Corbicula Biomonitoring in the Anacostia Watershed

Final Report to the DC Water Resources Research Center
Dr. Harriette L. Phelps
June 20, 2003

ABSTRACT
The 10 km freshwater Anacostia River estuary of Washington, DC, is one of Chesapeake Bay's three Regions of Concern and one of America's ten worst 'rivers'. Concerns are a fishing advisory from chlordane and PCBs, and a depauperate benthos. Asiatic clams (*Corbicula fluminea*) from the confluent healthy Potomac River estuary were translocated to watershed and estuary sites for eight weeks and tissues analyzed for 21 pesticides, 28 PCB congenors, 18 PAHs and 6 metals. Metal bioacumulations were not significently increased over origin. At all estuary locations only tPAHs were significently increased. Clams placed just above tide in three of five main tributaries had significently increased tPCBs, tPAHs and pesticides (chlordane and DDT), depending on tributary. Clams in two of 10 subtributaries had high chlordane accumulation; three had high low-molecular-weight PCB accumulation and one had high low-molecular-weight PAH accumulation. Although translocated clams had significently increased contaminant concentrations within two weeks, 11 of 16 contaminant totals at four main tributary sites in 2002 were statistically similar to 2001. It appears Anacostia estuary fishery-bioavailable contaminants of concern are coming from tributaries. Corbicula translocation studies are used as an inexpensive and rapid freshwater 'Clam Watch' to find major watershed sources of bioavailable contaminants. These sources must be identified for any effective Anacostia River remediation.

INTRODUCTION

The 10 km Anacostia River estuary continues to be a seriously impacted body of water that is a major focus of the District of Columbia. There is considerable evidence of toxic input from the fishing advisory (chlordane and PCBs), in fish tumors (PAHs) and the depauperate benthos. Part I in 2001 was to begin to find the sources of bioavailable contaminants in the Anacostia watershed. It was carried out by translocating Corbicula fluminea clams from the healthy Potomac estuary to four major Anacostia tributaries just above head of tide, and at three estuary sites. After eight weeks clam tissues were analyzed for EPA priority pollutants including PAHs, PCBs, pesticides and metals. All estuary sites had total clam PAHs significently higher than reference Potomac clams from the site of origin but no other contaminants. No clams at two tributaries (Northwest Branch, MD and Hickey Run, DC) had contaminant class totals significently exceeding reference. Northeast Branch (MD) clams had total PAH 3X reference clams and total pesticides 1.5X reference. Lower Beaverdam Creek (MD) clams had total PCB 4X reference.

Objective A of the 2002-2003 study was to examine clam contaminant accumulation at

two major remaining potential sources to the Anacostia, the Watts Branch tributary (DC/MD), and the large Washington, DC O Street Sewage Pump Station Outfall (O Street outfall). Objective B was to localize contaminant sources in Northeast Branch (MD), Lower Beaverdam Creek (MD) and Watts Branch tributaries by biomonitoring with clams at upstream subtributaries. Objective C was to determine long term contaminant bioaccumulation with consecutive clam sampling at a single site. Objective D was to repeat the 2001 contaminant bioaccumulation study at the four major Anacostia tributaries. All these objectives had continued involvement of DC undergraduate research students.

METHODOLOGY

Objectives A and B

Objectives A and B to determine clam contaminant accumulation at the two major remaining potential sources to the Anacostia (the O Street outfall in the estuary and Watts Branch tributary) and to locate sources of contaminants within the Northeast Branch (MD) and Lower Beaverdam Creek (MD) tributaries started 5/3/02 when Corbicula fluminea clams were obtained from the Potomac estuary 5 km below the Anacostia at Fort Foote (MD). The water temperature was 15 deg. C. Clams were 18 - 29mm, in brooding status, and kept dry on blue ice during translocation to Anacostia sites the same day. Shellfish mesh bags or weighted cages with 50-60 clams each were placed at five sites: the lower estuary O street DC outfall (OS), the Lower Beaverdam Creek MD subtributary (LBH), the Watts Branch DC tributary above head of tide (WAT02A); and the Northeast Branch (MD) subtributary sites of Indian Creek MD (ICL) and Little Paint Branch MD (LPB) (Fig. 1). A Fort Foote control sample was taken. GPS was taken at all sites and TidbiT temperature monitors were attached to cages at the O street outfall (OS) and Lower Beaverdam Creek subtributary (LBH) sites.

On 6/28/02 (56 days, 8 weeks) cages were recovered at all sites except LBH which was recovered four days later on 7/2/02 (60 days). The clams were washed, placed for 24 hours in three changes of spring water at room temperature for depuration, frozen to open shells, shucked, and the tissues refrozen and hand-carried to Severn-Trent Laboratories (STL) in Sparks, MD for chemical analyses. STL filled out chain-of-custody forms and carried out EPA Priority Pollutant analysis of the clam tissues, including 21 pesticides, 29 PCB congenors, 18 PAH's and five metals (Cu, Cd, Fe, Zn and Cr). Results were available in five weeks.

Statistical comparison among contaminant totals was by t test using the equation for Severn-Trent Laboratory analytical variability: SD = 0.175(mean) - 1.12 (n = 9) (Phelps 2002), so 2.05 SD = 37% (mean) for 95% confidence limits .

On 7/2/02 Corbicula were obtained from the Potomac for Objective B deployment to the upstream Beaverdam Creek (BDC) subtributary and the Indian Creek North subtributary (ICN) of the Northeast Branch. The cages were recovered on 9/15/02 (75 days, 10 weeks).

Objective C

On 7/25/03 Corbicula were obtained from the Potomac for Objective C, to determine long term contaminant bioaccumulation by consecutive sampling from a single site. Two hundred clams were translocated to the Northeast Little Paint Branch Lower subtributary (site PBL) (Fig. 1). On 8/5/02 (11 days) Sample NE1 was collected from site PBL, and on 8/21 (27 days) sample NE2 was collected. Clams were depurated, frozen, and tissues removed and taken to STL for analyses as before. On 9/20/02 the PBL clam bag was found buried in gravel and all clams were dead, so the experiment was ended early.

Objective D

On 8/30/02 Corbicula were obtained from the Potomac for Objective D, to repeat the 2001 clam contaminant bioaccumulation study at major Anacostia tributaries. Clams were placed in shellfish bags at the same just-above-tide tributary sites of the 2001 study: Northeast Branch MD, (NEB02), Northwest Branch, MD (NWB02) and Lower Beaverdam Creek, MD (LBC02)

On 8/30/02 additional Corbicula were obtained from the Potomac for Objective D and expansion of Objective B. Clams were placed at Hickey Run tributary, DC (HRL02), Watts Branch High (WBH) and Watts Branch Low (WBL) subtributary sites, and a second sample at the earlier Watts Branch site (WAT02B) (Fig. 1). On 8/31 clams were placed at the Northeast Branch subtributary of Indian Creek Upstream (ICU) (Fig. 1). A temperature monitor was attached at the Northwest Branch site.

On 10/25/02 (66 days, 8.3 weeks) the clam cages at Indian Creek Upstream (ICU), Hickey Run (HRL) and Northeast Branch (NEB) were recovered. The Northeast Branch (NEB) clam cage was found buried in gravel and all clams were dead.

On 10/27 (68 days, 8.5 weeks) the clam cages at Watts Branch (WAT02B) and its tributaries (WTL and WTH) were recovered.

On 10/28 the (69 days, 8.6 weeks) the clam cage at Lower Beaverdam Creek (LBC) was recovered.

RESULTS AND DISCUSSION

GPS locations of clam translocation sites in the Anacostia estuary and watershed were mapped by ArcView (USGS) (Table 1, Fig. 1).

Figure 1. Locations of Corbicula clam translocation sites in the Anacostia watershed.

Table 1. Study site GPS locations on Anacostia and Potomac River estuaries and tributaries.

	Site	GPS
Potomac River Estuary	Fort Foote MD (FF)	N38^{0}46.460', W077^{0}01.770'
Anacostia Watershed		
MD Tributary	Northeast Branch (NEB)	N38^{0}57.621', W078^{0}55.583'
	Northwest Branch (NWB)	N38^{0}56.741', W076^{0}56.855'
	Lower Beaverdam Creek High (LBH)	N38^{0}54.729',W076^{0}54.539'
	Indian Creek Low (ICL)	N38^{0}59.623', W076^{0}55.161'
	Indian Creek North (ICN)	N39^{0}01.364', W076^{0}54.212'
	Beaverdam Creek (BDC)	N39^{0}00.968', W076^{0}53.862'
	Paint Branch Longterm (PBL)	N38^{0}58.541', W076^{0}55.180'
	Little Paint Branch (LPB)	N38^{0}59.437',W076^{0}56.126'
	Watts Branch Low (WTL)	N38^{0}53.481', W076^{0}54.779'
	Watts Branch High (WTH)	N38^{0}53.475', W076^{0}54.870'
DC Tributary	Hickey Run Low(7/24/01) (HRL)	N38^{0}54.586', W076^{0}57.710'
	Watts Branch (WAT)	N38^{0}54.395', W076^{0}56.942'
DC Estuary	O Street Outfall (OS)	N38^{0}52.353', W077^{0}00.237'

In the cages that were not buried the percent clam survival ranged from 34 to 100 percent (Table 2). Increased mortality was found at Watts Branch Low (WTL), O Street Outfall (OS) and Watts Branch (WAT02A) (Table 2).

Table 2. Percent survival of caged clams at Anacostia watershed sites.

	WTL	OS	WAT	WTH	PBL	LPB	ICL	ICN	LBH	LBC	NWB	HRL
% Survival	34	51	66	97	100	95	100	99	95	95	100	97

TidbiT temperature monitors attached to shellfish bags at the O street estuary (OS), Paint Branch Longterm (PBL) and Northwest Branch (NWB) sites indicated water temperatures ranged from a high of 32 deg C to a low of 11 deg C at sites over the course of the 2002 translocations. This is within tolerance and activity temperatures of Corbicula clams.

Clams translocated to Anacostia sites on 5/3/02 that were recovered on 6/28/02 and 7/2/02 (8 to 9 weeks) (Objectives A and B).

Tissues were analyzed by Severn-Trent laboratory for 21 pesticides, 29 PCB congeners, 18 PAH's and six metals (Cu, Cd, Fe, Zn, As and Cr) (Table 3). Contaminant totals of the source clams from Potomac (Fort Foote) are used as a reference control because that ecosystem is consdered healthy.

Table 3. Contaminant totals in clam tissues (ug/Kg dry weight) at 8 to 9 weeks (5/3/ - 7/2/02).

	FF1	OS	WAT02A	LPB	ICL	LBH
T Metals x .01	77	47	62	65	66	108
T PAHs	391	1262*	4612*	905*	2789*	2183*
T Pesticides	48	124*	103*	76	97*	72
T PCBs	79	175*	130*	131*	86	88

* Statistically greater than Potomac (Fort Foote) ($p < .05$)

Site Key: FF1 (Fort Foote Control), OS (O Street Outfall), WAT02A (Watts Branch tributary), LPB (Paint Branch subtributary of the Northeast Branch), ICL (Indian Creek Low subtributary Of Northeast Branch), LBH (Lower Beaverdam High subtributary of Lower Beaverdam Creek).

This first group of clams included a set suspended directly in the large Washington, DC O Street Sewage Pump Station Outfall (OS) entering the lower third or basin part of the Anacostia estuary (Fig. 1). Studies of Anacostia sediment contaminants have found "hot spots" in this region of the Anacostia and implicated this outfall as a major source of several contaminants (Velinsky and Ashley 2001). Clam survival was relatively low (Table 1) but the contaminant totals were not significently different from clams placed at other sites in the lower basin third of the Anacostia estuary in 2001 (Navy Yard, NY and Washington Gas Light, WG) (Phelps 2002) (Fig. 1, Fig. 2).

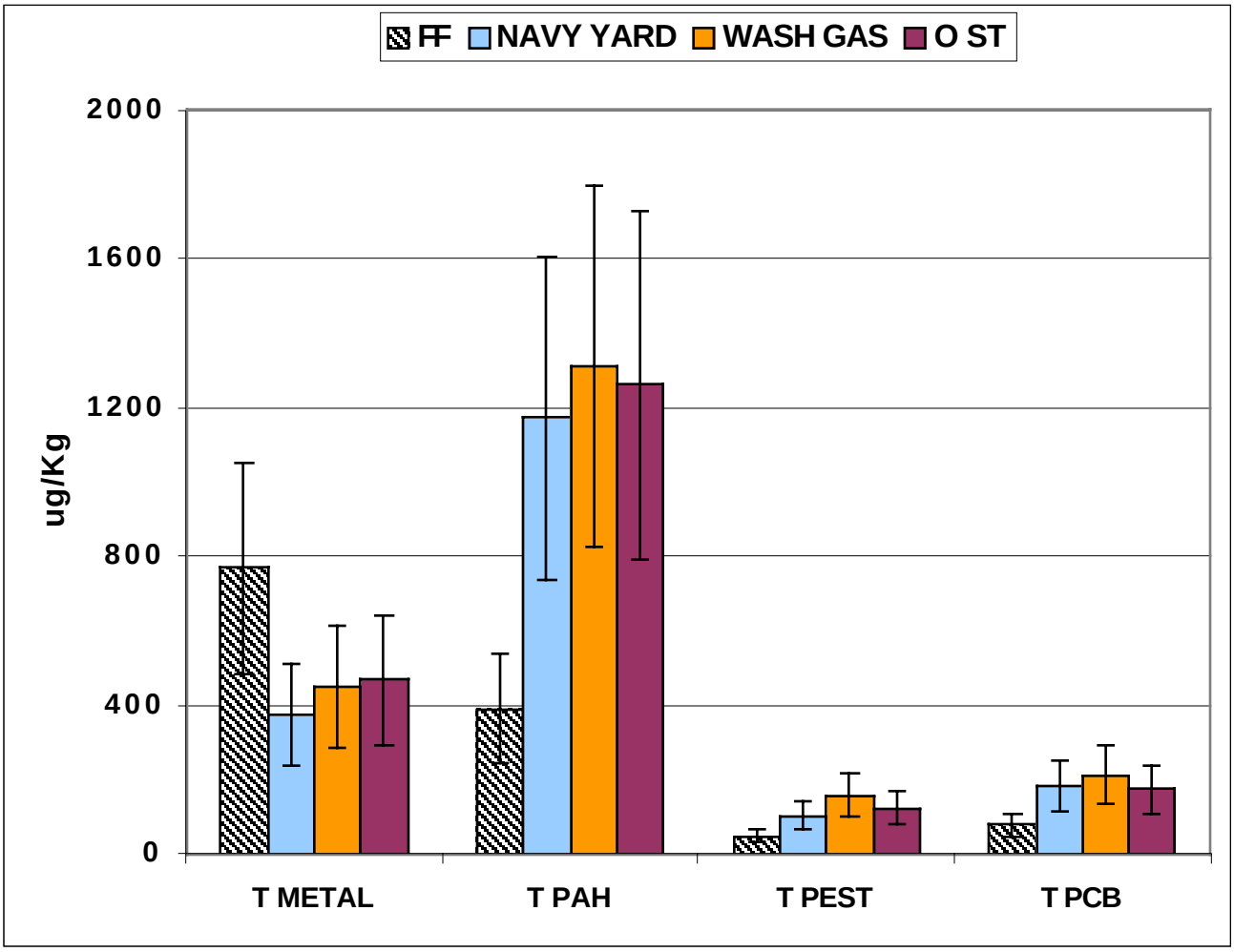

Figure 2. Contaminant class total concentrations in clams translocated to sites in the lower Anacosita estuary basin. Fort Foote, Potomac(FF), Navy Yard (NY), Washington Gas Light (WG), and the O Street Sewage Pumping Station (OS). Error bars are 2 X analytical standard deviation (37%).

Long term bioccumulation of contaminants in Corbicula clams (Objective C).

Clams sampled sequentially at the Lower Paint Branch site showed statistically significent increase over original Potomac levels by 11 days for tPAHs, tPCBs and tPesticides, but not tMetals which seldom exceed Potomac levels in the Anacostia watershed (Table 4).

Table 4. Consecutive contaminant accumulation (ug/Kg dry weight) in clam tissues at 11 and 27 days (Lower Paint Branch).

	FF (Potomac)	11 days	27 days
T Metals x.01	71	73	73
T PAHs	598	1804*	882*
T Pesticides	30	50*	43*
T PCBs	73	128*	107*

* Statistically greater than Potomac (Fort Foote) ($p < .05$)

Clams translocated to upstream subtributary sites and 2001 Anacostia tributary sites on 8/30/02. recovered 10/25/02 and 10/27/02 (8 to 9 weeks) (Objectives B and D).

Tissues were analyzed by Severn-Trent laboratory for 21 pesticides, 29 PCB congeners, 18 PAH's and six metals (Cu, Cd, Fe, Zn, As and Cr) (Table 5), except for WTL and WTH where there was insufficient tissue for metal and PCB analyses.

Table 5. Contaminant totals (ug/Kg dry weight) in clam tissues at 8 to 9 weeks (8/30 - 10/25/02).

	FF2	NWB02	LBC02	ICN	BDC	HRL02	WAT02B	WTL	WTH
t Metals x.01	71	100	166*	96	90	79	94	--	--
t PAHs	598	933*	1345*	2581*	431	1888*	1193*	1576*	1126*
t Pesticides	30	58*	68*	46	42	63*	106*	225*	98*
t PCBs	73	64	326*	72	59	126*	115*	--	--

* Statistically greater than Potomac (Fort Foote) ($p < .05$)

Northeast Branch Contaminants and Subtributaries

The highly urbanized Northeast Branch tributary contributes about 45% of Anacostia river input (Warner et al. 1997). In 2001, clams translocated to the Northeast Branch tributary just above head of tide had the highest total pesticides of any tributary, with 88% chlordane (alpha plus beta) (Table 6, Phelps 2001).

Table 6. 2001 totals of EPA Priority Pollutants in Anacostia tributary clam tissues.

(ug/Kg)	tMetals(x.01)	tPCB	tPAH	tPesticides
Potomac FF 2001 avg.	800	134	398	249
Northwest Branch	660	83	637	77
NortheastBranch	73	187	1442*	740*
Lower Beav.Creek	1189	666*	855	295
Hickey Run	498	97	785	42

* Statistically greater than Potomac (Fort Foote) average ($p < .05$)

The Northeast Branch clams above head of tide but below the Paint Branch subtributary (PBL) had high pesticide and chlordane concentrations not found in clams placed in upstream subtributaries from the University of Maryland (LPB), the Beltsville Industrial Center (ICN) and the USDA Beltsville Agricultural Research Center (BDC) ((Fig. 1), Fig. 3).

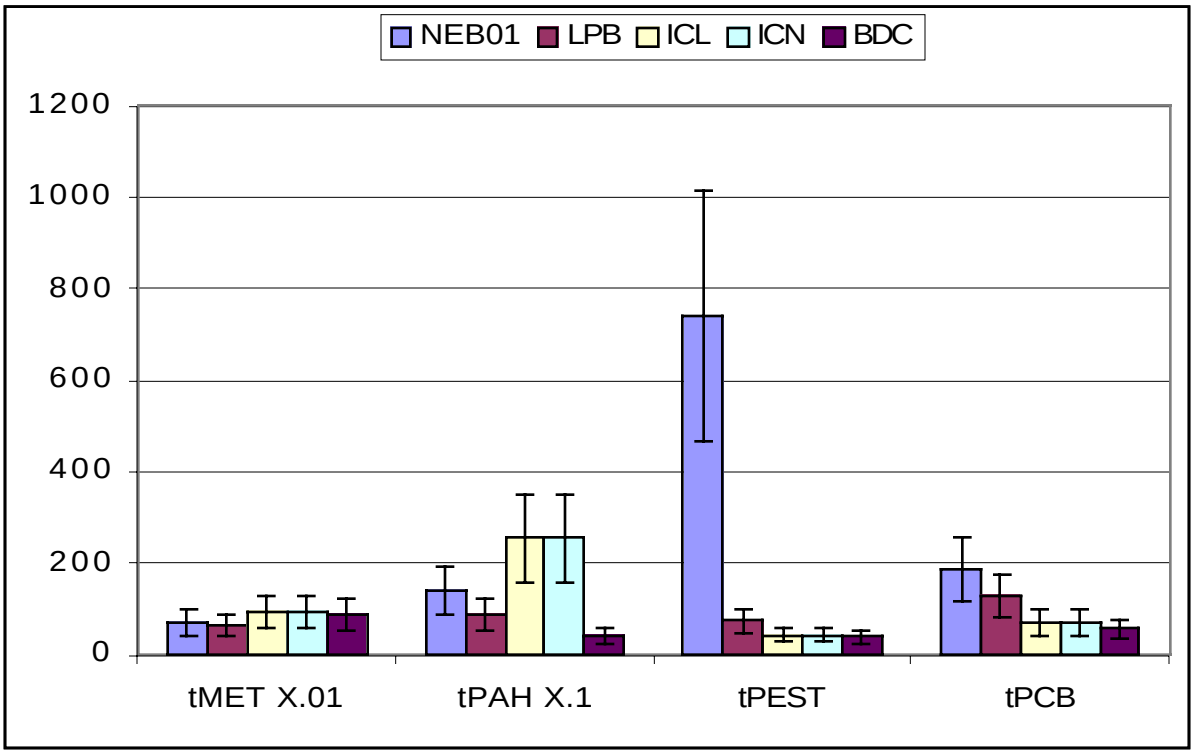

Figure 3. Clam contaminant concentrations in the Northeast Branch and its subtributaries. Key: NEB01 (Northeast Branch in 2001), LPB (Lower Paint Branch), ICL (Indian Creek Low), ICN (Indian Creek North), BDC (Beaverdam Creek)

Lower Beaverdam Creek Contaminants and Subtributaries

Lower Beaverdam Creek has the highest industrial watershed area of the 13 Anacostia tributaries and subtributaries and is 99% located in Prince George's County (Warner et al. 1997). Lower Beaverdam Creek clams had levels of PCBs and total pesticides significently exceeding Potomac reference clams in 2001 and 2002 (Table 5, Table 6). Clams in the one subtributary tested (LBH) did not have PCBs or pesticides exceeding reference (Table 3).

Watts Branch Contaminants and Subtributaries.

Although Watts Branch is a relatively small tributary contributing about 3% of total Anacostia tributary input, the first set of clams recovered there on 6/28/02 (WAT02A) had the highest total PAH bioaccumulation of any site (Table 2). This WAT02A PAH profile was high

in low-molecular-weight PAHs, especially napthalenes (Fig. 4). The PAH bioaccumulation in the Watts Branch clams recovered later on 10/27/02 (WAT02B) was only 26% of 6/28 (Table 5). It appears the 6/28 Watts Branch clam bioaccumulation was indicative of an tributary source involving low-molecular-weight PAHs that had dispersed by 10/27. The increased PAHs may also have been related to higher runoff in spring. There was no statistically significent difference in total metals, pesticides or PCBs among the 6/28/02 and 10/27/02 clams placed just above tide in Watts Branch (Fig. 4).

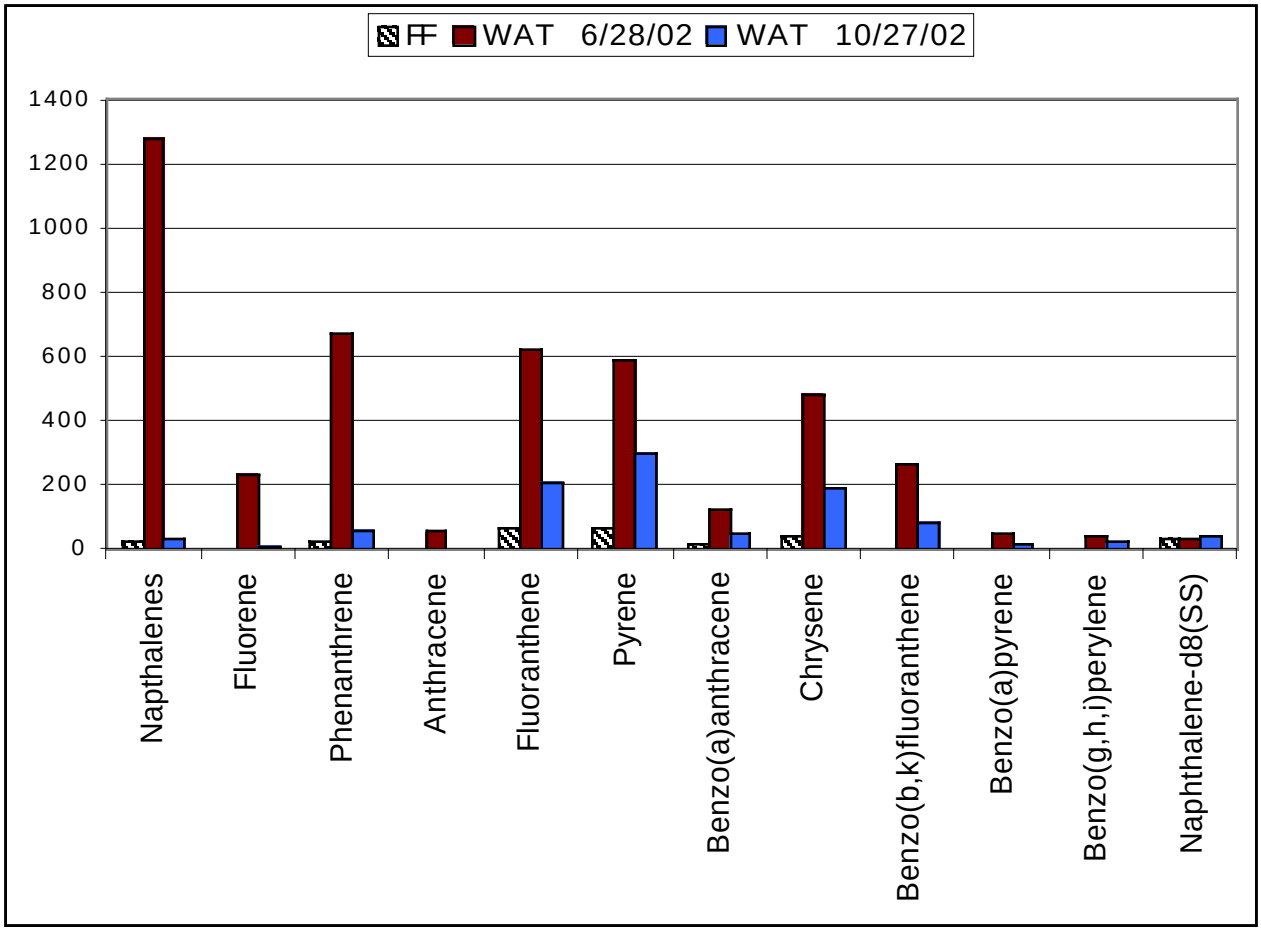

Figure 4. PAH congenors in Potomac clams collected 5/3/02 (FF), and Watts Branch clams collected 6/28/02 (WAT02A) and 10/2702 (WAT02B).

Chlordane and PCBs in the Anacostia watershed.

Chlordane, is one of two Anacostia fish tissue contaminants responsible for the fishing advisory and is a pesticide shown to cause liver and nerve damage. Chlordane use except for termite control was banned by EPA in1983, and all use banned in 1988. The average total chlordane (alpha + beta) (27 ug/Kg) in tributary clams was 2X the Potomac (FF) average

(11ug/Kg) (Fig. 5). Chlordane in clams at the 2001 Northeast Branch site (NEB 01) (240 ug/Kg) was 9X average and at the 2002 Watts Branch Low (WATL) (172 ug/Kg) subtributary was 6X average with both exceeding the FDA fish consumption chlordane action level of 100 ug/Kg. Chlordane was somewhat higher than average in Lower Beaverdam Creek clams in 2001 (LBC 01) and Watts Branch High clams in 2002 (WATH).

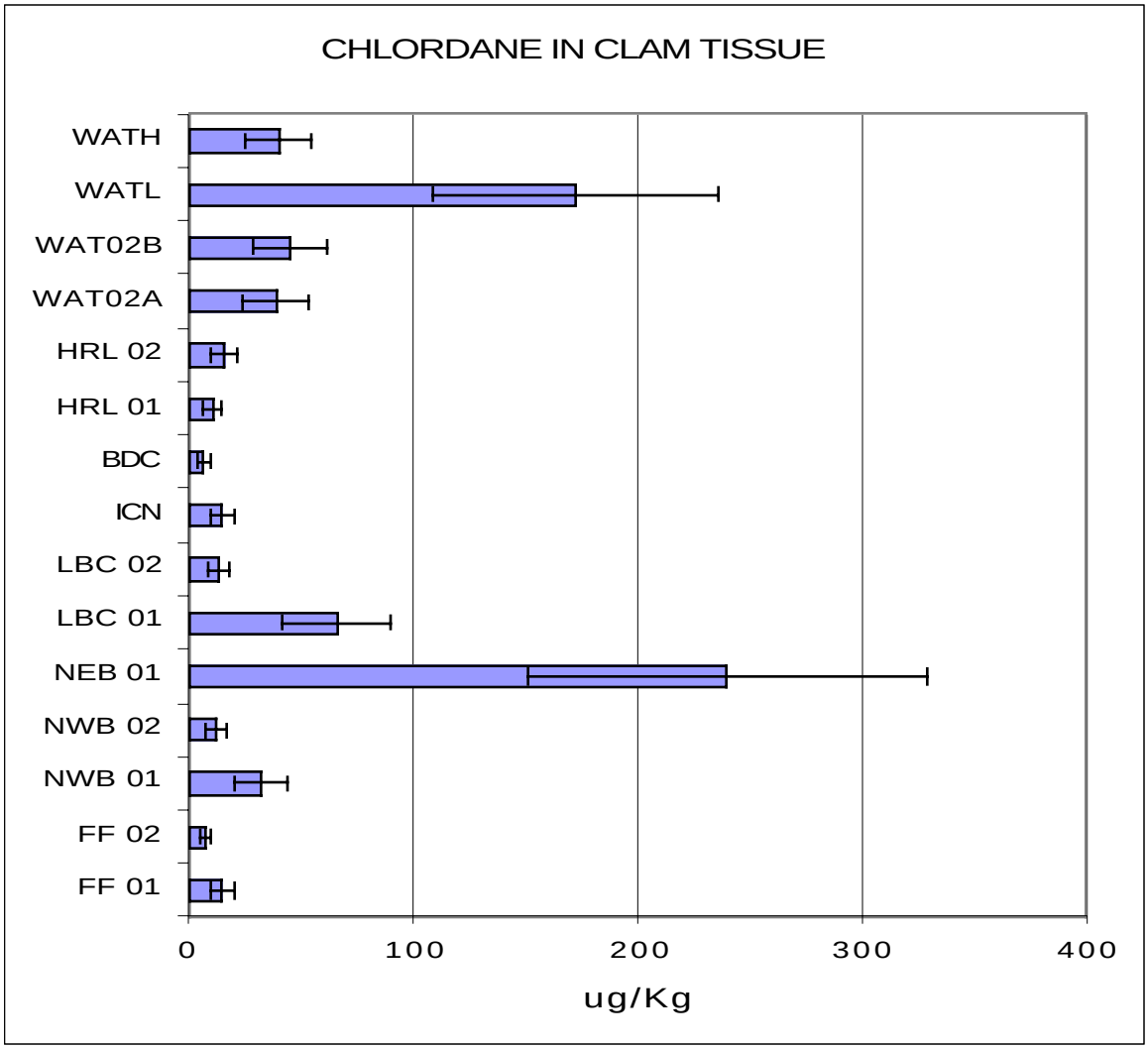

Figure 5. Chlordane bioaccumulation by clams at 2001 and 2002 Anacostia sites and control. Key: FF2 (Fort Foote Control), NWB02 (Northwest Branch 2002), LBC02 (Lower Beaverdam Creek 2002), ICN (Indian Creek North subtributary of the Northeast Branch), BDC (Beaverdam Creek subtributary of the Northeast Branch), BM02(Bladensburg Marina 2002), HRL02 (Hickey Run Low 2002), WAT02B (Watts Branch, second 2002 sample), WTL (Watts Branch Low subtributary of Watts Branch), WTH (Watts Branch High subtributary of Watts Branch).

PCBs are one of two contaminants in Anacostia fish tissues responsible for the Anacostia fishing advisory. Total PCBs in clams at Lower Beaverdam Creek (326 ug/Kg) exceeded the FDA food action level of 200 ug/Kg (Table 5). PCB congenor homologs in clams at tributaries with PCBs significently increased over reference (Table 3, Table 5) showed Lower Beaverdam Creek clams high in the lighter weight tri, tetra and penta homologs (Fig. 6).

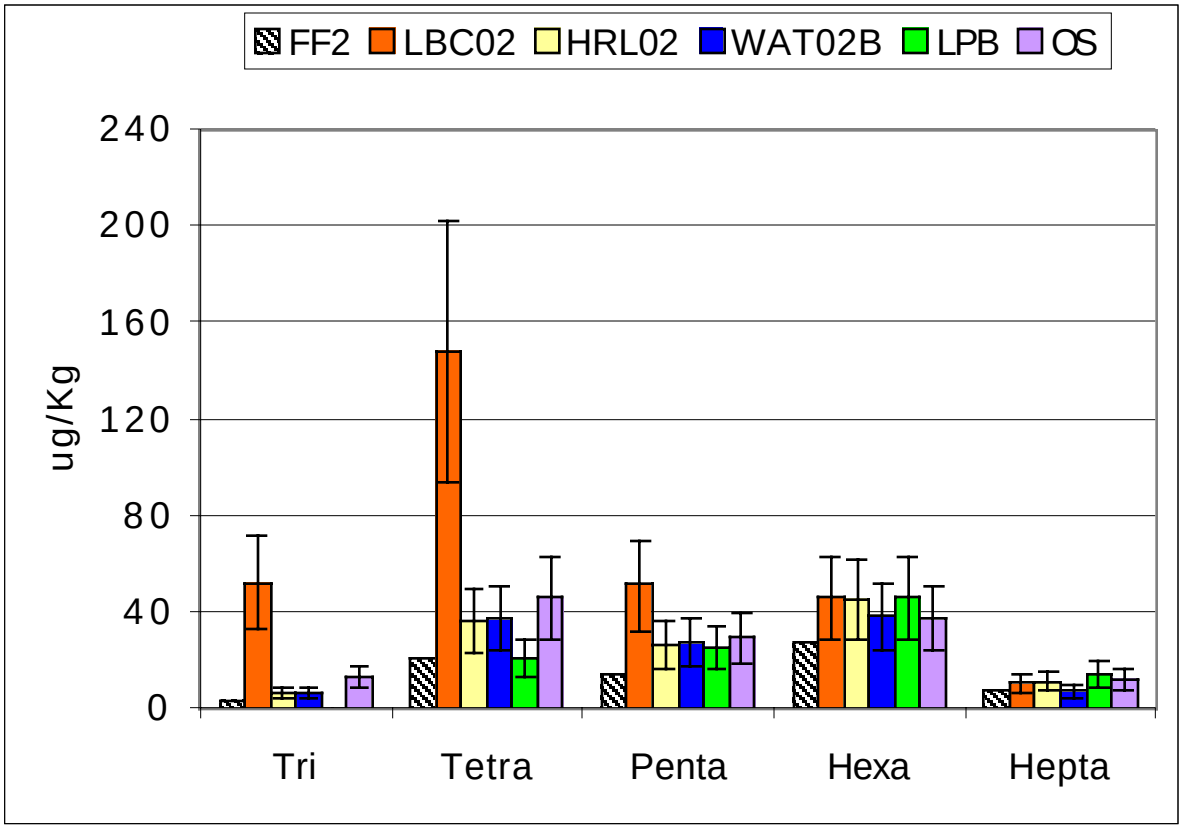

Figure 6. PCB homolog groups in clams at the Potomac Fort Foote site (FF) and at Anacostia watershed sites with significently higher total PCBs (2002): Lower Beaverdam Creek (LBC02), Hickey Run Lower (HRL02) and Watts Branch (WAT2). Error bars are 2x analytical SD = 37% mean.

Objective D. The 2002 clam contaminant totals at four major tributary sites just above head-of-tide at Northwest Branch (NWB), Lower Beaverdam Creek (LBC) and Hickey Run (HRL) were compared to 2001 totals (Fig. 7). The Watts Branch tributary contaminant totals (WAT02A and WAT02B) were collected 6/28/02 and 10/27/02. The 2002 Northeast Branch sample was lost.

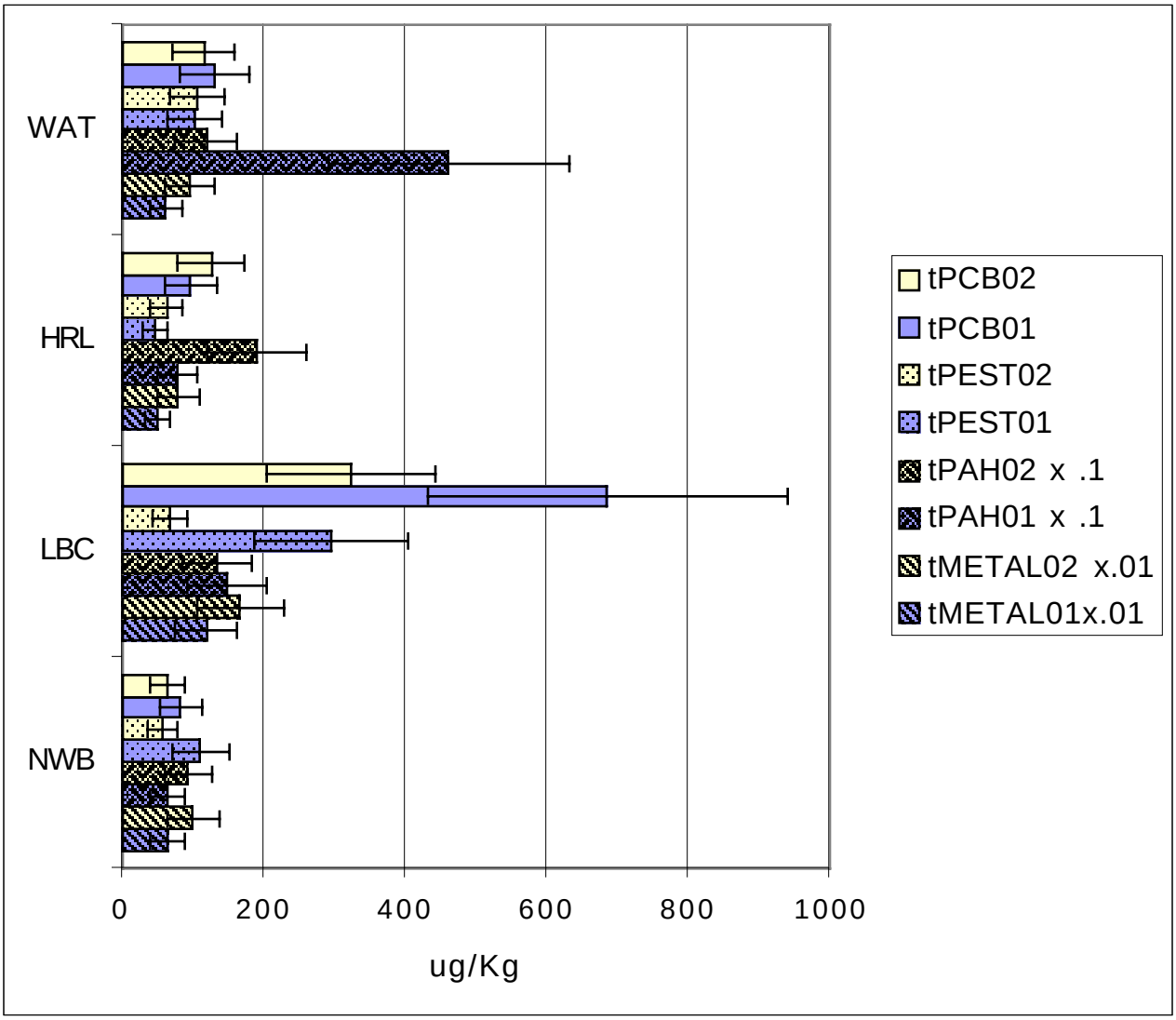

Figure 7. Comparison of contaminant class totals in clams translocated to major Anacostia tributary sites just above head of tide in 2001 and 2002.
Key: WAT (Watts Branch), HRL (Hickey Run), LBC (Lower Beaverdam Creek), NWB (Northwest Branch).

CONCLUSIONS

In the Anacostia estuary the contaminant concentrations in clams placed directly in the Washington DC O Street Sewage Pump Station Outfall were not statistically different from concentrations at other sites in the lower basin third (Fig. 1, Fig. 2). This is similar to results using SPMD monitoring in this area (Pinkney et al., 2003). Tidal mixing apparently prevents contaminant source localization in the estuary portion of the Anacostia. Tidal mixing is not a problem for contaminant source localization in the fluvial Anacostia watershed.

The finding of significent increase over Potomac levels in clam contaminants as soon as two weeks after translocation suggests Corbicula may reach final concentrations levels more rapidly than mussels (Roesjadi et al. 1984) (Table 4). Completion of this study in 2003 may lead to a shortening of deployment time for Corbicula bioaccumulation studies.

A repeat of clam biomonitoring at four major tributary above-tide locations in 2001 and 2002 found 11 of 16 contaminant totals (75%) were statistically similar ($p < .05$) (Table 3, Table 5, Fig. 5). All Northwest Branch clam contaminant totals (metals, PAHs, PCBs and pesticides) had no signficent difference among 2001 and 2002. Lower Beaverdam Creek had a signficent decrease in total pesticides and total PCBs in 2002, although PCBs remained the highest of any site. The Lower Beaverdam Creek watershed is 99% in Prince George's County. At Hickey Run, entirely in DC, there was a statistically signficent increase in total PAH's in 2002. Hickey Run has a history of episodic petroleum releases. At Watts Branch, examined twice in 2002, the first clam set had high total PAHs due mostly to napthalenes that were not present in the second set. The early PAH peak may have been due to a spill that was dissipated three months later. This 75% similarity among 2001 and 2002 clam biaccumulation totals suggests consistent tributary contamination can be detected.

Chlordane concentrations (along with PCBs) are responsible for the present Anacostia fishing advisory (Velinsky and Cummins 1994). Chlordane is persistant in soil, slow to break down and not very soluble in water. Because of chlordane's 30 year ban and extensive former use for termite control in this area point sources were not expected. However, the finding of two tributaries/subtributaries (Northeast Branch below Lower Paint Branch and Watts Branch Low) with high clam chlordane levels suggests there may be deposits of chlordane-contaminated sediments eroding into those watersheds. Using Clam Watch technique it is hoped to more closely define those stream reaches that are the source of chlordane. Finding and remediating those high-level chlordane sources may be both necessary and sufficient to remove the Anacostia fishing advisory based on chlordane.

PCBs (polychlorinated biphenyls) have 209 congenors, produce health effects, can bioaccumulate to high levels in aquatic animals and have not been manufactured in the US since 1977. PCB levels in some species of Anacostia fish are above the FDA action level and responsible for the fishing advisory. In the Anacostia, high PCB levels have been found in lower

estuary basin sediment 'hot spots' (Velinsky and Ashley 2001). Total PCBs in all clams translocated to all Anacostia estuary sites exceeded Potomac reference (Fig. 2) but only three locations in Anacostia tributaries (Table 3, Table 5). High concentration in clams (4X reference, exceeding FDA action levels) of fresh, volatile lower molecular weight PCB congenors were characteristic of Lower Beaverdam Creek clams (Phelps 2001). The Lower Beaverdam Creek watershed has the highest industrial area among Anacostia tributaries (Warner et al 1997).

Clams translocated from the nearby freshwater Potomac to seven upstream subtributary sites in Anacostia watershed tributaries found statistically increased PAHs at all sites, increased pesticides at three sites, increased PCBs at one site, and no increase over Potomac levels in total metals (Table 3, Table 5). This eliminated several subtributaries as major sources of contaminants, and implicated others. Specifically, in Lower Beaverdam Creek the Lower Beaverdam High subtributary was found not a significent contaminant source (Table 3), in Watts Branch the Watts Branch Low (WTL) subtributary (MD) contributed a majority of the chlordane and PAH contamination (Table 5); at the Northeast Branch tributary (NB) the Beaverdam Creek subtributary (BDC) did not contribute significent bioavailable contaminants or pesticides although draining the large Beltsville Agricultural Research Center which has a CERCLA site (Table 5). However the Indian Creek North (ICN) subtributary from the Beltsville Industrial Center had high 4X clam PAH levels (Table 5) and the Lower Paint Branch subtributary (LPB) from the University of Maryland had clams with PCB levels statistically greater than reference (FF) (Table 3). The majority (6 of 7) upstream subtributary sites with statistically increased clam contaminant levels were in Prince Georges County, MD.

The advantages of using the hardy freshwater Asiatic clam (Corbicula flumina) to locate pollutant sources in watersheds is similar to the use of marine mussels in the worldwide Mussel Watch program to monitor coastal pollutants (Dougherty and Cherry 1988, Crawford and Luoma 1993, O'Connor and Beliaeff 1995, Chase 2001). Shellfish bioaccumulate suspended and dissolved bioavailable water contaminants without detoxicification or elimination. Shellfish can be translocated to specific locations for periods of weeks or months to biomonitor the aquatic environment. The Asiatic clam is now naturalized on several continents (Asia, North and South America, Europe) and has been deployed for contaminant monitoring in place of endangered local mussel species (Hartley and Johnston 1983, Colombo et al. 1995). The present study demonstrates the usefulness of translocated Asiatic clams in finding major sources of EPA priority pollutants in an urban watershed. This 'Clam Watch' program can be an effective screening methodology in freshwater watersheds that is much more rapid and less expensive than intensive water monitoring methods employed later for more thorough investigation.

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