Fish health issues in relation to contaminants in urban settings

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Presentation to
EPA Chesapeake Bay Program
Scientific and Technical Advisory Committee

Integrating Science and Developing Approaches to Inform Management for Contaminants of Concern in Agricultural and Urban Settings

May 22, 2019

Urbanization vs. fish health

- Stormwater
- Nutrients leading to low dissolved oxygen—hypoxia—endocrine disruption
- Point sources
- Waste sites—PCBs, PAHs, metals
- Toxic tributaries—endocrine disrupters?
- Heat islands
- Engine exhaust, pavement sealants, tire particles
- Diseases, reproductive impairment

Yellow perch reproduction in urban vs. rural watersheds of the Chesapeake Bay

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Department of Environmental Science and Technology
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U.S. Geological Survey
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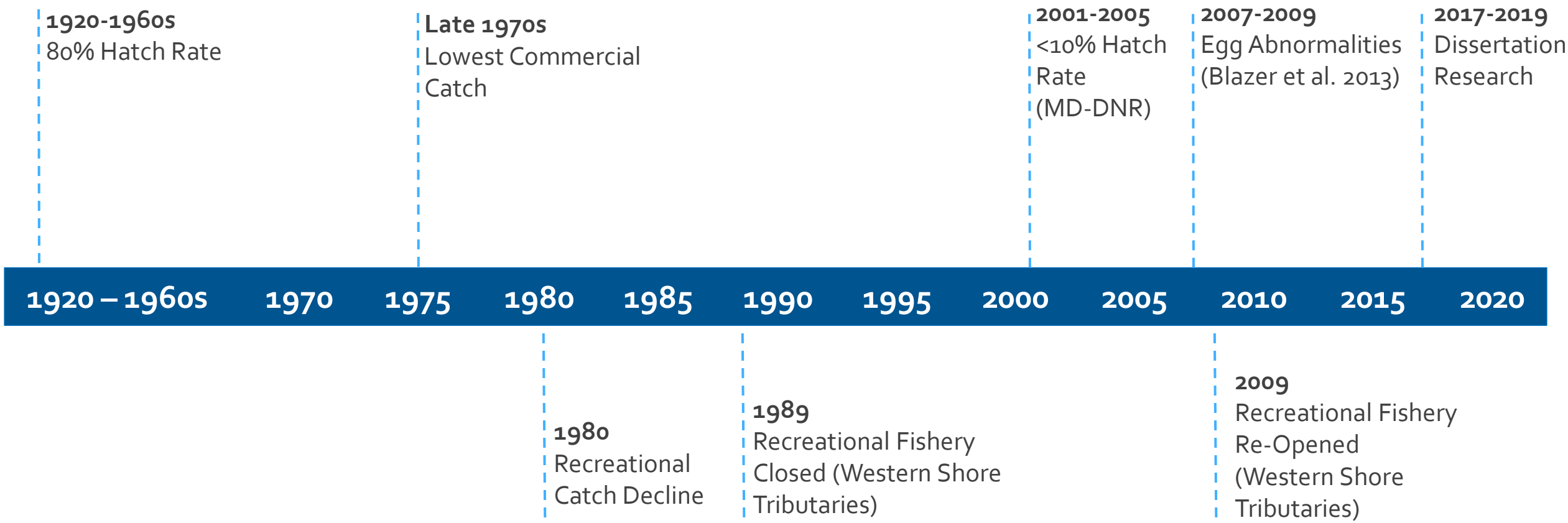
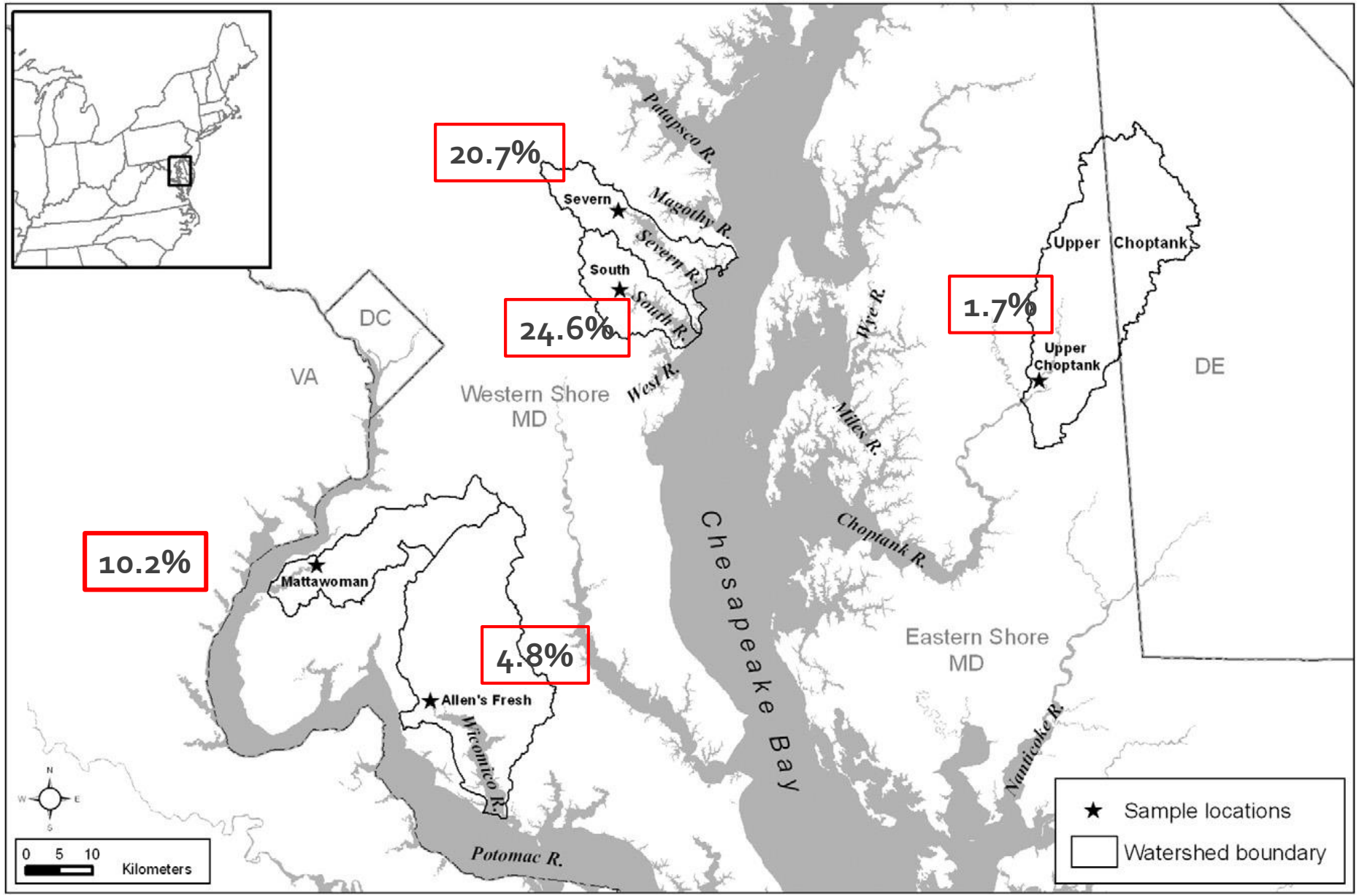
Dramatic Decline of Yellow Perch Fisheries & Egg Hatching *(Western Shore Populations)*



% Impervious surface in yellow perch watersheds

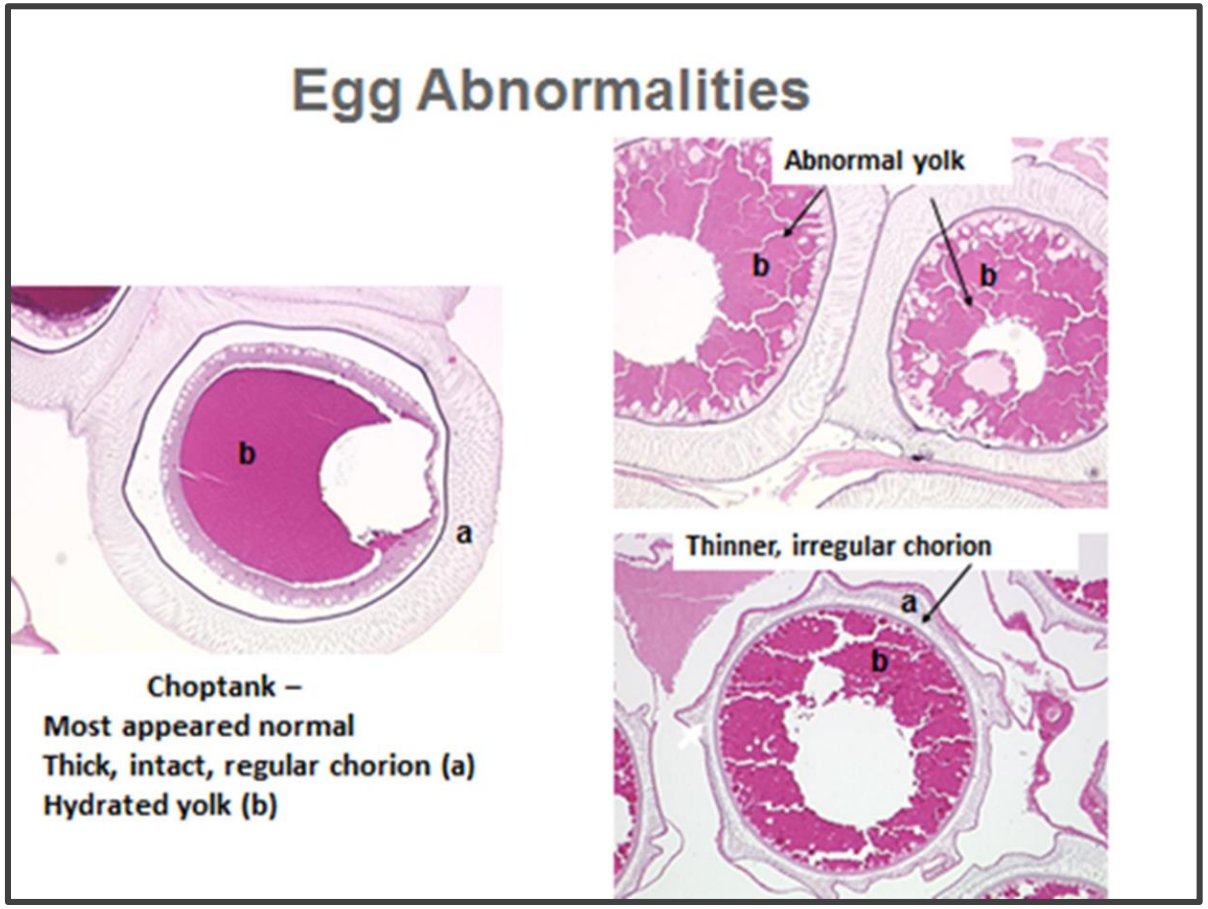


Blazer et al. 2013. Reproductive health of yellow perch *Perca flavescens* in selected tributaries of the Chesapeake Bay. *Science of the Total Environment* 447:198-209.

Experimental Design

- Sampled during spawn from 2007-2009
- 5 rivers: W. Shore: Severn, South, Allen's Fresh, Mattawoman
- E. Shore: Choptank

- High incidence of oocyte abnormalities in Western Shore tributaries
- Abnormal yolks: Choptank 0-20%; South: 36-50%; Severn 58-70%. Also abnormal membranes (chorion) in similar pattern.



Spatiotemporal Investigation of Yellow Perch (*Perca flavescens*) Reproductive Health from Chesapeake Bay Tributaries: Genetics, Hormones, and Histopathology

Alex MacLeod, Ph.D. dissertation research in progress

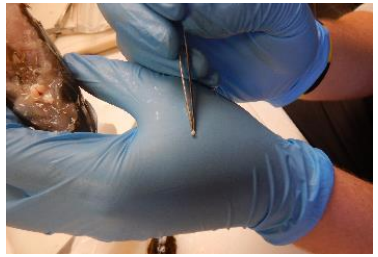
DEPARTMENT OF ENVIRONMENTAL SCIENCE & TECHNOLOGY

www.enst.umd.edu

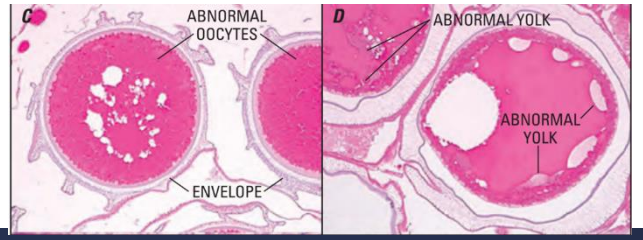
Research Objectives

- Characterize sequence of normal gonadal development in a yellow perch population of the Chesapeake Bay based on genetics, biochemistry, and histology to discover key biomarkers for assessing reproductive condition
- Compare yellow perch reproductive development across three Chesapeake Bay tributaries using genetics, biochemistry, and histology
- Support findings with chemical analyses using passive samplers and tissue analysis.

GENE EXPRESSION
(Pituitary, Liver, Gonad)



HISTOPATHOLOGY
(LIVER, GONAD, GILLS, ANTERIOR & POSTERIOR KIDNEY, SPLEEN)



PLASMA HORMONES & PROTEIN

Conclusions

Reproductive impairment—starting place for study

Lines up with urbanization

Need to determine mechanisms

First start with the fish and learn what is normal and what pathway is disrupted

Then chemical measurements—in tissues and water to look for association

Tumor Prevalence in Brown Bullhead in the Anacostia River and Tidal Potomac Watershed: 1996-2016

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Presentation to:

STAC Contaminant Workshop

May 22, 201

COAUTHORS

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George Washington University
Medical Center

Peter Sakaris,
Georgia Gwinett College

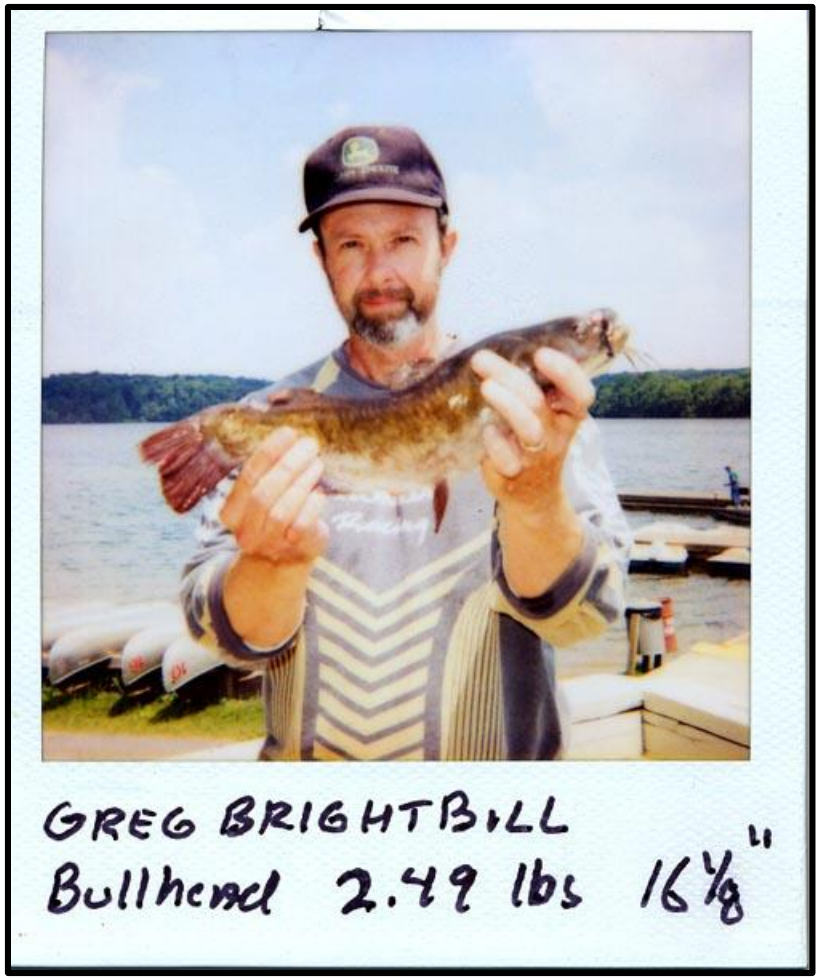
Mike Rutter, Penn State - Erie

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

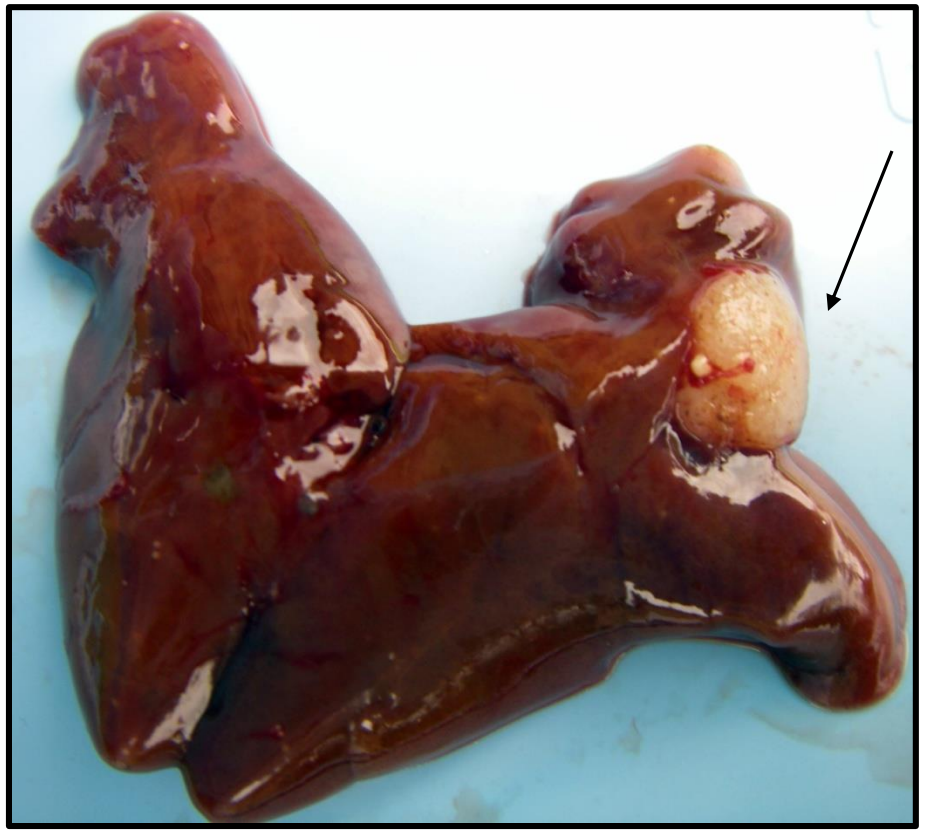
FUNDING: DC DEPT ENERGY & ENVIRONMENT

Background

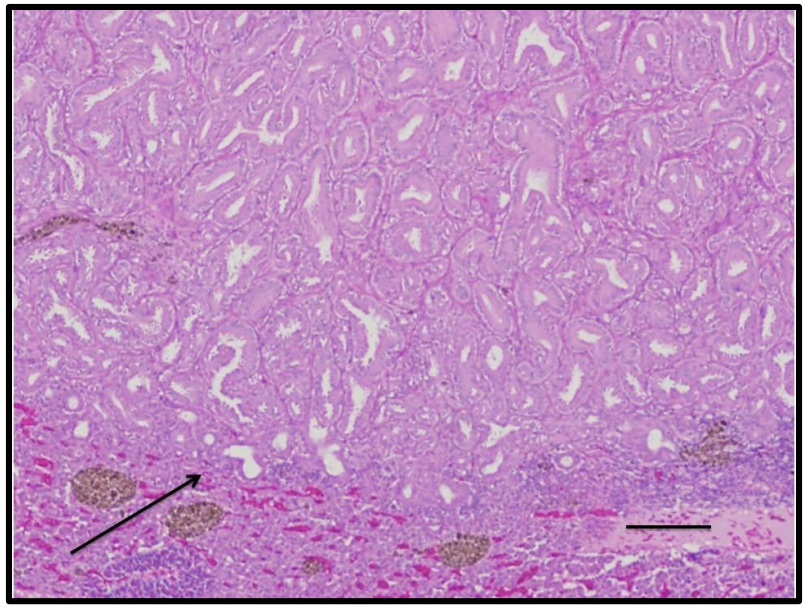
- Cancer-causing chemicals enter rivers, estuaries, and coastal waters and build up in sediments
- Some bottom-dwelling and feeding fish species develop tumors
- Over past 40 years tumor surveys have been used as an environmental indicator of habitat quality: Puget Sound, Great Lakes, Chesapeake Bay



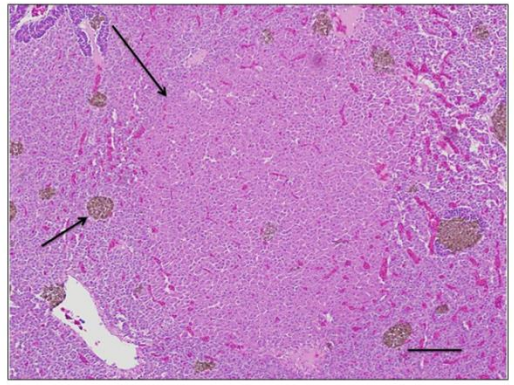
- Brown bullhead: ideal species
- Bottom feeder
  - Small home range (2 km in Anacostia)
  - Sensitive—develops skin and liver tumors
  - Great Lakes and Chesapeake Bay tribs up to 8 ppt



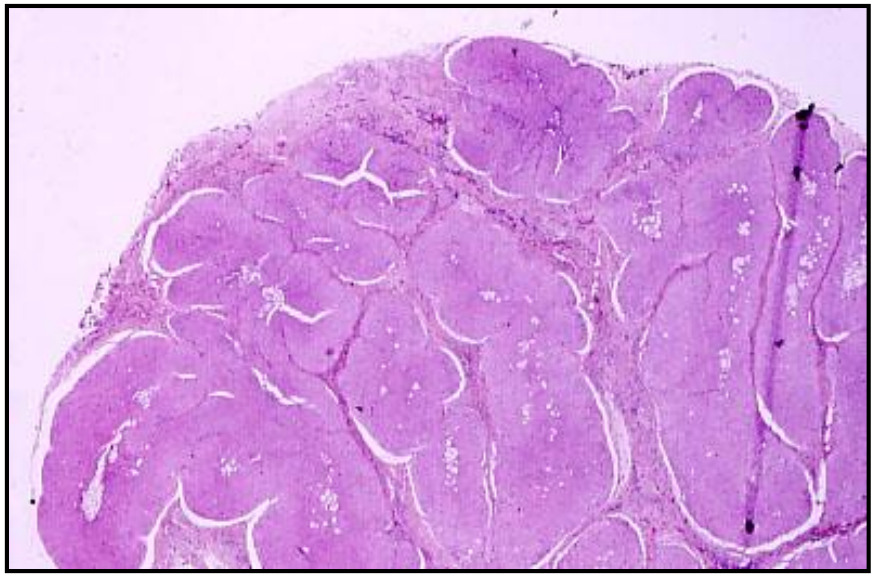
Liver tumors

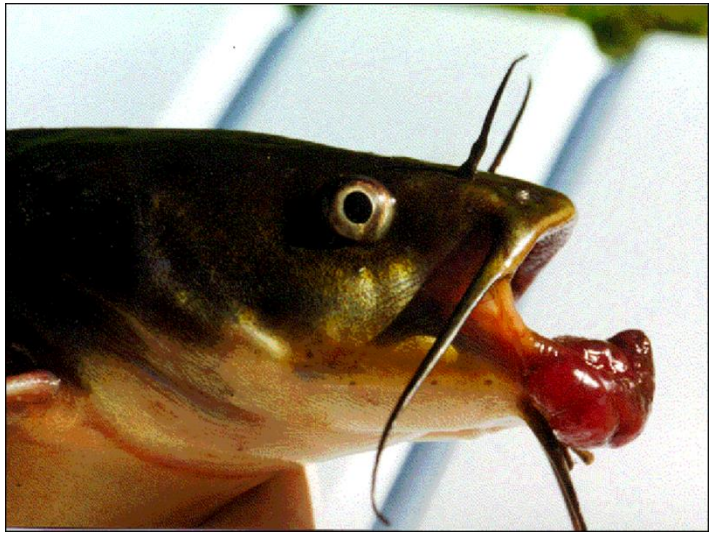


Cholangiocarcinoma



Hepatocellular carcinoma

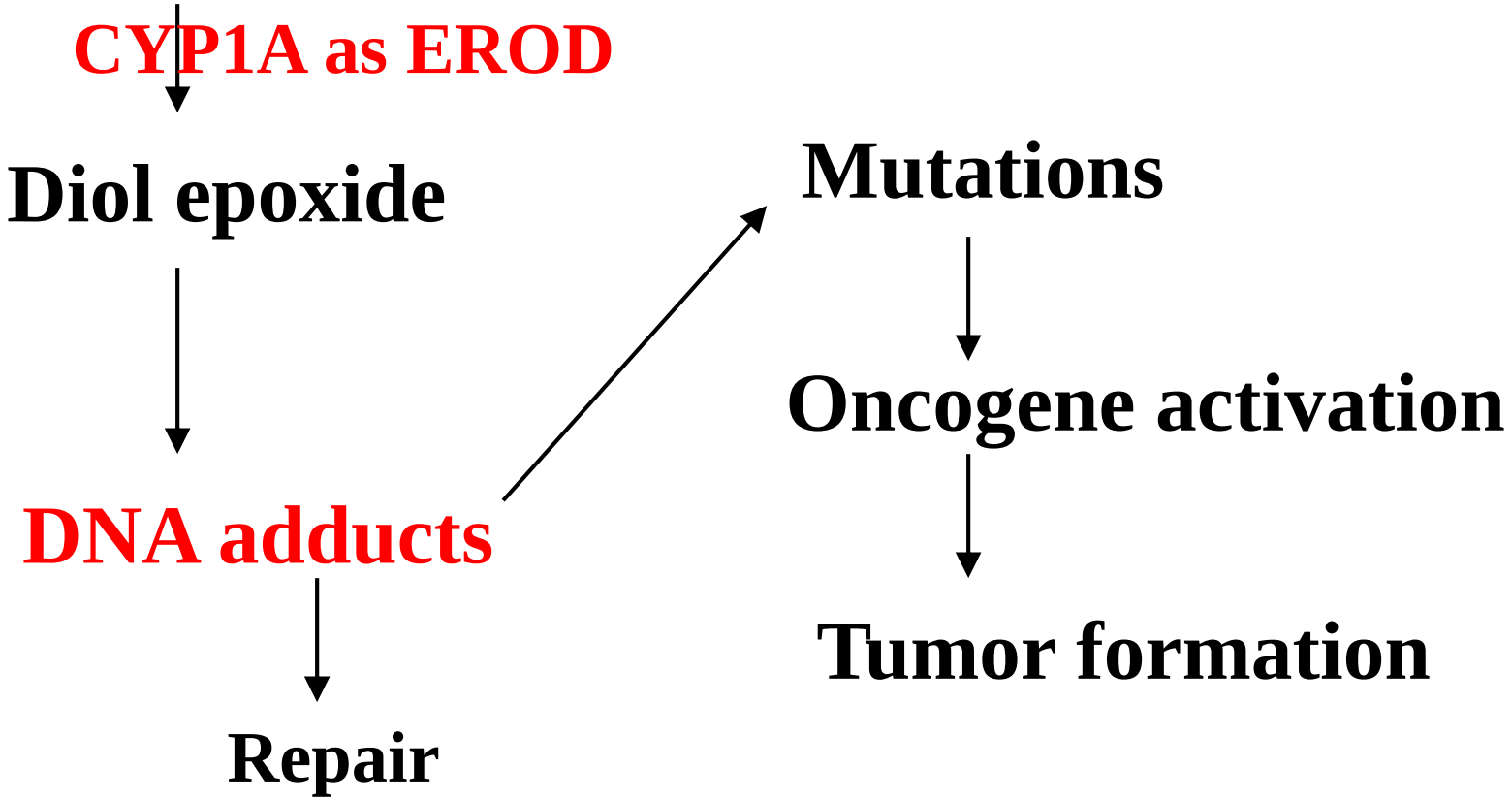


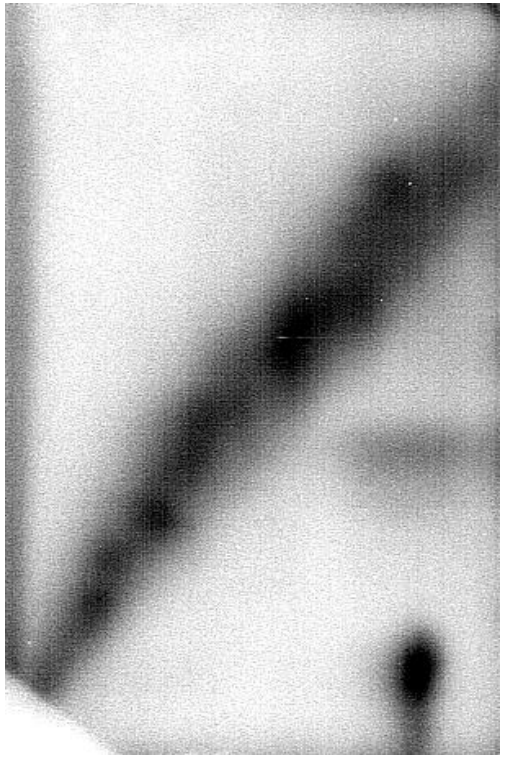


Skin lesions diagnosed as squamous cell carcinomas,

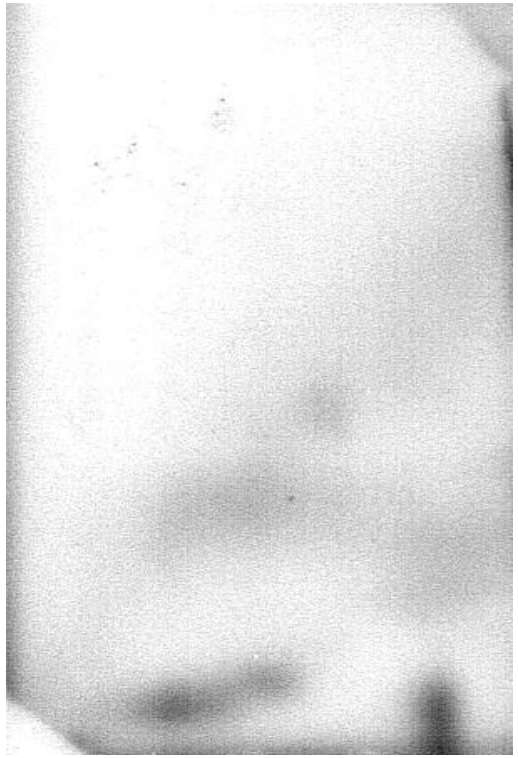
Relationship of biomarkers of PAH exposure

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

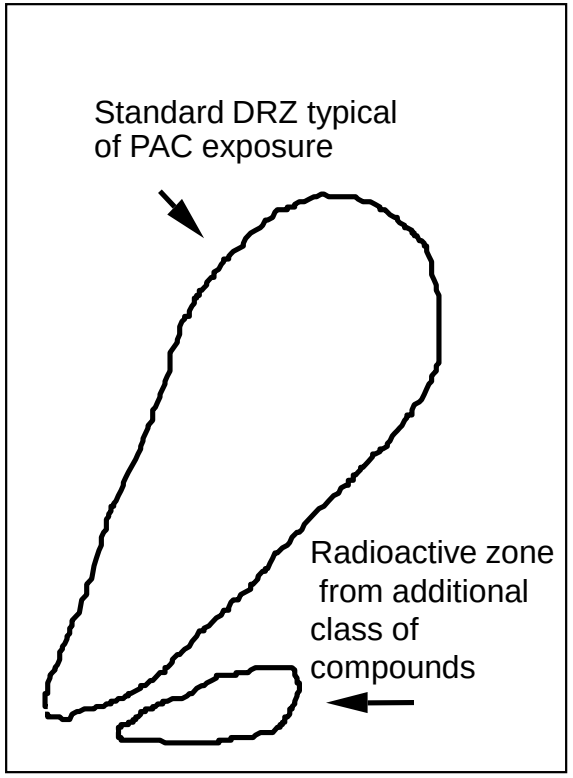




Anacostia River



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).

LIVER CARCINOGENESIS IN FISH

PAHs

↓

DNA adducts

PCBs,
DDT

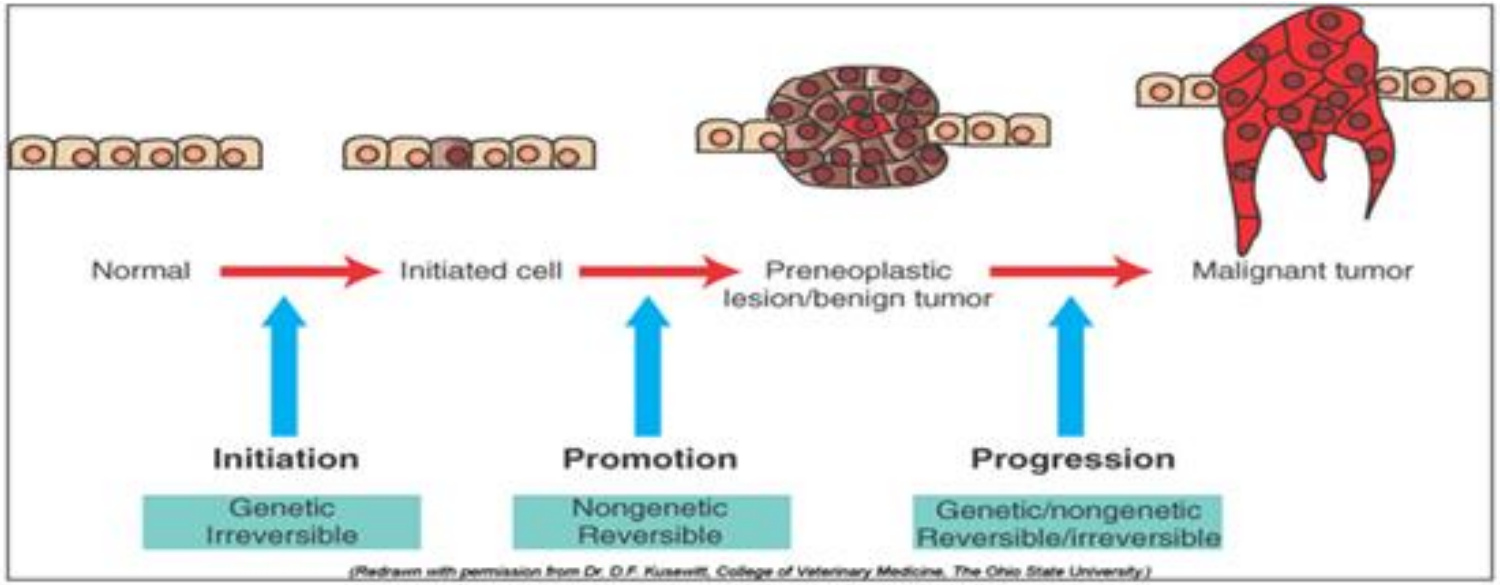
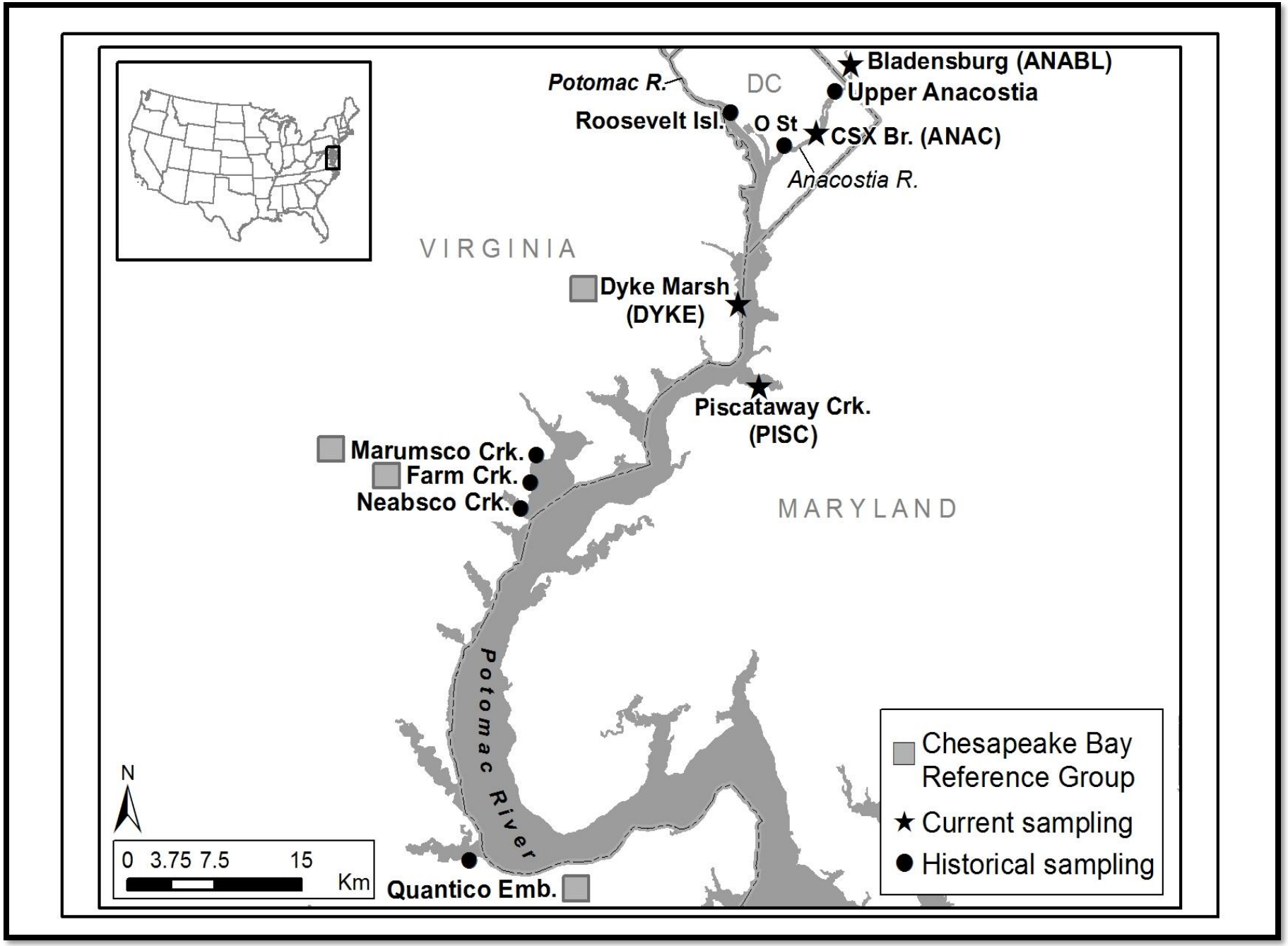


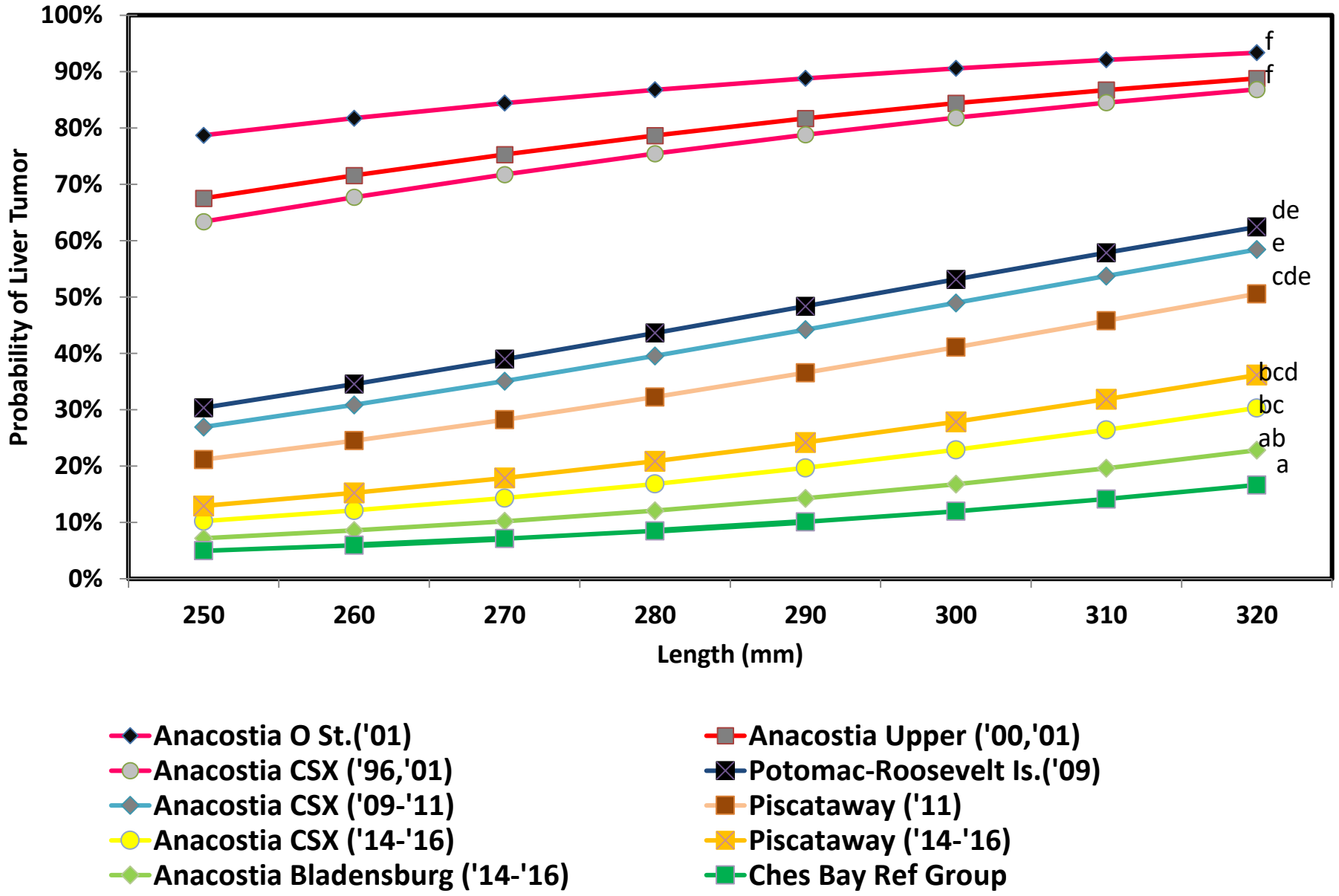
Figure 06-20. Illustration of stepwise tumor development. Initiated cells have irreversible genetic damage. In the presence of a promoter, these initiated cells expand to form a preneoplastic lesion or benign tumor. With further genetic and epigenetic alterations, a malignant tumor emerges from a subclone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

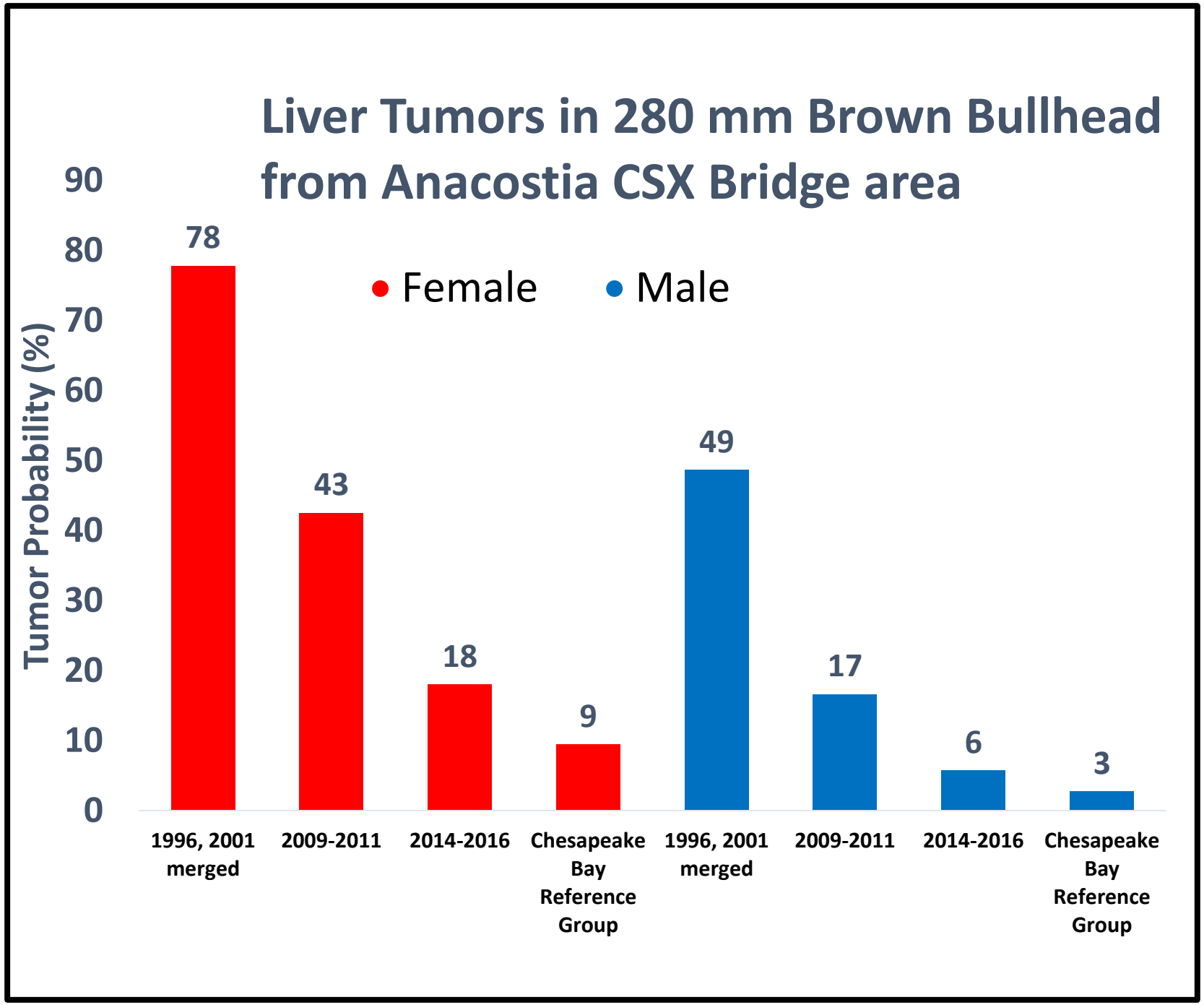
OBJECTIVES: 2014-16 Study

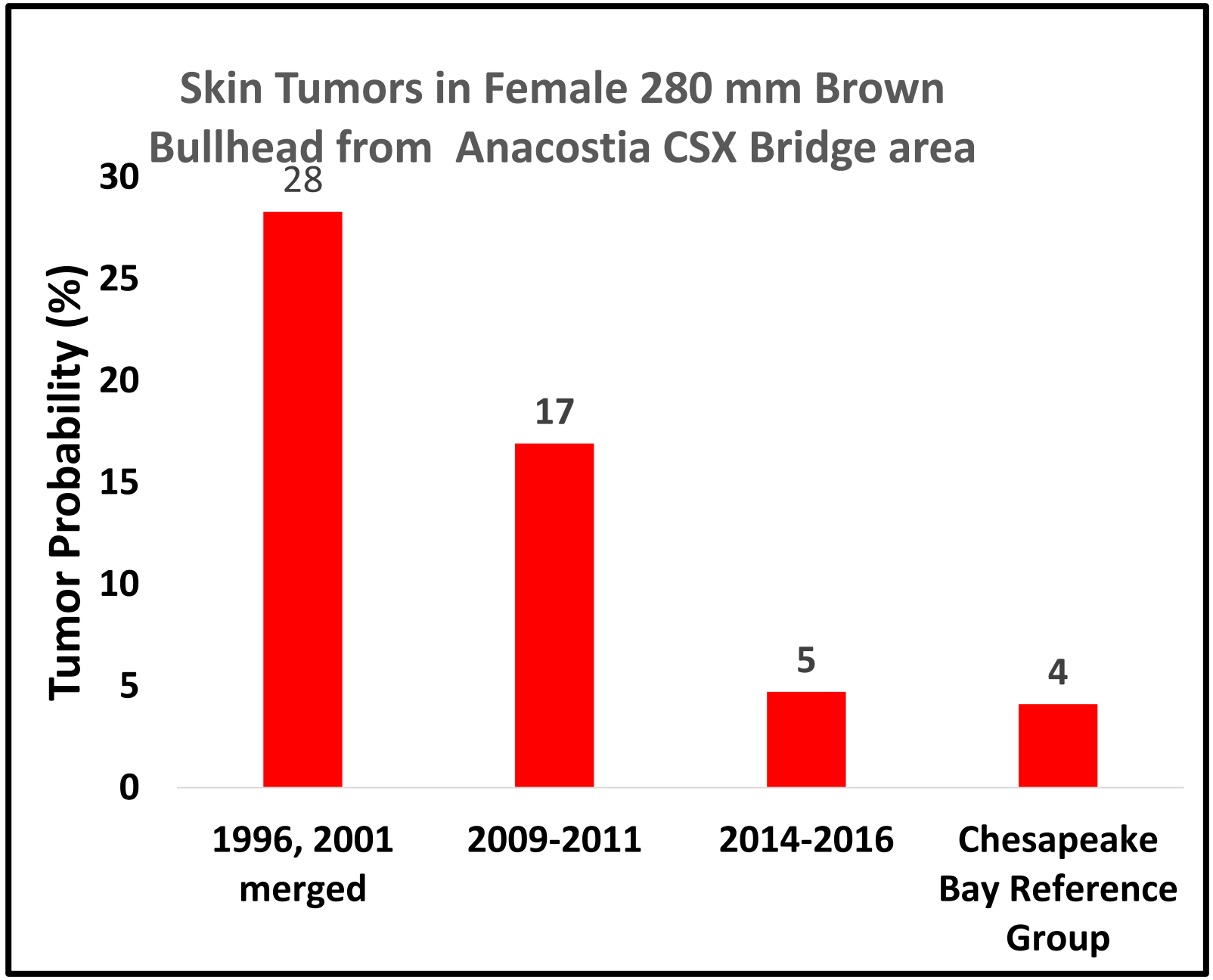
1) compare tumor prevalence in Anacostia vs. neighboring areas and vs. past (trend analysis)
2) analyze 25-year database to identify reference locations and test age, length, sex, and weight as covariates in logistic regression
3) evaluate linkages with exposure to PAHs, polychlorinated biphenyls (PCBs), and DDT to explain trends

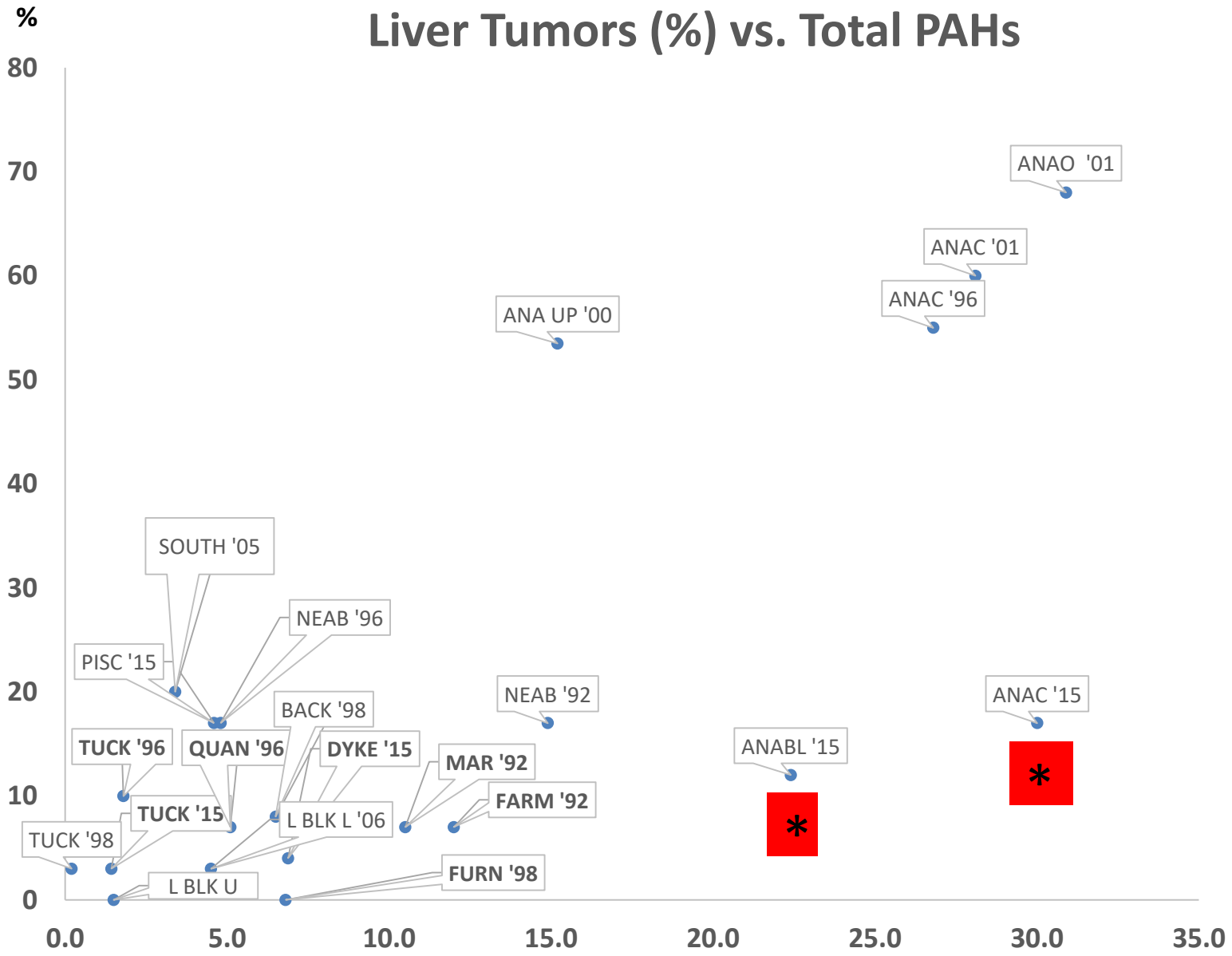

Bladensburg (ANABL)
Upper Anacostia
Potomac R.
DC
Roosevelt Isl.
O St
CSX Br. (ANAC)
Anacostia R.
VIRGINIA
Dyke Marsh
(DYKE)
Piscataway Crk.
(PISC)
Marumsco Crk.
Farm Crk.
Neabsco Crk.
MARYLAND
Potomac River
Quantico Emb.
N
0 3.75 7.5 15
Km
Chesapeake Bay Reference Group
Current sampling
Historical sampling

LIVER TUMOR PROBABILITIES: FEMALES




Liver Tumors in 280 mm Brown Bullhead from Anacostia CSX Bridge area
Tumor Probability (%)
90
80
70
60
50
40
30
20
10
0
Female
Male
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 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)

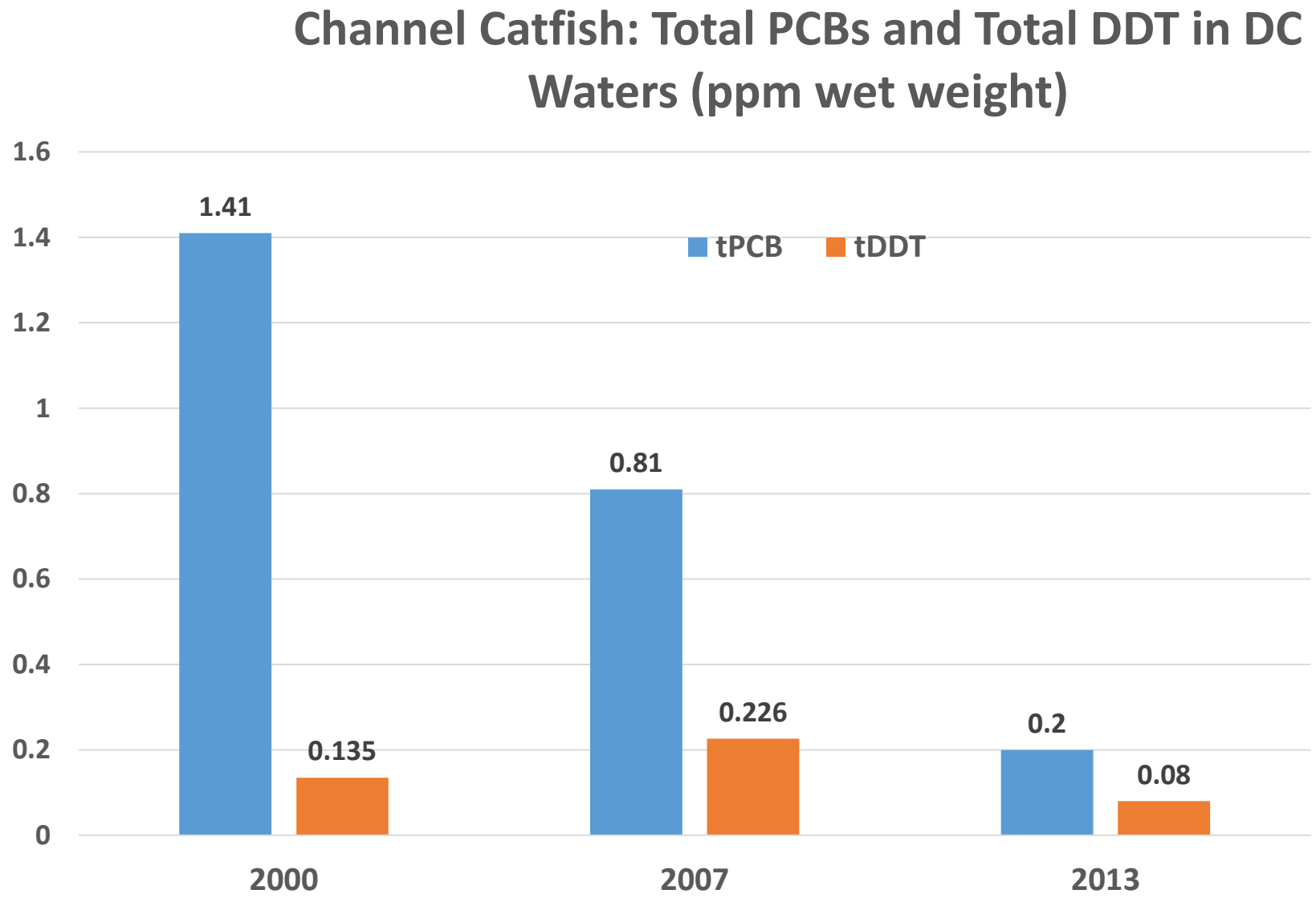
Why are liver tumors decreasing in the Anacostia bullheads?

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

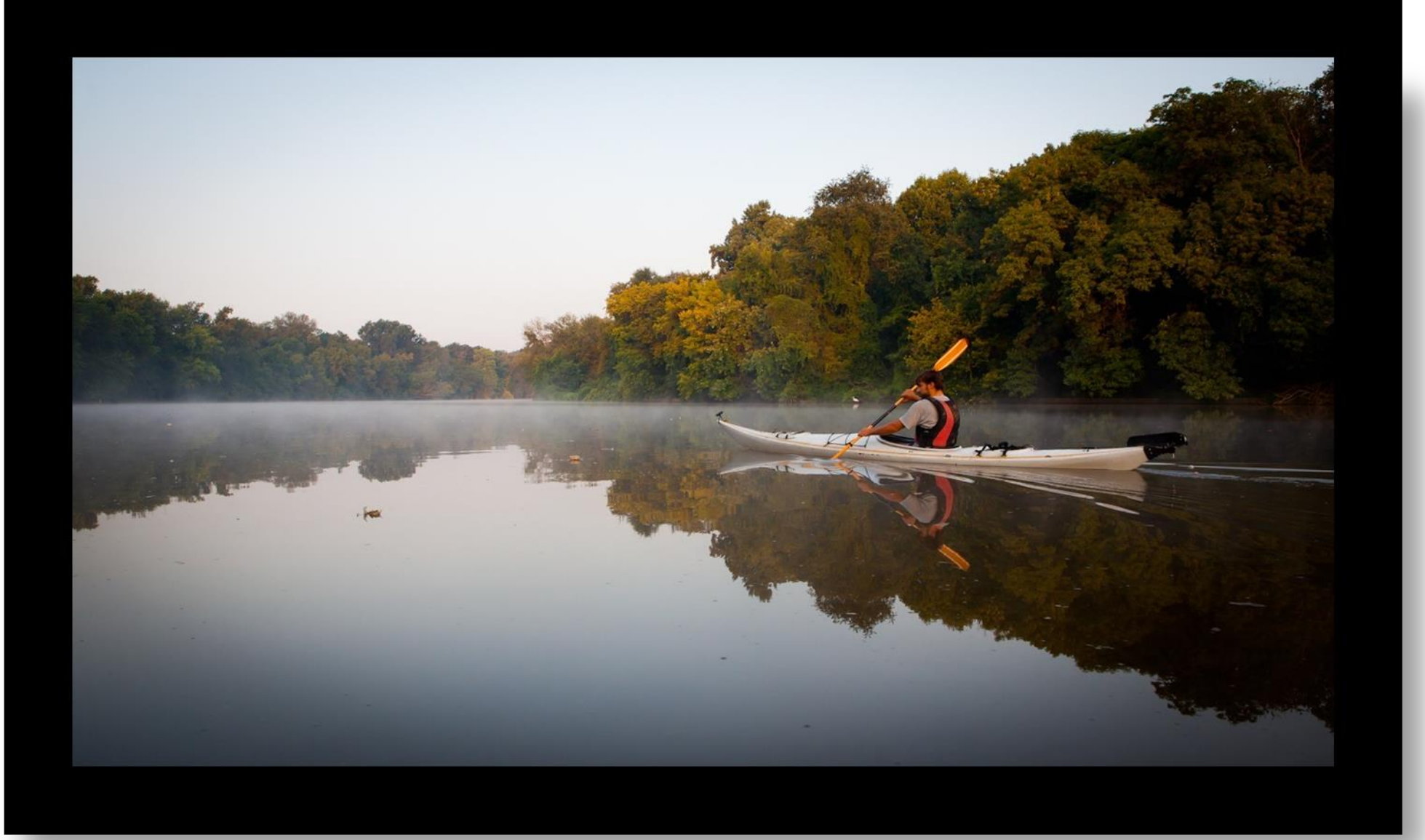
PCB, DDT exposure

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


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 tumors in Anacostia brown bullheads since 1996
- Liver tumors: linked to exposure to PAHs (initiators), PCBs and DDT compounds (promoters); skin tumors not linked with PAHs from other studies
- 2014-16: Piscataway Creek=Anacostia but nearby Dyke Marsh = background—local issue in Creek, not diagnostic of an urban signal



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Pinkney, A.E., J.C. Harshbarger, M.A. Rutter, and P.C. Sakaris. 2019 Trends in liver and skin tumor prevalence in brown bullhead (*Ameiurus nebulosus*) from the Anacostia River, Washington, DC, and nearby waters *Toxicologic Pathology* 47:174-189.