UPPER OHIO NAVIGATION STUDY, PENNSYLVANIA
ENVIRONMENTAL APPENDIX

Mussel Survey

Native Mussel Screening Survey
Upper Ohio River Navigation Study
January 2009

Note to Reader:

Freshwater mussels, though distributed worldwide, reach their greatest diversity in North America, east of the Mississippi River. U.S. mussel populations have been in decline since the late 1800s, most precipitously over the last 30 years. Of the variety of threats to native species, the single most important is considered to be habitat destruction[1]. Currently, three-quarters of North America's native freshwater mussel species are considered endangered, threatened, or species-of-special-concern, and an appreciable number of species are now known to be extinct[2].

Native mussels are valuable components of ecosystems; they improve water quality by filtering large volumes of water, and they often provide information on pollutant types, levels, and timing. Current or systematically-collected data regarding native mussels on the Upper Ohio, however, has been lacking. As such, the goal of these surveys was to qualitatively assess the presence, diversity, and distribution of mussels throughout the project area to define baseline conditions.

In order to develop baseline knowledge regarding mussel resources and their distribution in the upper Ohio River, the District contracted for diving and habitat surveys between August 19 and September 4, 2008. Surveys were performed at a total of 35 non-random locations between Ohio River navigation mile 1.7 and 34.4, with six sites in the Emsworth Pool, 12 sites in the Dashields Pool, 13 sites in the Montgomery Pool, and four sites in the New Cumberland Pool.

A total of 110 live mussels, representing six species, were collected using transect searches, timed spot dives, and shoreline searches. Pink heel-splitters (*Potamilus alatus*), mapleleaf (*Quadrula quadrula*), and threehorn warty back (*Obliquaria reflexa*) comprised over 96% of all mussels. The three other species with live specimens were fluted shell (*Lasmigona costata*), fatmucket (*Lampsilis siliquoidea*), and fawnsfoot (*Truncilla donaciformis*). Two additional species, fragile papershell (*Leptodea fragilis*) and deertoe (*T. truncata)*, were only collected as fresh-dead shell material. No evidence of federal or state endangered or federal candidate species was detected; however, several species encountered are proposed for special state status in PA.

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[1] **Conservation Status of Freshwater Mussels of the United States**… Williams et al., *Fisheries* 18(9), 1993.
[2] **Native Freshwater Mussels,** NCRS Fish and Wildlife Habitat Management Leaflet, No. 46, January 2007.

Most mussels (78%) were found in 15 feet of water or shallower. Suitable mussel habitat was found to be widely available at many sites, but largely unoccupied. Mussel communities within the study area were considered to be “poor” (Emsworth Pool), “marginal” (Montgomery Pool), and “fair” (Dashields and New Cumberland pools), tentatively based on a combination of physical conditions, presence/absence of live mussels, and species diversity/composition.

Native Mussel Screening Survey
Upper Ohio River Navigation Study

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***Presented to*:**

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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The U. S. Army Corps of Engineers Pittsburgh District (District) provided funding for this project, while D'Appolonia administered it. Ms. Jenny Crock was the District's primary point-of-contact and technical point-of-contact, and Mr. Tom Maier (District) assisted as a biologist. Mr. Gary Householder was the District Diving Coordinator and Mr. Charley Weight (District) approved diving operations in the field. Mr. Alan Halperin and Mr. Chris Lewis were the primary points of contact for D'Appolonia. Mr. Jason Harkcom was the Supervisory Biologist for Skelly and Loy, Inc. (Skelly and Loy). Mr. Daniel Lakamp was Dive Supervisor for EnviroScience, Inc. (ES) and Mr. Timothy Willaman was the ES Field Safety Officer and a tender. Mr. Matthew Walsh (ES), Mr. James Hartman (ES), Mr. Mike Hanway (ES), and Mr. Daniel Lakamp were the divers for this project. Mr. Greg Zimmerman was the ES Project Manager, malacologist, and GPS/GIS specialist. Dr. Marty Huehner (ES) was a field malacologist, provided QA/QC of data, and served as the field manager in any absence of Mr. Greg Zimmerman. The report was written by Mr. Greg Zimmerman and edited by Mr. Jason Harkcom (Skelly and Loy), Ms. Jennifer Davis (ES), and Dr. Marty Huehner. Large portions of the Introduction and Methods sections of this report were taken directly from the District's scope of work.

EXECUTIVE SUMMARY

The Pittsburgh District of the U.S. Army Corps of Engineers is evaluating the feasibility of modernizing the three oldest locks and dams on the Ohio River Navigation (Emsworth, Dashields, and Montgomery Locks and Dams) as part of the Upper Ohio River Navigation Study, Pennsylvania. These three facilities, the earliest of which was built in 1922, are deteriorating structurally and may be in need of updates that will better accommodate future commercial navigation needs. Data regarding the status, condition, and distribution of biological and physical resources within the study area are required to evaluate various alternatives for modernization of these facilities

EnviroScience, Inc. (ES) was contracted under D'Appolonia and in association with Skelly and Loy, Inc. to provide freshwater mussel and habitat services to the District in support of this project. Diving and habitat surveys were completed between August 19 and September 4, 2008, under optimal field conditions. A total of 35 non-random locations in Pennsylvania were evaluated between Ohio River navigation mile 1.7 and 34.4: six sites in the Emsworth Pool, 12 sites in the Dashields Pool, 13 sites in the Montgomery Pool, and four sites in the New Cumberland Pool.

Overall, a total of 110 live mussel specimens were collected using transect searches, timed spot dives, and shoreline searches. Recent evidence of eight species was collected; two species were collected only as fresh dead shell material. No evidence of federal or state endangered or federal candidate species was detected. Of the mussel species encountered, the threehorn wartyback (*Obliquaria reflexa)* and the deertoe (*Truncilla truncata*) are suggested as sensitive indicator species by the U.S. Fish and Wildlife Service and several of the species encountered have been proposed for special state status by the State of Pennsylvania. The deertoe has a proposed state status of "extirpated" and the fawnsfoot (*Truncilla donaciformis*) is currently proposed as status "unknown". Most mussels (78%) were found in 15ft of water or less. Suitable mussel habitat was found to be widely available at many sites but largely unoccupied.

Mussel communities within the study area were considered to be "poor" (Emsworth Pool), "marginal" (Montgomery Pool), or "fair" (Dashields and New Cumberland pools), tentatively based on a combination of physical conditions, presence/absence of live mussels, and species diversity / composition.

While the present study improved our baseline understanding of mussel resources and their distribution within the upper Ohio River, additional survey work will likely be necessary as the District continues its analysis. The data gathered in this study, along with the GIS files generated using these data, should be a useful asset to the Upper Ohio River Navigation Study and to the District as it further refines the data needs and proceeds with analysis of modernization alternatives for these facilities.

INTRODUCTION

Background

The U.S. Army Corps of Engineers, Pittsburgh District (District) is conducting a feasibility-level study for modernization of the three locks and dams on the Ohio River in Pennsylvania (Emsworth, Dashields, and Montgomery Locks and Dams). The congressionally designated title of this study is, "Upper Ohio River Navigation Study, Pennsylvania." Of primary concern is the deteriorating structural condition of these three oldest navigation facilities on the Ohio River, dating from 1922. Adequacy of lock chamber capacity to accommodate future commercial navigation needs is a secondary concern to be evaluated. As part of the feasibility study, the District will also investigate opportunities for ecosystem restoration projects in association with, or independent of, any proposed navigation improvements. The formulation process to be followed in the study will entail compliance with federal environmental laws and executive orders.

To support both compliance and ecosystem restoration planning, the District is compiling known environmental information on the status and condition of biological and physical resources in the study area. Where data gaps exist, the District will assess the need for further studies . One area in which little current or systematically collected data is available is regarding freshwater native mussel (unionid) population studies in the upper Ohio River. Development of information on native freshwater mussel populations in the Upper Ohio River is likely to be important in evaluating the influence of existing and future navigation facilities and commercial navigation. For this reason, the District developed a scope of work to complete mussel surveys in the upper Ohio River and subsequently contracted EnviroScience, Inc. (ES) through D'Appalonia and in association with Skelly and Loy, Inc. to complete the project.

Project Goals and Work Products

The purpose of this study was to gather and assess information on the presence, distribution, and types of native freshwater mussels within the study area. This study was also designed to provide a qualitative assessment of presence, diversity, and distribution of mussels throughout the project area in order to define a baseline condition for environmental compliance documentation. Further goals were to evaluate the study findings in light of prior knowledge and research, and to make recommendations for further work associated with interpreting the mussel data and how navigation facility improvements would impact species populations.

The study area consisted of Ohio River navigation miles (NM) 0.0 to 35.0 that included 35 non-random sampling sites deemed to have a high probability of having native mussels. These 35 sites were broken down into specific pools as follows: Emsworth Pool had six sites, Dashields Pool had 12 sites, Montgomery Pool had thirteen sites, and the New Cumberland Pool had four sites. The lock chambers and the "Restricted Areas" in the immediate vicinity of each of the navigation structures were off-limits for sampling.

The District developed the following study objectives relevant to the assessment of environmental conditions and evaluation of alternative navigation system modernization alternatives:

1) Is there potential native mussel habitat in the upper Ohio River and if so, is it occupied by freshwater mussels?
2) What are the native unionids inhabiting the upper Ohio River?
3) What do the study results indicate for potential of native mussels in unsurveyed portions of the river?
4) Do mussel concentrations occur in proximity to potential lock and dam improvement projects which may require additional sampling at a later date?

A secondary purpose of this study was to develop information that would be compatible with the District's Geographical Information System (GIS) database of the study area, so that the results of the field sampling could be incorporated into a compatible database. The field tasks were therefore conducted using Differential Global Positioning System (DGPS) equipment for spatial determination of the beginning and ending points of transects and other sampling points. Additionally, during preparation of the sampling plan, evaluations of side scan sonar and bathymetry data available from the Pennsylvania Fish and Boat Commission (PFBC) and the District were reviewed.

Current Status of Freshwater Mussels

Freshwater mussels are found on all continents except Antarctica and have reached by far their greatest species richness in North America, particularly in drainages of the southeastern and Midwestern United States. Turgeon et al. (1998) recognized 297 unionid species (includes a number of subspecies; Margaritiferidae = five species; Unionidae = 292 species) within drainages of the U.S. and Canada from the Rio Grande basin and northward. Comparatively, other continents/regions historically contained a fraction of this unionid richness, for example: Australia = 17 species, India = 54 species, China = 38 species, Europe and the former Soviet Union = 10 species and Africa = 56 species.

Of the 297 freshwater mussel species recognized in the U.S. and Canada, over 70% are considered endangered, threatened, or of special concern, including 21 species presumed to be extinct (Williams et al., 1993). Currently, the U. S. Fish and Wildlife Service (USFWS) lists 62 unionid species as endangered, eight as threatened, and 19 as candidates for federal listing (USFWS, 2008). The waters of Pennsylvania historically contained a rich assemblage of freshwater mussels totaling at least 65 species (Bogan, 1993a). Of these species, 44 are believed to still inhabit Pennsylvania, while 21 are considered extirpated (no longer inhabiting Pennsylvania). The historical distribution of all these species amongst the six major drainages in the state are as follows: 53 in the Ohio River, 24 in Lake Erie, two in the Genesee River, six in the Potomac River, 12 in the Susquehanna River, and 14 in the Delaware River (Bogan, 1993a, 1993b). Currently, mussel fauna within Pennsylvania's Ohio River basin, which encompasses the Allegheny River and its tributaries, includes two known extant federally endangered species (*Epioblasma torulosa rangiana* [northern riffleshell], and *Pleurobema clava* [clubshell]), as well as six presumably extirpated federally endangered species and two species (*Plethobasus cyphyu*s and *Villosa fabalis*) which are candidates for federal listing (USFWS, 2008). The Pennsylvania Department of Conservation and Natural Resources (DCNR, 2008), officially lists only the northern riffleshell and clubshell as state endangered, but also lists 20 species with a proposed state endangered or threatened status in Pennsylvania (not including species presumed extirpated). In December of 2008, the Pennsylvania Fish and Boat Commission proposed to elevate five species to state threatened or endangered including the salamander mussel (*Simsonaias ambigua*), rabbitsfoot (*Quadrula c. cylindrica*), snuffbox (*Epioblasma triquetra*), sheepnose, and rayed bean.

Unionid Biology and Ecology

Adult freshwater mussels range in size from a few centimeters (e.g., *Simpsonaias ambigua* and *Villosa fabalis*) to over 300mm (e.g., *Megalonaias nervosa*) and have lifespans ranging from <10yr (e.g., *Utterbackia imbecillis*) (Cummings and Mayer, 1992) to >100yr (i.e., *Margaritifera margaritifera*) (Heller, 1990; Bauer, 1992). They are relatively sedentary and feed on microscopic material (e.g., algae, diatoms, bacteria, and dissolved organic matter) that they siphon and filter out of the water column. Although it is not clear how they utilize different materials for energy, they can differentially separate filtered material by size with ciliary action on the gill surface; food is swept towards the mouth and other material (along with mucus) is rejected out the excurrent siphon as pseudofeces (Paterson, 1984; McMahon, 1991). Juvenile mussels are <1mm in length and are believed to use ciliary action and sweeping movements of their foot to collect food (= pedal feeding; Gatenby et al., 1997; Yeager et al., 1994). Mussels can control uptake of water and particulate matter by adjusting filtration rate (Burky, 1983), often in conjunction with siphon and valve posture, which is well correlated with environmental stimuli such as photoperiod and water flow (Englund and Heino; 1996). Mussels are capable of moving laterally (several meters per day) and vertically (burying) using their strong, tongue-like foot. In clear waters, “trails” left in the substrate are often observed in areas where they move to avoid immersion or, presumably, to find more preferable habitat; however several studies have shown that mussels on average move very little throughout the year (2.9m/yr [Balfour and Smock, 1995]; 0.6cm/day [Amyot and Downing, 1997]). Amyot and Downing (1998) reported that most lateral movement occurs during reproduction. Mussels are also known to bury in winter (Balfour and Smock, 1995; Amyot and Downing, 1997), as well as in response to environmental stress (Sparks and Strayer, 1998).

Unionid species (and individuals within species) attain sexual maturity at different rates, but most probably start reproducing between three and five years of age. Reproduction is initiated when male mussels release sperm into the water column. If the sperm happens to be siphoned from the passing water by a female, then fertilization of the eggs (held in the female’s gills) will occur. A few species exhibit hermaphroditism (male and female sexual organs in the same individual). The embryos develop within the gills until they are ready for release as glochidia (larval stage). This brooding time varies among species but generally follows one of two strategies: 1) tachytictic brooders, or “short-term” brooders, hold their glochidia for several weeks to several months, with development starting in the spring/summer and glochidial release occurring in the summer/fall, or 2) bradytictic brooder, or “long-term” brooders hold their glochidia for development over winter, with development generally starting in the summer and release occurring the following summer. However, glochidial release timing and frequency (more than once per year) appears to be a function of water temperature (Watters, 2000). The glochidia are unique in that in they require attachment to the gills or fins of a fish host to complete metamorphosis from the larvae stage to a juvenile mussel (except in the salamander mussel [*Simpsonaias ambigua*], which uses the mudpuppy as a host). Often, only one or several fish species act as successful hosts for each unionid species, which clearly confounds the success of offspring survival. To increase the likelihood of host/parasite interactions, various mussel species have evolved extensions of the soft mantle tissue near the siphons (which can mimic aquatic insects and fish) or develop mucoid strands or structures (super conglutinates) that lure potential hosts nearby to increase the likelihood of larval attachment (Haag and Warren, 1998; Hartfield and Butler, 1997). Glochidial transformation on the fish host occurs within one week to many months (Cummings and Mayer, 1992), depending on the mussel species. Newly transformed juveniles are then sloughed off by the fish host and settle in the substrate; unfortunately, little is known about juvenile habitat requirements.

In general most unionid species prefer waters with moderate flow conditions and a heterogeneous mixture of substrate composed of larger particles (e.g., cobble and large gravel) for substrate stability and smaller particles (e.g., small gravel, sand and small amounts of silt or clay) that allow for burrowing into the substrate. Mussels are uncommon in high velocity areas because they are subject to dislodgement from the substrate, and juveniles are prohibited from settling. Additionally, most unionid species are not usually found in unstable substrate (Cvancara, 1972; Strayer and Ralley, 1993) or depositional areas (slow flow) because soft or shifting substrate can smother the mussels (Ellis, 1936; Fuller, 1974). The distribution of mussels in streams is generally patchy (Downing and Downing, 1992), and is a culmination of such factors as host fish distribution, larval settlement conditions, and a complex combination of hydraulic variables (e.g., shear stress) at varying levels of flow (discharge) conditions (Layzer and Madison, 1995). However, despite our inability to accurately predict unionid distribution based on microhabitat characteristics (Strayer and Ralley, 1993), the relationship between general hydrologic conditions and general species composition is certainly apparent (Vannote and Minshall, 1982; Cummings and Mayer, 1992; Watters, 1994; Di Maio and Corkum, 1995). In most lotic (riverine) systems, mussel distribution across the stream channel is often concentrated in a longitudinal (upstream to downstream) “band” between the bank and main channel. Habitat near the bank is typically limited by slow flow, sedimentation, temperature extremes, and possible emersion (during low flow); whereas habitat in the stream channel’s deepest area (thalweg) is limited by erosive velocities, scour, and relatively impervious substrate.

Unionid species have adapted in a variety of ways to deal with various habitat conditions. The most apparent, and perhaps important, traits are modification of the shell to facilitate processes such as burial (or non-burial), anchoring, and anti-scouring. The shell is composed internally of calcium carbonate (primarily nacre) with an external proteinaceous covering (periostracum) that prevents dissolution of the shell in freshwater. The great variety of shell sizes among species (e.g., several centimeters to over 300mm length) is the most obvious indication of habitat differentiation. For example, intra-specific (within a species) and inter-specific (among different species) shell length tends to increase with stream size; shell obesity (width) is positively correlated with stream size and negatively with water velocity (Rhoads and Lutz, 1980). More specifically, alterations in individual shell morphometry have been linked with habitat conditions such as flow (Green, 1972), substrate (Bailey et al., 1983), and various aspects of water quality such as temperature, pollutants, water hardness, and pH (Bailey and Green, 1988; Hinch et al., 1989; see also review by Tevesz and Carter, 1980). Other morphological variations of the shell include sculpture or ornamentation in the form of knobs, pustules (bumps), ridges, and ripples, which assists with burial, anchoring, or reduction of sediment scouring around the shell (Watters, 1994). Some species can exhibit sexually dimorphic shells characteristics, whereby the posterior-ventral margin of the shell is inflated in females due to outward pressure from the marsupial gills filled with glochidia; however, this differential shell morphology is not believed to have any adaptive advantages for such species.

Unionids can alter many important abiotic and biotic characteristics of freshwater ecosystems (Vaughn and Hakenkamp 2001, Gutiérrez et al. 2003). For example, unionid mussels remove substantial amounts of sediments and phytoplankton from the water column as they filter feed (Strayer et al. 1994, Strayer et al. 1999), and they influence the benthos by disturbing sediments during burrowing, depositing pseudofeces, and excreting wastes (Vaughn and Hakenkamp 2001, Vaughn et al. 2004). Furthermore, unionids shells in mussel beds in fine-grained sediments provide a complex physical structure inhabited by benthic invertebrates and fish (Beckett et al.1996, Gutiérrez et al. 2003). Also, large densities of live mussels may have a substantial influence on substrate compaction and potentially erosion (Zimmerman and de Szalay 2007).

Threats to Upper Ohio River Basin Unionids

Sand and Gravel Mining

For the aggregate industry, the Allegheny and Ohio Rivers provide a well sorted source of sand and gravel. Typically, these resources are mined by dredging operations that permanently destroy or severely modify existing habitat suitable for mussels. This practice originated long ago at a time when most natural resources were managed very differently. Today, the U.S. Corps of Engineers still approves such operations but is placing increasingly stringent restrictions on them. In many parts of the country, including Pennsylvania, aggregate dredging occurs within known habitat of freshwater mussel species that are federally listed as endangered. Currently, the District has approved sand and gravel dredging for the Allegheny River (Mile 0.0 - 69.5) and the Ohio River (Mile 0.0 - 40.0). Impact of dredging operations on freshwater mussels and their habitats are well understood and well documented. Primary Impacts are habitat destruction and direct killing of dredged mussels of all ages (Aldridge, 2000; Marking, 1979; Yokley, 1976). Secondary Impacts include downstream siltation, displacement of host fish, and destruction of host fish spawning areas (Aldridge,1987; Brown and Curole, 1997). Ecological impacts of habitat destruction are wide spectrum (deepening and reconfiguration of bed, reduction in oxygen levels, decrease in water circulation) and result in macroinvertebrate decline and decline of all species (especially fish) that feed on them (Nelson, 1993; Thorp and Covich, 2001; USACE 2006; Watters, 2000).

River Navigation

The U.S. Army Corps of Engineers owns, operates and maintains approximately 200 miles of navigable waterways and 23 navigation locks and dams on the Ohio, Allegheny and Monongahela Rivers in Western Pennsylvania. The Port of Pittsburgh is the second busiest inland port in the nation and the 13th busiest port of any kind. At 52 million tons of cargo per year, it is larger in tonnage than Baltimore, Philadelphia and St. Louis. The port's extent encompasses an eleven county area in southwestern Pennsylvania and supports more than 200 river terminals and barge industry service suppliers. On an annual basis, the port moves approximately $8 billion worth of goods, which equates to 53,000 jobs and more than $2 billion in income to the region. While its contributions to our economy are undeniable, the port's life and success is directly dependent on the efficient operation of the navigable waterway transportation system. In 2005, waterway traffic increased by 13 percent on the Ohio River and 16 percent on the Monongahela River and this trend is expected to continue (American Society of Civil Engineers, 2006).

Commercial shipping and its associated activities and structures present significant modifications to river ecosystem structure, species composition, and flow dynamics (Hartfield, 1993; Stein, 1972). Tow motor turbulence impacts the river bottom profoundly and in some cases (i.e. in a nine foot deep shipping channel) the propellers are very close to it. Shipping channels normally follow the thalweg (main channel) of a river. The thalweg, which is the deepest part of the river, is characterized by erosional hydraulic regimes and is often poor habitat for unionid mussels. Nearby mussel beds in shallow water can, however, be impacted by propeller turbulence and the load of silt it carries (Aldridge, D.W. 1987; Chaney, A. M. 1993). When dredging activities occur to keep the shipping channel open, to deepen it, or even form it, the impacts are likely similar to those of sand and gravel dredging. An additional product is dredge spoil, which can smother mussels (Marking, L.L. 1979), and must be disposed of with ecosystem integrity and mussel populations (beds) in mind.

Impoundments

Stream impoundment to create dams and locks have been shown to have substantial negative impacts on mussel populations (Vaughn and Taylor, 1999; Bates,1962; Blalock and Sickel, 1996; Harman, 1974; Suloway et al, 1981; Williams, Fuller, and Grace, 1992). Essentially, riffle and run habitats become pools with their attendant drop in water velocity, increase in silt accumulation (Chaney, 1993; Dennis, 1984; Payne, Miller, and Shaffer, 1999), and decrease in dissolved oxygen. Many of the more specialized and sensitive mussel species cannot tolerate these conditions. An often overlooked effect of stream impoundment on unionids is that they alter the species makeup of the fish community. Important fish host species typical of riffle and run habitats such as darters become replaced by lotic species such as catfish and exotic / invasive species (e.g., European carp). Unionids may be able to persist for decades within an area following impoundment, but they may effectively cease to reproduce due to an absence or scarcity of fish hosts (S. Ahlstedt, pers. obs.). Fish host species may be unable to negotiate the dams and subsequently the dispersal of mussels during their parasitic stage is hampered. Ultimately, host fish species can be eliminated from reaches of the river with subsequent extirpation of the mussel species that depend on them.

Exotic Species and Other Impacts

Over the decades, numerous species from other lands have been unintentionally and intentionally introduced into U.S. inland waters. The greatest recent impact was produced by a small bivalve mollusk (*Dreissena polymorpha*, the zebra mussel). Due to its rapid reproduction (a typical zebra mussel female produces 30,000 eggs per season) and dispersal via a planktonic larva, these animals have spread widely with the unwitting help of boaters, commercial traffic, fishermen, and others (Herbert, et al, 1991). They have led to the decline of unionid mussels because the zebra mussels attach to unionid shells, sometimes by the thousands, and suffocate indigenous mussels (Ricciardi, Whoriskey, and Rasmussen,1995; Ricciardi, Whoriskey, and Rasmussen,1996; Nalepa,1994; Haag et al, 1993). Most of the unionids in Lake Eire have been extirpated by this introduced pest, and Ohio River unionid populations continue to be negatively affected.

Another introduced species is the Asian clam, *Corbicula fluminea*, which was intentionally brought to North America in the early 1900’s as a food item. It occurs widely in Pennsylvania waters and may displace indigenous unionids. Whether the displacement is through competitive exclusion or simply because Asian clams came to occupy habitats where unionids were extirpated remains uncertain. Many exotic fish species also occur in Pennsylvania rivers and lakes. The danger these animals pose to unionids is that they are often extremely competitive and will drive indigenous fish species away from their habitats. This means that the usual fish host for many unionid species will decline in numbers or become unavailable. One of the newest fish threats to unionids and native gastropods is the Asian black carp (*Mylopharyngodon piceus*) which was brought to the U.S. for various uses but primarily to control snails in aquaculture. This species is a molluscivore and has specialized pharyngeal teeth capable of crushing relatively large snails and unionids. The species has escaped from aquaculture and is currently known from locations within the Mississippi and lower Ohio River.

Point-source and Other Threats to Unionid Mussels

Similarly, industrial point source pollution effects have been well documented by the above authors. These threats can manifest as continual or intermittent discharge or as a single event that is associated with an accident or lack of maintenance,

Oil and Gas Operations

Since Drake's first oil well at Titusville (1859), petroleum extraction, transportation, and refining operations have been part of Western Pennsylvania's countryside. Potential impacts of these operations occur through accidents that produce oil spills, through brine spills, and by pipeline construction, maintenance, and leaks. Toxicity of crude oil and brine to aquatic life has been established (Hart and Fuller, 1974; Commonwealth of Pennsylvania, Department of Environmental Protection, 1998; Andreasen and Spears, 1983).

Railroad and Roadway Crossings

Bridge construction (Stein, 1972) and maintenance or replacement, spills from either road or rail hazardous carriers, and road salt application all provide threats, albeit sometimes unpredictable ones, to freshwater mussels. Vehicle and railway accidents can cause significant damage to unionids and their habitat (G. Zimmerman, unpub. data; Virginia Department of Game and Inland Fisheries, 2008).

Municipal Wastewater

Municipal wastewater discharge (see below) and it's deleterious effects on streams and the biotic communities in them has been well documented (Fuller and Hart, 1974) In addition to carrying toxins and nutrients, wastewater is chlorinated before it is discharged or can simply be inadequately treated.

Another serious threat to stream water quality is the Combined Sewer Overflow (CSO). According to the U. S. Environmental protection Agency (2008): "Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies. These overflows, called combined sewer overflows (CSOs), contain not only storm water but also untreated human and industrial waste, toxic materials, and debris. They are a major water pollution concern for the approximately 772 cities in the U.S. that have combined sewer systems."

Coal Mining, Washing, and Distribution Operations

The coal industry impacts streams in a number of ways. Extraction can produce acid mine drainage, which creates unsuitable habitat for freshwater mussels and many other aquatic species. Washing operations produce coal slurry, a suspension of fine coal dust and its attendant toxins (including sulfur, arsenic, and heavy metals). Accidental discharge of coal slurry into streams can have serious consequences (Ludlow, 2008). Coal slurry contains fine particulate matter that clogs the feeding apparatus of mussels, and additionally contains toxic components such as arsenic and mercury that adversely affect mussels' health (Ludlow, 2008).

NonPoint Source Pollution

Nonpoint sources of stream degradation are often difficult to identify and include lawn care chemicals, ineffective septic systems, improper disposal of various chemicals, runoff of agricultural chemicals (fertilizers, pesticides, and herbicides) and poorly managed golf courses. Poor construction practices, aggressive farming techniques, allowing livestock free access to sensitive streams all contribute damage to unionid mussel populations.

METHODS

Semi-Quantitative Survey Design

Surveying methods were based on methods provided in the District's Scope of Work (May 29, 2008) and data collection methods were based on the District's scope. The purpose of the survey design was to:

1. Reliably detect mussel concentrations within the sampling area with good repeatability within sites and between sites;

2. Provide a semi-quantitative method for determining relative abundance information so that any mussel resources encountered could be accurately mapped;

3. Collect habitat (observed substrate type %) and depth concurrent with mussel searches;

4. Detect the presence of mussel resources in the general vicinity using bank searches for middens and other mussel concentrations.

These methods did not result in a precise mussel concentration (density) estimate or exact substrate composition data; that would have required quantitative sampling and a much greater level of effort. However, due to the high level of mussel survey experience among divers (>100hrs of survey experience for most divers), data collection was expected to be consistent (and therefore, comparable) and meet the goals of identifying important mussel concentrations and habitat.

A total of 35 transects were established perpendicular to flow between Ohio River mile 1.7 in Pittsburgh, Pennsylvania, and 34.4, near Shippingport, Pennsylvania (Figure 1). The study site locations were initially based on 35 locations provided by the District as part of the scope of work. Each proposed site location was pre-screened using both field and desktop methods. The proposed locations were first compared to available data prior to field operations. ES examined the locations in relation to available river bathymetry data, navigational charts, and best scientific judgment within a GIS (ESRI ArcGIS9.1) using their best scientific judgement. Most sites were considered suitable for study. Approximately 30% of the proposed site locations were relocated a few hundred meters or to the opposite bank based on available river bathymetry as well as their proximity to possible sources of artificial and natural riverbed disturbance (e.g., barge fleeting areas and upstream tributary confluences). The revised sites were then plotted in the GIS and transferred to the dive vessel's navigation system.

A second level of site screening was performed in the field by the Field Manager prior to diving. Pre-determined coordinates of each proposed site were used by the Team to navigate to each general location using the boat's onboard GPS / depth sounder (Garmin GPSmap 178c Sounder). The diving team then used the dive vessel's depth sounder to examine the river bottom for several hundred to one thousand meters upstream and downstream from the proposed site. The river bottom profile (from the shoreline to riverward), shoreline, and surrounding land use was examined for features that might positively or negatively indicate the presence of unionid concentrations. Bottom profiles that appeared to be very irregular and/or very deep (>30ft) were generally considered poor habitat for mussels as the area was assumed to contain large substrates or debris (e.g., boulder or sunken barges), or to have been commercially dredged. Municipal and industrial discharges were also avoided. In contrast, bottom profiles that were relatively shallow (<25ft) and showed an even or gradually sloped profile were considered likely habitat. Areas near bridges and pipelines were also considered likely habitat for unionids, as these areas are off-limits to gravel mining. In a few cases, site locations were moved due to the proximity of municipal and industrial intakes because of diver safety concerns. Due to the high level of pre-screening that was performed prior to diving operations, it was unnecessary to move any transect because of strong evidence of gravel mining or dredging.

Diving and Search Methods

Diving operations were performed following the EnviroScience's S*afe Practices Manual for Diving and Underwater Operations* (on file with the Pittsburgh District). All diving operations used a minimum of a five-person dive team. A Dive Plan, Anticipated Hazards Analysis, and dive team member qualification summary, was pre-approved by the District Diving Coordinator (Mr. Gary Householder), and on site by the District Diving Inspector (Mr. Charley Weight).

Diving was conducted by one surface supplied air (SSA) diver using a Kirby Morgan (17B, 27K, or 57) diving helmet with full duplex (two-way) diver to surface and diver to diver communications. A standby diver was suited with a harness and prepared to dive in the event of a stricken diver. The dive vessel was a 24ft open johnboat with a landing craft style bow for diver water entry and exit and a 150hp outboard engine. Although the vessel was not anchored for most of the surveys, "liveboating" techniques were not used as the engine was never in operation while the diver was in the water. Typically, the diver entered the water at the shore and proceeded along the transect riverward, pulling the dive vessel along the transect in the process.

Diving transects consisted of weighted lines marked in 10.0m (32.8ft) increments with the zero mark placed at the water's edge. The start and end points of the transect were recorded by DGPS (Trimble GeoXT). In the event of poor satellite reception at the bank, an offset DGPS point was collected at a known distance from the transect start by using a rangefinder or the dive vessel's GPS. All transects were a minimum of 100m long. However, most transects were extended to 150m or more because we suspected that the 100m transect length did not adequately sample habitats located mid-river that were holding some mussels. In some cases (e.g., Site 12, Site 15) transects were extended completely or nearly completely across the river.

Diving mussel searches were completed along the bottom following transect lines perpendicular to the flow of the river. Divers searched the river bottom visually and by feel, regularly sweeping away silt and excavating the substrate (one to two inches) for buried individuals by hand. All mussels (live and dead) were placed in a mesh bag with each 10m x 1m (L x W) sample along the transect being kept discrete from other samples. If the diver found two or more mussels within a $1m^2$ area, the information was reported to topside and noted. Each 10m segment required a minimum of 5min, however less time was spent in unsuitable habitat (*i.e*., trees, unstable sand, concrete, rip-rap). More effort was expended in areas of suitable habitat (stable mud, sand, gravel, or cobble mixes) or where mussels were detected. Relative substrate composition (percent substrate size; modified Wentworth Scale) of each habitat was estimated by the diver and reported to topside via two-way diver/tender communications. Depth readings were also regularly collected using a pneumofathometer and using the dive vessel's depth sounder. Shoreline searches for spent mussel shells and mussel middens were also performed 80m upstream and downstream from each Site.

Mussel Handling Procedures

Collection bags were returned to the boat with the diver and the samples were processed by a trained malacologist. All live mussels were identified, counted, measured, and sexed (sexually dimorphic species only) and their location on the transect noted. All dead shells were scored as either fresh dead (lustrous nacre, dead <1yr), weathered dead (dull or chalky nacre, dead one to many years), or subfossil (heavily weathered and fragmented, dead many years to many decades) and noted as present. Live mussels were kept submersed in ambient river water or in live wells before and after processing. Mussels were kept cool and moist during processing and were not out of the water more than five minutes. All live mussels were returned to the exact area of their collection. Digital images of most mussel species were taken as well as images of representative site habitats and riparian vegetation. The presence and abundance of zebra mussels (*Dreissena polymorpha*) and any remnant zebra mussel byssal threads was noted and recorded. Representative specimens of snail species were also collected when available.

Quality Control

To maintain high quality data, two measures of quality control were implemented to ensure thorough mussel collection and accurate habitat assessments by the divers. First, the project malacologist (Mr. Gregory Zimmerman) conducted an orientation on proper search methods and habitat assessment to standardize data collection and reduce diver bias. Second, all divers on this project had previous experience with mussel searches and were familiar with the methods and protocol. A diver proven to effectively collect mussels (*e.g.*, Mr. Matthew Walsh; >200hrs survey experience) periodically confirmed the survey work of the other divers and during the survey the results of his survey transects were compared to the results of other divers collecting in similar areas. All divers were found to produce similar results in terms of catch per unit effort, when in similar and nearby habitats (e.g., Figure 3; note mussel abundance follows a consistent trend from upstream to downstream despite different collectors).

RESULTS AND DISCUSSION

Survey Conditions

Field surveys were completed August 19th – 29th and on September 4, 2008. Field conditions were very good during the course of both field events; river flows were below normal and river visibility was good (>45cm on bottom). Working visibility on bottom was often less than optimal once the bottom was disturbed due to the silty nature of the areas being surveyed and low river flow. The weather was sunny to partially cloudy, and warm with a light wind (<5mph). Air temperatures averaged between 70^{o} - 85^{o} F (21.1^{o} – 29.4^{o}C), and water temperatures were between 74^{o} - 79^{o}F (23.3^{o} – 26.1^{o}C).

Summary of Unionids Collected within the Study Area

Overall, the mussel community was found to be relatively low in terms of density and diversity relative to other mussel communities recently surveyed farther downstream within the middle Ohio River (e.g., Ecological Specialists 2000; EnviroScience 2007a) and within the navigable pools of the Allegheny River (e.g., EnviroScience 2007b). No evidence of federal or state endangered or federal candidate species was detected. Most of the study area was found to have a low relative density of mussels or no mussels at all. Assuming a 50% efficiency, mussel density rarely reached or exceeded an estimated 0.4 mussels / m^2 (Figures 2 - 7).

A total of 110 live mussels were collected representing six species from all sites and all methods (Table 1). Two additional species, the fragile papershell (*Leptodea fragilis*) and the deertoe (*Truncilla truncata*) were collected from fresh dead shell material only. The pink heelsplitter (*Potamilus alatus)* was dominant (51.8%) and the mapleleaf (*Quadrula quadrula)* was subdominant (37.3%). Together, those two species in addition to the threehorn wartyback (*Obliquaria reflexa*) (7%) comprised over 96% of all mussels. Two live fawnsfoot (*Truncilla donaciformis*) were also collected and this should be noted due to this species' state status of "unknown" within Pennsylvania and its extremely small size (<40mm). The deertoe is also of interest as it is currently listed as "extirpated" within Pennsylvania. The deertoe and threehorn wartyback are both species proposed by the USFWS, PFBC, and the Adaptive Management Group (Appendix A) as indicator species indicative of flowing water and large river habitats where federal and state protected species may occur. Individual survey results for the Emsworth, Dashields, Montgomery, and New Cumberland pools are provided in Tables 2 - 5, respectively. Representative digital images of selected mussel species are included in Appendix B.

Unionids were detected in a wide variety of habitats at an average depth of 11.5ft, and a maximum depth of 26ft. Most mussels (78%) were found in 15ft of water or less (Figure 8). Mussels were not limited to shoreline areas and approximately 48% of the individuals collected were 50m or greater from shore. Habitat availability did not appear to be a limiting factor in mussel distribution. Live mussels were, on average, associated with substrates composed of 17% silt, 22% sand, 20% gravel, 18% cobble, 17% boulder, and 6% other (mud, wood, and bedrock). Sand and to a lesser extent cobble appeared to be the best predictors for mussel presence. Transect segments associated with mussels were found to have, on average, 15% more sand and 4% more cobble than non-mussel sites. Segments without mussels were found, on average, to be composed of 7% more mud and 5% more boulder than sites with mussels. Many of the areas investigated appeared to have large amounts of suitable but largely unoccupied habitat (e.g., Site 14). Most of the substrate compositions between and within sites were similar; therefore care should be taken when interpreting the substrate data relative to mussel presence or absence due to the qualitative nature of the data.

When compared to other areas of the Ohio River, the study area likely has relatively fewer mussels and fewer species per unit of effort. For example, Ecological Specialists (2000) showed 18 or more live species of unionids collected from between the Hannibal and Meldahl pools during various studies between 1969 and 1999. In contrast, evidence of only eight species was found during this project. Of note, the same document reported that eight live species were collected from the New Cumberland Pool; four of which were not collected in the present study; bringing the total "recent" (since 1969) species count for that pool to nine.

Live zebra mussels (*Dreissena polymorpha*) were common on live unionids within the the study area and, in particular, the New Cumberland Pool. Old zebra mussel byssal thread scars were present on most of the mussels encountered (Appendix B). Zebra mussels may have a significant negative influence on the local mussel population within the New Cumberland Pool. Many live and fresh dead unionids there were found with up to 10% of their total area infested by zebra mussels.

Summaries of the mussel species collected, their location, and their respective proposed state status for all sites are presented in Table 1. Few species were found to be actively reproducing with the exception of the threehorn wartyback and mapleleaf, as evidenced by small individuals (Table 1; Appendix C). However, because the sampling method was tactile, smaller individuals (e.g., fawnsfoot) were more likely to be overlooked. The fawnsfoot and deertoe may be expanding their range within the project area based on their presence within the project area and recent nearby observations. In 2008, EnviroScience found that the fawnsfoot was one of the most common species in Pool 2 of the Allegheny River, at NM 12.5 and composed 60% of the mussel fauna. The deertoe was also observed to be expanding its range within the upper Ohio River by Ecological Specialists (2000). Both the fawnsfoot and deertoe largely utilize freshwater drum (*Aplodinotus grunniens*) and sauger (*Sander canadensis*) as fish hosts which may, likewise, be expanding or recovering within the project area.

The individual narrative results for each group of sites within each Ohio River pool is provided below. The potential for native unionid populations within each pool of the Ohio River was tentatively categorized as:

1. Poor. Based on a limited number of sampling locations, the area was found to sustain only a very low (≤1 mussel / 100 linear meters of diver search effort) level of non-listed / non-sensitive unionids although suitable habitat was present. Threatened and endangered species were considered not likely to be present within the reach. While the area may warrant some further study, other areas should receive a higher priority.
2. Marginal. Based on the limited number of sampling locations, the area was found to sustain areas of low (≤ 3 mussels / 10 linear meters of search effort) levels of mussel resources, including some indicator species and / or suitable habitat. The area may warrant further qualitative studies to define the extent of mussel distributions and species present, however; relatively dense (>1 mussel /m^2) mussel concentrations appeared to be uncommon and the possibility of threatened and endangered species appeared to be unlikely.
3. Fair. Some areas were found to sustain at least moderate (≥ 3 mussels / 10 linear meters of search effort) concentrations of unionids, including indicator species and suitable habitat. The area likely warrants further studies to define the extent of mussel distributions including relatively dense (>1 mussel /m^2) concentrations, and possible sensitive, threatened, or endangered species.

Emsworth Pool Sites 1 – 6 (NM 1.7 – 5.2)

The Emsworth Pool mussel community was considered to be “poor” in terms of a resident mussel community based on the five survey locations investigated (Figure 2). Only one live fatmucket (*Lampsilis siliquoidea*) and one fresh dead pink heelsplitter were encountered (Table 2). The locations and relative distribution of mussel resources encountered within the Emsworth Pool are presented in Figure 2. Detailed results for the Emsworth Pool, including species composition, status, relative abundance, and size structure of unionids are presented in Table 2. A general description of each site within the pool is provided below in Table 6.

Table 6. Summary of Method and Results for Each Site within Emsworth Pool.

~NM	Bank	Site	Description	Type(s)	Length (m)	Mussels
1.7	Island	1	West channel of Brunot Island	Transect	100	0
2.4	Left	2	West channel of Brunot Island	Transect	120	1
3.5	Left	3	Ohio River mainstem	Transect	150	0
4.5	Island	4	Upstream tip of Davis Island to Ohio River Mainstem	Transect	150	0
4.9	Island	6	Upstream tip of Neville Island to Ohio River Mainstem	Transect Spot Dive (2)	150	0
5.2	Right	5	Ohio River mainstem	Transect	100	0

The river substrate within the Emsworth Pool was found to include suitable mussel habitat and should be considered as a potential area for future habitat restoration. The average depth within transect segments was 16.8ft and the maximum depth was 28ft (Site 3). The dominant observed substrates were, on average, gravel (30%), cobble (25%) boulder (17%), and mud (11%). Other substrates, such as woody debris, were noted in minor percentages. The riparian zone was variable but included many large tracts of heavy industry.

Dashields Pool Sites 8 – 18 (NM 6.4 – 11.9)

The Dashields Pool unionid community was considered to be "fair" in terms of a resident mussel community based on the 12 survey locations investigated (Figure 3); however, this area likely merits further study. All live individuals were encountered in the upstream reaches of the pool near Neville Island; from below the Emsworth Locks and Dams (NM 6.2 mainstem and backchannel) to approximately NM 9.0. The upstream reach of the pool had many characteristics of suitable mussel habitat including clean-swept substrates in moderate river flow. No live mussels were encountered from the 4 sites surveyed downstream from NM 9.0 on the Ohio River mainstem (sites 11, 16, 17, and 18).

A total of 42 live unionids and 6 species (5 live + 1 fresh dead) were encountered including the fawnsfoot (Table 4). One additional live unionid was collected during a spot dive at Site 14. While some moderate concentrations of mussels were found in this river reach, it remains unknown why more mussels were not detected in this area considering the availability of suitable habitats. The locations and relative distribution of mussel resources encountered within the Dashields Pool are presented in Figure 3. Detailed results for the Dashields Pool, including species composition, status, relative abundance, and size structure of unionids are presented in Table 3. A general description of each site within the pool is also provided in the table below.

Table 7. Summary of Method and Results for Each Site within Dashields Pool.

~NM	Bank	Site	Description	Type(s)	Length (m)	Mussels
6.4	Island	14	Neville Island to Ohio River mainstem	Transect Spot Dive(2)	160	7
6.9	Island	15	Neville Island across mainstem channel to right descending bank	Transect	260	7
7.0	Island	12	Neville Island backchannel	Transect	170	8
7.5	Right	8	Ohio River mainstem	Transect	150	3
7.6	Island	12.5	Neville Island backchannel	Transect	100	4
7.8	Right	9	Ohio River mainstem	Transect	150	3
8.6	Island	10	Neville Island to Ohio River mainstem	Transect	150	3
8.9	Island	13	Neville Island backchannel	Transect	150	10
9.7	Island	16	Neville Island to Ohio River mainstem	Transect	150	0
9.9	Right	11	Ohio River mainstem	Transect	150	0
10.6	Right	17	Ohio River mainstem	Transect	150	0
11.8	Right	18	Ohio River mainstem	Transect	150	0

We completed an additional transect (Site 12.5) to increase sampling coverage because the Neville Island backchannel was found to have relatively good habitat and moderate concentrations of mussels upstream (Site 12) and downstream (Site 13) from there (Figure 3). Also, the proposed Site 7 and Site 15 were combined into a single 260m transect (Site 15) that went completely across the main channel between Neville Island (start) and to the right descending bank (end).

The river substrate within the upper Dashields Pool included suitable mussel habitat and some concentrations of native mussels, and therefore was considered a potential area for future habitat restoration, avoidance, or mitigation. The average depth within transect segments was 15ft in the mainstem of the Ohio River and 9.5ft in the backchannel of Neville Island. The maximum depth was 28ft (Site 17 and Site18). The dominant observed substrates were, on average, gravel (24%), cobble (22%) boulder (14%), and a relatively even mix of silt, mud, and sand (11%, 13%, and 13%, respectively). Other substrates, such as woody debris, were noted in minor percentages. The riparian zone was variable but included tracts of heavy industry residential, and urban land use.

Montgomery Pool Sites 19 - 31 (NM 13.5 – 29.4)

The Montgomery Pool unionid community was considered to be “marginal” in terms of a resident mussel community based on the 12 survey locations investigated (figures 4 and 4). Mussel distribution within the pool was patchy; with live mussels detected immediately downstream from the Dashields Locks and Dam at NM 13.3 (Site 19), and then again continuously between NM 16.7 (Site22) to NM 26.2 (Site 29). No live mussels were detected downstream from NM 26.2 within the Montgomery Pool (Figure 4). While mussels were consistently present throughout much of this reach, the relative abundance of mussels was very low; on average less than one mussel was found for every 100 linear meters of search effort.

A total of 17 live unionids and 4 species (3 live + 1 fresh dead) were encountered within the Montgomery Pool (Table 7). While some moderate concentrations of mussels were found in this river reach, it remains unknown why more mussels were not detected in this area considering the availability of suitable habitats. Direct evidence of commercial gravel mining was common (Appendix B) which may, in part, explain the irregular distribution and the relatively low abundance and diversity of unionids in this reach of the Ohio River. The locations and relative distribution of mussel resources encountered within the Montgomery Pool are presented in Figure 4 and 5. Detailed results for the Montgomery Pool, including species composition, status, relative abundance, and size structure of unionids are presented in Table 4. A general description of each site within the pool is provided below in Table 8.

Table 8. Summary of Method and Results for Each Site within Montgomery Pool.

~NM	Bank	Site	Description	Type(s)	Length (m)	Mussels
13.4	Right	19	Ohio River mainstem	Transect	200	1
13.9	Left	20	Ohio River mainstem	Transect	150	0
15.5	Left	21	Ohio River mainstem	Transect	150	0
16.7	Left	22	Ohio River mainstem	Transect	270	6
17.4	Right	23	Ohio River mainstem	Transect	150	1
18.1	Left	24	Ohio River mainstem	Transect	150	3
19.5	Right	25	Ohio River mainstem	Transect	150	2
22.5	Right	26	Ohio River mainstem	Transect	150	1
23.1	Right	27	Ohio River mainstem	Transect	100	1
24.2	Left	28	Ohio River mainstem	Transect	200	1
26.2	Left	29	Ohio River mainstem	Transect	150	1
27.9	Right	30	Ohio River mainstem	Transect	150	0
29.5	Right	31	Ohio River mainstem	Transect	100	0

The river substrate within the Montgomery Pool was found to include suitable mussel habitat and some low concentrations of native mussels, and therefore was considered a potential area for future habitat restoration. The average depth within transect segments was 19ft and the maximum depth was recorded as 54ft (Site 31). However, the depths recorded within Site 30 and Site 31 were later suspect and it was deemed likely that the boat's depth sounder was misaligned when those readings were recorded. The diver's pneumofathometer read approximately 20ft less during dive surveys. The maximum depth within the pool, excluding the suspected data, was 28ft (Site 28). The dominant substrate within many transect segments consisted of silt over top of cobble / gravel / boulder substrates; however the presence of heavy silt did not preclude the presence of mussels. The dominant observed substrates were, on average, silt (34%), gravel (18%), boulder (15%), and cobble (14%). Other substrates, such as woody debris, were noted in minor percentages. The riparian zone was variable but included tracts of industrial, residential, and suburban land use.

New Cumberland Pool Sites 32 - 35 (NM 31.8 – 34.4)

The New Cumberland Pool unionid community was considered to be “fair” in terms of a resident mussel community based on the 4 survey locations investigated (Figure 6). Mussels were consistently present throughout this reach at low levels with the exception of Site 32 which resulted in very high relative numbers of mussels per transect segment. Site 32 yielded 38% of all mussels found during the entire study and from within a relatively small area 0 to 70 meters from the right descending bank. Most mussels (~70%) were found in 10ft or less of water. A maximum of 10 mussels were collected per 10 linear meter segment at Site 32 (0m – 20m). An shell deposit containing several 100 fresh dead shells of the mapleleaf were found in a muskrat midden on shore, as well as two fresh dead deertoe.

A total of 49 live unionids and 5 species (3 live + 1 fresh dead + 1 weathered dead) were encountered (Table 9). The dominant species was the pink heelsplitter (61%) and the mapleleaf (35%) was subdominant. The locations and relative distribution of mussel resources encountered within the New Cumberland Pool are presented in Figure 6. Detailed results for the New Cumberland Pool, including species composition, status, relative abundance, and size structure of unionids are presented in Table 5. A general description of each site within the pool is also provided below in Table 9.

Table 9. Summary of Method and Results for Each Site within the New Cumberland Pool.

~NM	Bank	Site	Description	Type(s)	Length (m)	Mussels
31.8	Right	32	Ohio River mainstem	Transect	100	42
32.2	Right	33	Ohio River mainstem	Transect	100	1
32.6	Left	34	Ohio River mainstem	Transect	100	1
34.4	Right	35	Ohio River mainstem	Transect	150	5

The New Cumberland Pool was found to include suitable mussel habitat and some relatively high concentrations of native mussels (e.g. Site 32), and therefore was considered a potential area for additional studies, avoidance, mitigation, or future habitat restoration. However, only the upper section of this pool was investigated. The average depth within transect segments was 13.6ft and the maximum depth was recorded as 40ft (Site 32). The dominant substrate within many transect segments was silt over top of cobble / gravel / boulder substrates, however the presence of heavy silt did not preclude the presence of mussels. The dominant observed substrates were, on average, gravel (22%), silt (19%), and cobble (19%). boulder (16%), and mud (8%).

GIS and Electronic Work Products

Geographic Information System (GIS) software (ArcGIS 9.1) was used to compile the DGPS points and field notes into series of point shapefiles. A point theme was created that includes all habitat and mussel distribution information for every 10m of transect at the center of the respective segment. Each point contains information on substrate (percentage) and any mussel resources present including species, length, estimated density, and other recorded parameters. All shapefiles were created in WGS 1984, decimal degrees unless otherwise noted in the metadata. Shapefiles created for this project will be made available to the Pittsburgh District via FTP or CD-ROM. The GIS data files and Microsoft Excel database provided with this report contain highly-detailed mussel and substrate information for each site and from within each transect. This information should be useful as the District continues to evaluate various alternatives for the modernization of the Emsworth, Dashields, and Montgomery locks and dams.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Mussel communities within the study area were considered to be either “poor” (Emsworth Pool), “marginal” (Montgomery Pool) or “fair” (Dashields and New Cumberland pools) tentatively based on a combination of physical conditions, presence/absence of live mussels, and species diversity / composition. No sites, with the exception of Site 32 (New Cumberland), were found to meet or exceed Pennsylvania’s proposed criteria for protected mussel resources (Attachment A).

This project reasonably answered the four main project goals of the project, namely:

> *1) Is there potential native mussel habitat in the upper Ohio River and if so, is it occupied by freshwater mussels?*

The upper Ohio River was found to contain large areas unionid habitats, however these were largely unoccupied. Possible explanations include persistent or chronic water quality or sediment toxicity.

> *2) What are the native unionids inhabiting the upper Ohio River?*

The upper Ohio River was found to contain at least 8 extant species based on the present study (Table 1); all were found as either alive or fresh dead. A recent (2001) record of one additional species, the elktoe (*Alasmidonta marginata*) was found within the Montgomery Pool at NM 18 during a literature search of available data (see below). No evidence of federal candidate, threatened, or endangered species was detected. The deertoe was collected as fresh dead specimens only at Site 32 below the Montgomery Locks and Dam in the New Cumberland Pool. Based on the relatively few sites that were sampled relative to the size of the survey area, it is highly likely that other species will be detected from within the study area with additional survey work concentrating in areas of known mussel presence.

A number of other investigators and consultants are known to have completed similar surveys within the upper Ohio River study area (e.g., Aquatic Systems, CEC, Dinkins Biological Consulting, Jerry Diamond; Appendix D). Most of these surveys were conducted for commercial gravel mining operations and in some cases the methods and quality of the resulting data has been questioned by resource agencies (PennDOT Mussel Programmatic, in prep.). A review of over 24 mussel survey reports performed within the study area since 1996 by PennDOT indicated a total of 51 mussels from four species were collected within the Dashields, Montgomery, and New Cumberland pools. One species that was not detected during this survey, the elktoe (*Alasmidonta marginata*), was detected in the Montgomery Pool in 2001 by Aquatic Systems (2002). While it is difficult to compare the present study with these other, relatively recent surveys because slightly different locations were surveyed and different methods were employed, it is important to note that the present survey detected approximately twice the number of species and twice the number of individuals recorded from over 24 previous mussel surveys. Mussel species diversity and relative abundance as documented in this survey are obviously greater than previous studies have indicated.

> *3) What do the study results indicate for potential of native mussels in un-surveyed portions of the river?*

We designated each pool as either “poor”, “marginal”, or “fair” as to our best relative judgment of the potential of unionids within the study area. The Emsworth Pool appeared to have the least potential for unionids despite large areas of available habitat and at least 7 species of mussels being collected recently from the Allegheny River near the three rivers confluence (EnviroScience, 2002). The Montgomery Pool was found to have low, patchy concentrations of mussels and this area may deserve further study. The upper reaches of the Dashields Pool and the New Cumberland Pool were found to support low to moderately high (e.g., Site 32) concentrations of mussels and, in our opinion, demonstrated the highest potential for significant (>1 mussel / m^2) mussel populations and / or sensitive, candidate, threatened, or endangered species.

4) Do mussel concentrations occur in proximity to potential lock and dam improvement projects which may require additional sampling at a later date?

The tail waters of dams usually offer a number of attributes highly suitable for most unionids including; an availability of host fishes, oxygenated water, adequate river flow, clean swept substrates, protection from commercial dredging, and navigation traffic. All of the lock and dam tail water areas investigated appeared to have moderate to extensive amounts of suitable habitat for unionids; however most areas investigated in this study were largely unoccupied. Only the tail waters of the Emsworth and the Montgomery Locks and Dams were found to hold relatively low to moderate concentrations of mussels. These areas (including the restricted areas) will very likely require additional sampling to determine the extent, density, and composition of the resident unionid communities. As previously noted, unionid distributions tend to be related to overall hydrologic conditions and form “patchy” (Downing and Downing, 1992) communities. Therefore, a survey sampling method that employs better spatial coverage (more searches over more area) than what we used for this study should be employed in areas of suspected mussel resources. The design of the study should ensure that the level of sampling effort is adequate to meet the expected probability of target species detection (Strayer and Smith, 2003) and, if successful, provide better understanding of mussel distribution and relative density.

Recommendations for Future Study

Additional survey work will likely be necessary as part of the Upper Ohio River Study alternatives analysis process and to meet the requirements of state and federal resource agency review. Additional information may also be required to meet other federal reporting and permit requirements (e.g., NEPA). Using the methods of Strayer and Smith (2003) we based our recommendations on the following five considerations for the future study design:

1 *What are the potential study objectives?*

a) further define the distribution and composition of mussel resources within target areas of the study area (upper Dashields and New Cumberland pools);

b) identify areas of “significant” mussel resources (e.g., >0.5 mussel / m^2);

c) confirm, with at least 85% confidence, the presence or absence of target species (e.g., federal and state endangered species) within key areas (i.e., dam tail waters);

d) confirm the absence or relative absence of mussels from areas identified marginal or poor through additional sampling;

e) identify any other areas for screening (e.g., the Beaver River and other tributaries) that could potentially be affected by this project.

2 *What is the target population?*

a) unionids within the upper Dashields and New Cumberland pools

b) rare species (e.g., federal and state endangered species) that may exist at very low (<0.001 / m^2) densities

c) to a lesser extent, other locations within the project area

3 *What resources are available?*

a) unknown – resources will be best utilized by incorporating a stratified survey design where the most likely habitats (based on preliminary data) are given the most resources while other areas are surveyed using a similar method, just less intensively.

4 *What is known about the study area?*

a) water quality may be a limiting factor to unionids

b) areas known to have been recently commercially dredged are unlikely to contain mussels;

c) past mussel survey reports may be a useful resource to identify areas of potential mussel concentrations but may not necessarily indicate the absence of mussels.

5 *What is known about the mussel populations?*

a) mussel populations are usually of relative low (<0.5 / m^2) density;

b) most mussels (78%) are found in < 15ft of water but not limited to near bank areas.

Based on the above assumptions, results of this study, and our survey experience within the upper Ohio River and lower Allegheny River, we recommend that a stratified survey design be employed using transect searches as proposed by Smith (2006). We successfully used this survey design in Pool 6 of the Allegheny River to evaluate the effects of a large proposed discharge and detect for endangered species (EnviroScience, 2007b). Advantages of this method include:

1. Detection with a high probability of rare (T&E) species within the sampling area;
2. Provide a semi-quantitative method for determining relative abundance information so that any mussel resources can be mapped to the proposed alternative(s);
3. Collects habitat (observed substrate type %) concurrent with mussel searches;
4. Stratifies sampling effort so that most search effort is allocated to likely mussel habitats (i.e., depths ≤15ft);
5. Can be modified to cover a relatively large area;
6. Collects data in a systematic fashion conducive for GIS analysis and mapping.

Using the above method, the habitats within the study area would be stratified into units (i.e., poor, marginal, and fair; deep and shallow). More effort would be devoted to areas considered likely for mussel presence than to less likely areas. For example, 200 transects completely across the river could be completed in fair habitat, 50 in marginal, and 25 in poor habitat. The actual number of transects and spacing would depend on the available resources, the size of the target areas, and the desired level of rare species detection for a particular reach of the river. Another variation could include that only one of every three transects would extend beyond 15ft of river depth. Transect locations would use two - three random starts to prevent sampling bias. Other, alternative sampling methods that could be employed include “double sampling for stratification” (see Strayer and Smith, 2003), depending on the goals of the District.

In summary, the present study improved our basic of mussel resources and their distribution within the upper Ohio River. However, the results of the study are likely at too course a scale to preclude the presence of listed species or “significant” (>1 mussels / m^2) from some areas (e.g., Neville Island backchannel and downstream from the New Cumberland Locks and Dam). This information should be a useful asset to the Upper Ohio River Study and to the District as it further refines the data needs for this project.

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FIGURES

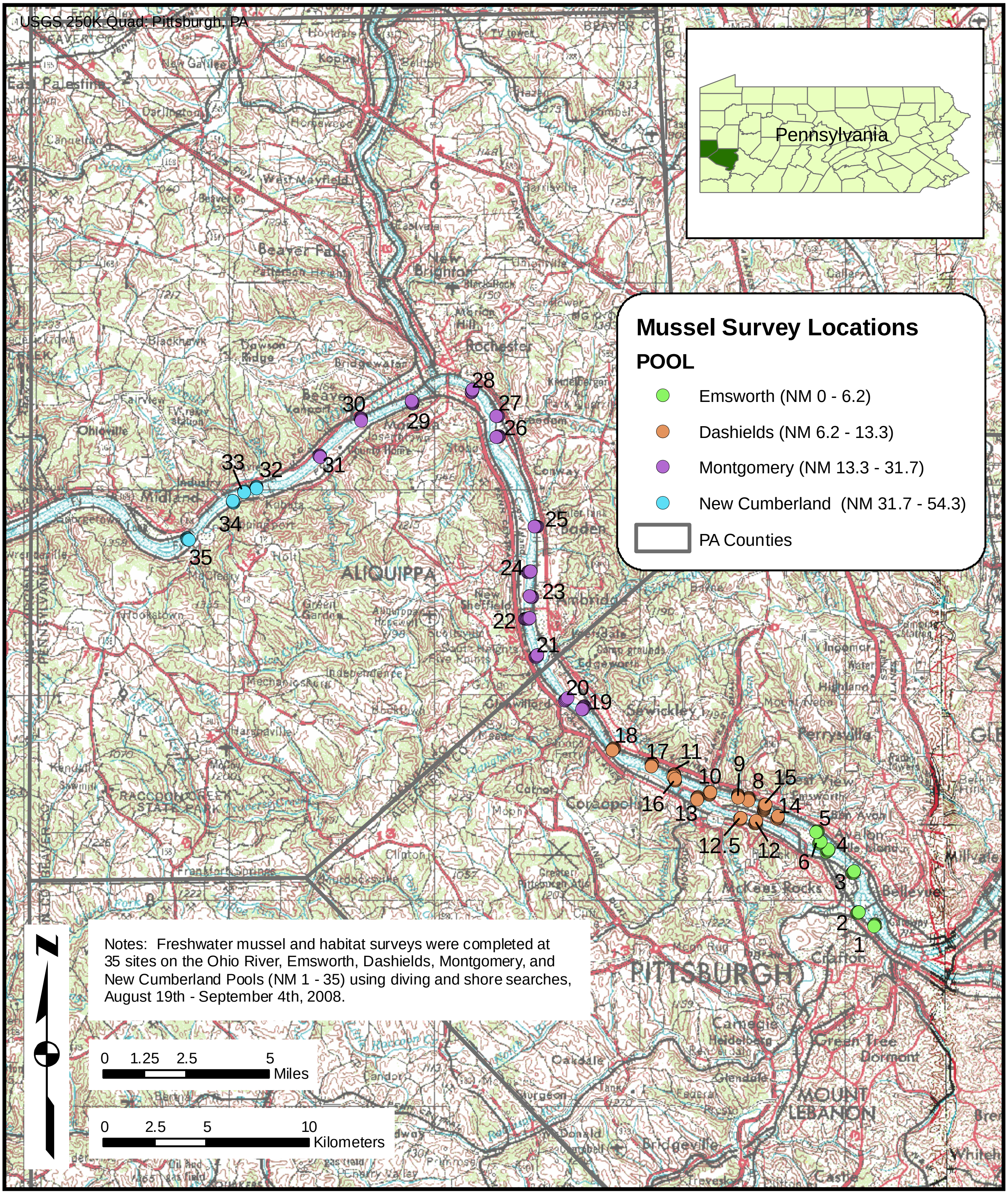


Figure 1. Site Locations by Ohio River Pool.

USACE Pittsburgh District
Upper Ohio River Mussel Screening

EnviroScience, Inc.
"Excellence in Ecological Monitoring"

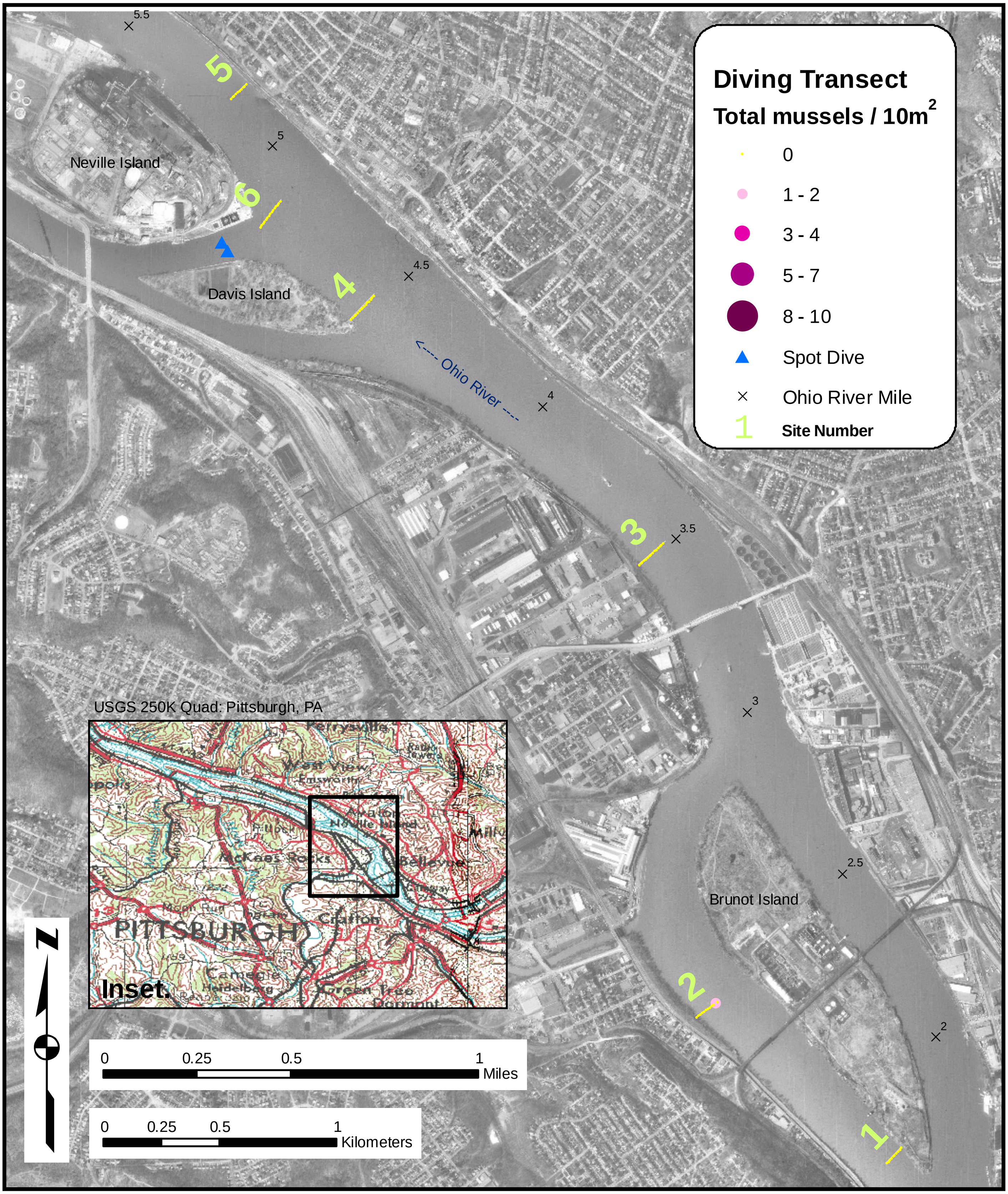


Figure 2.
Relative Mussel Distributions Emsworth Pool, NM 1.7 - 5.2.

USACE Pittsburgh District
Upper Ohio River Mussel Screening

EnviroScience, Inc.
"Excellence in Ecological Monitoring"

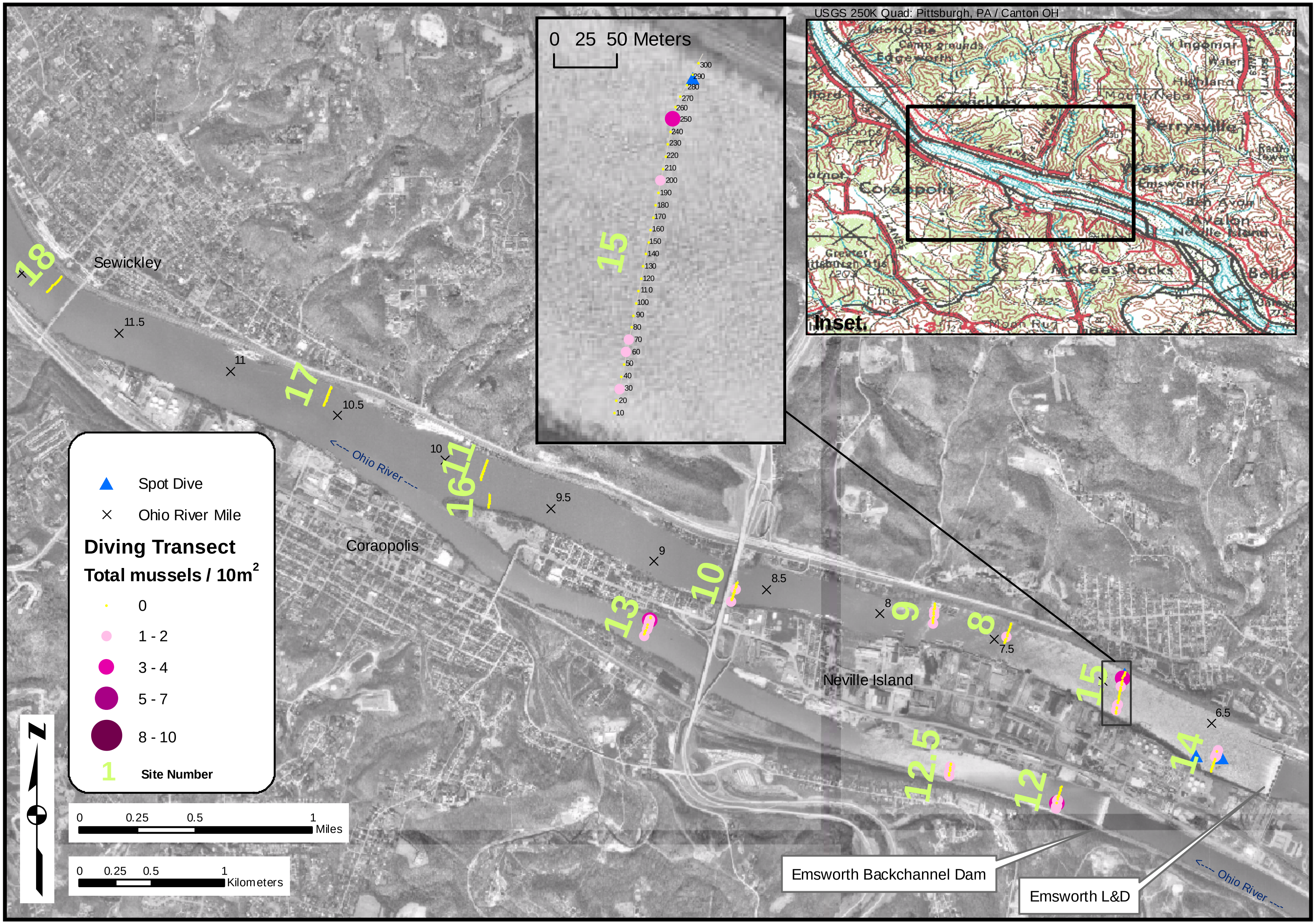


Figure 3.
Relative Mussel Distributions Dashields Pool,
NM 6.4 - 11.8.

USACE Pittsburgh District
Upper Ohio River Mussel Screening

EnviroScience, Inc.
"Excellence in Ecological Monitoring"

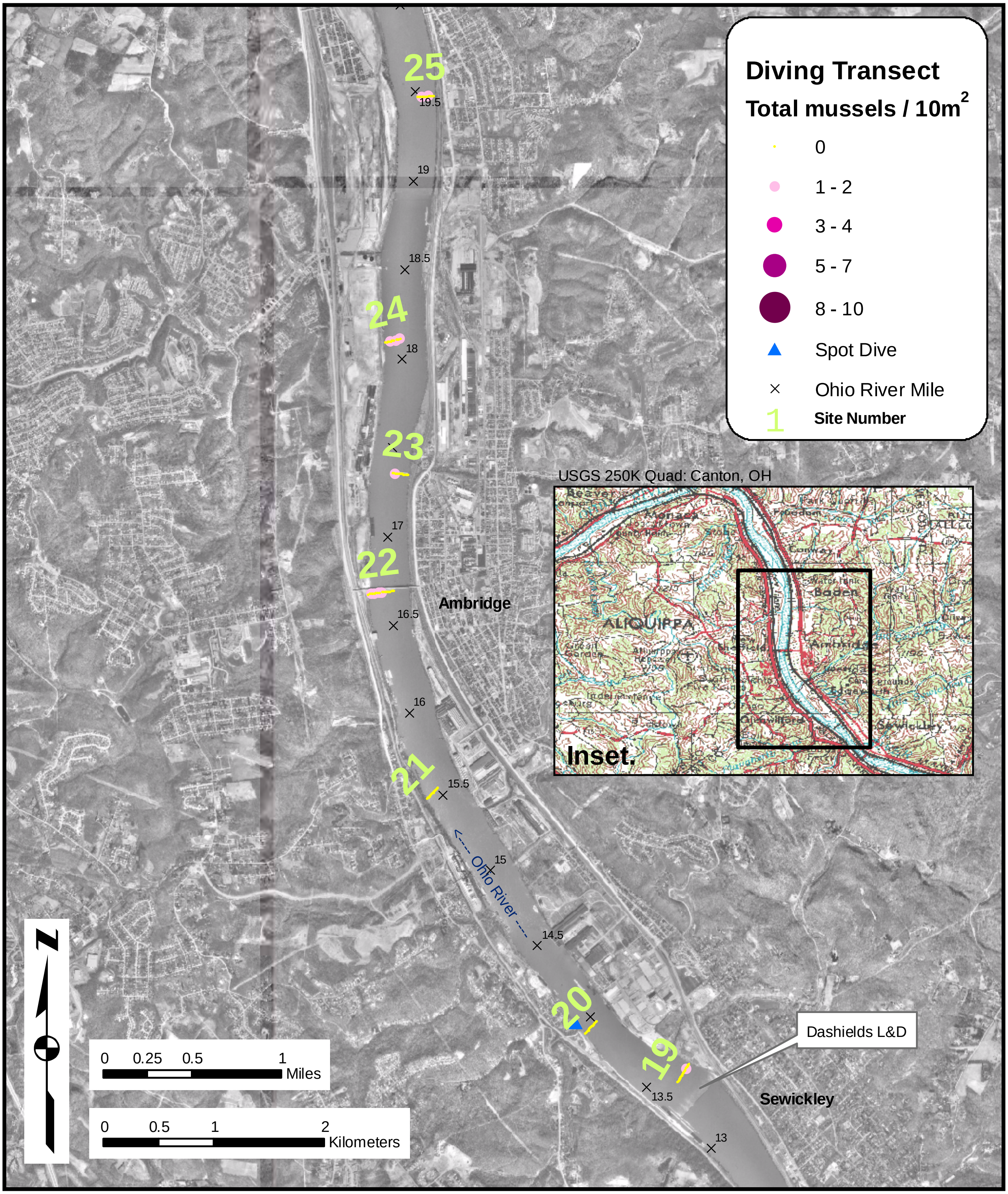


Figure 4.
Relative Mussel Distributions Montgomery Pool, NM 13.4 - 19.5.

USACE Pittsburgh District
Upper Ohio River Mussel Screening

EnviroScience, Inc.
"Excellence in Ecological Monitoring"

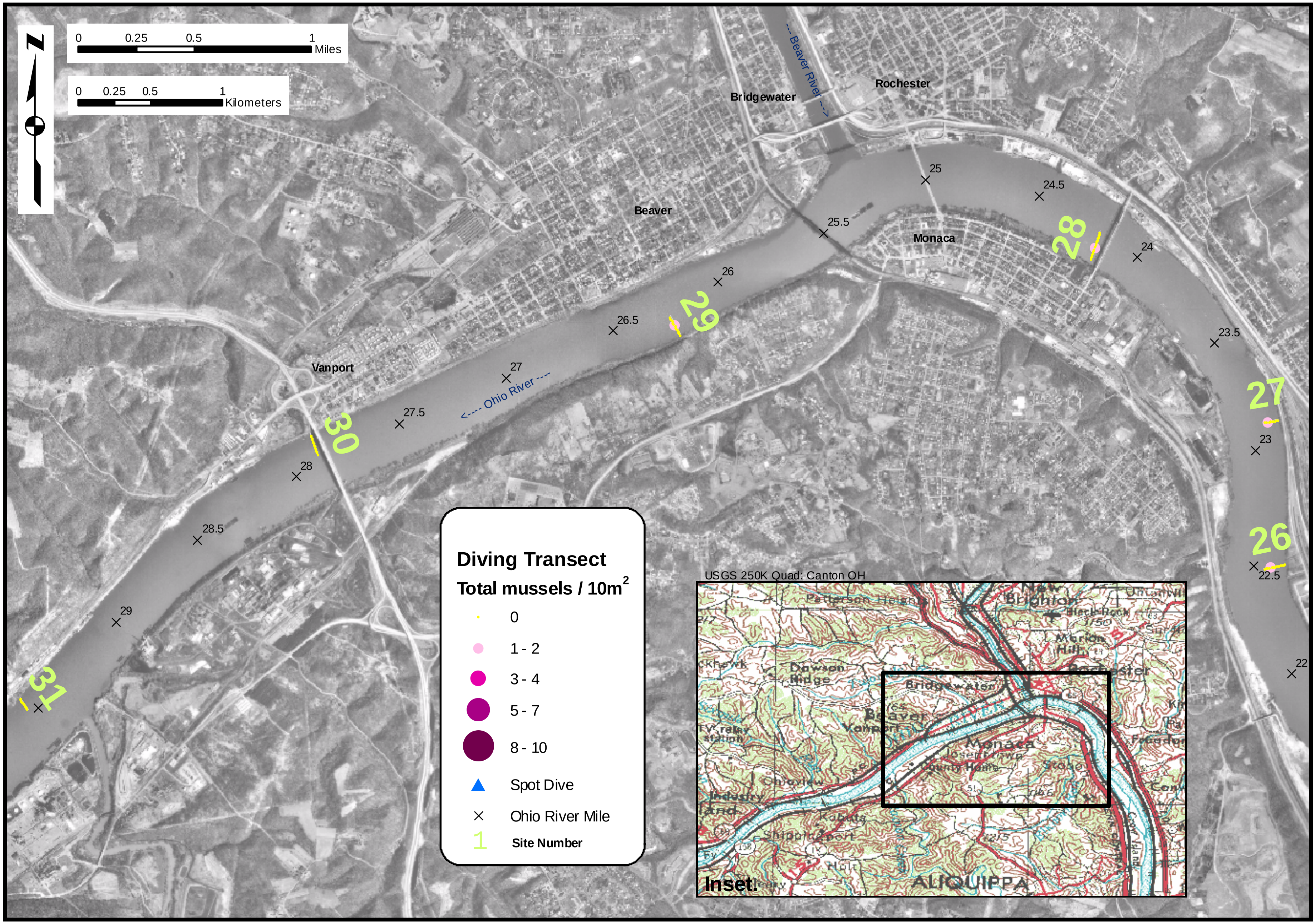


Figure 5.
Relative Mussel Distributions Montgomery Pool, NM 22.5 - 29.5.

USACE Pittsburgh District
Upper Ohio River Mussel Screening

EnviroScience, Inc.
"Excellence in Ecological Monitoring"

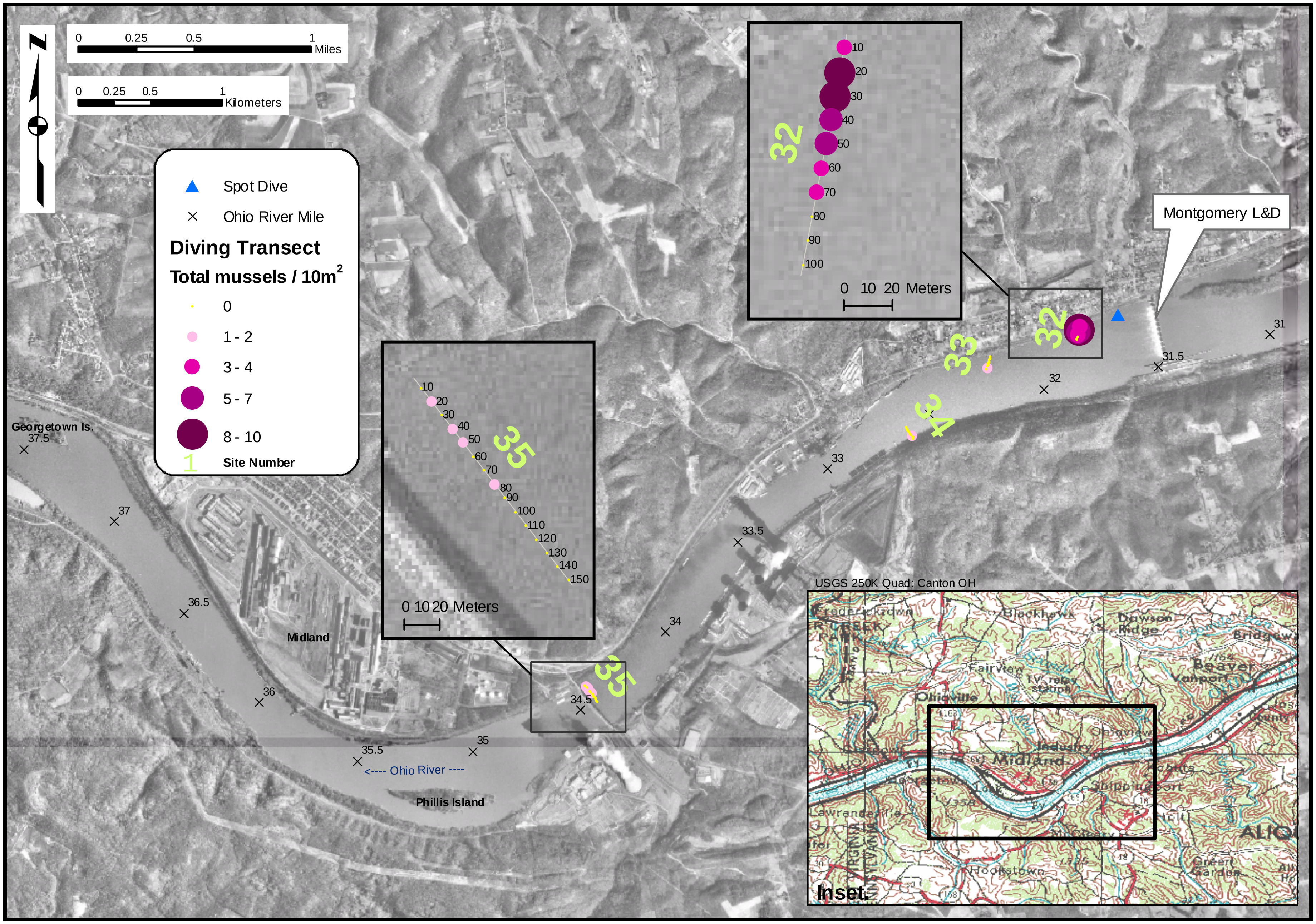


Figure 6.
Relative Mussel Distributions New Cumberland Pool, NM 31.8 - 34.4.

USACE Pittsburgh District
Upper Ohio River Mussel Screening

EnviroScience, Inc.
"Excellence in Ecological Monitoring"

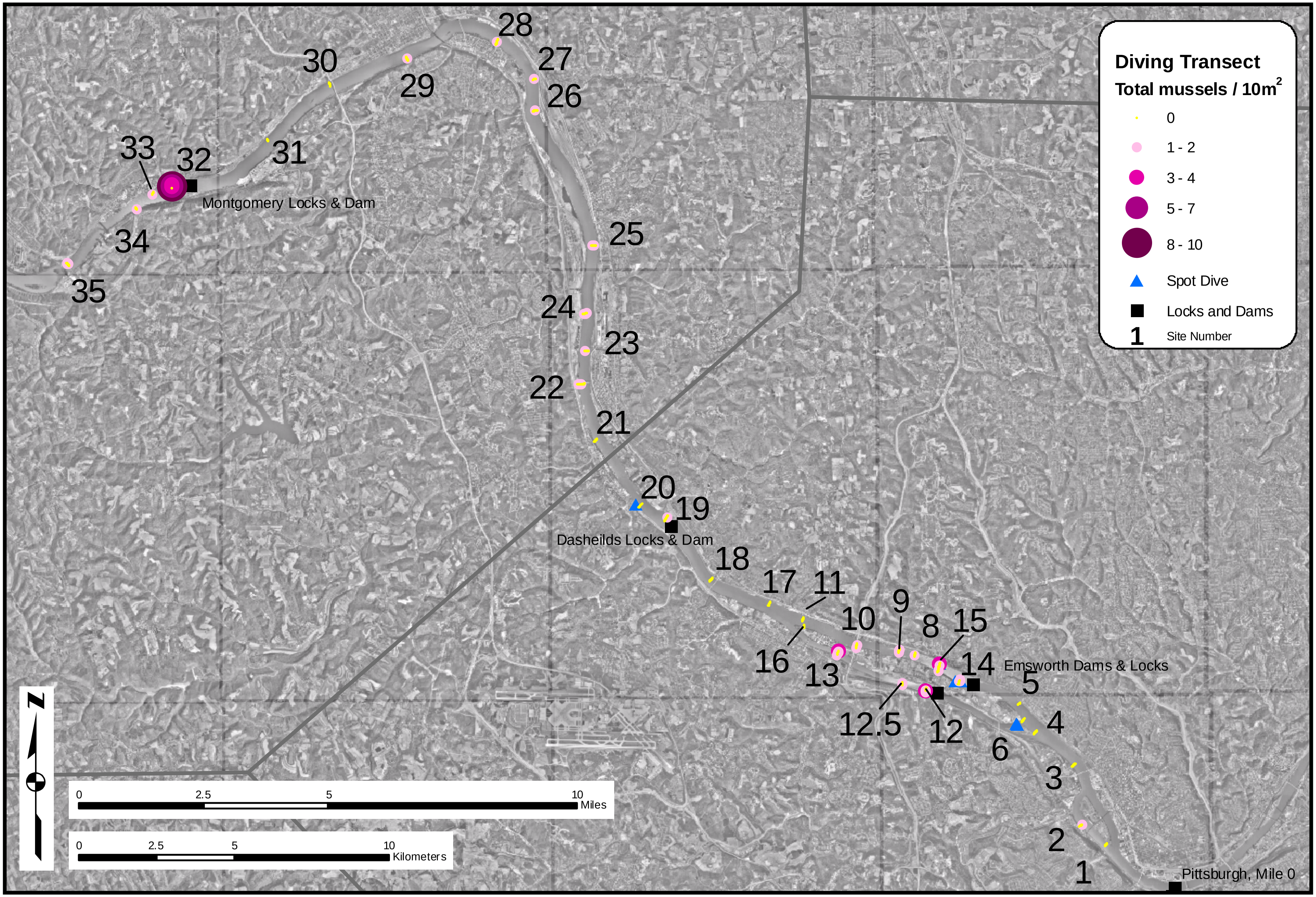
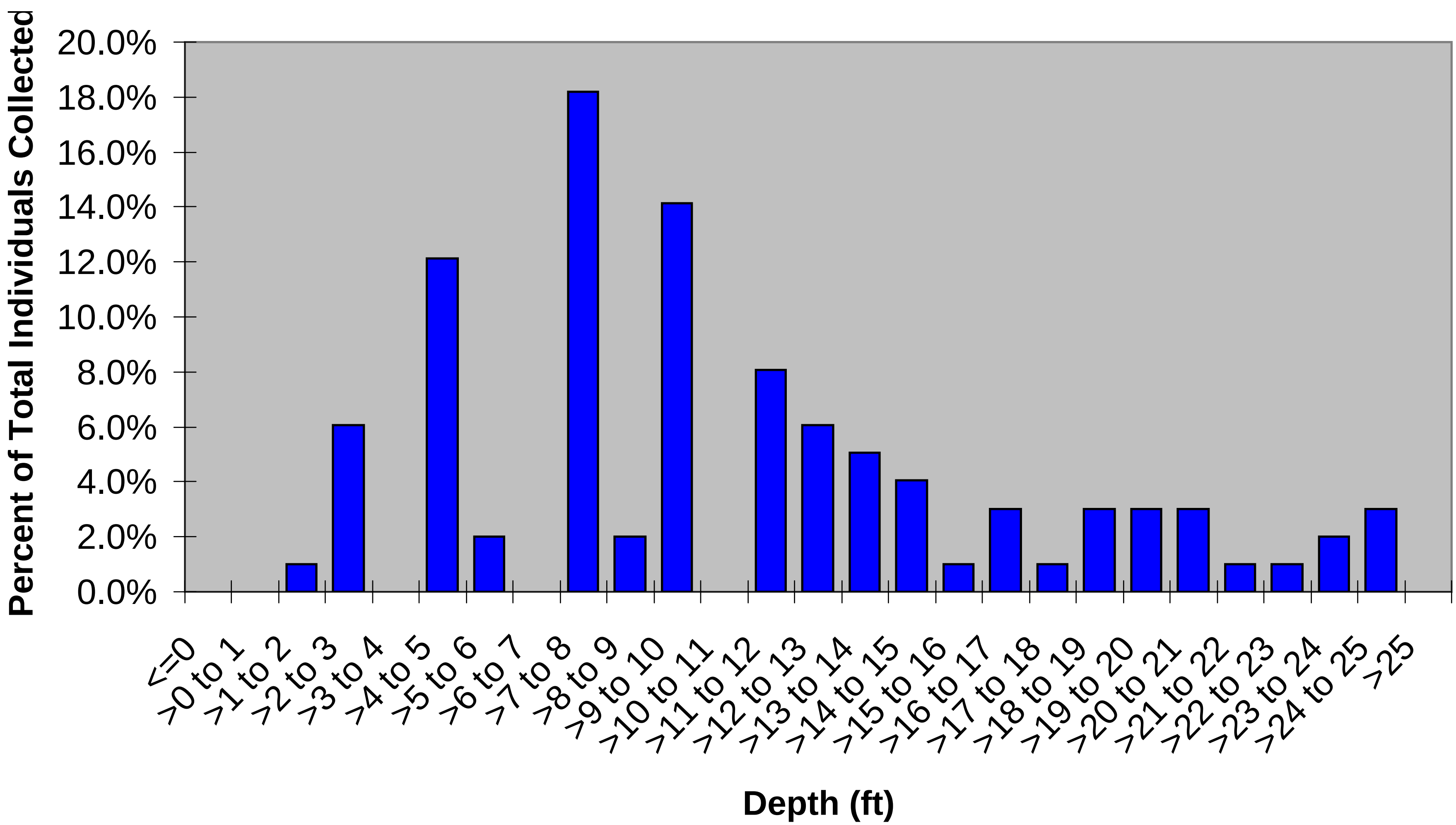


Figure 7.
Relative Mussel Distributions , All Sites.

USACE Pittsburgh District
Upper Ohio River Mussel Screening

EnviroScience, Inc.
"Excellence in Ecological Monitoring"

Figure 8. Number of Mussels Collected by Depth



TABLES

Table 1. Species Composition, Status, Abundance, and Size Structure of Unionid Mussels Collected at All Upper Ohio River Survey Sites (August 19 – September 4, 2008).

			Best Condition[2]				Length (mm)		
Species	Common Name	PA Status[1]	Live	FD	D	Relative frequency (% total)	min.	max.	avg.
Lasmigona costata	fluted shell		1		1	0.9%	114.5	114.5	114.5
Lampsilis siliquoidea	fatmucket		1			0.9%	122.4	122.4	122.4
Leptodea fragilis	fragile papershell	CR		6	3	0.0%			
Obliquaria reflexa	threehorn wartyback	PXT	8	11		7.3%	43.8	74.5	55.2
Potamilus alatus	pink heelsplitter	CR	57	8	6	51.8%	84.2	162.0	134.1
Quadrula quadrula	mapleleaf	PT	41	90		37.3%	27.7	119.0	78.7
Truncilla donaciformis	fawnsfoot	CU	2			1.8%	23.8	40.3	32.1
Truncilla truncata	deertoe	PXT		2		0.0%			
Total:			110	117	10	100.0%			
No. of Species (8 Total Live + Dead):			6	5	3				

[1] PE=PA proposed Endangered; PT=PA proposed Treatened; CR=PA proposed Candidate Rare; PXT=PA proposed Extirpated, N=PA proposed for review, CU=PA condition undetermined, note that none are officially listed by the PFBC to date.

[2] FD=fresh dead shell, D=includes weathered dead and subfossil shells

Table 2. Species Composition, Status, Abundance, and Size Structure of Unionid Mussels Collected at Emsworth Pool Survey Sites (August 19-20, 2008).

			Best Condition[2]				Length (mm)		
Species	Common Name	PA Status[1]	Live	FD	D	Relative frequency (% total)	min.	max.	avg.
Lampsilis siliquoidea	fatmucket		1			100.0%	122.4	122.4	122.4
Potamilus alatus	pink heelsplitter	CR		1		0.0%			
Total:			1	1	0	100.0%			
No. of Species (2 Total Live + Dead):			1	1	0				

[1] PE=PA proposed Endangered; PT=PA proposed Treatened; CR=PA proposed Candidate Rare; PXT=PA proposed Extirpated, N=PA proposed for review, CU=PA condition undetermined, note that none are officially listed by the PFBC to date.

[2] FD=fresh dead shell, D=includes weathered dead and subfossil shells

Table 3. Species Composition, Status, Abundance, and Size Structure of Unionid Mussels Collected at Dashields Pool Survey Sites (August 20-22, 2008).

Species	Common Name	PA Status[1]	Best Condition[2] Live	FD	D	Relative frequency (% total)	Length (mm) min.	max.	avg.
Lasmigona costata	fluted shell		1		1	2.3%	114.5	114.5	114.5
Leptodea fragilis	fragile papershell	CR		2		0.0%			
Obliquaria reflexa	threehorn wartyback	PXT	5	1		11.6%	43.8	57.5	50.2
Potamilus alatus	pink heelsplitter	CR	13	1		30.2%	99.2	160.0	135.3
Quadrula quadrula	mapleleaf	PT	22			51.2%	27.7	99.5	75.3
Truncilla donaciformis	fawnsfoot	CU	2			4.7%	23.8	40.3	32.1
Total:			43	4	1	100.0%			
No. of Species (6 Total Live + Dead):			5	3	1				

[1] PE=PA proposed Endangered; PT=PA proposed Treatened; CR=PA proposed Candidate Rare; PXT=PA proposed Extirpated,

N=PA proposed for review, CU=PA condition undetermined, note that none are officially listed by the PFBC to date.

[2] FD=fresh dead shell, D=includes weathered dead and subfossil shells

Table 4. Species Composition, Status, Abundance, and Size Structure of Unionid Mussels Collected at Montgomery Pool Survey Sites (August 23-26, 2008).

			Best Condition[2]				Length (mm)		
Species	Common Name	PA Status[1]	Live	FD	D	Relative frequency (% total)	min.	max.	avg.
Leptodea fragilis	fragile papershell	CR		4		0.0%			
Obliquaria reflexa	threehorn wartyback	PXT	1			5.9%	74.5	74.5	74.5
Potamilus alatus	pink heelsplitter	CR	14	5	2	82.4%	84.2	152.0	126.1
Quadrula quadrula	mapleleaf	PT	2			11.8%	70.0	83.6	76.8
Total:			17	9	2	100.0%			
No. of Species (4 Total Live + Dead):			3	2	1				

[1] PE=PA proposed Endangered; PT=PA proposed Treatened; CR=PA proposed Candidate Rare; PXT=PA proposed Extirpated,
N=PA proposed for review, CU=PA condition undetermined, note that none are officially listed by the PFBC to date.
[2] FD=fresh dead shell, D=includes weathered dead and subfossil shells

Table 5. Species Composition, Status, Abundance, and Size Structure of Unionid Mussels Collected at New Cumberland Pool Survey Sites (August 26 and September 4, 2008).

			Best Condition[2]				Length (mm)		
Species	Common Name	PA Status[1]	Live	FD	D	Relative frequency (% total)	min.	max.	avg.
Leptodea fragilis	fragile papershell	CR			3	0.0%			
Obliquaria reflexa	threehorn wartyback	PXT	2	10		4.1%	49.0	67.0	58.0
Potamilus alatus	pink heelsplitter	CR	30	1	4	61.2%	111.6	162.0	137.4
Quadrula quadrula	mapleleaf	PT	17	90		34.7%	48.8	119.0	82.6
Truncilla truncata	deertoe	PXT		2		0.0%			
Total:			49	103	7	100.0%			
No. of Species (5 Total Live + Dead):			3	4	2				

[1] PE=PA proposed Endangered; PT=PA proposed Treatened; CR=PA proposed Candidate Rare; PXT=PA proposed Extirpated,

N=PA proposed for review, CU=PA condition undetermined, note that none are officially listed by the PFBC to date.

[2] FD=fresh dead shell, D=includes weathered dead and subfossil shells

APPENDICES

APPENDIX A.

Adaptive Management Group Sampling Protocol

A Mussel Sampling Protocol to Assess Potential Commercial Dredging Sites in Pools 2, 3, 4, 5, 7, 8, and 9 in the Allegheny River and the Dashields, Montgomery, and New Cumberland Pools in the Ohio River, Pennsylvania

7 May 2007

Prepared by:

The Adaptive Management Group

Preface

This document describes a sampling protocol to be used for mussel surveys in the upper Allegheny and lower Ohio Rivers. It consists of background information on the protocol, as well as the actual mussel sampling protocol. This document was prepared by a multi-agency Adaptive Management Group (AMG). Information for this document was obtained from the scientific and government literature, results of past mussel surveys, and experiences of those on the AMG. The following individuals developed this document:

Name		Agency
Robert	Anderson	US Fish and Wildlife Service (USFWS)
John	Arway	Pennsylvania Fish and Boat Commission (PAFBC)
Frank	Borsuk	US Environmental Protection Agency (USEPA)
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Rita	Graham	PADEP
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Christopher	Kriley	Pennsylvania Department of Environmental Protection (PADEP)
Jessica	Martinsen	USEPA
Andrew	Miller	Ecological Applications, a consultant to the dredging Industry
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Thomas	Proch	PADEP
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Introduction

Background

Commercial sand and gravel dredging in the lower Allegheny and upper Ohio rivers (project area) is permitted by the U.S. Army Corps of Engineers (USACE) and the Pennsylvania Department of Environmental Protection (PADEP). The project area (Pools 2, 3, 4, 5, 7, 8, and 9 in the Allegheny River and the Dashields, Montgomery, and New Cumberland Pools in the Ohio River, Pennsylvania) is within the range of eight federally-protected mussel species (Family: Unionidae) (Table 1). Since suitable riverine mussel habitat exists in the project area, there is concern that one or more of these species could be present and be affected by proposed sand and gravel dredging.

Live specimens of two endangered species, the northern riffleshell (*Epioblasma torulosa rangiana*) and the clubshell (*Pleurobema clava*), have been collected in the northern portion of the project area. Recent surveys documented these two species in Pools 8 and 9 of the Allegheny River, and they could be found elsewhere in the project area. Environmental legislation protects individuals and populations of federally and state-protected mussel species from adverse effects of water resource projects. Therefore, before permits are granted to dredge specific river reaches, applicants must conduct mussel surveys using an approved sampling protocol.

Purpose and Scope

The purpose of this document is to provide a sampling protocol that will be used to obtain presence / absence data on federally and state-protected mussel species at selected river reaches in the project area. The mussel sampling protocol will also be used to obtain data on physical (substratum composition, water clarity, etc.) and biotic conditions (species richness, relative species abundance, Catch per Unit Effort (CPUE), etc.).

This protocol, developed as part of an adaptive management process, is intended to allow commercial sand and gravel dredging to occur within the project area without damaging federally and state-protected mussel species. This protocol was prepared for Glacial Sand & Gravel Company, Hanson Aggregates PMA, Inc., and Tri-State River Products, Inc.

This document consists of two parts. The first part presents background and rationale for the protocol. The second part contains the sampling protocol.

Background and Rationale for the Sampling Protocol

The Need for Adaptive Management

The Record of Decision prepared by the USACE (USACE 2006) for this project specified that an adaptive management process, to be implemented by a multi-agency group, will be used to assess and evaluate technical issues pertaining to commercial sand and gravel dredging. The Adaptive Management Group (AMG) consists of representatives from the following organizations: US Fish and Wildlife Service (USFWS), USACE, PADEP, Pennsylvania Fish and Boat Commission (PFBC), US Environmental Protection Agency, and the dredging industry. The USACE and PADEP lead the AMG. At the discretion of the USACE and PADEP, other individuals or organizations could be included in the adaptive management process.

The adaptive management approach to resource issues was first described by Holling (1978), and further refined by Forest Practices Branch, British Columbia (BC) Forest Service (1999), Salafsky et al. (2001), Gunderson et al. (1995), and many others. As described by the Record of Decision for this project (USACE 2006), this adaptive management process will develop improved and scientifically valid permit conditions or restrictions to enhance protection of aquatic and associated littoral and terrestrial biota and habitat. The process will facilitate avoiding or mitigating known or potential adverse environmental impacts associated with dredging. It will also identify river reaches where dredging could occur without causing substantial environmental damage. Surveys conducted using the sampling protocol will obtain physical and biotic data (mussel species richness, relative species abundance, CPUE) that can be used for decision making by the AMG. Finally, as stated in the Record of Decision, it is the intent of the adaptive management process and this protocol to avoid or mitigate adverse environmental impacts associated with the dredging, and to identify areas with limited environmental concern (U.S. Army Engineer District, Pittsburgh. 2006).

As described by Forest Practices Branch, BC Forest Service (1999), adaptive management is an iterative process that begins with 1) problem assessment, then proceeds to 2) study design, 3) study implementation, 4) monitoring of results, 5) evaluation of results, and finally, 6) adjustment to plans and procedures as needed. Concerning mussel sampling and presence / absence of endangered species, this process could be iterated many times as hypotheses are made, data are assembled and synthesized, and collecting methods are refined. As further described by Salafsky et al. (2001), appropriately executed adaptive management depends upon an understanding of traditions of science and philosophy (Pirsig 2005), careful integration of science and politics (Lee 1993), and an understanding of how organizations learn (Schon 1983, Senge 2006).

The *Committee on Scientific Issues in the Endangered Species Act* concluded that the Endangered Species Act requires not only sound science, but also innovative policy and management decisions (National Research Council 1995). Lee (1993) emphasized that when adaptive management brings about political change, social learning results. This mussel sampling protocol will use sound science to achieve a balance among common and endangered mussels and commercial sand and gravel dredging operations.

The AMG has developed a streamlined mussel sampling protocol for commercial sand and gravel dredging in the project area. This protocol reduces the area searched during a Phase II survey (i.e., when trigger conditions are met during Phase I) compared to the conditions described in the permits. The reduction of the Phase II survey is from a 2,000 ft (610 m) section of channel to 328 ft (100 m). The area of a Phase II is reduced even more in water deeper than 22.5 ft (6.9 m) if it appears that mussel species richness and abundance are reduced. In addition, the protocol allows sampling to occur during a single sampling event, without a Phase I report review by regulatory and resource agencies.

This protocol depends, as do all scientific protocols, on the independence and professional qualifications of the principal investigator to locate any protected mussel species and to correctly assess the mussel resource. Following the 2007 field season, the AMG will review survey results and past permit decisions to ensure that important aspects of this protocol—collecting methods, collection time, extent of the search area, and other basic assumptions—are appropriate. As appropriate, the AHG could extend or revise the protocol.

Study Reaches

Mussel surveys will be conducted in a study reach, defined as a river section that includes area to be dredged as well as all surrounding upriver, downriver, and lateral buffers (see below).

Buffers

For this protocol, protection of mussel resources requires buffers, or areas off-limits to dredging that are likely to be affected during and following aggregate removal. Such buffers are specific zones within a study reach set aside to protect the resource from indirect effects of commercial dredging. Buffers will be established upriver, downriver, and lateral to (shoreward) of the area to be dredged. Downriver buffers would protect mussels from resuspension and settlement of fine particulate material associated with aggregate removal. Upriver buffers would protect the mussel resource from sloughing and movement of substratum. The lateral buffer would include a zone extending at least 500 ft (152 m) on either side of the area to be dredged. These shoreward buffer zones could be less than 500 ft (152 m) wide in narrow river reaches where they extend on to shore. Lateral buffers protect from sedimentation and substratum movement as well as changes in water velocity adjacent to a deepened channel.

Use of Divers

Because water depths will be greater than 1.0 m, sampling will be done by divers equipped with scuba or surface supplied air. Therefore, certain procedures used by non-divers when collecting mussels (i.e., some parts described in Smith et al. 2001) were modified to make procedures applicable to the project area while continuing to be scientifically defensible. This protocol was also designed to be logistically efficient, cost-effective, and safe for divers and support personnel. Surveys could be conducted by one, two, or more divers; however, the actual search time in minutes, whether by one or more divers, is the important factor.

Scientific Basis for the Protocol

This protocol relies extensively on published and unpublished reports describing mussel sampling methods. Specifically, it is based upon: a survey conducted in a free-flowing (unimpounded) reach of upper Allegheny River by Smith et al. (2001), procedures used in the Ohio River (Ohio River Valley Ecosystem Subgroup 2004), proposed sampling methods developed by the dredging industry (Western Pennsylvania Dredging Group 2005), guidelines prepared by the USFWS (USFWS 2005), and methods used by the PADEP (PADEP 2006). Recommendations made by a sampling protocol review panel, convened in 2005 (Carline 2005), were also used to develop this protocol. Finally, recommendations made by the AMG, which met in Pittsburgh, PA on 22 and 23 January and on 21 March 2007, were integral to this protocol.

In addition to the above, many other mussel sampling procedures used in flowing water systems were reviewed. Protocols developed by federal and state biologists that were evaluated include those used for Wisconsin (WDNR 2005), Florida and Georgia (USFWS and GADOT 2005), Arkansas (USFWS 2001), and Minnesota (Davis and Eliason 2003). Basic discussions of mussel sampling by Miller and Payne (1993, 1998), Strayer and Smith (2003), Cummings and Bogan (2006), and the U.S. Army Engineer Research and Development Center (2006) were also consulted. The difficulty of ensuring that rare species are being collected has been studied by many scientists. Publications by Green (1993), Isom and Gooch (1996), Strayer (1999), Metcalfe-Smith et al. (2000), Smith et al. (2001, 2003), Heath (2003), Thompson (2004), and Smith (2006a) were consulted. Finally, the problem of rarity and how it can apply to the status of federally and state-protected species (Ehrlich and Ehrlich 1981; Rabinowitz 1981; Slobodkin 1986; Burke and Humprey 1987; Arita et al. 1990; Gaston 1994; and de Grammont and Cuaron 2006), and techniques for estimating the amount of sampling required to obtain rare species (Carline 2005, Smith 2006a) were examined.

Multiple sampling methods have been applied for a variety of purposes in lotic habitats throughout the United States. Some were designed to specifically deal with permitting issues related to dredging and other waterway modifications; others were designed to investigate more basic aspects of life history, ecology, and population demographics of common and uncommon mussel species. Nevertheless, the intent of this protocol is first to determine if federally and state-protected mussel species are present in a specific river reach, and second, to evaluate (or characterize) the overall mussel resource. Therefore, this protocol relies on qualitative sampling methods, which are preferred for detecting presence of rare mussel species (Miller and Payne 1993, Vaughn et al. 1997, Smith et al. 2001).

Both phases of this protocol rely on constrained rather than unconstrained searches. In a constrained search the diver is restricted to a pre-measured area or an underwater transect line. The area searched can be measured and an estimate of mussel density can be made. In addition, the diver can be timed so that information on sampling rate (i.e., CPUE) can be obtained. Likewise it is possible to estimate (or to prescribe) that a diver search substratum at a specific rate. The protocol review panel (Carline 2005) concluded that constrained sampling was more consistent and repeatable than unconstrained sampling mainly because it focused the collector in a specifically delineated area. In this protocol divers will be constrained in a 1-m-wide transect or in a cell typically measuring 50 m on a side.

Application of the Sampling Protocol

This protocol specifies procedures, plus personnel and equipment requirements, to conduct surveys at study reaches in the project area. Field survey results will be used to make permitting decisions for sand and gravel dredging operations. Nevertheless, the AMG has determined that some river reaches could be evaluated simply with data and information obtained by bathymetric mapping (side scan sonar images and/or 5-ft (1.5 m) water depth contours) and would not require field surveys for mussels. As part of the adaptive management process, the AMG will evaluate the use of bathymetric mapping to further streamline the granting of permits for selected river reaches.

The field sampling portion of this protocol consists of two phases. (As noted above, under certain conditions a field survey might not be required). The purpose of the first phase will be to determine either if federally or state-protected species are present or if biotic conditions indicate that it is likely that federally and state-protected species could be present. If it appears that endangered species could be in the study reach (i.e., certain trigger criteria are met; see below), then a second, more spatially intensive phase could be required. It is the intent of this protocol to have Phase I and II take place within the same study period. Therefore, if additional sampling is required, and conditions permit, the crew could proceed to directly to Phase II. Logistical problems (pertaining to weather, personnel, and equipment, etc.) could necessitate a slight delay between study phases. In addition, the permit applicant could chose to avoid an area based on Phase I results rather than invest resources in Phase II.

There are several reasons why Phase I and II should be conducted in the same study period. First, it will be less expensive and logistically more efficient to have all diving work conducted during a single time period (i.e., one mobilization of the survey crew). Second, having the two phases combined will ensure that abiotic conditions (water clarity, temperature, and velocity) are essentially the same throughout both phases. Third, this will ensure that Phase II is conducted at exactly the same location as Phase I. Finally, this will help to ensure that the same crew conducts both phases.

Trigger Criteria

Trigger criteria have been established that, if met, indicate that it is possible that one or more federally and state-protected mussel species are present but have not been located. Two types of trigger criteria are employed: 1) presence of one or more species that could indicate habitat is suitable for federally and state-protected mussels, and 2) specific density criteria. These are described in more detail below:

1. **Habitat conditions which could indicate that federally-protected species are present.** The USFWS prepared a list of mussel species typical of flowing-water, riverine habitat (Table 2). The federally-protected species whose historical ranged included the project area require such habitats.

2. **Density criteria**. Specific density criteria have been established that would trigger the Phase II survey. Collection data from Phase I will be adjusted based upon findings by Smith et al. (2001). Smith et al. (2001) reported that qualitative sampling (visual and search by feel) at a bridge replacement site in a free-flowing reach of the upper Allegheny River under-estimated mussel relative species abundance when compared with results from quantitative substratum sampling (excavation of 0.25 sq m quadrats). Findings were species-specific (e.g., 31 percent of clubshells and 52 percent of northern riffleshells present were located without substrate excavation). Therefore, for this protocol, actual counts (number of mussels collected) will be doubled to convert from an *observed* to an *actual* mussel density (see below).

Two density criteria will be applied to Phase I surveys that would require a Phase II:

1. A transect segment could have an *observed* density between 0.3 and 0.5 mussels/m^2 (*actual* density equal to 0.6 to 1.0 mussels/m^2). If a transect segment supported this density, <u>and</u> at least one species listed in Table 2, a Phase II survey would be triggered.

2. A transect segment could support an *observed* density of at least 0.5 mussels/m^2 (*actual* mussel density equal to at least 1.0 mussels/m^2), regardless of species composition.

These above criteria, if met or exceeded, would trigger a Phase II study.

Basis of the Phase II Design

Phase II survey design is based on information in Smith et al. (2001) in which collectors (referred to as observers) searched qualitatively in twenty-four mainly 2,500 m^2 cells placed within the entire area expected to be directly and indirectly affect by a proposed bridge replacement project. Smith et al. (2001) used divers in water deeper than 1.0 m and snorkelers in water less than 1.0 m deep. Observers were instructed to search a minimum of 240 min / cell (i.e., four observers each searched for 60 min). Observers worked by fanning away fine sediment, removing loose, non-embedded material, and raking loose sediment with fingertips in an effort to detect mussels. It was assumed that each observer searched at a rate of 0.5 m^2/min based on extensive comparisons between quadrats searched visually with those completed excavated (Smith et al. 2006).

Phase II of this protocol requires that divers search within a 2,500 m^2 cell, collect for a specific minimum time, and work at an estimated effective search rate. For this protocol, as in Smith et al. (2001), it is assumed that the effective diver search rate is 0.5 m^2 /min. Phase II of this protocol, as in Smith et al. (2001), requires that the minimum search time in the 50 by 50 m cell will be 240 min.

Application of the Adaptive Management Process

As described above, adaptive management for this project was envisioned to be iterative and used to facilitate needed adjustments based upon hypotheses, monitoring, evaluation, and synthesis. It is within the intent of the Record of Decision (USACE 2006) to apply adaptive management as the major mechanism to develop improved and scientifically valid permit conditions or restrictions that are required to protect aquatic and associated littoral and terrestrial biota and habitat. The intent of adaptive management will be to achieve a balance between survival of federally and state-protected mussel species and commercial utilization of aggregate. In addition to data on federally and state-protected species, the AMG will use other physical and biotic data obtained with this protocol for decision making. As this project proceeds it is likely that the AMG will evaluate and discuss the following, as well as many other, technical aspects of this protocol:

Appropriateness of data for decision process. Past permitting decisions will be reviewed to determine if they were reasonable and appropriate based upon the biotic and abiotic data obtained using the protocol.

Trigger criteria for Phase I studies. Phase I trigger criteria will be evaluated based on results of sampling.

Interpretation of biotic results for Phase II. Phase II sampling takes place in a larger area than Phase I (2,500 m^2 cells vs. 10 m^2 segments). Therefore, numeric criteria established for 10 m^2 segments would not necessarily apply to Phase II results. As data are obtained, the appropriateness of numeric criteria for both phases will be examined.

Efficiency and safety of the sampling protocol. Logistic aspects of the sampling protocol will be analyzed and adjustments made if needed.

Efficiency of the permitting process. All aspects of the permitting process will be evaluated.

Buffer areas. The size and use of buffer areas will be evaluated based on the results of new information.

Sampling restrictions. Any existing restrictions pertaining to water temperature, water clarity, weather, etc., will be examined for appropriateness and modified if necessary based on scientifically defensible information.

Clarification of the mussel concentration concept. The Record of Decision (USACE 2006) stated that density criteria for mussels (referred to as mussel concentration standards) were included in attachments to the permits. As future mussel surveys are conducted and results evaluated by the AMG, these mussel concentration standard for non-federal and non-state-protected species will be evaluated and further refined if necessary. Mussel concentration standards could vary throughout the study area depending on site-specific conditions (e.g., Pool 8 could be different from Montgomery Pool). If warranted, the AMG could recommend other biotic criteria (standards) to further protect common species.

Clarification of the significant mussel resource concept. The permit developed by the PADEP (2006) defines significant mussel resources differently than permits prepared by the USACE. The AMG will evaluate existing and new information on mussels to better define this concept. Since the project area is large (over 100 miles, 161 km) and river conditions vary throughout, a single definition will not likely apply for the entire project area. Carline (2005) recommended using a frequency distribution of representative data to define mussel resources significant in the project area.

Species that could indicate habitat suitable for federally and state-protected species. This protocol relies on a species list developed by the USFWS (Table 2) which could indicate mussel habitat based on descriptions in Parmalee and Bogan (1998). Adaptive management can be used to refine the list based on new and scientifically valid information.

Sampling Protocol

Background

The initial evaluation for dredging authorization will consist of performing bathymetric mapping of the proposed dredging and buffer areas. This mapping (at a scale of 1 inch to 100 ft, or 2.54 cm to 30.5 m) will consist of side scan sonar images, and/or water depth contouring at 5-ft (1.5 m) contour intervals. This mapping should be provided to the appropriate USFWS, USACE, PADEP, and PFBC representatives for review at least 30 days prior to proposed sampling.

Some portions of the project area are currently restricted from dredging based on physical barriers (bridges, submerged crossings, dams, public water intakes, and public water well fields, etc). Some of the remaining areas available for dredging authorization have been disturbed by past dredging. If such latter areas were permitted, then previously dredged areas would be re-dredged. Depending on water depths and other physical characteristics, these previously dredged areas are very unlikely to support live mussels. The AMG could suggest that, based on an evaluation of bathymetric mapping, such areas could be permitted for dredging without the need for mussel surveys. It is not the intent of regulatory and resource agencies to require the industry to expend time and money surveying areas that are unlikely to support live mussels.

This protocol describes procedures for collecting physical and biotic data at study reaches proposed for dredging that, based on a review of bathymetric mapping, are likely to support live mussels.

Purpose

The purposes of Phase I are: 1) to assess if endangered species are present, or 2) to determine if habitat and biotic conditions are suitable for federally and state-protected species. In other words, if Phase I results indicate that federally and state-protected species could be present, then either the species is assumed to be present and avoided or additional sampling would be conducted. The purpose of Phase II is to specifically search for federally and state-protected mussel species using a constrained, qualitative search. If conditions that would trigger Phase II are not met, then the site could be authorized for dredging.

Phase I Survey

Requirements. Requirements for Phase I sampling are based on the following (taken from USFWS 2005):

1. Mussel surveys will be overseen by a qualified individual with a valid scientific collector's permit and a special permit to collect threatened and endangered species. In addition, the individual must have experience successfully locating and identifying mussel species in the project area. The qualified individual will be present at all times during the survey. The PFBC and USFWS maintain lists of individuals qualified to collect mussels using this protocol; these organizations should be contacted if additional information is required. Assistants who search for mussels will have at least some previous experience successfully conducting such surveys.

2. Surveys will be performed between 1 May and 15 October, contingent upon suitable and safe weather and river discharge conditions. During this time mussels are likely to be more active and therefore more visible to divers, and more likely to re-burrow after being disturbed. Air and water temperatures will be no less than 55^{o} F (12.8^{o} C).

3. Mussel sampling will take place along transect lines placed perpendicular to the river bank that will extend through the reach to be dredged, and will also include the up, downriver, and lateral buffer zones that will not be directly disturbed by dredging but could experience indirect effects. Transects will be placed at 100-m increments (328 ft) throughout the study reach.

4. Each transect will be subdivided into 10-m segments.

5. Along each transect, paired divers will visual search an area one meter wide for mussels (0.5 m on each side of the transect). A visual search includes moving cobble and woody debris, hand-sweeping away silt and small detritus, and disturbing and probing the upper 2.5 – 5.0 cm (1-2 in) of substratum to better see mussels that could be partially buried (based on Smith et al. 2001). Since this is a qualitative survey of the substrate surface relying primarily on visual cues, minimum water visibility should be 0.5 m (20 in).

6. A minimum of 10 diver-min of searching will take place in each 10-m^2 segment in which mussels and/or suitable mussel habitat is present (paired divers will each spend half the time, or at least 5 min, searching half of the segment). If conditions in any 10-m^2 segments are determined to provide unsuitable mussel habitat, they will not be searched. Reasons for not searching a segment will be documented in writing. Unsuitable habitat includes bedrock or areas with at least 25 cm (10 in) of silt. It is understood that some habitats and conditions could be more complex and difficult to search because of presence of silt, possible zebra mussel colonization, large cobble, boulders and woody debris, or other factors. If additional search time is required, reasons will be documented in writing.

7. From each 10-m^2 segment, all observed mussels will be placed in a labeled mesh bag and brought to the surface for further processing and identification. All mussels will be recorded as occurring within a specific transect segment.

Observations of each diver be recorded and reported separately, although ultimately results will be summarized for each transect segment.

8. If no mussels are observed in two adjacent transects, with at least one transect containing apparently suitable mussel habitat, a free dive of at least 10 min per diver will be conducted between the two transects in the area of suitable mussel habitat. If live or fresh dead mussels are found between two transect lines, an additional transect line will be placed at that location and a search conducted as described above.

9. Mussels will be held long enough to identify, measure, and photograph, during which time they will not be exposed to temperature extremes. A series of color photographs will be taken of all live mussel species that are collected. The side, anterior, and posterior of each will be depicted in sufficient detail and clarity to identify it. All federally-protected mussels will be returned to the point of capture immediately following identification. No federally-protected mussels will be removed from the subject river reach.

10. A voucher specimen of each mussel species observed to be dead will be provided to the appropriate USFWS or PFBC representative.

11. Survey results, including data listed in Table 3 will be sent to the USFWS and PFBC following completion of the survey.

12. Bathymetric mapping of the site will occur before mussel surveys are conducted. This information will be sent to the appropriate USFWS, USACE, PFBC, and PADEP representatives. It is possible that some proposed areas will not require mussel surveys if bathymetric mapping indicates past dredging. An annual report of dredging activities will be prepared and submitted to PADEP. If requested, this report will be provided to representatives of USFWS, USACE, and PFBC.

Effectiveness. Mussel surveys will remain in effect for five years as per the USACE permit unless new information warrants reconsideration. The five-year period will commence when the field survey is completed.

Interpretation of Phase I Survey Results

Data from Phase I will consist of 1) a listing of the actual numbers of live unionid mussels present in each 10-m^2 segment of each transect, 2) A species list to include the actual numbers obtained per transect to prepare a table of relative species abundances for each river reach, and 3) Other required data and information listed on Table 3. Depending on survey results, any one of the following situations could apply:

River Reaches that Could Qualify for Dredging

Situation I. Either of the following two conditions, if met, would indicate that no Phase II survey is required and that the river reach could be dredged: 1) Transect segments support an *observed* density less than 0.3 mussels/m^2 (*actual* density less than 0.6 mussels/m^2) with no federally and state-protected species present; 2) Transect segments support an *observed* density between 0.3 and 0.5 mussels/m^2 (*actual* density between 0.6 and 1.0 mussels/m^2) with no species listed in Table 2 present.

The Need to Buffer a Study Reach, with no Phase II Survey Required

Situation II. If one or more live or fresh dead federally or state-protected mussel species are found, all direct and indirect dredging effects will be avoided in consultation with the USFWS. Buffer areas will be established so that no dredging will be permitted 1,500 ft (457 m) upriver, 500 ft (152 m) lateral to, and 500 ft (152 m) downriver of the federally and state-protected species. In some cases a larger buffer area could be required to avoid potential adverse effects. In this case no Phase II survey would be conducted.

Conditions to Trigger Phase II

Two situations could trigger a Phase II survey.

Situation III. A transect segment could have an *observed* density between 0.3 and 0.5 mussels/m^2 (*actual* density equal to 0.6 to 1.0 mussels/m^2) and support one or more species indicative of riverine conditions (Table 2). In this situation there are two possible actions: 1) buffers will be established so that no dredging will be permitted within at least 1,500 ft (457 m) upriver, 500 ft (152 m) lateral to, and 500 ft (152 m) downriver of the transect segment; or, 2) a Phase II survey (see below) will be conducted to determine if federally and state-protected species are present.

Situation IV. A transect segment could support an *observed* density of 0.5 or more mussels/m^2 (*actual* density equal to or greater than 1.0 mussels/m^2), regardless of species composition. This density is achieved if five or more mussels are observed within any 10-m^2 segment. In this situation either 1) buffers will be established so that no dredging will be permitted within at least 1,500 ft (457 m) upriver, 500 ft (152 m) lateral to, and 500 ft (152 m) downriver of the transect segment; or, 2) a Phase II survey (see below) will be conducted to determine if federally and state-protected species are present.

Planning the Phase II Survey

Assuming that transects are 100 m apart, the Phase II survey area includes a reach 50 m up and 50 m downriver of the central transect line. That is, the area should extend for a distance approximately half way between the central transect line and next nearest up- and downriver transect lines. It is assumed that the these cells are 50 m on a side (2,500 m^2), although cell size could vary under certain conditions (as in Smith et al. 2001)

The AMG determined that surveys will be spatially more intensive in shallow (rather than deep) and undisturbed (rather than disturbed) riverine habitat. Preliminary data from the Allegheny River suggest that mussel species richness and abundance appear to be greatest in water less than 20 ft (6.1 m) deep at normal pool. This is based on a study by Tamara Smith (Smith 2006b) who reported that the greatest mussel abundance and richness values (at eight transects in Pools 5-8 of the Allegheny River) were obtained in water less than 20 ft (6.1 m) deep, although depths up to 30 ft (9.1 m) were sampled. Additional data provided by the Pennsylvania Fish and Boat Commission (provided to the AMG in 2007) supported these findings and documented the occurrence of northern riffleshell at a depth of 20 ft in Pool 9 of the Allegheny River. Based on this information, the AMG determined that habitats less than 22.5 ft deep should be more intensively sampled than habitats greater than 22.5 ft (6.9 m) deep at normal pool. (Depths will be adjusted for river discharges to normal pool elevation). The additional 2.5 feet is conservative and considers 1) the small set of data in Smith (2006b), 2) the inherent variability in mussel distribution in rivers, 3) the difficulty of accurately and precisely measuring water depth in the field, and 4) the documented presence of at least one endangered species at a depth of 20 feet.

Implementing the Phase II Survey

The number of 50 by 50 m cells to be searched during Phase II will be determined by the suitability of the habitat (based upon water depth and physical disturbance caused by past dredging) immediately surrounding the transect where trigger conditions were met or exceeded during the Phase I survey. The following describes three conditions that could exist:

> **Habitat Condition I**. The area immediately surrounding the 10 m^2 transect segment (where trigger criteria to initiate Phase II were met) could be less than 22.5 ft (6.9 m) deep at normal pool and comprised of habitat considered to be suitable for riverine mussel species.
>
> In this circumstance, divers will delineate multiple 2,500 m^2 cells on either side of the transect line (extending halfway to the up- and halfway to the downriver transect line). Cells to be searched, however, will only be delineated in water less than 22.5 ft (6.9 m) deep at normal pool.
>
> **Habitat Condition II.** The area immediately surrounding the 10 m^2 transect segment (where trigger criteria to initiate Phase II were met) could be greater than

22.5 ft (6.9 m) deep at normal pool and comprised of habitat considered to be less suitable for riverine mussel species than those described immediately above (Habitat Condition I).

Since the transect which met trigger criteria is in water deeper than 22.5 ft (6.9 m), only a single 2,500 m^2 cell will be searched. This 2,500 sq m cell should be centered, to the extent possible, on the 10-m^2 transect segment where trigger criteria were met. This cell is centered on the line and extends up and downriver of the transect.

Habitat Condition III. The area immediately surrounding the 10 m^2 transect segment (where trigger criteria to initiate Phase II were met) could be comprised of habitat considered to be unsuitable for riverine mussel species because it was recently altered by past dredging or other similar disturbances.

In this circumstance, no Phase II survey will be conducted.

Sampling Procedure within Each Cell

Diver(s) will search the 2,500-m^2 area for a minimum search time of 240 min. If it is determined that one sub-area is substantially better than the other, then diver(s) could spend additional time where mussels are most likely to be found; however, the entire cell should be searched.

If conditions in any of these cells are determined to provide unsuitable mussel habitat, they will not be searched. Reasons for not searching a cell will be documented in writing. Unsuitable habitat includes bedrock or areas with at least 25 cm (10 in) of silt. Conversely, conditions in a cell could be more complex and difficult to search because of presence of silt, zebra mussel colonization, large cobble, boulders and woody debris, or other factors requiring additional search time to cover the area of the cell. When the qualified biologist who is on site determines that additional search time is required to effectively search a cell, the reasons will be documented in the survey report.

Data and Information Obtained during the Phase II Survey

Data and information obtained during the Phase II survey will consist of 1) a listing of the actual numbers of live and freshly dead unionid mussels present in the 2,500-m^2 cell, 2) An estimate of CPUE by dividing the number of live mussels actually collected by the total search time expended, and 3) A species list to include the actual numbers of live mussels and a relative species abundance table. Data and information will be submitted to appropriate agency personnel.

Suitability of Study Reaches for Dredging

Data collected during Phase II could lead to the following decisions being made:

> **Situation V**. If one or more live or fresh dead federally or state-protected mussel species are found, all direct and indirect dredging effects will be avoided in consultation with the USFWS. Buffer areas will be established so that no dredging will be permitted 1,500 ft (457 m) upriver, 500 ft (152 m) lateral to, and 500 ft (152 m) downriver of federally and state-protected species. In some cases a larger buffer area could be required to avoid potential adverse effects. This corresponds to Situation I, Phase I studies.

> **Situation VI.** If no federally or state-protected species are found, then the area could be suitable for dredging. As stated above, the AMG will evaluate and further refine mussel concentration standards (density criteria) for common mussel species. Therefore, if warranted, the AMG could ultimately recommend new standards, or possibly other biotic criteria, to further protect common mussel species.

Summary

The background, rationale, and a full description of a sampling protocol for common, as well as federally and state-protected freshwater mussel species in the project area have been presented. This protocol will be used to obtain data on physical (substratum composition, water clarity, etc.) and biotic conditions (species richness, relative species abundance, CPUE, etc.) in each study reach. This protocol, developed as part of an adaptive management process, will allow commercial sand and gravel dredging to occur within the project area without damaging federally and state-protected mussel species. In the future the AMG could modify the trigger criteria, study plans, and procedures as more data are collected and synthesized.

Table 1. Endangered species, candidate species, and mussel species of concern. The project area is within the reported range of these species. This table was taken from Appendix T of the USFWS (2005)

Species	Common name	Habitat	Status
Cyprogenia stegaria	fanshell	Lotic	Endangered
Epioblasma torulosa rangiana	northern riffleshell	Lotic	Endangered
Hemistena lata	cracking pearlymussel	Lotic	Endangered
Lampsilis abrupta	pink mucket	Lotic	Endangered
Obovaria retusa	ring pink	Lotic	Endangered
Plethobasus cooperianus	orange-foot pimpleback	Lotic	Endangered
Pleurobema clava	clubshell	Lotic	Endangered
Pleurobema plenum	Rough pigtoe	Lotic	Endangered
Plethobasus cyphyus	sheepnose mussel	Lotic	Candidate
Villosa fabalis	Rayed bean mussel	lotic	Candidate
Epioblasma triquetra	snuffbox	lotic	Species of concern
Quadrula cylindrica	rabbitsfoot	lotic	Species of concern
Simpsonaias ambigua	salamander mussel	generalist	Species of concern

Habitat description summarized from Parmalee and Bogan (1988) lotic – typical of flowing water and gravel and cobble substrates; lentic – minimal flow; sand or silt substrates; generalist – occurs in both habitat types.

Table 2. Species indicative of flowing water and large river habitats with stable substratum. The asterisk (*) indicates that the species is likely extirpated from the Ohio River and lower Allegheny River. This table was taken from Appendix T of the USFWS (2005)

Species	Common name	Habitat
Actinonaias ligamentina	Mucket	lotic
Alasmidonta marginata	Elktoe	lotic
*Cyclonaias tuberculata**	purple wartyback	lotic
Amblema plicata	Threeridge	generalist
*Ellipsaria lineolata**	butterfly mussel	lotic
*Elliptio crassidens**	elephant ear	lotic
Elliptio dilatata	Spike	lotic
Fusconaia flava	Wabash pigtoe	lotic
Fusconaia subrotunda	long-solid	lotic
Lampsilis fasciola	wavyrayed lampmussel	lotic
*Lasmigona compressa**	creek heelsplitter	lotic
Ligumia recta	Black sandshell	lotic
Obliquaria reflexa	threehorn wartyback	lotic
*Obovaria olivaria**	Hickorynut	lotic
Obovaria subrotunda	round hickorynut	lotic
*Pleurobema cordatum**	Ohio pigtoe	lotic
*Pleurobema rubrum**	pyramid pigtoe	lotic
Pleurobema sintoxia	round pigtoe	lotic
Ptychobranchus fasciolaris	Kidneyshell	lotic
*Quadrula metanevra**	Monkeyface	lotic
*Quadrula pustulosa**	Pimpleback	generalist
*Truncilla truncata**	Deertoe	generalist
*Tritogonia verrucosa**	pistolgrip mussel	generalist
*Villosa iris**	rainbow mussel	lotic

Table 3. Required and optional data and information for mussels surveys in the project area (based on USFWS 2005 and recommendations of this AMG).
Individual recording data
Divers
Mussel identifier
Surface weather conditions
Air temperature
Water temperature
Water visibility at collection points
Any notes on sampling methods and survey methodology
Site map
Reach description (River Miles, past river bed disturbances if known, substratum description, water clarity, etc.)
River discharge at nearest USGS station
Date and time of collections
All dive times
GPS coordinates of each dive transect
Substratum data. This is intended to be a visual description of grain size based on the Wentworth scale. See Wentworth (1922) and Carver (1978) for more information.
Estimate of relative compaction of substratum
Estimate of percent zebra mussel coverage
Unionid species list (note both live and dead)
Size range of mussels
Photographs of state-listed mussel species
Presence of live snails (optional)
Any other (optional) information the collector deems worthy to include
In addition, those conducting these surveys are encouraged to provide a brief statement describing their Quality Assurance Project Plan. This statement would describe specific planning, implementation, and assessment procedures for these mussel surveys as well as any specific quality assurance and quality control activities.

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APPENDIX B.

Digital Images Recorded at Sites

APPENDIX B.
DIGITAL IMAGES RECORDED AT SITES

Image 1. District diving representative Charley Weight performs field inspections on 8/19/08.

Image 2. The EnviroScience Dive team (Matthew Walsh, Daniel Lakamp, and Michael Hanway, L-R) and dive setup ready to begin field work aboard the survey vessel *E.O. Wilson* (ES file photo)

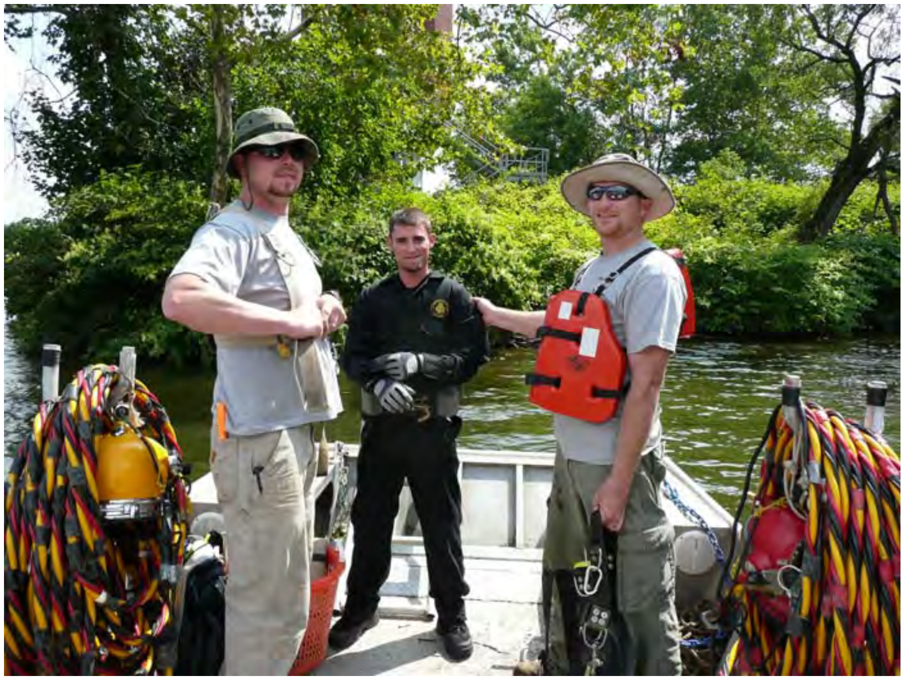


Image 3. Standby diver Matt Walsh (left), diver Jimmy Hartman (center), and tender / safety officer Tim Willaman (right) prepare for a spot dive near NM 4.8 on 8/19/08.

Image 4. View of a typical mussel sample divided into metered segments

Image 5. Shoreline habitat at SITE 3, 8-19-08

Image 6. View from the beginning of the transect at Davis Island, SITE 4, 8-19-08

Image 7. View of SITE 6 and industrial land use at Neville Island, 8-20-08

Image 8. View of SITE 5, 8-20-06

Image 9. View of the Emsworth mainstem Locks and Dam, near SITE 5, 8-20-06

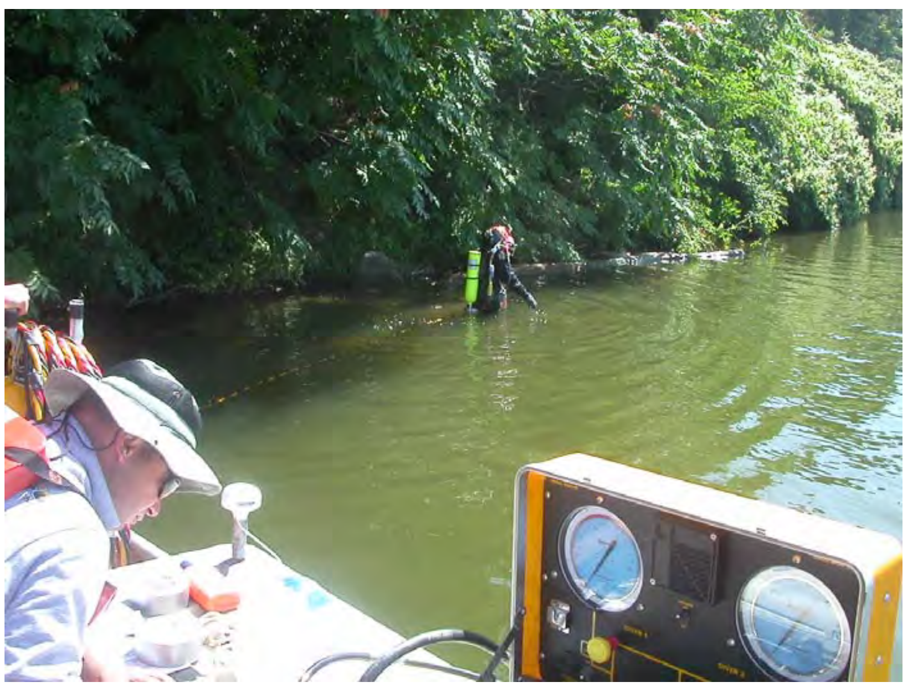


Image 10. A diver begins a search beginning at Neville Island at SITE 14, 8-20-08


Image 11. View of the right descending bank facing upstream from SITE 8 on 8-21-08

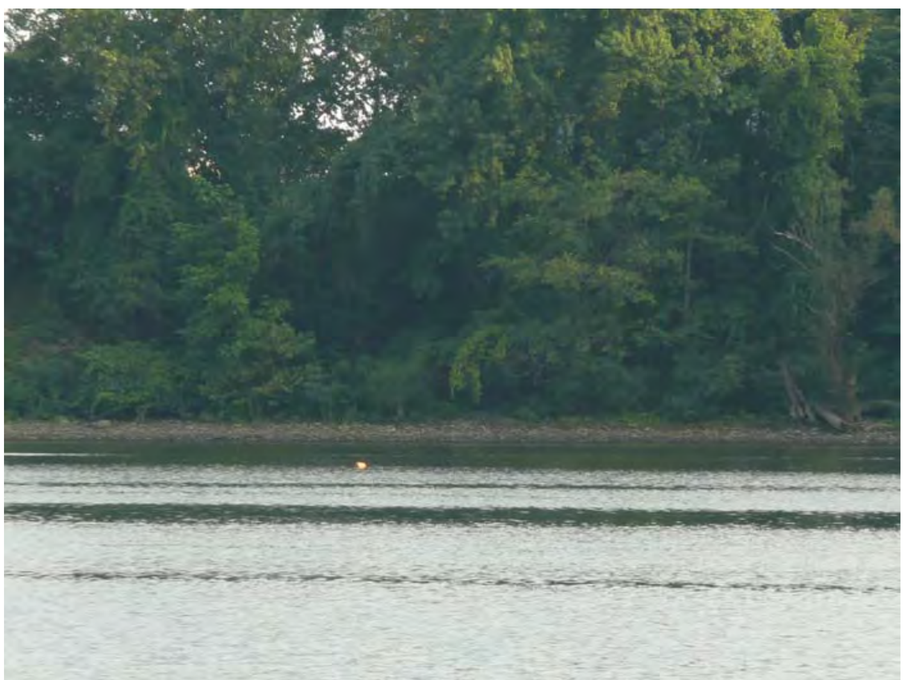


Image 12. View of the right descending bank shoreline habitat at SITE 11, 8-21-08

Image 13. View of the left descending shoreline and the backchannel area around Neville Island from SITE 13, 8-22-08

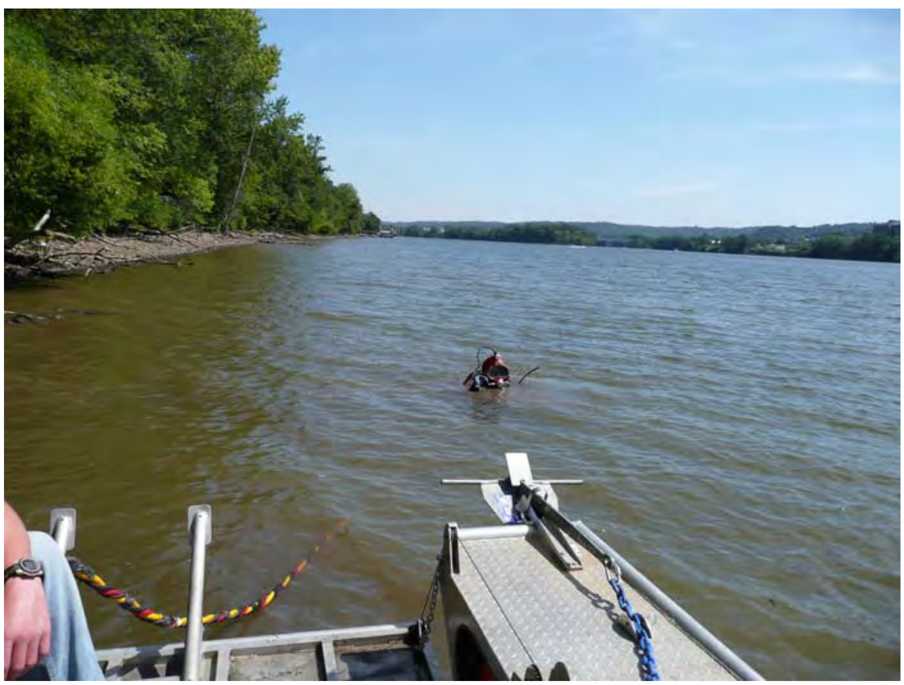


Image 14. View of the right descending bank facing upstream near the end of SITE15. This transect covered the entire channel between Neville Island, 8-22-08

Image 15. 8-22-08 SITE 15

Photo Credit: Skelly & Loy

Image 16. View from the river towards the right descending bank at SITE 24, 8-24-08

Photo Credit: Skelly & Loy

Image 17. View of a commercial gravel dredging operation near SITE 24, 8-24-08

Image 18. A male fatmucket (*Lampsilis siliquoidea*) from SITE 2, 8-19-08.
Note zebra mussel byssal scars on the posterior (left).

Image 19. View of a zebra mussel on the posterior margin of a pink heelsplitter (*Potamilus alatus*) on 8-20-08 at SITE 5

Photo Credit: Skelly & Loy

Image 20. Processing of mussels on 8-20-08 at SITE 14

Image 21. View of the pink heelsplitter (*Potamilus alatus*; left) and the mapleleaf (*Quadrula quadrula*; right), 8-20-08 SITE 14

Image 22. View of the mapleleaf (*Quadrula quadrula*), 8-20-08, SITE 14

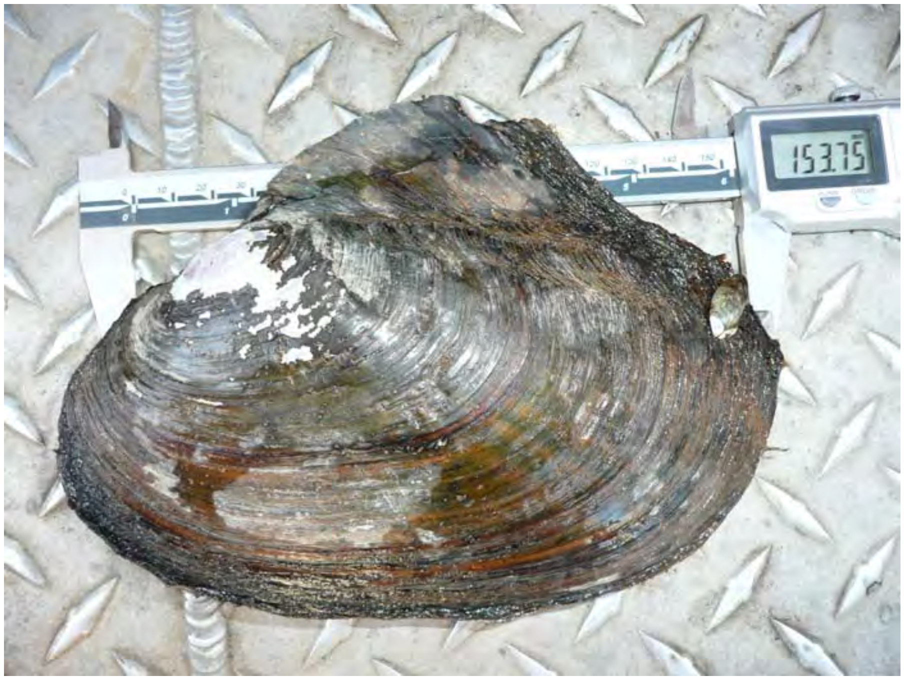


Image 23. View of the pink heelsplitter (*Potamilus alatus*), 8-20-08, SITE 14

Image 24. A weathered dead fluted shell (*Lasmigona costata*)
8-20-08 SITE14

Image 25. View of a threehorn wartyback (*Obliquaria reflexa*), 8-21-08 SITE 15


Image 26. View of assorted mussel species collected at SITE 15, 8-21-08

Image 27. View of a fresh dead fragile papershell (*Leptodea fragilis*)
SITE 16, 8-21-08

Image 28. View of an old male fawnsfoot (*Truncilla donaciformis*)
SITE 13, 8-22-08

Image 29. View of a juvenile / sub-adult mapleleaf (*Quadrula quadrula*)
SITE 12, 8-22-08

Image 30. View of a male fawnsfoot (*Truncilla donaciformis*)
SITE 12, 8-22-08

Image 31. A pink heelsplitter (Potamilus alatus) collected at SITE 19, 8-23-08

Image 32. Fresh dead fragile papershell (Leptodea fragilis) collected from SITE 24 on 8-24-08. Fresh dead shells of this species were commonly encountered but no live individuals were collected.

Image 33. Profile view of a zebra mussel infested fresh dead pink heelsplitter (*Potamilus alatus*) SITE 28, 8-25-08

Image 34. Posterior view of a zebra mussel infested fresh dead pink heelsplitter (*Potamilus alatus*) SITE 28, 8-25-08

Image 35. View of a zebra mussel infested fresh dead pink heelsplitter (*Potamilus alatus*) 8-25-08 SITE 26

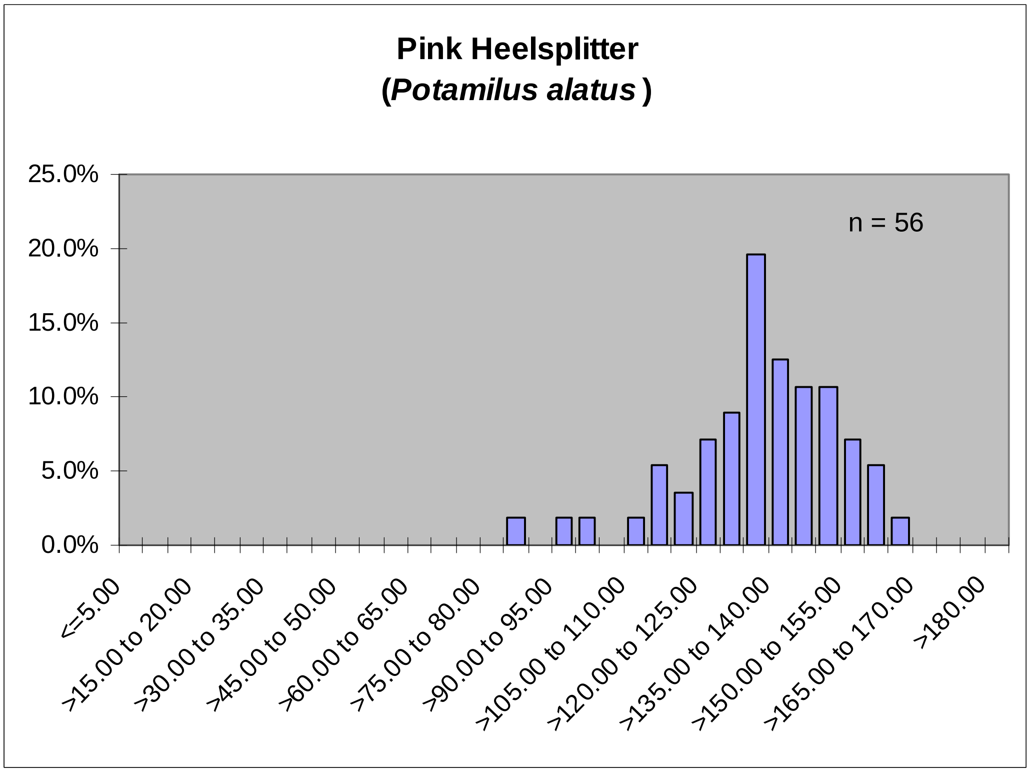
Fresh dead deertoe (*Truncilla truncata*) from muskrat midden sample from right descending bank, downstream of Montgomery Dam and Locks, Ohio River, SITE 32, 8/26/08.

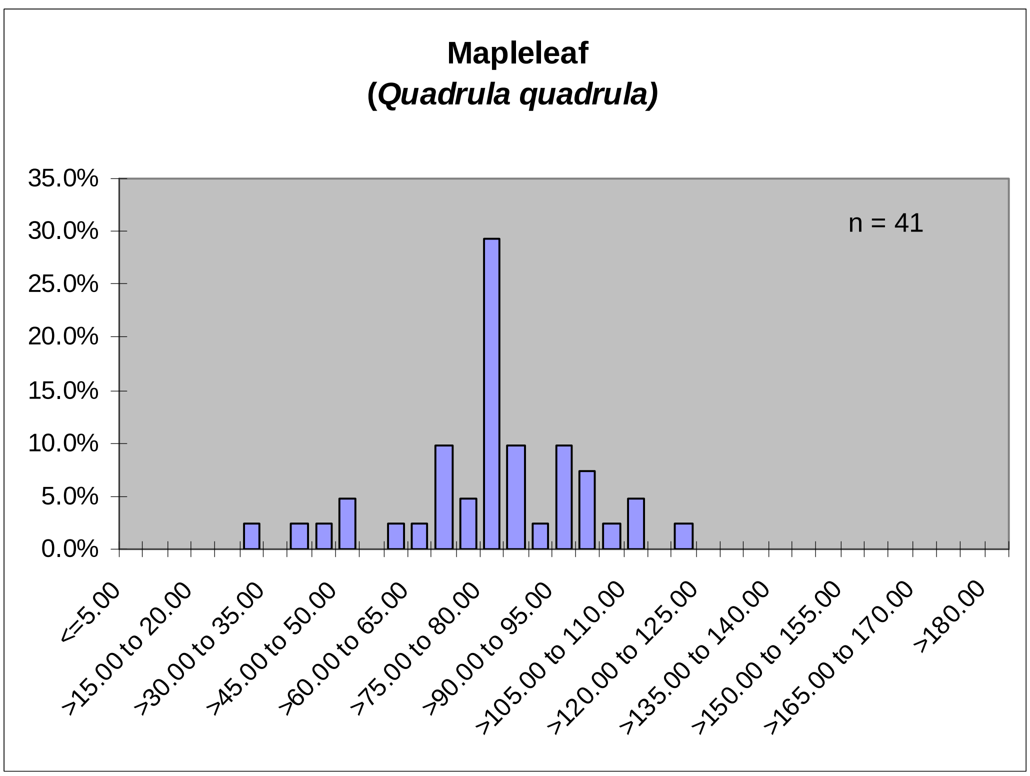
Muskrat midden sub-sample from right descending bank, immediately downstream of Montgomery Dam and Locks, Ohio River SITE 32, 8/26/08. 69% mapleleaf, 22% threehorn wartyback, 6% pink heelsplitter, 3% deertoe. Many of these specimens were fresh dead.

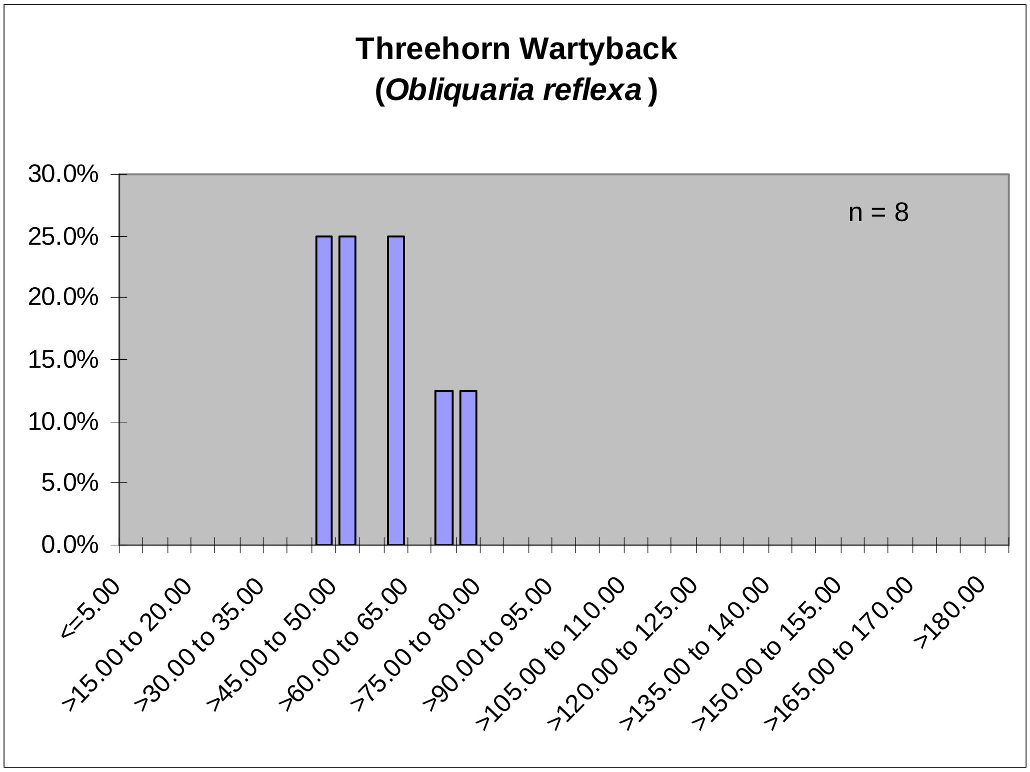
APPENDIX C.

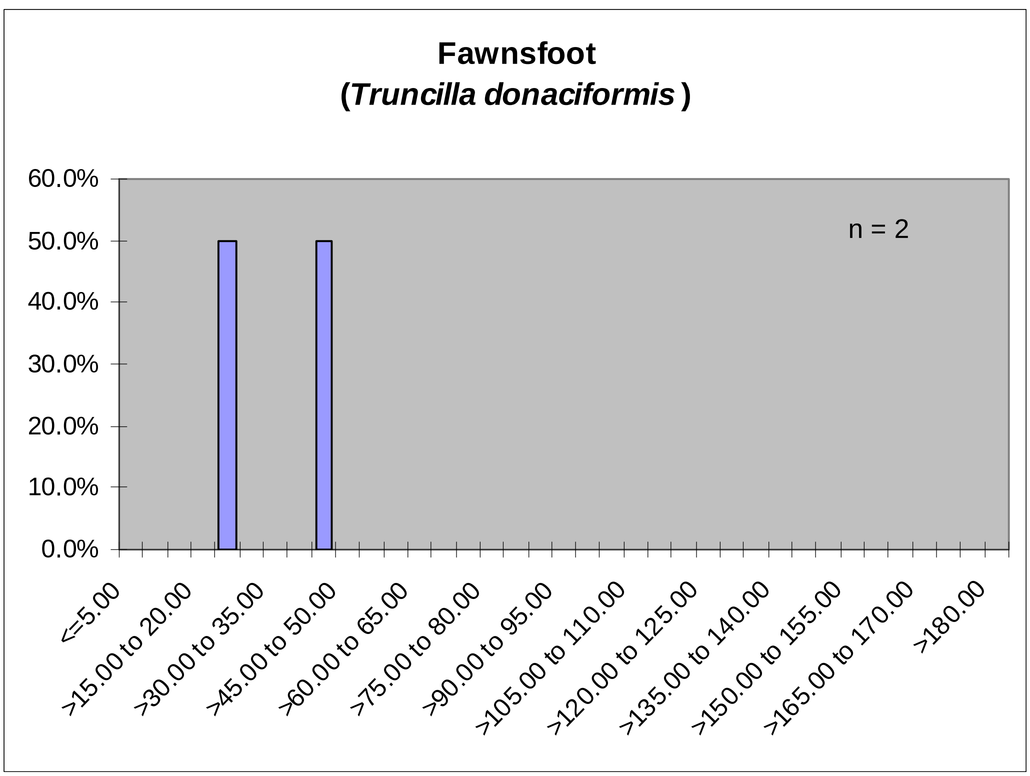
Length Histograms of Selected Mussel Species

APPENDIX C.
LENGTH HISTOGRAMS OF SELECTED MUSSEL SPECIES






Threehorn Wartyback
(Obliquaria reflexa)
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
n = 8
<=5.00
>15.00 to 20.00
>30.00 to 35.00
>45.00 to 50.00
>60.00 to 65.00
>75.00 to 80.00
>90.00 to 95.00
>105.00 to 110.00
>120.00 to 125.00
>135.00 to 140.00
>150.00 to 155.00
>165.00 to 170.00
>180.00


Fawnsfoot
(Truncilla donaciformis)
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
n = 2
<=5.00
>15.00 to 20.00
>30.00 to 35.00
>45.00 to 50.00
>60.00 to 65.00
>75.00 to 80.00
>90.00 to 95.00
>105.00 to 110.00
>120.00 to 125.00
>135.00 to 140.00
>150.00 to 155.00
>165.00 to 170.00
>180.00

APPENDIX D.

Recent Mussel Surveys Known from within the Study Area

Appendix D. Recent Mussel Surveys Known from within the Study Area

Aquatic Systems, A Service of McLaren/Hart, Inc., 1997. Mussel brailing survey report, Ohio River Montgomery Pool, miles 21.6 – 23.6, Beaver Co., PA, Sept. 1997. 5pp plus figures, tables and appendices.

Aquatic Systems, A Service of McLaren/Hart, Inc., 1997. Mussel brailing survey report, Ohio River New Cumberland Pool, miles 32.0 – 32.3, Beaver Co., PA, June 11. 1997. 5pp plus figures, tables and appendices.

Aquatic Systems, A Service of McLaren/Hart, Inc., 1998. Mussel brailing survey report, Ohio River New Cumberland Pool, miles 37.8 to 38.9, Beaver Co. PA, Sept. 14-16, 1998. 5pp plus figures, tables and appendices.

Aquatic Systems, Inc., 2001. Freshwater mussel diver survey report, right decending river segments mile points 36.5 to 37.1, New Cumberland Pool, Ohio River, Beaver Co., PA. 8pp plus figures, tables and appendices.

Aquatic Systems, Inc., 2002. Freshwater mussel dive survey final report, river mile 31.6 to 29.6, left descending river segments, Montgomery Pool, Ohio River, PA. 7pp plus figures, tables and appendices.

Aquatic Systems, Inc., 2004. Freshwater mussel dive survey final report – right descending river segments, river mile 21.8 to 20.5, Montgomery Pool, Ohio River, Beaver County, PA. 8pp plus figures, tables and appendices.

Aquatic Systems, Inc., 2004. Freshwater mussel dive survey final report – river mile segments 36.2 to 35.4, New Cumberland Pool, Ohio River, Beaver County, PA. 8pp plus figures, tables and appendices.

Aquatic Systems, Inc., 2005, Freshwater mussel dive survey report, right descending river segments 19.1 to 20.4, Montgomery Pool, Ohio River, Beaver Co., PA. 7pp plus figures, tables and appendices.

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