Tumor Prevalence in Brown Bullhead in the Anacostia River and Tidal Potomac Watershed: 1992-2016

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Presentation to:

Chesapeake Bay Program TCW

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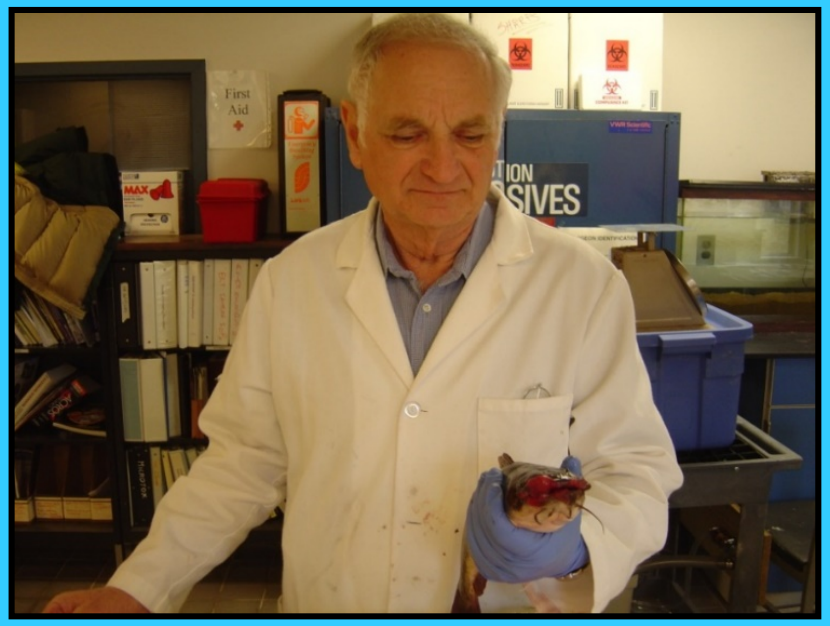

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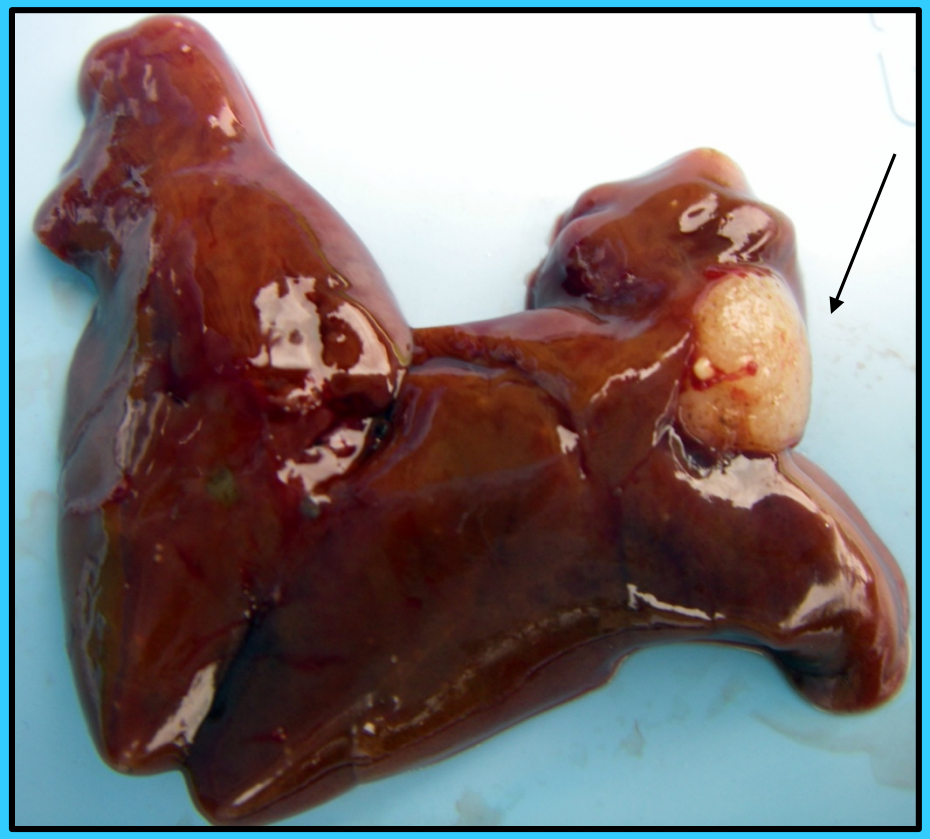
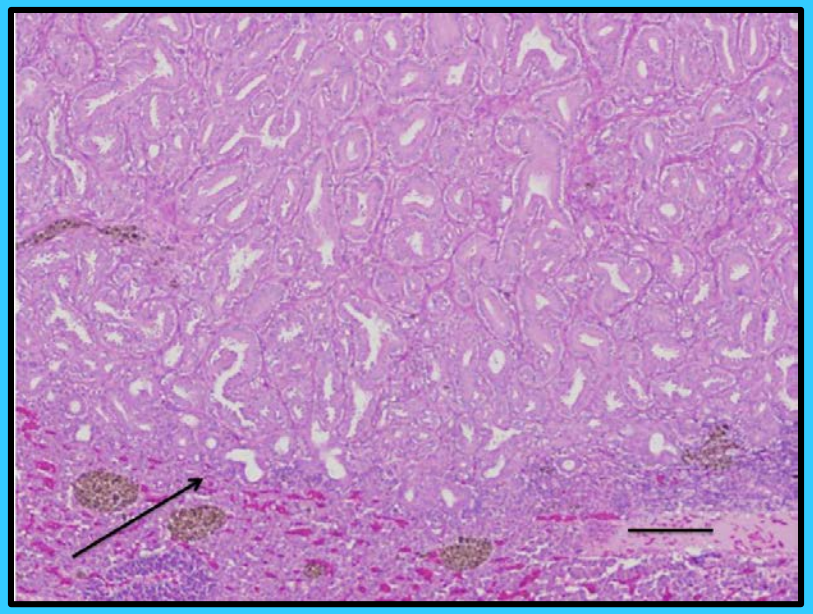
$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{dy}+w\frac{\partial u}{\partial z}\right)=$$
$$\rho g_x-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}\left[2\mu\frac{\partial u}{\partial x}+\lambda\nabla\cdot\mathbf{V}\right]+\frac{\partial}{\partial y}\left[\mu\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right]+\frac{\partial}{\partial z}\left[\mu\left(\frac{\partial w}{\partial x}+\frac{\partial u}{\partial z}\right)\right]$$
$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{dy}+w\frac{\partial v}{\partial z}\right)=$$
$$\rho g_y-\frac{\partial p}{\partial y}+\frac{\partial}{\partial y}\left[2\mu\frac{\partial v}{\partial y}+\lambda\nabla\cdot\mathbf{V}\right]+\frac{\partial}{\partial z}\left[\mu\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)\right]+\frac{\partial}{\partial x}\left[\mu\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right]$$
$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{dy}+w\frac{\partial w}{\partial z}\right)=$$
$$\rho g_z-\frac{\partial p}{\partial z}+\frac{\partial}{\partial z}\left[2\mu\frac{\partial w}{\partial z}+\lambda\nabla\cdot\mathbf{V}\right]+\frac{\partial}{\partial x}\left[\mu\left(\frac{\partial w}{\partial x}+\frac{\partial u}{\partial z}\right)\right]+\frac{\partial}{\partial y}\left[\mu\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)\right]$$

FUNDING:DC DEPARTMENT OF ENERGY & ENVIRONMENT

Background

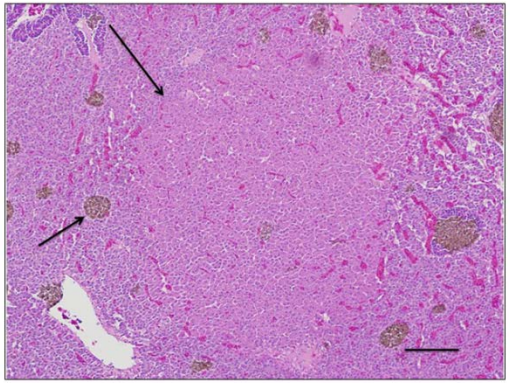
- Cancer-causing chemicals enter rivers, estuaries, and coastal waters and build up in sediments
- Some bottom-dwelling fish species develop tumors
- Tumor surveys have been used as an environmental indicator of habitat quality: Puget Sound, Great Lakes, Chesapeake Bay



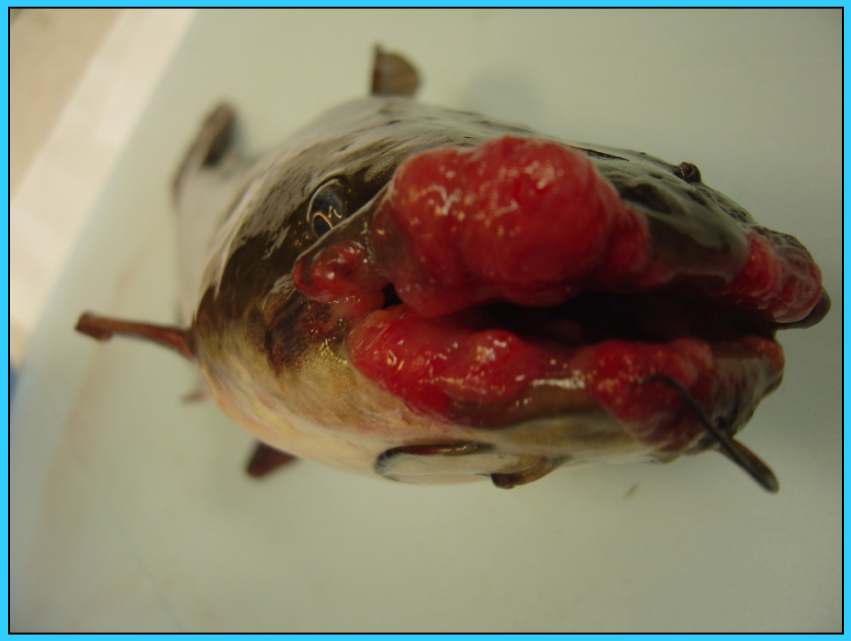


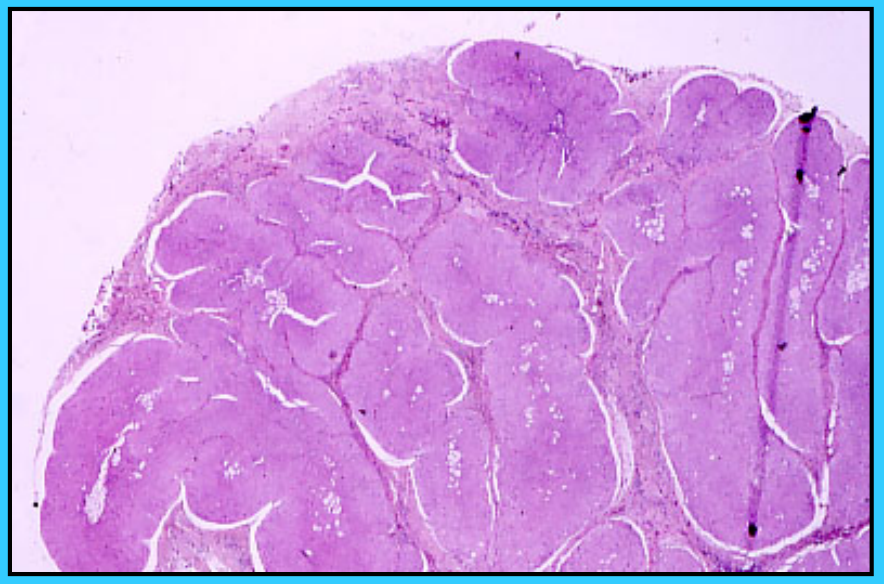
Cholangiocarcinoma

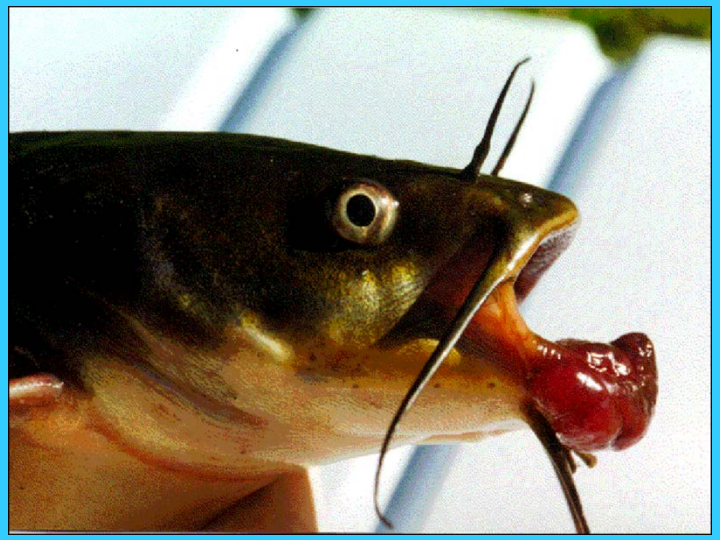
Liver tumors



Hepatocellular carcinoma







Skin lesions diagnosed as squamous cell carcinomas,

- Brown bullhead: ideal species
- Bottom feeder
  - Small home range (2 km in Anacostia)
  - Sensitive—develops skin and liver tumors
  - Great Lakes and Chesapeake Bay tribs up to 8 ppt

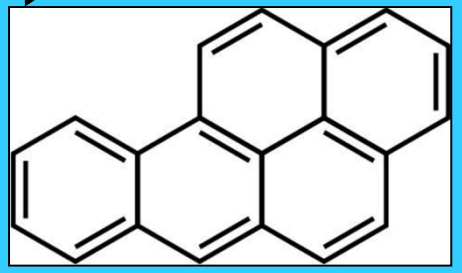
OBJECTIVES: 2014-16 Study

1) Anacostia vs. neighboring areas (space) and vs. past (trend)

2) analyze 25-year database to identify reference locations and test age, length, sex, and weight as covariates in logistic regression

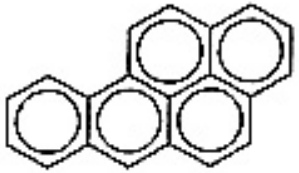
3) linkages with exposure to PAHs, polychlorinated biphenyls (PCBs), and DDT to explain trends

Polynuclear Aromatic Hydrocarbons (PAHs)



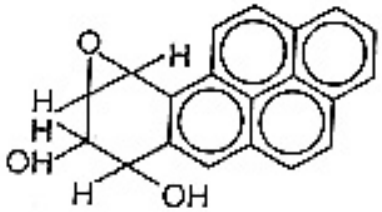
- Over 100 chemicals
- Found in fossil fuels-coal, gas, oil—tar, asphalt, pitch; runoff from roads, car exhaust, leaking oil
- Accumulate in sediments
- Some compounds cause cancer in humans, rats, mice, fish

Base adduct: benzo[a]pyrene



benzo[a]pyrene

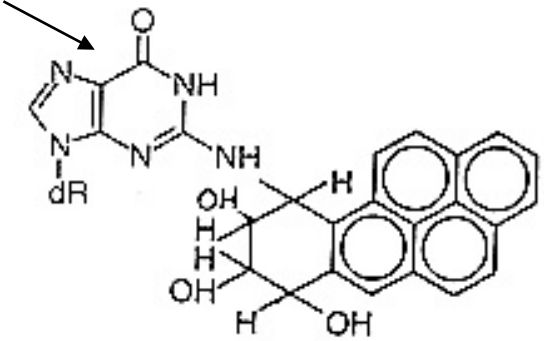
⇓ metabolic activation



benzo[a]pyrene diol-epoxide (BPDE)

⇓ DNA incorporation

DNA



BPDE - DNA adduct

Relationship of biomarkers of PAH exposure

- **Benzo(a)pyrene** → **Bile metabolites**

CYP1A as EROD ↓

Diol epoxide ↓

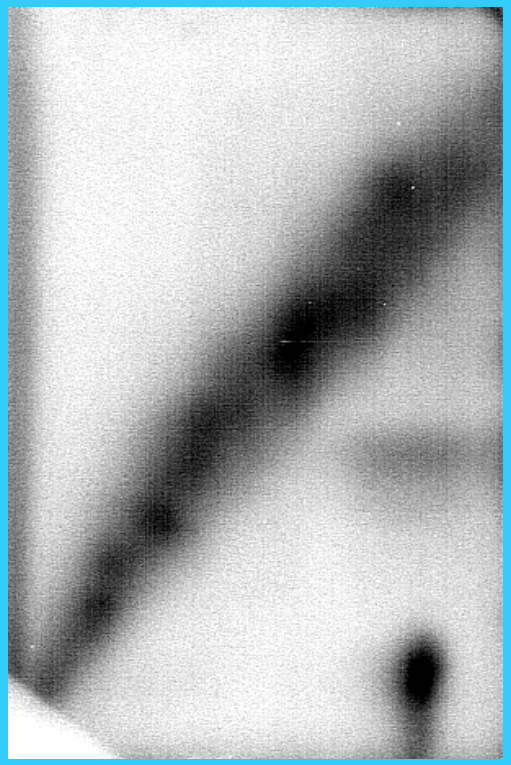
DNA adducts → **Mutations** ↓

Oncogene activation ↓

Tumor formation

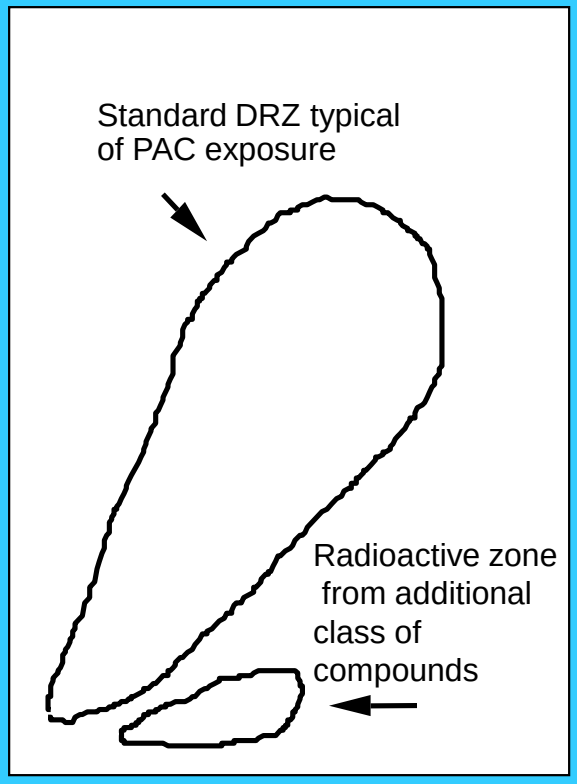
DNA adducts ↓

Repair



Anacostia River

Tuckahoe River



Schematic

Chromatograms of DNA adducts in brown bullhead livers from Anacostia and Tuckahoe Rivers and schematic. (DRZ= diagonal radioactive zone, PAC= polycyclic aromatic compound).

Polychlorinated biphenyls (PCBs): Banned (1979) but still in use

PCB-Contaminated Transformers containing between 50 and 499 ppm

PCB Transformer contains concentrations greater than 500 parts per million (ppm)

Other sources: capacitors, light ballasts, caulks, paints, pigments, inks

LIVER CARCINOGENESIS IN FISH

PAHs

↓

DNA adducts

PCBs,
DDT

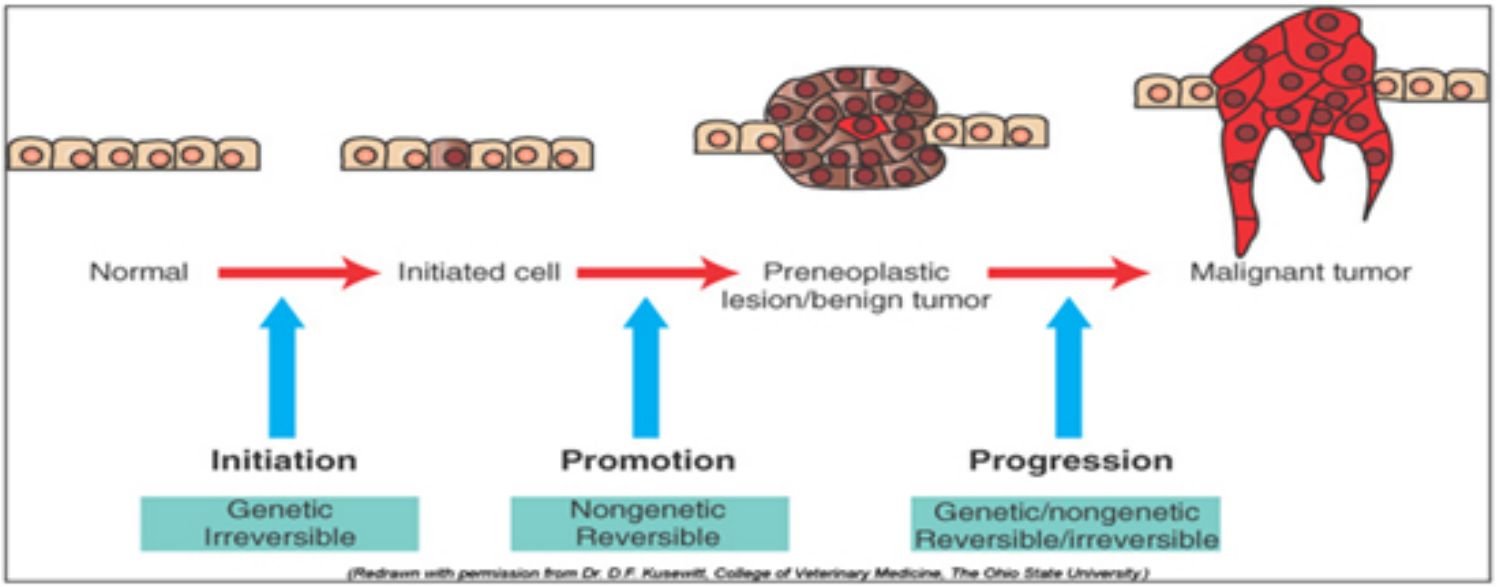
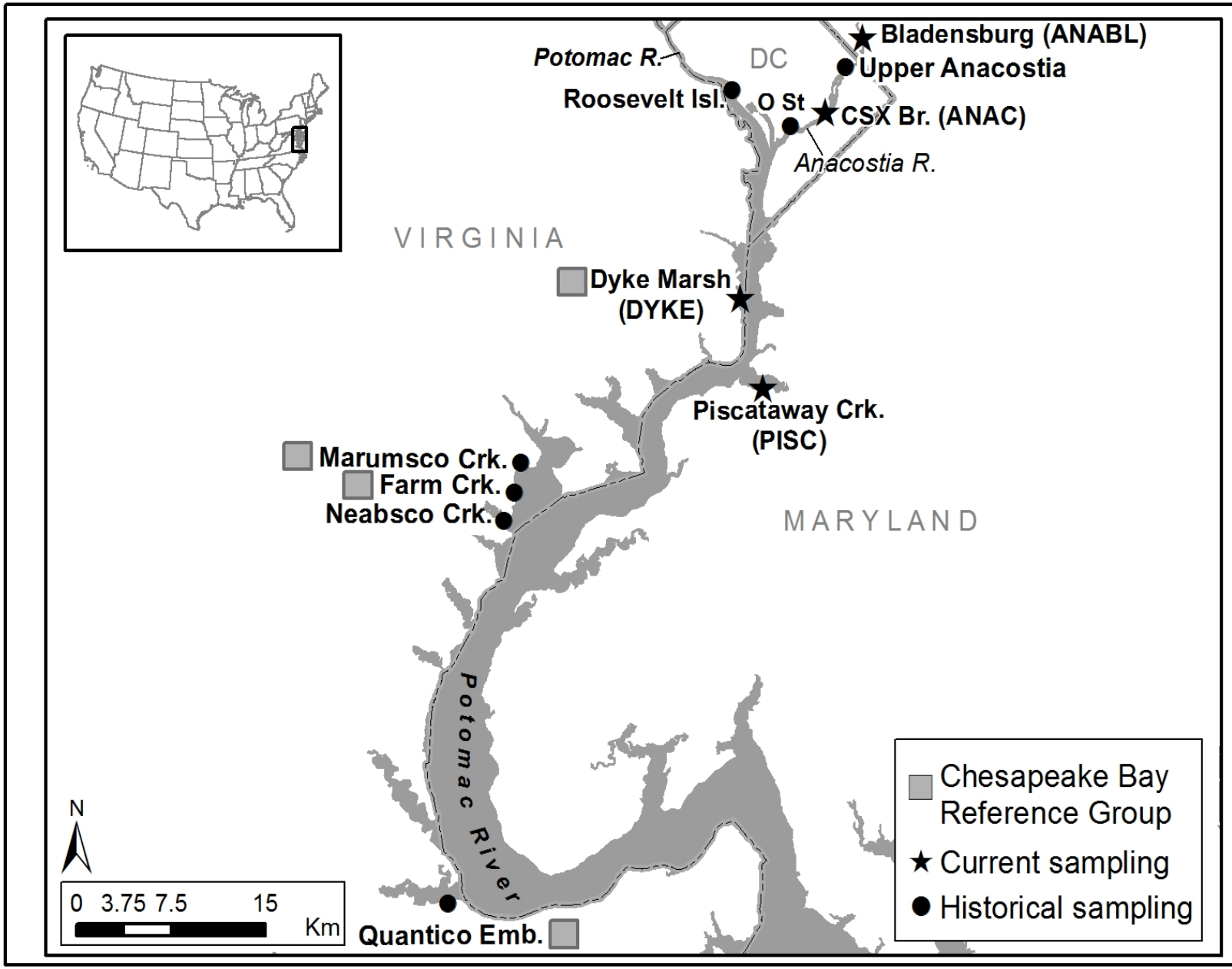
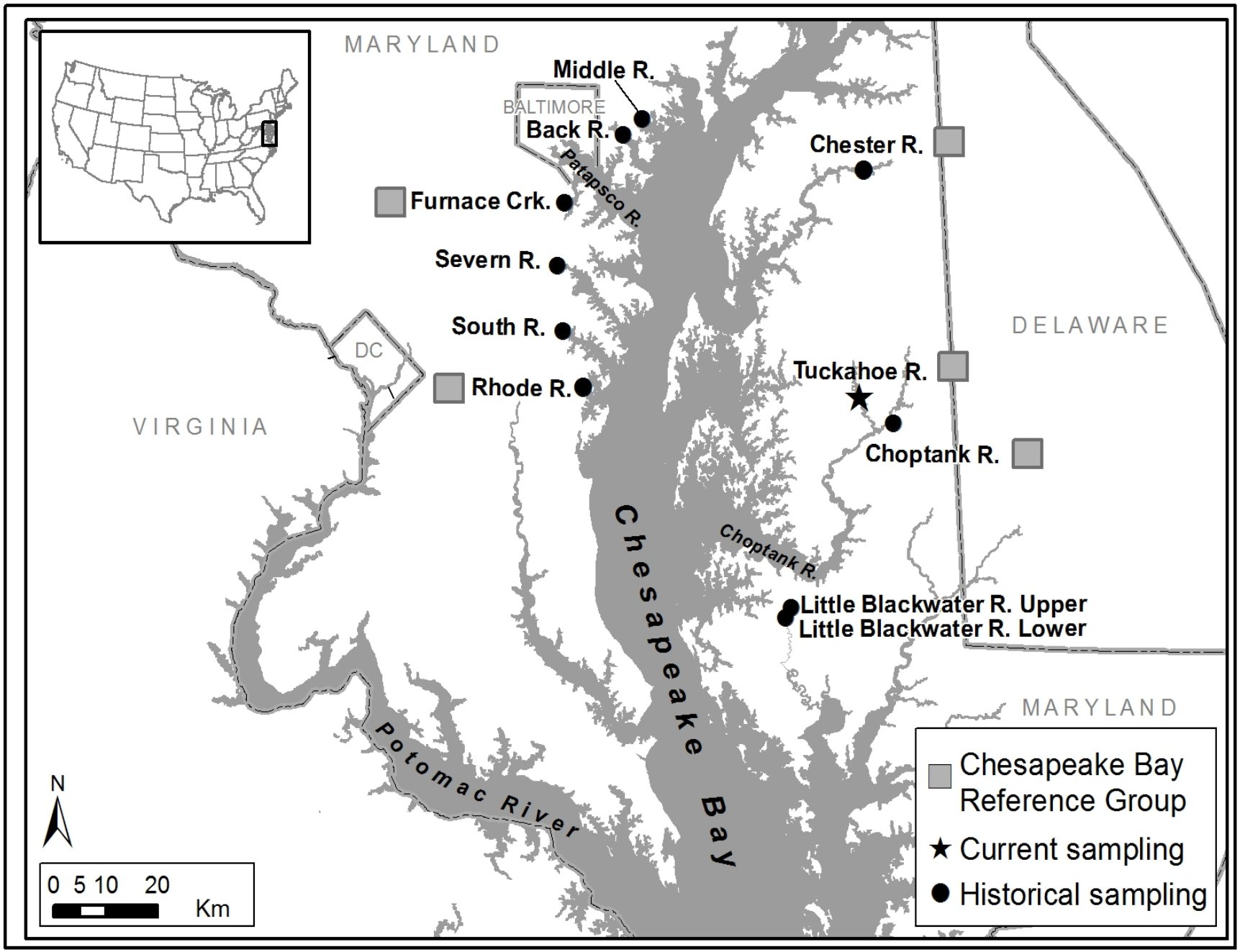


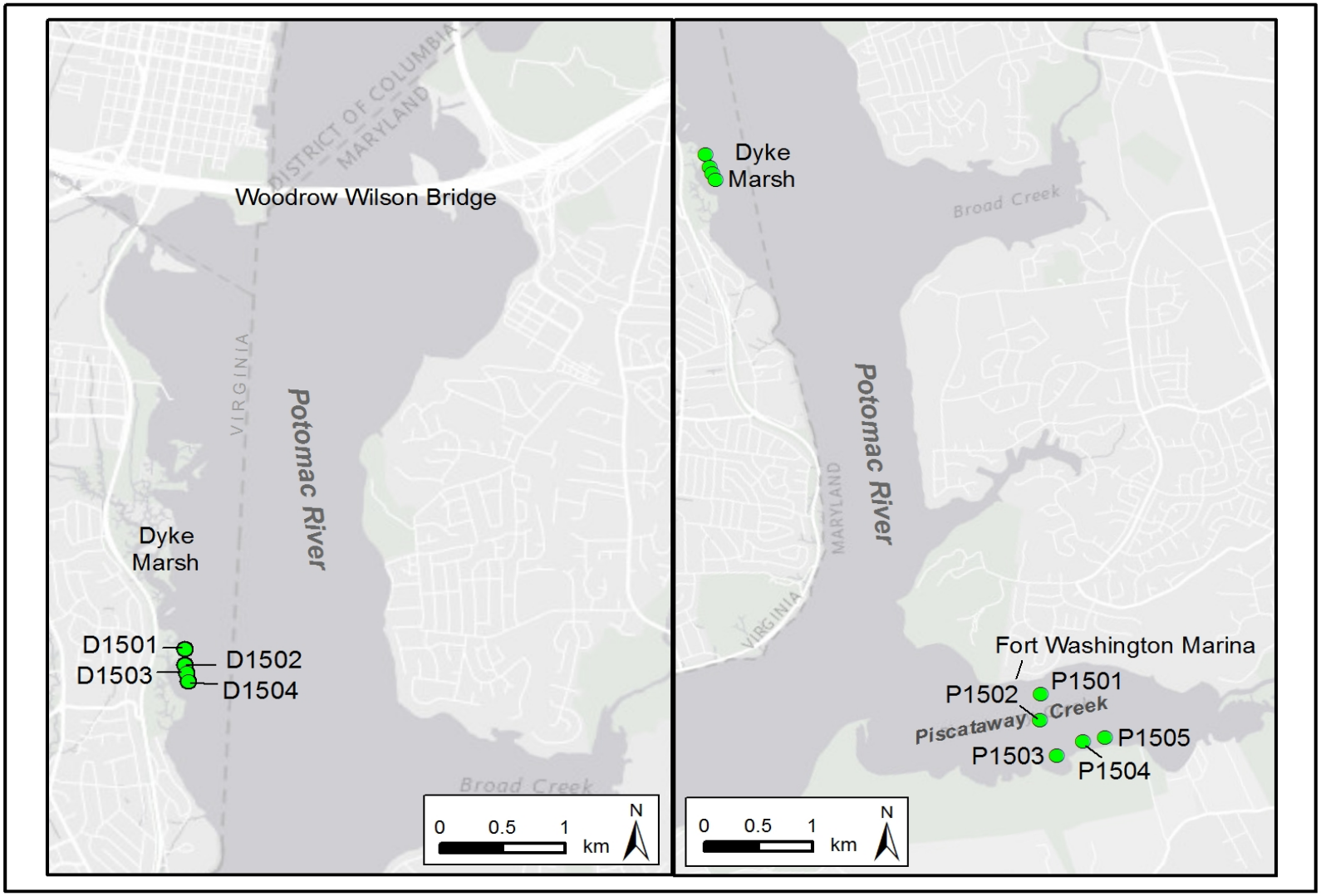
Figure 06-20. Illustration of stepwise tumor development. Initiated cells have irreversible genetic damage. In the presence of a promoter, these initiated cells expand to form a preneoplastic lesion or benign tumor. With further genetic and epigenetic alterations, a malignant tumor emerges from a subclone of cells within the benign precursor lesion. *(Redrawn with permission from Dr. D.F. Kusewitt, College of Veterinary Medicine, The Ohio State University.)*

Methods 2014-16

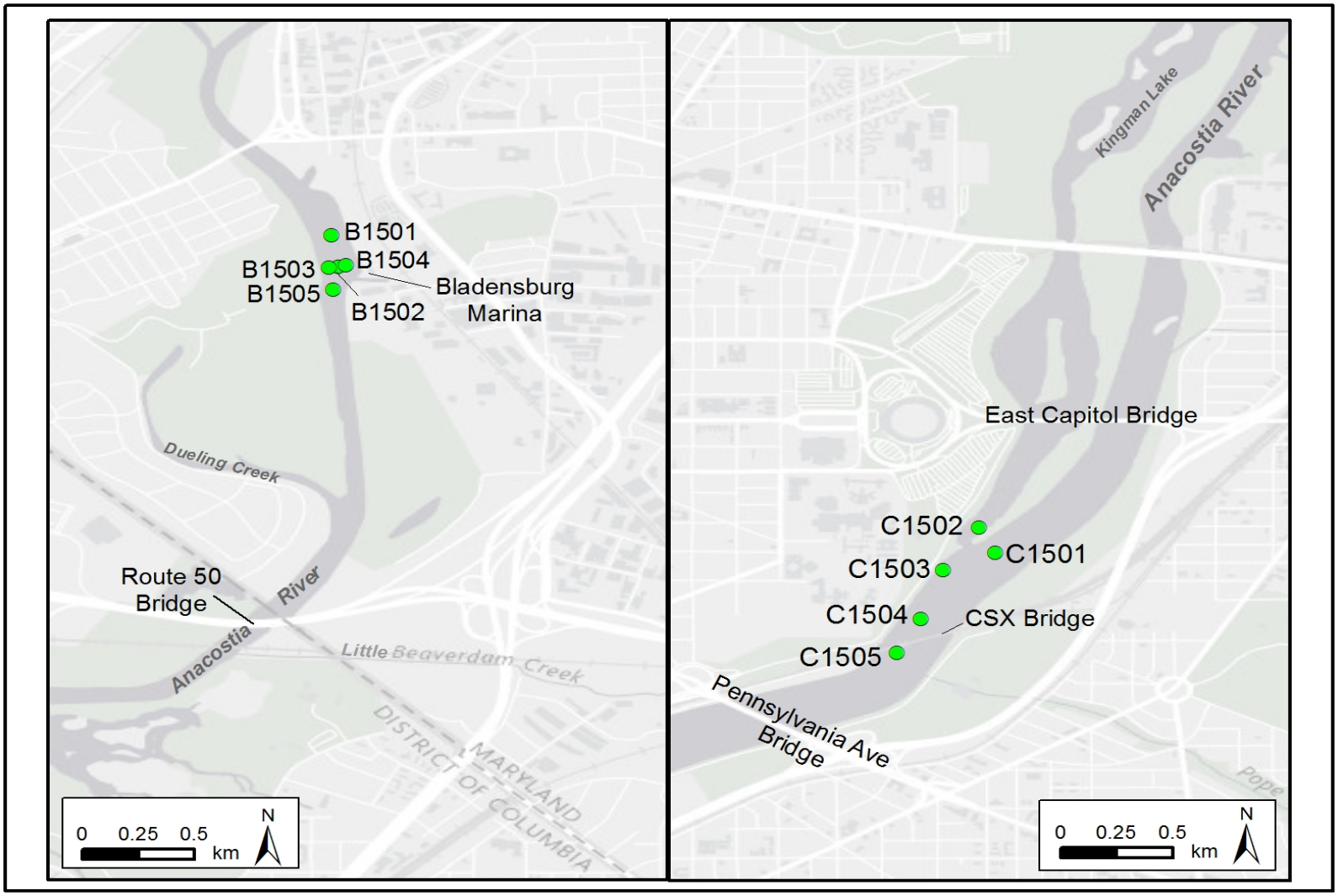
1) Collect ~ 50 brown bullhead > 250 mm
2) Lab necropsy then pathology
3) Aging
4) Logistic regression
5) Sediment chemistry: 2015: 5 samples per location and compare with 2000 data
6) Use sediment, fish tissue, and biomarker data to interpret results


Potomac R.
DC
Bladensburg (ANABL)
Upper Anacostia
Roosevelt Isl.
O St
CSX Br. (ANAC)
Anacostia R.
VIRGINIA
Dyke Marsh
(DYKE)
Piscataway Crk.
(PISC)
Marumsco Crk.
Farm Crk.
Neabsco Crk.
MARYLAND
Potomac River
Quantico Emb.
N
0 3.75 7.5 15
Km
Chesapeake Bay Reference Group
Current sampling
Historical sampling


MARYLAND
Middle R.
BALTIMORE
Back R.
Patapsco R.
Chester R.
Furnace Crk.
Severn R.
South R.
DC
Rhode R.
DELAWARE
Tuckahoe R.
VIRGINIA
Choptank R.
Chesapeake Bay
Choptank R.
Little Blackwater R. Upper
Little Blackwater R. Lower
MARYLAND
Potomac River
N
0 5 10 20
Km
Chesapeake Bay Reference Group
Current sampling
Historical sampling

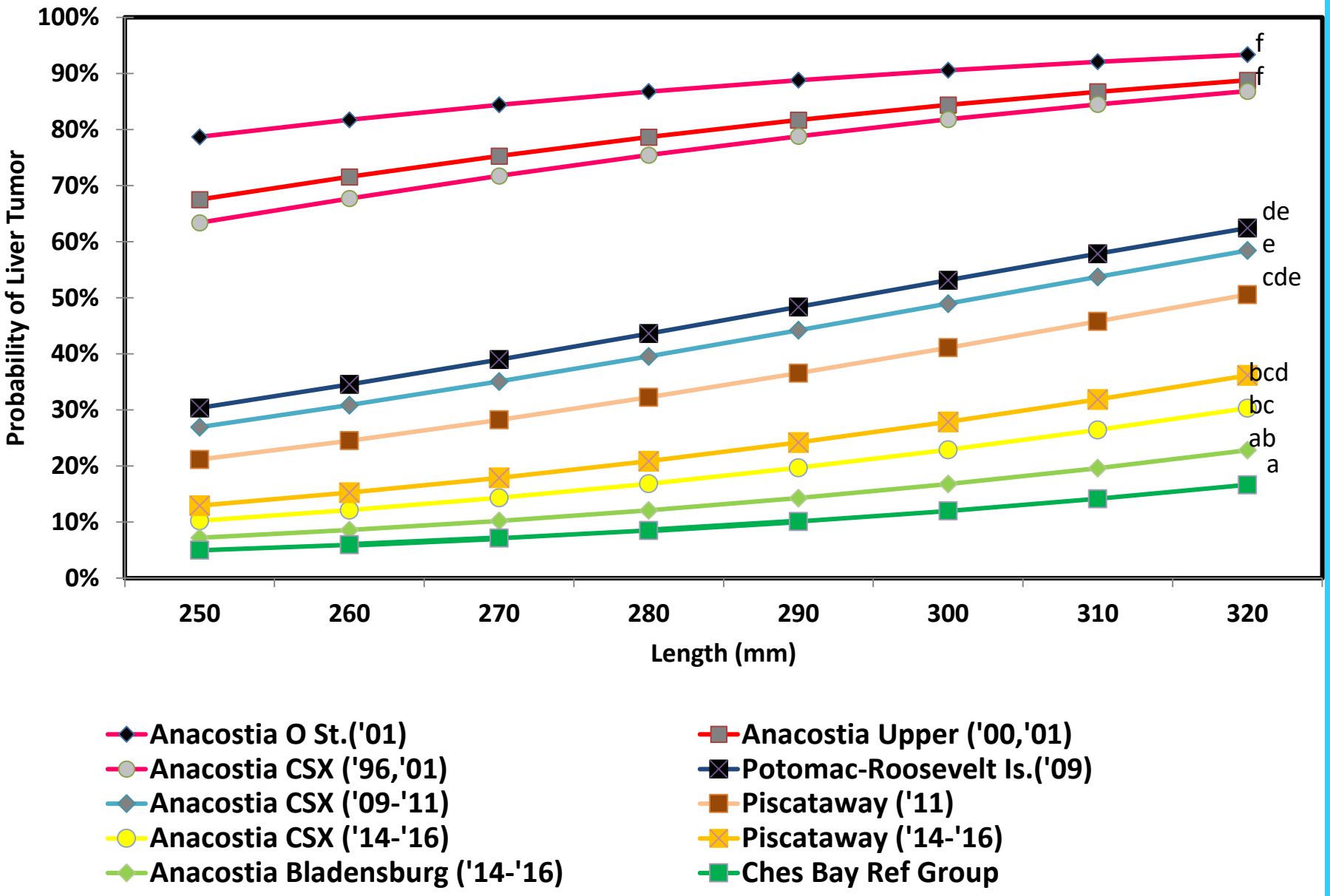


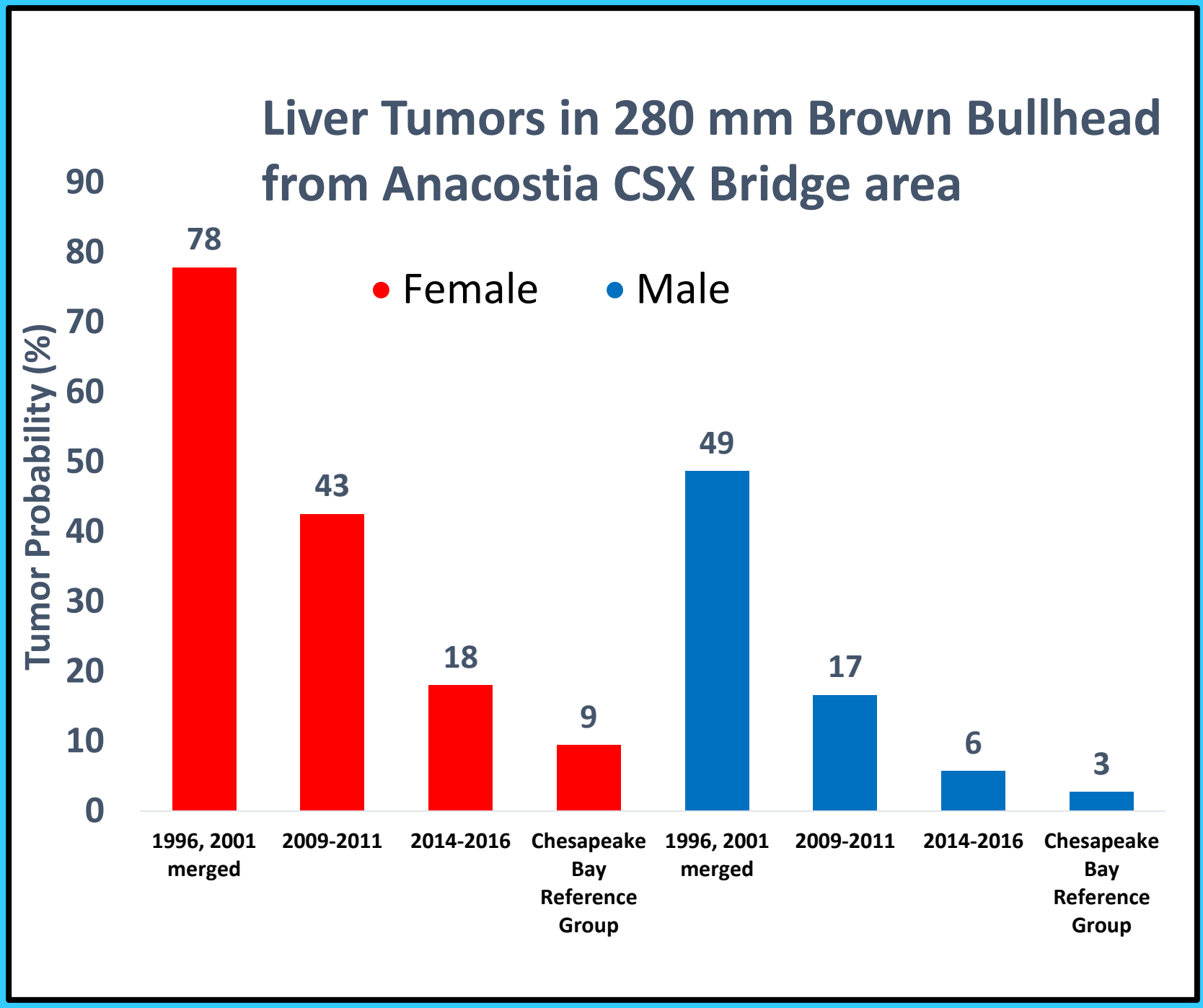
Potomac River showing the USFWS sediment sampling locations at Dyke Marsh (DYKE; left) and Piscataway Creek (PISC; right).



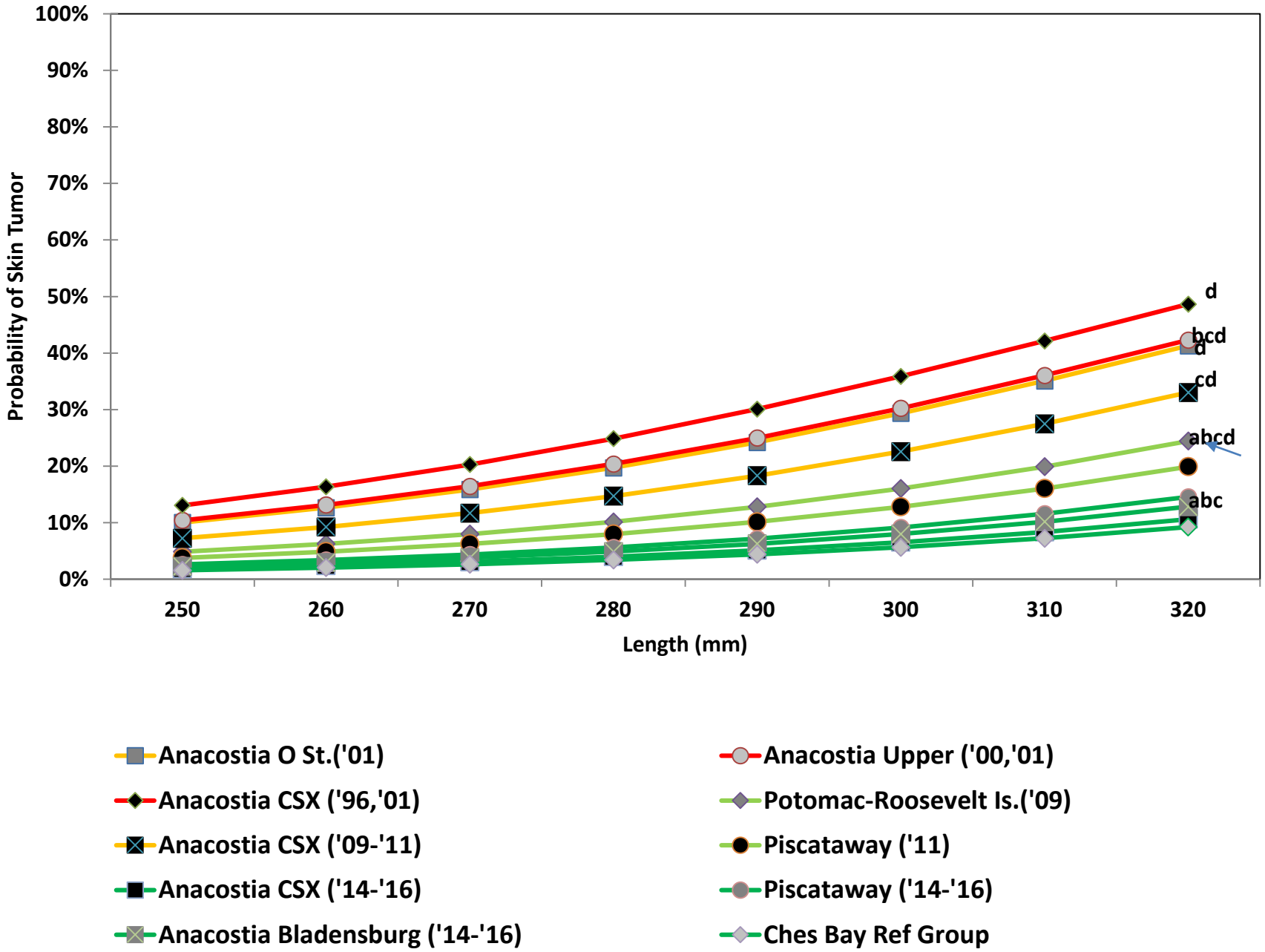
USFWS sediment sampling locations at Bladensburg (ANABL; left) and near the CSX Bridge (ANAC; right).

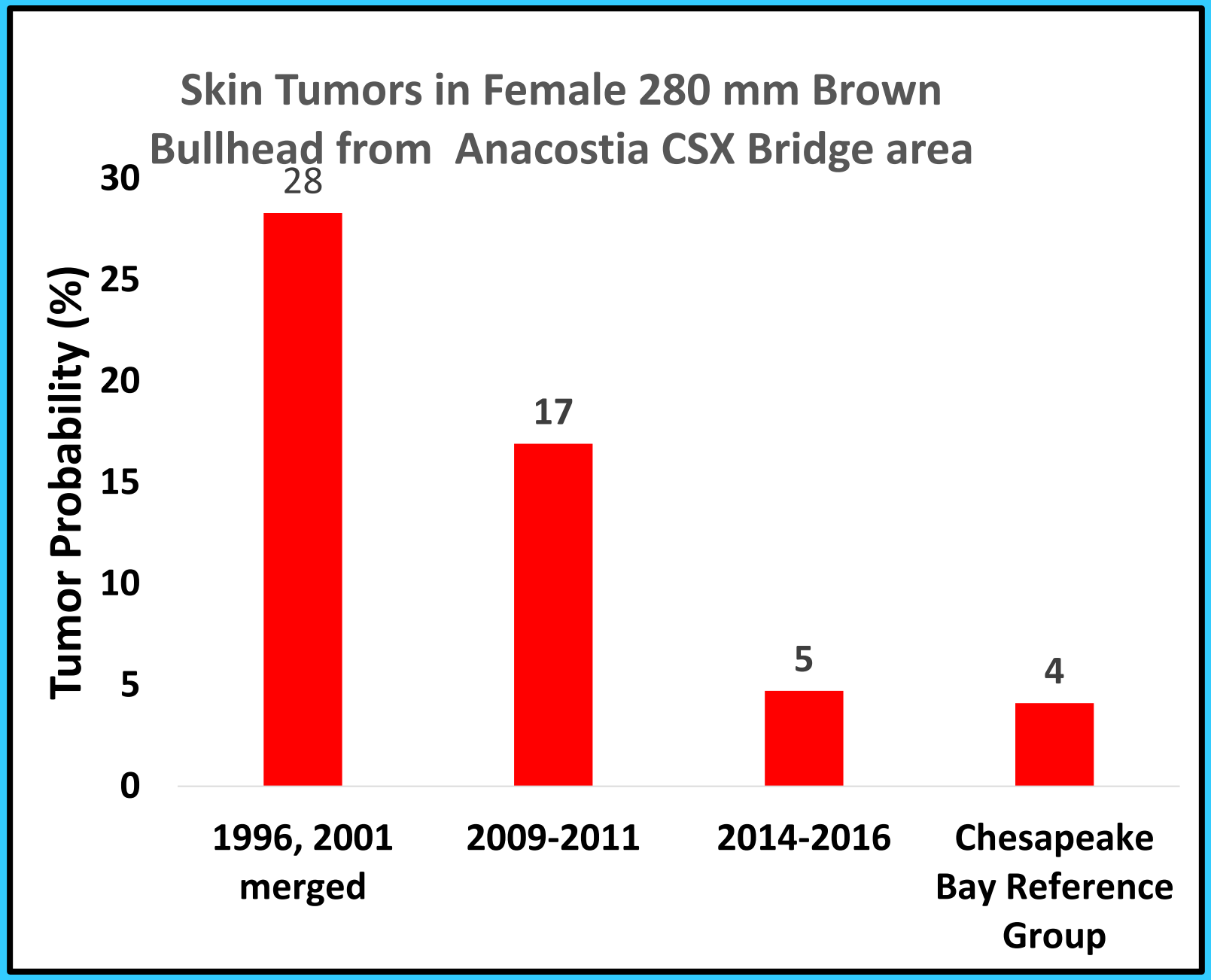
LIVER TUMOR PROBABILITIES: FEMALES

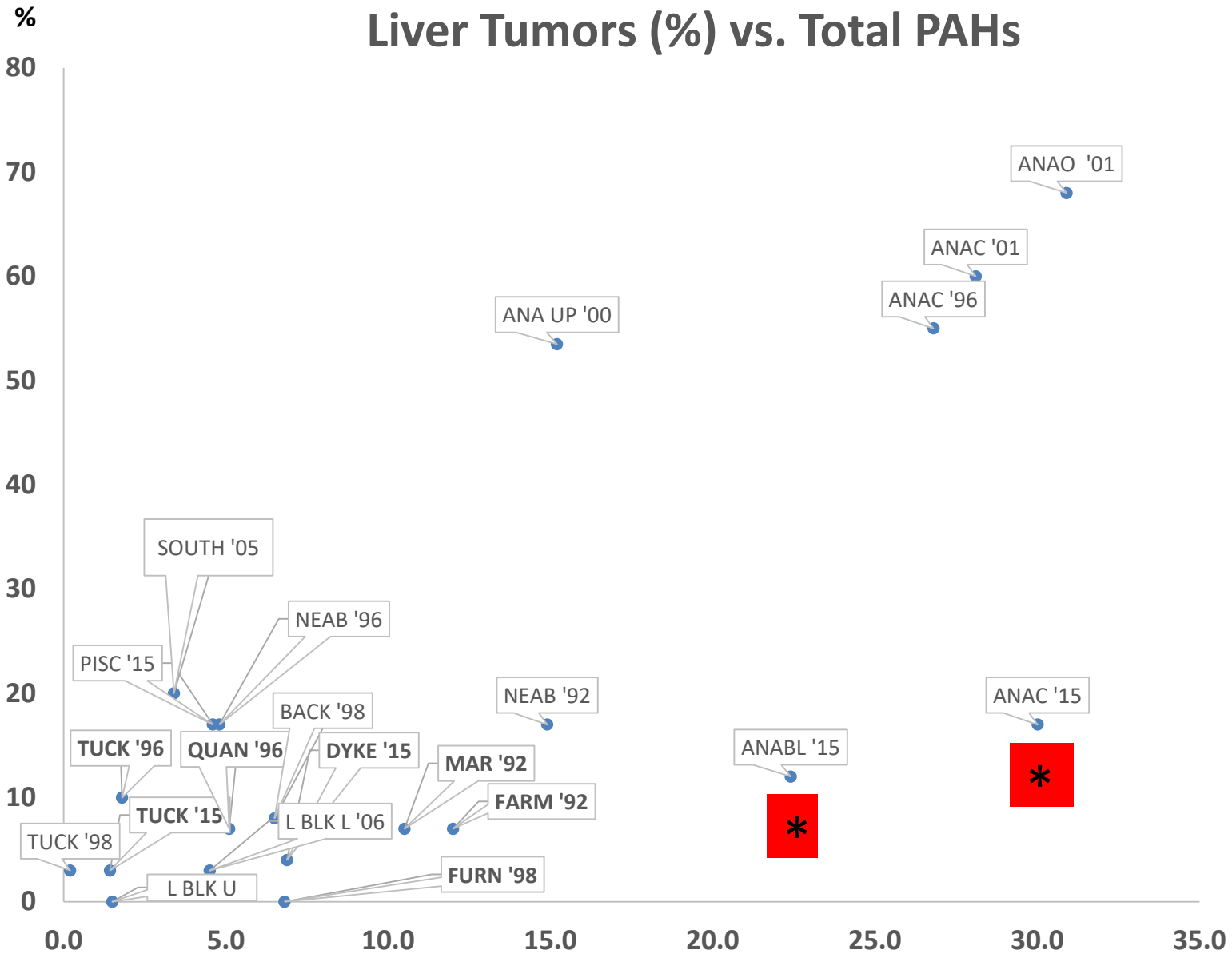



Liver Tumors in 280 mm Brown Bullhead from Anacostia CSX Bridge area
Female
Male
Tumor Probability (%)
0
10
20
30
40
50
60
70
80
90
78
43
18
9
49
17
6
3
1996, 2001 merged
2009-2011
2014-2016
Chesapeake Bay Reference Group
1996, 2001 merged
2009-2011
2014-2016
Chesapeake Bay Reference Group

SKIN TUMOR PROBABILITIES: FEMALES




Skin Tumors in Female 280 mm Brown Bullhead from Anacostia CSX Bridge area
Tumor Probability (%)
30
25
20
15
10
5
0
28
17
5
4
1996, 2001 merged
2009-2011
2014-2016
Chesapeake Bay Reference Group



Sediment total PAH (ppm)

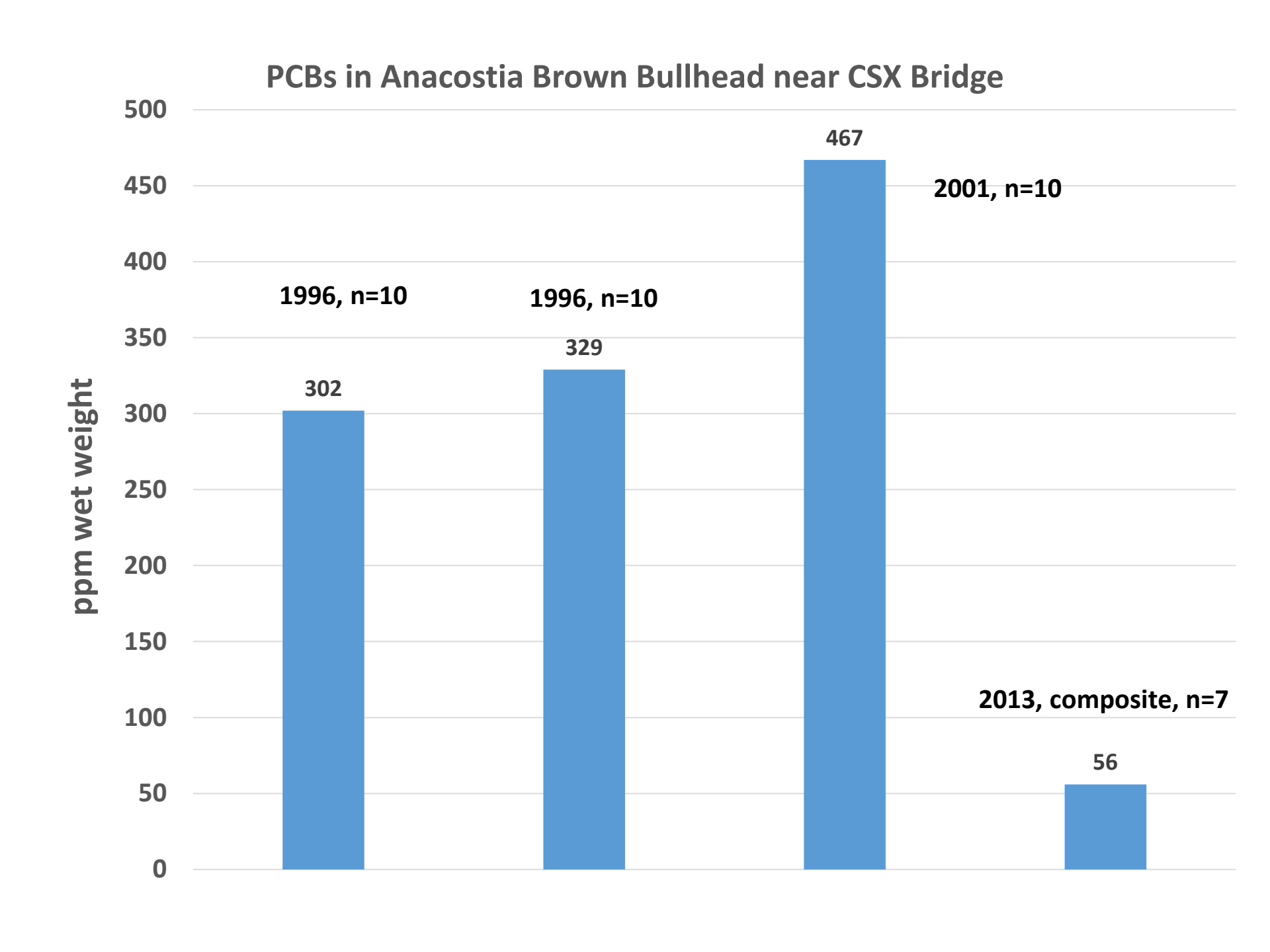
Why are liver tumors decreasing in the Anacostia bullheads?

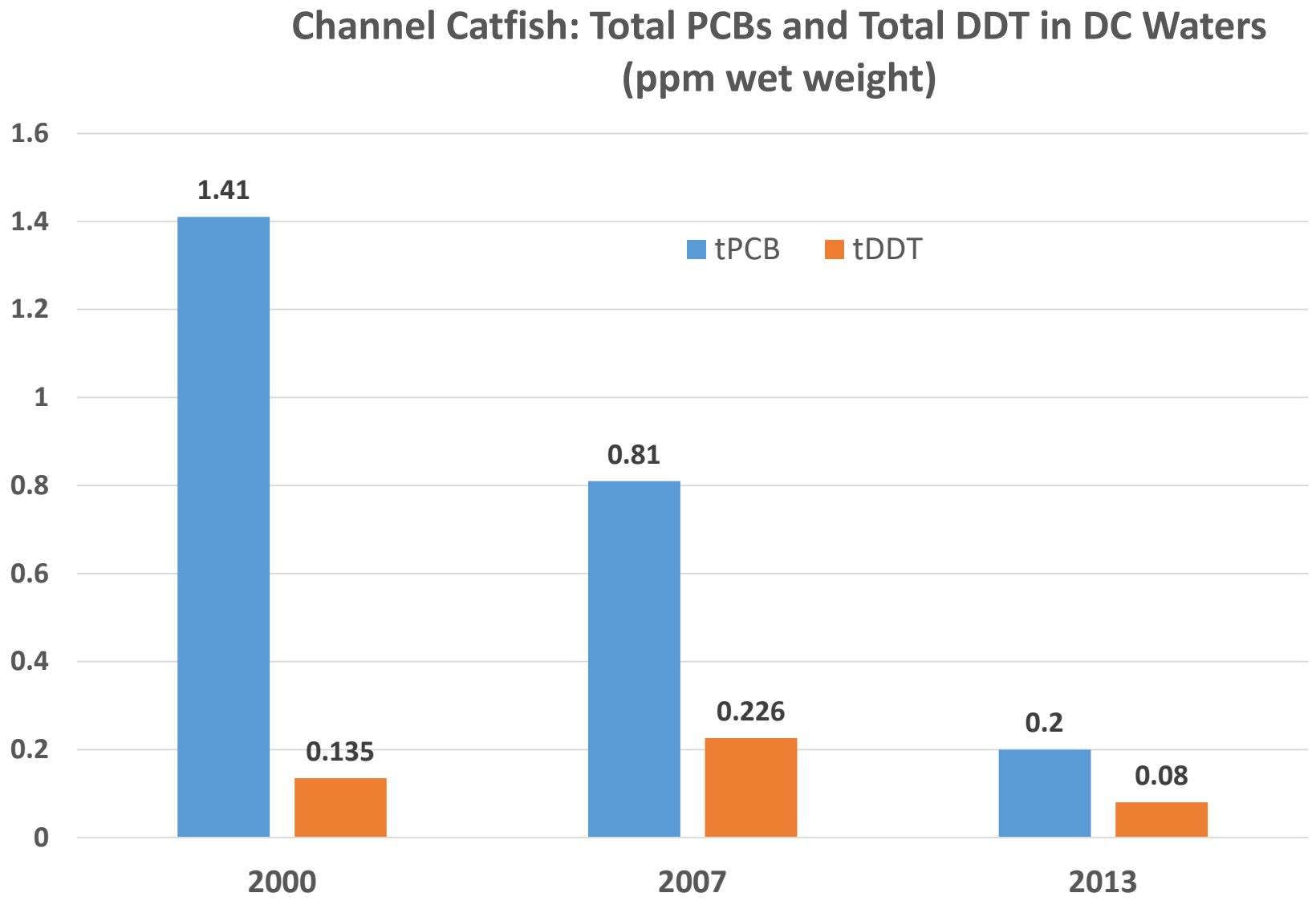
PAH exposure

- Sediment PAHs from collection areas: 2000 vs. 2015, maybe decreasing, few samples
- Fish data: 2-4 fold decrease in PAC-DNA adducts 2000 vs. 2009—small sample size

PCB, DDT exposure

- Sediment not consistent decrease: 2000 vs. 2015
- Fish tissue data: strong decreases-~6-8 fold


PCBs in Anacostia Brown Bullhead near CSX Bridge
ppm wet weight
500
450
400
350
300
250
200
150
100
50
0
1996, n=10
302
1996, n=10
329
467
2001, n=10
2013, composite, n=7
56


Channel Catfish: Total PCBs and Total DDT in DC Waters
(ppm wet weight)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
tPCB
tDDT
1.41
0.135
0.81
0.226
0.2
0.08
2000
2007
2013

Conclusions

- Large statistically significant decreases in liver (4-8X) and skin tumors (6-7X) in Anacostia brown bullheads since 1996
- Anacostia CSX: still 2X background for liver; skin now similar to background
- 2014-16: Piscataway Creek=Anacostia but Dyke Marsh = background
- Local signal

Recommendations

- Monitor tumors on a 5-year cycle to track trends in DC and nearby locations
- Use fish tissue and biomarkers to evaluate changes in exposure to liver carcinogens
- Why is the skin tumor prevalence dramatically decreasing in Anacostia bullheads?
  - Research to see if viruses may play a role

YEAR OF THE ANACOSTIA

- Tumors in fish: way down
- Fish tissue contaminants: down
- People enjoying the river: way up

Department of Energy & Environment: Dev Murali, Bryan King, Danny Ryan, Eric Thadey, Luke Lyon, Joe Swann

USFWS: Steve Minkinnen, Josh Newhard, Mike Mangold, John Gill, Ian Park, Rachel Harrison

Reports and papers

- Pinkney, A.E., J.C. Harshbarger, M.A. Rutter, and P.C. Sakaris. 2018. Tumor Prevalence in Brown Bullhead (*Ameiurus nebulosus*) in the Tidal Potomac River Watershed: 2014-2016. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office. CBFO-C18-01.
- Pinkney, A.E., J.C. Harshbarger, and M.A. Rutter. 2014. Temporal and spatial patterns in tumor prevalence in brown bullhead (*Ameiurus nebulosus*) in the tidal Potomac River watershed (USA). *J. Fish Diseases* 37:863-876.
- Pinkney, A.E., J.C. Harshbarger, N.K. Karouna-Renier, K. Jenko, L. Balk, H. Skarphéðinsdóttir, B. Liewenborg, and M.A. Rutter. 2011. Tumor prevalence and biomarkers of genotoxicity in brown bullhead (*Ameiurus nebulosus*) in Chesapeake Bay tributaries. *Science of the Total Environment* 410:248-257.
- Pinkney, A.E., J.C. Harshbarger, and M.A. Rutter. 2009. Tumors in brown bullheads (*Ameiurus nebulosus*) in the Chesapeake Bay watershed: Analysis of survey data--1992 through 2006. *J. Aquatic Animal Health* 21:71-81. [31]
- Sakaris, P.C., R.V. Jesien, and A.E. Pinkney. 2005. Brown bullhead, *Ameiurus nebulosus,* as an indicator species: seasonal movement patterns and home ranges within the Anacostia River, Washington, D.C. *Trans. Amer. Fish. Soc.* 134:1262-1270.
- Pinkney, A.E., J.C. Harshbarger, E.B. May, and W.L. Reichert. 2004. Tumor prevalence and biomarkers of exposure and response in brown bullheads (*Ameiurus nebulosus*) from the Anacostia River, Washington, D.C. and Tuckahoe River, Maryland. *Environ. Toxicol. Chem.* 23:638-647.
- Pinkney, A.E., J.C. Harshbarger, E.B. May, and M.J. Melancon. 2001. Tumor prevalence and biomarkers of exposure in brown bullheads (*Ameiurus nebulosus*) from the Tidal Potomac River Watershed. *Environ. Toxicol. Chem.* 20:1196-1205.

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