE) is expected to establish and meet measureable goals for sustaining and improving water and habitat conditions, thereby working to implement our Comprehensive Conservation Management Plan (CCMP). PDE has elevated healthy freshwater mussel populations as one of a limited subset of “driver” goals which facilitate ecosystem-based restoration in the Delaware River basin. This goal is based on the observation that mussels are very long-lived (up to 100 years) and sensitive to a variety of suboptimal conditions, ranging from water quality, water quantity, riparian cover, and fish passage. Hence, to achieve multiple goals for water and habitat conditions in any given water body, a simplified focus on achieving healthy assemblages of native freshwater mussels, living in abundance, will drive positive decision-making in support of broader CCMP actions and needs.

The water quality benefits of healthy natural mussel beds are only now being studied, but look to be sizeable. When active, each adult mussel filters gallons of water every day. Many streams that once supported dense populations of freshwater mussels no longer do. This loss of freshwater mussels is thought to contribute to degraded water quality and represents a negative feedback for ecosystem health. In those areas, mussel restoration should promote positive feedbacks to ecosystem health in the form of cleaner water, reduced erosion, and increased habitat complexity. For more information on the ecology and diversity of freshwater mussels in the Delaware River basin, please refer to Freshwater Mussels of the Delaware Estuary: Identification Guide & Volunteer Survey Handbook and other information at the following website: http://www.delawareestuary.org/freshwater-mussels.

Although many current mussel populations appear to be extremely depressed and constricted relative to historic levels, numerous scientists and managers believe that this represents an opportunity to
rebuild mussel populations. Countless streams and rivers that were once too polluted to support mussels have since been remediated to the point where mussel populations could again be sustained. However, blockages to fish passage, slow mussel growth, and other impediments stand in the way of mussels being able to naturally re-disperse and colonize these habitats. Hence, assisted recolonization can directly augment and expedite recovery since the natural dispersal of native populations can be slow or not possible.

**Freshwater Mussel Recovery Program (FMRP)**
The FMRP was launched in 2007 by PDE with the goal of conserving and restoring native freshwater mussels within the Delaware Estuary. This program complements PDE’s comprehensive watershed-based shellfish restoration strategy which also includes saltwater oysters and saltwater ribbed mussels. Together, these shellfish range from the headwaters to the Bay.

The FMRP consists of 9 activities:
- **Surveys** both qualitative and quantitative to identify potential restoration sites and provide data on extant populations.
- **Assessments** using caged mussels to determine the suitability of streams for restoration.
- **Conservation** of critical mussel habitat.
- **Restoration via Reintroduction** to determine survivability of mussels in restoration streams.
- **Restoration via Propagation** using hatchery methods to seed streams for water quality uplift and bolster mussel abundance.
- **Restoration via Habitat** to aid in mussel population carrying capacity.
- **Research and Monitoring** to understand mussel life history and its interaction with future environmental conditions.
- **Outreach** to educate the public about conservation and restoration of freshwater mussels.
- **Coordination** of mussel conservation and restoration work with partners within the region.

**Study Objective**
The goal of this study was to survey for any evidence of past or current freshwater mussels in freshwater ponds and streams on or adjacent to the property of Longwood Gardens in southeast Pennsylvania. This effort supports the FMRP by filling data gaps on current mussel distributions in areas that have not been previously surveyed. Areas that are found to still have mussels can then be prioritized for conservation, whereas suitable habitats without mussels can be considered for possible future restoration.

**Longwood Gardens Study Area**
The property of Longwood Gardens lies within Chester County, PA and is situated between the Brandywine Creek and Red Clay Creek (Fig. 1). Historical data suggest that these streams once held robust populations of freshwater mussels which may have extended into other waterways in the area including ponds and lakes. In order to investigate whether or not freshwater mussels were present within ponds of Longwood Gardens, five ponds were identified which had the greatest chance of supporting freshwater mussels based on the pond’s location, age, and hydrologic connectivity to flowing nearby streams. The names and locations of the study ponds are summarized in Table 1 and depicted in Figure 2.
Table 1. Name and location of study ponds within study area.

<table>
<thead>
<tr>
<th>Study Pond</th>
<th>Geographic Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Latitude (N)</td>
</tr>
<tr>
<td>Hourglass Pond</td>
<td>39.87569</td>
</tr>
<tr>
<td>Wetland Pond</td>
<td>39.87489</td>
</tr>
<tr>
<td>Abbondi Pond</td>
<td>39.87342</td>
</tr>
<tr>
<td>Nursery Pond</td>
<td>39.86463</td>
</tr>
<tr>
<td>Webb Barn Pond</td>
<td>39.87586</td>
</tr>
</tbody>
</table>

Figure 1. Notable streams of Southeast Pennsylvania and Delaware near Longwood Gardens.
Figure 2. Spatial context of study ponds within the Longwood Gardens property.
Methods

**Qualitative Freshwater Mussel Surveys**
Mussel surveys were performed by Dr. Danielle Kreeger and Kurt Cheng (Fig. 3) in each of the five study ponds previously identified within the Longwood Garden property. Surveyors waded around the perimeter of ponds as well as through the middle of ponds where feasible. Hand tools including metal scoops and rakes were used in conjunction with visual observation to detect evidence of freshwater mussels while limiting disturbance of existing habitat. Surveyors recorded qualitative observations of substrata and primary production in ponds. GPS coordinates were taken at all study ponds and survey times were recorded to calculate survey effort (# surveyors * survey duration).

**Water Quality Monitoring**
Water quality parameters including water temperature (°C), dissolved oxygen (mg/L, saturation %), specific conductance (mS/cm), and pH were monitored at all study ponds using a water quality sonde (YSI Pro+). Field personnel monitored water quality in the vicinity of where surveys were performed at a consistent depth (Fig. 4). Each water quality parameter was appropriately calibrated on the sonde prior to use in the field.
Results and Discussion

Mussel Surveys
Qualitative mussel survey results are presented in Table 2. Qualitative surveys did not yield evidence of extant mussels or historical mussel presence within any of the study ponds. Survey efforts were adjusted to the size and condition of the ponds to maximize efficiency of detecting freshwater mussels as well as evaluating benthic habitat that could support freshwater mussels in the future. Of all ponds surveyed, the Hourglass, Wetland, and Nursery ponds were determined to have suitable freshwater mussel habitat. Detailed survey results are discussed for each study pond below.

<table>
<thead>
<tr>
<th>Study Pond</th>
<th>Survey Effort (person hours)</th>
<th>Extant Mussels</th>
<th>Suitable Mussel Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourglass Pond</td>
<td>1.0</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Wetland Pond</td>
<td>1.0</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Abbondi Pond</td>
<td>0.5</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Nursery Pond</td>
<td>1.0</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Webb Barn Pond</td>
<td>0.5</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

*Table 2. Summary of qualitative survey efforts and findings.*

**Hourglass Pond**
A qualitative survey determined that there are no extant freshwater mussels in the Hourglass pond despite hydrological connectivity to the Brandywine River (Hourglass pond drains into Pocopson Creek which flows into the Brandywine River). Previous freshwater mussel surveys detected populations of the freshwater mussel *Elliptio complanata* in the Brandywine River (Kreeger, unpublished data). Surveyors noted adequate riparian cover, abundant floating duckweed vegetation (subfamily: *Lemnoideae*) and a variety of bottom types throughout the pond. The substrate along the pond’s perimeter was characterized by detritus mixed with large woody debris and other allochthonous material. Two areas on the opposite ends of the pond were characterized by a mix of sand and mud substrates. These two areas were deemed suitable for freshwater mussel reintroduction based on bottom type as well as water depth and water flow. One specimen of the Asian mystery snail, *Cipangopaludina* sp., was observed in the pond.

**Wetland Pond**
Surveyors did not find evidence of freshwater mussels in the Wetland pond which further advances our understanding of mussels in the area as the Wetland pond is hydrologically connected to the Red Clay Creek where no extant mussels were detected during previous surveys (Kreeger et al. 2014). However, other fauna such as turtles, fish, and birds were present in abundance. High water column productivity was observed which would serve as ample food resources for filter-feeding animals such as freshwater mussels. The pond’s substrate was predominantly soft mud and silt. The water depth of the pond was determined to be adequate for freshwater mussel survival. Based on water depth, food availability, and appropriate benthic conditions, the Wetland pond may serve as a candidate for caging studies with freshwater mussels.

**Abbondi Pond**
The Abbondi pond lies between the Wetland pond and East Branch Red Clay Creek and was not found to contain any evidence of freshwater mussels. Despite adequate water column productivity and presence of other fauna (e.g. turtles and fish), the pond may not serve as a candidate for future freshwater mussel restoration at this time. The substrate was very loose mud likely due to stormwater inputs creating an unstable bottom. Additionally, the pond was notably shallow which would increase the
likelihood of routine complete freezing in winter and high water temperatures in summer; both of these conditions do not support prolonged freshwater mussel survival.

**Nursery Pond**

The Nursery pond lies within the Red Clay Creek watershed and is relatively protected from stormwater inputs. In addition to good riparian cover, the Nursery pond was characterized with suitable bottom habitat including stable sand and mud. The water depth was also suitable for freshwater mussels throughout the majority of the pond. Large fish and turtles were in abundance along with floating vegetation and submerged aquatic vegetation. The Nursery pond was determined to have a high capacity to support freshwater mussels given current conditions.

**Webb Barn Pond**

Surveyors investigated shallow areas of the pond as well as the outfall and downstream creek of the pond. No freshwater mussel evidence was found. The pond’s surface was largely covered with water clovers (*Marsilea* sp.). The surrounding land use and topography likely encourage stormwater inputs to the pond rendering the area less suitable for freshwater mussels.

**Water Quality**

Water quality influences aquatic organisms and is especially important for animals like freshwater mussels which are generally sessile. Key water quality parameters monitored during mussel surveys in each of the five ponds are reported in Table 3. Water temperatures were generally consistent among all ponds and ranged from 18.8 – 23.2 °C. Dissolved oxygen within the ponds was variable (5.40 – 8.28 mg/L) as water temperatures fluctuated slightly in different ponds. Riparian cover and primary production in ponds influenced levels of dissolved oxygen in ponds though; ponds were sufficiently oxygenated to support freshwater mussels. Specific conductance was relatively similar across ponds and ranged from 0.201 – 0.459 mS/cm which is consistent with similar freshwater environments around the region. The pH of streams and ponds is an important aspect of water quality that can influence a mussel’s ability to grow and maintain its shell. The pH of study ponds ranged just over one order of magnitude (6.90 – 7.96) but still within the typical values seen in the region. Based on these data, the survey ponds surveyed have the capacity to support populations of freshwater mussels with regard to key water quality parameters.

**Table 3. Summary of water quality within all study ponds.**

<table>
<thead>
<tr>
<th>Study Pond</th>
<th>Water Temperature (°C)</th>
<th>Dissolved Oxygen (mg/L)</th>
<th>Dissolved Oxygen (Saturation %)</th>
<th>Specific Conductance (mS/cm)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourglass Pond</td>
<td>18.8</td>
<td>6.54</td>
<td>70.4</td>
<td>0.459</td>
<td>6.90</td>
</tr>
<tr>
<td>Wetland Pond</td>
<td>20.5</td>
<td>8.28</td>
<td>92.0</td>
<td>0.201</td>
<td>7.96</td>
</tr>
<tr>
<td>Abbondi Pond</td>
<td>23.2</td>
<td>5.40</td>
<td>63.2</td>
<td>0.389</td>
<td>7.29</td>
</tr>
<tr>
<td>Nursery Pond</td>
<td>23.2</td>
<td>5.65</td>
<td>66.2</td>
<td>0.248</td>
<td>7.40</td>
</tr>
<tr>
<td>Webb Barn Pond</td>
<td>22.5</td>
<td>6.78</td>
<td>78.4</td>
<td>0.396</td>
<td>7.29</td>
</tr>
</tbody>
</table>

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Next Steps

The qualitative freshwater mussel surveys that were performed will direct future mussel restoration efforts within the Longwood Garden property. Although no freshwater mussels were found in any study ponds, water quality data as well as qualitative substrate observations suggest that current conditions within Hourglass, Wetland, and Nursery ponds are suitable for freshwater mussels.

Several potential tactics could be used in the future to restore freshwater mussels into suitable habitats within these ponds:

- **Caged Mussel Reintroduction Tests.** Adult mussels can be collected in nearby Brandywine Creek (under PDE’s PA Scientific Permit) and deployed into candidate pond locations within cages, to prevent escape and avoid predation. Subsets of mussels are periodically removed from the cages over a one year period and sacrificed to assess their fitness. Mussel fitness would be contrasted among cages in different ponds to discern which pond location supports mussel condition best. Advantage is that this tactic is relatively low-cost and yields data on sublethal condition, and disadvantage is that it requires a small disturbance to a nearby natural population and no live animals are actually stocked.

- **Electrotagged Mussel Reintroduction Tests.** Adult mussels can be collected in nearby Brandywine Creek (under PDE’s PA Scientific Permit) and deployed freely into suitable substrates in shallow areas of candidate pond locations. Subsequent monitoring (twice per year) assesses shell lengths for animals that can be relocated with electronic detection gear. Shell growth rates would be contrasted for mussels deployed in different ponds to discern which pond supports mussel growth best. Advantage is that this tactic is relatively low-cost and yields some live animals in ponds that might serve as broodstock to seed restoration, and disadvantage is that it requires a small disturbance to a nearby natural population and shell growth is slow possibly taking years to detect differences.

- **Juvenile Grow-Out Tests.** Juvenile mussels are propagated in a hatchery using native genetic broodstock, and the young animals are deployed in floating baskets within different ponds. Once they attain a suitable size, they can then be tagged and planted in the substrates. Shell growth can be contrasted among ponds. Advantage is that this tactic does not impinge upon any nearby natural mussel beds (hatchery broodstock can be returned to source) and larger numbers of mussels can be stocked for seeding new populations. Disadvantage is higher costs for hatchery propagation, higher maintenance (need to clean baskets), and materials (e.g., dock access to floating baskets).

- **Juvenile Seeding.** Once candidate restoration sites are prioritized and a suitable site is selected, large numbers of mussel juveniles (possibly of >1 native species) can be reared in a hatchery and then relocated into the sites. A devoted hatchery for the Delaware River Basin is being planned, but until funding is secured and the facility is operational, seed availability will be constrained (hatchery in VA). Advantage is actual reintroduction of sufficient numbers to promote rapid population growth and attendant ecosystem service benefits. Disadvantage is higher cost and constrained current capacity; however, once a local hatchery is operational, costs will decrease and larger capacity would be possible.
Additional ancillary activities could include education and outreach programming, possible research studies, and links to nearby stream restoration.

Caging studies would be appropriate in all three ponds. Reintroduction studies would be appropriate in Hourglass and Nursery ponds due to their greater water clarity and practicality of monitoring. We recommend gathering initial data via caging and tagging studies before proceeding to juvenile grow out testing. For juvenile grow-out, the Nursery pond would be the prime candidate due to its superior benthic habitat and overall water quality.

**Literature Cited**


