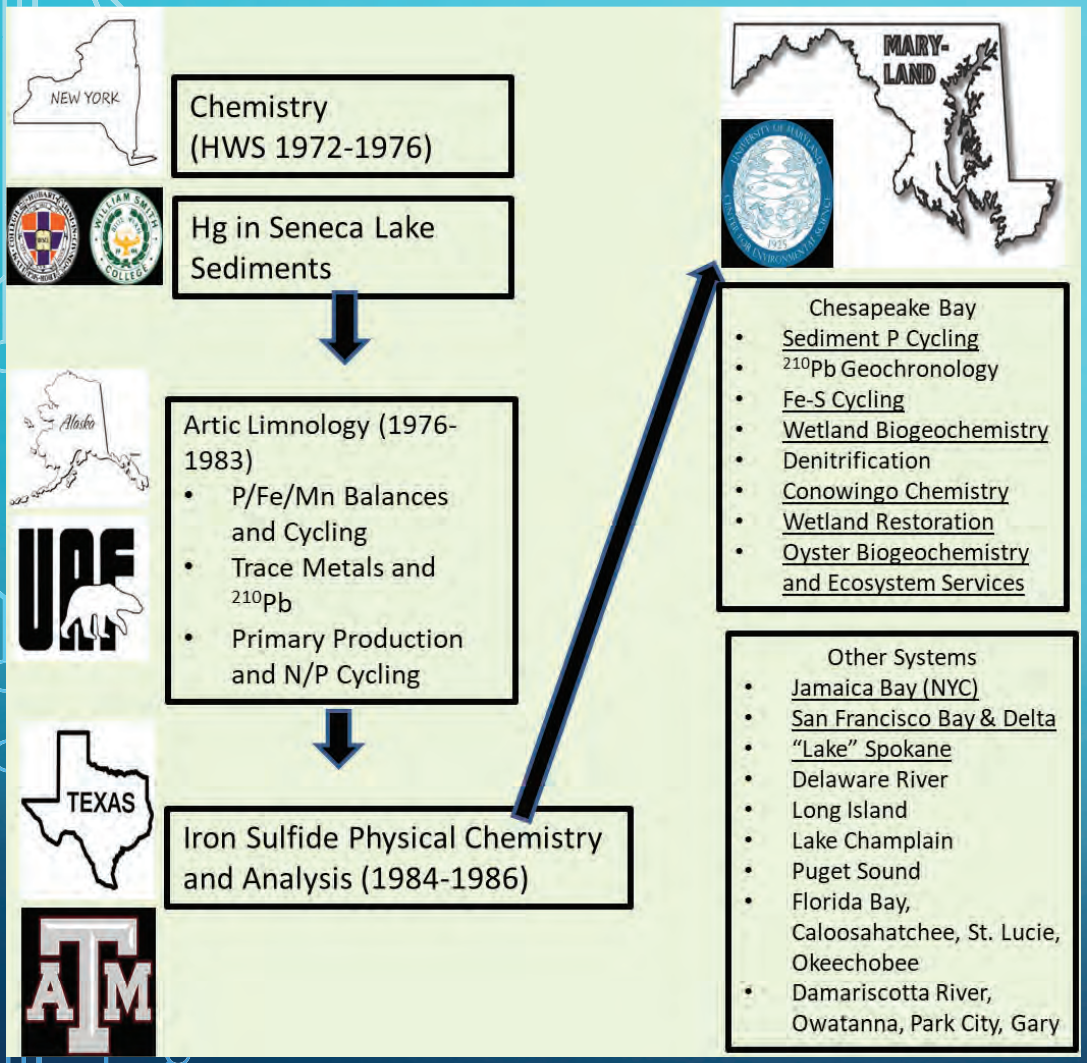
WATER QUALITY AND SEDIMENTS IN MARYLAND RESERVOIRS

JEFFREY CORNWELL

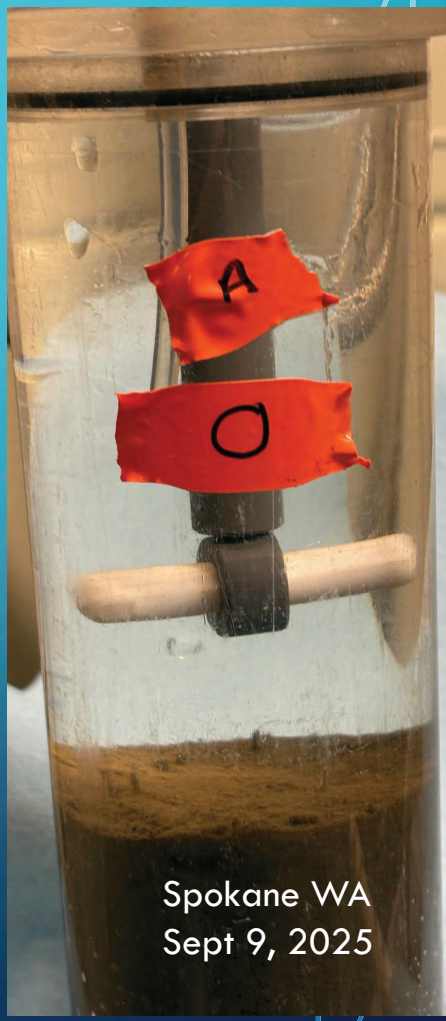
MICHAEL OWENS

ANDREA PAIN

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
HORN POINT LABORATORY

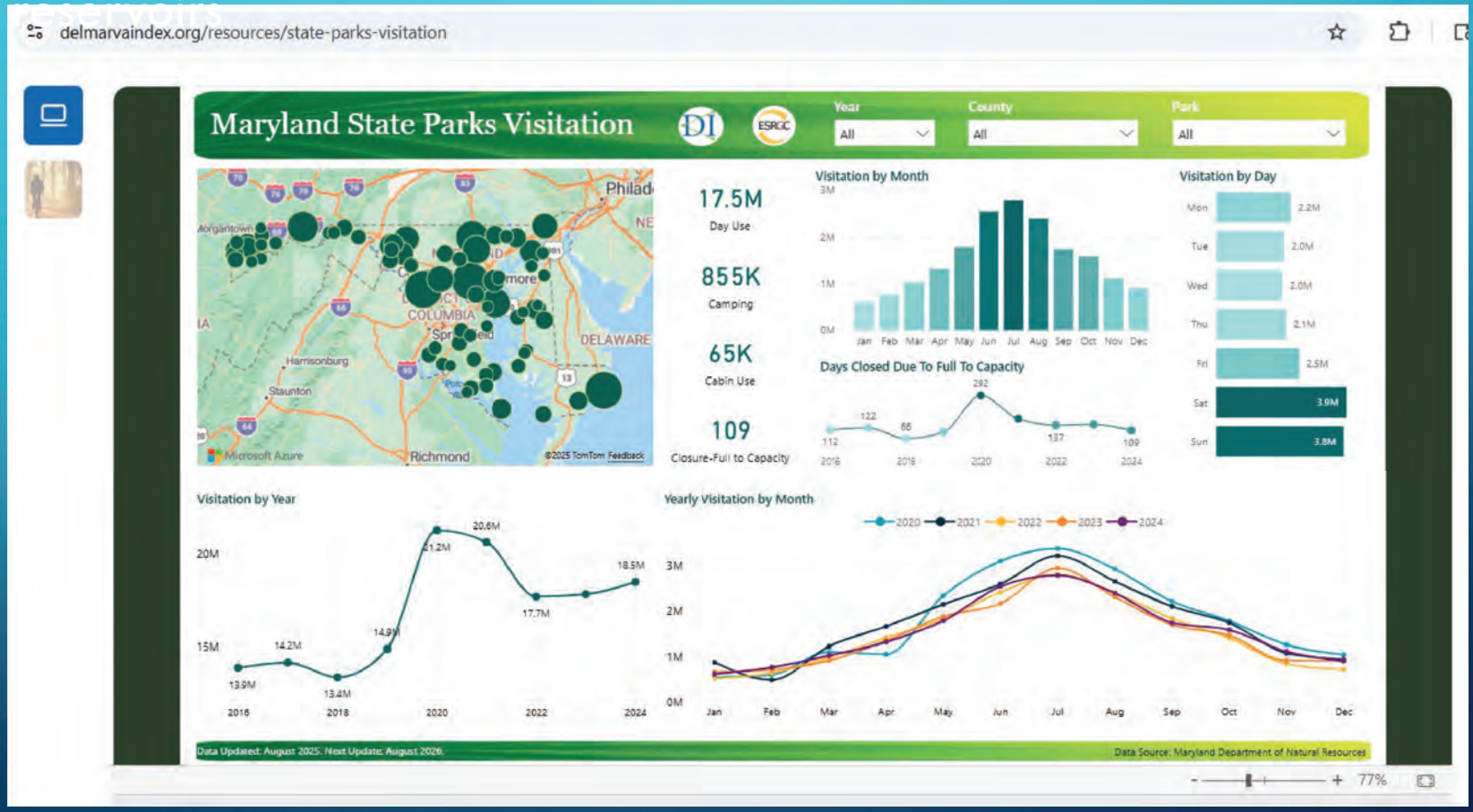


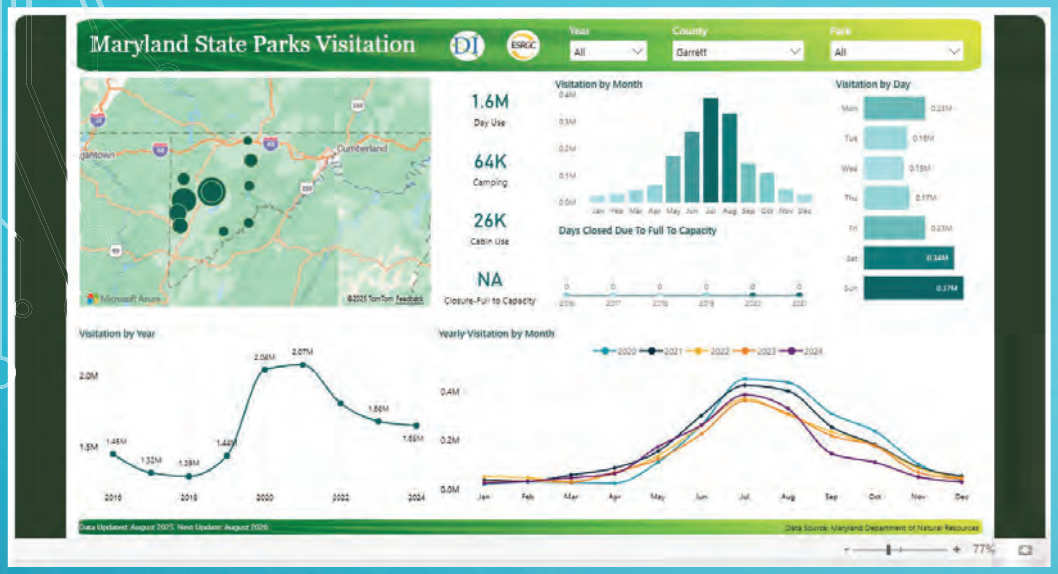
The measurement of biogeochemical processes in lakes, reservoirs, wetlands and estuaries generally utilizes similar approaches. Cores are collected for solid phase characterization and sediment-water exchange experiments are used to determine the effect of sediment processes on overlying water.



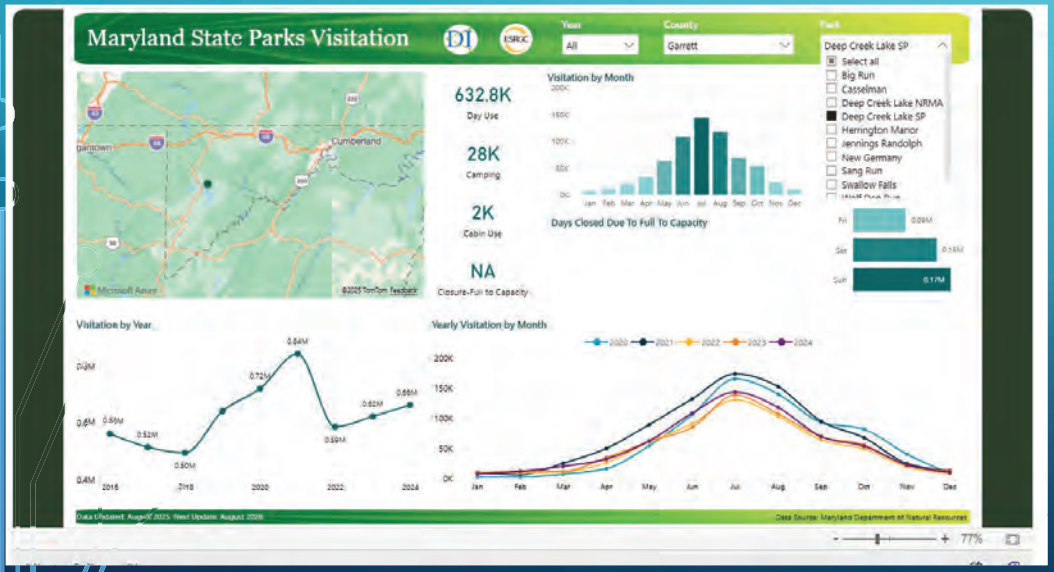
Spokane WA
Sept 9, 2025

Maryland State Parks get a lot of use!!. Many of them have aquatic features – estuarine rivers, bays, ocean beaches and freshwater reservoirs



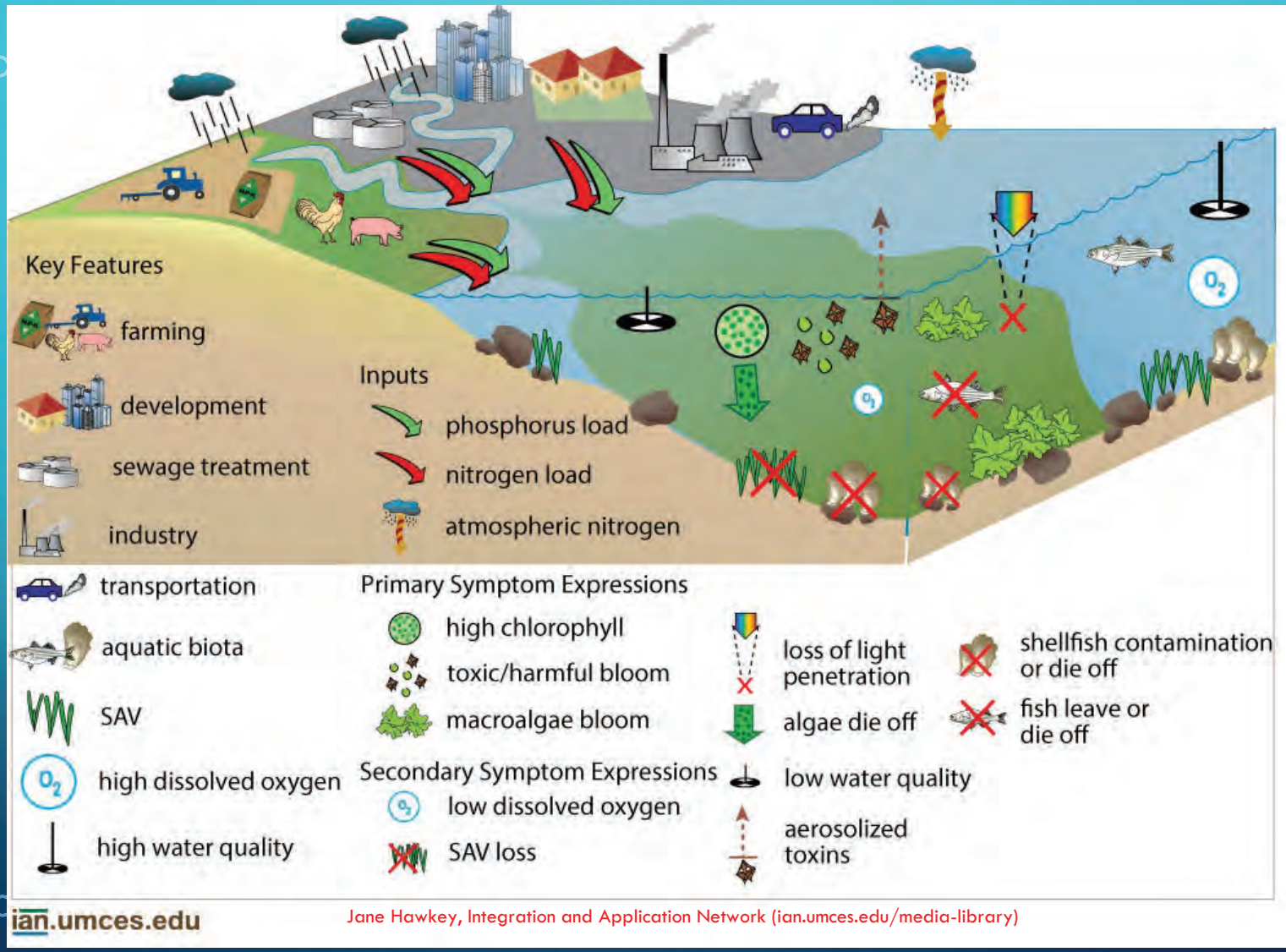


Garrett County



Deep Creek State Park

Consequently, water quality matters for recreation and water supply, there are concerns for water quality and fish habitat with all dams, including those that generate power

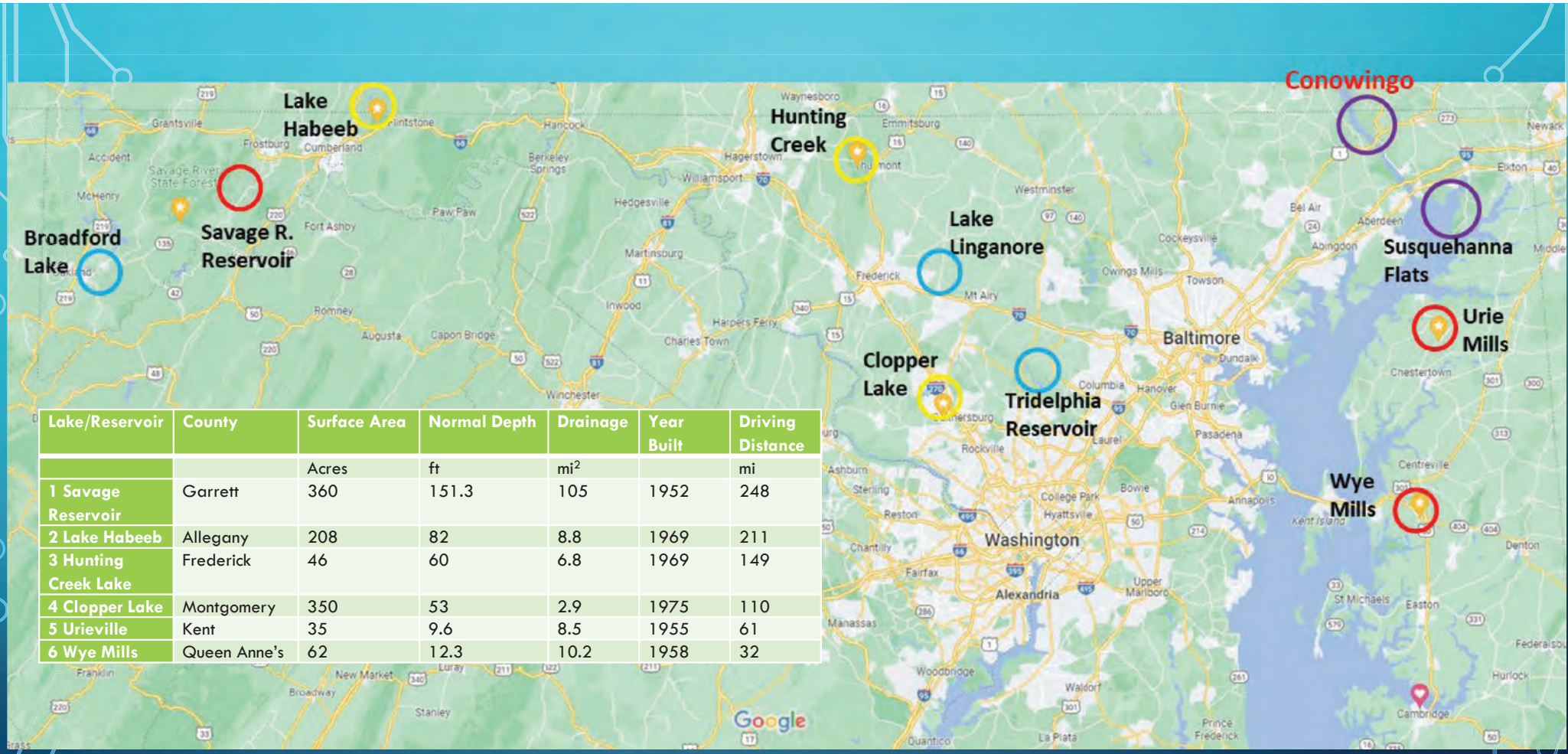


Jane Hawkey, Integration and Application Network (ian.umces.edu/media-library)

Perhaps our two biggest water quality worries (from a chemists perspective):

1. Harmful algae: cyanobacteria, especially Microcystis, can have serious health issues for pets and humans (microcystins are hepatotoxins)
2. Anoxia: limits the living space for mobile creatures, destroys benthic animal communities

Maryland reservoirs have experienced both



Lake/Reservoir	County	Surface Area	Normal Depth	Drainage	Year Built	Driving Distance
		Acres	ft	mi^2		mi
1 Savage Reservoir	Garrett	360	151.3	105	1952	248
2 Lake Habeeb	Allegany	208	82	8.8	1969	211
3 Hunting Creek Lake	Frederick	46	60	6.8	1969	149
4 Clopper Lake	Montgomery	350	53	2.9	1975	110
5 Urieville	Kent	35	9.6	8.5	1955	61
6 Wye Mills	Queen Anne's	62	12.3	10.2	1958	32

Maryland has no natural lakes, but lots of reservoirs. My lab has visited all of these.


Habeeb


Clopper

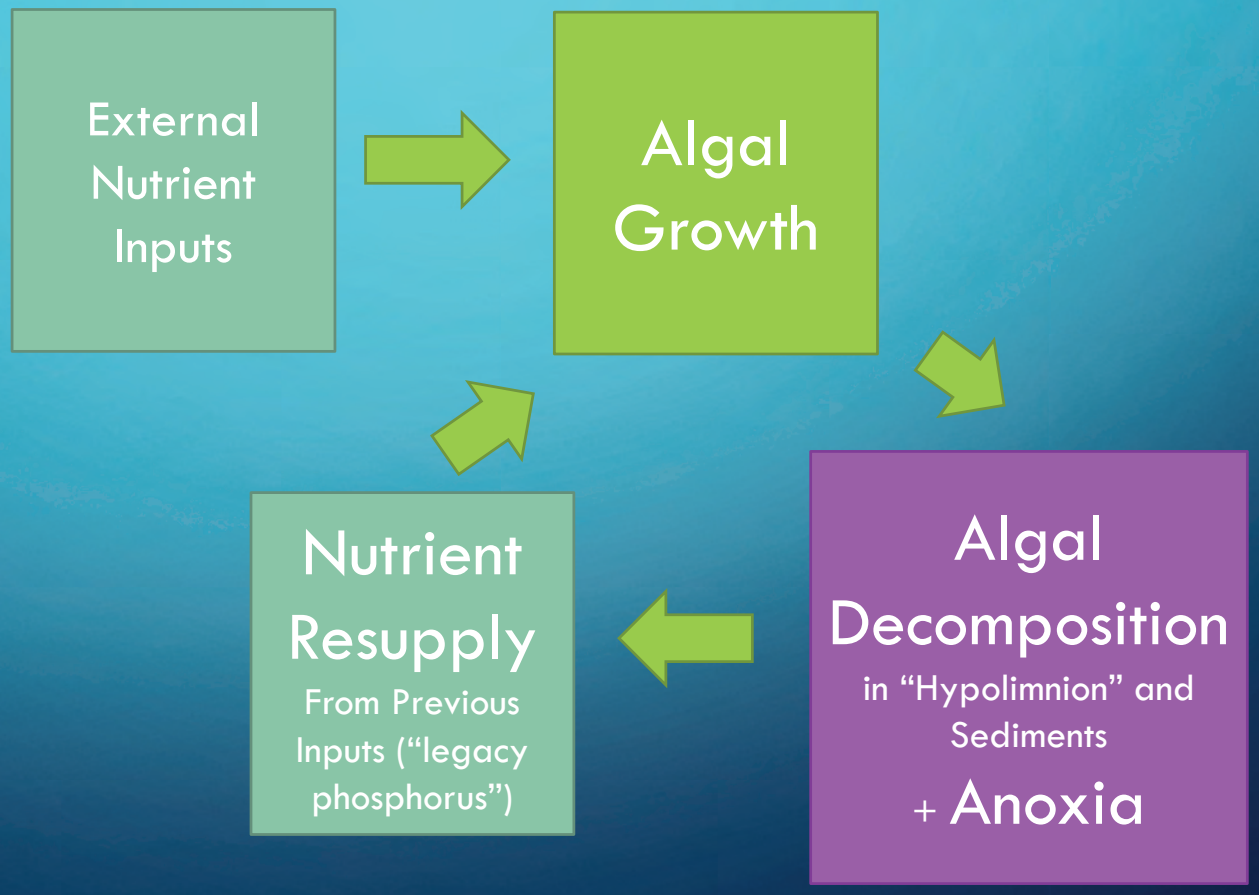

Urieville


Wye Mills Reservoir

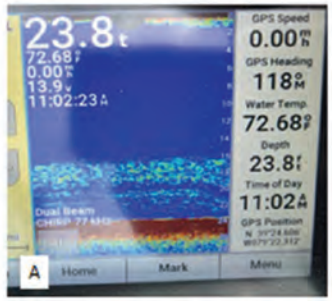

Conowingo
Reservoir

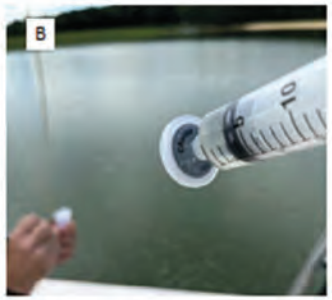

Linganore

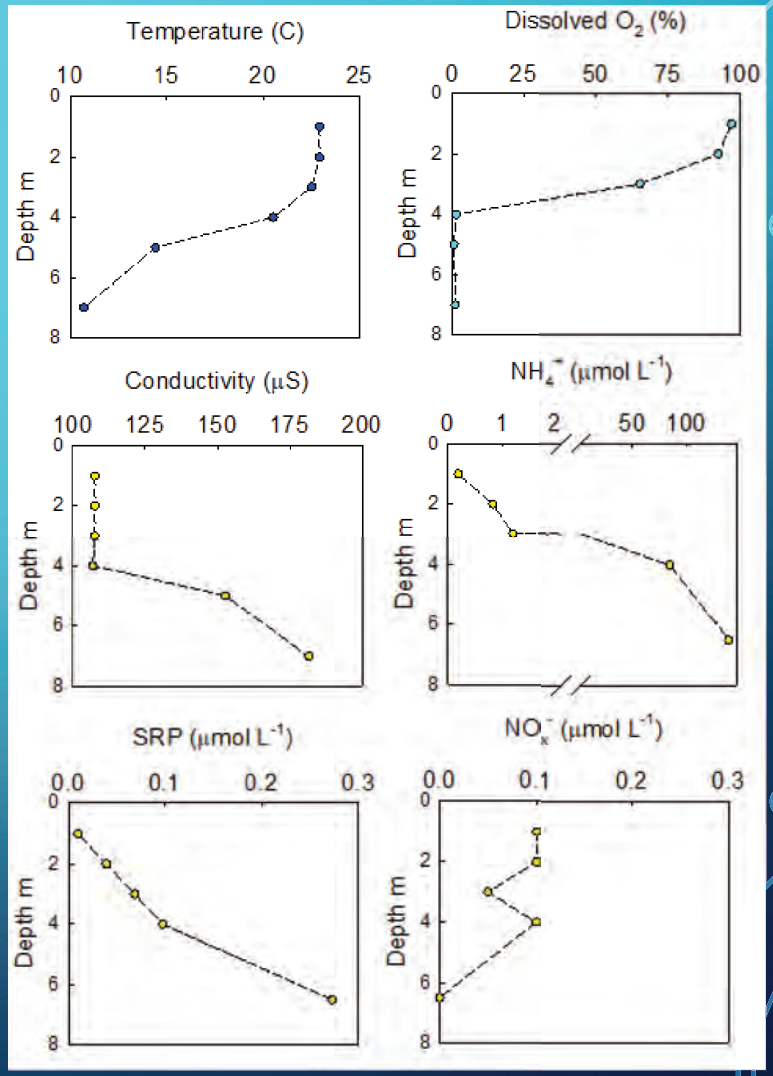
Algal growth is fueled by nutrients (N and P) coming from the land, air, and from resupply from the bottom



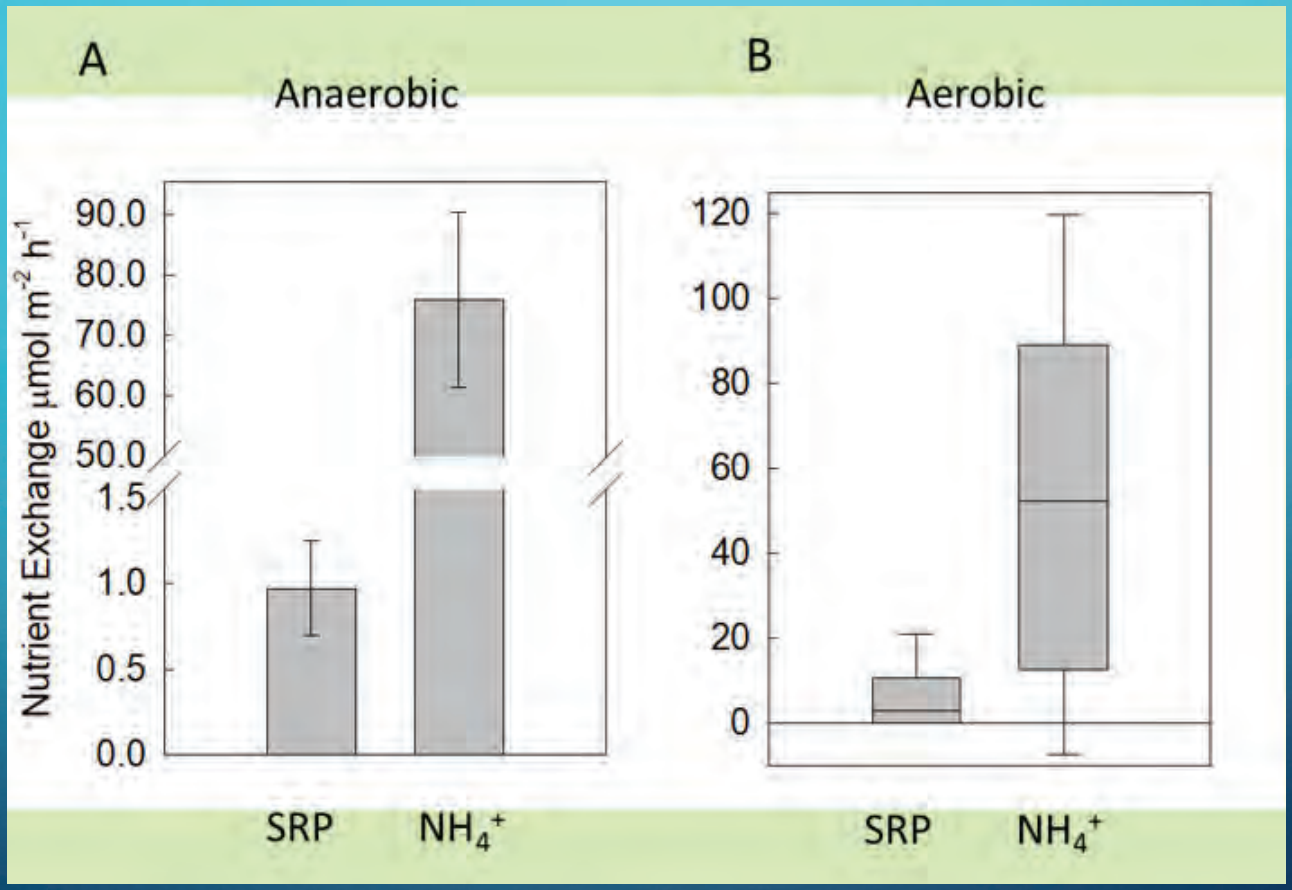
Broadford Lake 2022

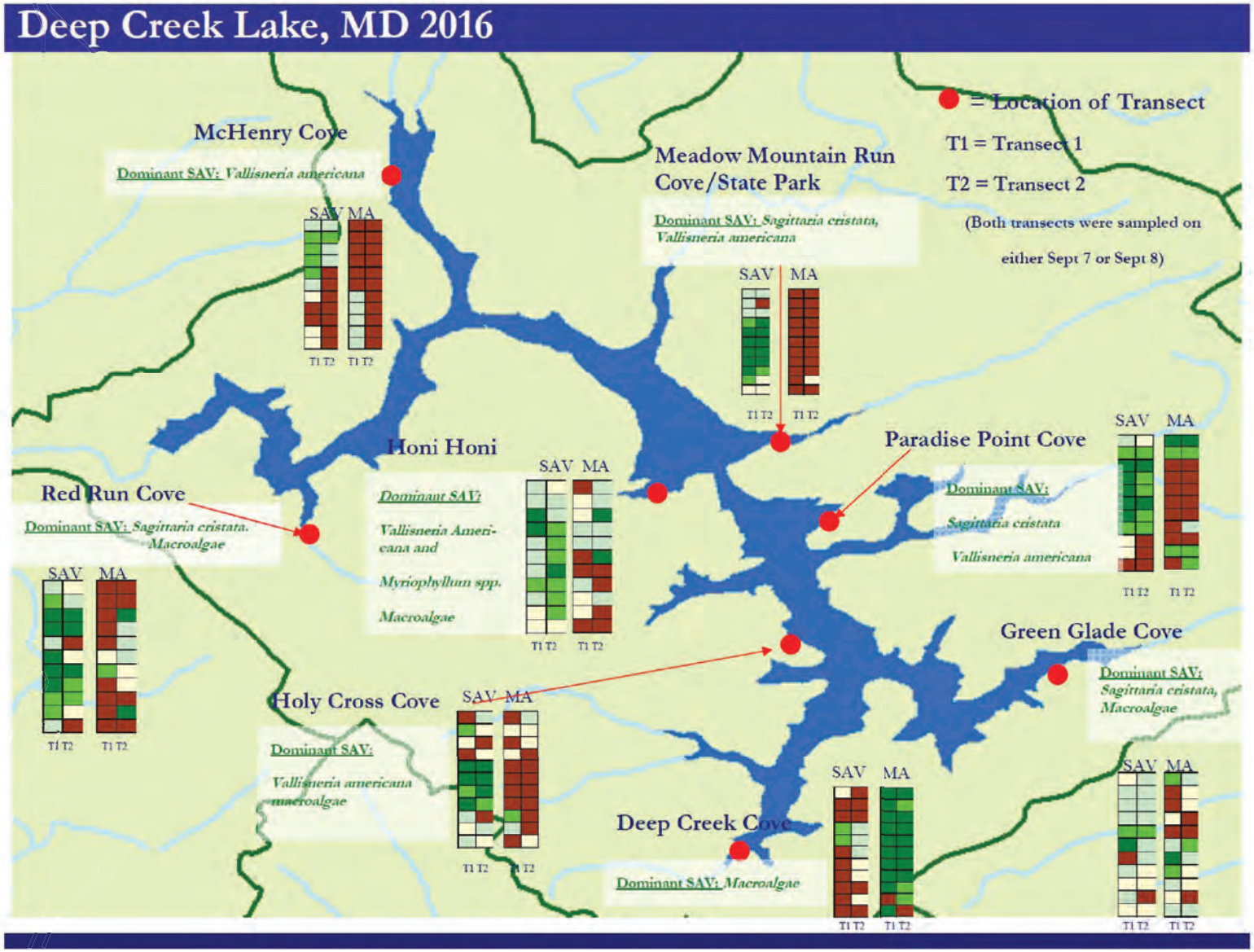






Broadford


A
Anaerobic
B
Aerobic
Nutrient Exchange µmol m-2 h-1
90.0
80.0
70.0
60.0
50.0
1.5
1.0
0.5
0.0
120
100
80
60
40
20
0
SRP
NH4+
SRP
NH4+



MARYLAND DEPARTMENT OF NATURAL RESOURCES

Resource Assessment Service

Deep Creek Lake Submerged Aquatic Vegetation Survey 2016

Report of Survey Activity and Results

Prepared For

Maryland Department of Natural Resources

Maryland Park Service

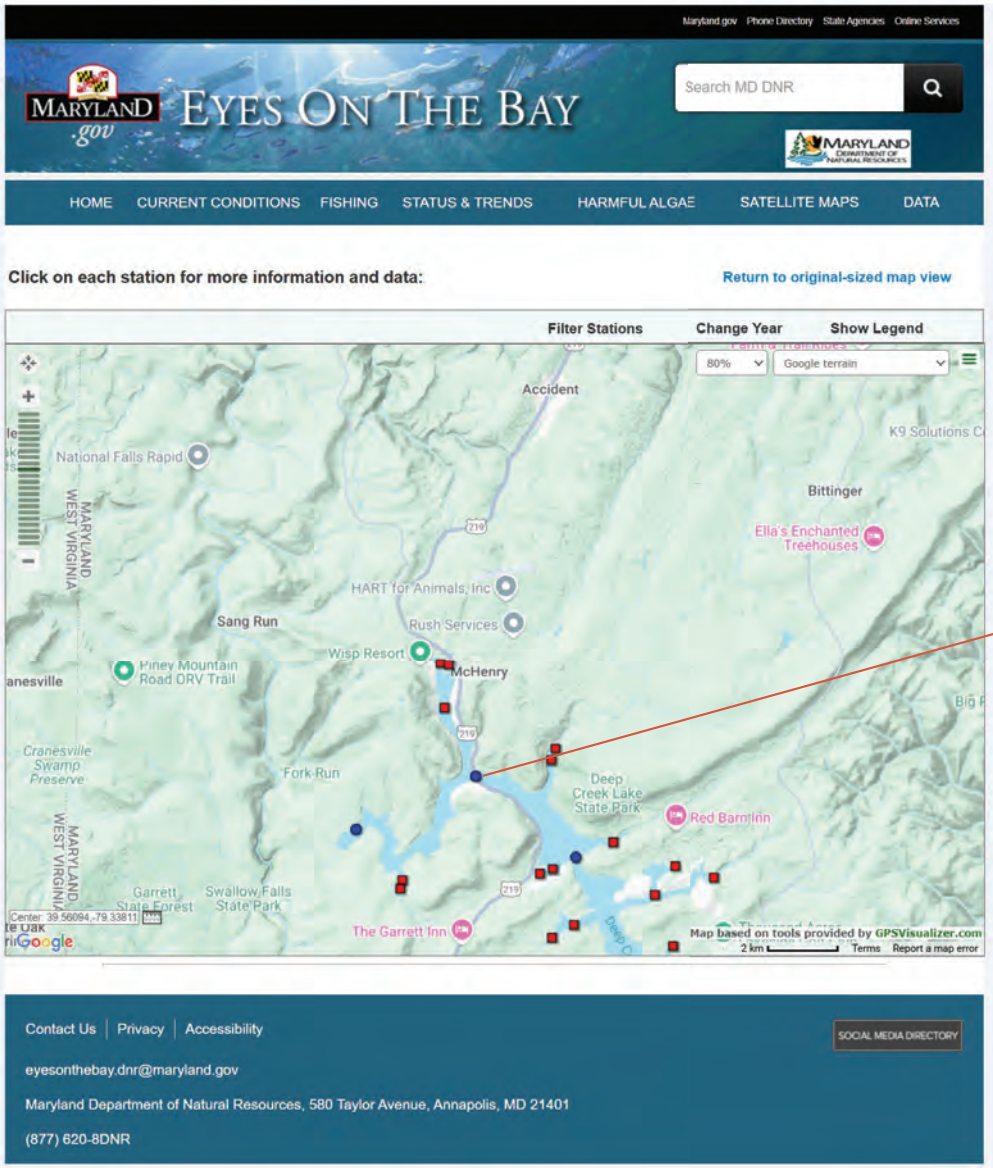
Prepared by

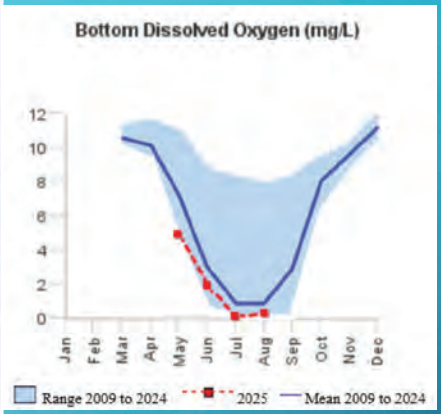
Julie Bortz,

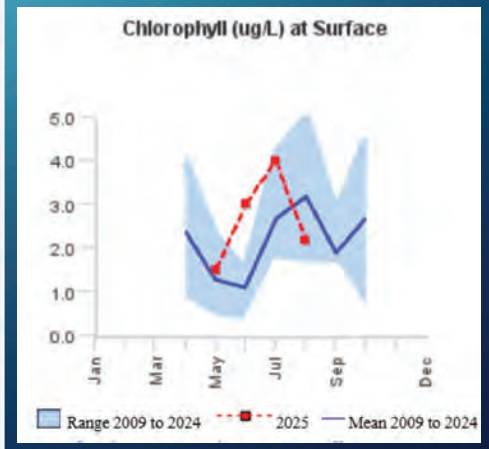
Brooke Landry and Rebecca Golden

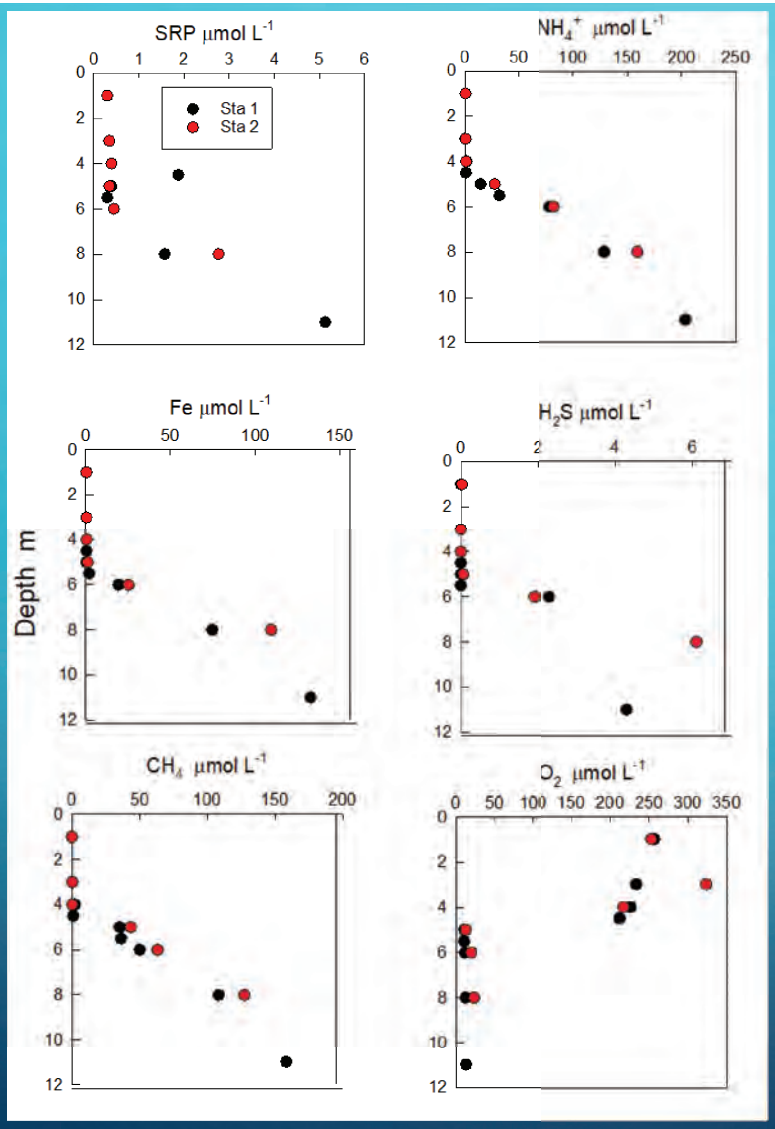
Maryland Department of Natural Resources

Anoxia forms via the consumption of oxygen as algae decomposes in bottom waters. Because of physical stratification of the water via temperature-related differences in density, oxygen in the atmosphere cannot resupply it to bottom waters.



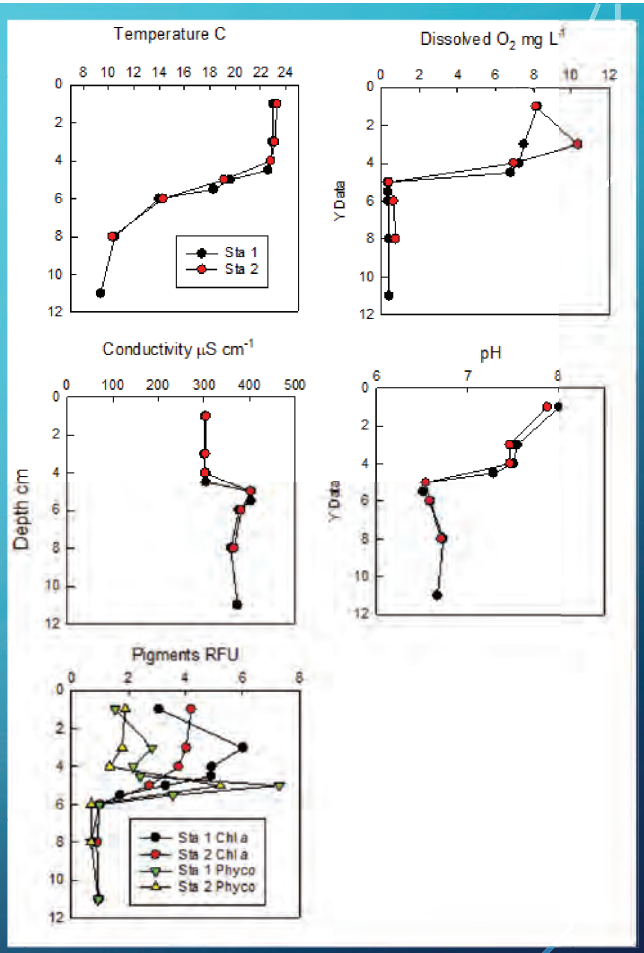






Clopper Lake Vertical Profiles – Lots of Chemical Cycling

Sept 2023



ONGOING WORK

- One more sampling period for Urieville, Wye, and Savage River. Savage River Reservoir has really rocky sediments, so not too much sediment chemistry…
- Comprehensive report on sediment chemistry of 6 reservoirs, 1 journal publication
- Will be discussing Deep Creek Lake sediment chemistry with DNR to see if they want a 2026 study
- Involved with Conowingo Reservoir discussions of mitigation (Maryland Dept. of the Environment, USACE, USEPA)

cornwell@umces.edu

Mercury Cycling in an Evolving Reservoir

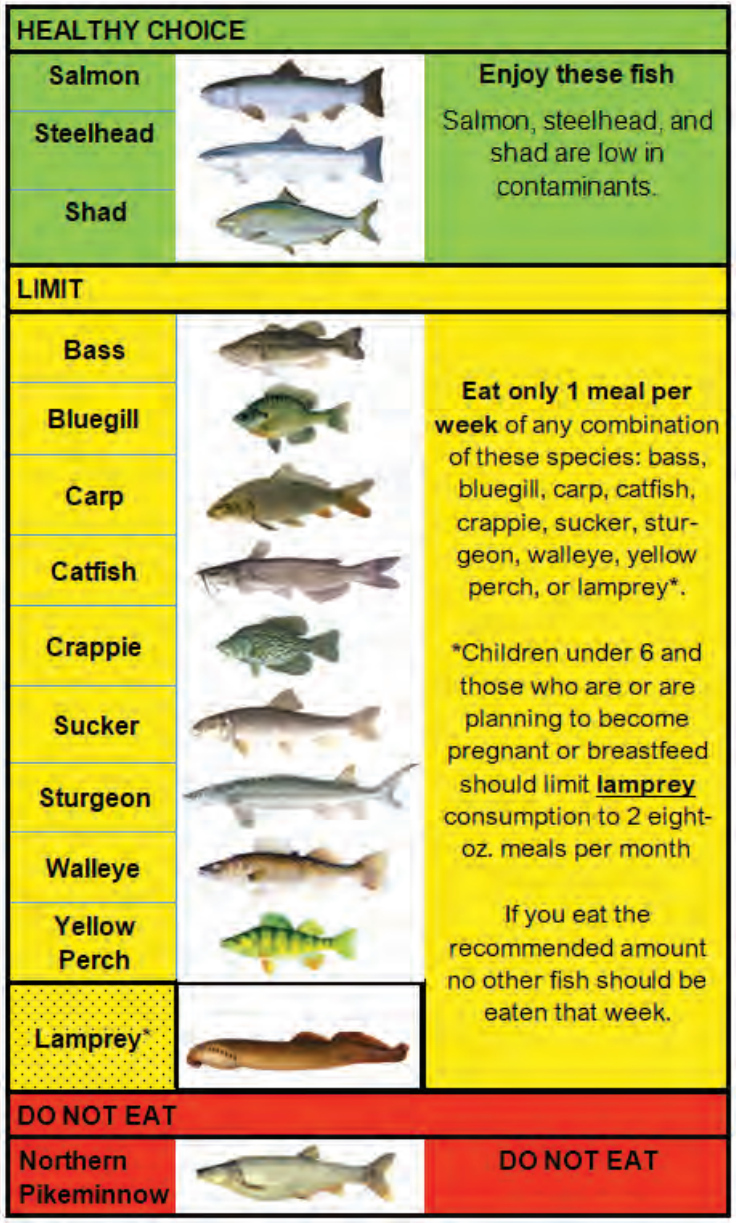
Deep Creek Lake - A system under stress?

Research is funded by a
grant from Maryland DNR

Andrew Heyes
Ryan Woodland
Chesapeake Biological Laboratory

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY

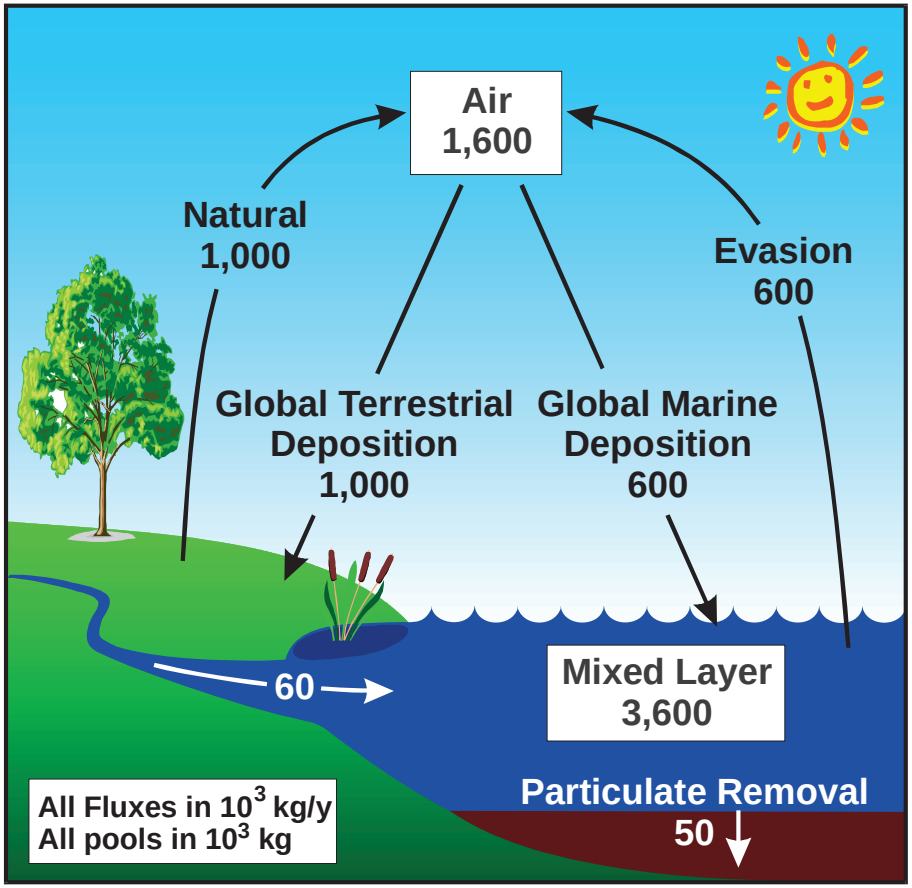
From Oregon Health



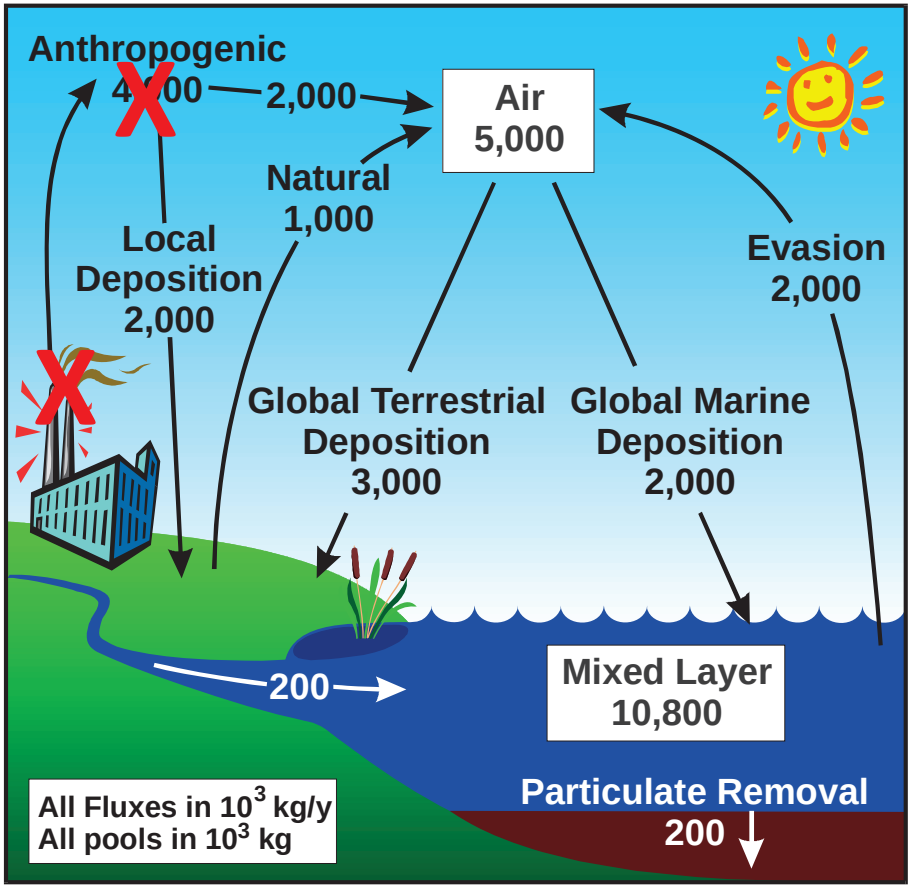
https://www.oregon.gov/oha/ph/healthyenvironments/recreation/fishconsumption/pages/mid-columbia.aspx

Global Mercury Cycle

Pre-industrial



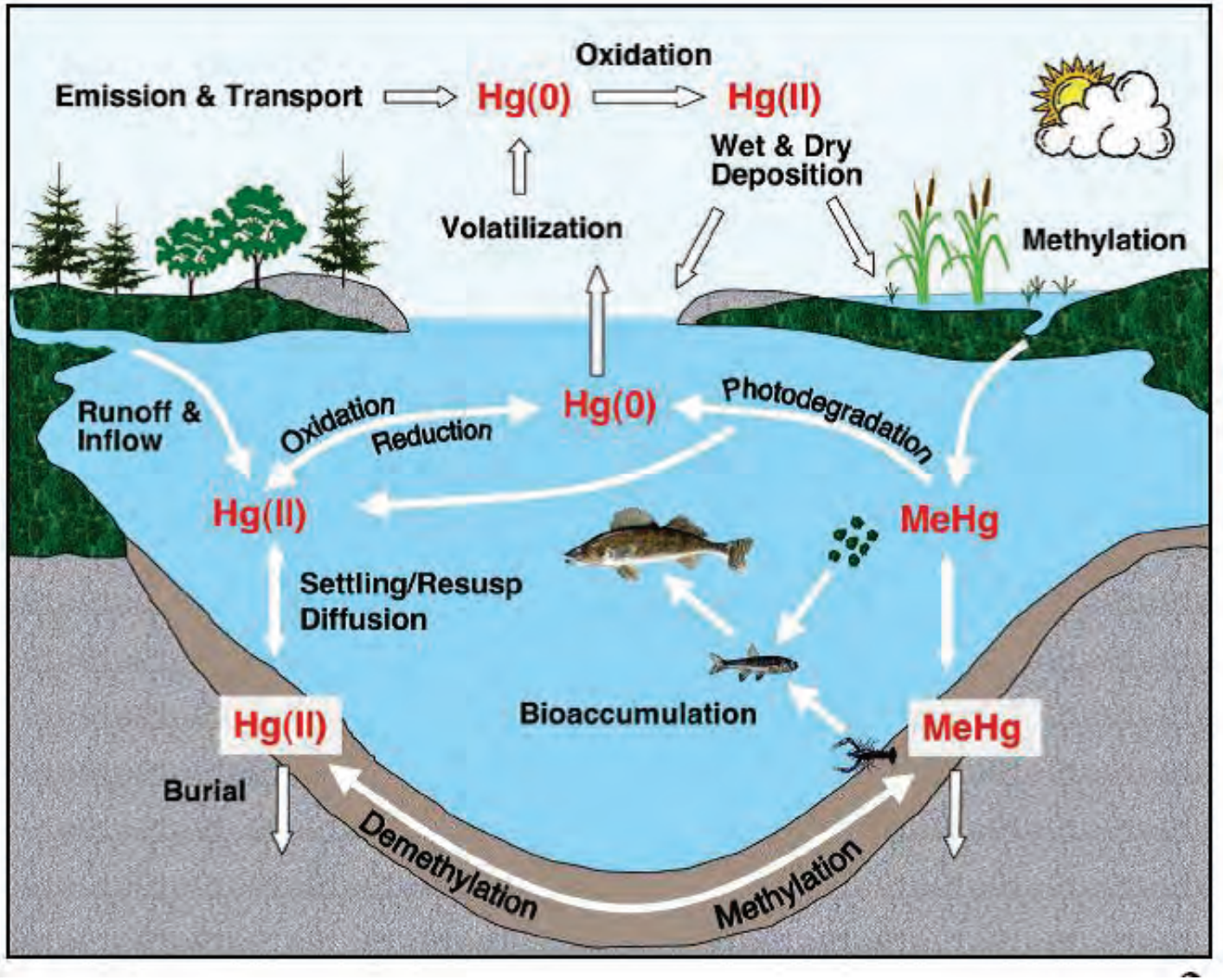
Current



Mason et al. 1994

https://doi.org/10.1016/0016-7037(94)90046-9

R.P. Mason, W.F. Fitzgerald, F.M.M. Morel,
The biogeochemical cycling of elemental mercury: Anthropogenic influences,
Geochimica et Cosmochimica Acta, Volume 58, Issue 15, 1994,
Pages 3191-3198



Engstrom, Daniel R. 2007. “Fish respond when the mercury rises.” Proceedings of the National Academy of Sciences 104, no. 42: 16394-16395.

Methylmercury is accumulated by organisms faster than it is lost

more at risk

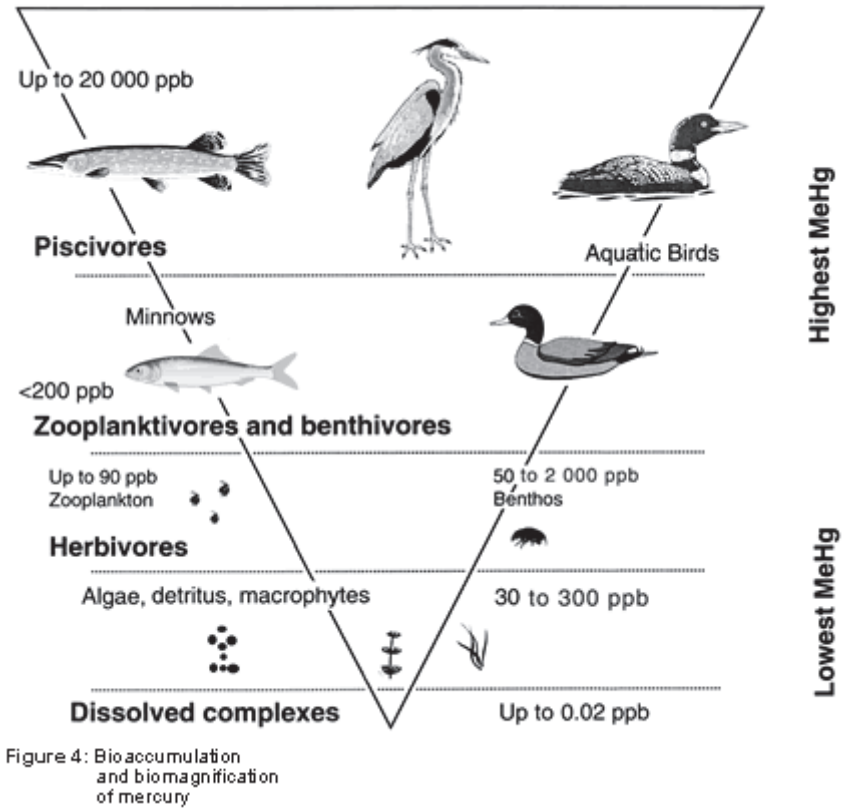
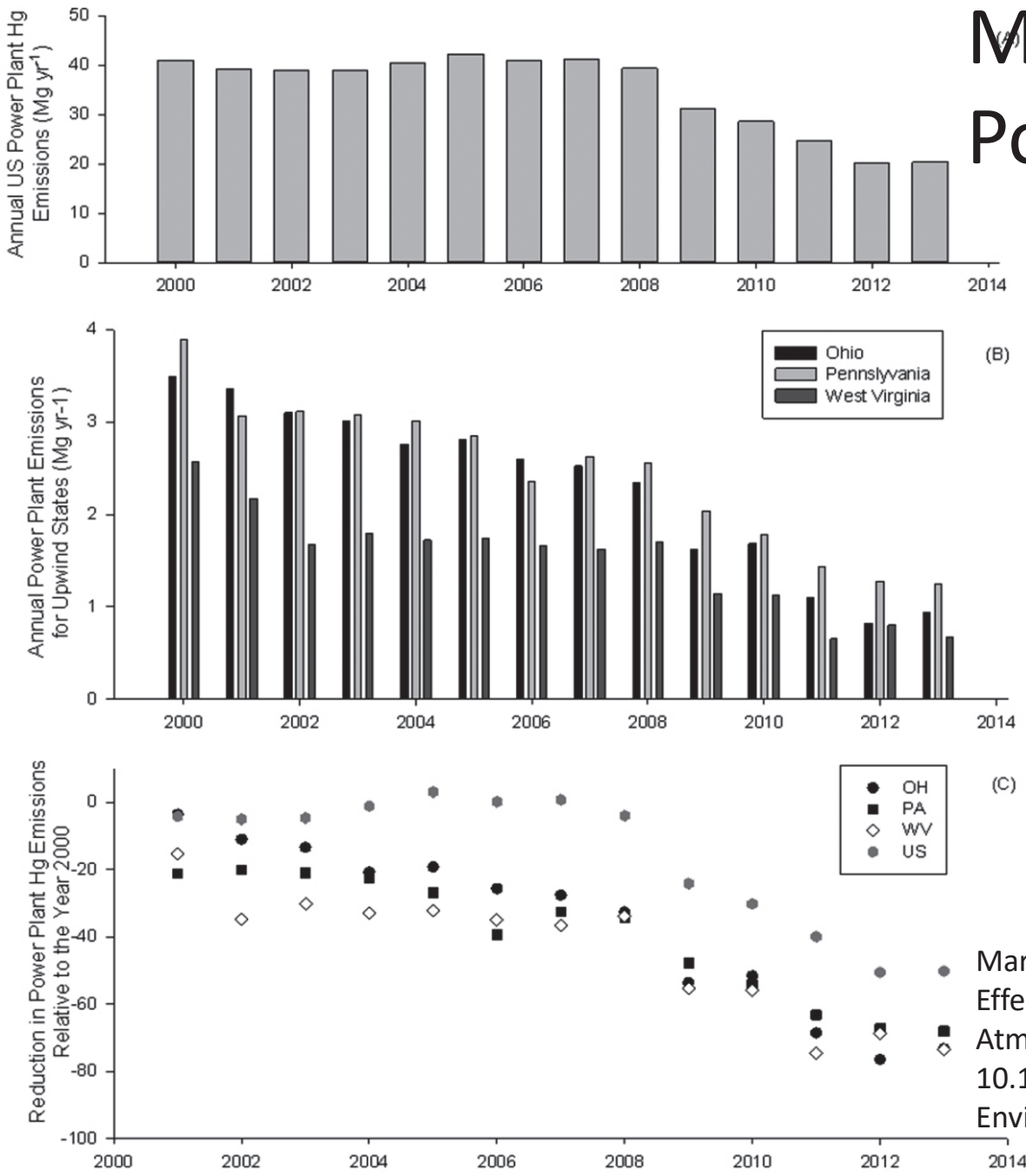


Figure 4: Bioaccumulation and biomagnification of mercury

Bioaccumulation of Hg really means methylmercury

Mercury Emissions Power Plants



Mark S. Castro*,† and John Sherwell. 2016. Effectiveness of Emission Controls to Reduce the Atmospheric Concentrations of MercuryDOI: 10.1021/acs.est.5b03576
Environ. Sci. Technol. 2015, 49, 14000−14007

Maryland's Response

Multi component study looking at the impact of reduced Hg emissions

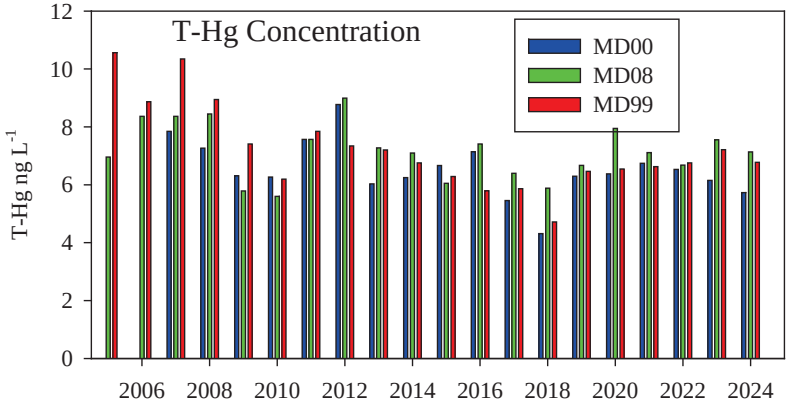
1) **Hg deposition**
2) Observing Hg and MeHg flux from watersheds
3) **Accumulation of Hg in fish using young of the year fish**

Wet deposition

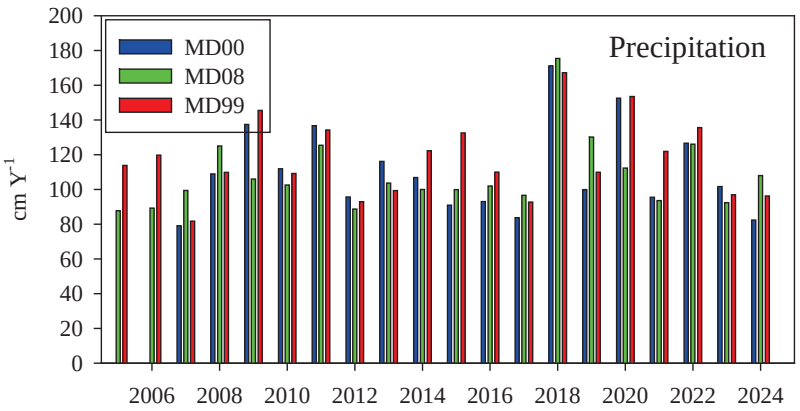
MD00 Edgewater MD
MD08 Piney Reservoir MD
MD99 Beltsville MD

Wet deposition is at most half the annual loading with the rest occurring as dry deposition

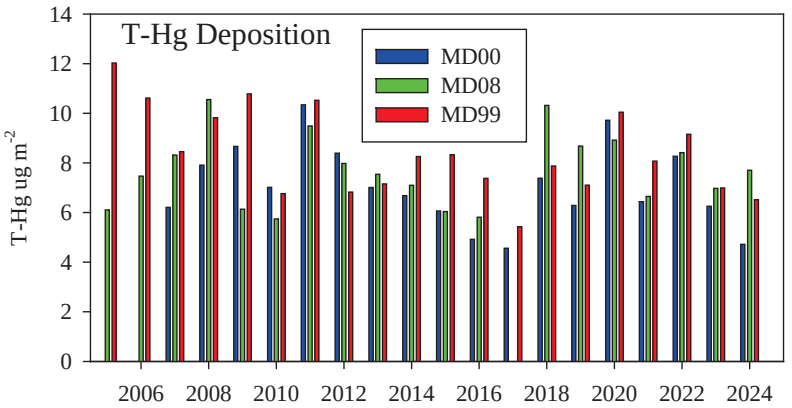
a)



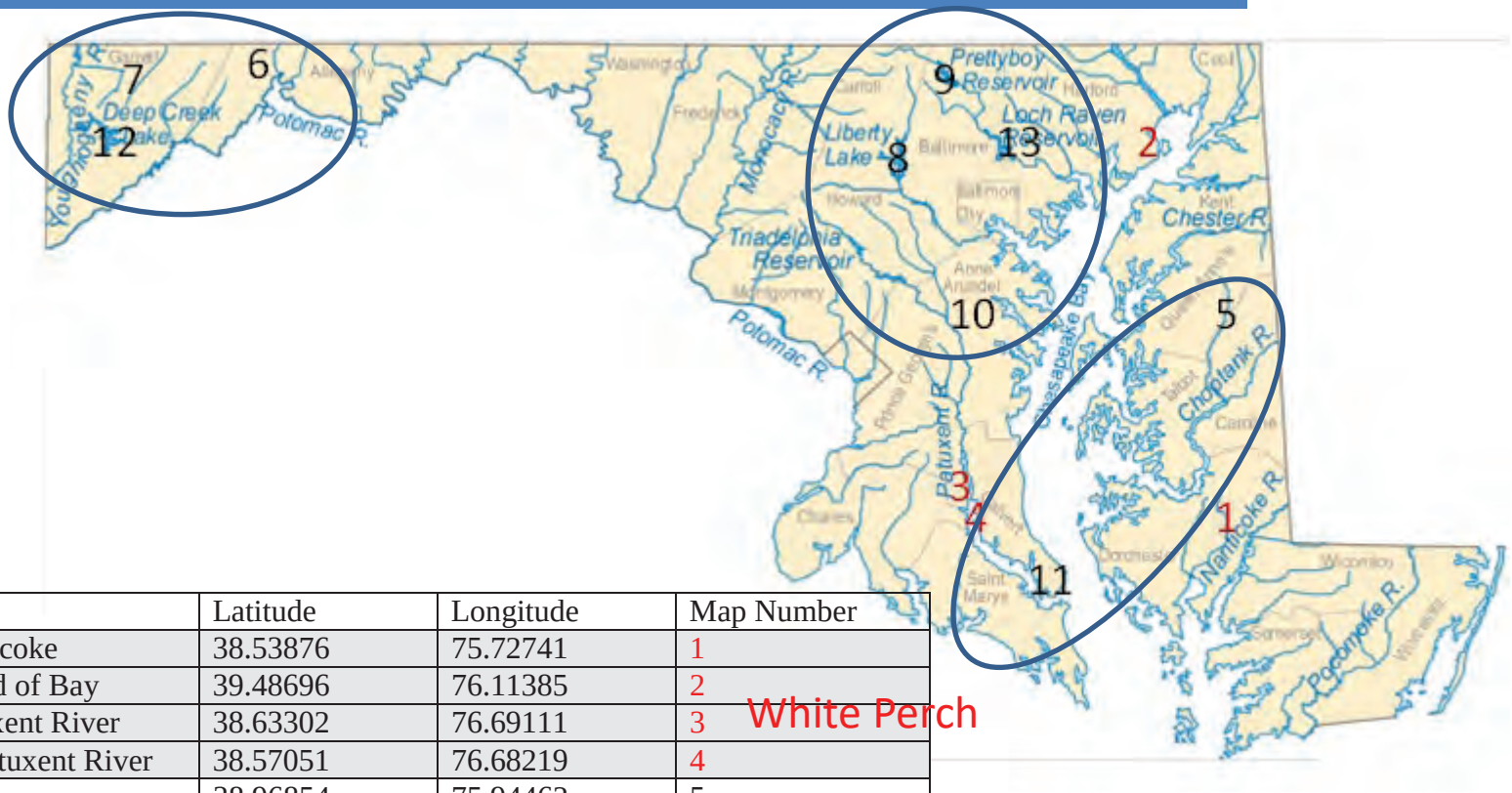
b)



c)



Young of the Fish Year Study

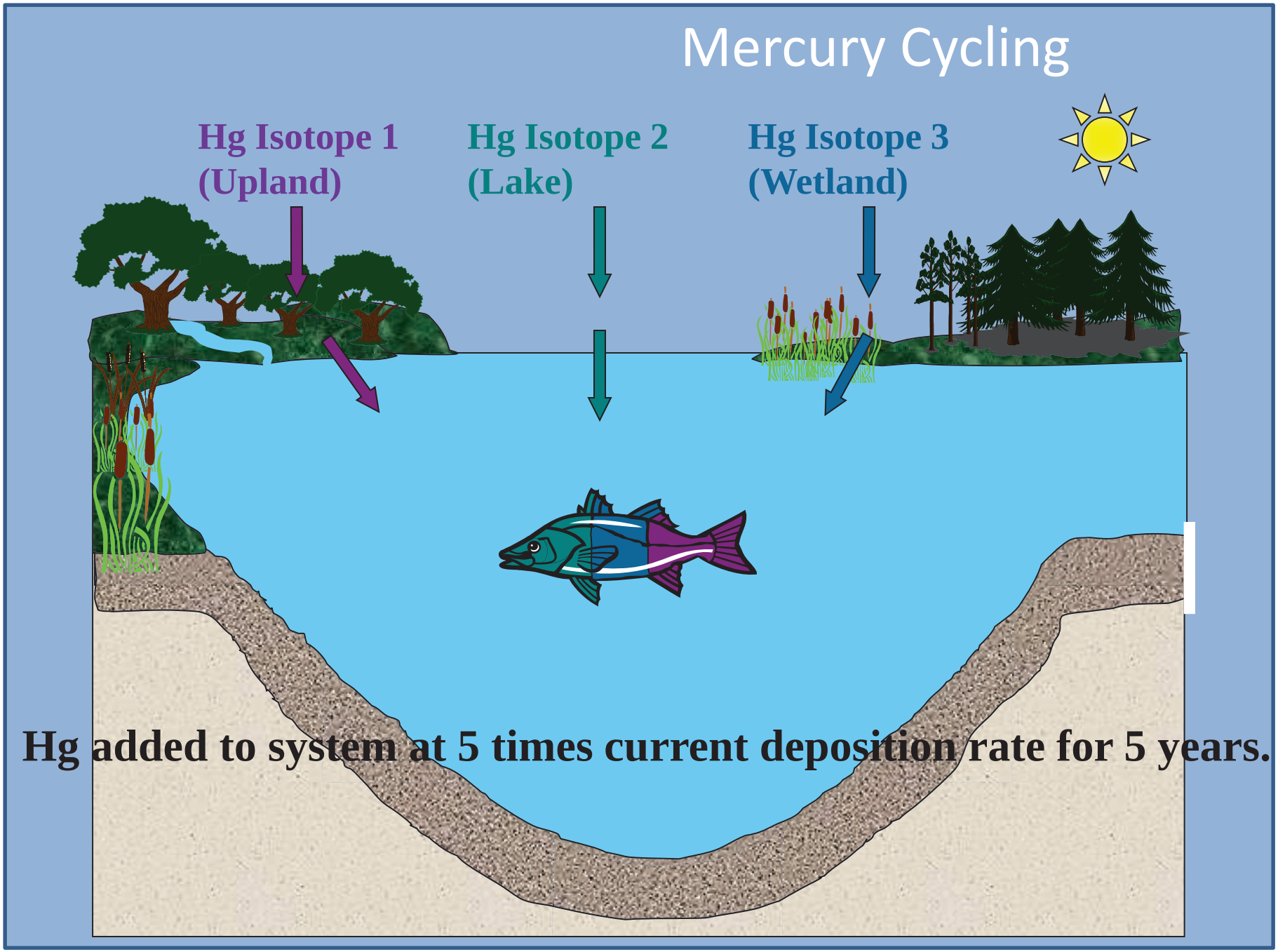


Site	Latitude	Longitude	Map Number
Sharptown-nanticoke	38.53876	75.72741	1
Plum-Point Head of Bay	39.48696	76.11385	2
Mill Town Patuxent River	38.63302	76.69111	3
Eagle Harbor Patuxent River	38.57051	76.68219	4
Tuckahoe Lake	38.96854	75.94462	5
Piney Reservoir	39.70842	79.0018	6
Savage River Reservoir	39.54327	79.13751	7
Liberty Reservoir	39.44576	76.88376	8
Prettyboy Reservoir	39.65239	76.74183	9
Cash Lake	39.03199	76.79729	10
Lake Lariat	38.37774	76.42265	11
Deep Creek	39.55807	79.35482	12
Loch Raven	39.46250	76.57814	13

White Perch

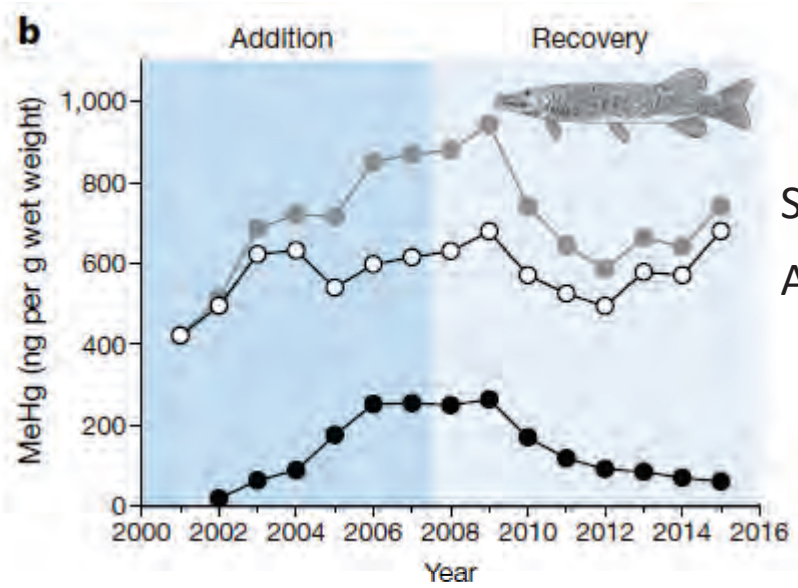
Bass

Mercury Cycling



Hg added to system at 5 times current deposition rate for 5 years.

Predatory Pike

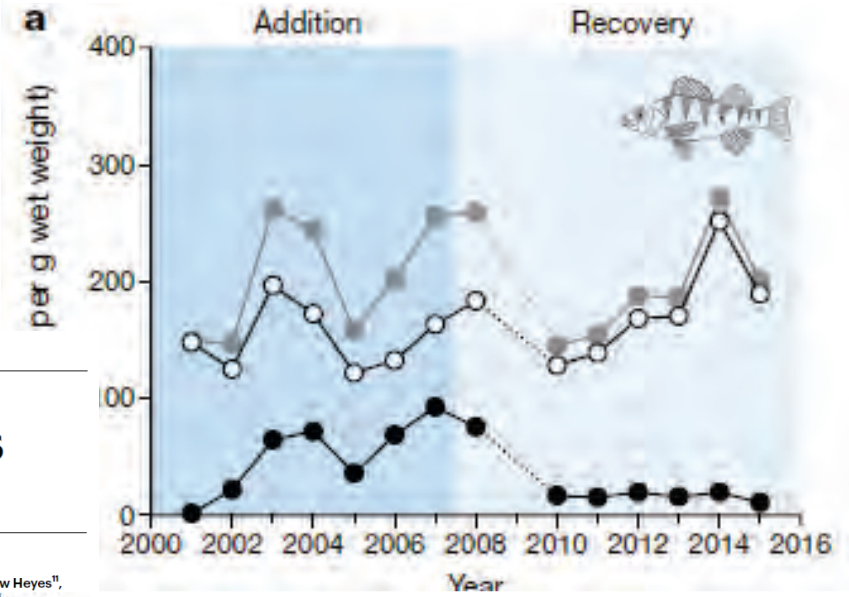


Sp+ Amb

Ambient

Spike

Year plus 1 Yellow Perch



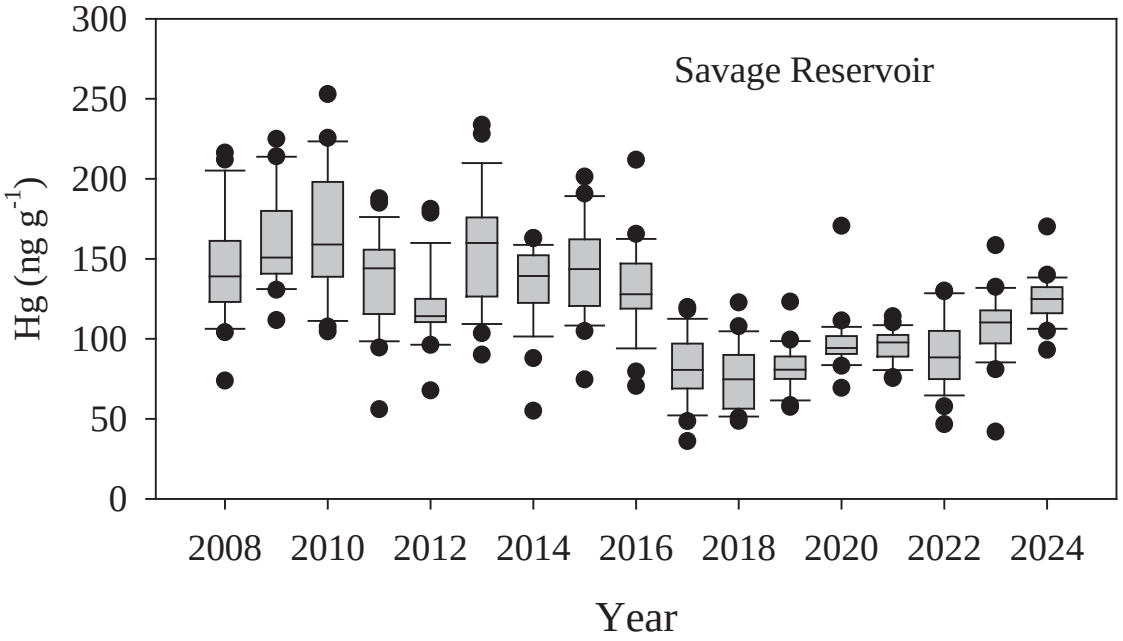
Article

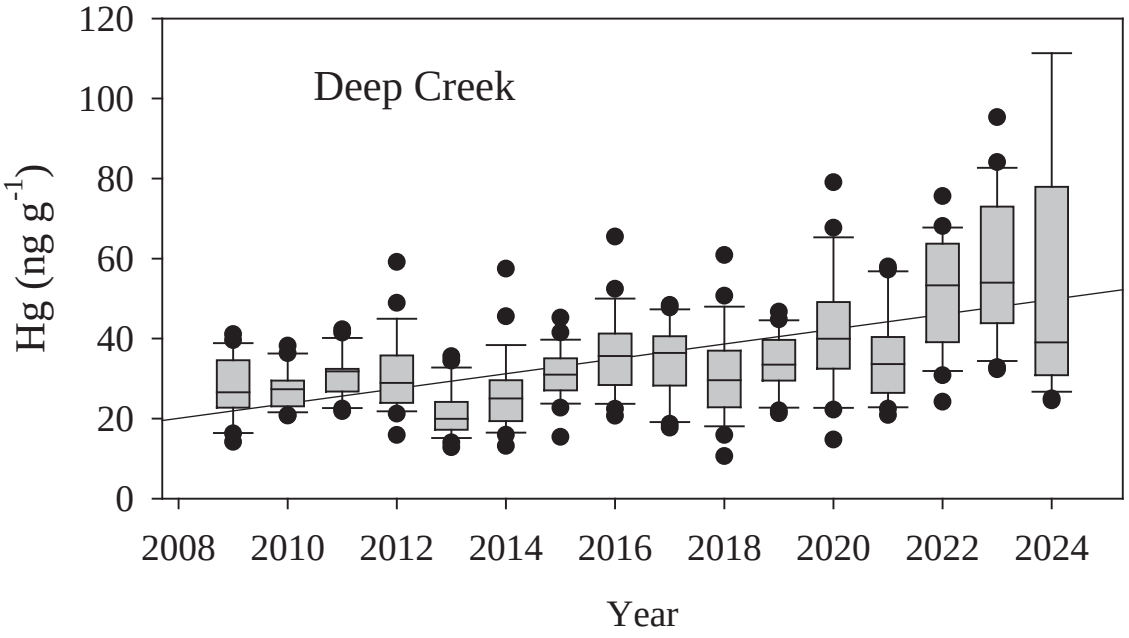
Experimental evidence for recovery of mercury-contaminated fish populations

https://doi.org/10.1038/s41586-021-04222-7
Received: 15 January 2021
Accepted: 9 November 2021
Published online: 15 December 2021
Open access

Paul J. Blanchfield[1,2,3]✉, John W. M. Rudd[1,17], Lee E. Hrenchuk[1,3], Marc Amyot[4], Christopher L. Babiarz[5], Ken G. Beaty[1], R. A. Drew Bodaly[1], Brian A. Branfireun[6], Cynthia C. Gilmour[7], Jennifer A. Graydon[8], Britt D. Hall[9], Reed C. Harris[10], Andrew Heyes[11], Holger Hintelmann[12], James P. Hurley[13], Carol A. Kelly[1,17], David P. Krabbenhoft[14], Steve E. Lindberg[15], Robert P. Mason[16], Michael J. Paterson[1,3], Cheryl L. Podemski[1], Ken A. Sandilands[1,3], George R. Southworth[15], Vincent L. St Louis[8], Lori S. Tate[1,19] & Michael T. Tate[14]

Young of Year Large Mouth Bass





25 individual fish

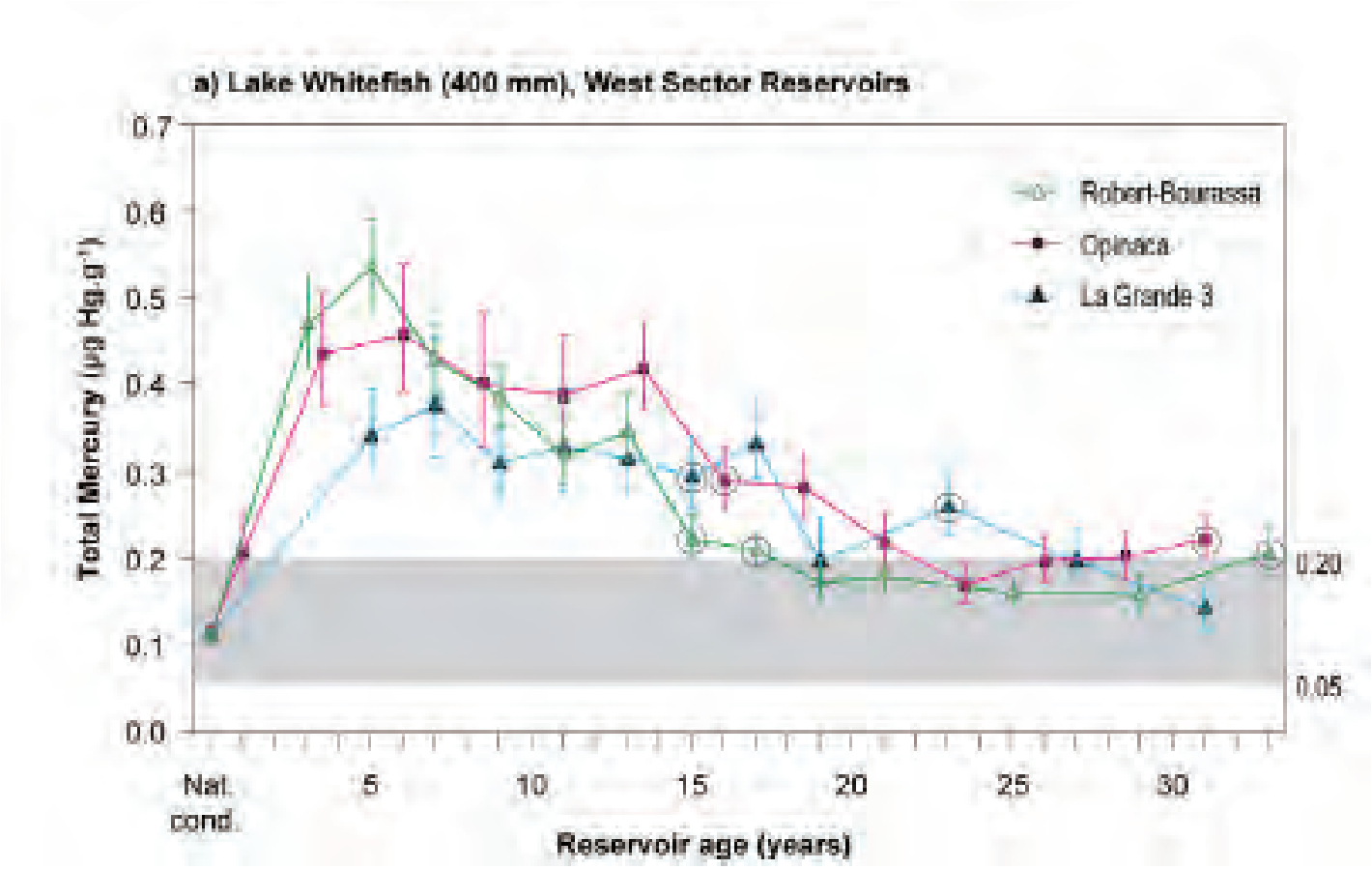
Why the increase?

Reservoir Management – primarily water level manipulations

Growth on the watershed –
Has it changed Hg loading or system biogeochemistry?

Food web - has it changed – what are the YOY bass eating?

Lake activity?

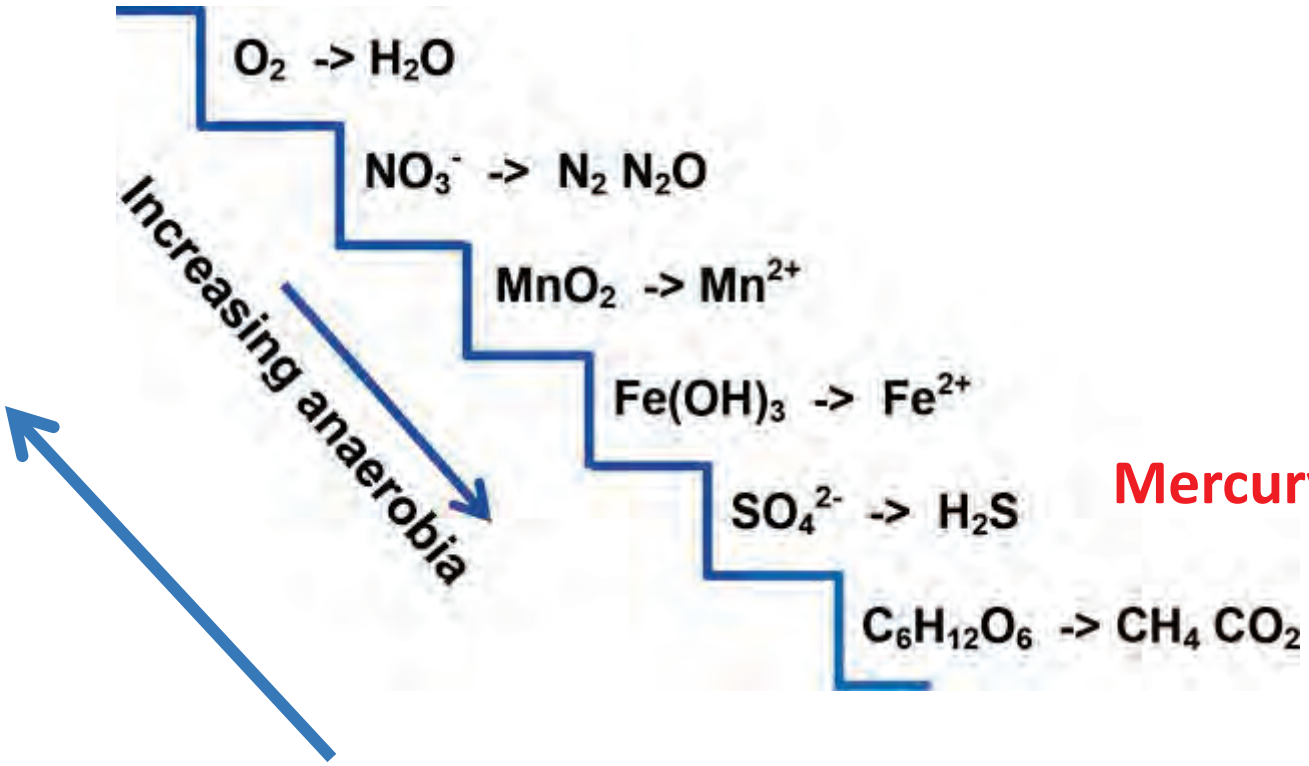


So What's the problem, Deep Creek lake is 100 years old?

François Bilodeau, Jean Therrien & Roger Schetagne (2017) Intensity and duration of effects of impoundment on mercury levels in fishes of hydroelectric reservoirs in northern Québec (Canada), Inland Waters, 7:4, 493-503, DOI: 10.1080/20442041.2017.1401702

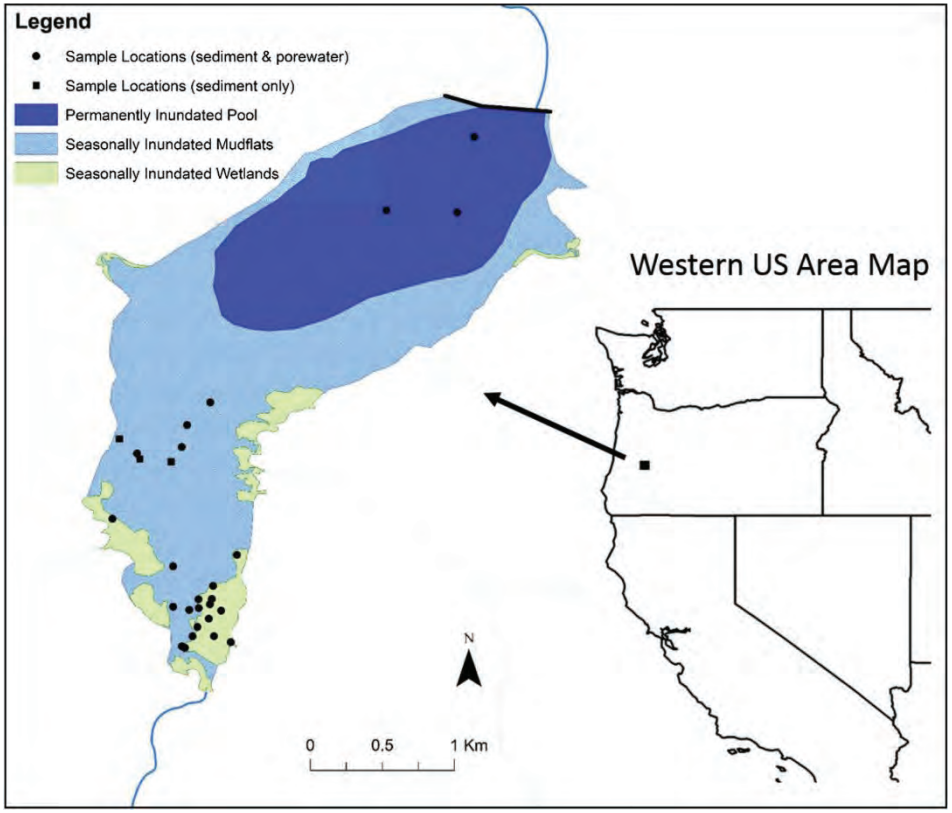
Water Level Manipulations

Increases in the supply of MeHg drives the increase in MeHg in fish



Mercury methylation

Reservoir operation can create problems



Environmental Pollution 222 (2017) 32–41

Contents lists available at ScienceDirect

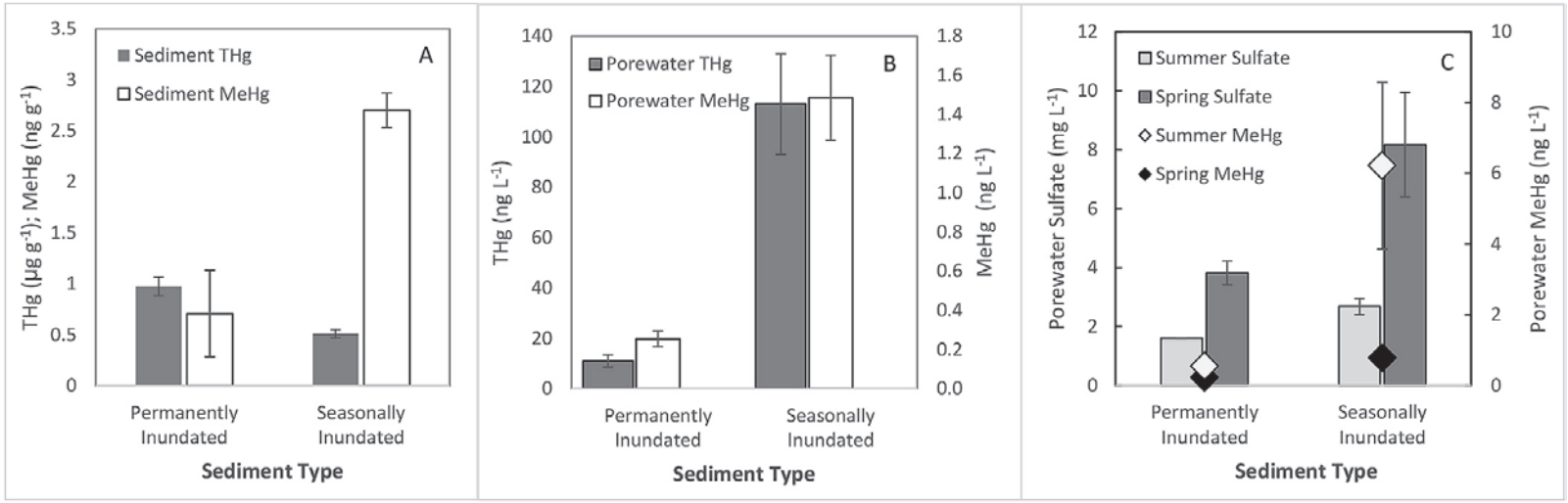
Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Water-level fluctuations influence sediment porewater chemistry and methylmercury production in a flood-control reservoir☆

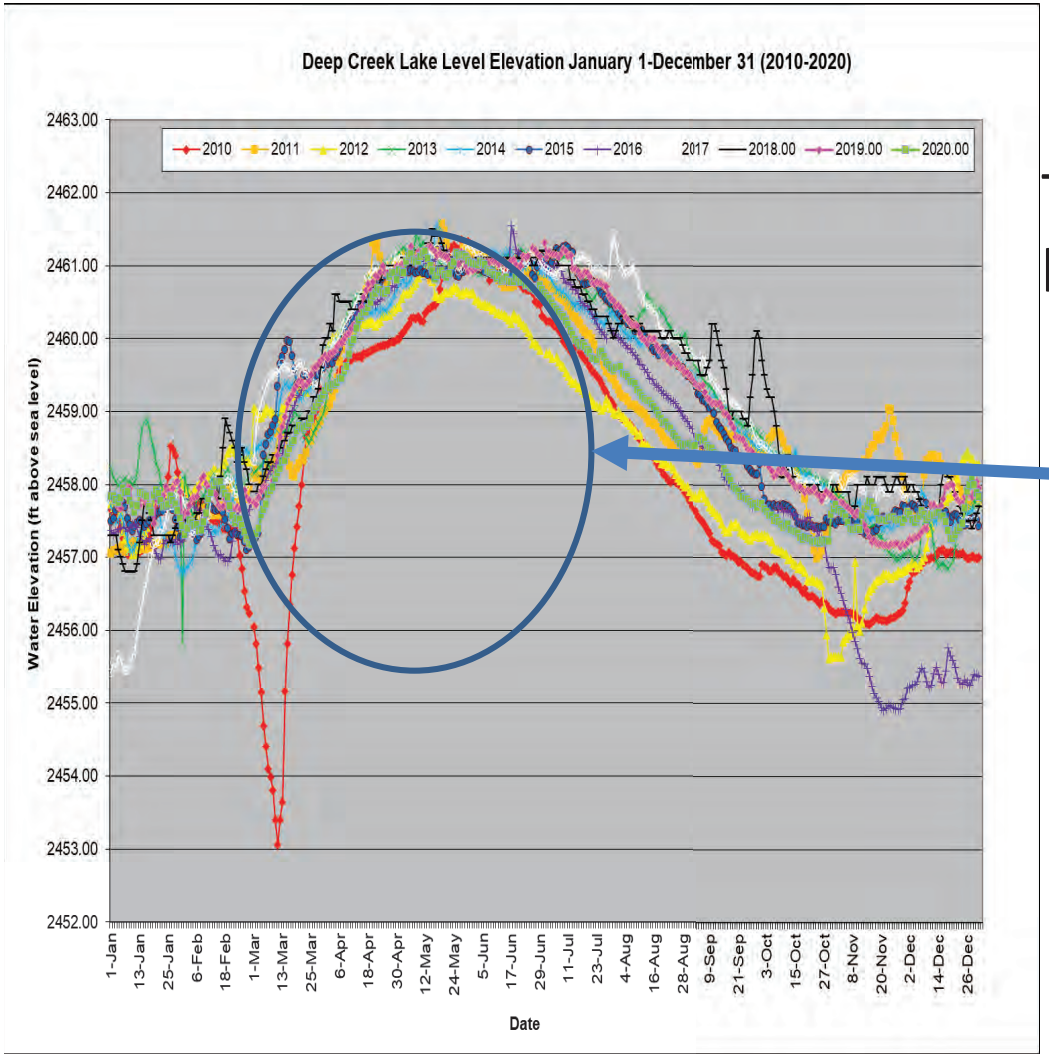
Chris S. Eckley [a], Todd P. Luxton [b, *], Jennifer Goetz [b], John McKernan [b]

[a] US Environmental Protection Agency, Region-10, 1200, 6th Ave Seattle, WA 98101, USA
[b] US Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, 26 West Martin Luther King Drive, Cincinnati, OH 45268, USA



Deep Creek Reservoir

Water Level fluctuations in Deep Creek Lake



3 ft

These fluctuations extend back to 1996 at least?

YOY fish exposure

Desire to lower 6 feet

What does this water level manipulation look like?

Lake is filling in

Is this sediment exposure during drawdowns stimulating Hg methylation?

Coves are important areas for young fish

DEEP CREEK LAKE ARROWHEAD COVE DREDGING PROJECT LESSONS LEARNED REPORT

FINAL

Prepared for:

Garrett County Government
203 S 4th St #207
Oakland, MD 21550

Prepared by:

Maryland Environmental Service
259 Najoles Road
Millersville, MD 21108

Maryland ENVIRONMENTAL SERVICE

September 2024

Questions

Will the dredging have an adverse short-term effect by:
1) Uncovering sediment higher in inorganic Hg
2) Mixing the sediment and stimulating Hg methylation

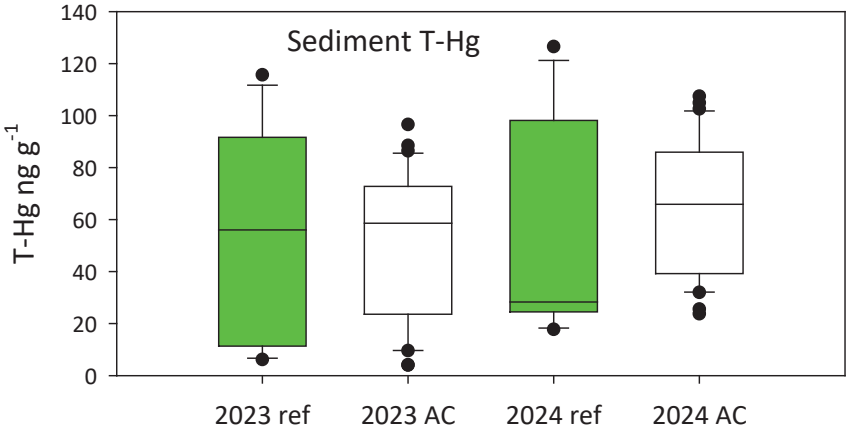
Will the dredging have a long term beneficial effect
by maintaining water over the sediment year round?

Before Sampling Oct 2023

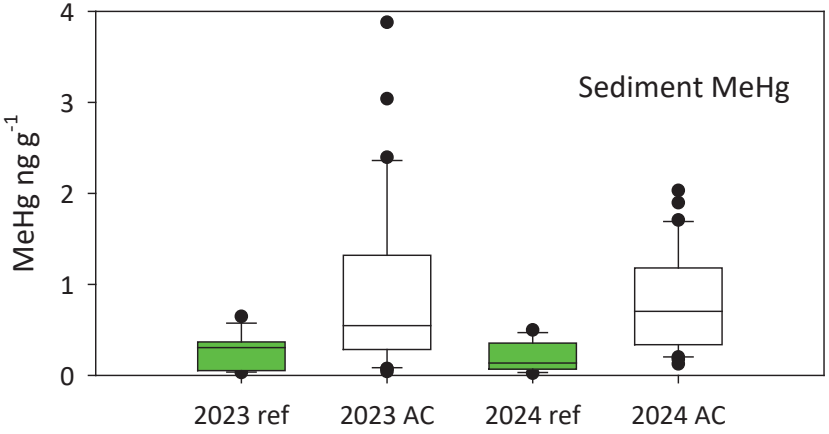
Sampling Plan

10 stations sampled in Arrowhead
5 stations in the adjacent cove
Measure T-Hg, MeHg and %OM

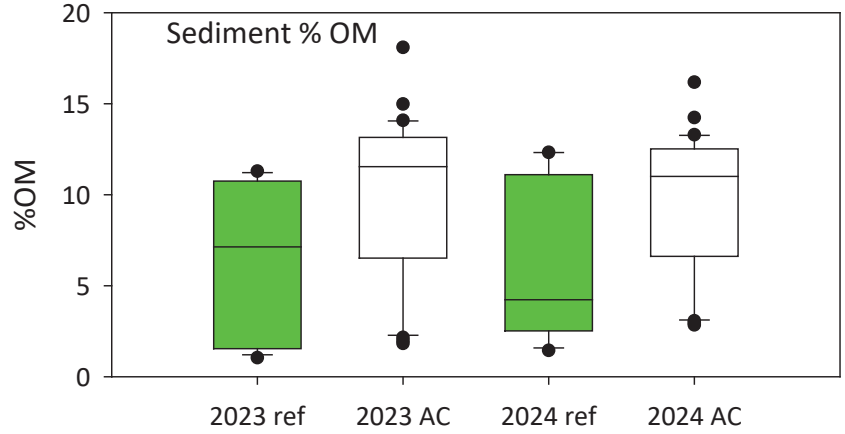
After Sampling Oct 2024



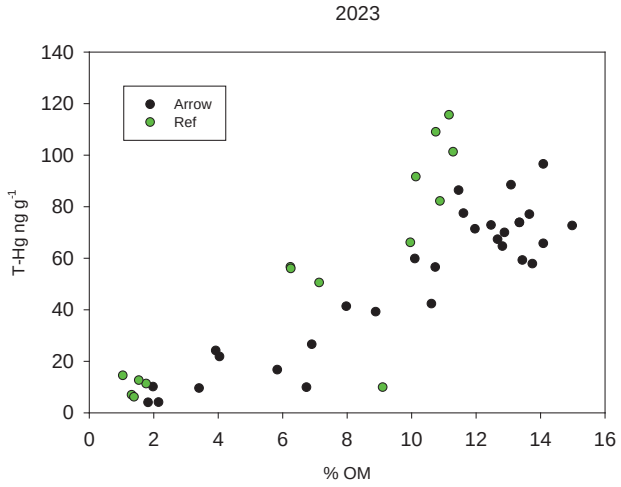
No Difference in T-Hg



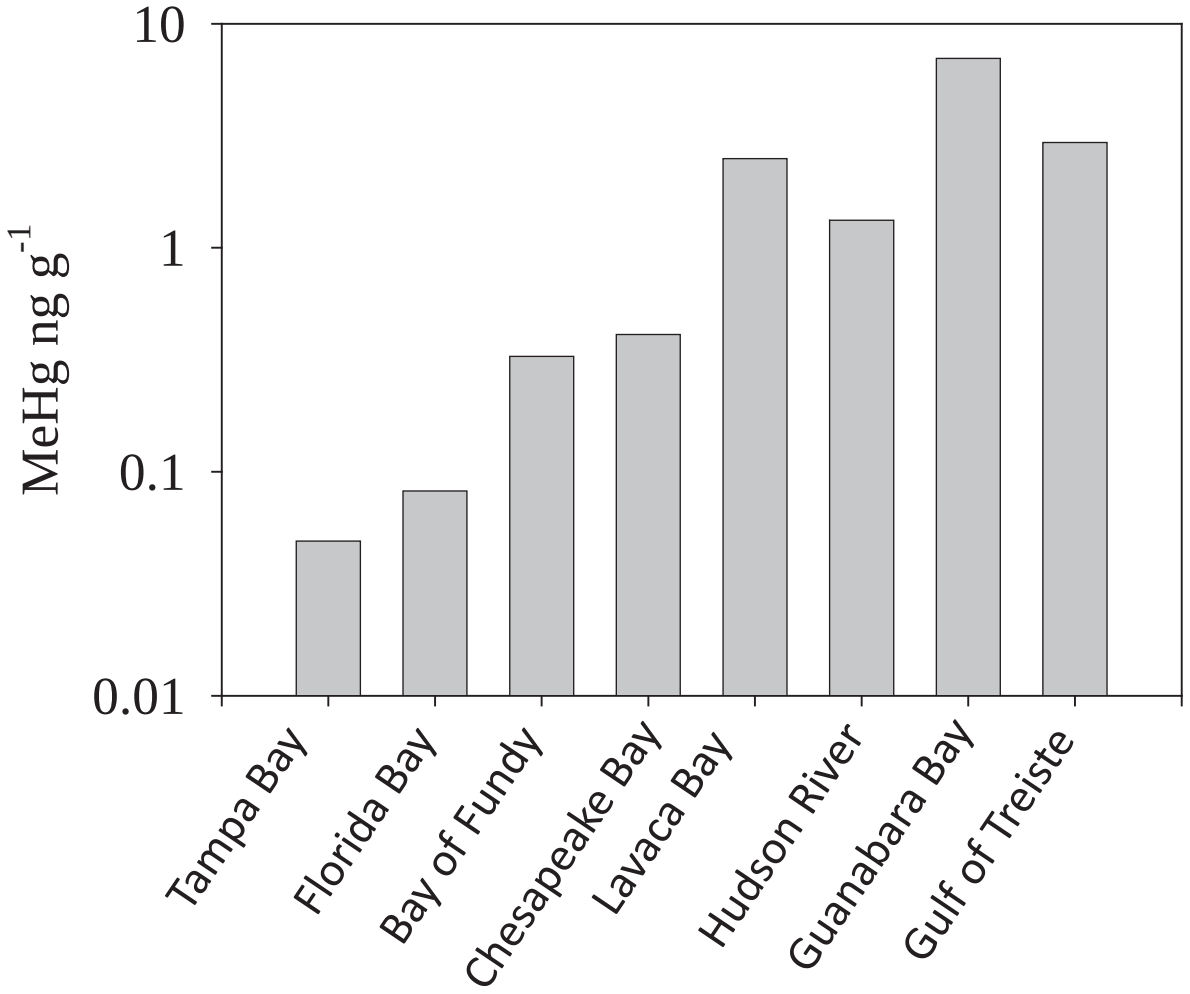
No Difference in MeHg



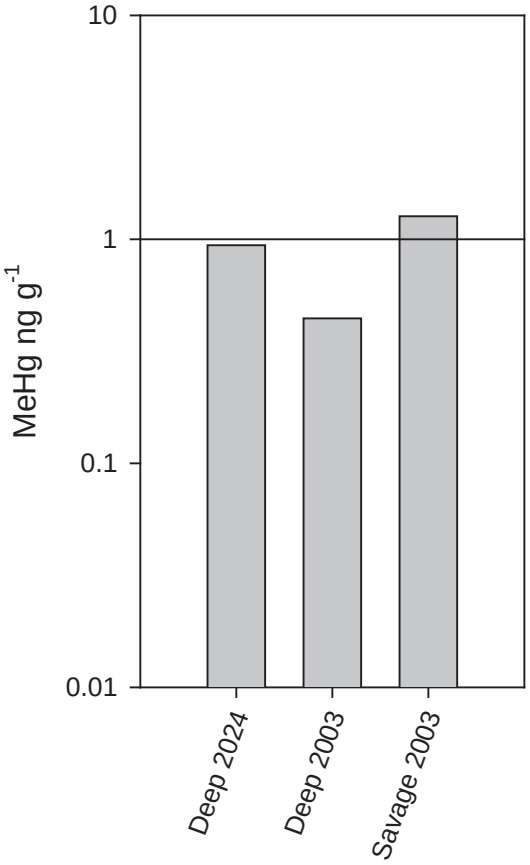
Organic matter content controls difference between reference and Arrowhead Cove



Methylmercury Concentrations in Estuarine Sediment



Reservoirs



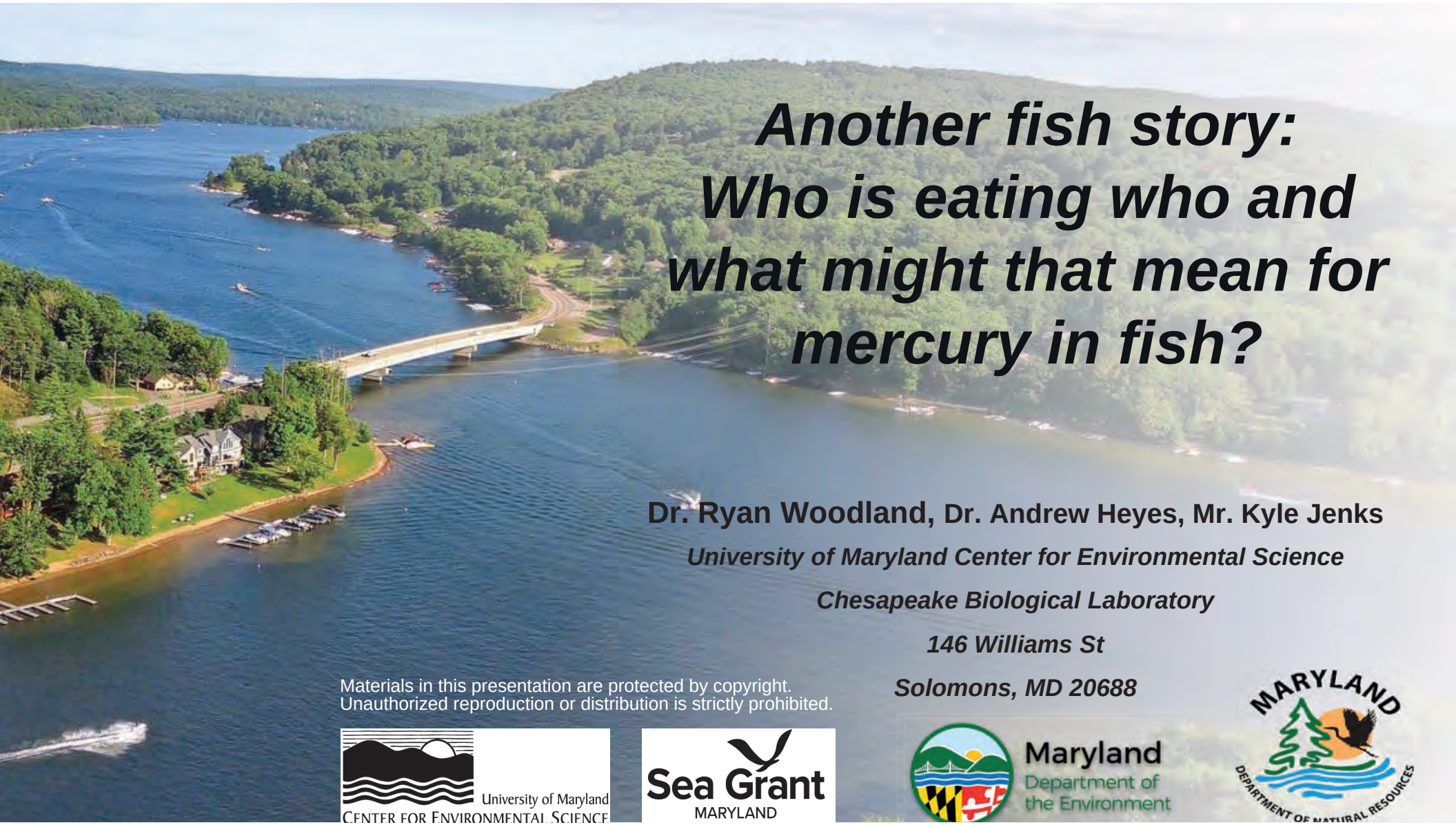
2024 was very dry and the sediment was exposed
Perhaps not a fair reflection of any longer term response

Conclusions

Dredging had no short-term impact on Hg cycling
Will it have a beneficial longer term impact?

Observations
Influence on system biogeochemistry

Reservoir is filling in with sediment
Growth on the watershed
Boat activity on the Lake



Another fish story: Who is eating who and what might that mean for mercury in fish?

Dr. Ryan Woodland, Dr. Andrew Heyes, Mr. Kyle Jenks

University of Maryland Center for Environmental Science

Chesapeake Biological Laboratory

146 Williams St

Solomons, MD 20688

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Sea Grant
MARYLAND

Maryland
Department of
the Environment

MARYLAND
DEPARTMENT OF NATURAL RESOURCES

How and where does mercury enter and progress through Deep Creek Lake's food web?

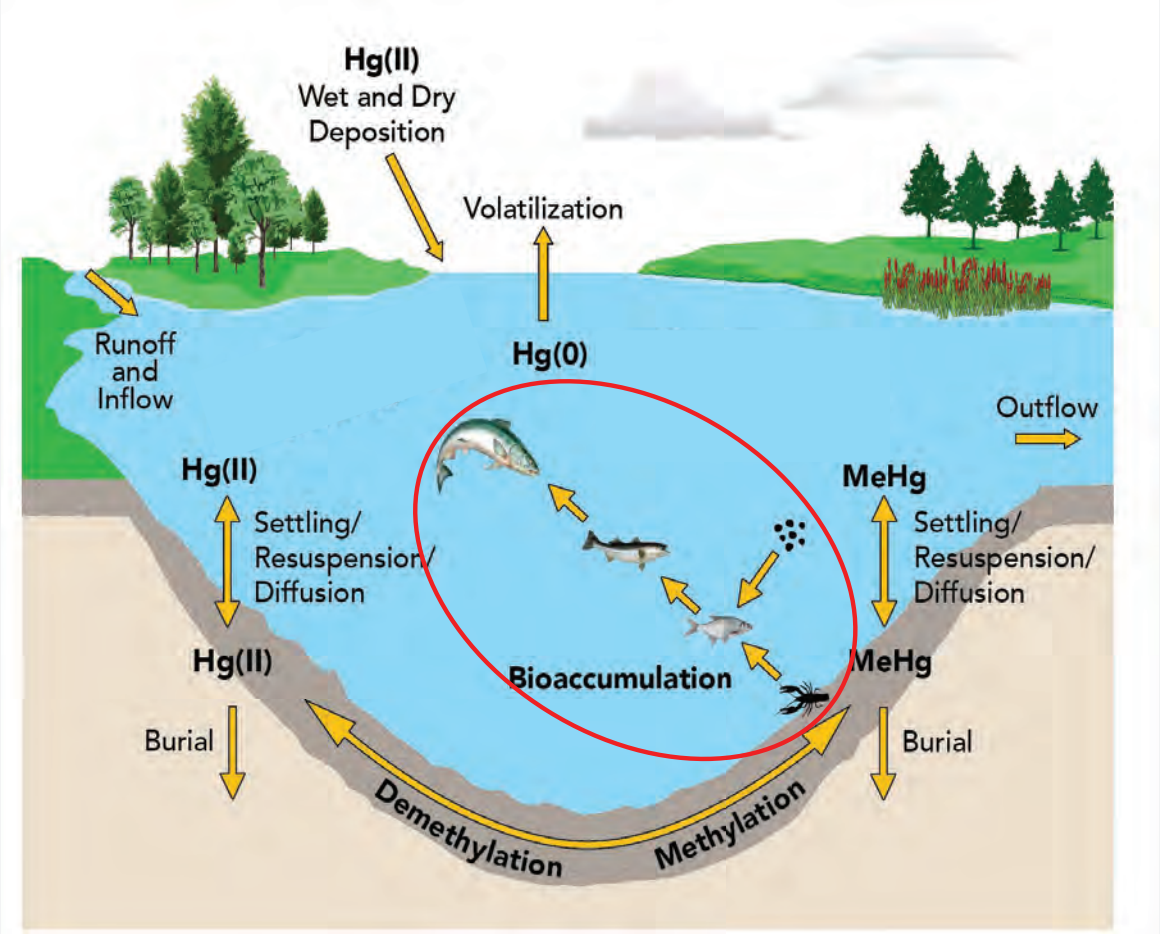


Image: Missouri DNR

How and where does mercury enter and progress through Deep Creek Lake's food web?

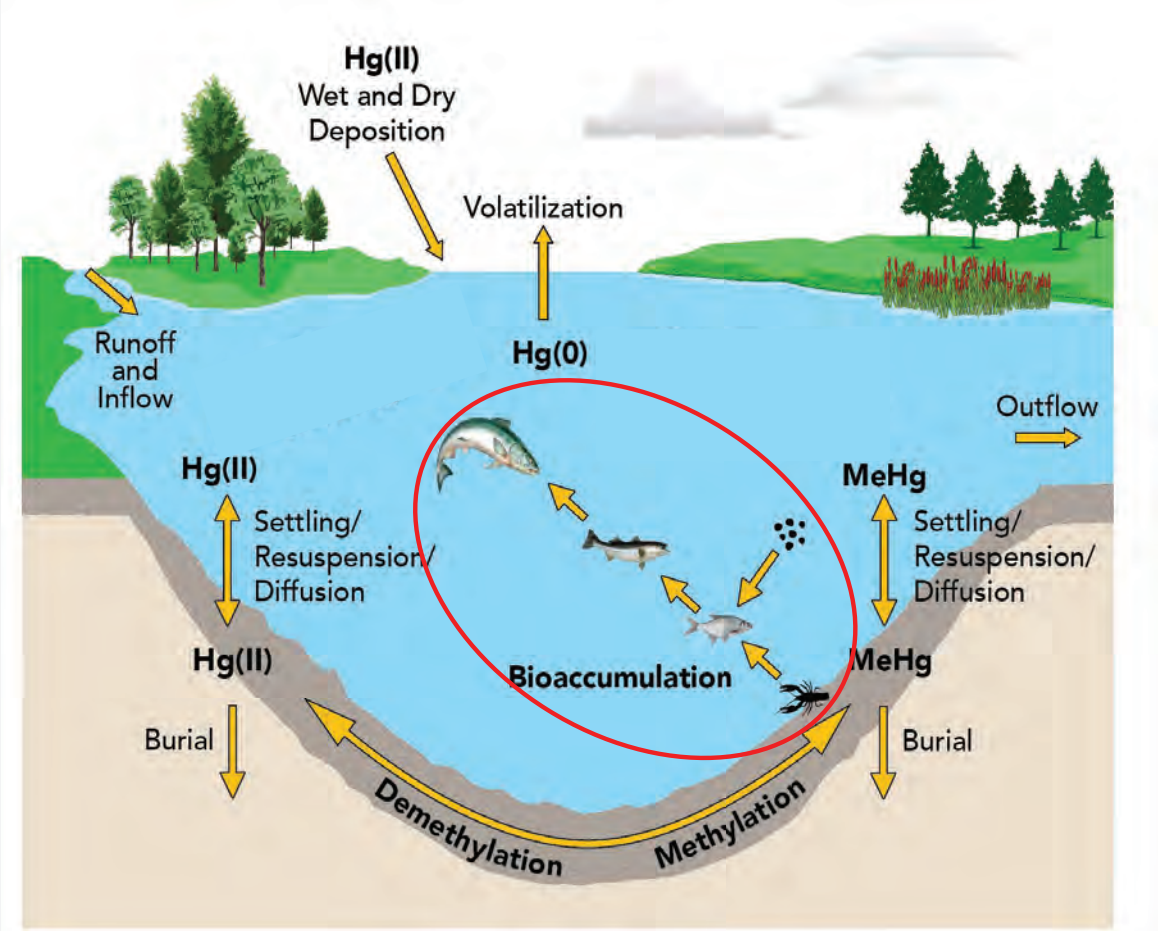
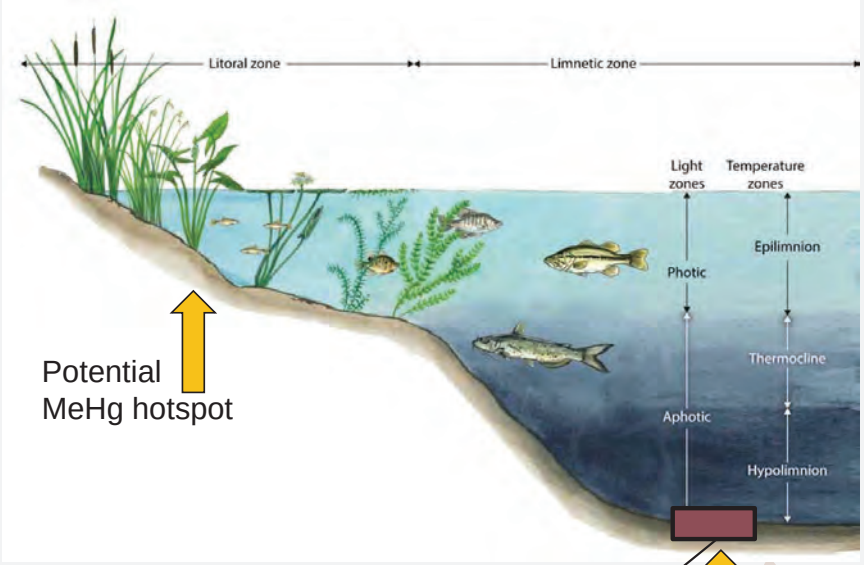
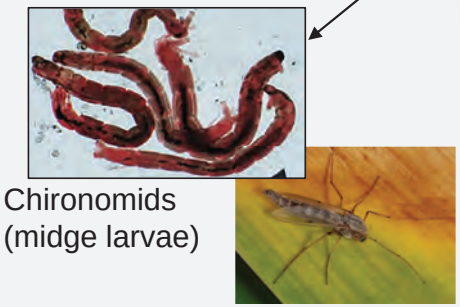


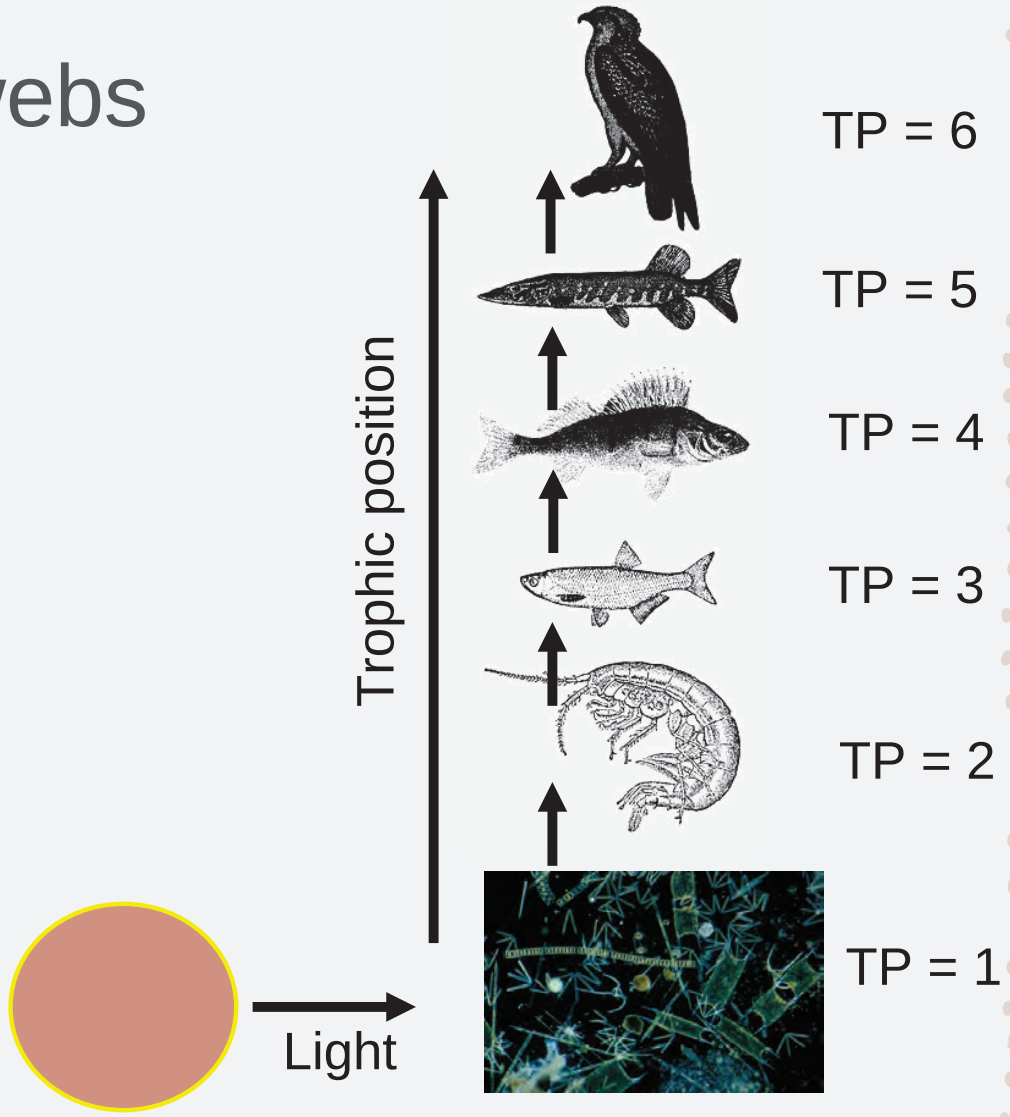
Image: Missouri DNR





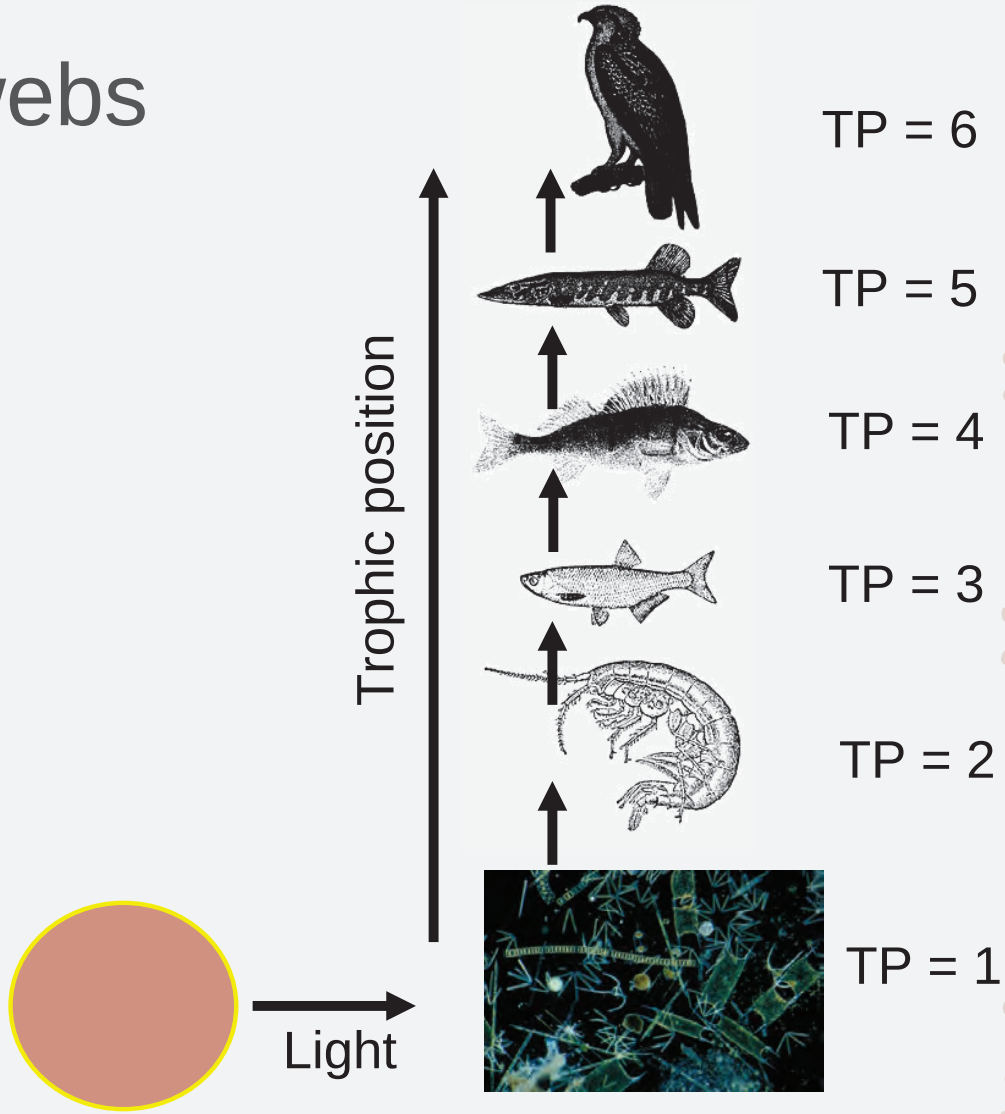
Chironomids
(midge larvae)

Food chains & food webs



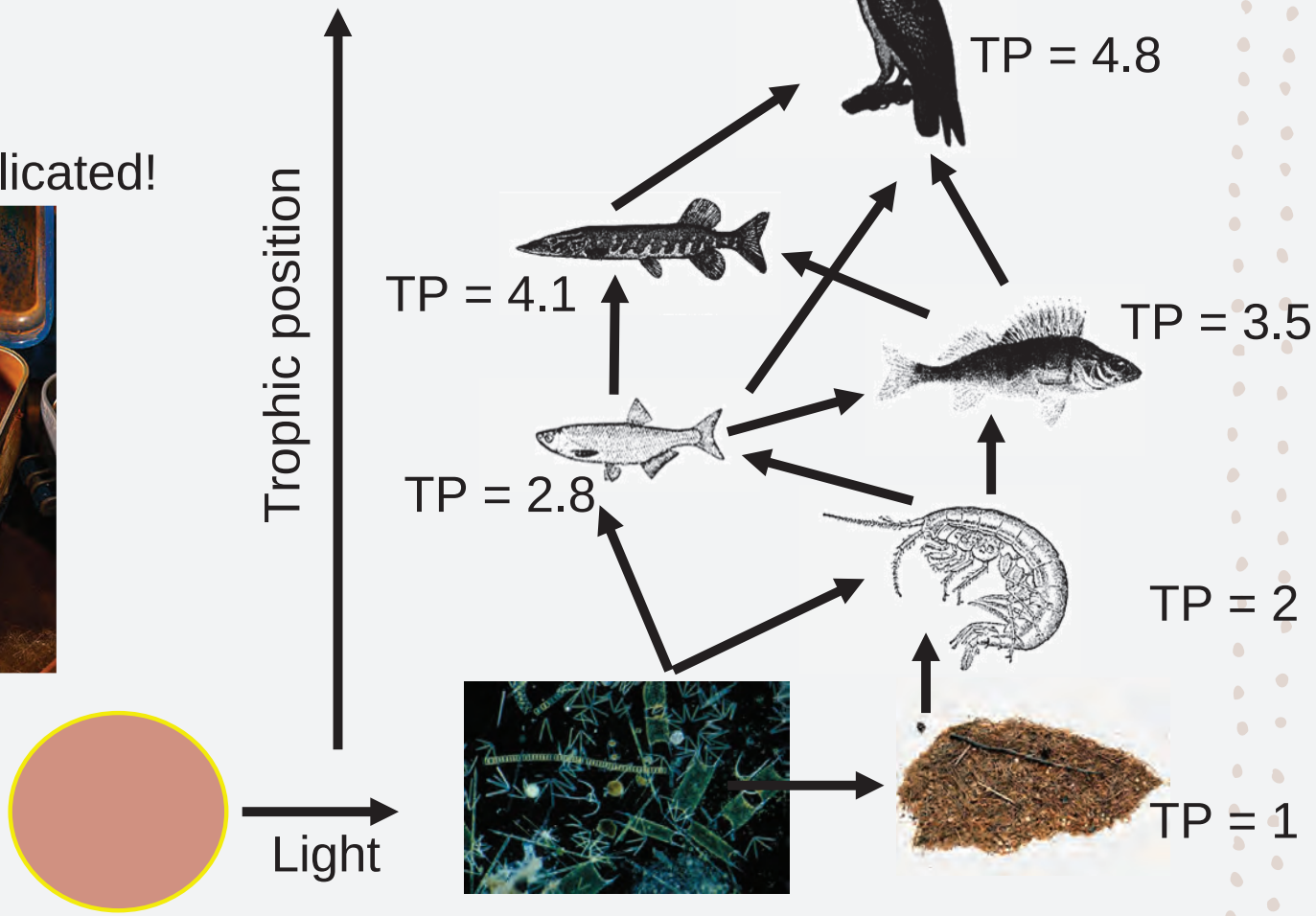
Food chains & food webs

Most fishers *plan* for something more complicated!



Food chains & **food webs**

Most fishers *plan* for something more complicated!



How do we study food webs?

Direct studies: analysis of stomach contents or observational studies

Indirect studies: analysis of biomarkers, chemicals or other indicators that tell us about the diet indirectly (stable isotopes)

What questions are we asking?

How mercury passes through food web: body size, diet relationships and trophic position (**THIS PRESENTATION**)

Where mercury passes into the food web: shallow versus deep habitats? Lake area hotspots? (**FUTURE WORK**)

Sampling Deep Creek Lake's food web: fish, invertebrates and organic matter

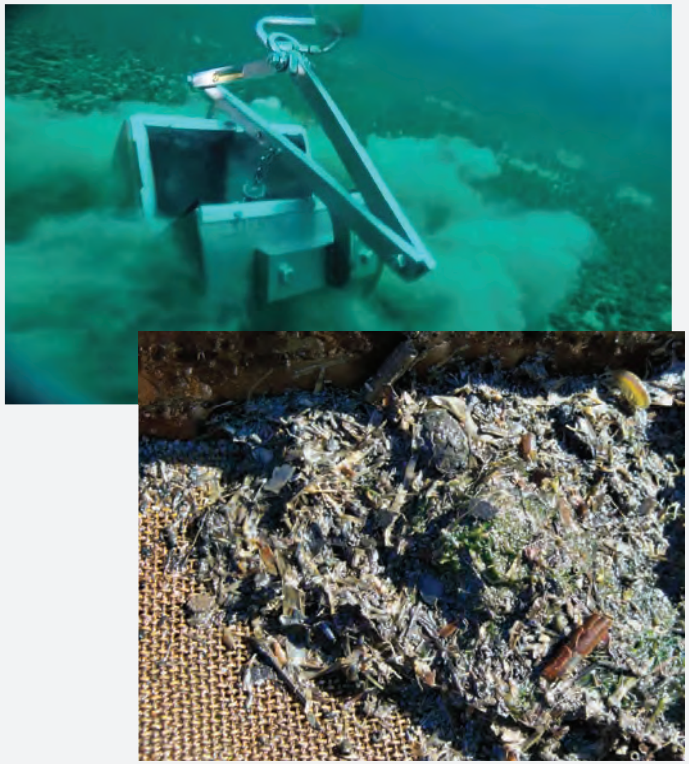
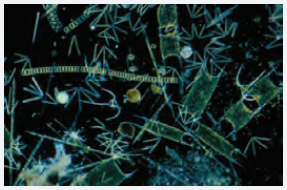


Image: Maryland MDDNR

Food web analysis







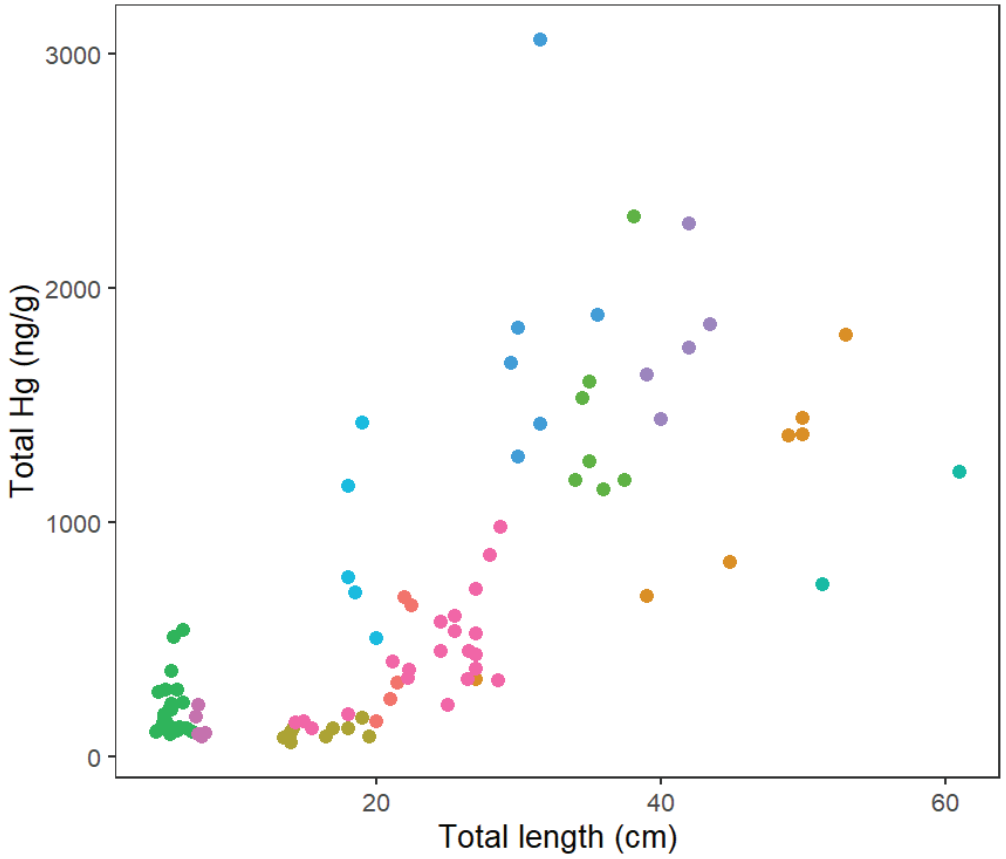








Larger fish usually have more mercury – *but not always*!

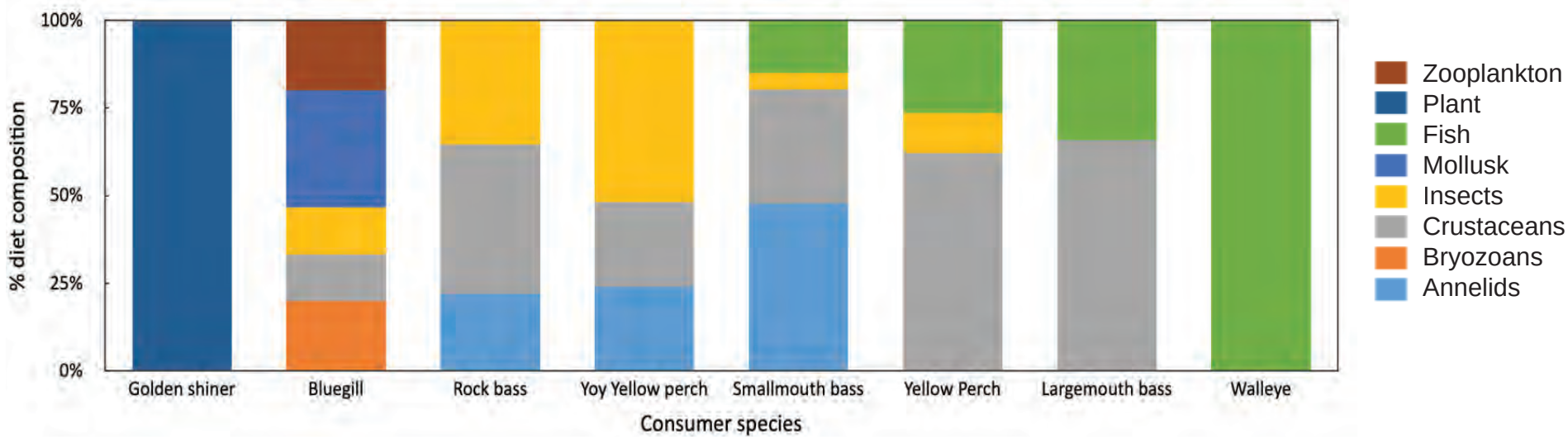


Stomach contents – some expected findings, some surprises!

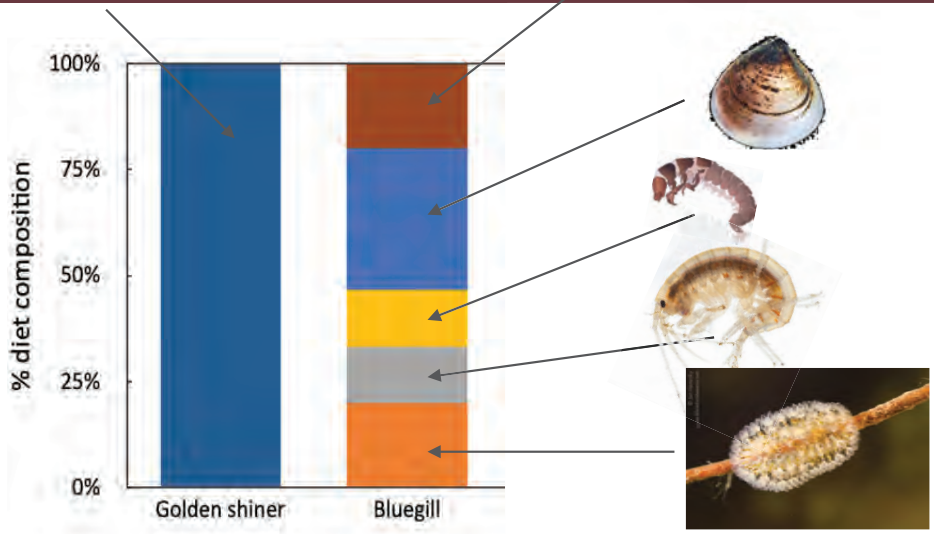
Mr. Kyle Jenks (St. Mary's College of Maryland; Hanrahan Foundation / Maryland Sea Grant summer intern)

Dried prey items

Stomach contents differ among species

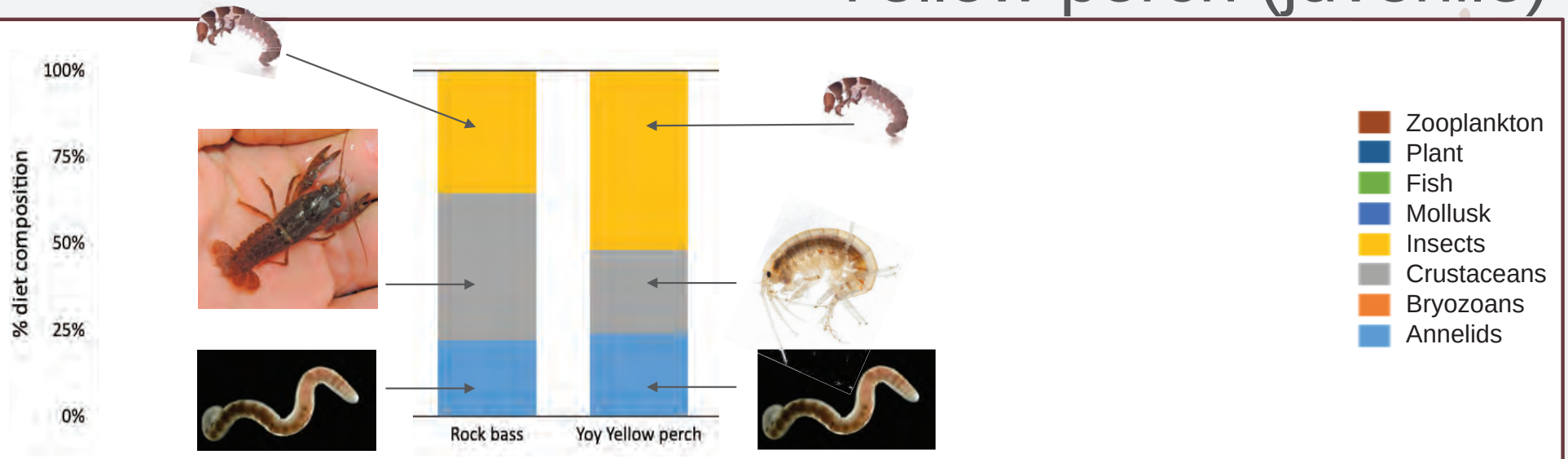


Golden shiner & Bluegill

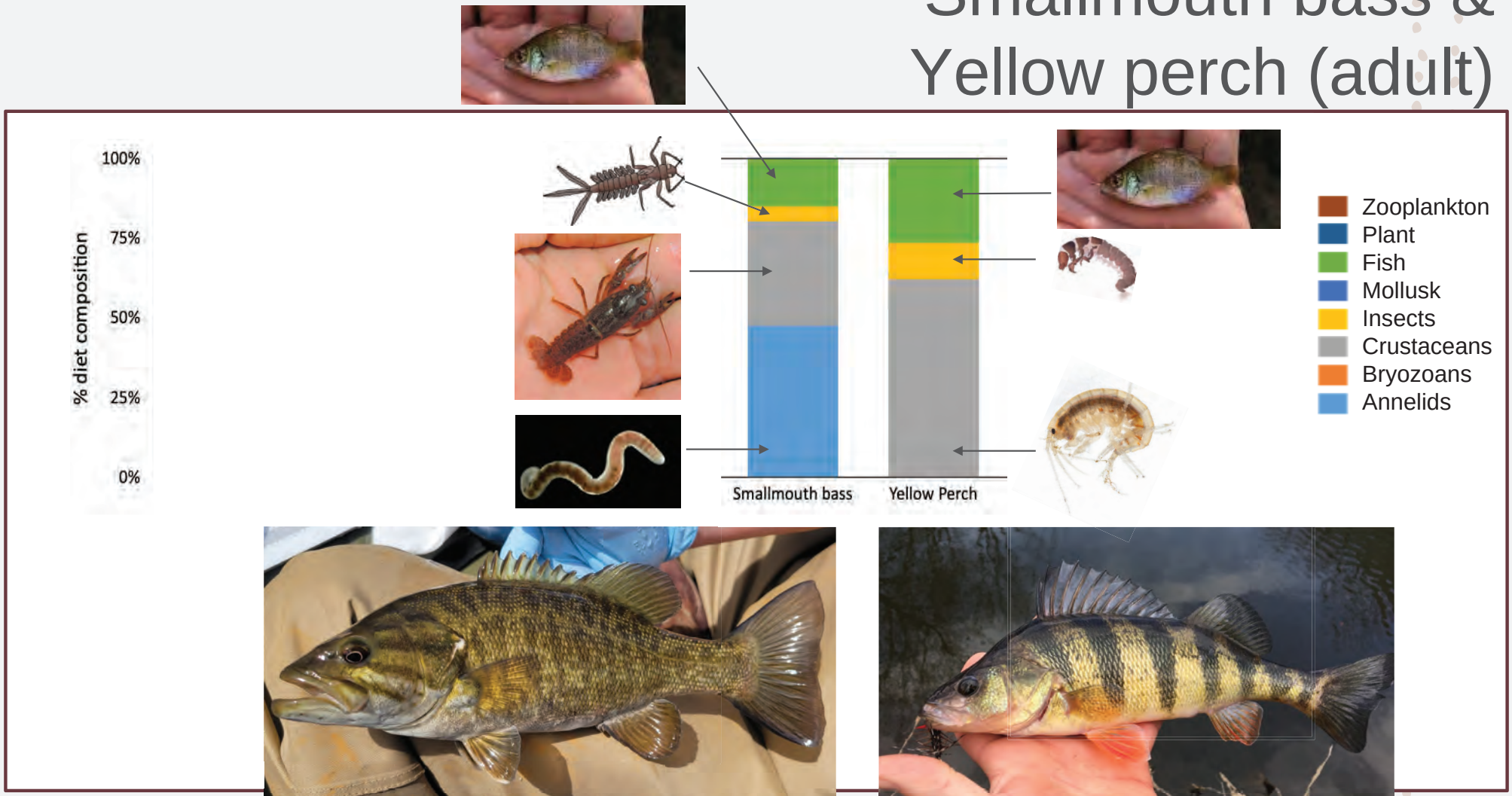


Zooplankton
Plant
Fish
Mollusk
Insects
Crustaceans
Bryozoans
Annelids

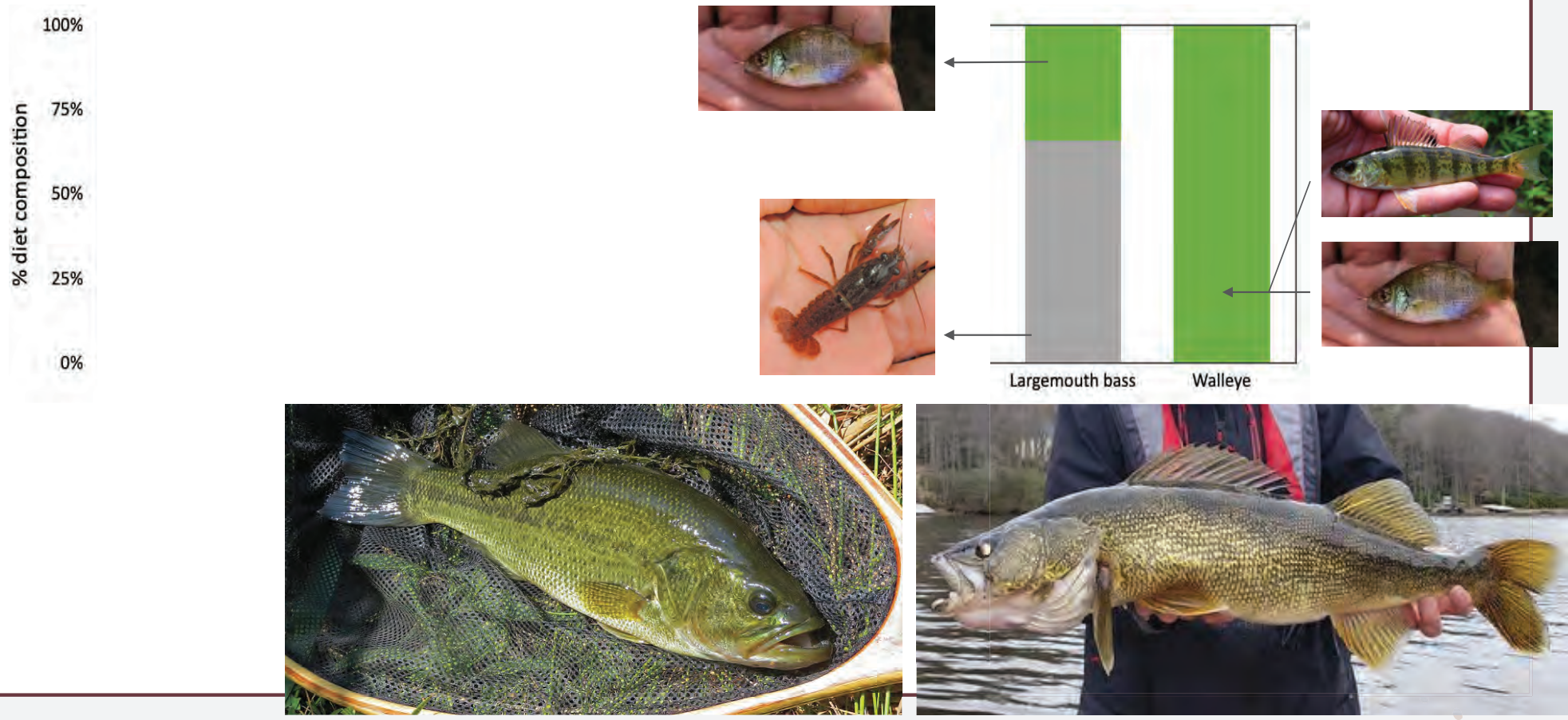
Rock bass and Yellow perch (juvenile)



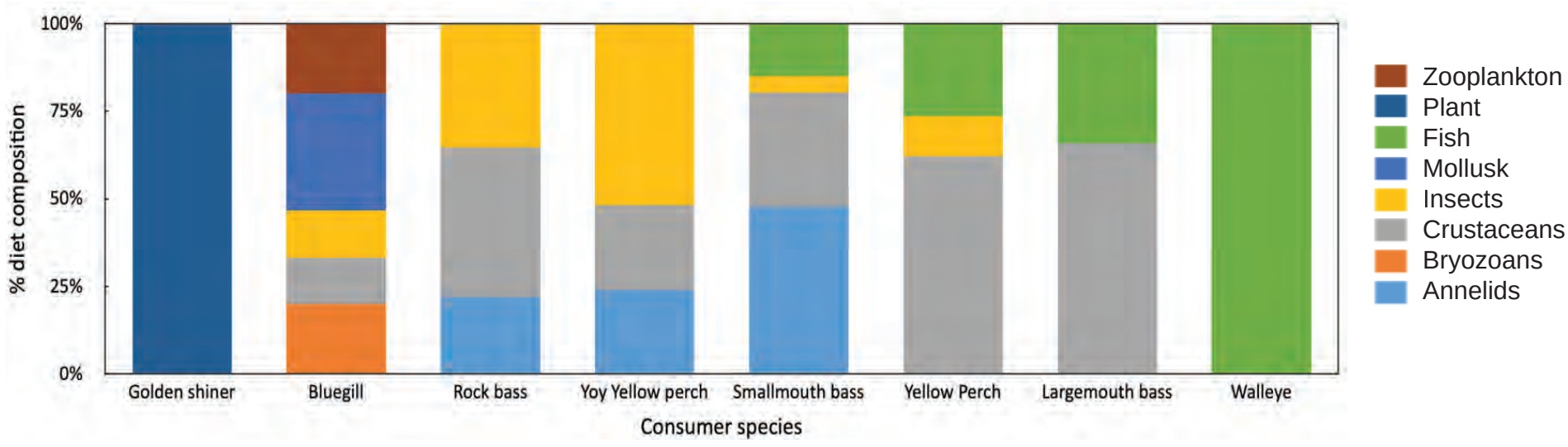
Smallmouth bass & Yellow perch (adult)



Largemouth bass & Walleye

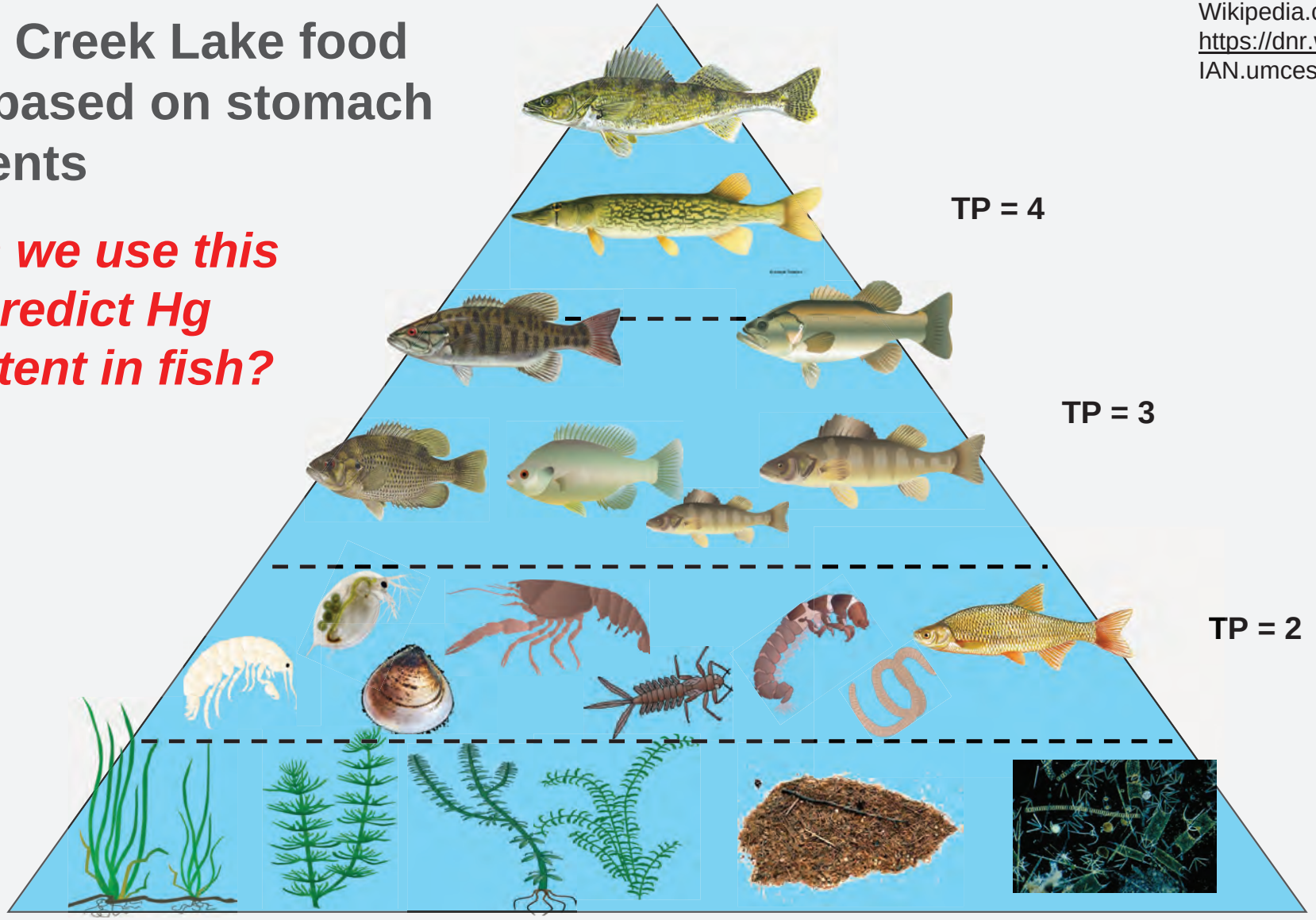


So…what does this look like as a food web?



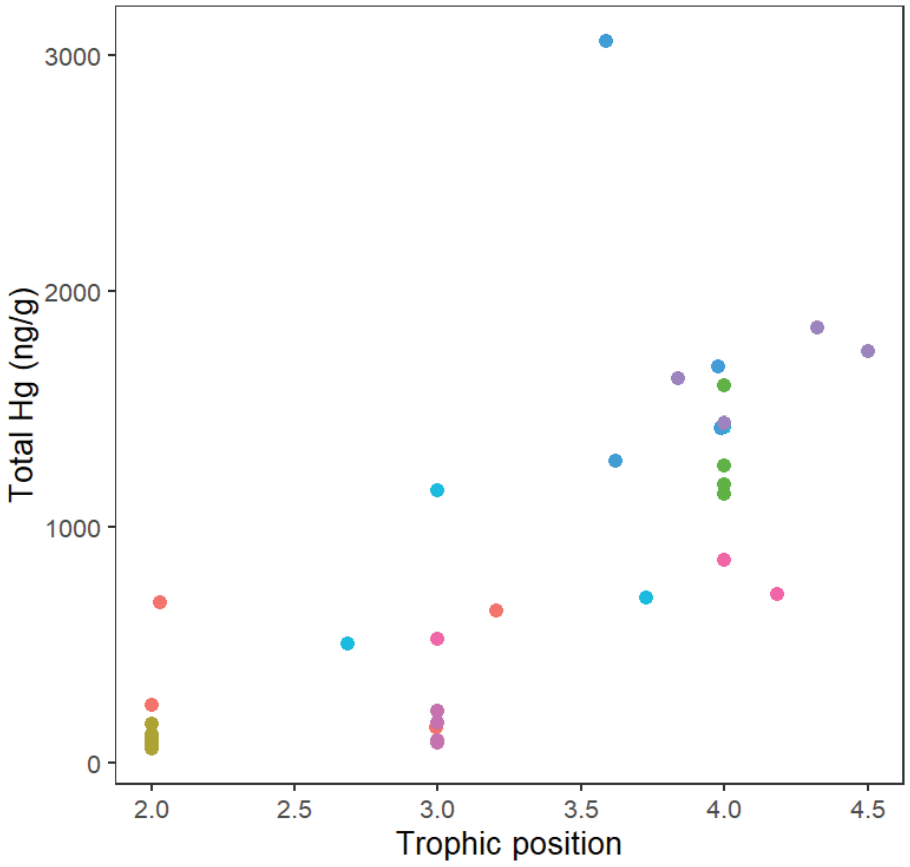
Deep Creek Lake food web based on stomach contents

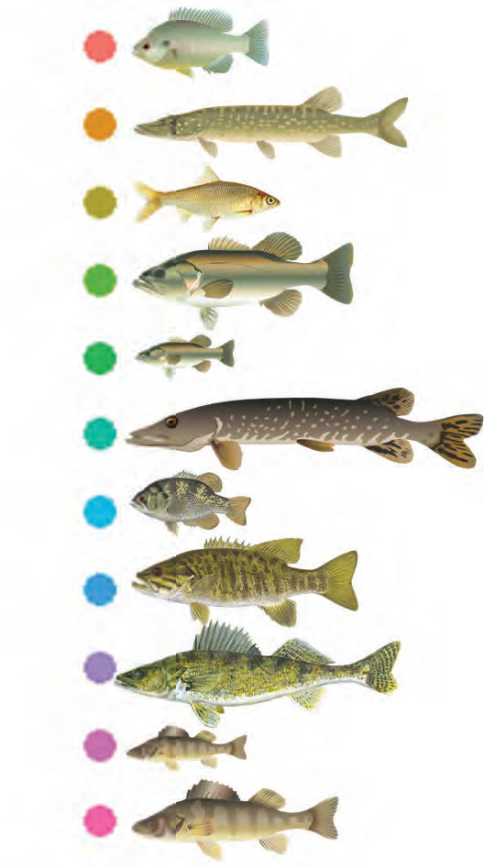
Can we use this to predict Hg content in fish?



Wikipedia.com, https://dnr.wisconsin.gov/, IAN.umces.edu, USFWS.gov

Our diet data is okay, but not a great predictor (too noisy)





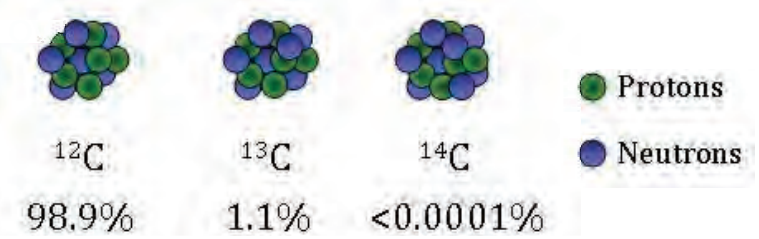
The last tool to explore food web structure?

Stable isotopes: biomarkers that tell us about the diet indirectly

→ *stable isotopes can tell us about long-term diet*

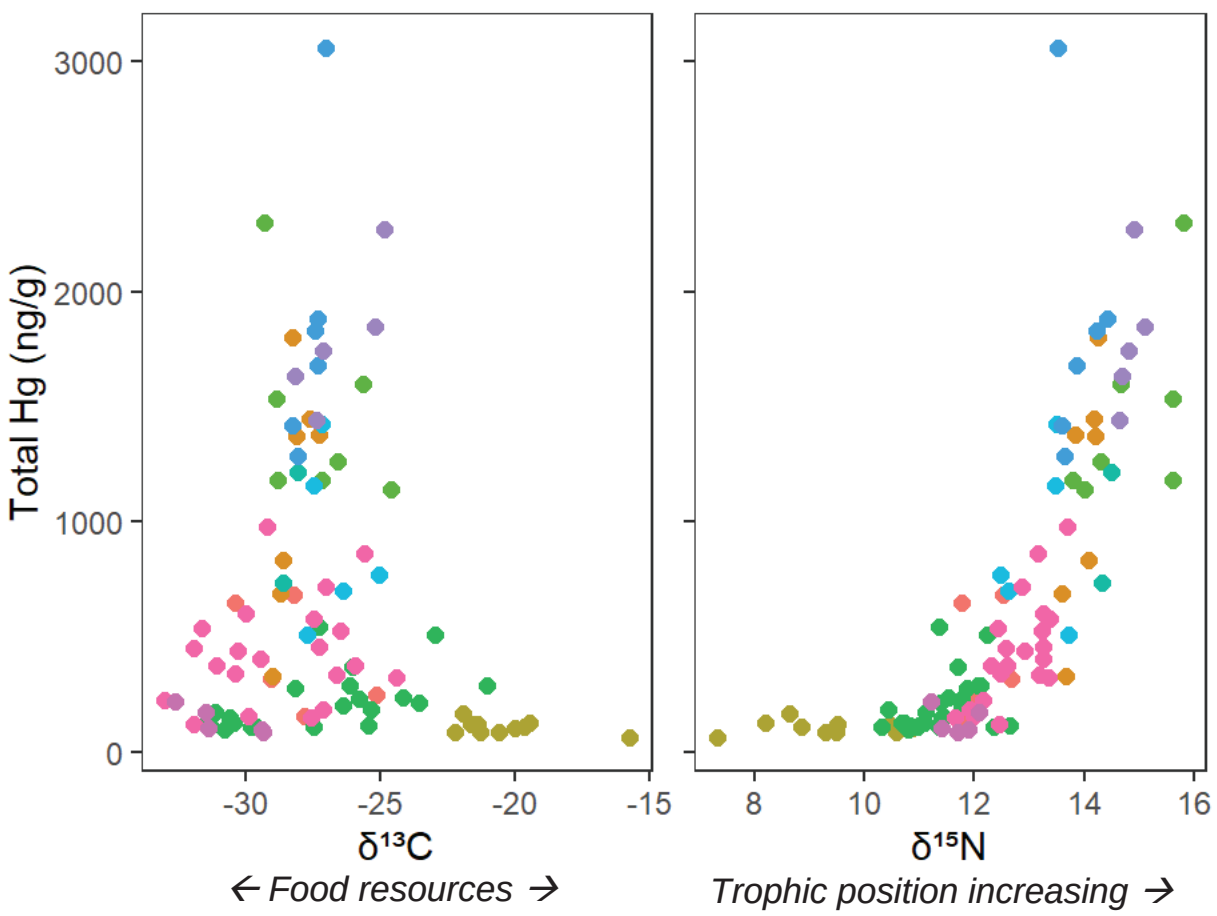
- Carbon (^{12}C and ^{13}C) & nitrogen (^{14}N and ^{15}N) stable isotopes

→ *An isotope is a version of an element with a different number of neutrons*

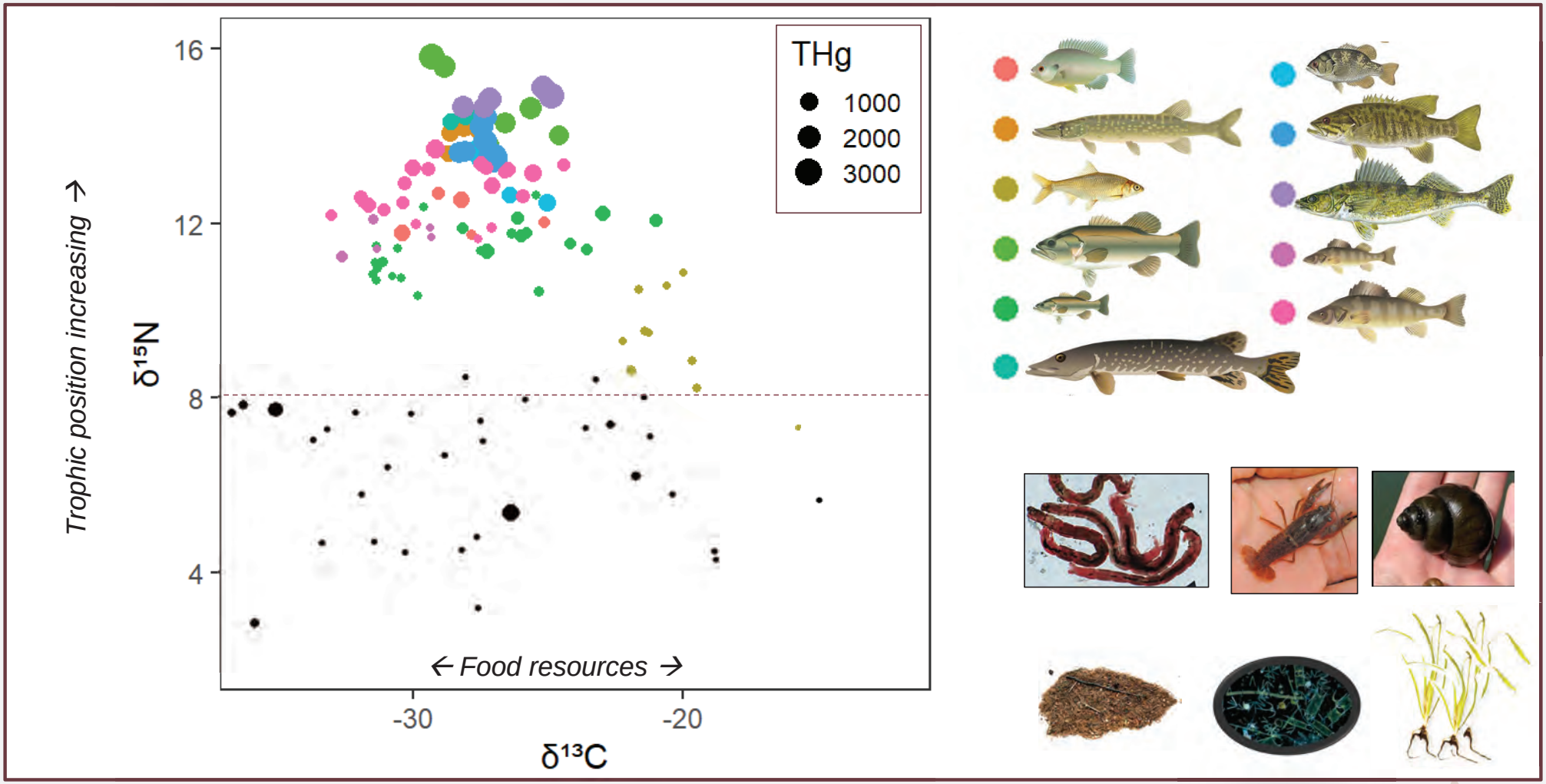


- Nitrogen ($\delta^{15}N$) – how high in the food web are fish (trophic position)
- Carbon ($\delta^{13}C$) – where the food comes from (organic matter source)

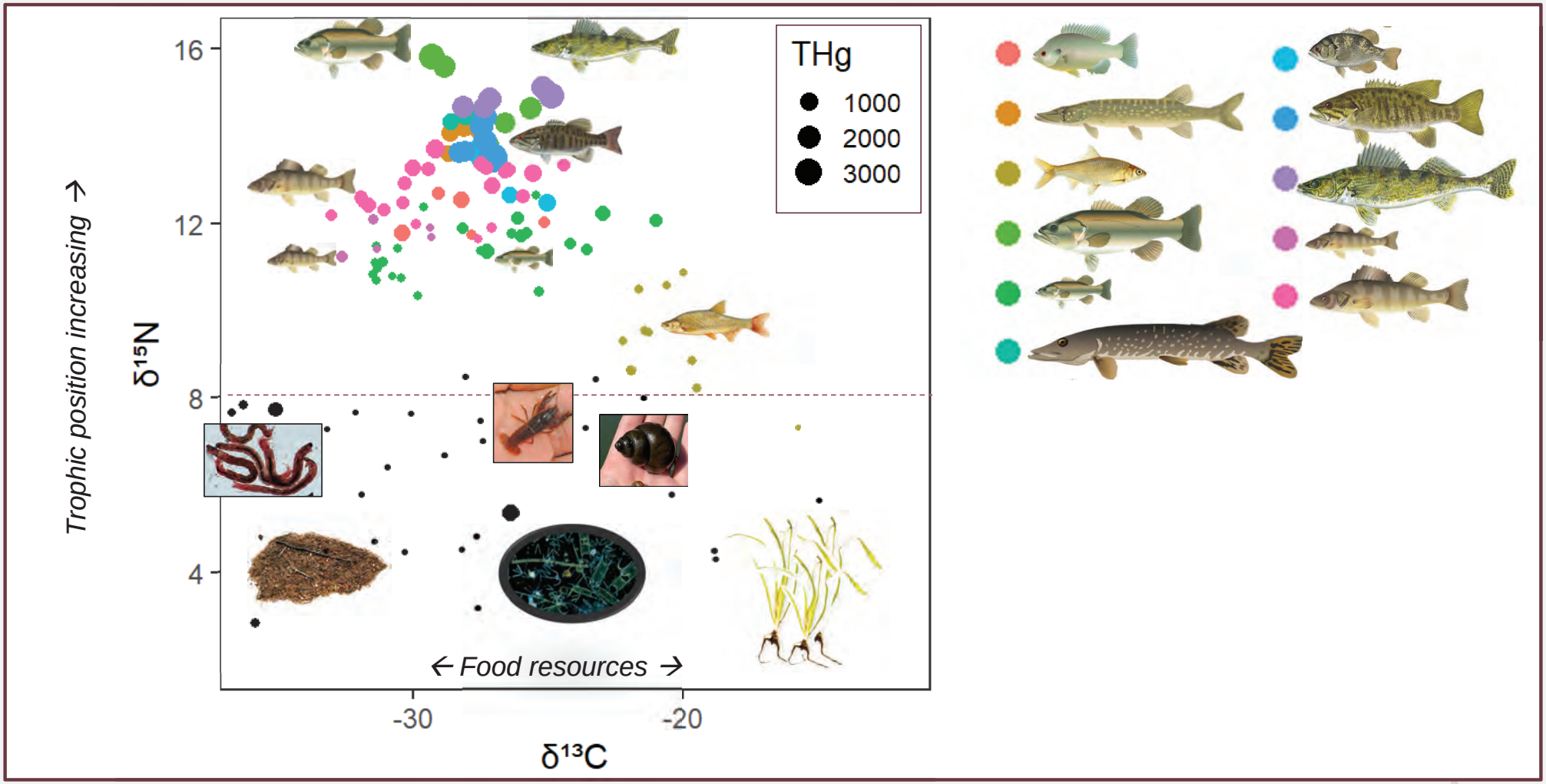
Stable isotopes are good predictors of Hg!



Using both isotopes to understand food web structure



Using both isotopes to understand food web structure



Findings and next steps

- Stomach contents and body size → *predict mercury but are noisy*
- Stable isotopes → *consistent indicator of food web structure and mercury predictor*
- Future work – model food web through space
  - “Hotspots” for mercury transfer?
  - Shallow vs deep water contributions

Acknowledgments

Matt Sell (MD DNR)
Kenny Wampler (MD DNR)
Chris Luckett (MDE)
Chris Flight (MDSG)
Dr. Mike Allen (MDSG)
Dr. Fredrika Moser (MDSG)
Theresa Murphy (CBL/UMCES)
Pauline Lawrence (CBL/UMCES)
Matt Stefanak (CBL/UMCES)
Lucas Sell
Clayton Woodland