

**2005 Caged Clam Study to Characterize PCB Bioavailability in the
Impaired Watersheds Throughout the State of Maryland**



DEPARTMENT OF THE ENVIRONMENT
Field Evaluation Division, Science Services Administration
416 Chinquapin Round Road
Annapolis, Maryland 21401

FINAL

Charles Poukish

Chris Lockett

Anna Soehl

August 25, 2009

Acknowledgments

The authors wish to thank for their efforts the many talented individuals who helped bring this report to fruition. In particular, thanks go to Matthew Stover, Matthew Rowe, Jeff Carter, Nicholas Kaltenbach, John Hill, and Bridget Hill for contributing to the field efforts. Special thanks also go to Matthew Stover and Nicholas Kaltenbach for their GIS expertise and map-making contributions and to Leonard Schugam for help with project oversight and data interpretation.

Table of Contents

Acknowledgments	ii
Table of Contents	iii
List of Tables	iv
List of Figures.....	iv
List of Maps	iv
List of Abbreviations	v
Executive Summary	vi
1. INTRODUCTION.....	1
2. PROJECT DESIGN.....	3
2.1. Reference Site Selection	3
2.2. 2005 Study Station Selection	5
2.3. Clam Collection Methods	8
2.4. Cage Deployment Methods.....	8
2.5. Cage Retrieval.....	9
2.6. Clam Depuration.....	10
2.7. Sample Handling and Preparation	10
2.8. Data Interpretation	10
3. SUMMARY OF RESULTS	13
3.1. Watersheds with Minimal Increase (2x RT) in Clam tPCB Level	14
3.2. Watersheds with Low Increase (3x RT) in Clam tPCB Levels	17
3.3. Watersheds with Elevated Increases (>3x RT) in Clam tPCB Levels.....	22
REFERENCES.....	31
Appendix A – Scientific Collection Permit	A1
Appendix B – tPCB Results for Each Composite (ng/g-wet weight).....	B1
Appendix C – Summary of tPCB Results for Each Watershed	C1
Appendix D – List of Analyzed PCB Congeners.....	D1
Appendix E – Station Coordinates and Description.....	E1

List of Tables

Table 1. tPCB Concentrations in Composited Clam Samples at the Reference Site (Upper Choptank River at Red Bridges)..... 4
Table 2. 2005 Maryland Clam Study Station Summary..... 6

List of Figures

Figure 1. Normal Distribution and Multiples of Standard Deviation..... 12
Figure 2. Distribution of the Magnitude of Increase in tPCB Clam Concentrations..... 13

List of Maps

Map 1. Location Map of the Reference/Control Site (Upper Choptank River at Red Bridges). 4
Map 2. Maryland 2005 Clam Study Areas. 5
Map 3. Summary of the Highest tPCB Concentrations Measured in Each Watershed 13
Map 4. Caged Clam Station Locations and Concentrations in the Bohemia River Watershed. 14
Map 5. Caged Clam Station Locations and Concentrations in the Corsica River Watershed... 15
Map 6. Caged Clam Station Locations and Concentrations in the Sassafras River Watershed 16
Map 7. Caged Clam Station Locations and Concentrations in the Gwynns Falls Subwatershed 17
Map 8. Caged Clam Station Locations and Concentrations in the Bush River Watershed..... 18
Map 9. Caged Clam Station Locations and Concentrations in the Lower Elk River Watershed 19
Map 10. Caged Clam Station Locations and Concentrations in the Northeast River Watershed 20
Map 11. Caged Clam Station Locations and Concentrations in the Patapsco River Subwatershed 21
Map 12. Caged Clam Station Locations and Concentrations in the Jones Falls Watershed 22
Map 13. Caged Clam Station Locations and Concentrations in the Back River Watershed..... 23
Map 14. Caged Clam Station Locations and Concentrations in the Back Creek Watershed (Chesapeake and Delaware Canal)..... 24
Map 15. Caged Clam Station Locations and Concentrations in the Upper Elk River Watershed25
Map 16. Caged Clam Station Locations and Concentrations in the Anacostia River Watershed26
Map 17. Caged Clam Station Locations and Concentrations in the South River Watershed..... 27
Map 18. Caged Clam Station Locations and Concentrations in the Lower Susquehanna River Watershed..... 28
Map 19. Caged Clam Station Locations and Concentrations in the Lower Patapsco River Subwatershed 29
Map 20. Caged Clam Station Locations and Concentrations in the Middle Chester River Watershed..... 30

List of Abbreviations

ASTM	American Society of Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
DNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
ng/g	Nanograms per gram
PCBs	Polychlorinated Biphenyls
RT	Reference Threshold
SD _{ref}	Reference Site Standard Deviation
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
tPCBs	Total Polychlorinated Biphenyls
UMCES	University of Maryland Center for Environmental Science
\bar{x}_{ref}	Reference Site Mean

Executive Summary

Under the authority of the Federal Clean Water Act, Maryland Department of the Environment (MDE) is responsible for monitoring and assessing attainment of water quality standards in State waters, listing impaired waters on the State's Integrated Report, and developing Total Maximum Daily Loads (TMDLs) to address each of the impairments. A total of 37 assessment units are currently listed on Category 5 (i.e., *water body is impaired, does not attain the water quality standard, and a TMDL is required*) of the Maryland 2008 Integrated Report, as impaired by polychlorinated biphenyls (PCBs). The majority of these listings are due to elevated PCB levels in fish tissue (MDE 2008).

PCBs are a class of man-made compounds that were manufactured and used for a variety of industrial applications, including coolants and lubricants in electrical equipment (ATSDR 2000). In the late 1970s, concerns regarding potential human health effects led the United States government to take action to cease PCB production, restrict PCB use, and regulate the storage and disposal of PCBs. Despite these actions, PCBs are still being released into the environment through fires or leaks from old PCB containing equipment, accidental spills, burning of PCB containing oils, leaks from hazardous waste sites, etc. As PCBs tend to bioaccumulate in aquatic organisms including fish tissue, people who ingest fish may become exposed to PCBs. In fact, elevated levels of PCBs in edible parts of fish tissue are one of the leading causes of fish consumption advisories in the United States.

Due to the widespread historical uses as well as complex fate and their persistence, PCBs are ubiquitous in the environment and exist in a vast range of concentrations and congeners. They tend to cycle between various environmental media such as air, water, and soil and can be also found far away from where they were initially used and released, even in such remote locations as the Arctic (Gustafsson et al. 2005). This makes it difficult to determine which levels of PCBs should be considered as background levels and which are indicative of ongoing local sources. In 2005, as a cost saving measure, the Science Services Administration (SSA) began the process of PCB source tracking by performing PCB bioavailability studies to characterize Maryland subwatersheds draining to the PCB impaired tidal waters as (i) those with no apparent sources and (ii) those with relatively significant sources of PCB runoff. Results of this study were intended as the first screening tool that could be used to focus future search efforts towards identifying and cleaning up the largest ongoing sources of PCB contamination. Follow-up sampling (e.g., sediment, soil, etc.) could then be carried out in areas determined to be relatively high in PCB runoff. This report summarizes that effort.

Staff biologists collected Asiatic Clams, *Corbicula fluminea*, from a relatively uncontaminated resident population in the Upper Choptank River at Red Bridges. Caged clams were deployed at the reference site (as a control) and in 15 other Maryland 8-digit watersheds (i.e., test watersheds). Samples were retrieved, depurated, frozen, and stored for tissue removal and PCB analysis after 14 and 28 days of deployment. The exposed clams were analyzed for PCBs using a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999). The PCB analysis presented in this document is based on total PCB (tPCB) concentrations that are calculated as the sum

of the detected PCB congeners/congener groups representing most common congeners that were historically used in the Aroclor commercial mixtures.

A total of 149 composite samples were analyzed from 70 stations deployed throughout 15 Maryland 8-digit watersheds. The mean tPCB concentration for each station was compared to the established Upper Choptank River reference threshold (RT). Of the 70 stations, 15 did not exceed the RT, while 33 stations demonstrated minimal or low increase (i.e., 2x RT or 3x RT, respectively). The remaining 22 stations had concentrations between 4 to 49 times higher than the RT.

This information will be used to focus future restoration efforts or develop effective TMDLs and plans for PCB mitigation. Sites with 0-3x RT concentrations will be given the lowest priority for action or future study, however, the significance of the runoff from the associated subwatersheds on the downstream impairment will be evaluated via future TMDL analysis. Sites with concentrations that are several times the threshold (i.e., $\geq 4x$ RT) will be given a higher priority for action or future study.

1. INTRODUCTION

Under the authority of the Federal Clean Water Act, Maryland Department of the Environment (MDE) is responsible for monitoring and assessing attainment of water quality standards in State waters, listing impaired waters on the State's Integrated Report, and developing Total Maximum Daily Loads (TMDLs) to address each of the impairments. A total of 37 assessment units are currently listed on Category 5 (i.e., *water body is impaired, does not attain the water quality standard, and a TMDL is required*) of the Maryland 2008 Integrated Report, as impaired by polychlorinated biphenyls (PCBs). The majority of these listings are due to elevated PCB levels in fish tissue (MDE 2008).

PCBs are a class of man-made compounds that were manufactured and used for a variety of industrial applications. They consist of 209 related chemical compounds (congeners) that were manufactured and sold as mixtures under various trade names (QEA 1999). Each of the 209 possible PCB compounds consists of two phenyl groups and one or more chlorine atoms. The congeners differ in the number and position of the chlorine atoms along the phenyl group. From the 1940s to the 1970s, they were extensively used as heat transfer fluids, flame retardants, hydraulic fluids, and dielectric fluids because of their dielectric and flame resistant properties. They have been identified as a pollutant of concern due to the following:

1. They are bioaccumulative and can cause both acute and chronic toxic effects.
2. They have carcinogenic properties.
3. They are persistent organic pollutants that do not readily breakdown in the environment.

In the late 1970s, concerns regarding potential human health effects led the United States government to take action to cease PCB production, restrict PCB use, and regulate the storage and disposal of PCBs. Despite these actions, PCBs are still being released into the environment through fires or leaks from old PCB containing equipment, accidental spills, burning of PCB containing oils, leaks from hazardous waste sites, etc. As PCBs tend to bioaccumulate in aquatic organisms including fish tissue, people who ingest fish may become exposed to PCBs. In fact, elevated levels of PCBs in edible parts of fish tissue are one of the leading causes of fish consumption advisories in the United States.

Due to the widespread historical uses as well as complex fate and their persistence, PCBs are ubiquitous in the environment and exist in a vast range of concentrations and congeners. They tend to cycle between various environmental media such as air, water, and soil and can be also found far away from where they were initially used and released, even in such remote locations as the Arctic (Gustafsson et al. 2005). This makes it difficult to determine which levels of PCBs should be considered as background levels and which are indicative of ongoing local sources. In 2005, as a cost saving measure, the Science Services Administration (SSA) began the process of PCB source tracking by performing PCB bioavailability studies to characterize Maryland subwatersheds draining to the PCB impaired tidal waters as (i) those with no apparent sources and (ii) those with relatively significant sources of PCB runoff. Results of this study were intended as the

first screening tool that could be used to focus future search efforts towards identifying and cleaning up the largest ongoing sources of PCB contamination. Follow-up sampling (e.g., sediment, soil, etc.) could then be carried out in areas determined to be relatively high in PCB runoff.

Monitoring programs use a variety of indicators of contamination. While each approach has its limitations, the caged bivalves (including Asiatic Clam, *Corbicula fluminea*) have been successfully used as study organisms to screen for bioavailable PCB sources, including PCBs in fresh and marine waters. Bivalves are frequently used in biological monitoring studies because of their widespread distribution and abundance in study areas, sedentary habits, hardiness, and ability to bioaccumulate pollutants without excessive mortality (Farrington 1983; Elder and Collins 1991). Asiatic Clams feed primarily on phytoplankton (algae) and take up PCBs both from the water column and from food.

Recently adopted standards for caged bivalve studies (Salazar and Salazar 2003; ASTM 2005) were used as guidance for designing this project. The rationale for using bivalve exposure studies, as opposed to ambient water quality grab samples or extensive sediment studies is that by using living organisms, the results focus on those PCB congeners that are bioavailable to the aquatic organisms (i.e., a fraction of tPCB that enter the food web). Also, because clams filter-feed over an extended period of time, the results are representative of average longer-term conditions, which would not be captured with the use of grab ambient water column samples.

2. PROJECT DESIGN

MDE personnel carried out all of the activities associated with clam collection, deployment, and retrieval. Staff biologists collected Asiatic Clams from a relatively uncontaminated population in the Upper Choptank River at Red Bridges (i.e., reference site). Caged clams were deployed in the Upper Choptank River at Red Bridges (as a control) and in 15 other Maryland 8-digit watersheds (i.e., test watersheds). Samples were retrieved, depurated, frozen, and stored for tissue removal and PCB analysis after either 14 or 28 days of deployment. PCB analytical services were provided by the University of Maryland Center for Environmental Science (UMCES). PCB congeners were identified and quantified by high resolution gas chromatography with electron capture detection. UMCES uses a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999), in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248, and 1262) are determined based on their chromatographic retention times relative to the internal standards (PCB 30 and PCB 204). Based on this method, 86 chromatographic peaks can be quantified (see Appendix D). Some of the peaks contain one PCB congener, while others are comprised of two or more co-eluting congeners. The PCB analysis presented in this document is based on tPCB concentrations that are calculated as the sum of the detected PCB congeners/congener groups representing most common congeners that were historically used in the Aroclor commercial mixtures. The mean tPCB concentration for each station was compared to the established Upper Choptank River reference threshold (RT).

2.1. Reference Site Selection

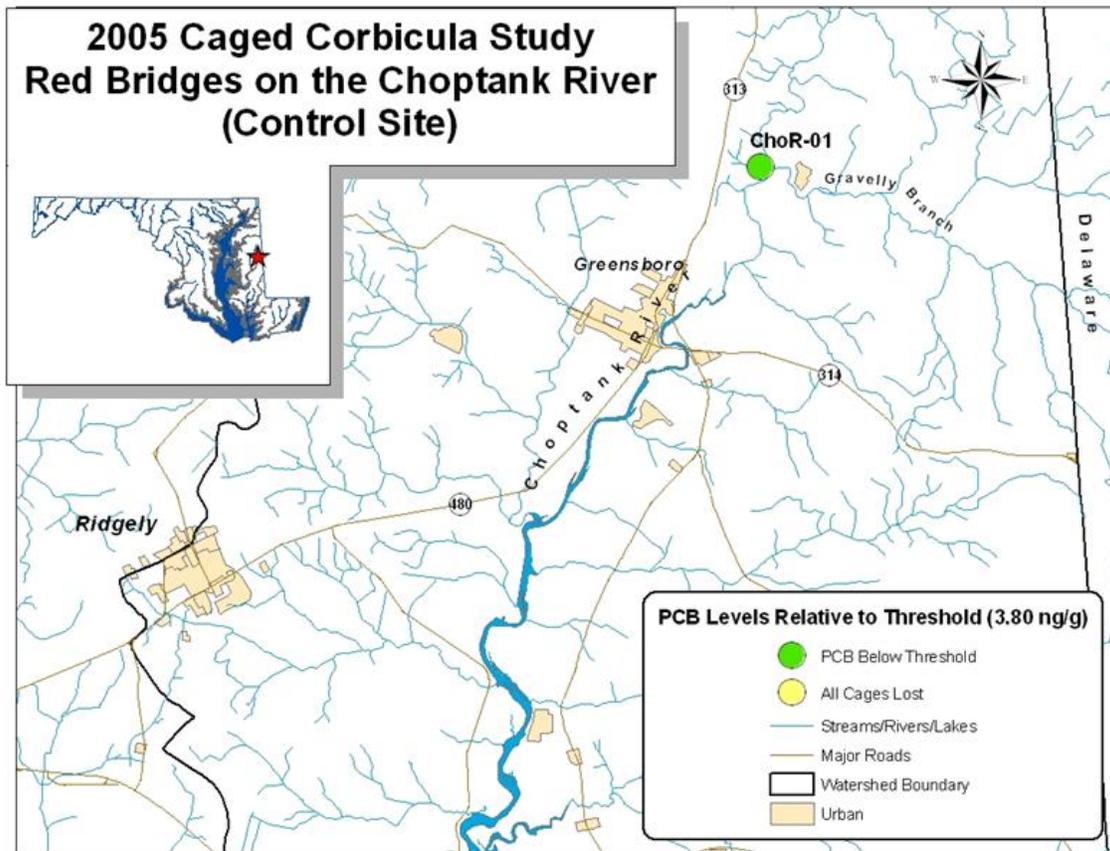
Based on the historical data and land use information, the Upper Choptank River watershed was not suspected to have any significant local sources of PCB contamination. For this reason a Red Bridges location (Map 1) was selected as a reference site. To confirm the validity of this selection, over 500 resident clams were collected at this site, split into 10 composites of 50 to 62 clams, and analyzed for PCBs (see Table 1).

The mean clam tPCB concentrations at the reference site were relatively low ($\bar{x}_{\text{ref}} = 2.80$ ng/g, $SD_{\text{ref}} = 0.31$ ng/g, $n = 10$). The clams from this site were thus considered to be good candidates to be used as reference organisms and their concentrations became the basis for the RT used to evaluate observed test site concentrations (see Section 2.8).

Additionally, to test whether caging of clams could result in higher uptake of PCBs by the study organism compared to concentrations found in the resident clams collected directly from the streambed, two control cages (containing 67 and 76 resident clams) were deployed at the reference site. The tPCB concentrations in the control clam tissue (2.03 ng/g and 2.45 ng/g) did not increase as a result of caging; indicating that caging should not result in higher uptake of PCBs by the study organism. Thus, increase in clam concentrations can be assumed to be caused by higher PCB levels at the study site than at the reference site.

Table 1. tPCB Concentrations in Compositied Clam Samples at the Reference Site (Upper Choptank River at Red Bridges)

Site ID	tPCBs (ng/g-wet)	Number of Individual Clams in a Composite
ChoR1ref1	2.52	50
ChoR1ref2	2.66	50
ChoR1ref3	2.49	50
ChoR1ref4	2.57	50
ChoR1ref5	2.45	50
ChoR1ref6	3.32	50
ChoR1ref7	2.85	62
ChoR1ref8	3.13	62
ChoR1ref9	2.89	62
ChoR1ref10	3.11	62
Mean (n=10)	2.80	
Standard Deviation	0.31	

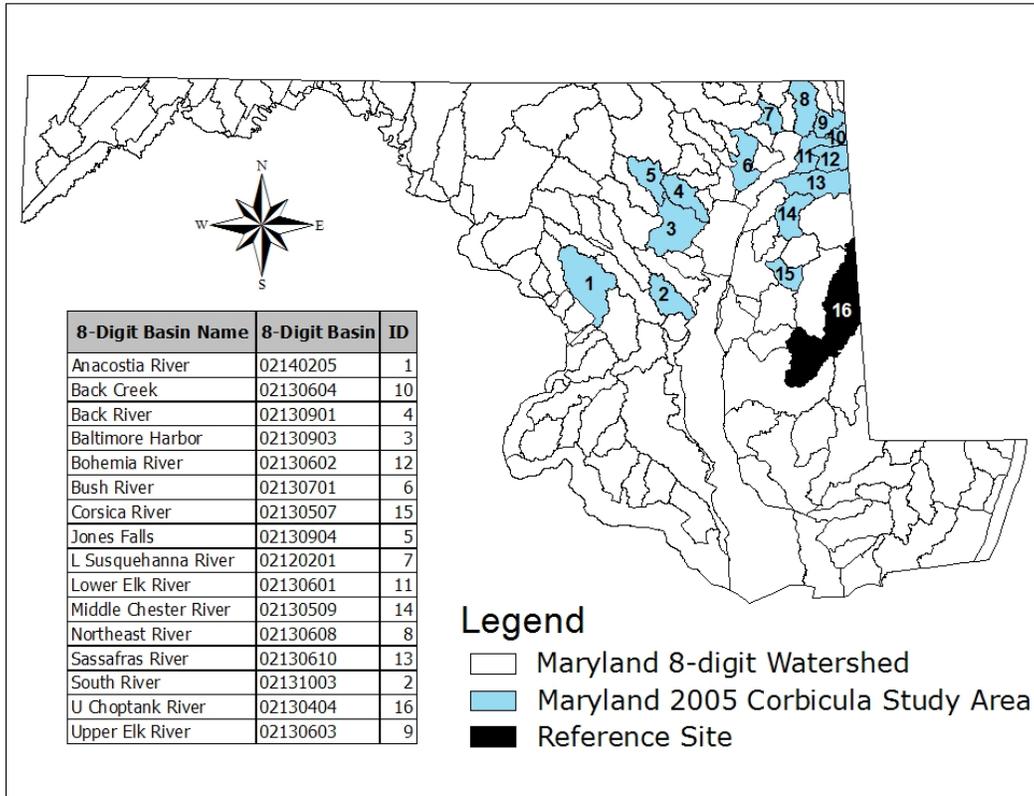


Map 1. Location Map of the Reference/Control Site (Upper Choptank River at Red Bridges)

2.2. 2005 Study Station Selection

A total of 15 Maryland 8-digit watersheds draining to the PCB impaired tidal waters were targeted for this study (Map 2). These watersheds include:

1. Anacostia River,
2. Back Creek (Chesapeake and Delaware Canal),
3. Back River,
4. Baltimore Harbor (including Gwynns Falls, Lower Patapsco River, and Patapsco River subwatersheds),
5. Bohemia River,
6. Bush River,
7. Corsica River,
8. Jones Falls,
9. Lower Elk River,
10. Lower Susquehanna River,
11. Middle Chester,
12. Northeast River,
13. Sassafras River,
14. South River, and
15. Upper Elk River.



Map 2. Maryland 2005 Clam Study Areas

As previously explained, the Upper Choptank River watershed at Red Bridges was selected as the reference site (see Section 2.1, Map 1, and Map 2).

The number of stations targeted to help bracket PCB sources was contingent on the size and configuration of each studied watershed. On average about five stations were selected in each of the targeted Maryland 8-digit watershed (Table 2). Individual stations within each of the studied watersheds were selected based on the following criteria:

1. Sampled stations collectively should represent as large a portion of the 8-digit watershed as possible.
2. Stations should be placed in areas that would allow results between subwatersheds to be compared and contrasted.
3. All stations should be placed close to their downstream confluences but above tidal influence.
4. All stations should be located near road crossings.

Table 2. 2005 Maryland Clam Study Station Summary

Station	Watershed Name	Watershed Code	Comments	Map
AnaR-01	Anacostia River	02140205	4wk & rep cage lost	Map 16
AnaR-02	Anacostia River	02140205		
AnaR-03	Anacostia River	02140205	4wk cage lost	
AnaR-04	Anacostia River	02140205		
BacC-01	Back Creek	02130604	Tidal	Map 14
BacC-02	Back Creek	02130604		
BacC-03	Back Creek	02130604	Tidal	
BacC-04	Back Creek	02130604		
BacR-01	Back River	02130901		Map 13
BacR-02	Back River	02130901		
BacR-03	Back River	02130901		
BacR-04	Back River	02130901	2wk & 4wk cage lost	
BacR-05	Back River	02130901		
BalH-01	Baltimore Harbor	02130903		Map 7 Map 11 Map 19
BalH-02	Baltimore Harbor	02130903		
BalH-03	Baltimore Harbor	02130903		
BalH-04	Baltimore Harbor	02130903		
BalH-05	Baltimore Harbor	02130903	2wk & 4wk cage lost	
BalH-06	Baltimore Harbor	02130903		
BalH-07	Baltimore Harbor	02130903		
BalH-08	Baltimore Harbor	02130903		
BalH-09	Baltimore Harbor	02130903		
BohR-01	Bohemia River	02130608		Map 4
BohR-02	Bohemia River	02130608		
BohR-03	Bohemia River	02130608		
BohR-04	Bohemia River	02130608		
BohR-05	Bohemia River	02130608		
BusR-01	Bush River	02130701		Map 8
BusR-02	Bush River	02130701		

Station	Watershed Name	Watershed Code	Comments	Map
BusR-03	Bush River	02130701		
BusR-04	Bush River	02130701		
CorR-01	Corsica River	02130507		Map 5
CorR-02	Corsica River	02130507		
CorR-03	Corsica River	02130507		
CorR-04	Corsica River	02130507		
CorR-05	Corsica River	02130507		
CorR-06	Corsica River	02130507		
JonFeX	Jones Falls	02130904		Map 12
JonF-01	Jones Falls	02130904	4wk cage lost	
JonF-02	Jones Falls	02130904		
JonF-03	Jones Falls	02130904		
JonF-04	Jones Falls	02130904	4wk cage lost	
JonF-05	Jones Falls	02130904		
LEIR-01	Lower Elk River	02130601		Map 9
LEIR-02	Lower Elk River	02130601		
LEIR-03	Lower Elk River	02130601		
LEIR-04	Lower Elk River	02130601		
LEIR-05	Lower Elk River	02130601		
LSuR-01	Lower Susquehanna River	02120201		Map 18
LSuR-02	Lower Susquehanna River	02120201		
LSuR-03	Lower Susquehanna River	02120201		
LSuR-04	Lower Susquehanna River	02120201	100% mortalities/low water	
MChR-01	Middle Chester River	02130509	2wk, 4wk&rep combined; Tidal [*]	Map 20
MChR-02	Middle Chester River	02130509		
MChR-03	Middle Chester River	02130509	2wk & 4wk combined; Tidal [*]	
MChR-04	Middle Chester River	02130509	Tidal [*]	
MChR-05	Middle Chester River	02130509	all cages lost; Tidal [*]	
NEaR-01	Northeast River	02130608	Tidal [*]	Map 10
NEaR-02	Northeast River	02130608		
NEaR-03	Northeast River	02130608		
NEaR-04	Northeast River	021306i08		
NEaR-05	Northeast River	02130608	Tidal [*]	
NEaR-06	Northeast River	02130608		
SasR-01	Sassafras River	02130610		Map 6
SasR-02	Sassafras River	02130610		
SasR-03	Sassafras River	02130610		
SouR-01	South River	02131003		Map 17
SouR-02	South River	02131004		Map 17
ChoR-01**	U Choptank River	02130404		Map 1
UpER-01	Upper Elk River	02130603		Map 15
UpER-02	Upper Elk River	02130603		
UpER-03	Upper Elk River	02130603	4wk cage lost	
UpER-04	Upper Elk River	02130603		
UpER-05	Upper Elk River	02130603		
UpER-06	Upper Elk River	02130603		

Notes: *Tidal – indicates stations that have been determined to be tidally influenced.

** Reference Site.

The station code was designed to indicate several distinguishing features about each station. For instance, the hypothetical sample code **BacR-01_A_field_rep** indicates that this station is located in the Back River watershed (BacR), it is the most downstream station in the sub-watershed (01), and the cage was exposed for two weeks (suffix “A” signifies two week exposure, while “B” signifies four week exposure). In cases where a replicate was also deployed, the final suffix “field_rep” was used (data is presented in Appendix B).

2.3. Clam Collection Methods

Clam collection was authorized by Maryland Department of Natural Resources (DNR) (see permit information in Appendix A). Clams were collected with clam rakes, shovels, and benthic sieves. All specimens were sifted through a 1/2” mesh wire to ensure that they represented a relatively narrow size range. Only clams too large to pass through the mesh were kept for the study.

A total of about 10,000 clams were collected on June 20 and 23 of 2005. In order to destroy any gill brood that might have been present, those clams that were to be kept for study purposes were immediately placed in a cooler, near but not in direct contact with ice, and cooled to just below 40° F. This sterilization technique was initiated to minimize the risk of establishing Asiatic Clams, an exotic but well-established species throughout Maryland waters, at the study sites.

2.4. Cage Deployment Methods

Cages were constructed of either 3/8” black polyethylene screen or 1/4” galvanized hardware cloth. The polyethylene cages were used in all systems where metals, in addition to PCBs, were also being analyzed. The hardware cloth cages were used at all other sites.

At the beginning of the study it was determined that a composite of 40 individual clams yields the minimum amount of tissue required for analysis (i.e., 10 grams). Consequently, at least 50 clams were deployed in each cage to provide sufficient tissue for analysis even if clam mortality rate reached as high as 20%.

On the day after collection, clams were divided among deployment teams and placed in cages at the study sites. At the time of the deployment, in-situ water quality (i.e., temperature, pH, conductivity, salinity, dissolved oxygen, and dissolved oxygen percent saturation) was measured at all stations using a multi-parameter field unit (i.e., Hydrolab).

Cages were placed in the stream bottom and secured by any practical means. When possible, the cages were tied with 3/16” braided nylon cord to permanent structures (i.e., tree roots, fallen trees, sign posts, bridge pilings). In cases where no such structure was available, the cages were tied to 8-pound concrete blocks and placed in the stream. Deployment teams noted the exact locations of the cages (i.e., distance from the road and specific location within the stream) and documented the exact latitude and longitude collected with hand-held Global Positioning System (see Appendix E).

The specific length of the exposure period was derived from previous work by Dr. Phelps (2003, 2007) indicating that exposed clam tissue tPCB concentration increases for the first two weeks of deployment, at which point the concentrations become asymptotic to a theoretical maximum. It also has been reported that the clams often start to die off less than four weeks after being deployed. For the purpose of this study, clams were deployed for two- and four-weeks at each of the study sites.

For quality assurance/quality control, replicate cages were deployed at one randomly selected site within each 8-digit study watershed. Approximately half of the replicate cages were retrieved after a two-week exposure. The other half was retrieved after a four-week exposure. Table 2 denotes stations where some two-week, four-week, and replicate samples have been lost.

2.5. Cage Retrieval

After each exposure period (i.e., two- or four-weeks) one cage of clams was retrieved (two cages if a replicate was deployed). In order to ensure that a sufficient minimum sample size (i.e., 40 clams) was available, field crews recorded signs of mortality (i.e., odor or gaping shells). Each cage representing a composite sample was assigned a unique identifier. This information was written on a TYVEK® label and added to each cage. The cages were then placed in coolers, insulated from direct contact with ice, and transported to the lab for depuration.

Anomalies, which did not have significant effect on the study but nevertheless are worth mentioning, include:

- At the time of retrieval, MDE field crew noted some level of sedimentation on the cages collected from the following stations: SasR-1_A, SasR-1_B, SasR-1_B_field_rep, UpER_1_A, BacR_5_B, and BacR_3_B. However, with the exception of one stations (BacR_5_B), where four-week results were lower than the corresponding two-week results, the sedimentation had no noticeable impact on the results.
- A total of 9 cages were found to be out of the water, or were believed to have experienced sustained low water conditions, resulting in significant mortalities. These included: BacC_3_B, BalH_2_B, BalH_6_A and B, LsuR_1_A, LsuR_1_B, LsuR_1_B_field_rep, LSuR_4_A, and LSuR_4_B. In spite of this, only the four-week results from BalH_2_B were lower than the corresponding two-week results. LSuR_4_A and LSuR_4_B cages had 100% mortality.
- A total of 12 cages were either lost or stolen. They include BacR_4_A, BacR_4_B, BalH_5_A, BalH_5_B, JonF_1_B, JonF_4_B, MchR_5_A, MchR_5_B, UpER_3_B, AnaR_1_B, AnaR_1_B_field_rep, and AnaR_3_B. Two stations (MChR_1 and MChR_3) required combining the two- and four-week cages into one sample due to significant mortalities observed during the two-week exposure period. These stations were tidal and had elevated conductivity.

2.6. Clam Depuration

Retrieved clams were removed from the cages at the MDE laboratory. The dead clams were counted, recorded, and discarded. Mortality averaged 9% and primarily occurred at stations that were either tidal with elevated conductivity, or where cages became exposed during low water conditions. To exclude the gut contents of the clams and focus on the bioaccumulated portion of the contaminants, the clams were depurated for 24 hours. For depuration purposes, the clams were placed back into their respective cages. The cages were then placed into trays containing two gallons of aerated well water from the Aquia aquifer (containing no PCBs, chlorine, or fluoride). Each tray was aerated using a single air stone powered by an aquarium air pump. The water was changed twice during the 24-hour depuration process. During each water change, cages were quickly transferred to clean containers with fresh water and aeration. Each holding tray was emptied and rinsed to remove any solid matter or film that could be responsible for cross contamination between samples. All trays were returned to the rotation after receiving replacement spring water.

2.7. Sample Handling and Preparation

Test clams deployed in tributaries where only organic pollutants were to be tested were packaged differently from those in tributaries where metals were also to be analyzed. Clams that were to be analyzed for metals were placed in a Nasco WHIRL-PAK® plastic bag along with the TYVEK® label. Each composite sample was then placed in a second plastic bag (Ziploc®) with a more detailed label and immediately deposited into a freezer. Clams that did not need to be analyzed for metals were wrapped in aluminum foil with the TYVEK® label, and then placed in a Ziploc® bag and labeled.

All clam samples were delivered to the UMCES frozen and still in their shells. Prior to analysis, each composite was partially thawed and pried open with clean lab utensils. The soft tissues were shucked into composites of 40 or more clams, placed in clean glass vials, and refrozen until UMCES staff were able to analyze the samples. Prior to analysis, the tissue was blended, the PCBs were extracted, and PCB analysis was performed.

2.8. Data Interpretation

Due to the widespread historical uses as well as complex fate and their persistence, PCBs are ubiquitous in the environment and exist in a vast range of concentrations and congeners. They tend to cycle between various environmental media such as air, water, and soil and can be also found far away from where they were initially used and released, even in such remote locations as the Arctic (Gustafsson et al. 2005). This makes it difficult to determine which levels of PCBs should be considered as background and which are indicative of ongoing local sources.

As no appropriate statistical tools have been identified to help with data interpretation, mainly due to limited number of observations from each site, a best professional judgment magnitude of increase RT approach has been used to group the sites into those with low and high priority for action or future study.

The use of the magnitude of increase RT approach involved: (i) establishing an Upper Choptank River RT, (ii) comparing the mean tPCB concentrations from each station to the established RT, and (iii) determining the priority for action.

The RT was calculated as the mean tPCB concentration from the reference site plus three standard deviations (Formula 1).

$$\begin{aligned} RT &= \bar{x}_{\text{ref}} + (3 \times SD_{\text{ref}}) && \text{(Formula 1)} \\ RT &= 2.7999 \text{ ng/g} + (3 \times 0.3083 \text{ ng/g}) = 3.7239 \text{ ng/g} \approx 3.72 \text{ ng/g} \end{aligned}$$

Where:

\bar{x}_{ref} – reference site mean

SD_{ref} – reference site standard deviation

Given the relatively low tPCB concentrations measured in the clam tissue at the reference site and small sample size of the reference dataset, the RT was derived in a way that minimizes the probability that it could be exceeded due to chance alone. As illustrated in Figure 1, in a normally distributed dataset, the probability of a random sample exceeding the mean by three standard deviations due to chance alone is less than 1%, and is even less likely at the high tail of the distribution curve.

For interpretation purposes, each of the study sites was represented by a single result derived by averaging tPCB results for matching replicate samples. Furthermore, because a paired-sample t-test ($t = -0.65$, $df = 62$, $p = 0.52$) indicates that no significant difference exists between concentrations of clams deployed over two- and four-weeks, to yield a single result for each station, results from clams exposed over two- and four-weeks were also averaged (Appendix B).

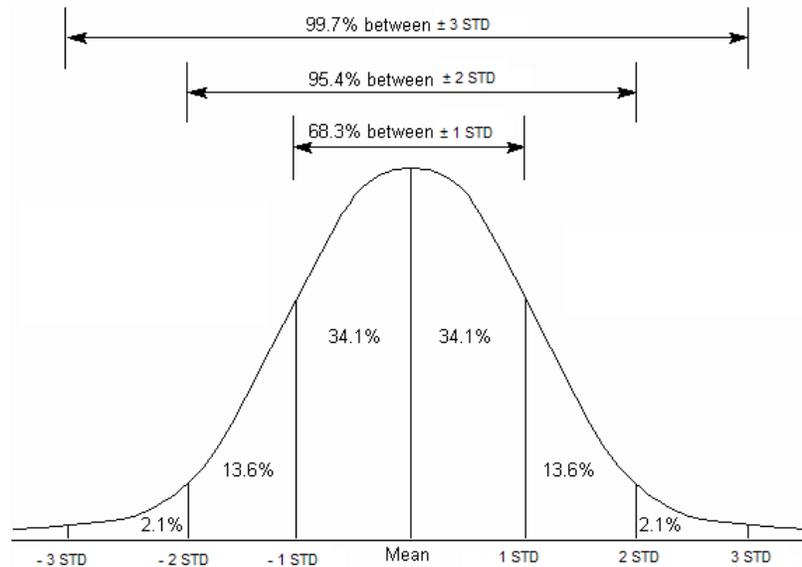


Figure 1. Normal Distribution and Multiples of Standard Deviation

The mean exposure results for each station are presented in terms of magnitude of increase (i.e., the number of times by which the RT was exceeded). For example, all results between 3.72 and 7.44 ng/g were classified as two times the threshold (i.e., 2x RT), results between 7.44 and 11.17 ng/g as three times the threshold (i.e., 3x RT), etc. Since the purpose of this study was to identify watersheds with apparent local sources of PCBs, not all increases in concentrations are given the same priority for action. Means below the threshold are considered to reflect no increase in tPCB concentrations compared to the reference levels. The 2x RT category is considered to reflect a minimal increase and 3x RT category is considered to reflect a low increase. Sites with 0-3x RT concentrations will be given the lowest priority for action or future study, however, the significance of the runoff from the associated subwatersheds on the downstream impairment will be evaluated via future TMDL analysis. Sites with concentrations that are several times the threshold (i.e., $\geq 4x$ RT) will be given a higher priority for action or future study.

This information will be used to focus future restoration efforts or develop effective TMDLs and plans for PCB mitigation. While a large number of stations fell in the no, minimal, and low increase categories, several subwatersheds will need to be studied further to determine the possible ongoing sources of PCBs.

3. SUMMARY OF RESULTS

Of the 70 stations represented in this study, 15 did not exceed the RT (i.e., did not increase in tPCB concentrations), 25 stations demonstrated minimal increase (i.e., 2x RT), and another 8 demonstrated low increase (i.e., 3x RT). The remaining 22 stations had concentrations between 4 to 49 times higher than the reference threshold (Figure 2) and will be given a high priority for action or future study. This section presents a summary of the results by watershed.

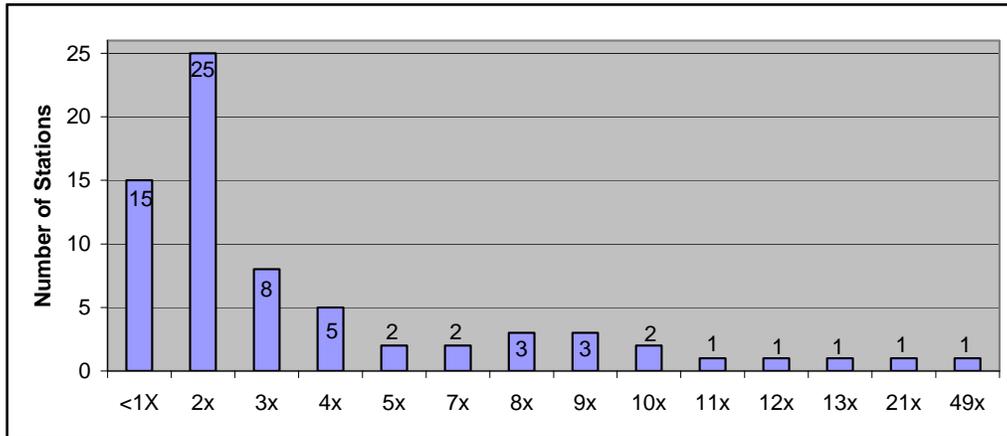
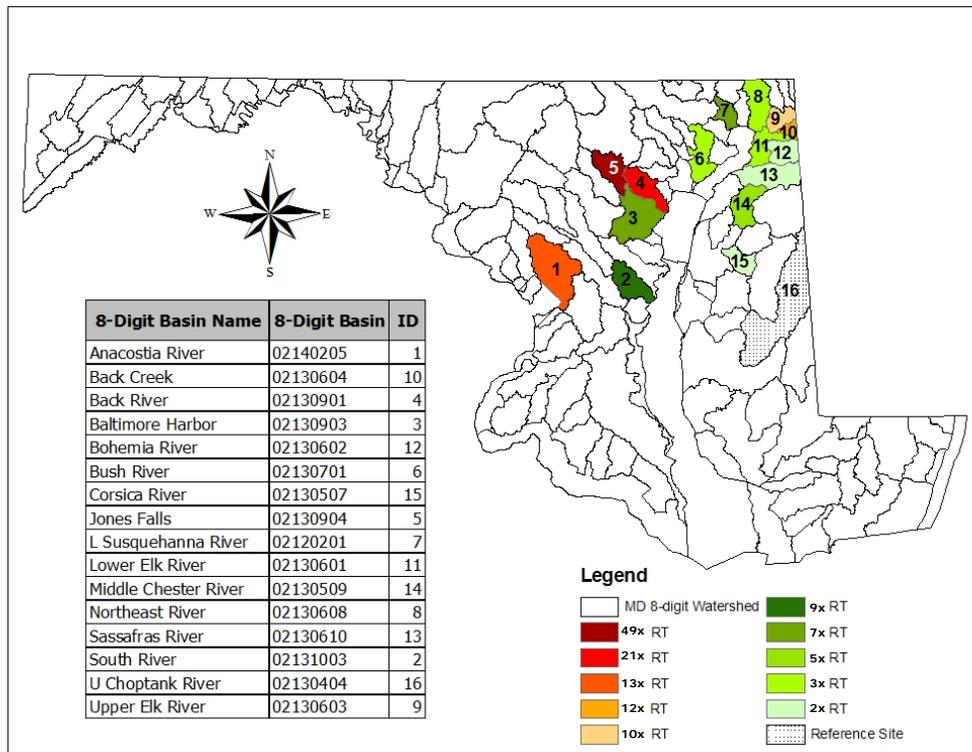


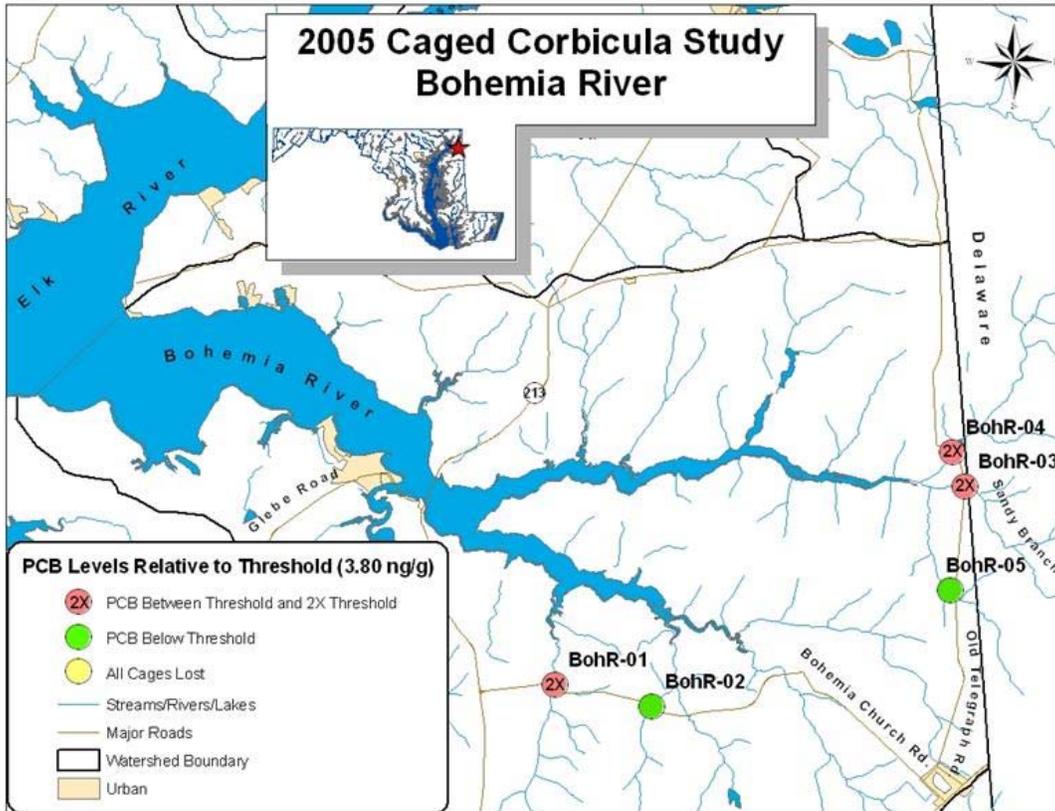
Figure 2. Distribution of the Magnitude of Increase in tPCB Clam Concentrations



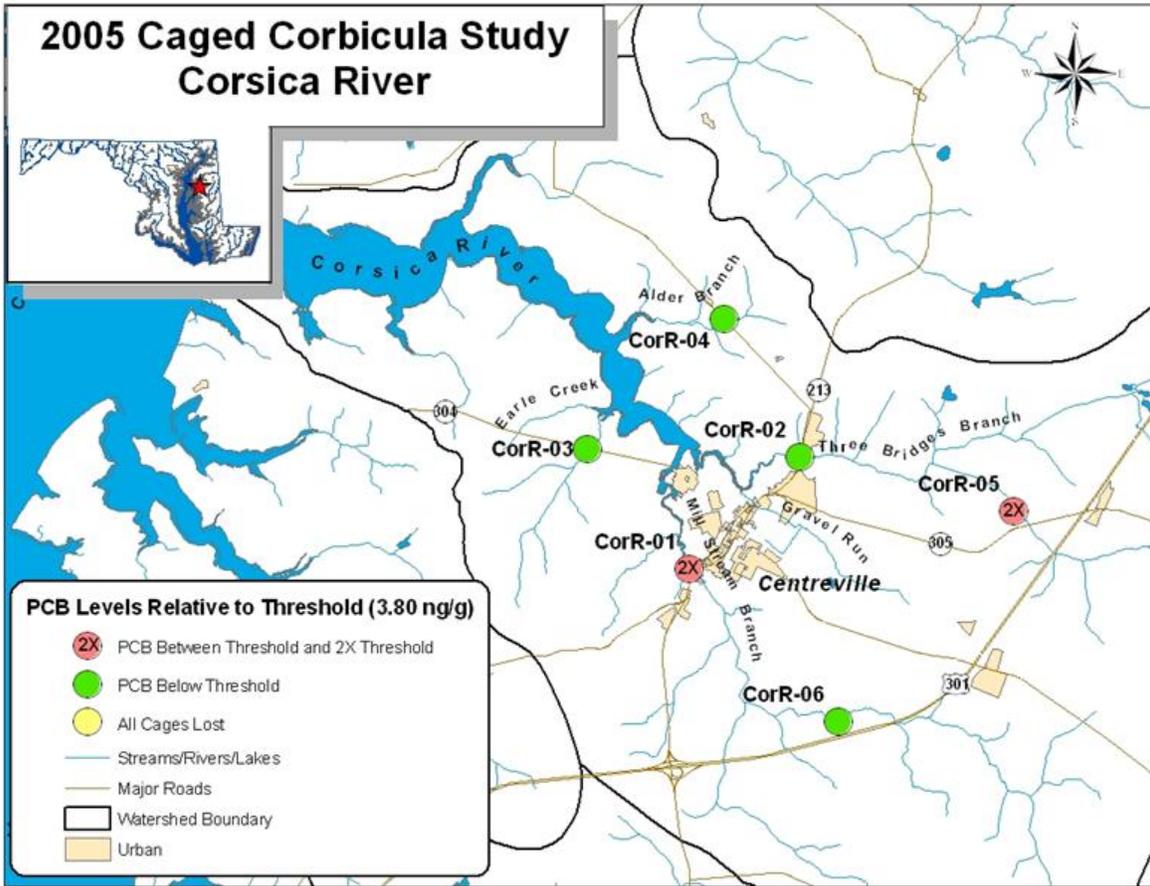
Map 3. Summary of the Highest tPCB Concentrations Measured in Each Watershed

3.1. Watersheds with Minimal Increase (2x RT) in Clam tPCB Level

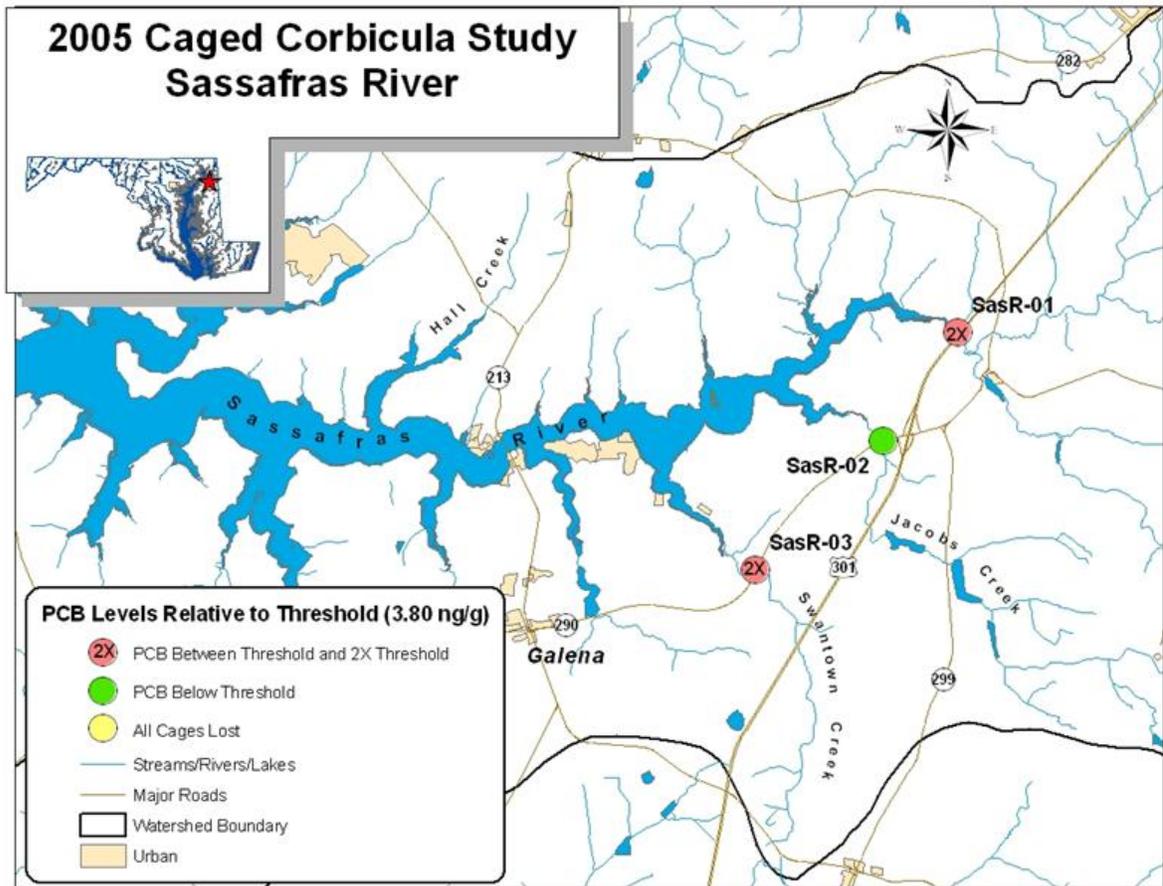
Bohemia, Corsica, and Sassafras River watersheds are considered the least contaminated of the study watersheds. None of the stations within these watersheds had higher concentrations than 2x RT (see: Map 4, Map 5, and Map 6). These sites will be given a low priority for action or future study, however, the significance of the runoff from the associated subwatersheds on the downstream impairment will be evaluated via future TMDL analysis.



Map 4. Caged Clam Station Locations and Concentrations in the Bohemia River Watershed



Map 5. Caged Clam Station Locations and Concentrations in the Corsica River Watershed



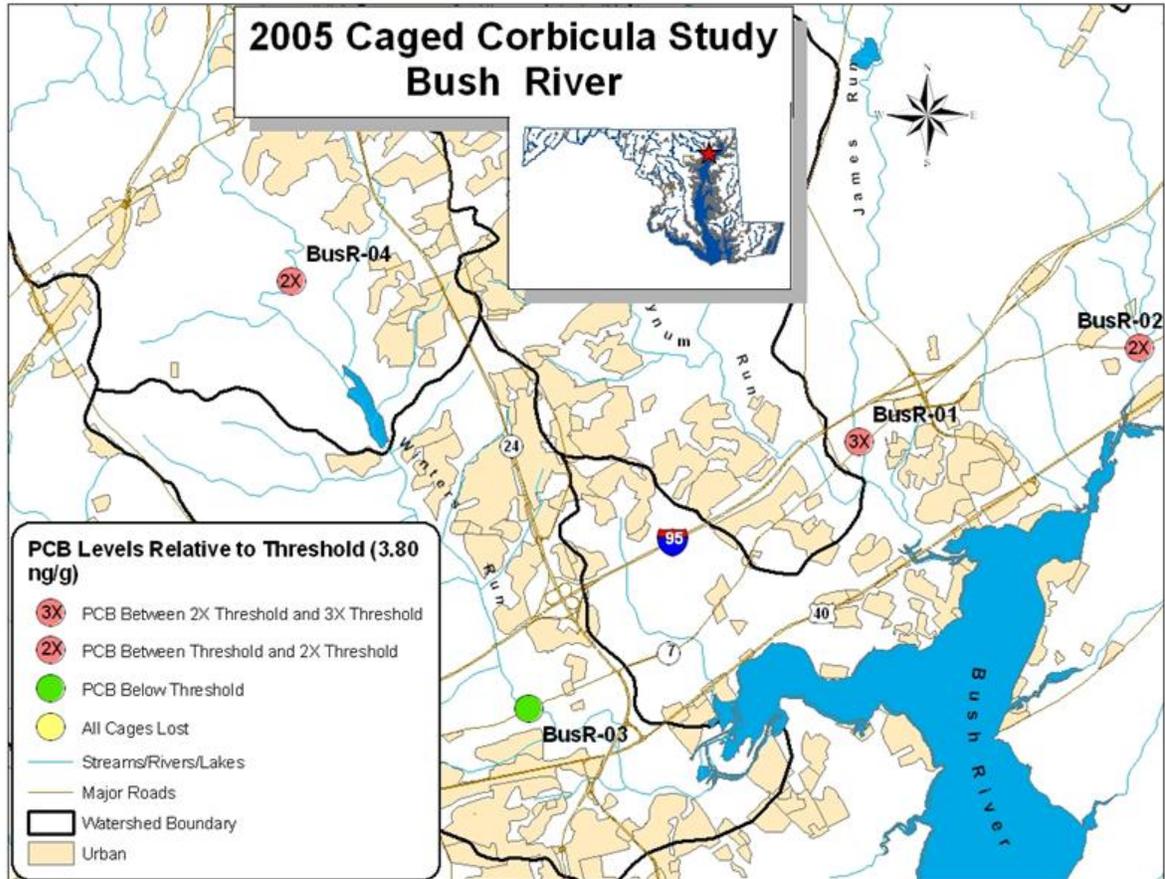
Map 6. Caged Clam Station Locations and Concentrations in the Sassafras River Watershed

3.2. Watersheds with Low Increase (3x RT) in Clam tPCB Levels

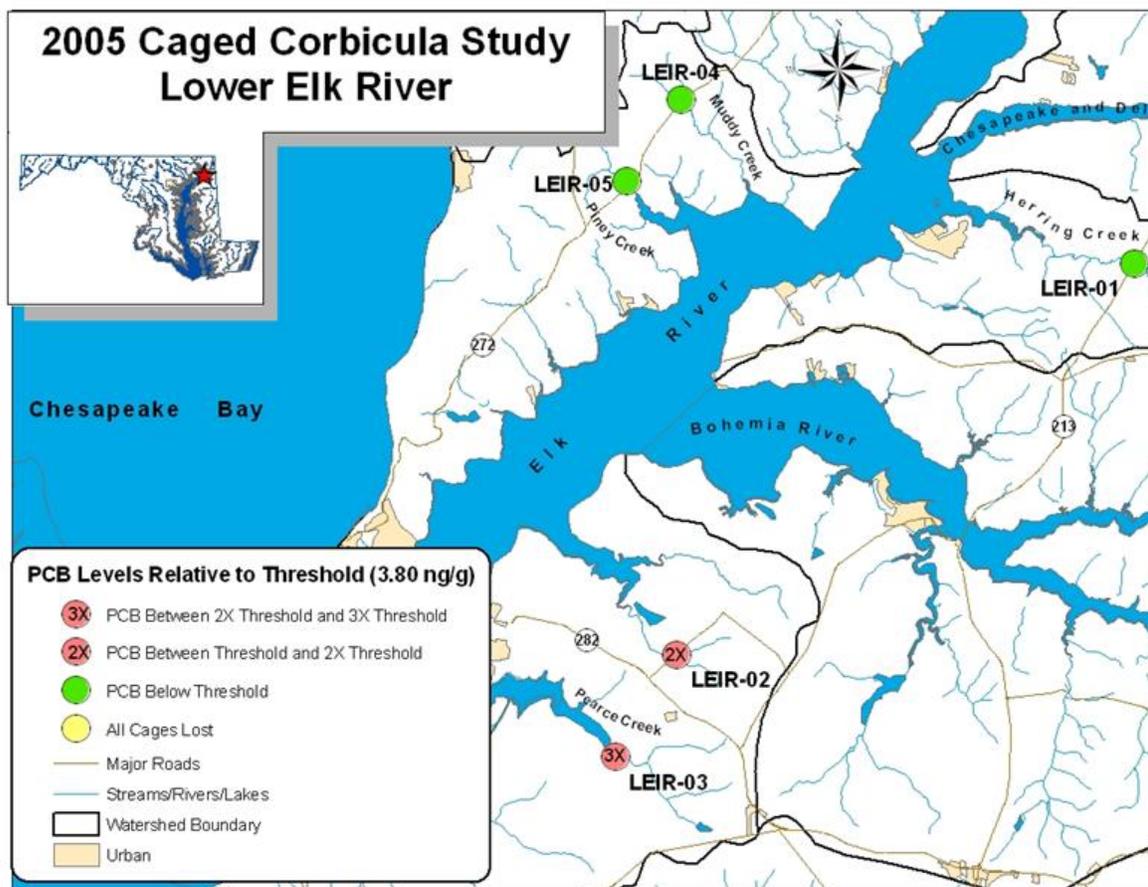
Five watersheds/subwatersheds contained one or more stations with tPCB concentrations no higher than 3x RT. They include Gwynns Falls (Map 7), Bush River (Map 8), Lower Elk River (Map 9), Northeast River (Map 10), and Patapsco River (Map 11). These sites will be given a low priority for action or future study, however, the significance of the runoff from the associated subwatersheds on the downstream impairment will be evaluated via future TMDL analysis.



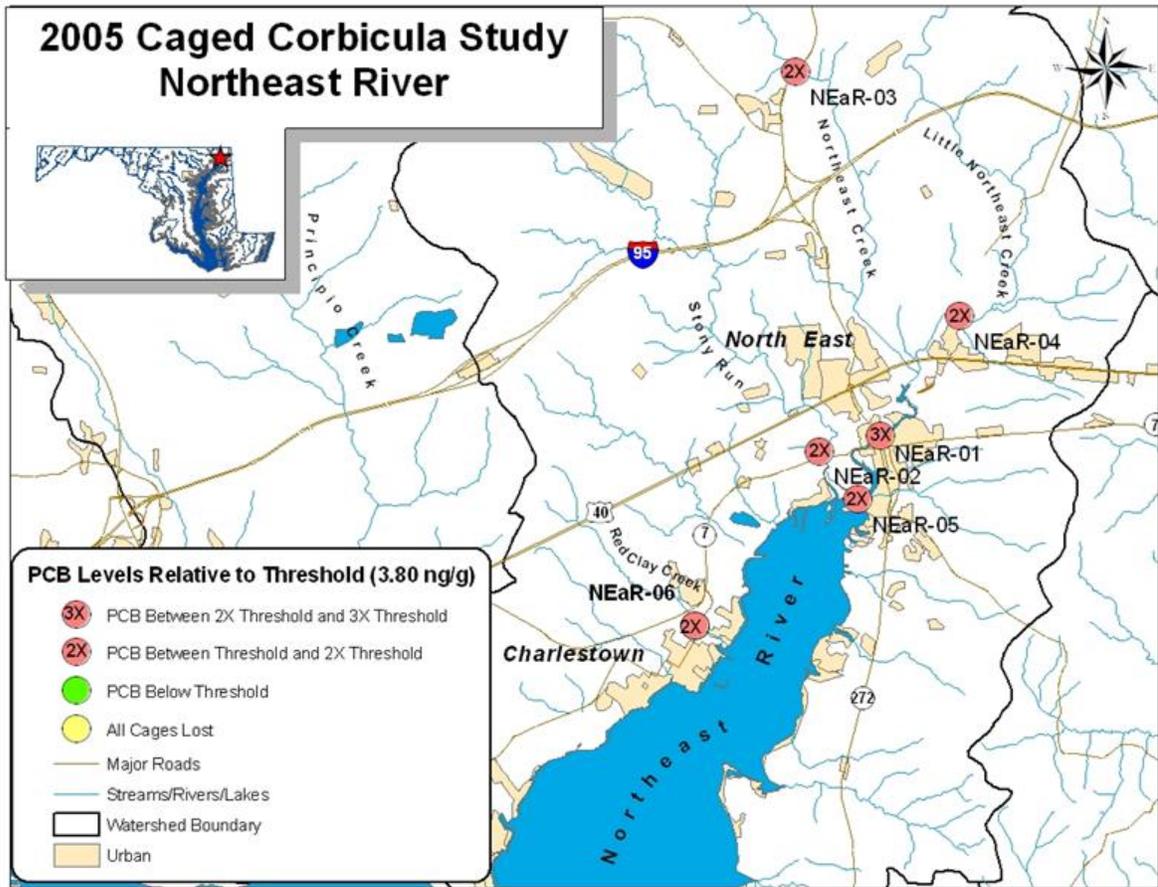
Map 7. Caged Clam Station Locations and Concentrations in the Gwynns Falls Subwatershed



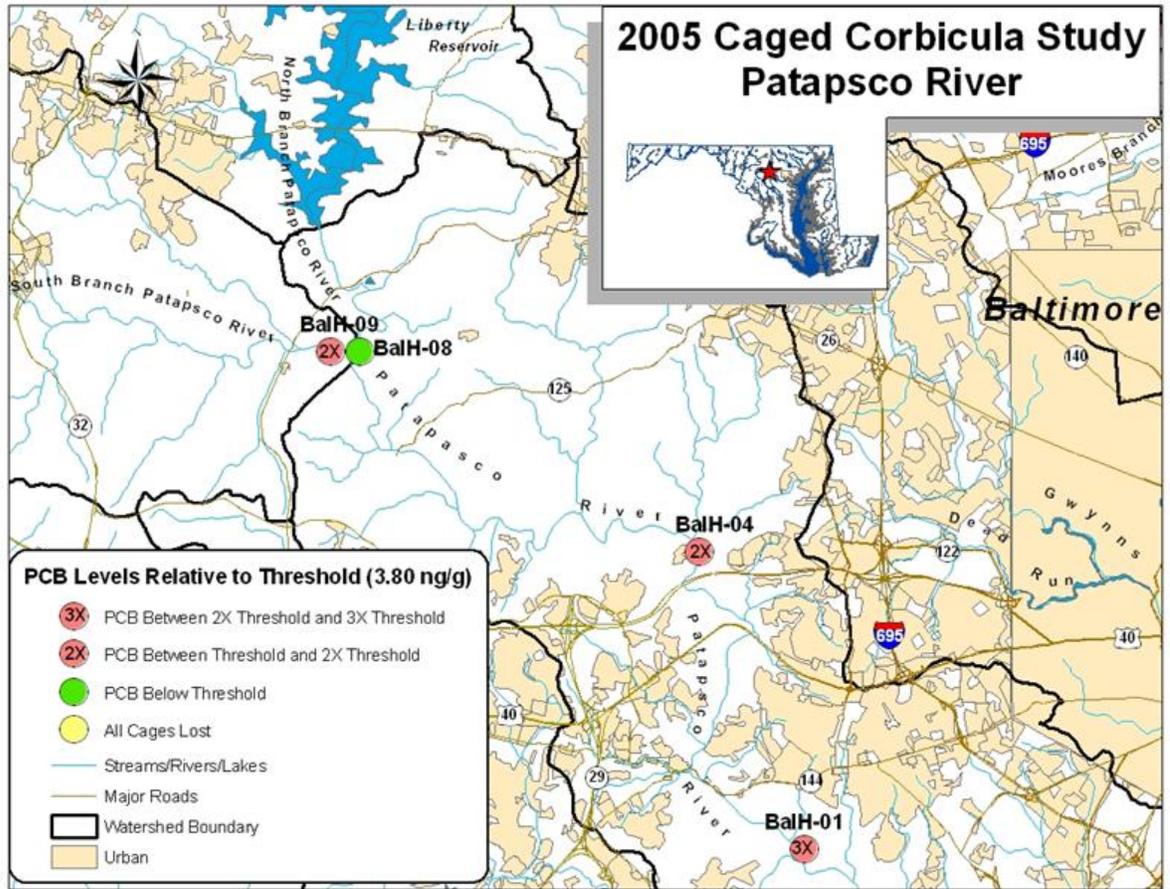
Map 8. Caged Clam Station Locations and Concentrations in the Bush River Watershed



Map 9. Caged Clam Station Locations and Concentrations in the Lower Elk River Watershed



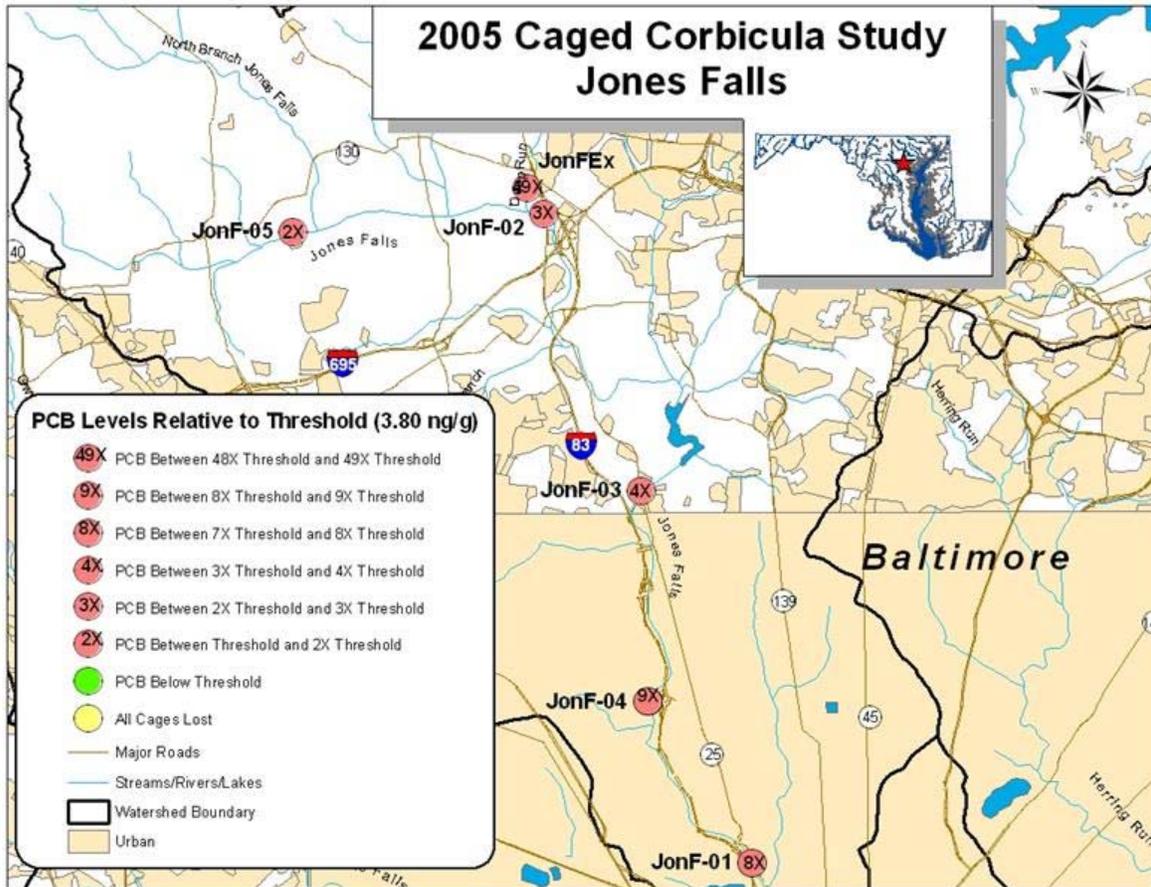
Map 10. Caged Clam Station Locations and Concentrations in the Northeast River Watershed



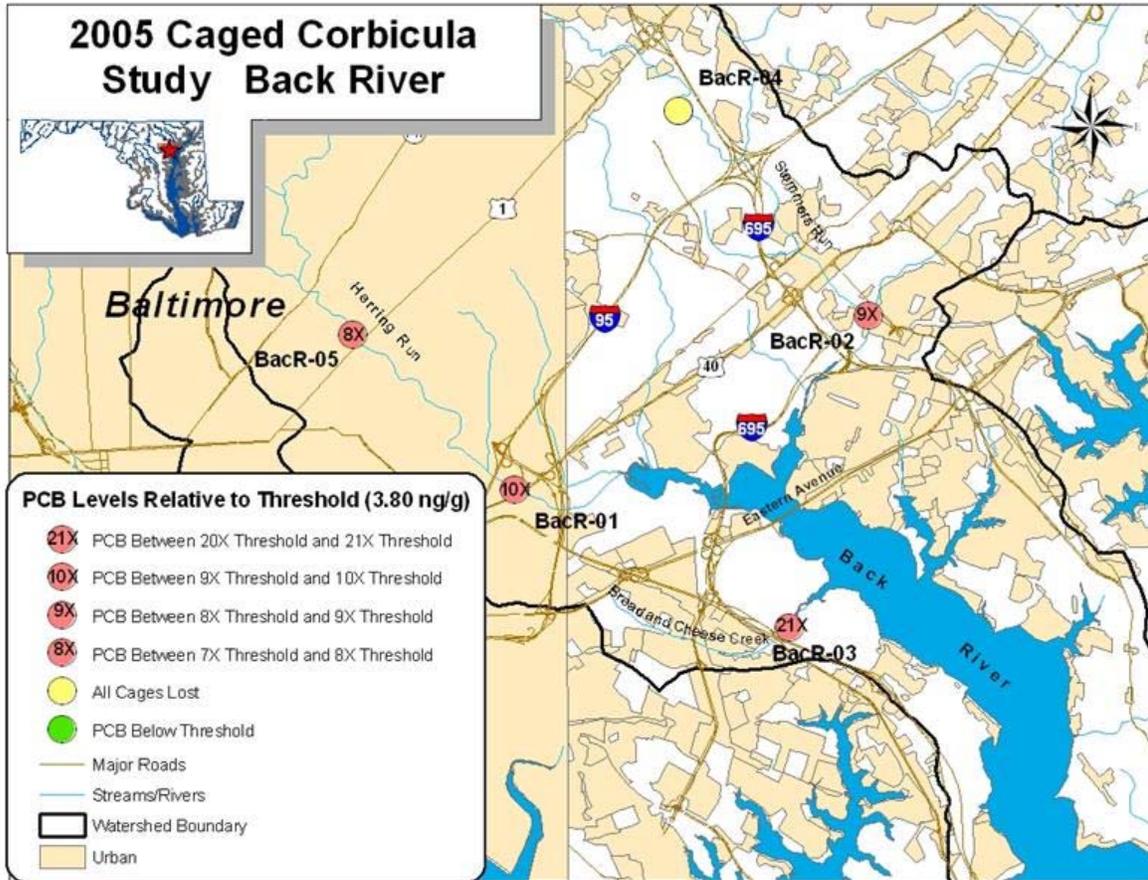
Map 11. Caged Clam Station Locations and Concentrations in the Patapsco River Subwatershed

3.3. Watersheds with Elevated Increases (>3x RT) in Clam tPCB Levels

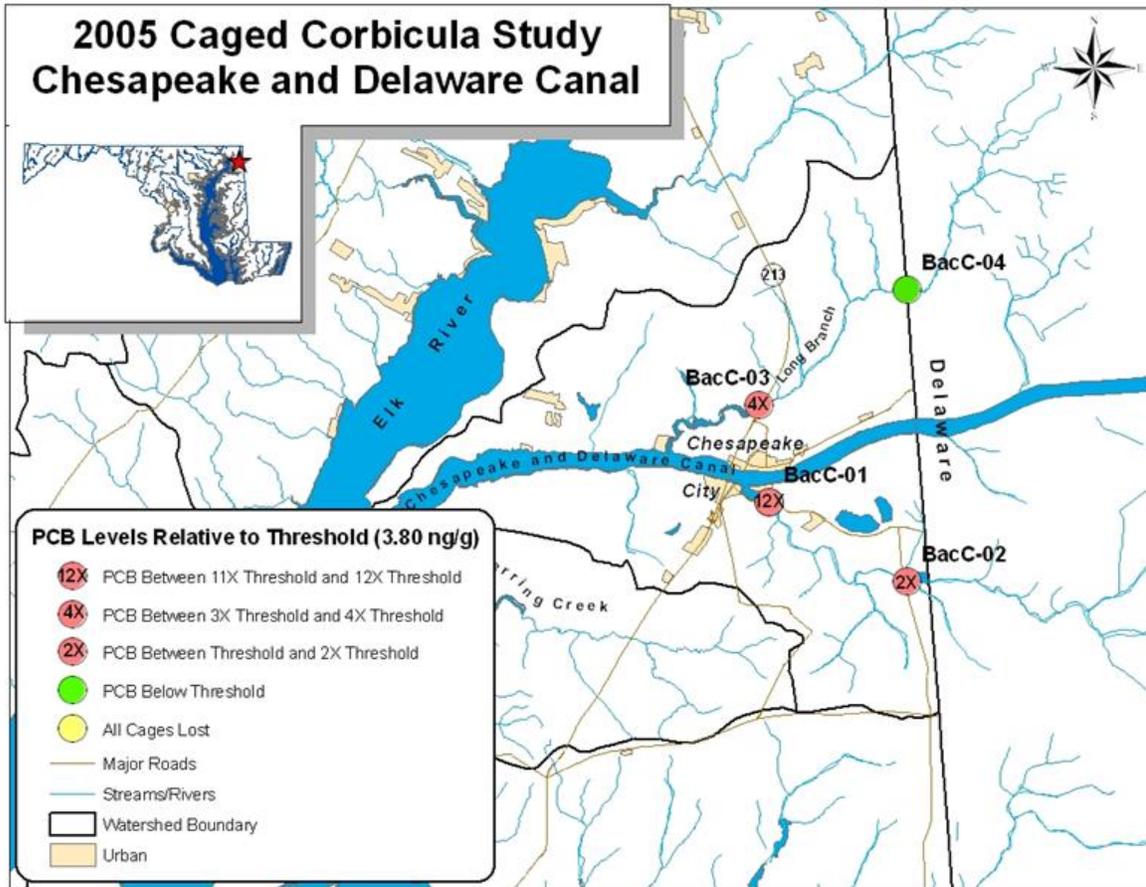
A total of 9 of watersheds/subwatersheds contain at least one station with tPCB concentrations above 3x RT. These include Jones Falls (Map 12 - JonFex is the overall highest at 49x RT), Back River (Map 13), Back Creek (Map 14 – Chesapeake and Delaware Canal), Upper Elk River (Map 15), Anacostia River (Map 16), South River (Map 17), Lower Susquehanna River (Map 18), Lower Patapsco River (Map 19), and Middle Chester River (Map 20). These sites will be given a high priority for action or future study.



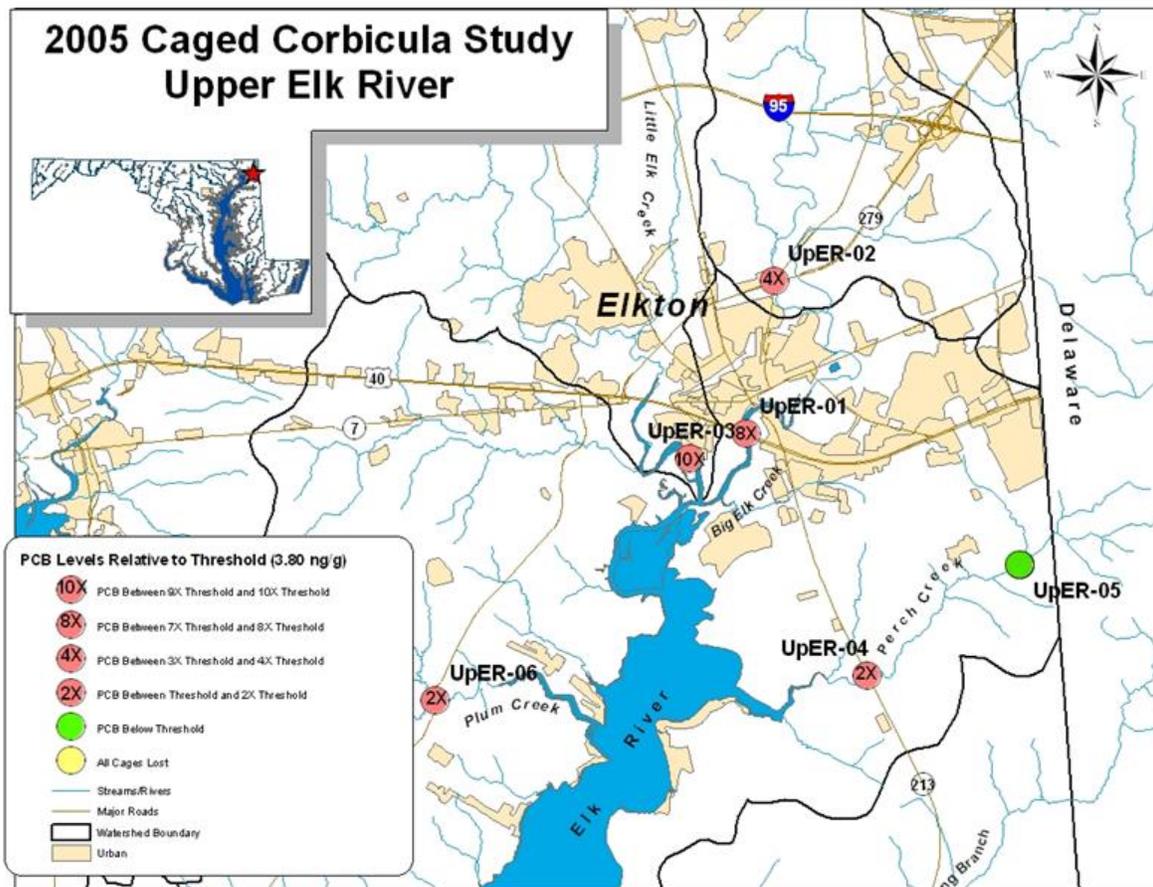
Map 12. Caged Clam Station Locations and Concentrations in the Jones Falls Watershed



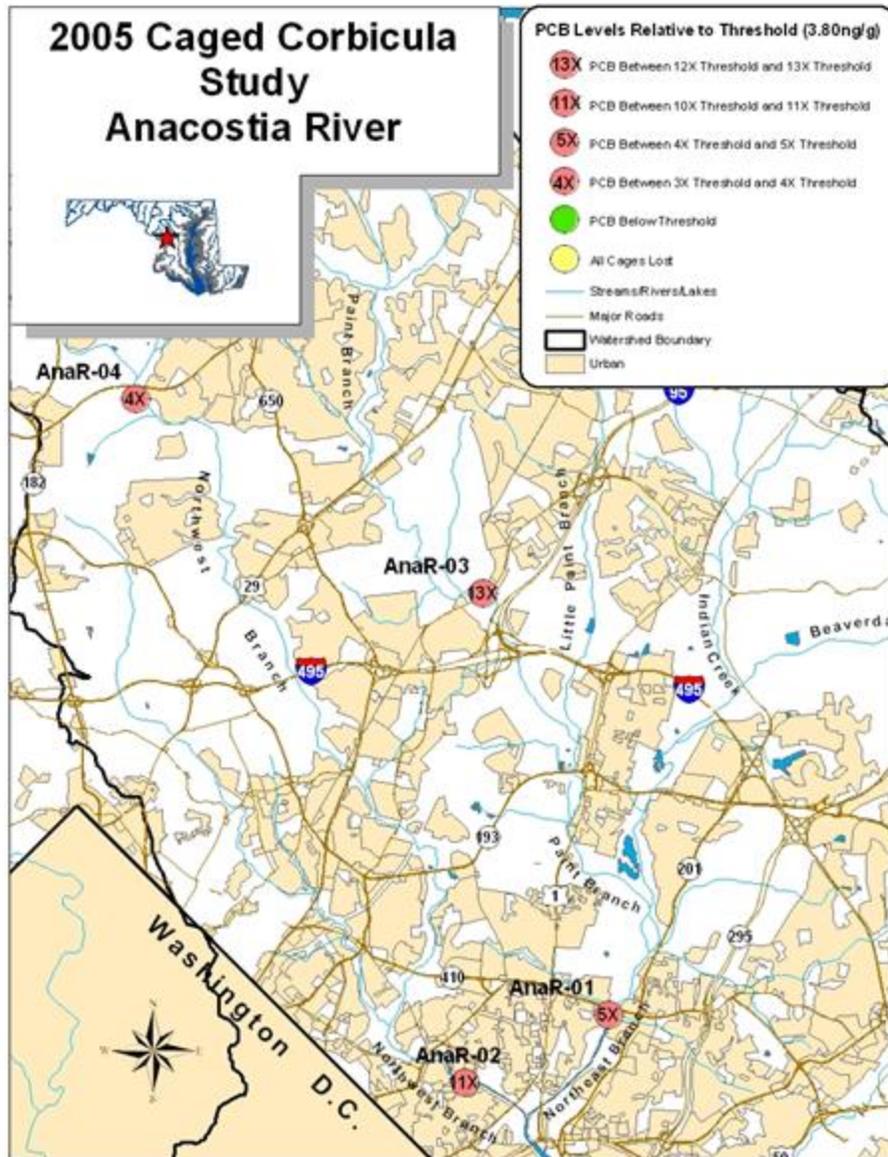
Map 13. Caged Clam Station Locations and Concentrations in the Back River Watershed



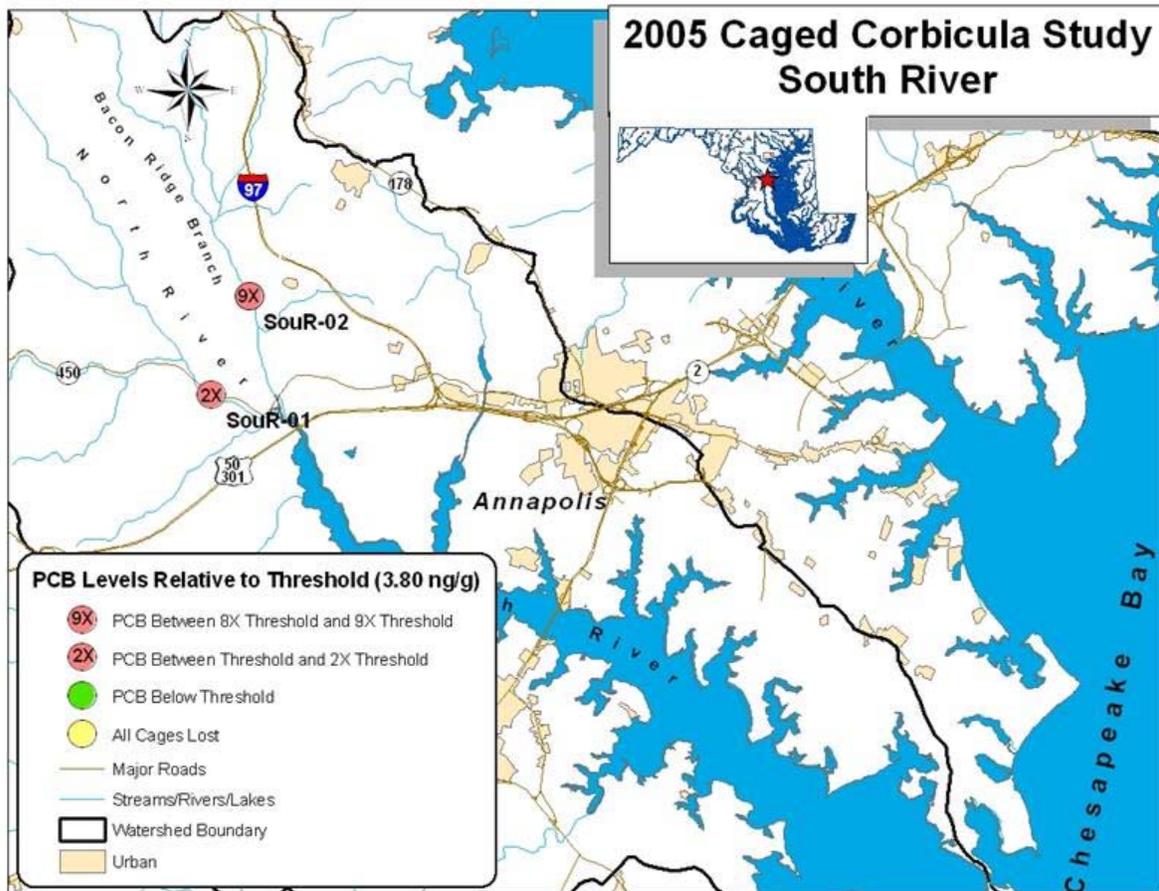
Map 14. Caged Clam Station Locations and Concentrations in the Back Creek Watershed (Chesapeake and Delaware Canal)



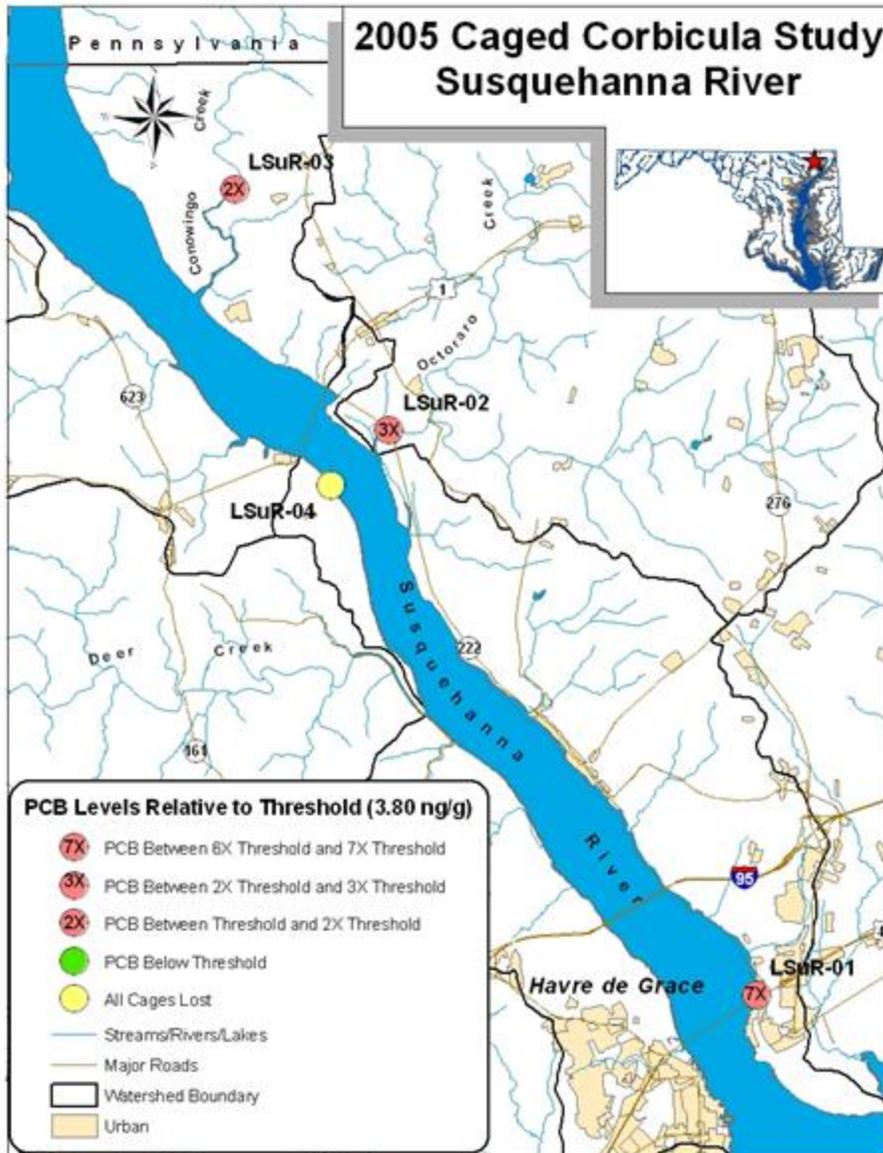
Map 15. Caged Clam Station Locations and Concentrations in the Upper Elk River Watershed



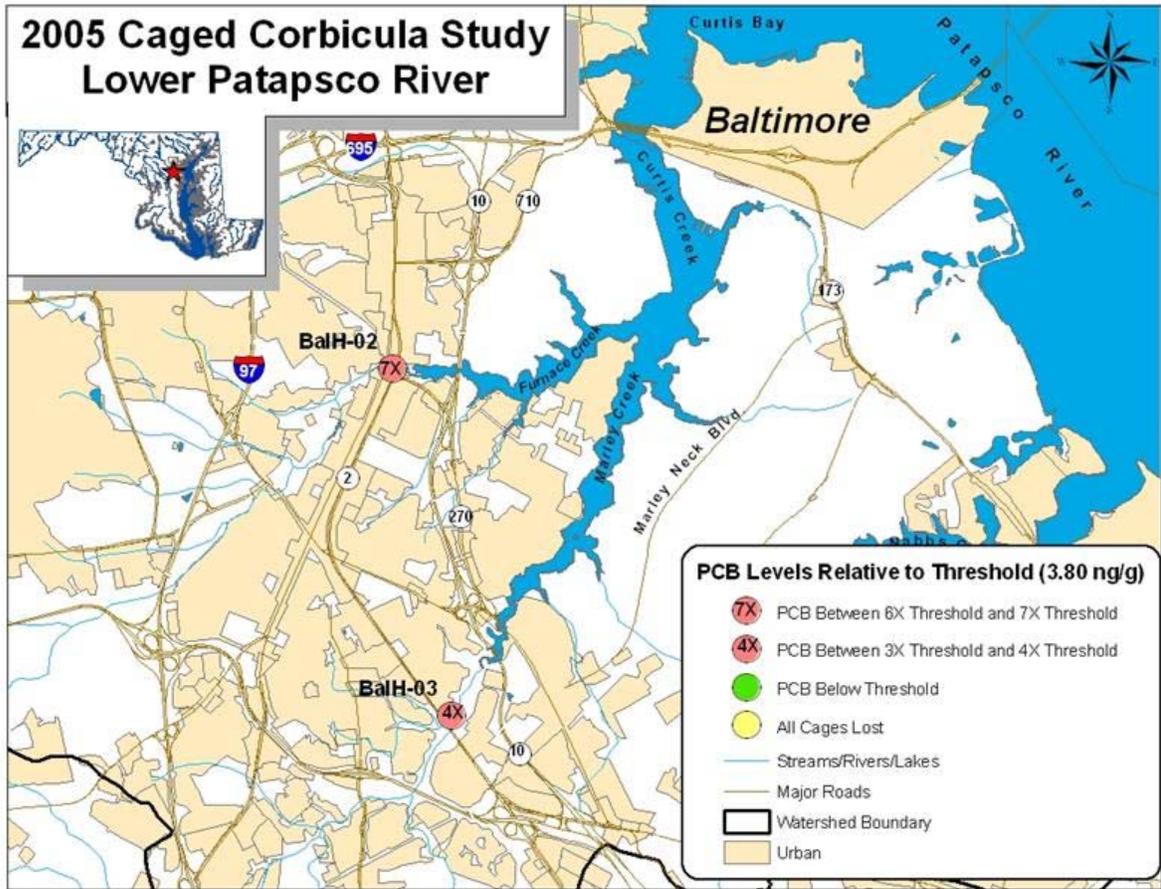
Map 16. Caged Clam Station Locations and Concentrations in the Anacostia River Watershed



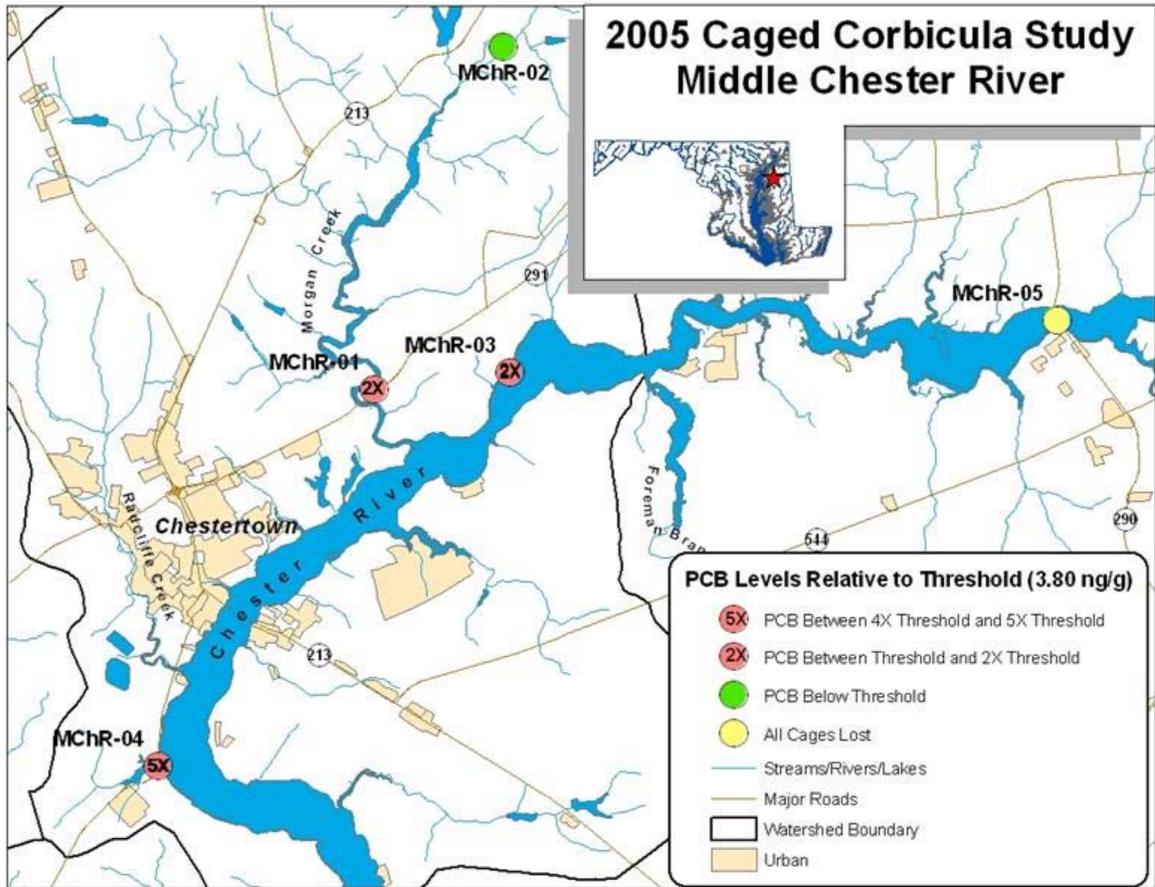
Map 17. Caged Clam Station Locations and Concentrations in the South River Watershed



Map 18. Caged Clam Station Locations and Concentrations in the Lower Susquehanna River Watershed



Map 19. Caged Clam Station Locations and Concentrations in the Lower Patapsco River Subwatershed



Map 20. Caged Clam Station Locations and Concentrations in the Middle Chester River Watershed

REFERENCES

- Ashley, J.T.F., and J.E. Baker. 1999. Hydrophobic Organic Contaminants in Surficial Sediments of Baltimore Harbor: Inventories and Sources. *Environmental Toxicology and Chemistry* 18(5):838-849.
- ASTM (American Society of Testing and Materials). 2005. *Standard #E-2122: Standard Guide for Conducting in-situ Field Bioassays with Marine, Estuarine, and Freshwater Bivalves*. Conshocken PA: 2005 Annual Book of ASTM Standards.
- ATSDR (Agency for Toxic Substances and Disease Registry). 2000. *Toxicological Profile for Polychlorinated Biphenyls (PCBs)*. U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, Atlanta, Georgia. Also Available at: <http://www.atsdr.cdc.gov/toxprofiles/tp17-p.pdf>.
- Farrington, J.W., E.D. Goldberg, R.W. Risebrough, J.H. Martin, and V.T. Bowen. 1983. US Mussel Watch 1976–1978: an overview of the trace metal, DDE, PCB, hydrocarbon and artificial radionuclide data. *Environmental Science and Technology* 17:490–496.
- Elder, J. F. and J. J. Collins. 1991. Freshwater molluscs as indicators of bioavailability and toxicity of metals in surface-water systems. *Reviews in Environmental Contamination and Toxicology* 92:31-19.
- Gustafsson O., P. Andersson, J. Axelman, T.D. Bucheli, P. Komp, M.S. McLachlan, A. Sobek, and J.O. Thorngren. 2005. Observations of the PCB distribution within and in-between ice, snow, ice-rafted debris, ice-interstitial water, and seawater in the Barents Sea marginal ice zone and the North Pole area. *Science of the Total Environment* 342(1-3):261-79.
- Liebert, D.P. 2006. Sources of Polychlorinated Biphenyls to Maryland Fish [Master Thesis]. College Park, MD: University of Maryland.
- MDE (Maryland Department of the Environment). 2008. *The 2008 Integrated Report of Surface Water Quality in Maryland*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/2008_Final_303d_list.asp..
- QEA (Quantitative Environmental Analysis, LLC). 1999. PCBs in the Upper Hudson River – Volume I, Historical Perspective and Model Overview. Albany, NY: Quantitative Environmental Analysis, LLC – Prepared for General Electric Company.
- Phelps, H. L. 2003. *Corbicula Biomonitoring in the Anacostia Watershed*. Washington, D.C: Report to the DC Water Resources Research Center:18. Also available at <http://water.usgs.gov/wrri/02grants/prog-compl-reports/2002DC5B.pdf>.
- Phelps, H. L. 2007. *Active Clam Biomonitoring for Sources of EPA Priority Pollutants in the Anacostia River Watershed, DC and MD*. A paper presented to the 13th Annual Maryland Water Monitoring Council Conference, December 6, 2007.

Salazar, M.H., and S. M. Salazar. 2003. Field Test Procedures Using Freshwater and Marine Bivalves. In *Standard Methods for the Examination of Water and Wastewater, 21st ed.*, edited by L.S. Clesceri, A.D. Eaton, and E.W. Rice. Washington, DC: American Public Health Association, American Waterworks Association, Water Environment Federation.

Appendix A – Scientific Collection Permit

Report of Activity for Scientific Collection Permit For the calendar year 2005 Permit Number SCP200580

January 5, 2006

Permit holder:
Maryland Department of the Environment
416 Chinquapin Round Road
Annapolis, MD 21401

Overview

The study was designed to assess the bioavailability of PCBs and metals in rivers listed on the 303(d) list of impaired waters. The Department collected Asian Clams Corbicula fluminea from a clean source, placed them in cages, and deployed them in several locations within each respective watershed. After a set time period, the cages were removed and the clam tissue was analyzed for contaminants. Relative differences in the tissue concentrations will be used to identify potential contaminant sources for TMDL development. DNR/MBSS data indicates that Corbicula fluminea are established in all watersheds defined in this study.

Collection Date	Location of Collection	Number Collected	Disposition	
06/06/05	Choptank River at Red Bridges	200	Collected and analyzed for baseline data	
06/20/05	As above	500	Collected for additional baseline data	
06/20/05	As above	6000	Deployed	Back Creek tributaries (CE) (n=4 stations)
			Deployed	Back River tributaries (BA) (n=5 stations)
			Deployed	Bush River tributaries (HA) (n=4 stations)
			Deployed	Corsica R. tributaries (QA) (n=6 stations)
			Deployed	middle Chester R. tributaries (KE) (n=5 stations)
			Deployed	Elk River tributaries (CE) (n=10 stations)
			Deployed	Northeast R. tributaries (CE) (n=6 stations)
			Deployed	Sassafras R. tributaries (CE, KE) (n=3 stations)
06/23/05	As above	4000	Deployed	Anacostia R. tributaries (PG, MO) (n=4 stations)
			Deployed	Baltimore Harbor tributaries (BA, BC, AA, CL) (n=9 stations)
			Deployed	Bohemia River tributaries (CE) (n=5 stations)
			Deployed	Elk River tributaries (CE) (n=1 station)
			Deployed	Jones Falls tributaries (BA, BC) (n=6 stations)
			Deployed	South River tributaries (AA) (n=2 stations)
			Deployed	Susquehanna R. tributaries (CE) (n=4 stations)
07/05/05	As above	275	Deployed	Choptank River at Red Bridges (CO) (control)

For additional information please contact the Department at the enclosed address, phone, or email.

Regards,

Chris Luckett, Maryland Department of the Environment

Appendix B – tPCB Results for Each Composite (ng/g-wet weight)

The station code was designed to indicate several distinguishing features about each station. For instance, the hypothetical sample code **BacR-01_A_field_rep** indicates that this station is located in the Back River watershed (BacR), it is the most downstream station in the sub-watershed (01), and the cage was exposed for two weeks (suffix “A” signifies two week exposure, while “B” signifies four week exposure). In cases where a replicate was also deployed, the final suffix “field_rep” was used.

Station	tPCBs	Mean tPCBs for Each Station	Magnitude of Increase for Each Station
AnaR1_A	17.62	17.62	5x
AnaR2_A	43.79		
AnaR2_A_field_rep	38.37		
AnaR2_B	40.1	40.59	11x
AnaR3_A	45.71	45.71	13x
AnaR4_A	11.53		
AnaR4_B	13.32	12.43	4x
BacC1_A	37.44		
BacC1_B	45.78	41.61	12x
BacC2_A	5.66		
BacC2_A_lab_rep	6.3		
BacC2_B	5.84		
BacC2_A_field_rep	5.66	5.87	2x
BacC3_A	12.35		
BacC3_B	15.61	13.98	4x
BacC4_A	2.57		
BacC4_B	2	2.29	<1x
BacR1_A	24.25		
BacR1_A_field_rep	40.02		
BacR1_B	40.73	36.43	10x
BacR2_A	41.01		
BacR2_B	22.16	31.59	9x
BacR3_B	86.06		
BacR3_A	63.01	74.54	21x
BacR5_A	34.94		
BacR5_B	23.72	29.33	8x
BalH1_A	8.46		
BalH1_A_field_rep	8.59		
BalH1_B	9.29	8.91	3x
BalH2_A	25.92		
BalH2_B	23.7	24.81	7x
BalH3_A	11.2		
BalH3_B	11.17	11.19	4x

Station	tPCBs	Mean tPCBs for Each Station	Magnitude of Increase for Each Station
BalH4_A	7.34		
BalH4_B	4.09	5.72	2X
BalH6_A	5.54		
BalH6_B	10.55	8.05	3X
BalH7_A	12		
BalH7_B	7.1	9.55	3X
BalH8_A	3.75		
BalH8_B	3.57	3.66	<1X
BalH9_A	5.87		
BalH9_B	6.49	6.18	2X
BohR1_A	5.34		
BohR1_A_field_rep	5.27		
BohR1_B	3.82	4.56	2X
BohR2_A	3.3		
BohR2_B	4.09	3.7	<1X
BohR3_A	3.43		
BohR3_B	4.99	4.21	2X
BohR4_A	3.51		
BohR4_B	4.8	4.16	2X
BohR5_A	1.82		
BohR5_B	3.69	2.76	<1X
BusR1_A	13.53		
BusR1_B	3.65		
BusR1_B_field_rep	9.83	10.14	3X
BusR2_A	5.53		
BusR2_B	6.14	5.84	2X
BusR3_A	2.78		
BusR3_B	3.17	2.98	<1X
BusR4_A	3.89		
BusR4_B	5.02	4.46	2X
CorR1_A	2.65		
CorR1_A_field_rep	2.1		
CorR1_B	5.53		
CorR1_B_lab_rep	5.45	3.93	2X
CorR2_A	2.25		
CorR2_B	2.87	2.56	<1X
CorR3_A	1.64		
CorR3_B	3.78	2.71	<1X
CorR4_A	2.29		
CorR4_B	4.37	3.33	<1X
CorR5_A	3.38		
CorR5_B	4.25	3.82	2X

Station	tPCBs	Mean tPCBs for Each Station	Magnitude of Increase for Each Station
CorR6_A	1.77		
CorR6_B	1.57	1.67	<1X
JonF1_A	21.46		
JonF1_A_field_rep	34.37	27.92	8X
JonF2_A	8.91		
JonF2_B	8.09	8.5	3X
JonF3_A	10.66		
JonF3_B	12.26	11.46	4X
JonF4_A	30.14	30.14	9X
JonF5_A	4.91		
JonF5_B	6.13	5.52	2X
JonFEx_A	256.68		
JonFEx_B	104.36	180.52	49X
LEIR1_A	3		
LEIR1_B	3.65		
LEIR1_B_field_rep	3.38	3.26	<1X
LEIR2_A	4.78		
LEIR2_B	5.86	5.32	2X
LEIR3_A	14.49		
LEIR3_B	4.57	9.53	3X
LEIR4_A	3.9		
LEIR4_B	1.93	2.92	<1X
LEIR5_A	3.18		
LEIR5_B	3.4	3.29	<1X
LSuR1_A	17.63		
LSuR1_B	35.14		
LSuR1_B_field_rep	30.24	25.16	7X
LSuR2_A	5.13		
LSuR2_B	10.2	7.67	3X
LSuR3_A	4.35		
LSuR3_B	5.26	4.81	2X
MChR1_A_B	5.64	5.64	2X
MChR2_A	2.91		
MChR2_B	4.25	3.58	<1X
MChR3_A_B	5.86	5.86	2X
MChR4_A	19.03		
MChR4_B	13.56	16.3	5X
NEaR1_A	5.96		
NEaR1_A_field_rep	13.73		
NEaR1_B	9.2	9.52	3X
NEaR2_A	6.87		
NEaR2_B	5.23	6.05	2X

Station	tPCBs	Mean tPCBs for Each Station	Magnitude of Increase for Each Station
NEaR3_A	5.09		
NEaR3_B	5.85	5.47	2X
NEaR4_A	6.21		
NEaR4_B	8.22	7.22	2X
NEaR5_A	5.74		
NEaR5_B	7.08	6.41	2X
NEaR6_A	9.52		
NEaR6_B	2.26	5.89	2X
SasR1_A	3.84		
SasR1_B	4.64		
SasR1_B_field_rep	3.23	3.89	2X
SasR2_A	2.37		
SasR2_B	2.46	2.42	<1X
SasR3_A	2.8		
SasR3_B	6.56	4.68	2X
SouR1_A	10.49		
SouR1_A_field_rep	3.03		
SouR1_B	2.51	4.63	2X
SouR2_A	31.66		
SouR2_B	28.64	30.15	9X
UpER1_A	19.2		
UpER1_A_field_rep	30.11		
UpER1_B	33.87	29.26	8X
UpER2_A	5.1		
UpER2_B	20.75	12.93	4X
UpER3_A	37.16	37.16	10X
UpER4_A	3.3		
UpER4_B	6.78	5.04	2X
UpER5_A	2.92		
UpER5_B	4.22	3.57	<1X
UpER6_A	4.35		
UpER6_B	6.38	5.37	2X

Appendix C – Summary of tPCB Results for Each Watershed

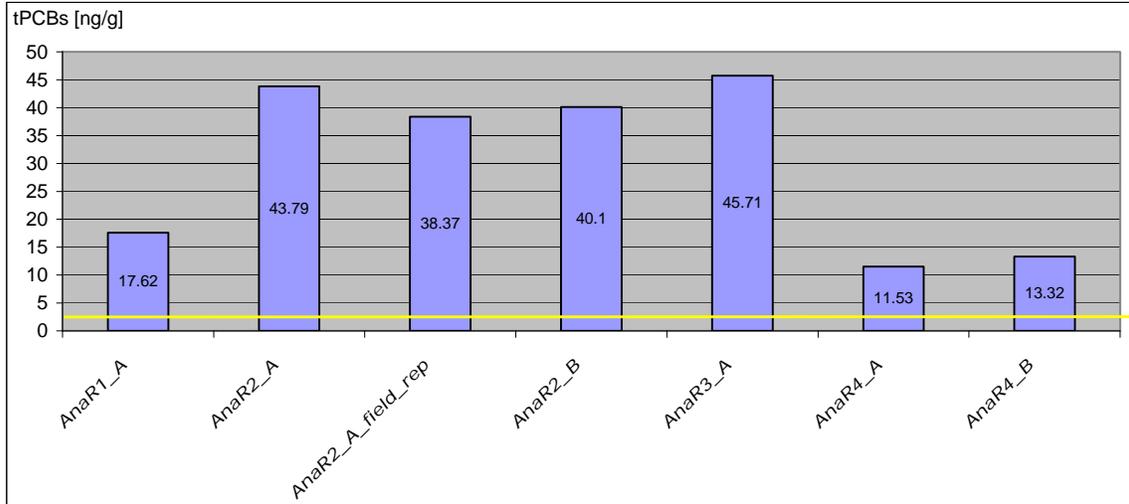


Figure C- 1. Results from Anacostia River Stations

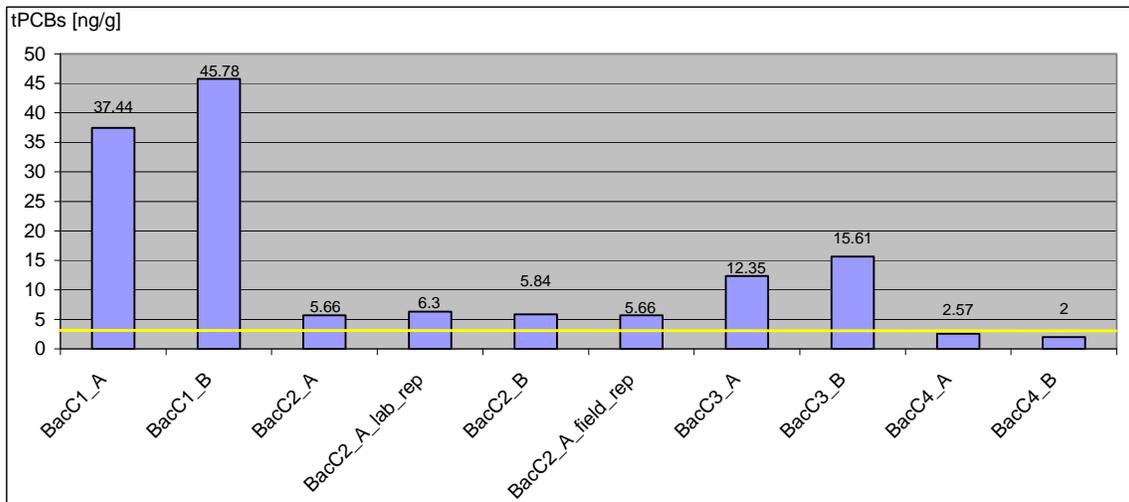


Figure C- 2. Results from Back Creek Stations (Chesapeake and Delaware Canal)

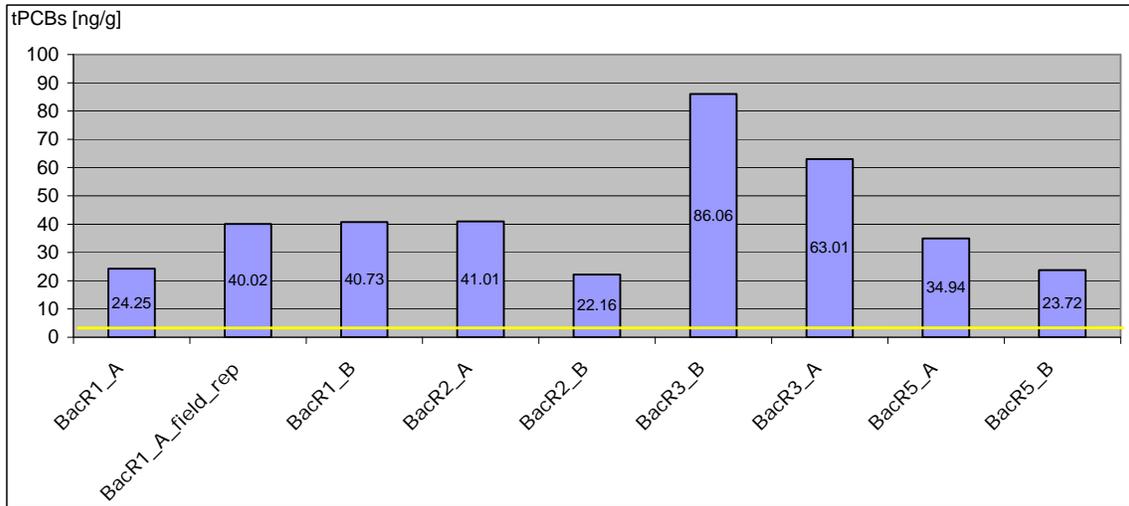


Figure C- 3. Results from Back River Stations

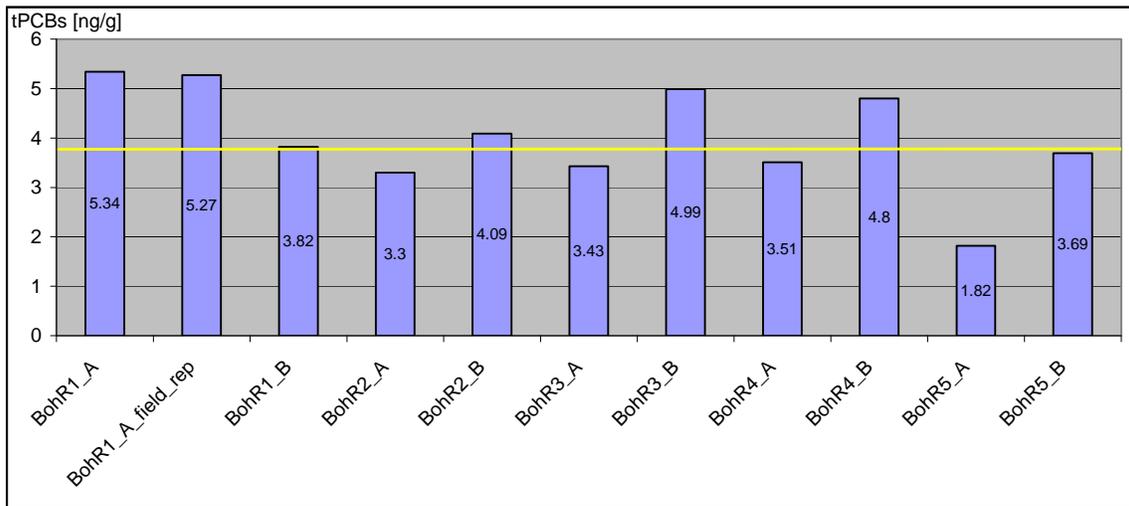


Figure C- 4. Results from Bohemia River Stations

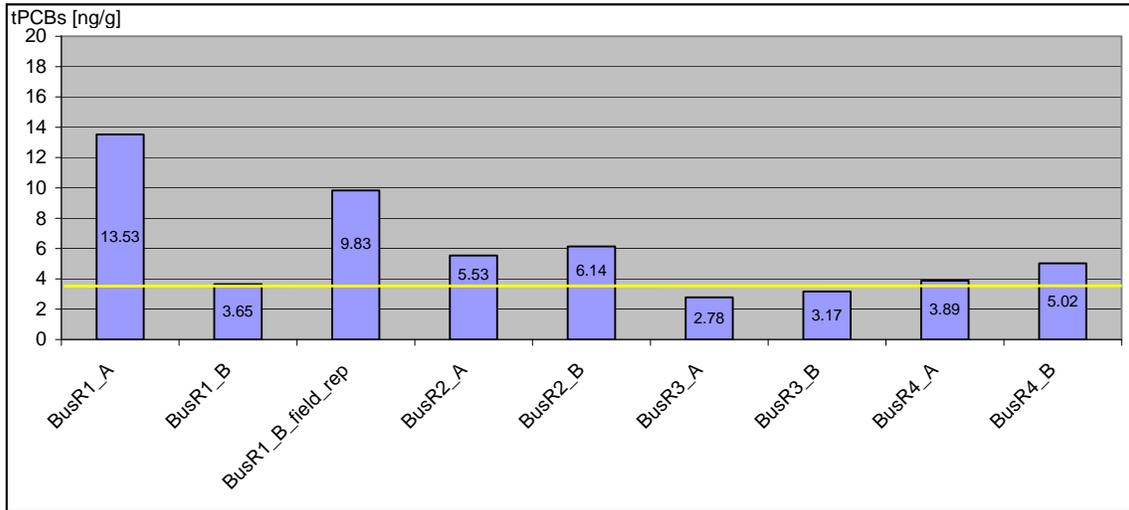


Figure C- 5. Results from Bush River Stations

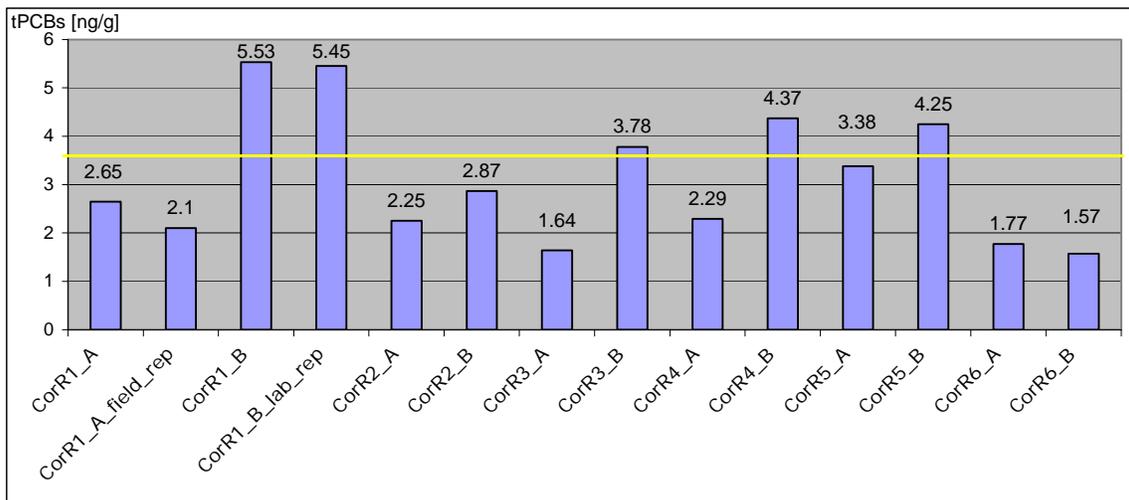


Figure C- 6. Results from Corsica River Stations

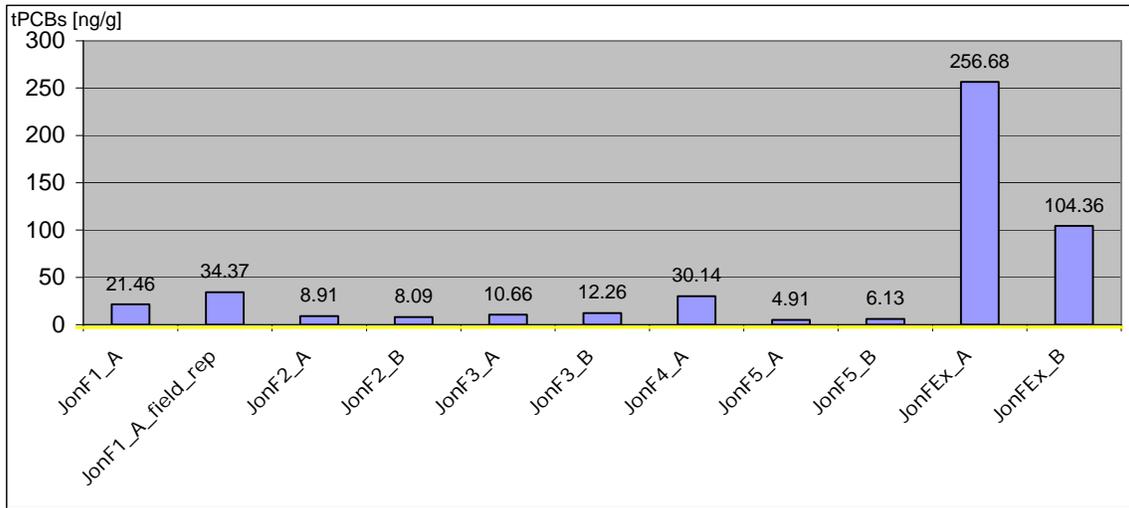


Figure C- 7. Results from Jones Falls River Stations

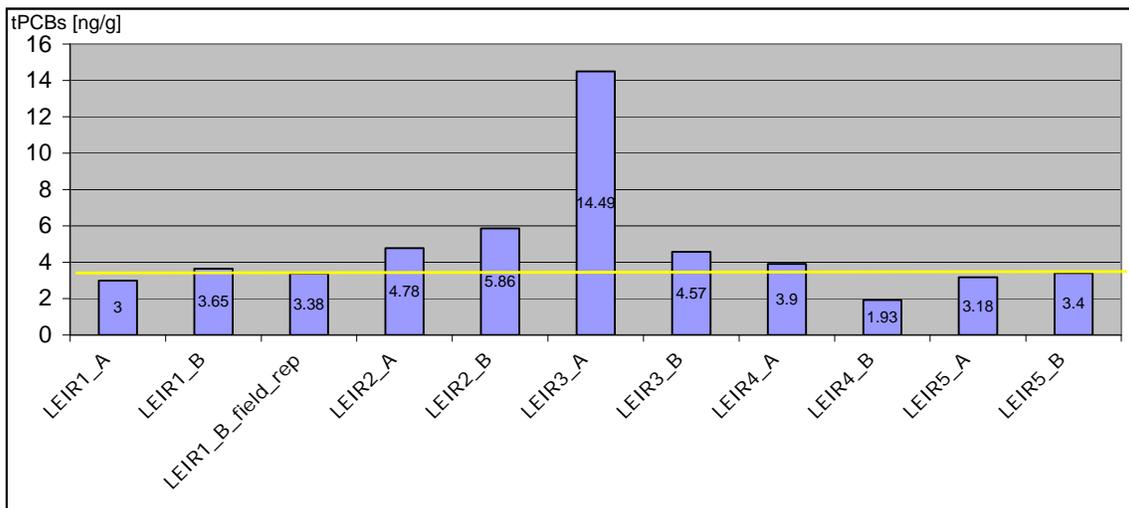


Figure C- 8. Results from Lower Elk River Stations

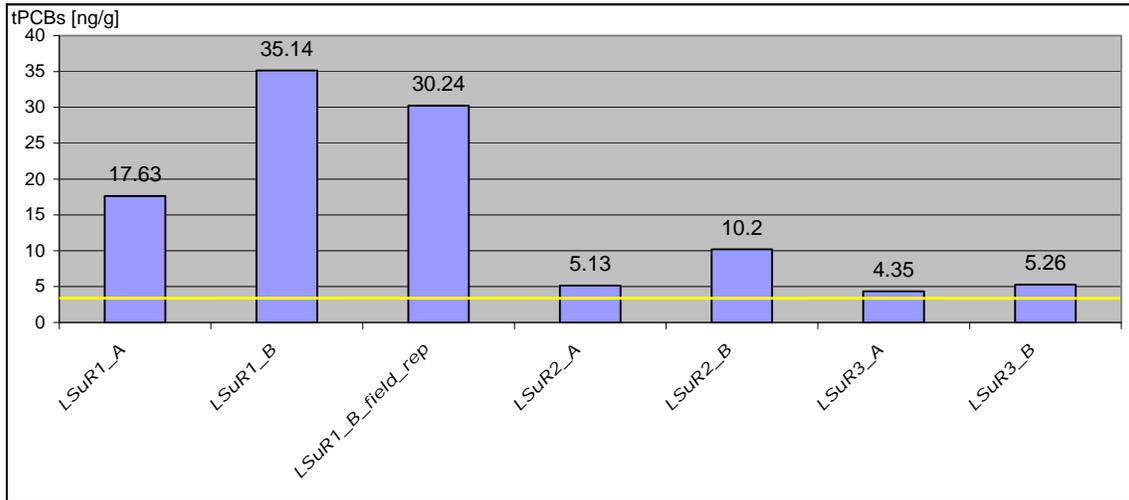


Figure C- 9. Results from Lower Susquehanna River Stations

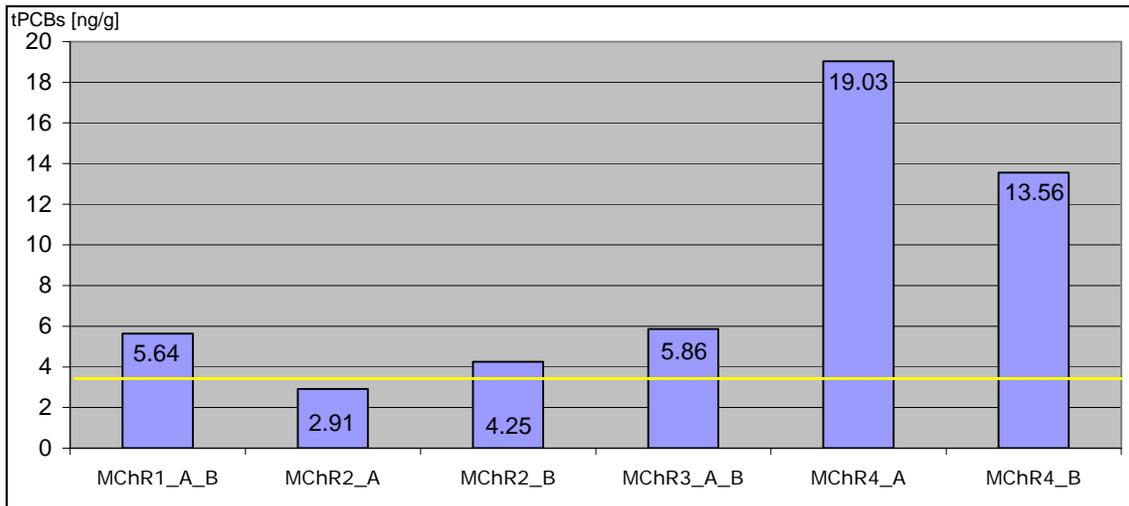


Figure C- 10. Results from Middle Chester River Stations

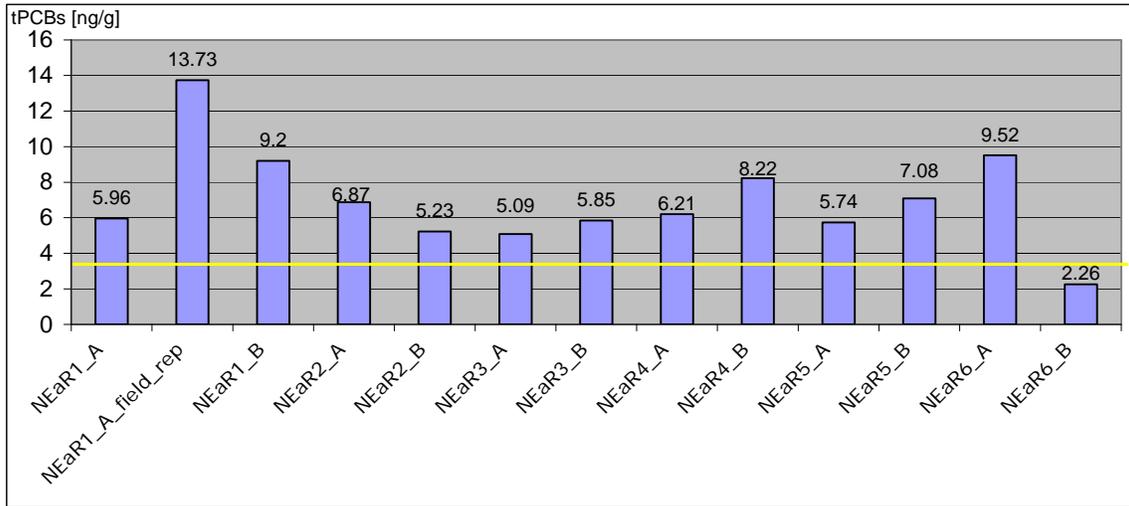
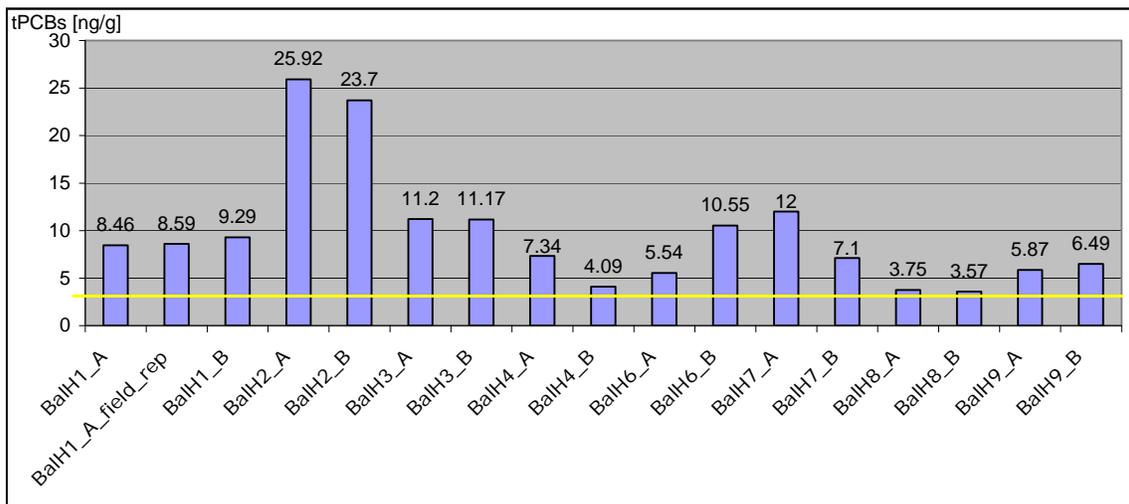


Figure C- 11. Results from Northeast River Stations



**Figure C- 12. Results from Patapsco River Stations
(Gwynns Falls, Lower Patapsco River, and Patapsco River Subwatersheds)**

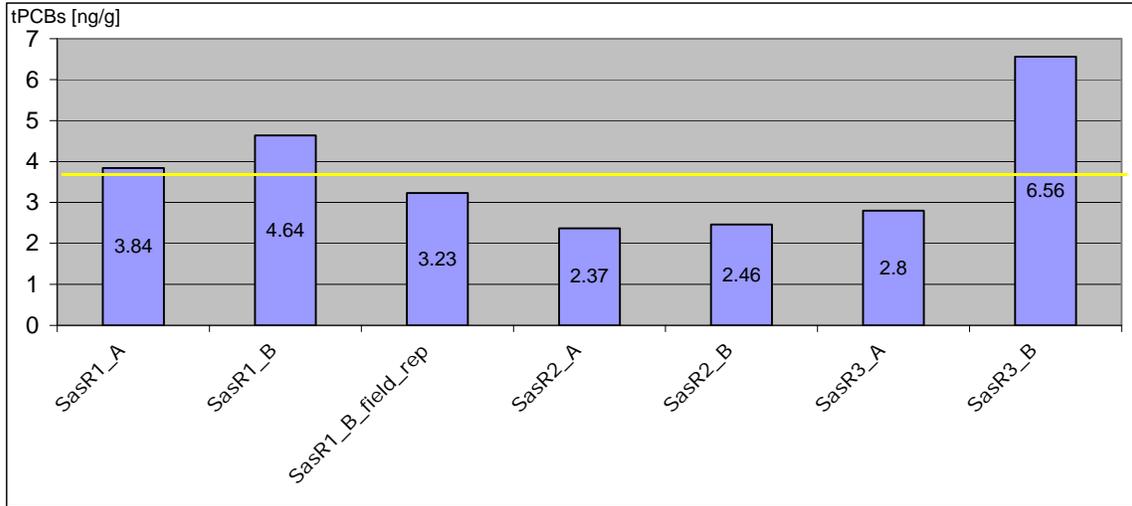


Figure C- 13. Results from Sassafra River Stations

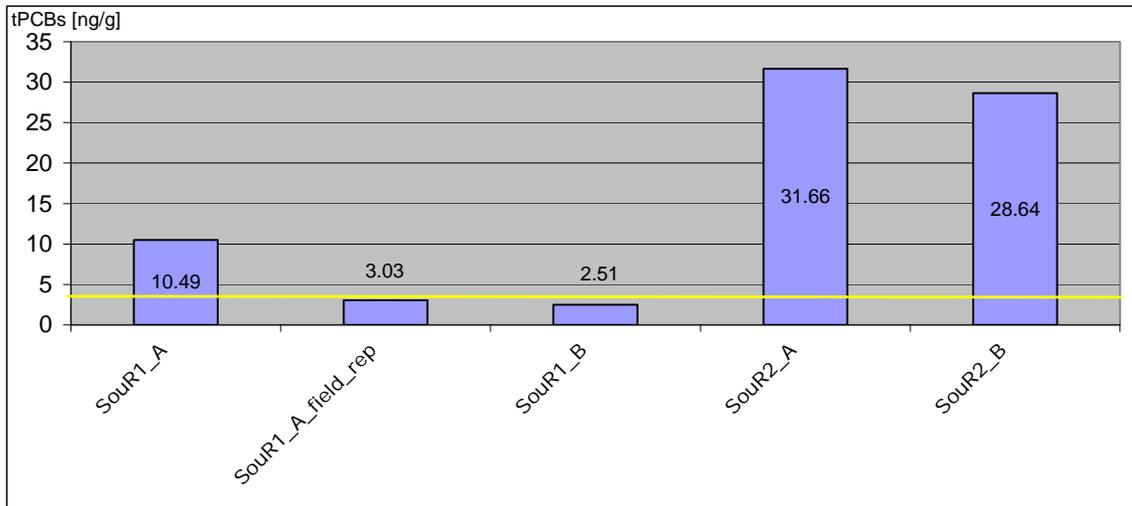


Figure C- 14. Results from South River Stations

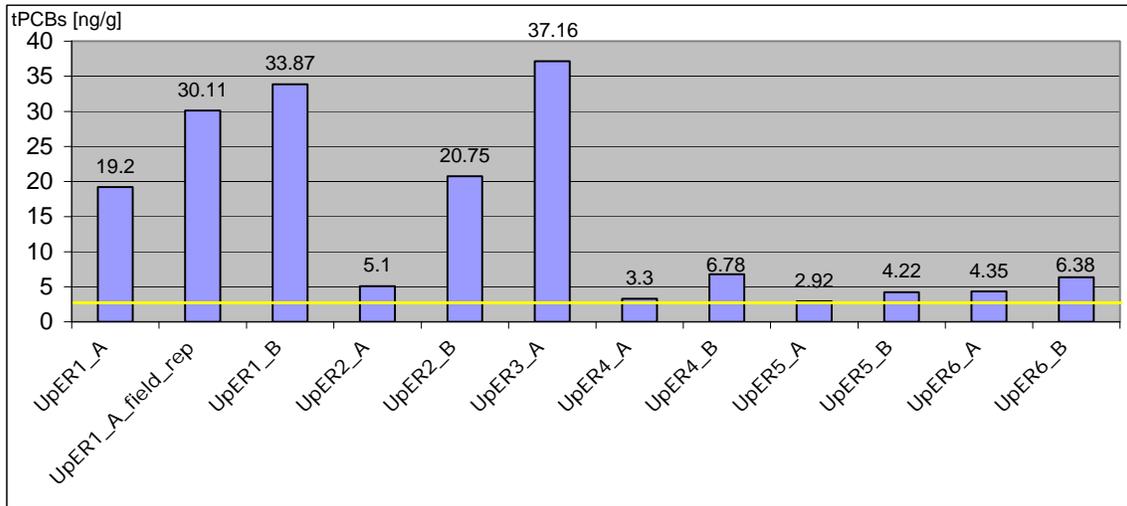


Figure C- 15. Results from Upper Elk River Stations

Appendix D – List of Analyzed PCB Congeners

Polychlorinated biphenyl (PCB) analytical services were provided by the University of Maryland Center for Environmental Science (UMCES). PCB congeners were identified and quantified by high resolution gas chromatography with electron capture detection. UMCES uses a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999), in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248, and 1262) are determined based on their chromatographic retention times relative to the internal standards (PCB 30 and PCB 204). Based on this method, 86 chromatographic peaks can be quantified (see Table J-1). Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners. The PCB analysis presented in this document is based on total PCB concentrations that are calculated as the sum of the detected PCB congeners/congener groups representing most common congeners that were historically used in the Aroclor commercial mixtures.

1	45	110, 77	177
3	46	114	180
4, 10	47, 48	118	183
6	49	119	185
7, 9	51	123, 149	187, 182
8, 5	52	128	189
12, 13	56, 60	129, 178	191
16, 32	63	132, 153, 105	193
17	66, 95	134	194
18	70, 76	135, 144	197
19	74	136	198
22	81, 87	137, 130	199
24	82, 151	141	201
25	83	146	202, 171, 156
26	84, 92	157, 200	203, 196
29	89	158	205
31, 28	91	163, 138	206
33, 21, 53	97	167	207
37, 42	99	170, 190	208, 195
40	100	172	209
41, 64, 71	101	174	
44	107	176	

Appendix E – Station Coordinates and Description

Site Name	Latitude	Longitude	Description
AnaR1	38.960	-76.926	Northeast Branch at Riverdale Rd. Xing.
AnaR2	38.949	-76.957	Northwest Branch at 38th Ave. Xing.
AnaR3	39.032	-76.953	Paint Branch at Powder Mill Rd. Xing.
AnaR4	39.064	-77.029	Northwest Branch at Old Randolph Rd. Xing.
BacC1	39.525	-75.807	Back Creek at 2nd St. Xing, along C&D Mooring Basin.
BacC2	39.514	-75.781	Back Creek at Old Telegraph Road Xing, d/s of Sammons Pond.
BacC3	39.539	-75.808	Long Branch at Rt. 213 Xing.
BacC4	39.555	-75.781	Long Branch along Woods Rd., near DE line.
BacR1	39.305	-76.539	Herring Run at Pulaski Highway Xing.
BacR2	39.330	-76.474	Northeast Ck., at Golden Ring Rd and Judy Ave. intersect.
BacR3	39.285	-76.489	Bread and Cheese Ck., at North Point Blvd and I695 Xing.
BacR4	39.359	-76.509	Stemmer's Run at Lilian Holt Dr. Xing.
BacR5	39.328	-76.569	Herring Run at Rt. 1 Xing.
BalH1	39.252	-76.765	Patapsco River at Ilchester Road Bridge Xing.
BalH2	39.183	-76.614	Sawmill Ck., at Rt. 2 Xing.
BalH3	39.146	-76.606	Marley Ck., at Rt. 2 Xing.
BalH4	39.311	-76.792	Patapsco River at Frederick Rd (Rt. 99) nr. Hollifield Gage.
BalH5	39.277	-76.662	Gwynns Falls at Rt. 1 Xing.
BalH6	39.327	-76.725	Gwynns Falls at Woodlawn Cemetery.
BalH7	39.421	-76.782	Gwynns Falls at Reisterstown Rd. Xing.
BalH8	39.352	-76.880	No. Br. Patapsco R., east of McKeldin Rec Area.
BalH9	39.352	-76.888	So. Br. Patapsco R., South of McKeldin Rec Area.
BohR1	39.434	-75.848	Trib of Little Bohemia Ck., at Bohemia Church Rd.
BohR2	39.431	-75.830	Trib of Little Bohemia Ck., at Bohemia Church Rd.
BohR3	39.460	-75.774	Sandy Branch at Old Telegraph Road, near DE line.
BohR4	39.465	-75.776	Bohemia Mill Pond at Old Telegraph Rd.
BohR5	39.446	-75.777	Trib of Great Bohemia Ck., at Middle Neck Road.
BusR1	39.477	-76.261	James Run at Rt. 7 Xing.
BusR2	39.488	-76.215	Gray's Run, at Rt 7 Xing.
BusR3	39.443	-76.316	Winter's Run at Rt. 7 Xing.
BusR4	39.498	-76.354	Winter's Run at Whitaker Mill Rd. Xing.
ChoR1	38.997	-75.786	Choptank River at Red Bridges Road.
CorR1	39.040	-76.073	"Old" Mill Stream Branch at Rt. 213 crossing.
CorR2	39.054	-76.068	Three Bridges Branch at Rt. 213 crossing.
CorR3	39.055	-76.089	Trib of Earle Ck., at Rt. 304 Xing.
CorR4	39.072	-76.067	Alder Branch at Spaniard Neck Rd. Xing.
CorR5	39.047	-76.020	Three Bridges Branch at Hope Rd. Xing.
CorR6	39.020	-76.049	"Old" Mill Stream Branch at Rolling Bridge Rd. Xing.
JonF1	39.322	-76.631	Jones Falls at Falls Road (+Chesnut) Mt. Vernon Mill.
JonF2	39.414	-76.668	Jones Falls at Falls Road Xing.

Site Name	Latitude	Longitude	Description
JonF3	39.375	-76.650	Jones Falls at Falls Road Xing., below Lake Roland.
JonF4	39.345	-76.650	Jones Falls at Cold Spring Lane Xing.
JonF5	39.412	-76.714	Jones Falls at Stevenson Rd. Xing.
JonFEx	39.417	-76.671	Deep Run at Meadowood Park.
LEIR1	39.506	-75.832	Herring Creek at Rt. 213 Xing.
LEIR2	39.441	-75.933	Cabin John Ck., at Pinewood Rd. Xing.
LEIR3	39.424	-75.946	Pearce Ck., at Stemmer's Run Rd. Xing.
LEIR4	39.534	-75.930	Muddy Ck., at Old Elk Neck Rd. Xing.
LEIR5	39.521	-75.942	Piney Ck., at Old Elk Neck Rd. Xing.
LSuR1	39.566	-76.079	Susquehanna R., at Perryville municipal ramp.
LSuR2	39.660	-76.156	Octoraro Ck., at Rt. 222 (Susquehanna River Rd.).
LSuR3	39.701	-76.189	Conowingo Ck., at Pilot Town Road
LSuR4	39.651	-76.169	Susquehanna R., at Fisherman's Park, below dam.
MChR1	39.236	-76.037	Morgan Creek at Morgnec Rd. Ramp (Rt. 291)
MChR2	39.280	-76.015	Morgan Creek at Perkins Hill Rd.
MChR3	39.238	-76.015	Chester River at Buckingham Rd. Ramp
MChR4	39.188	-76.073	Unnamed Trib at Rt. 289 (Quaker Neck Rd.), yacht club.
MChR5	39.244	-75.924	Chester River at Rt. 290 (Crompton Rd.), Crompton.
NEaR1	39.603	-75.943	Little Northeast Creek at Mauldin Road(Main St.), Town of
NEaR2	39.601	-75.953	Stony Run at Rt. 7 Xing
NEaR3	39.649	-75.956	Northeast Ck., at Northeast Rd (Rt. 272) Xing.
NEaR4	39.618	-75.930	Little Northeast Creek at Mechanics Valley Rd. Xing.
NEaR5	39.595	-75.947	Northeast River at Northeast Community Park
NEaR6	39.579	-75.974	Red Clay Ck., at Rt. 267 Xing.
SasR1	39.378	-75.808	Sassafras River at Rt. 301 Xing.
SasR2	39.364	-75.820	Jacobs Creek at Rt. 290 (Galena Sassafras Rd.) Xing.
SasR3	39.348	-75.841	Swantown Creek at Rt. 290 (Galena Sassafras Rd.) Xing.
SouR1	38.986	-76.622	North River below Rutland Road Xing.
SouR2	39.002	-76.615	Bacon Ridge Branch at Chesterfield Road
UpER1	39.602	-75.834	Big Elk Creek at Rt. 40 Xing.
UpER2	39.622	-75.829	Big Elk Creek at Rt. 279 (Elkton Rd.) Xing.
UpER3	39.599	-75.843	Little Elk Creek at Oldfield Point Rd. Xing
UpER4	39.571	-75.814	Perch Ck., at Rt. 213 Xing.
UpER5	39.585	-75.789	Perch Ck., above confluence, 100 yds u/s of Hutton Rd. Xing.
UpER6	39.569	-75.885	Plum Ck., at Old Elk Neck Rd. Xing.