Pennsylvania

Department of Environmental Protecton

Coastal Resources Management

March, 2020

Qualitative Survey of the Spatial Extent of Freshwater Mussel Beds in the Pennsylvania Portion of the Tidal Delaware River using Side Scan Sonar Imaging and Underwater Video

Tom Wolf, Governor

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

pennsylvania
COASTAL RESOURCES MANAGEMENT

Patrick McDonnell, Secretary

0410-RE-DEP5314 10/2020 G-2425Apr20

pennsylvania
COASTAL RESOURCES MANAGEMENT

About the Pennsylvania Coastal Resources Management Program

The Pennsylvania Coastal Resources Management Program (CRM) within the Department of Environmental Protection (DEP) was established under Executive Order 1980-20 issued by Governor Dick Thornburg on September 22, 1980. Shortly thereafter, the U.S. Department of Commerce approved Pennsylvania's Coastal Zone Management Plan under the authority of the federal Coastal Zone Management Act of 1972. DEP's Compacts and Commissions Office coordinates and implements the CRM program to execute sound coastal management program policies in Pennsylvania's two coastal areas: the Lake Erie and Delaware Estuary Coastal Zones.

CRM receives funding from the National Oceanic and Atmospheric Administration (NOAA) to administer the Pennsylvania Coastal Resources Management Program and provide grants to local governments, state agencies and nonprofit organizations to undertake projects in the coastal zones. Since the program's federal approval in 1980, the Pennsylvania Coastal Resources Management Program has provided over 50 million dollars in funding for coastal zone projects that advance the program policies described within the NOAA-approved Coastal Zone Management Plan. CRM also directly implements policies described within the program plan through in-house technical activities and competitive contracts.

This survey was conducted under Policy 3.4 – Fisheries Management/Studies which states: *It is the policy of the Coastal Resources Management Program to undertake detailed technical studies of coastal fisheries, their aquatic habitats, and associated issues that impact their management.*

Acknowledgements

This project was completed with funding from NOAA. The Pennsylvania Department of Environmental Protection also appreciates the consultation and coordination provided by the following organizations to help make this project possible:

U.S. EPA Region III – Field Services Branch

U.S. EPA Region III – Scientific Dive Unit

Partnership for the Delaware Estuary

Academy of Natural Sciences

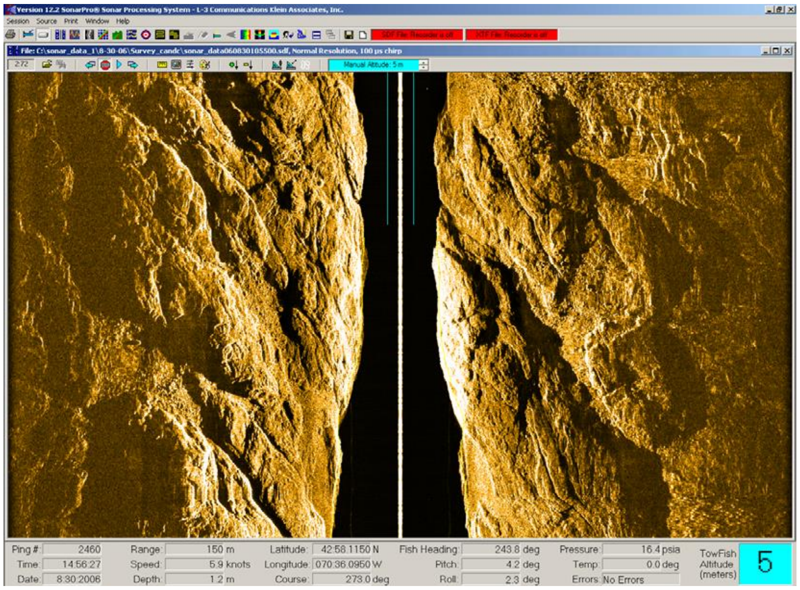
Pennsylvania Fish and Boat Commission

Cover photo of freshwater mussels provided courtesy of the Partnership for the Delaware Estuary.

Introduction

Freshwater mussels are imperiled throughout Pennsylvania. Efforts are underway to reestablish mussel populations in watersheds where their populations are severely impaired or where they are thought to be extirpated. In the mid to late-2000's significant but localized populations of mussels were rediscovered within the tidal mainstem of the Delaware River. Subsequent surveys in 2010 and 2011 documented the presence of nine species of freshwater mussels (PDE 2012). The full spatial extent of freshwater mussels in the Delaware Estuary is largely unknown. These populations are at risk of disturbance from human activity if their locations and statuses remain unknown to federal and state natural resources agencies. If adequately documented, their bed locations can inform future targeted survey activities and provide a basis for conditions for permitted activities that may impact threatened and endangered species. Appropriately managed, they can also provide seed-stock for mussel reintroduction programs.

There have been efforts to survey and document a few known mussel beds in the Delaware Estuary using wading, snorkel, and dive transect population survey techniques. These techniques can provide high-resolution spatial data that incorporates species composition. Spatial coverage is limited, however, and large surveys can be time-intensive and require a substantial workforce. Furthermore, localized mussel populations cannot be surveyed if their locations remain unknown or undocumented. Remote sensing technologies can allow for very broad spatial coverage to document the locations and extents of existing, potentially unknown mussel populations with a small crew and in a relatively short time-period. Information gathered via remote sensing, once compiled and mapped, can help to inform future localized survey efforts and make natural resource agencies aware of mussel areas that may be at risk of future impacts.



File: C:\sonar_data_1\8-30-06\Survey_candc\sonar_data060830105500.sdf, Normal Resolution, 100 µs chirp

Ping #: 2460
Time: 14:56:27
Date: 8:30:2006
Range: 150 m
Speed: 5.9 knots
Depth: 1.2 m
Latitude: 42:58.1150 N
Longitude: 070:36.0950 W
Course: 273.0 deg
Fish Heading: 243.8 deg
Pitch: 4.2 deg
Roll: 2.3 deg
Pressure: 16.4 psia
Temp: 0.0 deg
Errors: No Errors

Figure 1: High resolution side scan image of a bedrock substrate. The white line is the path of the sonar (travelling toward the top of the image) and the black area is the water column between the sonar and the substrate. Image courtesy of Klein Marine Systems, Inc.

Side scan sonar is a remote sensing technology that uses sound impulses to create an image-like representation of the bottom of a waterbody (Figure 1). Dual transducers project sound impulses on a down angle to each side of the sonar device as it travels through the water and listen for the echoes returning off of the bottom and other targets. On a graphic waterfall display, a single pair of echoes (single ping) is plotted as a line of pixels extending outward from each side of a centerline (the sonar's path). The elapsed time from the sounding of the ping to the return of the echo determines each pixel's lateral position (distance from the centerline of the display) and the intensity of the echo detected at that point in time determines the brightness of the pixel. As the sonar travels through the water, the lines of pixels are stacked together to form an image-like representation of the bottom beneath the path that the sonar travelled. In post-processing, the left and right sonar channels can be stitched together to form contiguous swath (removing the black area representing the water column, see Figure 1). The swaths from parallel and overlapping sonar passes can then be mosaicked together to cover a larger area and create a landscape-scale picture of the bottom that reflects substrate characteristics and the position and orientation of targets of interest.

The images represented in a side scan sonar record cannot be interpreted like typical images. Each pixel's brightness is determined by the intensity of the echo received by the transducer, rather than reflected light. The intensity of the echo is determined by a number of factors related to substrate and target characteristics. In general, the primary substrate and target characteristics that affect the intensity of the echo, and thus pixel brightness, include:

	Brighter		**Darker**
Hardness:	Hard – reflects more energy		Soft – absorbs more energy
Roughness:	Rough – scatters more energy	vs.	Smooth – cleanly deflects more energy
Angle of Incidence:	Acute – returns more energy		Oblique – deflects more energy away

Additionally, interactions occur between these factors that also contribute to pixel brightness. For instance, a smooth surface that is at an oblique angle to the sonar impulse will produce very little backscatter and will deflect much of the sonar energy away from transducer. It will thus appear dark in the sonar record. A rougher surface at the same angle will scatter more acoustic energy back to the transducer and will appear brighter. The opposite becomes true as the angle of incidence steepens. A smooth surface that is more perpendicular to the sonar impulse will reflect more energy back to the transducer and appear brighter, whereas a rough surface will scatter more energy away from the transducer and appear darker. Interpreting acoustic images is therefore heavily dependent upon ground-truthing to confirm targets and substrates and to build a catalogue of how patterns in the sonar imagery relate to the physical conditions within the waterbody. Once a catalogue of acoustic representations and associated physical conditions has been developed, it can be used to delineate and identify features and locate targets within a georeferenced side scan mosaic.

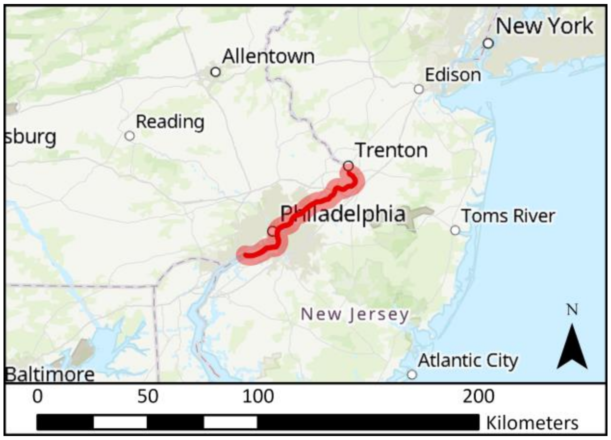
Previous research has demonstrated that mussels in soft sediments (sands or silts) can be detected with side scan sonar (Powers et al., 2014). Mussel shells reflect a strong echo against the backdrop of acoustically-absorbent soft sediments. The contrast in the sonar record between the bright shells and dark substrate creates a pattern that is readily identifiable, particularly in areas where there is some separation between individual mussels or clusters of mussels. Densely populated mussel beds, however, can mimic cobble areas in acoustic imagery. Thus, mussel populations can be difficult to differentiate acoustically within a hard substrate setting. Visual confirmation is necessary to accurately delineate mussel populations in these areas. Underwater video can confirm both substrate features and the presence of mussels while side scan imagery provides full coverage to fill in the gaps between grab sample locations.

The intent of this project is to provide a baseline estimate of the current spatial extent of freshwater mussels in Pennsylvania's portion of the tidal Delaware River using georeferenced side scan sonar hydroacoustic imaging techniques with site-specific underwater video confirmation. The final spatial dataset and supporting documentation is available upon request to state, federal, and local environmental resource agencies and federally recognized National Estuary Programs (NEPs). This report is intended to accompany the spatial dataset to provide comprehensive information on the methods and techniques used to generate the Geographic Information System (GIS) layers.

Methods

Survey Area

Figure 2: Survey area



The area planned for the initial survey extended from the upriver confluence of Biles Creek with the Delaware River in Falls Township, Bucks County to the Delaware state line in Delaware County, Pennsylvania (Figure 2). The intended survey area extended laterally from the Pennsylvania shoreline to the New Jersey State Line along the centerline of the Delaware River. Due to equipment issues late in the survey, the final area was restricted at the downriver extent to the southern shore of Little Tinicum Island in Tinicum Township, Delaware County. Surveys of the northern watercourse passage by Little Tinicum Island, all waters downstream of Little Tinicum Island to the state line with Delaware, and the Schuylkill River were not completed. Nearshore bathymetry in some areas dictated a vessel course that did not allow the Pennsylvania shoreline to come within range of the sonar. In other areas, shipping traffic or anchorages prevented the survey from extending laterally all the way to the New Jersey state line in the middle of the river. Throughout the survey area coverage extends at least into the maintained federal navigation channel. The final covered area of the survey reflects these noted constraints.

Side scan sonar

Acoustic data were collected in April through October of 2017 and 2018 using a TriTech Starfish 450F towed side scan sonar system with a 450kHz nominal frequency utilizing CHIRP pulse compression and a pulse length of 400µs. Range per channel was set at 50m. Survey tracks were planned to provide at least a 25% overlap in adjacent swath coverage with a preferred overlap target of 50%. Positional data were collected with a system-integrated Starfish GPS (SiRF III) with a horizontal accuracy of 10m. Acoustic and GPS data were recorded using TriTech Starfish Scanline data acquisition, recording, and display software.

Data files were exported from the Scanline software in XTF format and imported into SonarTRX Pro (x64 with PlusPack) for post processing. Prior to applying layback corrections (along-track offset between the GPS and sonar sensors), processed image mosaics were exported from SonarTRX Pro in GeoTIFF format for display in ESRI ArcGIS over an aerial imagery basemap. Features identifiable in both the georeferenced aerial imagery and in the acoustic images (bridge supports, piers, etc.) served as spatial controls. To correct for layback and other spatial offsets, measurements were taken between structures visible in georeferenced aerial imagery and their representations in the acoustic mosaic. Measurements were also taken between submerged features present in overlapping side scan passes to determine the along-track offsets in adjacent passes. An average layback offset correction value was calculated for each sonar pass and each pass was then reprocessed in SonarTRX to apply the correction. Only a single layback correction value was applied in post-processing for each sonar file and each sonar file constituted a single pass. During data collection, the GPS antenna was placed in-line with the sonar towfish on the starboard side of the towing vessel. Thus, no across-track offset corrections were applied in post processing. Final mosaicking of the processed acoustic image tiles was performed in ESRI ArcGIS. Sonar passes were mosaicked as individual layers so that adjacent overlapping passes could be reordered to provide different viewing perspectives during image analysis. Groups of pass-layers were organized into sections and each section was named to reflect its river-mile coverage.

Underwater video

Acoustic image mosaics were reviewed in ESRI ArcGIS to inform video site planning. Sites for underwater video collection were selected according to observed changes in substrate features and suspected mussel populations based on the acoustic imagery and were mostly arranged into clusters. Sites were selected to positively identify acoustically observed features, catalogue how feature-types are presented in the acoustic record, bracket feature transitions, and confirm feature continuity. Areas where mussels were suspected based on review of the acoustic imagery were given priority. Coordinates for planned video sites were exported from ESRI ArcGIS and packaged for upload to the survey vessel chartplotter with Garmin Homeport software. Video site clusters were named according to the approximate one-tenth river mile with individual sites distinguished by a trailing alpha-sequence. The alpha-sequence was generally ordered from shore-to-channel, although a few supplemental sites added later may be located shoreward of earlier-sequenced sites.

Video sampling efforts were scheduled to maximize collection around slack tides, when visibility was least impaired. The survey team navigated to the planned site locations using a Garmin GPSMAP 741xs chartplotter. The boat was anchored upstream (e.g., downriver during a flood tide) of the site location such that the net effects of wind and current would allow the boat to be positioned within 50 feet of the targeted coordinates. Most of the videos were collected with the boat positioned within 20 feet of the targeted coordinates. Once the boat was settled under anchor, the time, water depth (boat echosounder), and actual position (chartplotter) of the boat were recorded. Video was collected using a SplashCam Delta Vision Industrial HD drop camera weighted with a 14-lb downrigger ball to counteract water current effects and were recorded on an Atomos Ninja IV video monitor/recorder. Approximately 2-5 minutes of bottom time were recorded for each location (depending on visibility and camera stability) and field observations were recorded on the data sheet.

Videos were reviewed individually by two team members on desktop computers in an office setting where they could be displayed on larger screens and playback could be manipulated. Playback speed was slowed to 20-50% of real-time during desktop review to better observe mussel presence. Video observations recorded in the field while watching the real-time display on the 4.5-inch viewing screen were unreliable and were frequently revised upon desktop review. A representative screen capture was saved from each video for display in ESRI ArcGIS. For each site, categorical assignments were made upon consensus, according to Table 1:

Table 1: Mussel density and Wentworth substrate categories assigned to underwater video locations upon review and consensus of two team members.

Mussel Density Categories	
None	no individuals observed
Sporadic	widely spaced, ≤ 2 per m^2
Common	narrow spacing, $> 2 \leq 15$ per m^2
Bed	tightly packed, reef, > 15 per m^2

Substrate Categories	
Boulder	> 256mm
Cobble	$> 64 \leq 256$mm
Pebble	$> 2 \leq 64$mm
Sand	$> 0.0625 \leq 2$mm
Silt	≤ 0.0625mm

The mussel density and grain size values in Table 1 served only as a guide. With no indications of scale in the recorded bottom video, reviewers were not able to quantify the mussels within a given area. The mussel density category assigned to each video location was done so in consensus and according to the best judgement of the investigators. To avoid the inclusion of dead individuals or empty shells, only mussels with a visible mantle or fully closed mussels in an upright orientation within the sediment were considered a positive result. Likewise, substrate categories on the Wentworth size class scale were assigned subjectively, in consensus, and according to the best judgement of the investigators. The team did not collect substrate samples for grain size analysis; substrate categories were assigned by video review alone. In mixed substrates or, in a few instances along substrate boundaries, substrate classification was made according to the apparently predominant substrate by coverage area. After the analysis of the video recordings was complete, the data were imported into ESRI ArcGIS for display as point features. The point features were symbolized by color according to mussel density category, labelled by mussel density category, substrate category, and the presence of *Corbicula* and submersed aquatic vegetation (SAV), and displayed over the processed side scan mosaics to aid in the development of mussel polygon features. Dense SAV beds can interfere with the acoustic impulses, obscuring the river bottom, and Corbicula is an invasive clam which, in high densities, can appear similar to mussel beds in the sonar record. The point features and their categorical assignments are displayed in the GIS layer at the coordinates recorded at the time of field collection.

Video point data were supplemented by a separate dive transect survey conducted by the United States Environmental Protection Agency (EPA) Region III Scientific Dive Unit in an area with established mussel populations within cobble and boulder substrates. Eight dive transects were planned at roughly 150 – 240m intervals along a 1500m stretch of cobble and boulder substrate. Transect locations were chosen to intersect with observed changes in sonar reflectivity and to refine mussel density categorical polygon resolution within the cobble and boulder features. Mussel counts and substrate observations were made, and video was collected at stations located at 20m intervals along each transect starting at approximately 10m of water depth and extending toward the shoreline. The data for each station were imported into ESRI ArcGIS for display as point data. The points were symbolized by color according to mussel density category and labelled by mussel density category, substrate category, and the presence of Corbicula and SAV. The transect station point features were displayed over the processed side scan mosaics to aid in the development of mussel polygon features. The detailed protocol for this supplemental dive survey is included in this report as Appendix B.

Mosaic interpretation and polygon feature development

In ESRI ArcGIS software, video location points were displayed over sonar mosaics. Detected mussel populations visible in the sonar were delineated and confirmed by referencing the video record. As lines were drawn, they were assigned a subjective confidence value of 1 (least), 2, or 3 (greatest), based on the quality of the acoustic data and the availability of recorded video for the feature. No delineations were drawn between mussel population categories of “Bed” or “Common” because limitations in sonar target separation prevented these areas from being differentiated acoustically. Mussel population features with clear boundaries and even texture with two or more consistent ground truth sampling points were delineated with a confidence of “3”. Lines for areas with gradual transitions in mussel population were drawn within the transition area at the discretion of the investigator. Mussel density categories were, in some cases, assigned based solely on available sonar image data where the characteristics of the sonar images were comparable to other sites that had supporting video data. Isolated mussels detected by video that were not part of a larger mussel population feature detected by sonar were not delineated as separate features. These video point features were assigned a mussel population category of “Sporadic” and may appear isolated within a polygon feature delineated as

"None." Similarly, isolated video sites where no mussels were detected occasionally appear within regions delineated as "Sporadic" when the sonar record and other nearby video clearly indicated that a contiguous but sporadic population is present.

Mussel populations were not able to be differentiated acoustically within cobble or boulder substrates because the mussels mimic the substrate in acoustic characteristics. Video ground truthing was necessarily more extensive in these areas. Where multiple video samples showed consistent mussel density within a hard substrate feature, the mussel population was assumed to extend to boundary of the feature. Where a break in the mussel population was documented by video within a hard substrate feature, the line was drawn to split the difference between points where mussels were detected and those where they were not. The delineations in these areas are necessarily coarser in detail than those in softer substrates and were assigned a confidence value of 1.

The supplemental dive transect survey conducted by the EPA Region III Scientific Dive Unit (previously discussed) was completed within a specific area of hard substrates. Data from eight transects were collected along a 1,500m stretch of boulder and cobble substrates to further refine the delineations within this area. The protocol for the dive transects survey is included as Appendix B in this report.

Results and Discussion

CRM collected 286 line-miles of side scan sonar data along approximately 46 river-miles of the Delaware Estuary. A total non-overlapping area of 1,747 hectares was imaged and delineated by mussel population category. Approximately 10% of the surveyed area was mapped in the common/bed mussel density category. Total areas of mapped mussel extent by population density is shown in Figure 3.

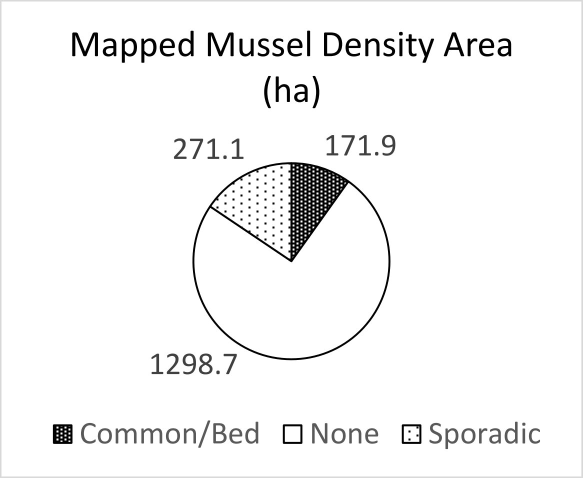


Figure 3: Relative coverage of mapped mussel density categories within the survey area.

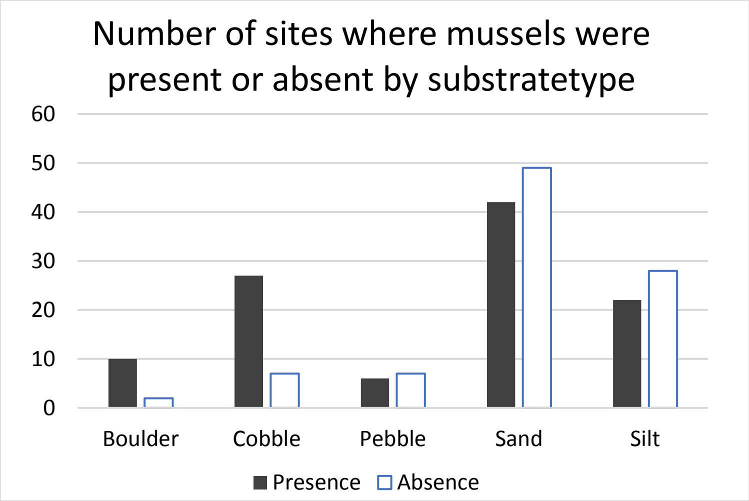


Figure 4: Mussel presence or absence by substrate type as recorded by underwater video.

Underwater video was recorded at 223 locations within the survey area to confirm substrate composition and the categorized mussel population density. Distribution of the data by presence or absence of mussels among substrate types is shown Figure 4. The survey was not designed to evaluate mussel-substrate associations. Nevertheless, an apparent positive association with cobble substrates was observed. A statistical analysis is problematic because the sampling method employed was not randomized. The objective of this survey was simply to document the spatial coverage of mussel beds in the estuary. As a result, the video sampling locations were chosen selectively and intended to specifically investigate features observed in the acoustic imagery. Video observation sites were specifically chosen to bracket changes in observed bottom type, confirm feature continuity, or confirm presence or absence of mussels as interpreted acoustically.

In developing the polygon features for mussel density categories, the finest-detail delineation results with the greatest confidence were obtained in areas of soft substrates (silts and sands) and those substrates occupied most of the survey area. The presence or absence of mussels in these areas is easily identifiable in side scan sonar imagery. Bare silt and submerged, unvegetated mudflats holding no mussels present in the sonar as featureless, smooth surfaces with a darker color tone than more coarse sands or hard substrates. Scattered or widely dispersed mussels in soft substrates appear in the acoustic images as a pattern of bright dots against the dark background provided by the sediments (Figure 5).

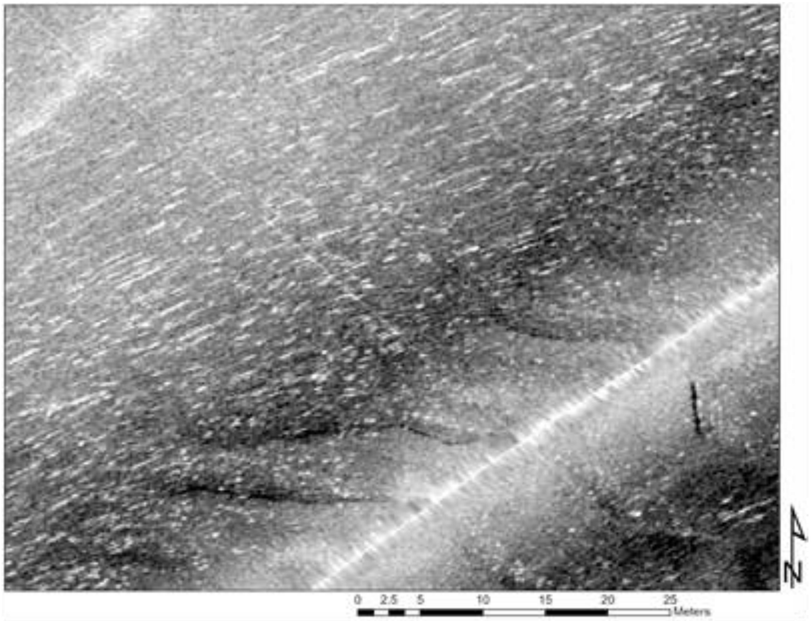


Figure 5: Dispersed mussels in soft sediment are readily identifiable in side scan sonar imagery.

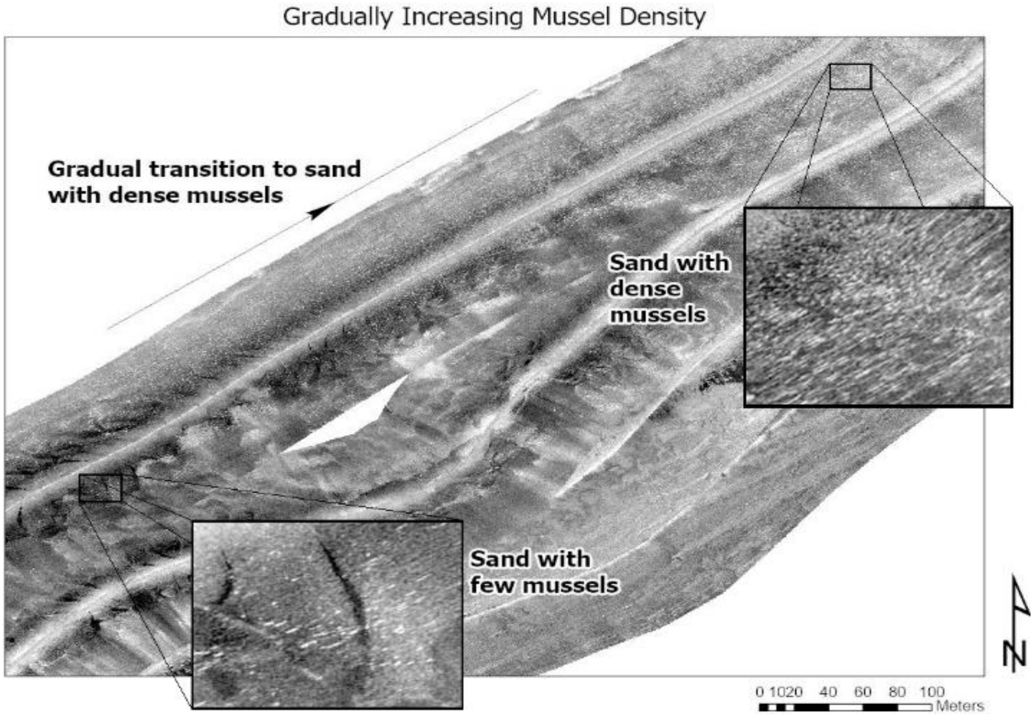


Figure 6: Gradual transitions of mussel population density in soft sediments are detectable with side scan sonar.

Underwater video in areas exhibiting this pattern confirmed that the hard targets embedded within the sediments were individual or small groups of mussels. It should also be noted that the side scan sonar will only detect echoes from mussels that are at least partially exposed at the substrate-water interface. Individuals fully buried within the sediment will not produce an echo and will therefore not be detected by this method.

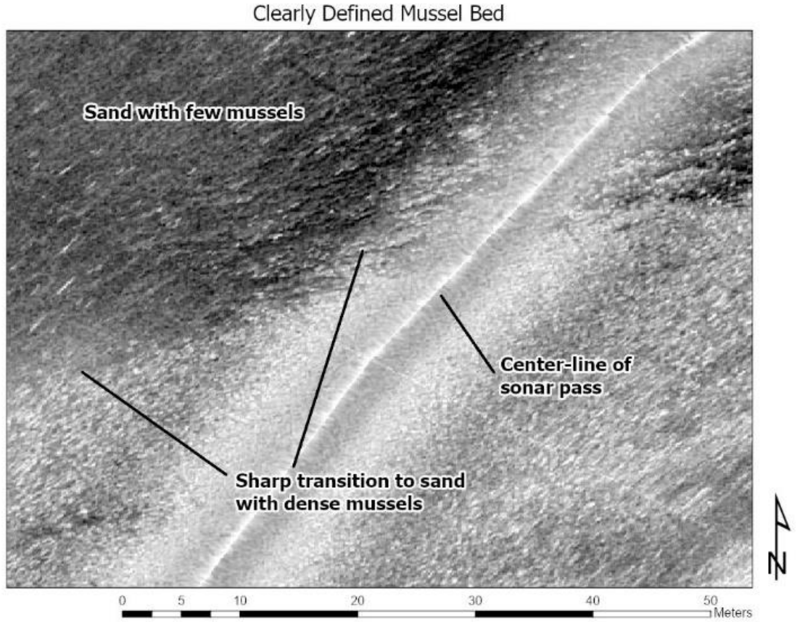


Figure 7: Well defined mussel beds in soft sediments show up clearly with side scan sonar.

Soft sediments with moderate to high densities of mussels are similar in appearance to cobble areas in the acoustic images. Ground truthing in these areas is vital to accurately identify whether the mapped feature is a cobble area or mussel bed. The transition areas between areas of low and high mussel densities in soft sediments were observable in acoustic imagery and variable in width (Figures 6 and 7). Mussel density category boundaries in areas with discernable, but gradual changes in density (see Figure 6) were delineated at the discretion of the investigators. Mussels were not observed in high densities within sandy areas with local conditions (substrate and current) sufficient to build large (10+ meters across) sand waves (Figure 8). Likewise, mussel populations designated as "common" or "bed" were not observed in areas with pebble substrates.

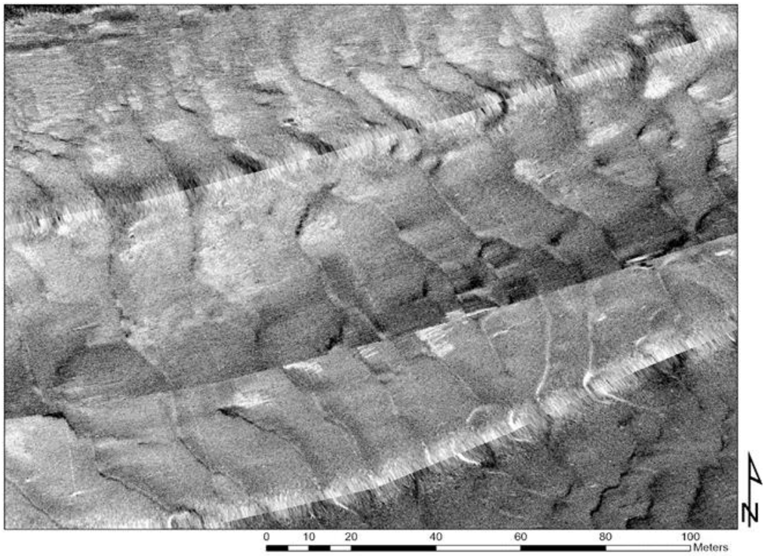


Figure 8. Mussels were generally not observed in areas with conditions sufficient to build large (~10+ m) sand waves.

The polygon features for mussel density categories developed from this effort and point features representing video collection sites have been packaged as GIS layers and, along with the side scan image mosaics, were used to develop an ESRI ArcMap document (.mxd) with preserved symbology. Additionally, the point features representing video locations have been hyperlinked to call up a representative screen shot from the collected video. This map and spatial datasets are intended to be used for general information for the evaluation of impacts to freshwater mussels from activities within the Delaware Estuary. It is also intended to serve as a screening tool to inform new or ongoing localized mussel population studies aimed at documenting species composition and aiding freshwater mussel recovery efforts.

Availability of Spatial Datasets

Throughout the planning and development of this survey, CRM has coordinated with the U.S. Environmental Protection Agency, the Partnership for the Delaware Estuary, the Academy of Natural Sciences, and the Pennsylvania Fish and Boat Commission. CRM is not posting the spatial datasets related to this survey onto any publicly available data repository. Common concerns from all partners and advisors about the sensitivity of spatial data relating to the location of freshwater mussel populations in the Delaware Estuary are shared by CRM. Data sets will be provided upon request to federal, state, and local government agencies and to any federally recognized National Estuary Program. The spatial data will also be made available via ArcGIS Online to properly vetted organizations.

Requests for the dataset should be made in writing to:

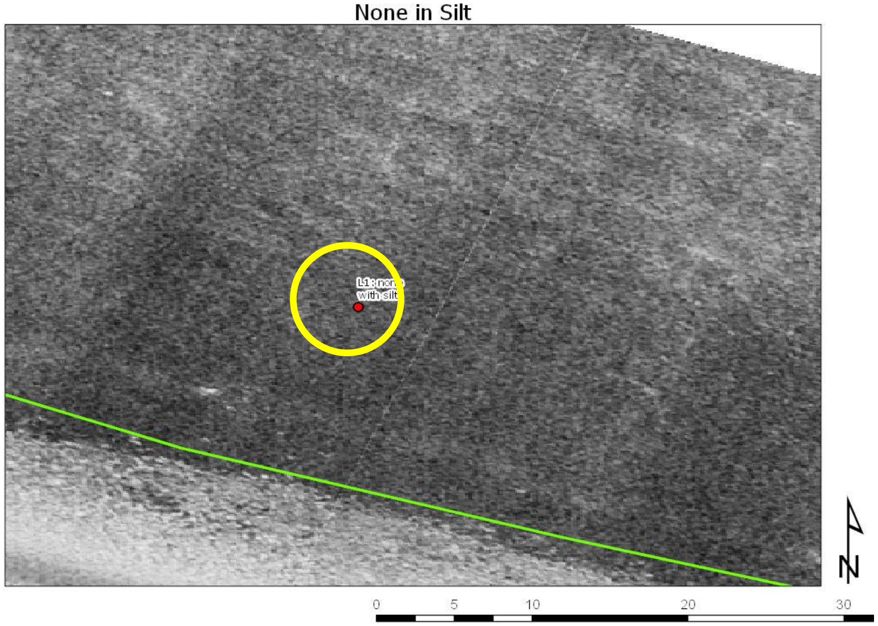
Matthew Walderon
Coastal Resources Program Specialist
Compacts and Commissions Office
P.O. Box 8465
400 Market Street, 10th Floor
Harrisburg, PA 17105-8465
mwalderon@pa.gov

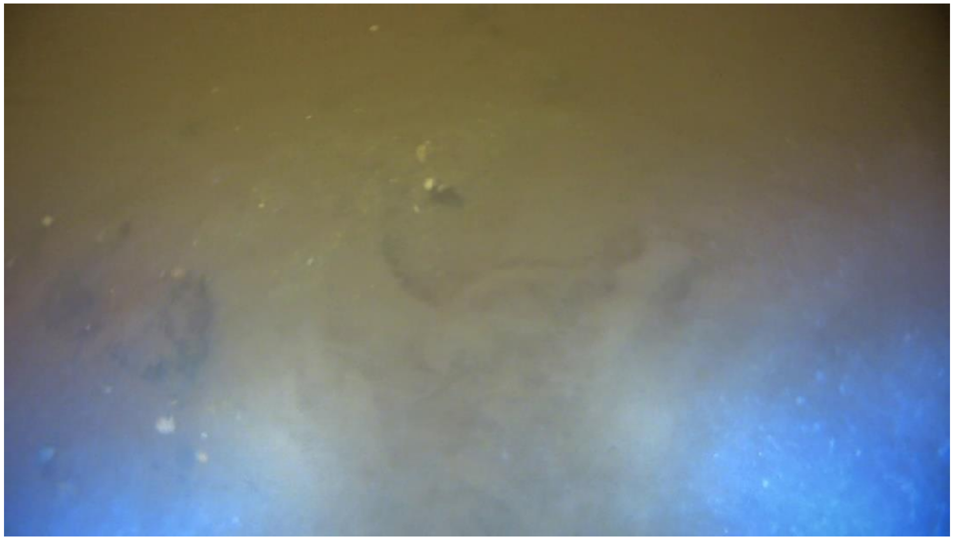
Appendix A:

Representations of Substrate and Mussel Density Combinations in Side Scan Sonar Images along with Photographic Example*

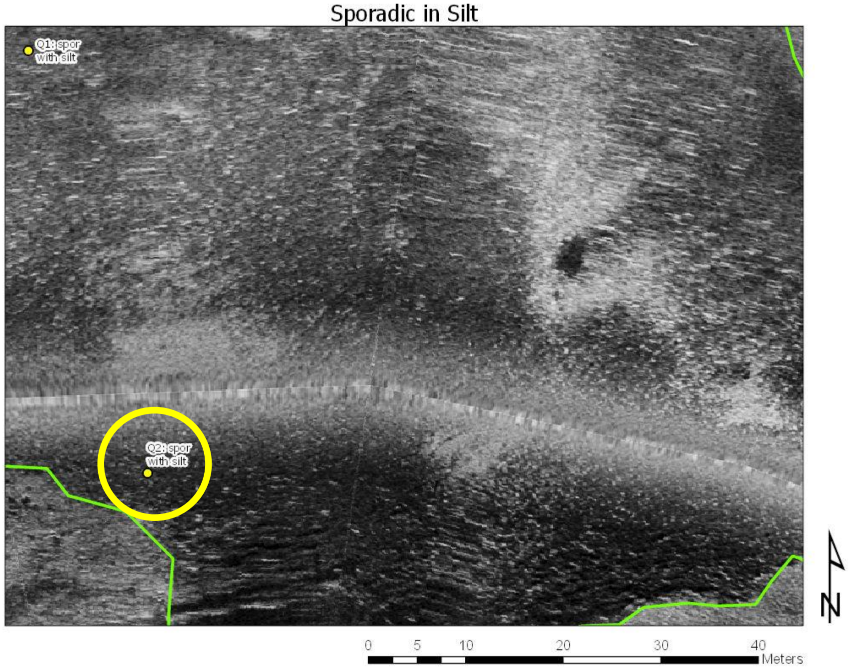
*Site where the shown photograph was taken is indicated by the point feature in the accompanying side scan image example.

Silt with None



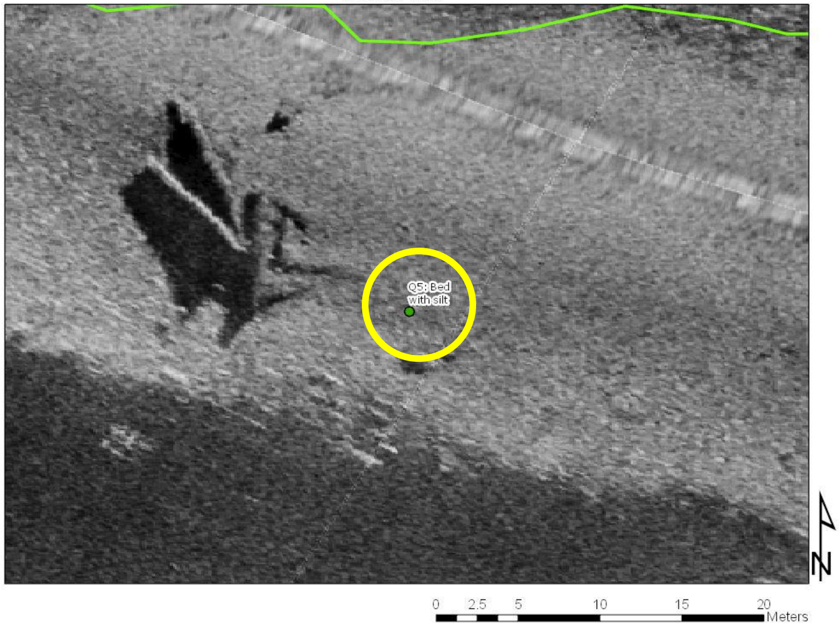


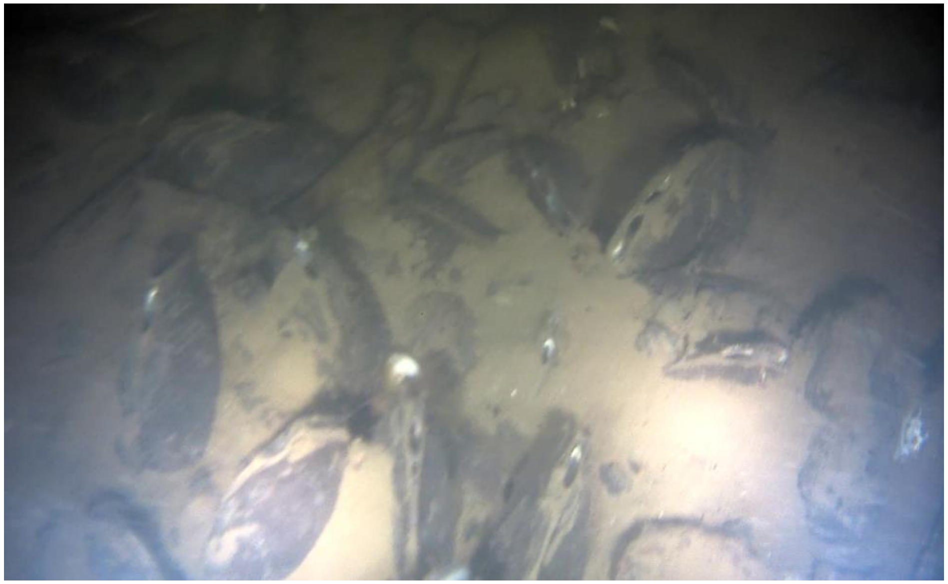
Silt with Sporadic



Silt/Sand with Bed

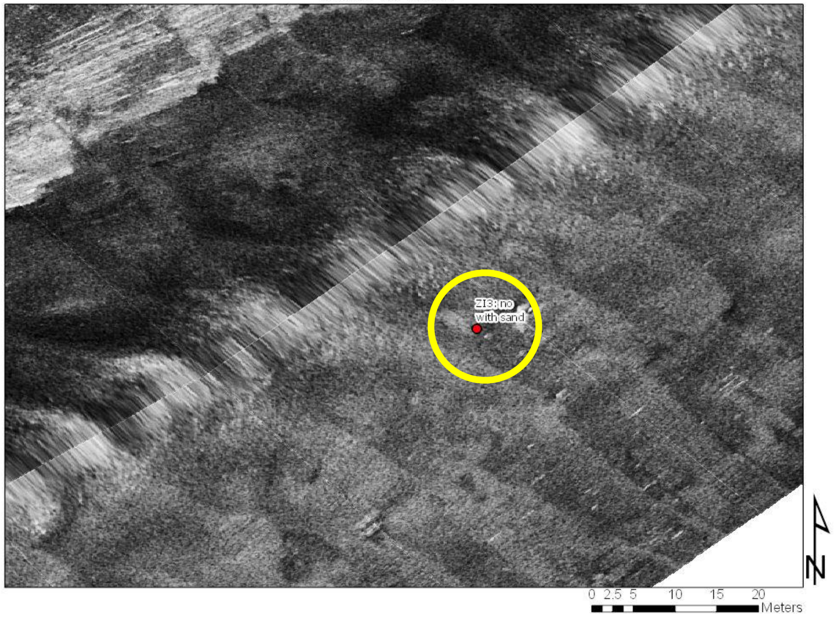
Bed in Silt

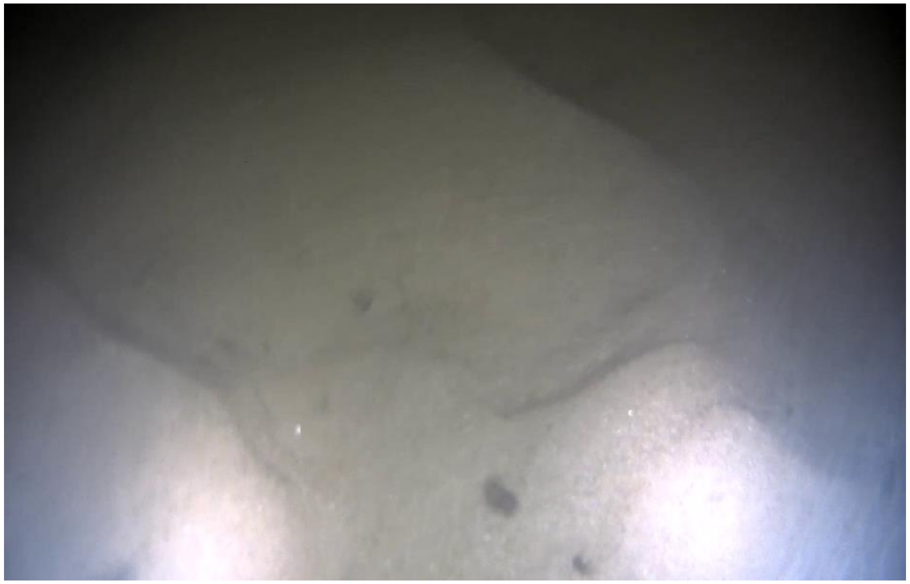




Sand with None

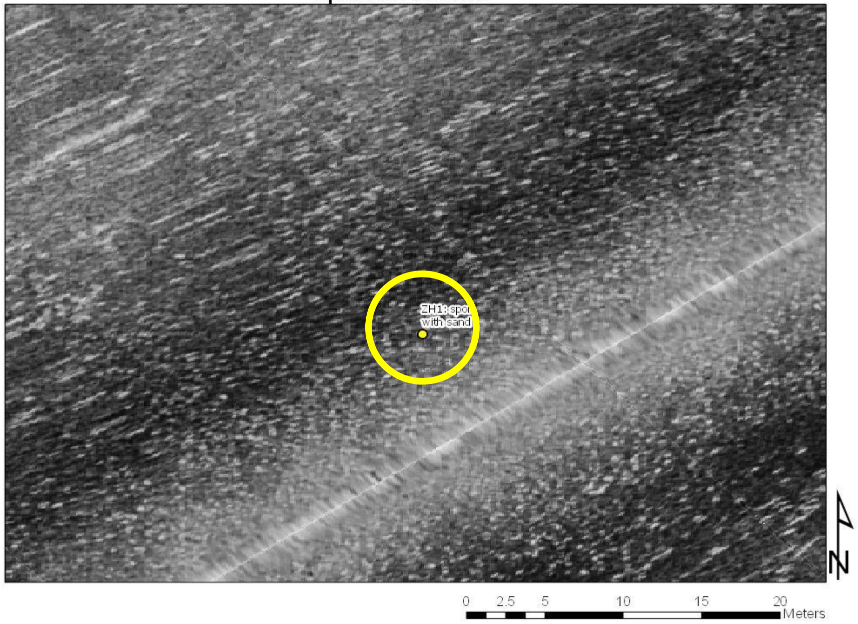
None in Sand

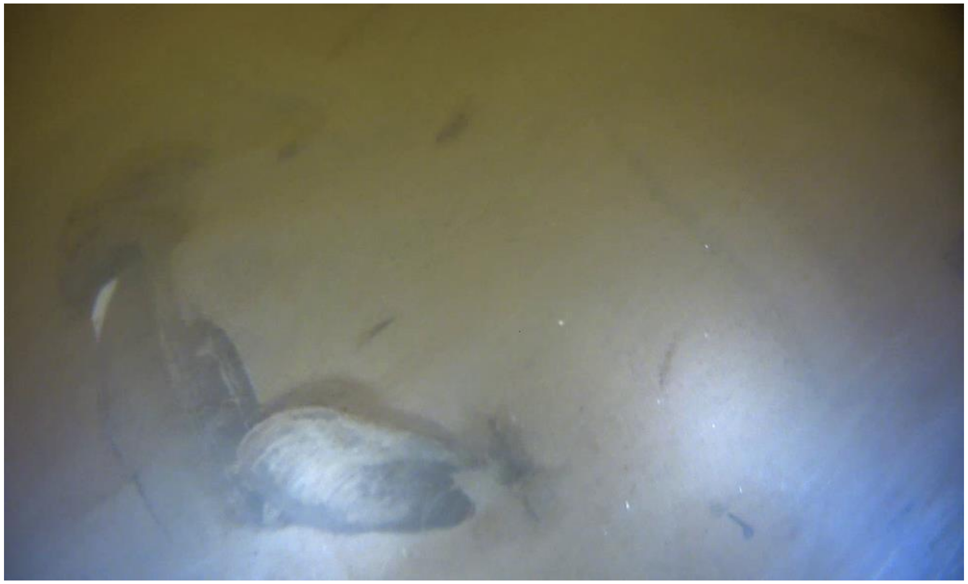




Sand with Sporadic

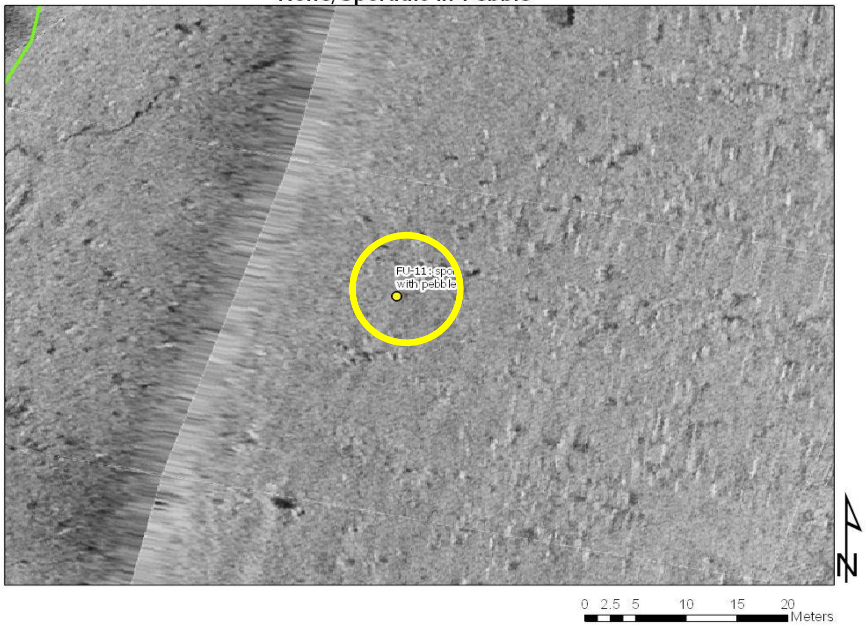
Sporadic in Sand





Pebble with None/Sporadic

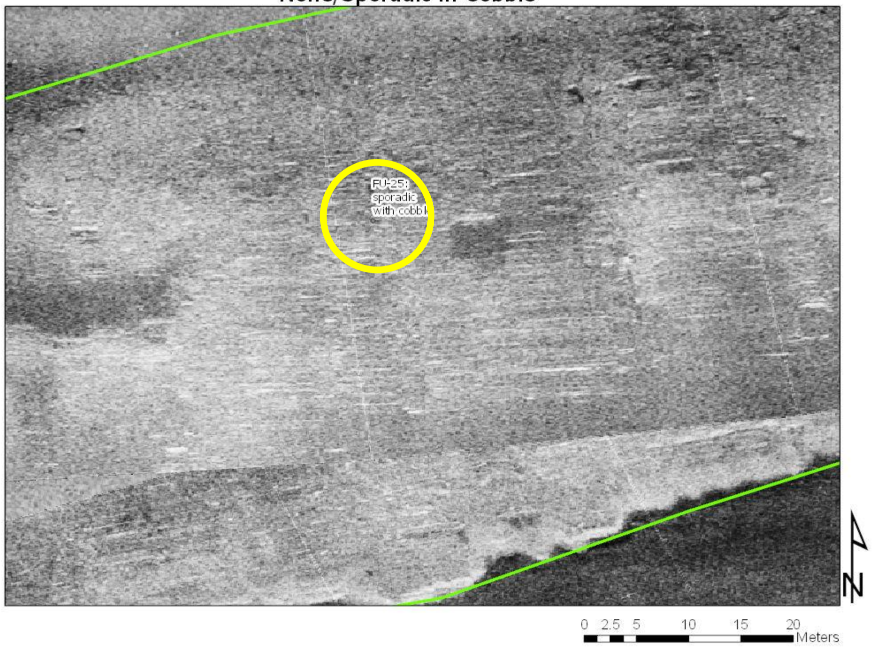
None/Sporadic in Pebble



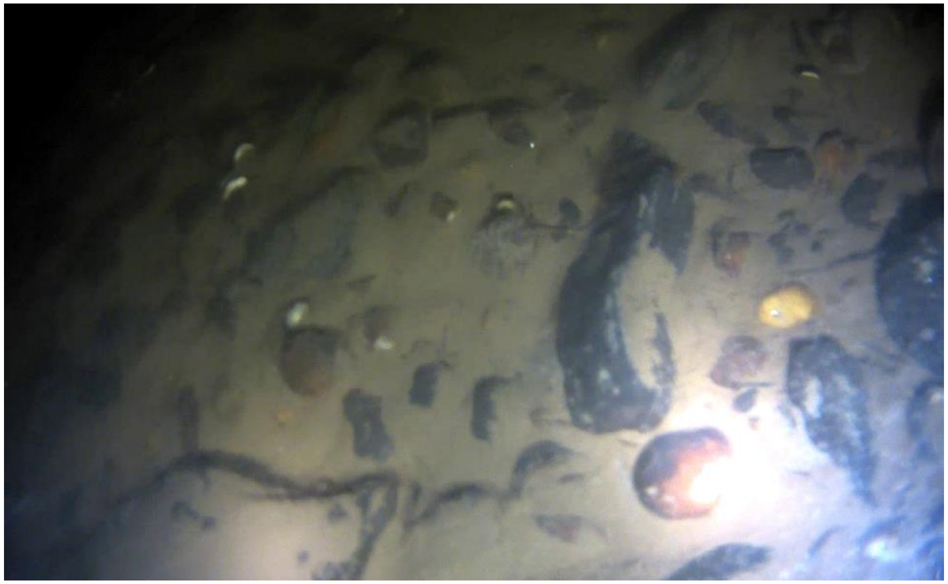
Pebble with Common/Bed

Not observed

Cobble with None/Sporadic

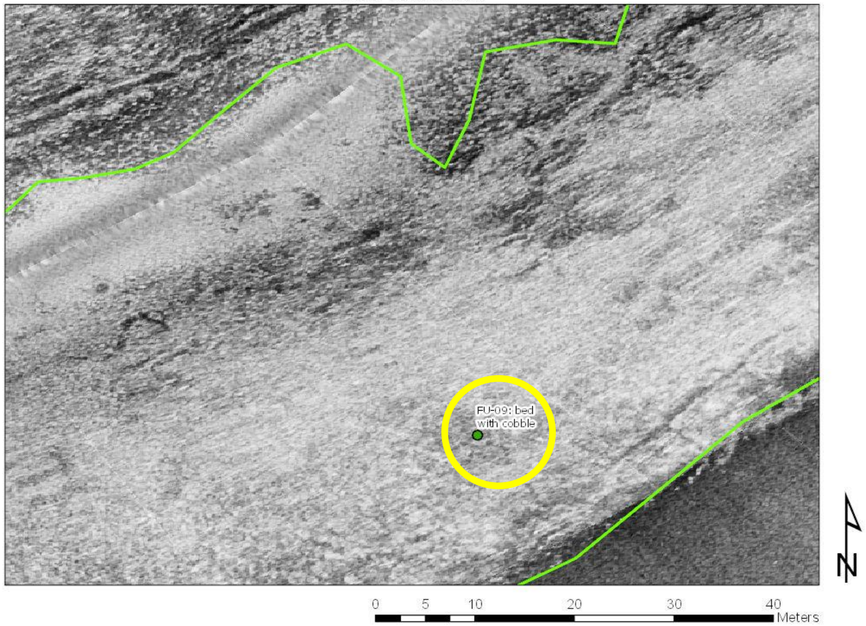


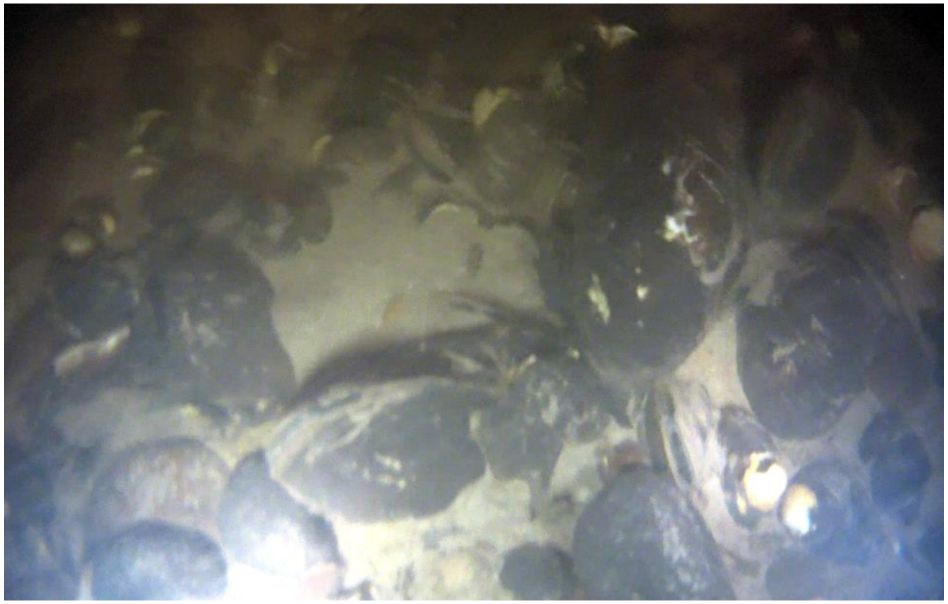
None/Sporadic in Cobble



Cobble with Common/Bed

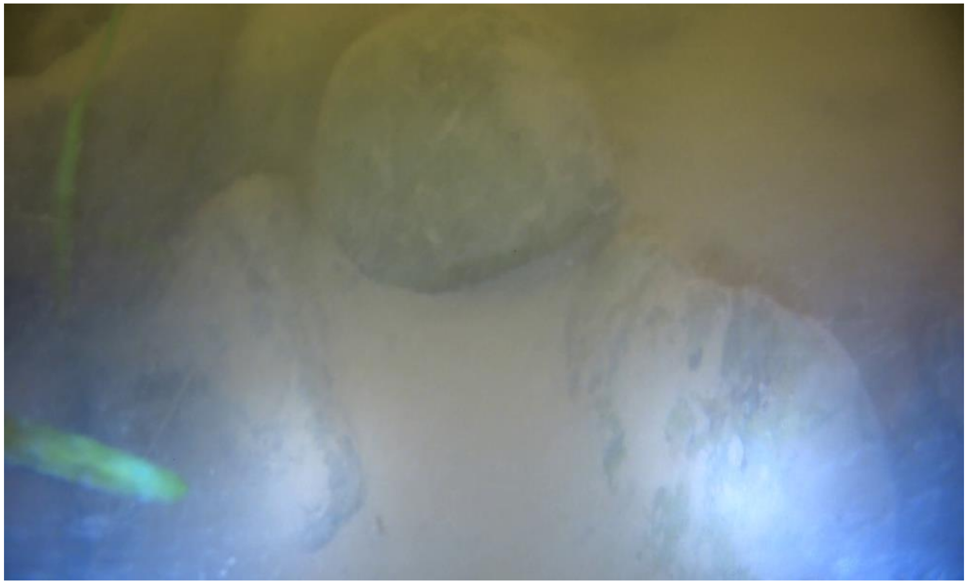
Bed in Cobble





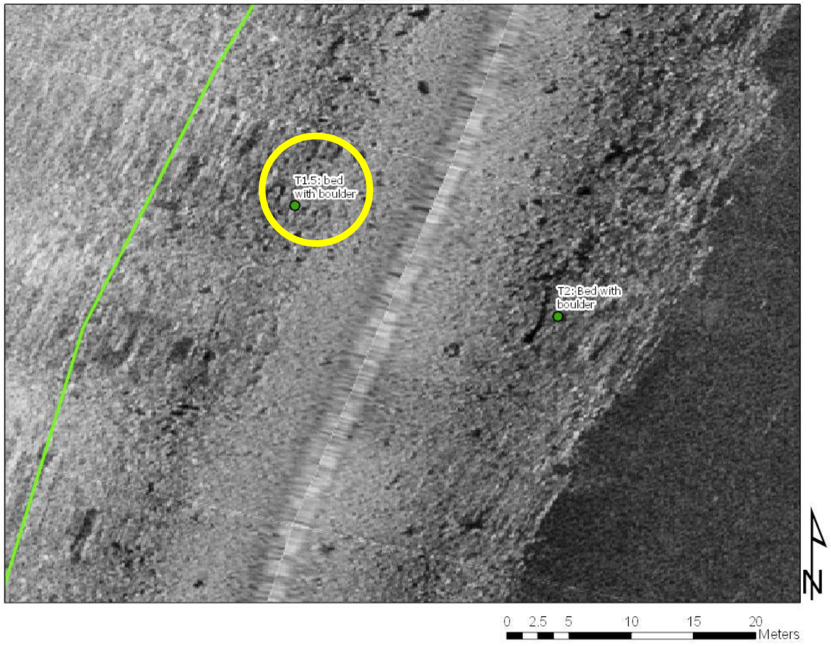
Boulder with None/Sporadic

None/Sporadic with Boulder



Boulder with Common/Bed

Bed with Boulder



Appendix B:

U.S. EPA. Mid-Atlantic Region 3
Scientific Dive Unit
Operation Report
July 11-August 19, 2019
PADEP Freshwater Mussel Survey

Specific locational data has been redacted.

U.S. EPA Mid-Atlantic Region 3
Scientific Dive Unit
Operation Report
July 11-August 19, 2019
PADEP Freshwater Mussel Survey

Dates of Operation:	July 11-12, and August 19, 2019
Site:	Delaware River, above Bristol, PA
Location:	See Dive and Safety Plan
Vessel:	EPA R/V Parker
Chief Scientist:	Matt Walderon, PADEP
Survey Scientist:	Brad White
Dive Masters:	Brad White
Scientists/Divers:	Dave Light, Nate Doyle, Jim Adamiec
Captain/Crew:	Mike Mansolino
Prepared by:	Brad White, Alternate Unit Dive Officer (UDO)

Background, Objectives and Schedule

See PADEP Freshwater Mussel Survey Dive and Safety Plan.

Weather Conditions

Date	Air Temp (F)	Weather
7/11	68-84	Mostly sunny
7/12	72-86	Overcast to partly sunny
8/19	70-91	Hazy to mostly sunny

Water Conditions

Date	Water Temp (F)	Visibility (ft)	River Flow (cfs)*	Tide Stage
7/11	79	1-3	8,590	Slack high
7/12	77	1-2	21,000**	Slack high
8/19	81	5-10	6,500	Slack low

* River flow as recorded at USGS Gauge 01463500 (Delaware River at Trenton, NJ)
**Significant rain event occurred the evening of 7/11/19

Summary of Activities

On July 11-12, and August 19, 2019, the SDU assisted PADEP to complete a quantitative freshwater mussel survey on the Delaware River near Bristol, Pennsylvania. PADEP has been mapping freshwater mussel beds using sidescan sonar. In this reach of the river, the substrate is primarily rock (boulder, cobble, rock) and PADEP was concerned their interpretation of the sonar imaging may not accurately reflect actual mussel densities. The objectives of the SDU diver survey were to visually determine the density of freshwater mussels, determine substrate type, and capture video from transects determined by PADEP.

Divers completed dives along eight transects, perpendicular to the shoreline, at locations determined by PADEP. Along each transect, divers collected data using 1 square meter quadrats every 20 meters, up to 100 meters from the starting position nearest the navigational channel. Data collected included substrate type (boulder, cobble, pebble, silt and sand) live mussel density, and suvey depth. The mussel density was ranked among four categories established by PADEP. Only those mussels visible above the substrate were counted. Divers also collected live video from each suvey location.

A summary of data collected from each survey point is provided in Attachment 1. Diver field data sheets are provided in Attachment 2.

Dive Statistics

Location	Purpose	Date	Depth (ft)	Conditions	Breathing gas	Name of Diver	Total # Dives	Total Hyperbaric Exposure Days	Dive Master
Bristol, PA	PADEP mussel survey	7/11/19	41	Delaware River, freshwater	Air	Jim Adamiec Dave Light	4 4	2	Brad White, Nate Doyle
Bristol, PA	PADEP mussel survey	7/12/19	33	Delaware River, freshwater	Air	Brad White Nate Doyle	3 3	2	Dave Light, Brad White
Bristol, PA	PADEP mussel survey	8/19/19	30	Delaware River, freshwater	Air	Nate Doyle Jim Adamiec	3 3	2	Brad White, Dave Light

Changes from Dive and Safety Plan

A modification to the method upon which divers would transit along each transect was discussed with PADEP and implemented for each of the three dives. The method employed was to first establish a set transect between the channel side buoy and shore side buoy that was made of a weighted line dropped in as a straight a line as practicable. The weighted line had knots tied at 20 meter intervals. The 0 meter survey location was at the channel side buoy. The overall length of each transect was dictated by the distance from the navigational channel (the edge of navigational channel dictated the limit of diving – no diving was conducted in the channel itself) to shore. The maximum transect length was 100 meters.

This modification was made in an effort to provide the straightest transect line possible, and thus allow PADEP to relatively easily establish a geo-referenced position for each survey point along the transects after the fact. As originally described in the Dive and Safety Plan, divers were to navigate along a predetermined compass bearing as they laid out a transect line at 20 meter intervals. There was concern that while the divers would be able to maintain the predetermined compass bearing, current would introduce drift during the dive. In the end, this modified method proved to be an efficient and safe way to collect the data. This modified method was used for all three days of data collection.

Since divers were not running along compass bearings, but instead a pre-deployed transect line that was run from two weighted buoys, actual coordinates for each terminal end of the transects were recorded in the field by PADEP using GPS. The tables below show the planned and actual coordinates of each transect.

PLANNED

		Transect Begin			
Priority	Station	LAT	LONG	Bearing (°T)	Bearing (°M)*
3	121.3	[redacted]	[redacted]	300	288
1	121.4	[redacted]	[redacted]	303	291
2	121.5	[redacted]	[redacted]	296	284
4	121.6	[redacted]	[redacted]	302	290
5	121.7	[redacted]	[redacted]	307	295
6	121.9	[redacted]	[redacted]	333	321
7	122.0	[redacted]	[redacted]	339	327

*Magnetic declination (-12.21°) obtained from NOAA National Centers for Environmental Information, Geomagnetism Field Calculator: https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#declination

ACTUAL (recorded on-site from GPS)

		Transect Begin		Transect End	
Priority	Station	LAT	LONG	LAT	LONG
3	121.3	[redacted]	[redacted]	[redacted]	[redacted]
1	121.4	[redacted]	[redacted]	[redacted]	[redacted]
2	121.5	[redacted]	[redacted]	[redacted]	[redacted]
4	121.6	[redacted]	[redacted]	[redacted]	[redacted]
5	121.7	[redacted]	[redacted]	[redacted]	[redacted]
	121.8	[redacted]	[redacted]	[redacted]	[redacted]
6	121.9	[redacted]	[redacted]	[redacted]	[redacted]
7	122.0	[redacted]	[redacted]	[redacted]	[redacted]

Schedule of Activities

The third day of data collection was shifted to August 19, 2019 to accommodate staffing requirements. This change was reflected in the updated Dive and Safety Plan prepared for the August 19 date.

Next Steps

PADEP will compare the data and video footage collected by the SDU to the sonar imaging.

Conclusions

Careful assessment, design, planning, sequencing and collaboration/communication in the field resulted in a safe and successful collection of data and video footage that will enable PADEP to quantify live freshwater mussel beds in this area of river. It will also allow PADEP to compare sonar imaging data to diver-collected data and confirm or correct the interpreted sonar results.

As noted in the Water Conditions Table (above), dive operations on July 11 and 12 were conducted on slack high tide, while the operation on August 19 was conducted on slack low tide. The SDU typically conducts operations on the river during slack low tide, but due to staffing requirements and project timing determined to go ahead with the July survey dates. In-water visibility was significantly lower during the July surveys (slack high), as compared to the August survey (slack low). While the significant rain event that occurred the evening of July 11 would have likely resulted in turbid water at slack low tide, overall it seems river conditions result in improved visibility during slack low tide compared to slack high tide.

Attachment 1 – Data Summary Table

Date	Dive Window	Transect	Distance (m)	Depth (ft)	Substrate	Mussel Density	Divers	Tide Cycle
7/11/2019	1000 - 1035	121.3	0	37	Bld,Cbl,Sd	Sporadic	Adamiec/Light	Slack High
7/11/2019	1000 - 1035	121.3	20	17	Cbl,Sd,Slt	Bed	Adamiec/Light	Slack High
7/11/2019	1000 - 1035	121.3	40	15	Bld,Cbl,Sd	Bed	Adamiec/Light	Slack High
7/11/2019	1000 - 1035	121.3	60	18	Cbl(predominant), Pbl, Slt, Sd	Bed	Adamiec/Light	Slack High
7/11/2019	1000 - 1035	121.3	80	15	Slt	Bed	Adamiec/Light	Slack High
7/11/2019	1000 - 1035	121.3	100	7	Slt	None	Adamiec/Light	Slack High
7/11/2019	1120 - 1155	121.4	0	26	Cbl, Slt	None	Adamiec/Light	Slack High
7/11/2019	1120 - 1155	121.4	20	22	Bld, Sd	Common	Adamiec/Light	Slack High
7/11/2019	1120 - 1155	121.4	40	24	Sd, Slt, Pbl	Common	Adamiec/Light	Slack High
7/11/2019	1120 - 1155	121.4	60	11	Pbl	Bed	Adamiec/Light	Slack High
7/11/2019	1120 - 1155	121.4	80	9	Cbl, Pbl	None	Adamiec/Light	Slack High
7/12/2019	1040 - 1100	121.5	0	26	Bld (predominant), Cbl, Pbl	Common	Doyle/White	Slack High
7/12/2019	1040 - 1100	121.5	20	24	Cbl (predominant), Pbl	Bed	Doyle/White	Slack High
7/12/2019	1040 - 1100	121.5	40	20	Cbl, Pbl	Bed	Doyle/White	Slack High
7/12/2019	1040 - 1100	121.5	60	8	Cbl, Pbl	None	Doyle/White	Slack High
7/12/2019	1119 - 1139	121.6	0	31	Slt (predominant), Cbl	Common	Doyle/White	Slack High
7/12/2019	1119 - 1139	121.6	20	16	Slt	Sporadic	Doyle/White	Slack High
7/12/2019	1119 - 1139	121.6	40	8	Cbl, Slt	None	Doyle/White	Slack High
7/12/2019	1210 - 1228	121.7	0	19	Slt, Pbl, Cbl	Bed	Doyle/White	Slack High
7/12/2019	1210 - 1228	121.7	20	8	Slt	None	Doyle/White	Slack High
7/12/2019	1210 - 1228	121.7	30 (as advised)	5	Pbl	None	Doyle/White	Slack High
8/19/2019	1120 - 1136	121.8	0	21	Cbl, Pbl	Bed	Doyle/Adamiec	Slack Low
8/19/2019	1120 - 1136	121.8	20	8	Pbl, Slt	Bed	Doyle/Adamiec	Slack Low
8/19/2019	1120 - 1136	121.8	40	3	Slt	None	Doyle/Adamiec	Slack Low
8/19/2019	1146 - 1200	121.9	0	27	Cbl, Pbl	Bed	Doyle/Adamiec	Slack Low
8/19/2019	1146 - 1200	121.9	20	8	Bld, Cbl, Slt	Bed	Doyle/Adamiec	Slack Low
8/19/2019	1146 - 1200	121.9	40	3	Slt	None	Doyle/Adamiec	Slack Low
8/19/2019	1212 - 1235	122	0	23	Bld, Cbl	Common	Doyle/Adamiec	Slack Low
8/19/2019	1212 - 1235	122	20	12	Cbl, Sd	Bed	Doyle/Adamiec	Slack Low
8/19/2019	1212 - 1235	122	40	8	Slt	None	Doyle/Adamiec	Slack Low
8/19/2019	1212 - 1235	122	60	1	Slt	None	Doyle/Adamiec	Slack Low

Notes

Bld = Boulder
Cbl = Cobble
Pbl = Pebble
Sd = Sand
Slt = Silt
Distance = direction is from channel to shore
None = No mussels present
Sporadic = <2 mussels per 1m quadrat
Common = ≥2 to <15 mussels per 1m quadrat
Bed = ≥15 mussels per 1 m quadrat

Attachment 2 – Diver Field Data Sheets

EPA R3 Scientific Dive Unit

Freshwater Mussel Survey for PADEP – Delaware River

Date:	7/11/19
Diver(s):	Light, Ademiac
Compass Bearing to Shore:	288
Transect Number:	12/03
Buoy Coordinates:	

Substrate Types		Mussel Density Categories
Boulder (>256 mm [>10"])	B	None
Cobble (64 to 256 mm [2.5 to 10"])	C	Sporadic (<2 m^2)
Pebble (4 to 64 mm [<2.5"])	P	Common (2 to 14 per m^2)
Sand	Sd	Bed (15+ per m^2)
Silt	ST	

60m: mostly Cobble 80m: Silt Only

Distance	Substrate	Mussel Density	Depth
0m	B, C, Sd	C	37
20m	C, Sd, St	B	17
40m	C, B, Sd	B	15
60m	C, P, St, Sd mostly	B	18
80m	St	B	15
100m	St	N	7

EPA R3 Scientific Dive Unit
Freshwater Mussel Survey for PADEF – Delaware River

Date:	7/16/14
Diver(s):	D [illegible] ADAM[illegible]
Compass Bearing to Shore:	291
Transect Number:	21.4
Buoy Coordinates:	

Substrate Types	Mussel Density Categories
Boulder (>256 mm [>10”])	None
Cobble (64 to 256 mm [2.5 to 10”])	Sporadic (<2 m^2)
Pebble (4 to 64 mm [<2.5”])	Common (2 to 14 per m^2)
Sand	Bed (15+ per m^2)
Silt	

Distance	Substrate	Mussel Density	Depth
0m	C, St	None	26
20m	B, Sd	Common (8)	22
40m	Sd, St, P	C ~~8~~ (3)	21
60m	P	B	11
80m	C, P	None	9
100m			

EPA R3 Scientific Dive Unit

Freshwater Mussel Survey for PADEP - Delaware River

Date:	7/11/19
Diver(s):	Ligbel, Adamsick
Compass Bearing to Shore:	
Transect Number:	121.5
Buoy Coordinates:	

Substrate Types	Mussel Density Categories
Boulder (>256 mm [>10"])	None
Cobble (64 to 256 mm [2.5 to 10"])	Sporadic (<2 m²)
Pebble (4 to 64 mm [<2.5"])	Common (2 to 14 per m²)
Sand	Bed (15+ per m²)
Silt	

Distance	Substrate	Mussel Density	Depth
0m	C B	C	27
20m	stopped because of		
40m	heavy current		
60m			
80m			
100m			

EPA R3 Scientific Dive Unit
Freshwater Mussel Survey for PADEP – Delaware River

Date:	7/12/19
Diver(s):	DOYLE / WHITE
Compass Bearing to Shore:	
Transect Number:	121.5
Buoy Coordinates:	

Substrate Types	Mussel Density Categories
Boulder (>256 mm [>10"])	None
Cobble (64 to 256 mm [2.5 to 10"])	Sporadic (<2 m^2)
Pebble (4 to 64 mm [<2.5"])	Common (2 to 14 per m^2)
Sand	Bed (15+ per m^2)
Silt	

Distance	Substrate	Mussel Density	Depth
0m	B > C/P	C	26
20m	C > P	B	24
40m	C/P	B	20
60m	C/P	N	8
80m			
100m			

EPA R3 Scientific Dive Unit
Freshwater Mussel Survey for PADEP – Delaware River

Date:	7/12/19
Diver(s):	N. DOYLE B. WHITE
Compass Bearing to Shore:	
Transect Number:	121.6
Buoy Coordinates:	

Substrate Types	Mussel Density Categories
Boulder (>256 mm [>10"])	None
Cobble (64 to 256 mm [2.5 to 10"])	Sporadic (<2 m^2)
Pebble (4 to 64 mm [<2.5"])	Common (2 to 14 per m^2)
Sand	Bed (15+ per m^2)
Silt	

Distance	Substrate	Mussel Density	Depth
0m	St > C	~~S~~ C*	31
20m	St	S	16
40m	C / St	N	8
60m			
80m			
100m			

Note - video review of 0 m shows Common mussel category

EPA R3 Scientific Dive Unit
Freshwater Mussel Survey for PADEP – Delaware River

Date:	7/12/14
Diver(s):	WHITE, DOYLE
Compass Bearing to Shore:	
Transect Number:	121.7
Buoy Coordinates:	

Substrate Types	Mussel Density Categories
Boulder (>256 mm [>10"])	None
Cobble (64 to 256 mm [2.5 to 10"])	Sporadic (<2 m²)
Pebble (4 to 64 mm [<2.5"])	Common (2 to 14 per m²)
Sand	Bed (15+ per m²)
Silt	

Distance	Substrate	Mussel Density	Depth
0m	SA / PYC	B	19
20m	St	N	8
30 ~~40m~~	P	N	5
60m			
80m			
100m			

EPA R3 Scientific Dive Unit
Freshwater Mussel Survey for PADEP – Delaware River

Date:	
Diver(s):	DOYLE, ADAMIEC
Compass Bearing to Shore:	
Transect Number:	121, 8
Buoy Coordinates:	

Substrate Types	Mussel Density Categories
Boulder (>256 mm [>10"])	None
Cobble (64 to 256 mm [2.5 to 10"])	Sporadic (<2 m^2)
Pebble (4 to 64 mm [<2.5"])	Common (2 to 14 per m^2)
Sand	Bed (15+ per m^2)
Silt	

Distance	Substrate	Mussel Density	Depth
0m	C, P	Bed	9'
20m	Silt P	Bed	8
40m	Silt	none, SAV	3'
60m			
80m			
100m			

1st

End Buoy

EPA R3 Scientific Dive Unit
Freshwater Mussel Survey for PADEP – Delaware River

Date:	
Diver(s):	Doyle, Adamiec
Compass Bearing to Shore:	
Transect Number:	121.9
Buoy Coordinates:	

Substrate Types	Mussel Density Categories
Boulder (>256 mm [>10"])	None
Cobble (64 to 256 mm [2.5 to 10"])	Sporadic (<2 m^2)
Pebble (4 to 64 mm [<2.5"])	Common (2 to 14 per m^2)
Sand	Bed (15+ per m^2)
Silt	

Distance	Substrate	Mussel Density	Depth	
0m	C, P	Bed	27	Start
20m	B(2), C, Silt	Bed	8	mostly Silt
40m	Silt (SAV)	none	3	End
60m				
80m				
100m				

EPA R3 Scientific Dive Unit
Freshwater Mussel Survey for PADEP – Delaware River

Date:	8/19/19
Diver(s):	Adamiec, Doyle
Compass Bearing to Shore:	
Transect Number:	122.0
Buoy Coordinates:	

Substrate Types	**Mussel Density Categories**
Boulder (>256 mm [>10"])	None
Cobble (64 to 256 mm [2.5 to 10"])	Sporadic (<2 m^2)
Pebble (4 to 64 mm [<2.5"])	Common (2 to 14 per m^2)
Sand	Bed (15+ per m^2)
Silt	

Distance	Substrate	Mussel Density	Depth
0m	B, C	C (4) common	23
20m	Cobble, Sand	Bed	12
40m	Silt	None	8
60m	Silt	None	1
80m			
100m			

Attachment 3 – Photographs

Tender preparing to hand 1 meter quadrat to diver

Frame grab from transect 121.4 showing numerous mussels, pebbles, and cobbles. 1 meter quadrat frame visible on left side of photograph

Diver recording data in limited visibility conditions

Divers prepare to be picked up by EPA R/V Parker

Attachment 4 - Dive Tender’s Field Log

EPA Dive Tender's Field Log

Date: 7/11/19

Location: FLORENCE BEND

Dive Master: NATHAN DOYLE / BRAD WHITE

Dive Platform: R/V PARKER

Site Description: F.W. TIDAL RIVER - DELAWARE

Dive Objectives: F.W. MUSSEL SURVEY FOR PADEP

		Initial OK		Tank		Pony		Time		Total	Max
Tender	Diver	In	Out	Start	End	Start	End	In	Out	Bottom Time	Depth
DOYLE	JIM ADAMIEC	JA	JA	2950	657			1000	1035	35	35
WHITE	DAVE LIGHT	DL	DL	3000	700			1000	1035	35	35
DOYLE	JIM ADAMIEC	JA	JA	3000	2400			1105	1110	5	~~26~~ 41
WHITE	DAVE LIGHT	DL	DL	3000	2500			1105	1110	5	~~26~~ 41
DOYLE	JIM ADAMIEC	JA	JA	2400	530			1120	1155	35	26
WHITE	DAVE LIGHT	DL	DL	2500	842			1120	1155	35	26
DOYLE	JIM ADAMIEC	JA	JA	2950	1950			1215	1225	~~27~~ 10	27
WHITE	DAVE LIGHT	DL	DL	2994	2000			1215	1225	~~27~~ 10	27

Notes: (jobs completed, problems encountered, equipment needed)

~ 1' VIZ. HIGH TIDE
1225 - ABORT DUE TO CURRENT

2nd TRANSECT BOUY & ANCHOR FOUND FLOATING
RESET BOUY

EPA Dive Tender's Field Log

Date: 7/12/19 **Location:** FLORENCE BEND

Dive Master: DAVE LECHT / BRAD WHITE **Dive Platform:** R/V PARKER

Site Description: F.W. TIDAL RIVER - DELAWARE

Dive Objectives: F.W. MUSSEL SURVEY FOR PADEP

		Initial OK		Tank		Pony		Time		Total	Max
Tender	**Diver**	**In**	**Out**	**Start**	**End**	**Start**	**End**	**In**	**Out**	**Bottom Time**	**Depth**
ADAMIEC	DOYLE	MD	ND	3027	1800	—	—	~~1140~~ 1	040/1100	20min	29
ADAMIEC	WHITE	BW	BW	3300	2000	—	—	~~1140~~ 1	040/1100	20min	29'
ADAMIEC	DOYLE	│	│	1800	990	—	—	1119	1139	20min	33'
ADAMIEC	WHITE	│	│	2000	1150	—	—	1119	1139	20min	33'
ADAMIEC	DOYLE	│	│	3362	2853	—	—	1210	1228	18min	19'
ADAMIEC	WHITE	│	│	3250	2700	—	—	1210	1228	18min	19'

Notes: (jobs completed, problems encountered, equipment needed)

USEPA R3 Dive Tender's Field Log

Date: 8/19/19

Location: Delaware River, Florence Bend

Dive Master: B. White

Dive Platform: RV Parker

Site Description: Slack low @ 1300 at ~~Roebl~~ Meenan Pier (Silu Concrete)

Dive Objectives: PADEP FW Mussel Survey

		Initial OK		Tank		Pony		Time		Total	Max	Total	Tank
Tender	**Diver**	**In**	**Out**	**Start**	**Out**	**Start**	**Out**	**In**	**Out**	**Bottom Time**	**Depth**	**Weight**	**#**
D Light	N. Doyle	✓	✓	3000	2125	—	—	1120	1136	16	22	23	1
Light	J. Ademiec	✓	✓	3000	2000	—	—	1120	1136	16	22	23	5
↓	N Doyle	✓	✓	2125	1300	–	–	1146	1200	14	30	23	1
	J Ademiec	✓	✓	2000	1200	–	✓	1146	1200	14	30	23	5
↓	N. Doyle	✓		3100	1920	–	–	1212	1235	23	23	23	3
	J. Adamiec	✓		3000	1980	–	–	1212	1235	23	25	23	2

121.8 | 121.9 | 122.0

Notes (Jobs completed, problems encountered, equipment issues):

Penn Chamber # 215 898 9099, Chamber operational a/o 1115

121.8 - 0, 20, 40 m

121.9 - 0, 20, 40 m

122.0 0, 20, 40, 60

Literature Cited

Partnership for the Delaware Estuary. March 2012. “Freshwater Mussel Recovery Program in the Delaware Estuary”. PDE Report No. 12-02. 41 pp.

Partnership for the Delaware Estuary. April 2013. “Freshwater Mussel Recovery Strategy for the Delaware Estuary and River Basin.

Partnership for the Delaware Estuary. 2012a. State of the Estuary 2012. Estuary News (Summer Edition), Vol. 22, Issue 4. http://www.delawareestuary.org/state-estuary

Powers, J; Brewer SK; Long, JM; Campbell, T. 2014. Evaluating the use of side-scan sonar for detecting freshwater mussel beds in turbid river environments. Hydrobiologia 743(1):127-137.