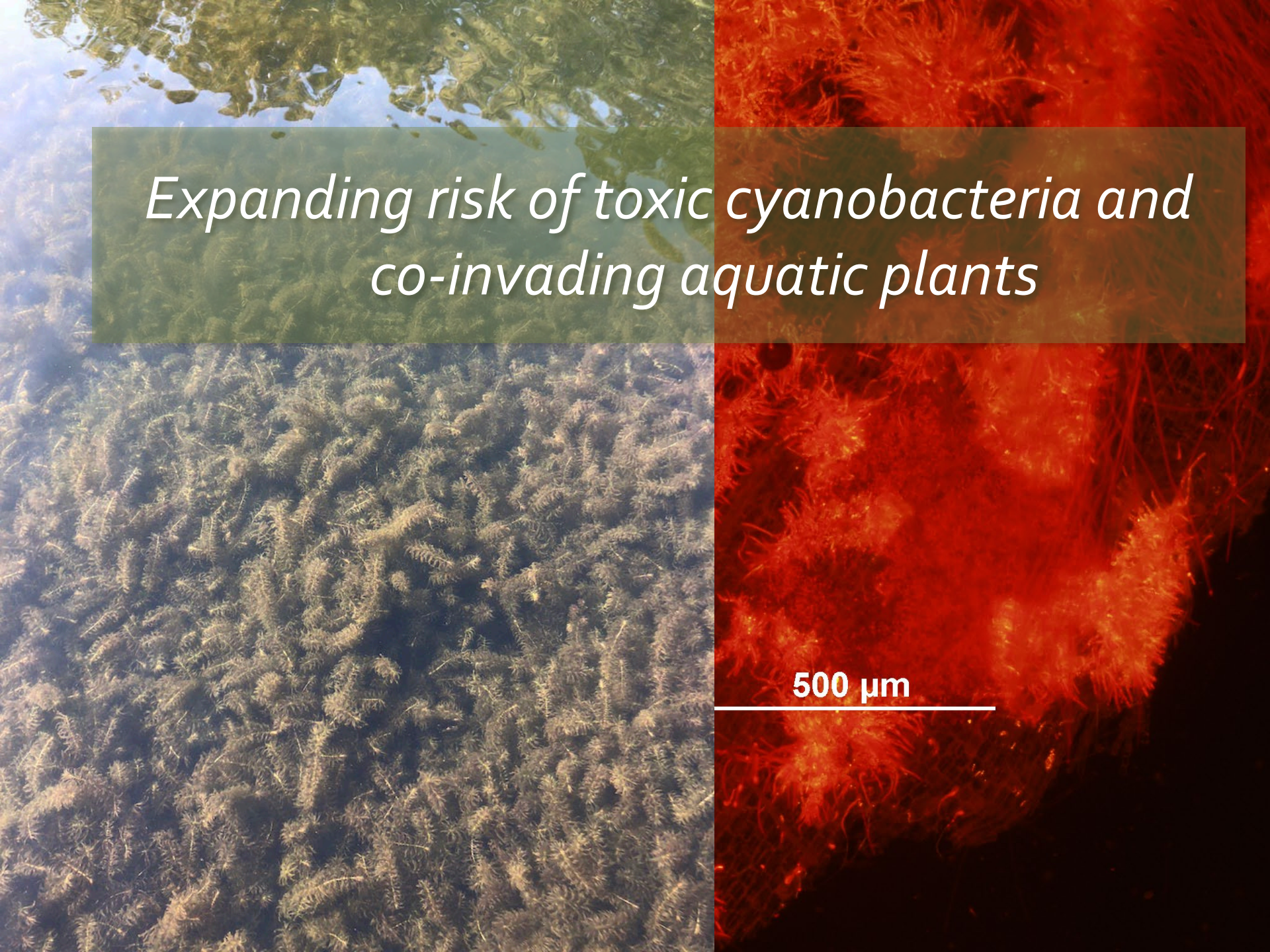
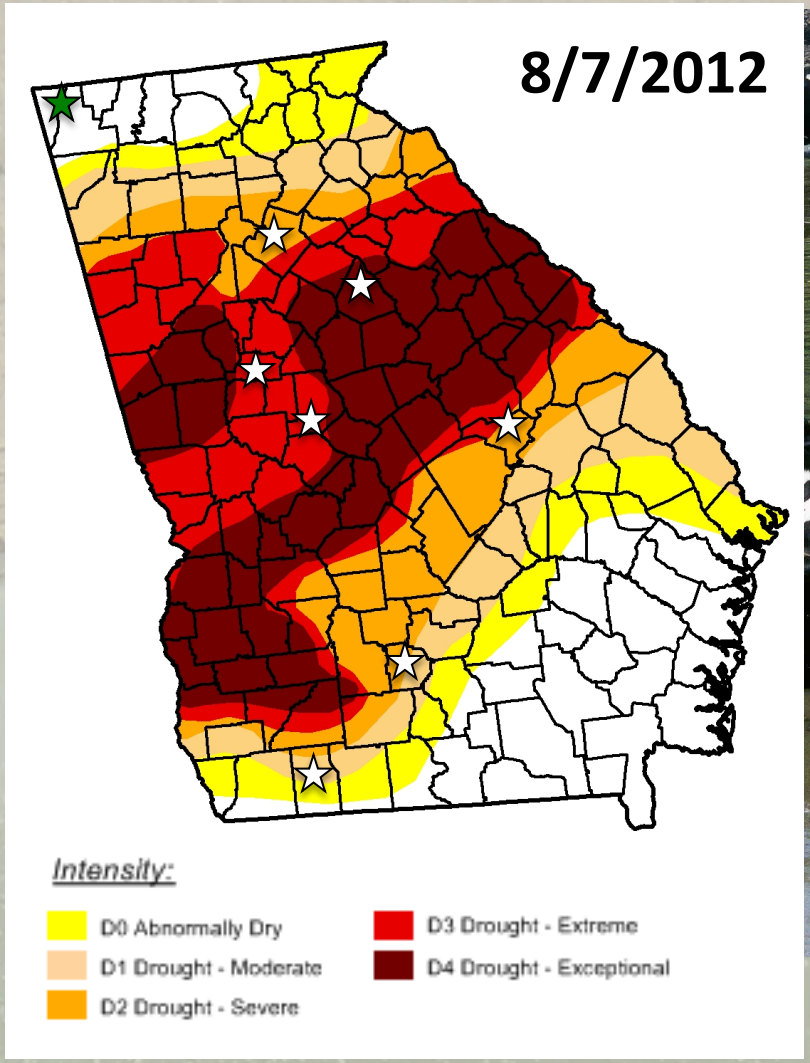
Expanding risk of toxic cyanobacteria and co-invading aquatic plants

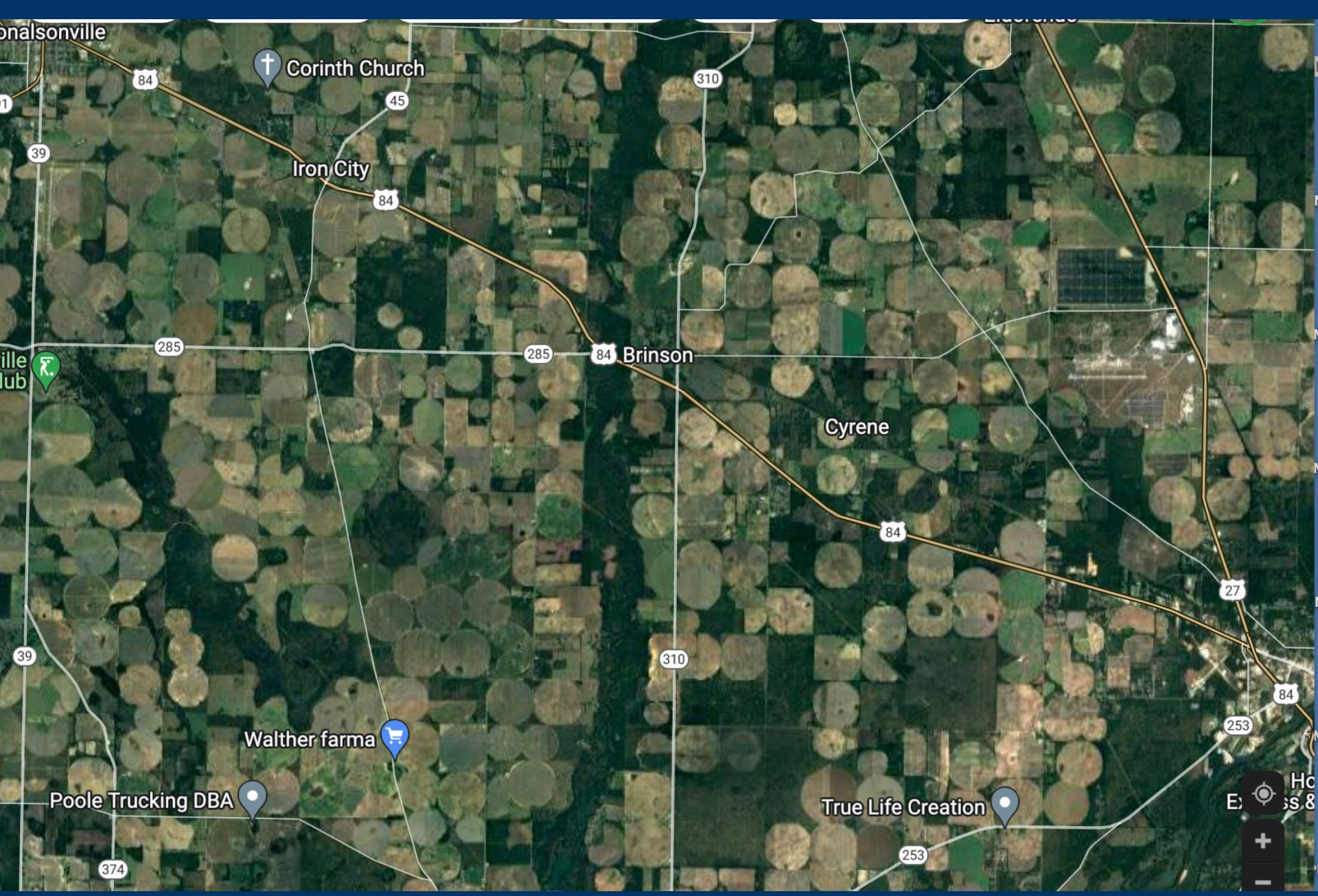



❖ Planktonic (water blooms)
✧ High nutrients P (+N)
✧ Warm, still water
Reynolds Plantation, onsite wastewater "treatment" through detention ponds

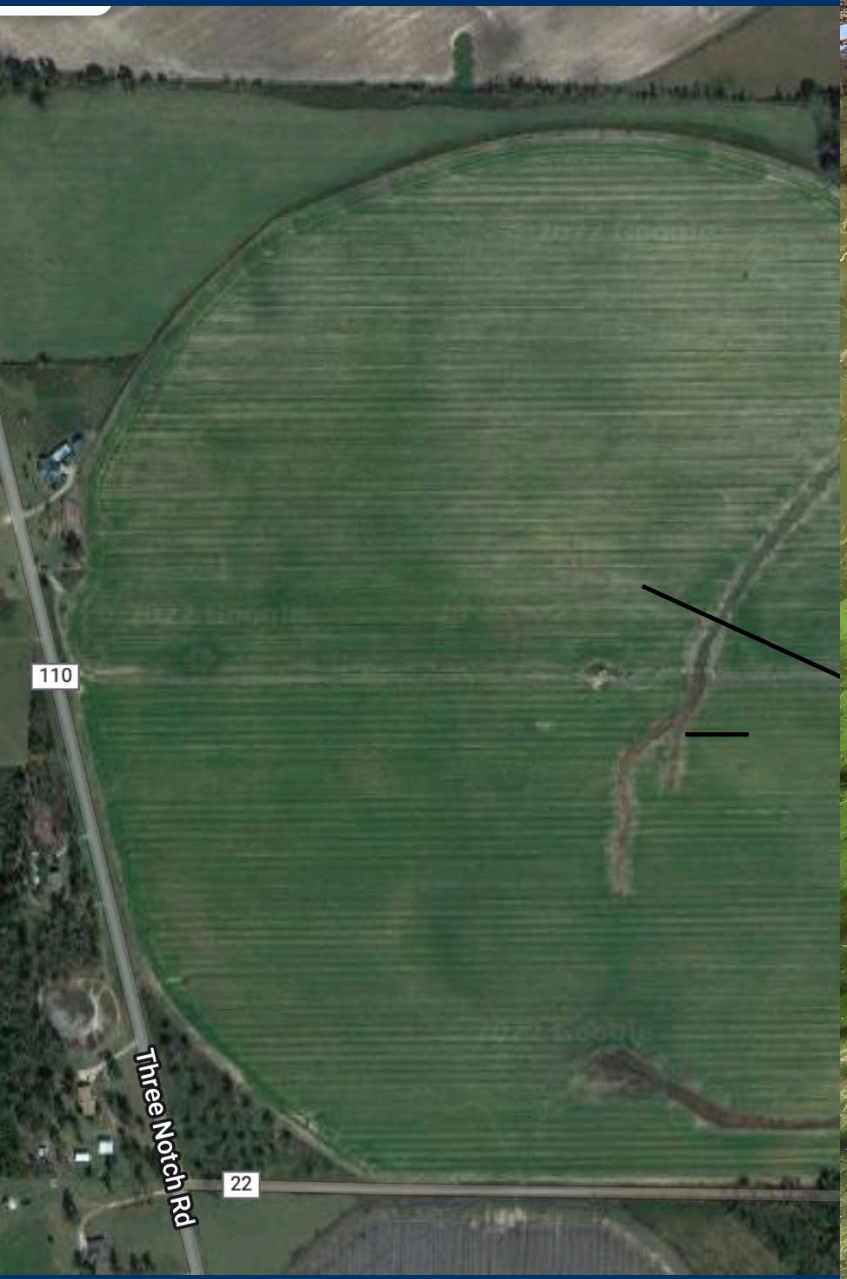
Drought Conditions

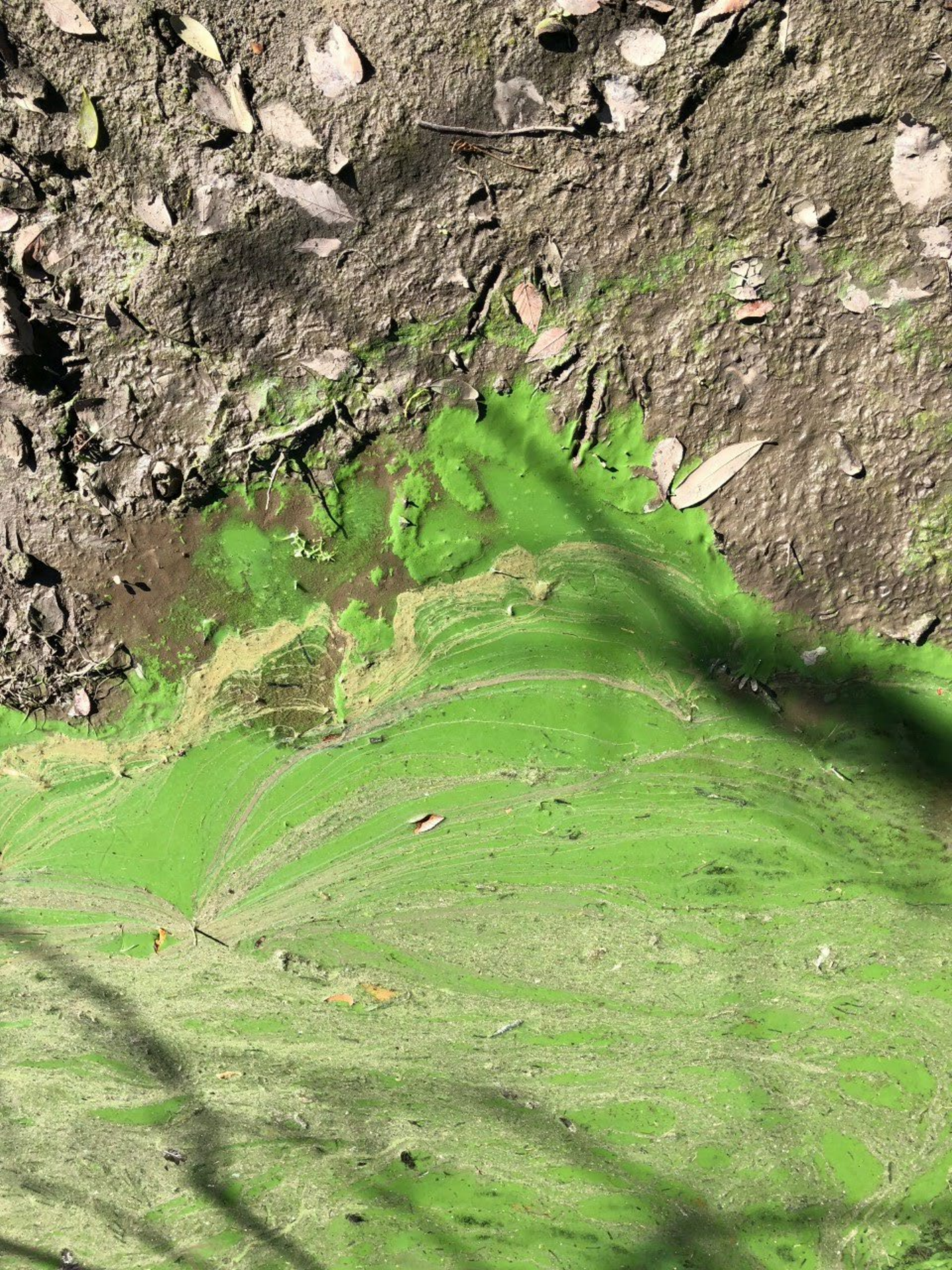


USDA (droughtmonitor.unl.edu)



January 2022 7 cattle deaths, Seminole County


110
Three Notch Rd
22



Hepatotoxins
"Liver toxins"

Microcystins

Injury to:

- Liver
- Spleen
- Kidneys
- Lungs
- Intestine
- Genotoxic

Chronic health effects at lower concentrations,
Acute at high concentration
Critical drinking water resource concern

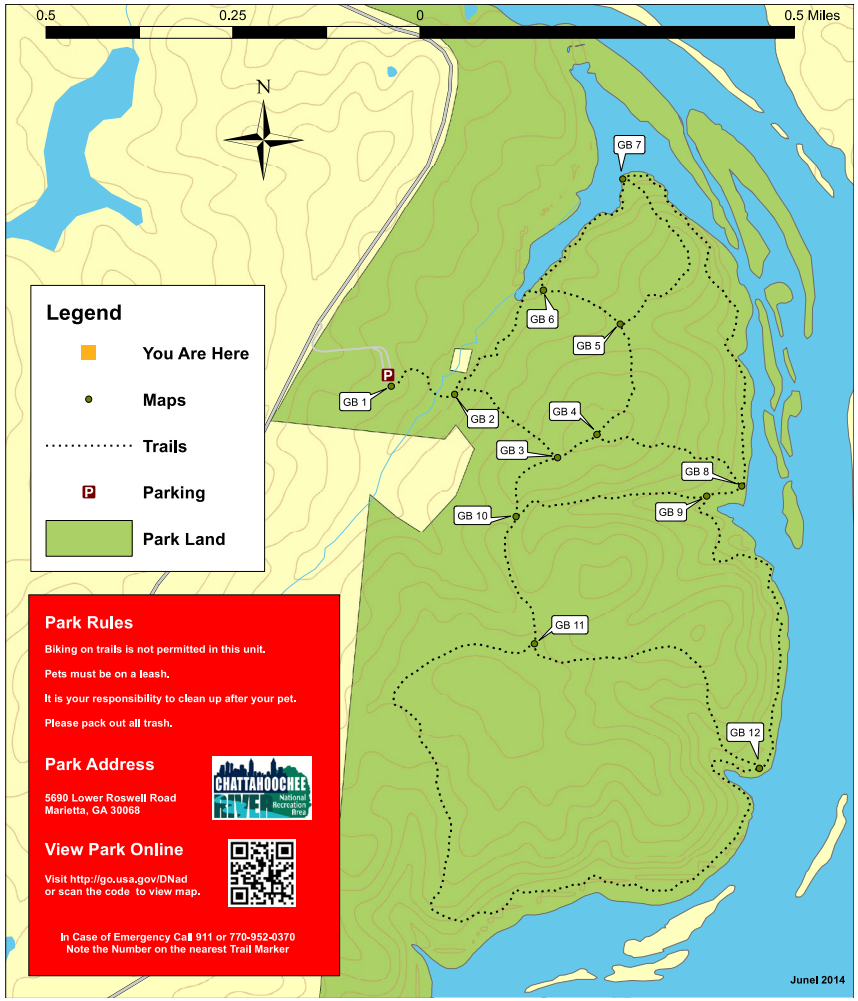

Chattahoochee
cyanoHAB
monitoring

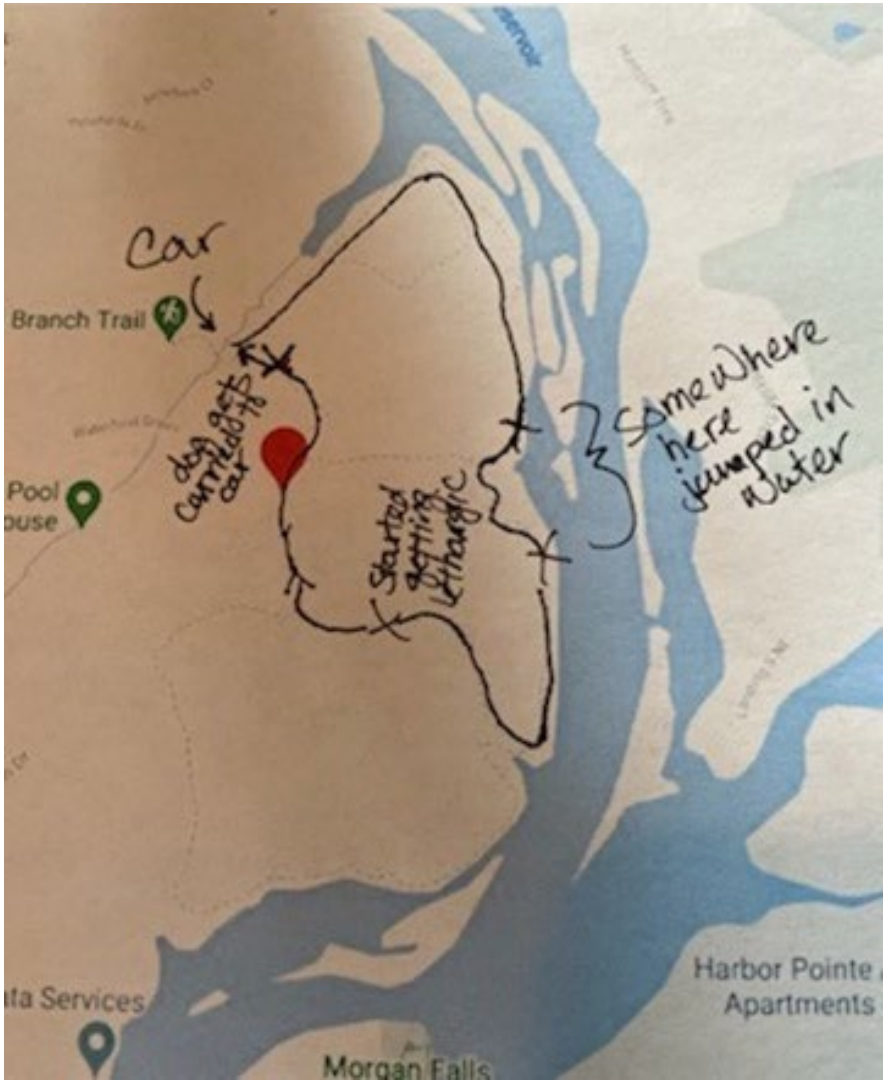
WSB-TV 2 ATLANTA

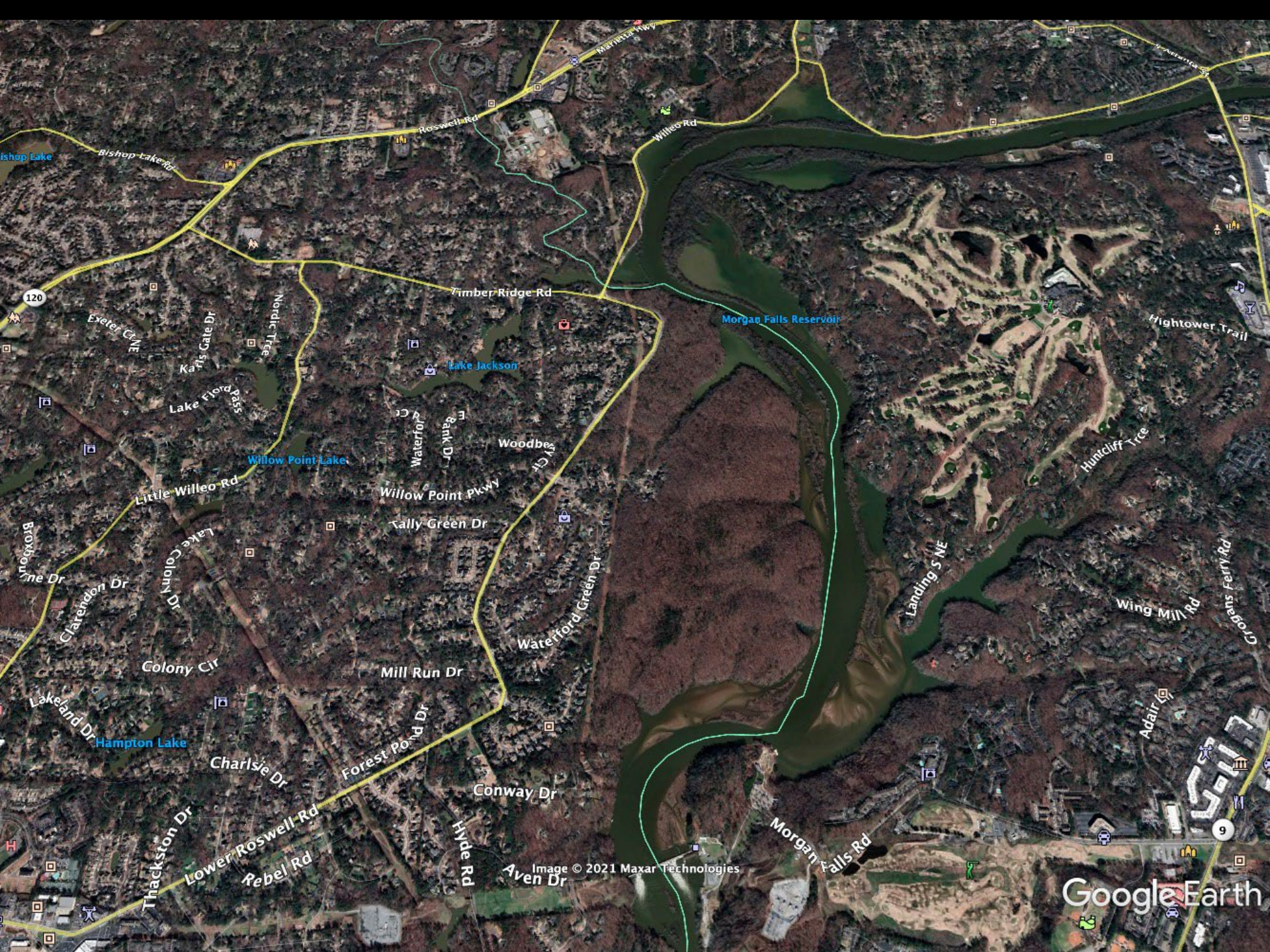
Weather • COVID-19 Vaccine • News • Video • Coronavirus • Traffic • Community • Contact Us • Upload Photos • Steals and Deals

A pet owner's warning: Beloved dog dies after swimming in lake fed by Chattahoochee River

https://www.wsbtv.com/news/local/north-fulton-county/pet-owners-warning-beloved-dog-dies-after-swimming-lake-fed-by-chattahoochee-river/W6NHKPE4NNHYZHTD7PJ2RBIKDA/


0.5
0.25
0
0.5 Miles
N
Legend
You Are Here
Maps
Trails
Parking
Park Land
GB 1
GB 2
GB 3
GB 4
GB 5
GB 6
GB 7
GB 8
GB 9
GB 10
GB 11
GB 12
Park Rules
Biking on trails is not permitted in this unit.
Pets must be on a leash.
It is your responsibility to clean up after your pet.
Please pack out all trash.
Park Address
5690 Lower Roswell Road
Marietta, GA 30068
CHATTAHOOCHEE RIVER National Recreation Area
View Park Online
Visit http://go.usa.gov/DNad
or scan the code to view map.
In Case of Emergency Call 911 or 770-952-0370
Note the Number on the nearest Trail Marker
Junel 2014

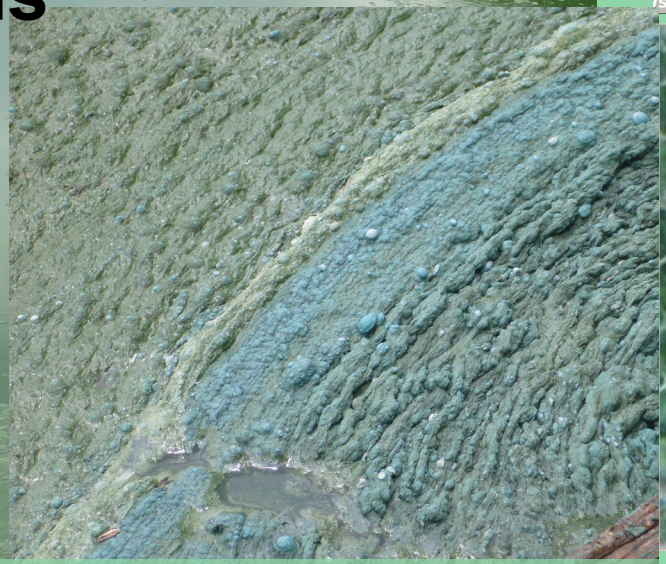

Car
Branch Trail
Pool
Harbor Pointe
Apartments
Morgan Falls


Roswell Rd
Willeo Rd
Bishop Lake Rd
Timber Ridge Rd
Morgan Falls Reservoir
Lake Jackson
Willow Point Lake
Little Willeo Rd
Willow Point Pkwy
Tally Green Dr
Waterford Green Dr
Mill Run Dr
Colony Cir
Hampton Lake
Charlsie Dr
Forest Pond Dr
Conway Dr
Lower Roswell Rd
Rebel Rd
Thackston Dr
Hyde Rd
Aven Dr
Morgan Falls Rd
Wing Mill Rd
Hightower Trail
Huntcliff Trce
Landing S NE
Adair Ct
Exeter Cir NE
Karls Gate Dr
Nordic Trce
Lake Flora Pass
Clarendon Dr
Lake Colony Dr
Brookhaven Dr
Image © 2021 Maxar Technologies
Google Earth

Neurotoxins
"nerve toxins"

Anabaena
Oscillatoria;Planktothrix

- **Anatoxin-a**
- **Saxitoxins**



Acute at relatively low concentrations

Nutrients: TN & TP
Microscopy: FlowCam:
Extraction: SPATT, snails, mussels, sediment, water
ELISA: initial screening to detect risk of algal toxins
HPLC/MS: specific determination of algal toxins
Bioassay: test for relative toxicity of extracts on brine shrimp and/or larval zebrafish

BenthoTorch
Measurement of Phytobenthos Fluorescence

Avian Vacuolar Myelinopathy (AVM)

- The beginning: 1st disease locations
- Disoriented birds and brain lesions
- Food chain transfer

- Invasive aquatic plants/cyanobacterial monitoring
- Field sentinel trials
- Laboratory toxin trials
- Expanding locations
- Expanding taxa
- Management solutions

Back to the beginning

1994/95 DeGray Lake, AR

29 bald eagle mortalities

1996/97 DeGray, Ouachita, Hamilton, AR

26 eagle mortalities, disease confirmed in American coots

"Avian Vacuolar Myelinopathy (AVM) is the most significant unknown cause of eagle mortality in the history of the United States"

Photo by Tom Murphy; SCDNR

Neurological impairment

- Eagle with drooping wings

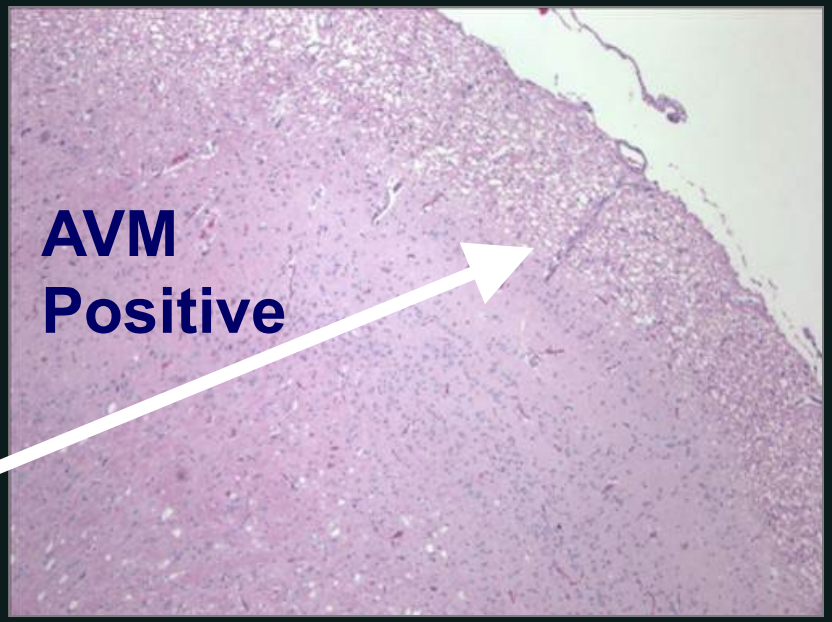
- Unresponsive coot

- Waterfowl and eagles wobble in flight
- Birds observed stumbling on land
- Coots may dive and then not right themselves
- Eagles may overshoot perches or fly into objects

Diagnosis: Unique brain lesions

National Wildlife Health Center

Southeastern Cooperative Wildlife Disease Study



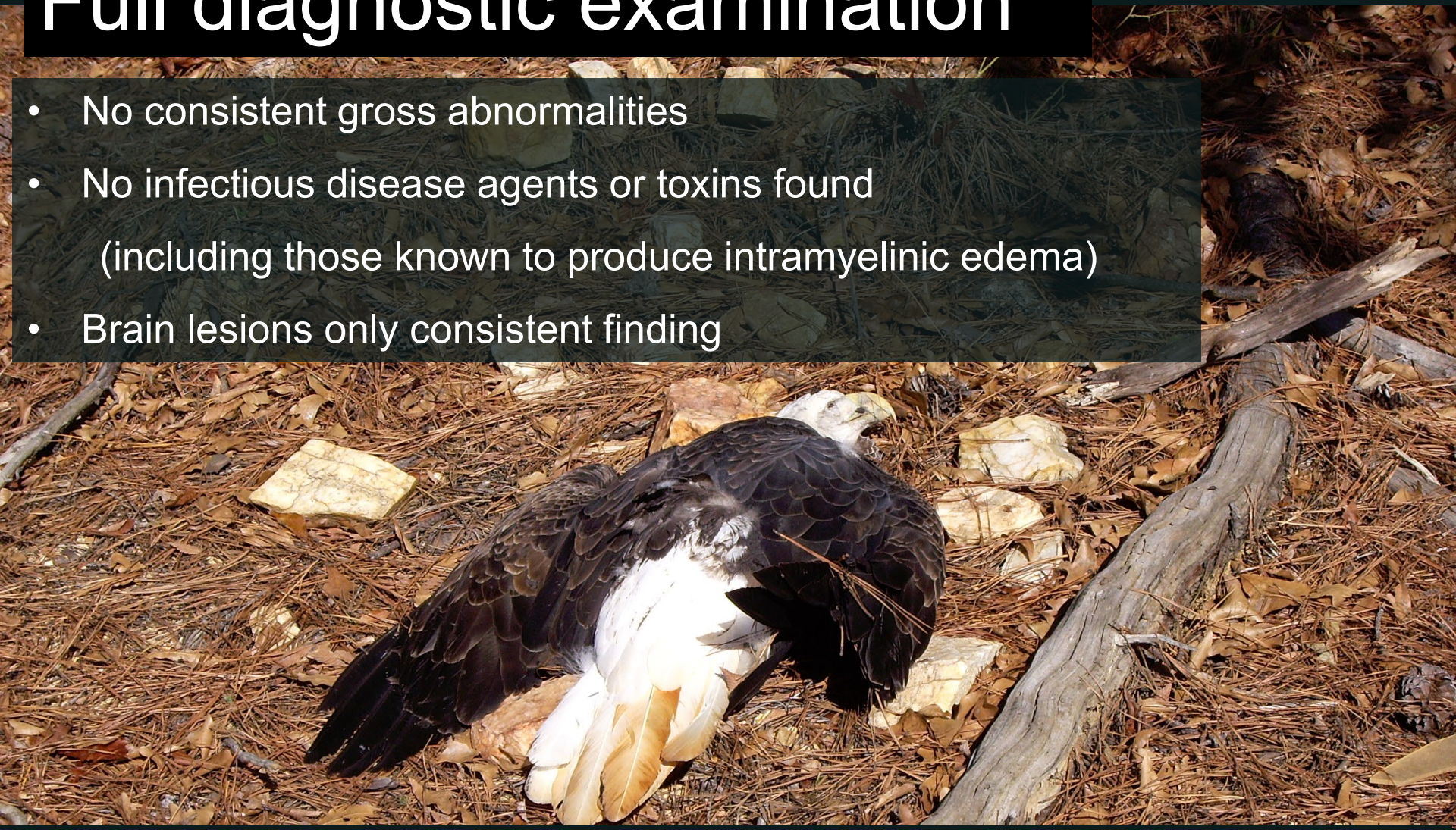
Open spaces in:
white matter of the central nervous system, specifically an intramyelinic edema

Thomas, NJ, CU Meteyer, and L Sileo, 1998. Epizootic vacuolar myelinopathy of the central nervous system of bald eagles (Haliaeetus leucocephalus) and American coots (Fulica American). Veterinary Pathology 35:479-487

Full diagnostic examination

- No consistent gross abnormalities
- No infectious disease agents or toxins found

  (including those known to produce intramyelinic edema)
- Brain lesions only consistent finding

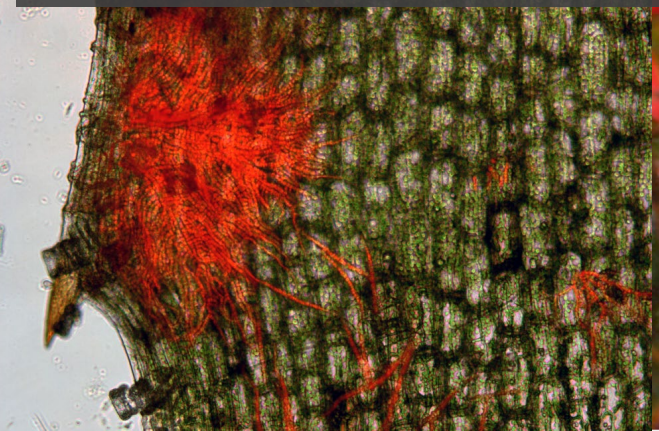


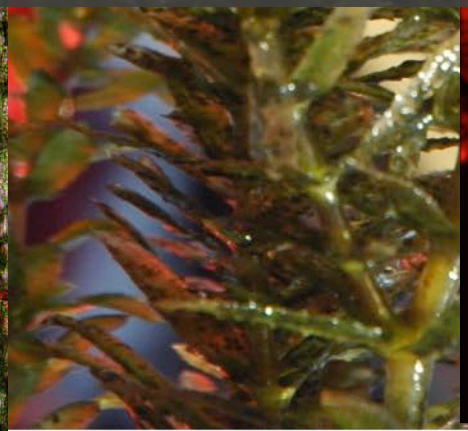
Thomas, NJ, et al, 1998.

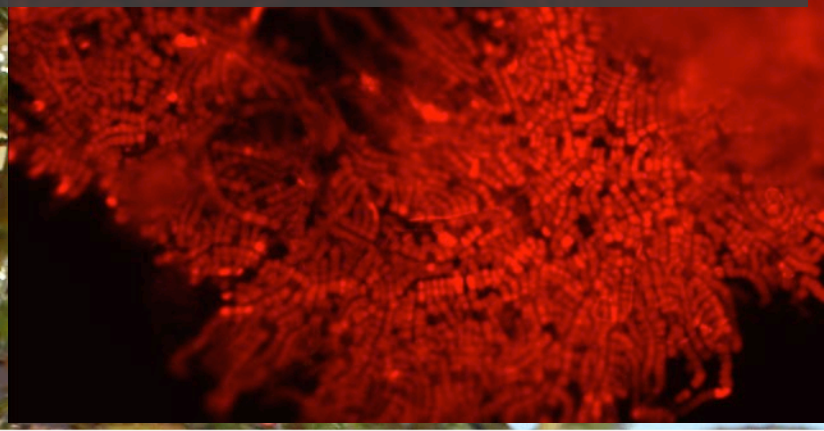
Dodder, NG, B Strandberg, T Augspurger, and RA Hites. 2003. Lipophilic organic compounds in lake sediment and American coot (Fulica americana) tissues, both affected and unaffected by avian vacuolar myelinopathy. Science Total Environment 311:81-89.

Novel cyanobacterial species growing on invasive aquatic plants all AVM sites

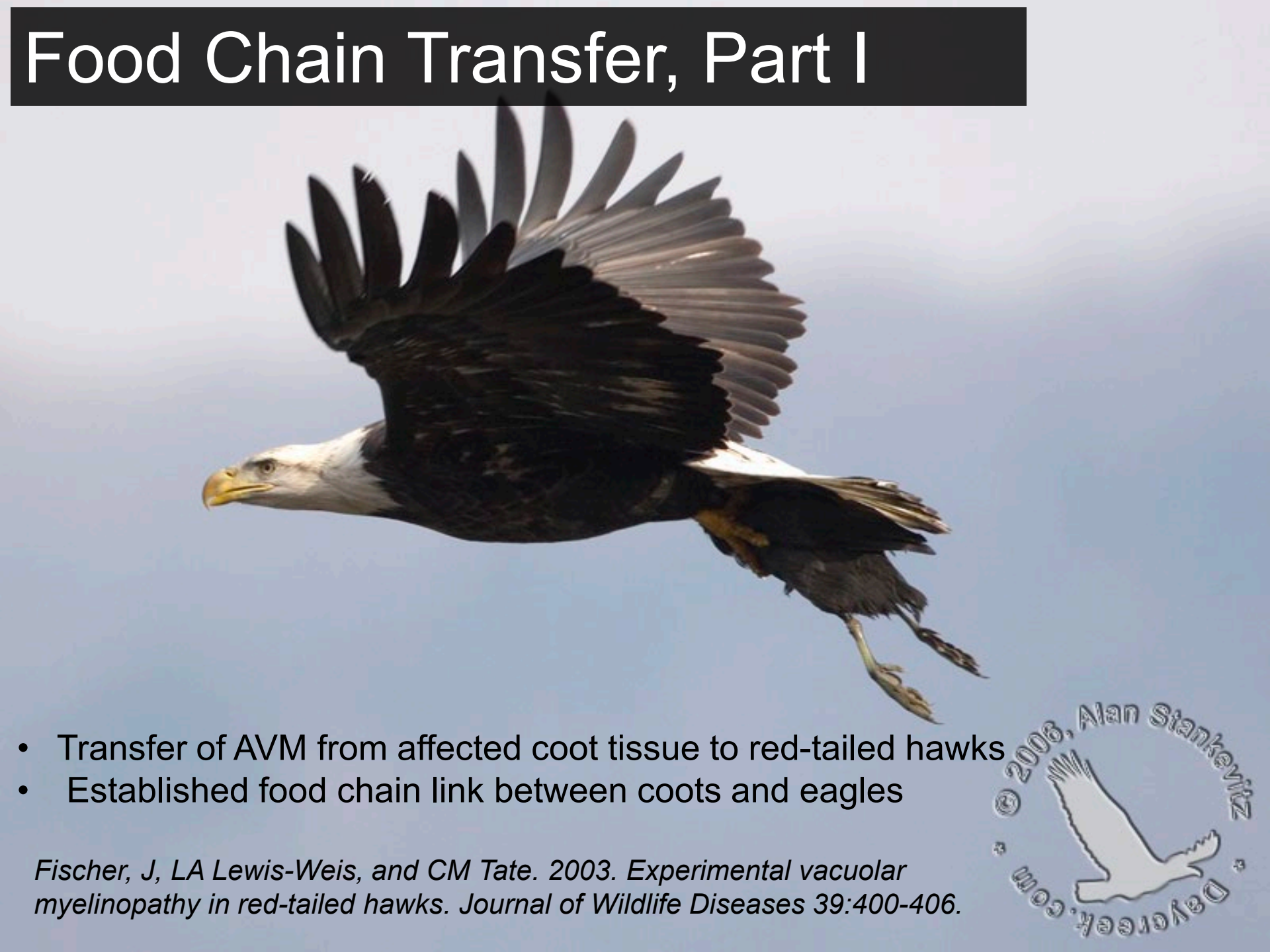
- Previously undescribed cyanobacterial species
- Cyanobacteria (or blue-green algae) are photosynthetic bacterial species that can produce liver and nerve toxins
- Grows as an epiphyte on hydrilla and other invasive exotic aquatic plants in all AVM sites







Food Chain Transfer, Part I

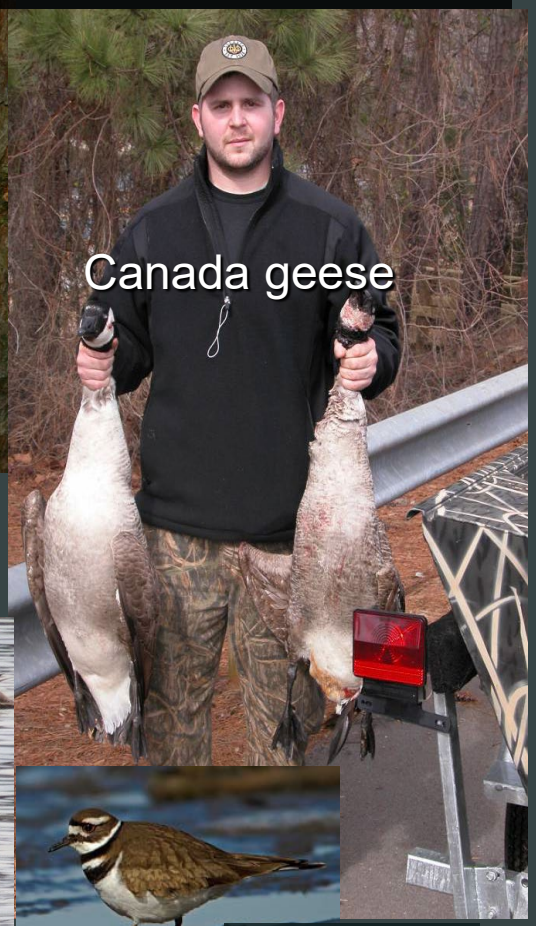


- Transfer of AVM from affected coot tissue to red-tailed hawks
- Established food chain link between coots and eagles

Fischer, J, LA Lewis-Weis, and CM Tate. 2003. Experimental vacuolar myelinopathy in red-tailed hawks. Journal of Wildlife Diseases 39:400-406.

Bird species with AVM brain lesions

Mallards, Ring-necked ducks
Buffleheads, American wigeon



Killdeer

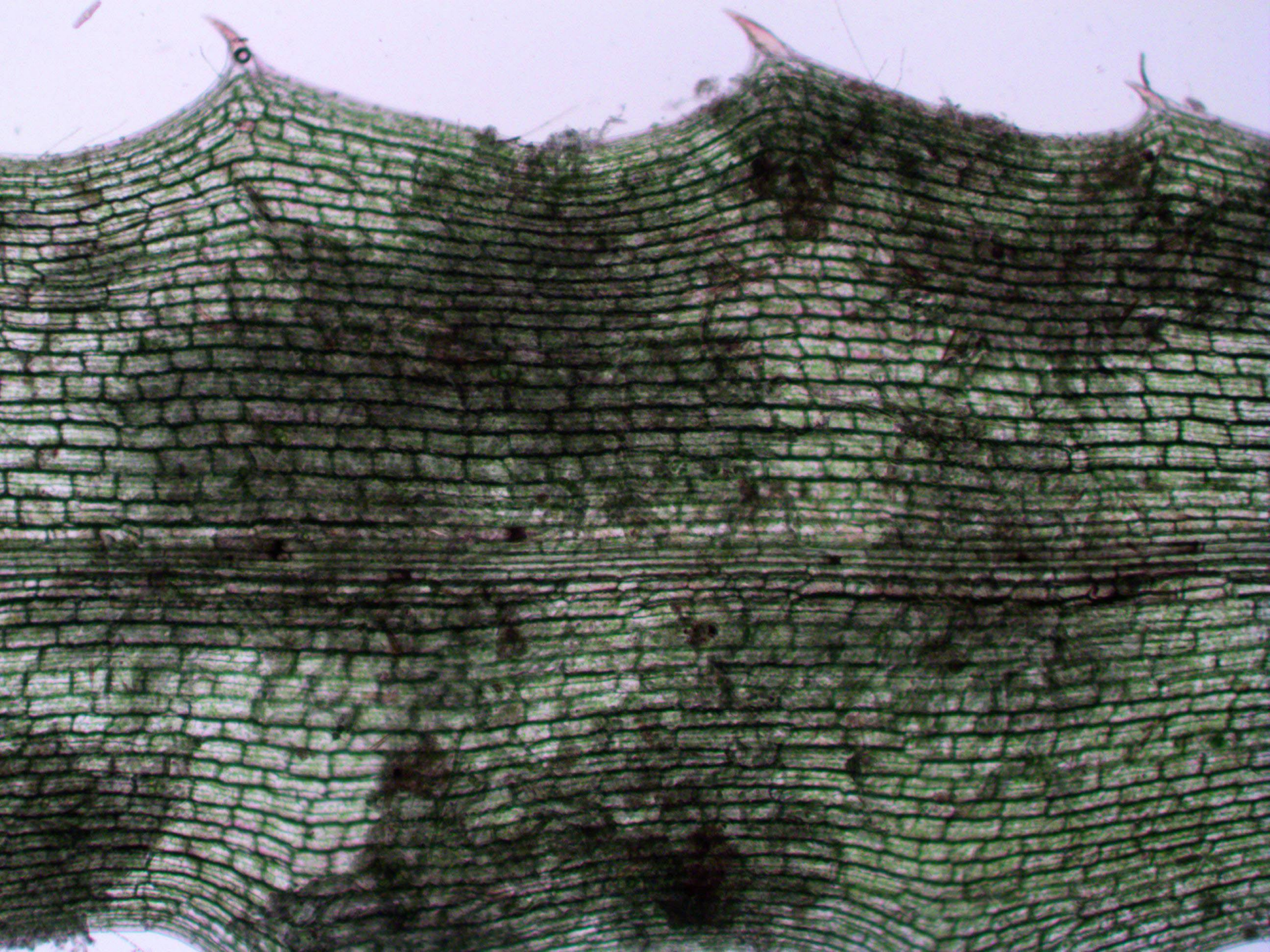
Augspurger, T, JR Fischer, NJ Thomas, L Sileo, RE Brannian, KJG Miller, and TE Rocke. 2003. Vacuolar myelinopathy in waterfowl from a North Carolina impoundment. JWD 39:412-417.

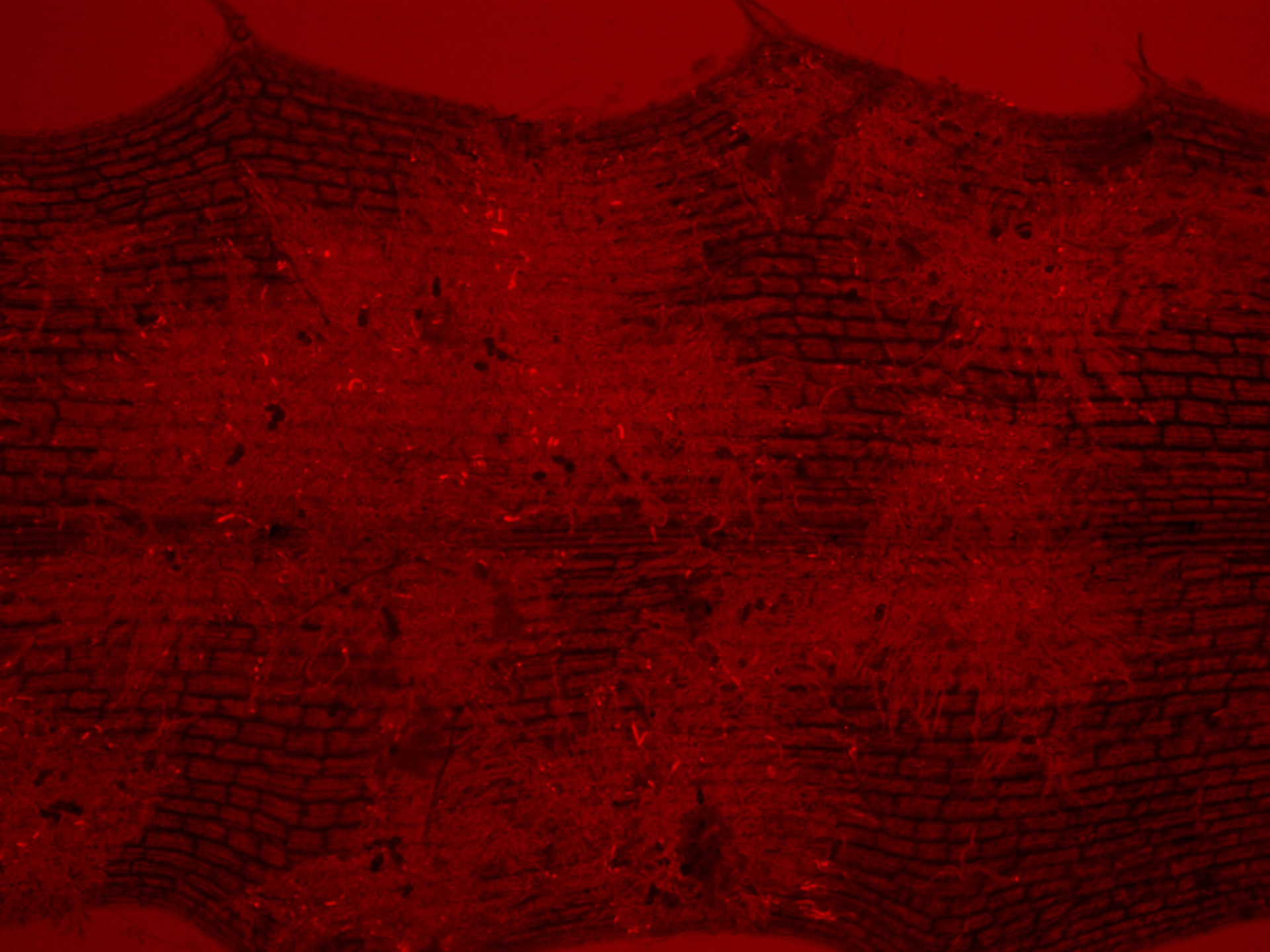
Fischer, J, LA Lewis-Weis, CM Tate, JK Gaydos, RW Gerhold, RH Poppenga. 2006. Avian vacuolar myelinopathy outbreaks at a southeastern reservoir. JWD 42:501-510

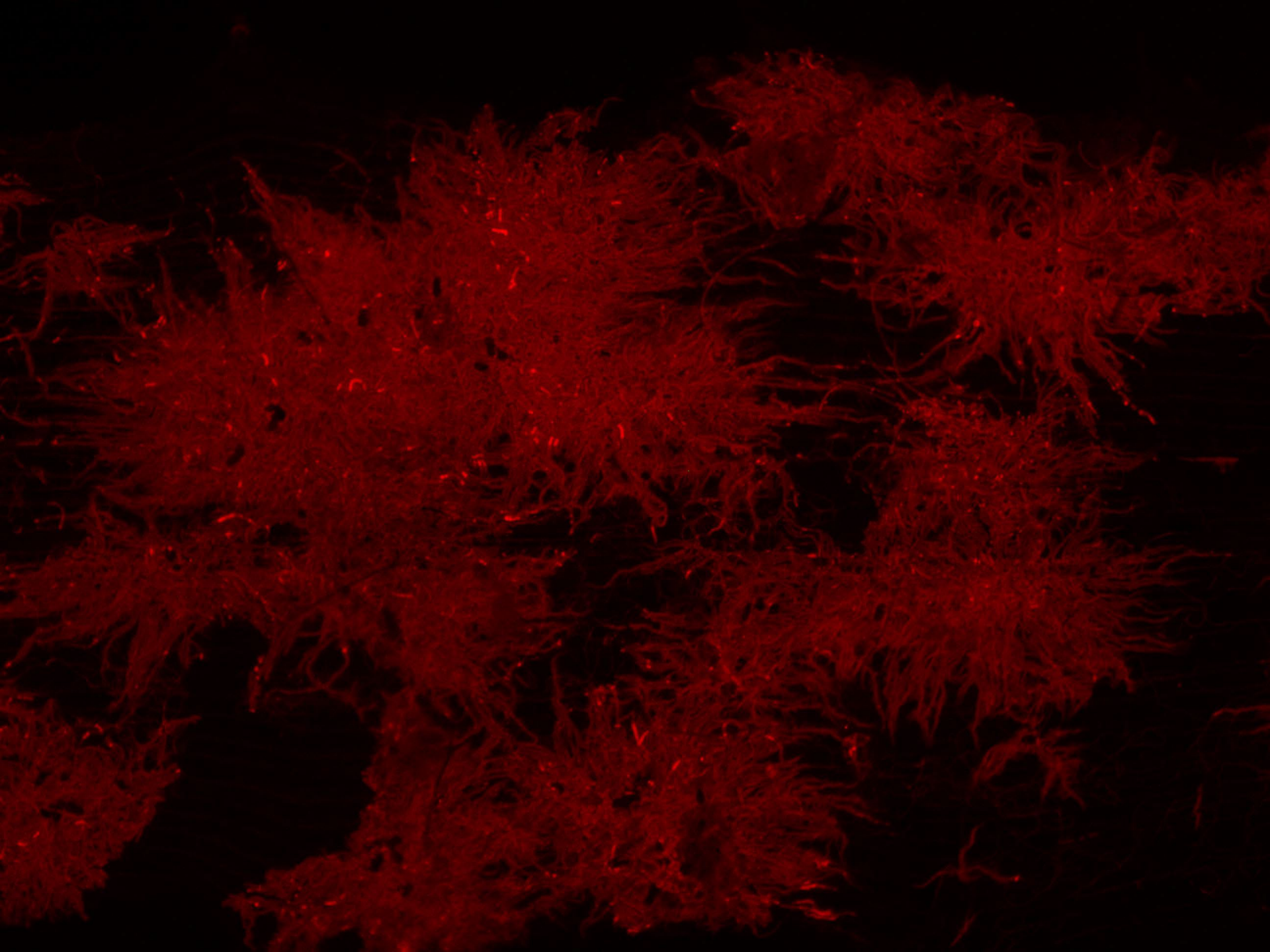
Reservoir surveys: 2001-present

All AVM Sites

- Man-made ponds/reservoirs
- Nutrients low to moderate
- No harmful algal blooms in the water
- Dense non-native aquatic plants

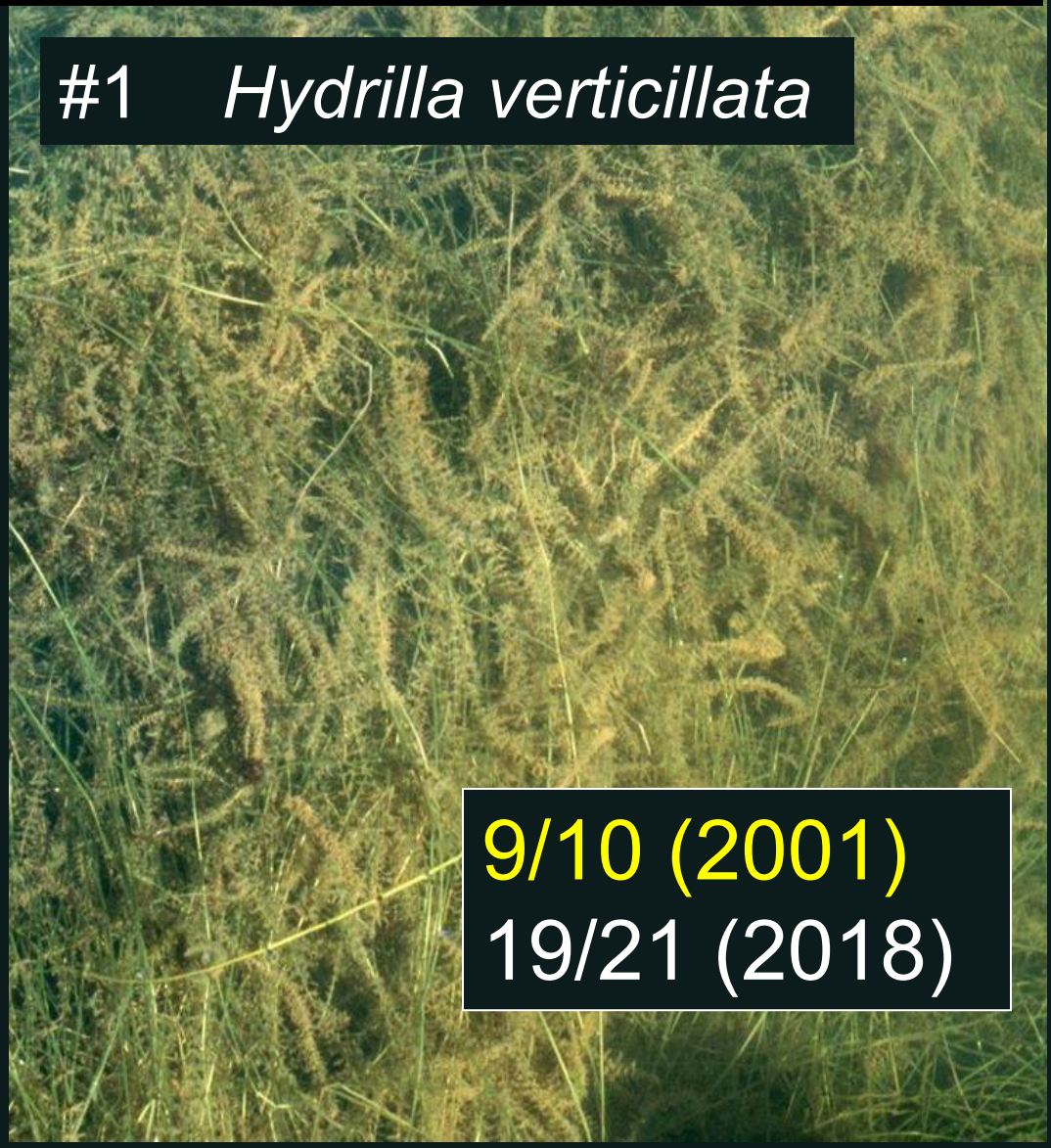






Submerged non-native aquatic plants

1994	DeGray Lake, AR
1996	Quachita, AR
1998	Woodlake, NC
1998	Thurmond, SC/GA
1998	Lake Juliette, GA
1998	Par Pond, SC
1998	L Lake, SC
1999	Lake Murray, SC
1999	Sam Rayburn, TX
2003	Davis Pond, SC
2003	Emerald Lake, GA
2005	Lake Horton, GA
2005	Smith Reservoir, GA
2005	Coachmans Trail, NC
2007	Lake Varner, GA
2010	Upper Towaliga, GA
2011	Longbranch, GA
2012	Lake Tohopekaliga, FL
2013	Lake Istokpoga, FL
2016	Kerr Reservoir, NC/VA
2018	Lake Tussehaw, GA

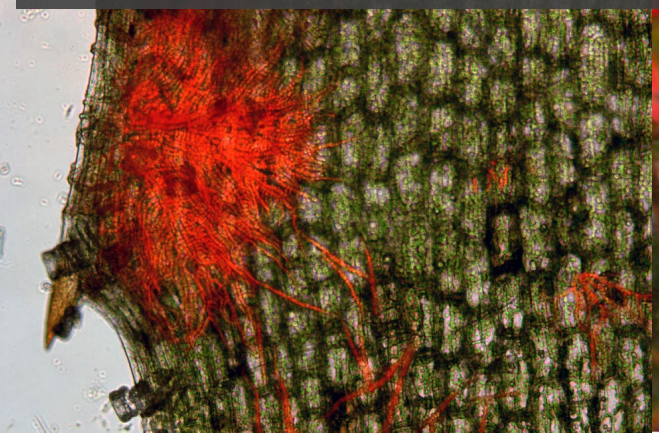


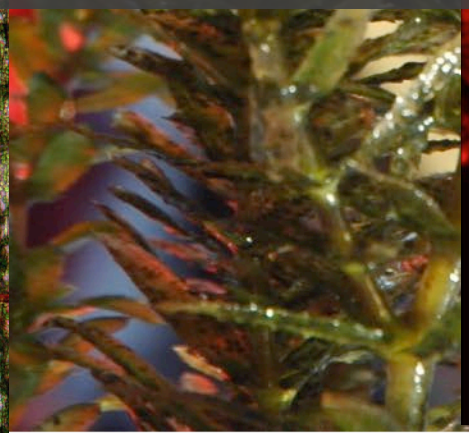
1997 Hamilton, AR
1998 SRS- L Lake, SC
1998 SRS-Par Pond, SC
1998 Lake Juliette, GA

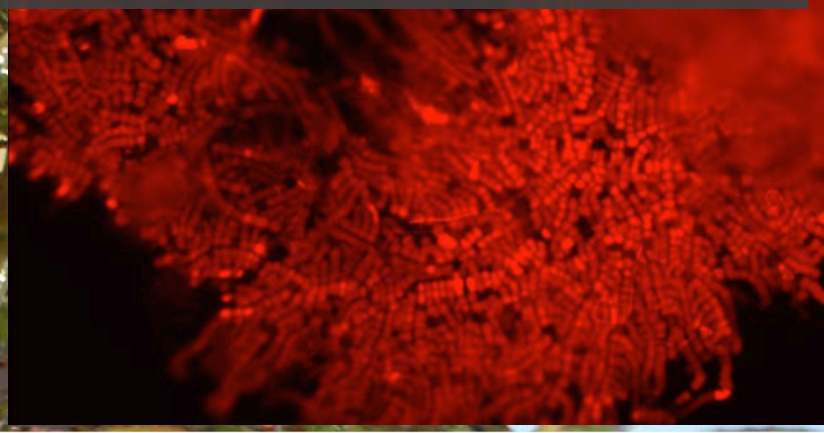
1994 DeGray Lake, AR
1996 Lake Ouachita, AR
1998 Lake Juliette, GA

Harmful cyanobacteria growing on invasive aquatic plants-- AVM sites

- Previously undescribed cyanobacterial species
- Cyanobacteria (or blue-green algae) are photosynthetic bacterial species that can produce liver and nerve toxins
- Grows as an **epiphyte on hydrilla** and other invasive exotic aquatic plants in all AVM sites

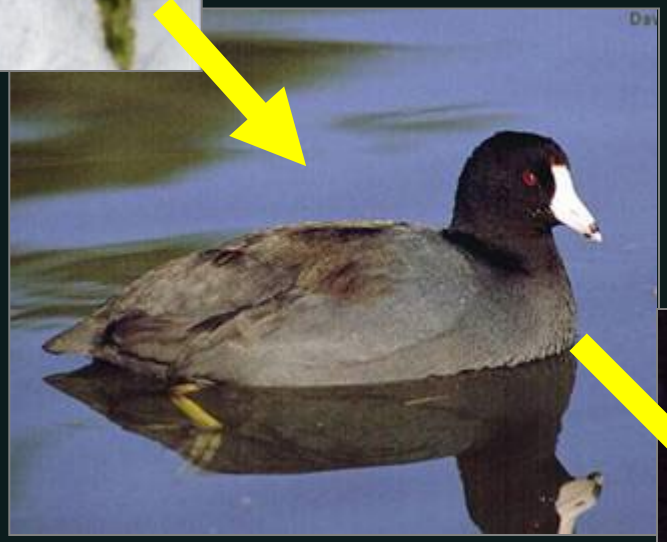






Food Chain Transfer Hypothesis

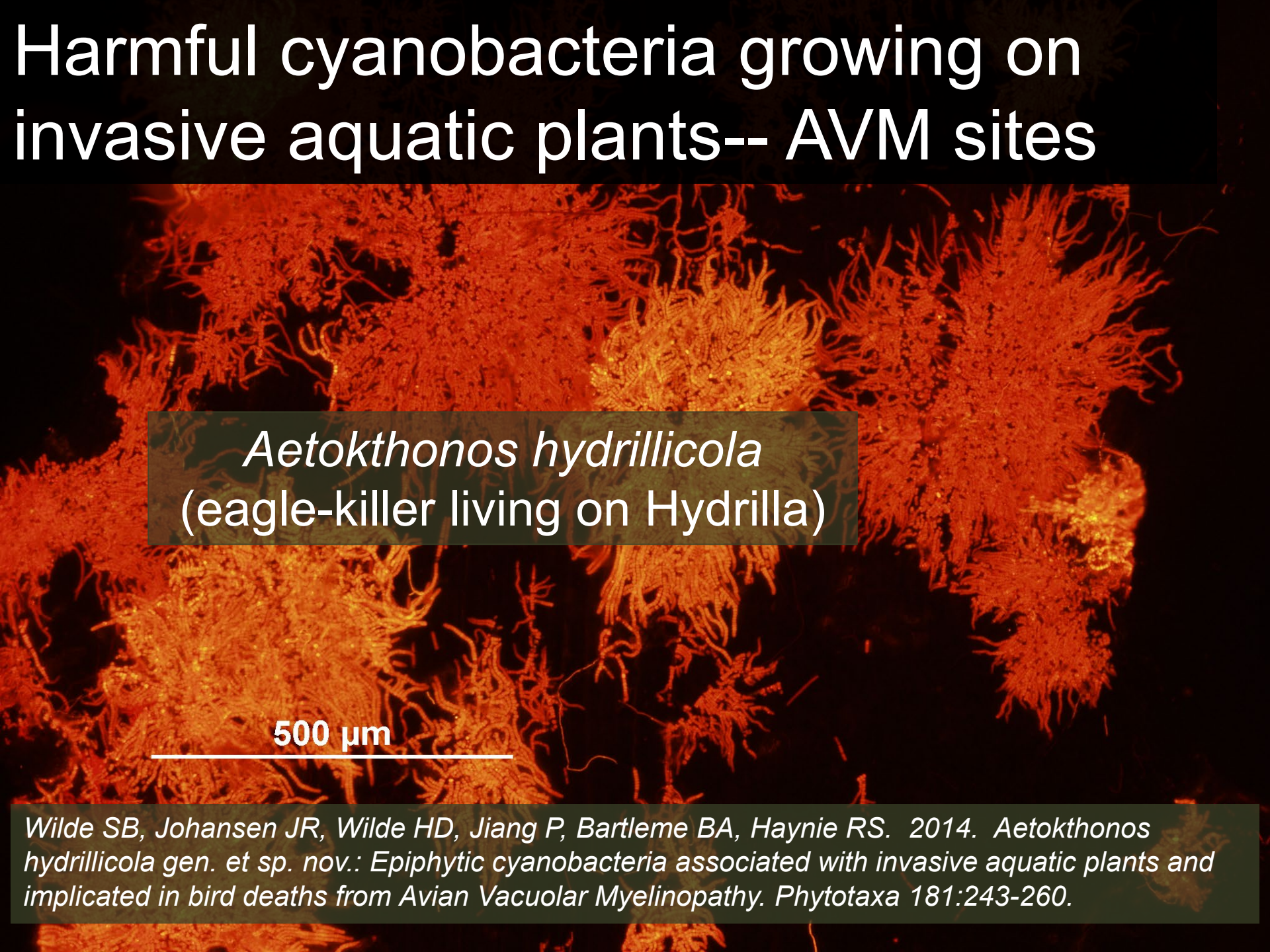
Potentially toxic cyanobacterial colonies on hydrilla and other aquatic plants in AVM sites



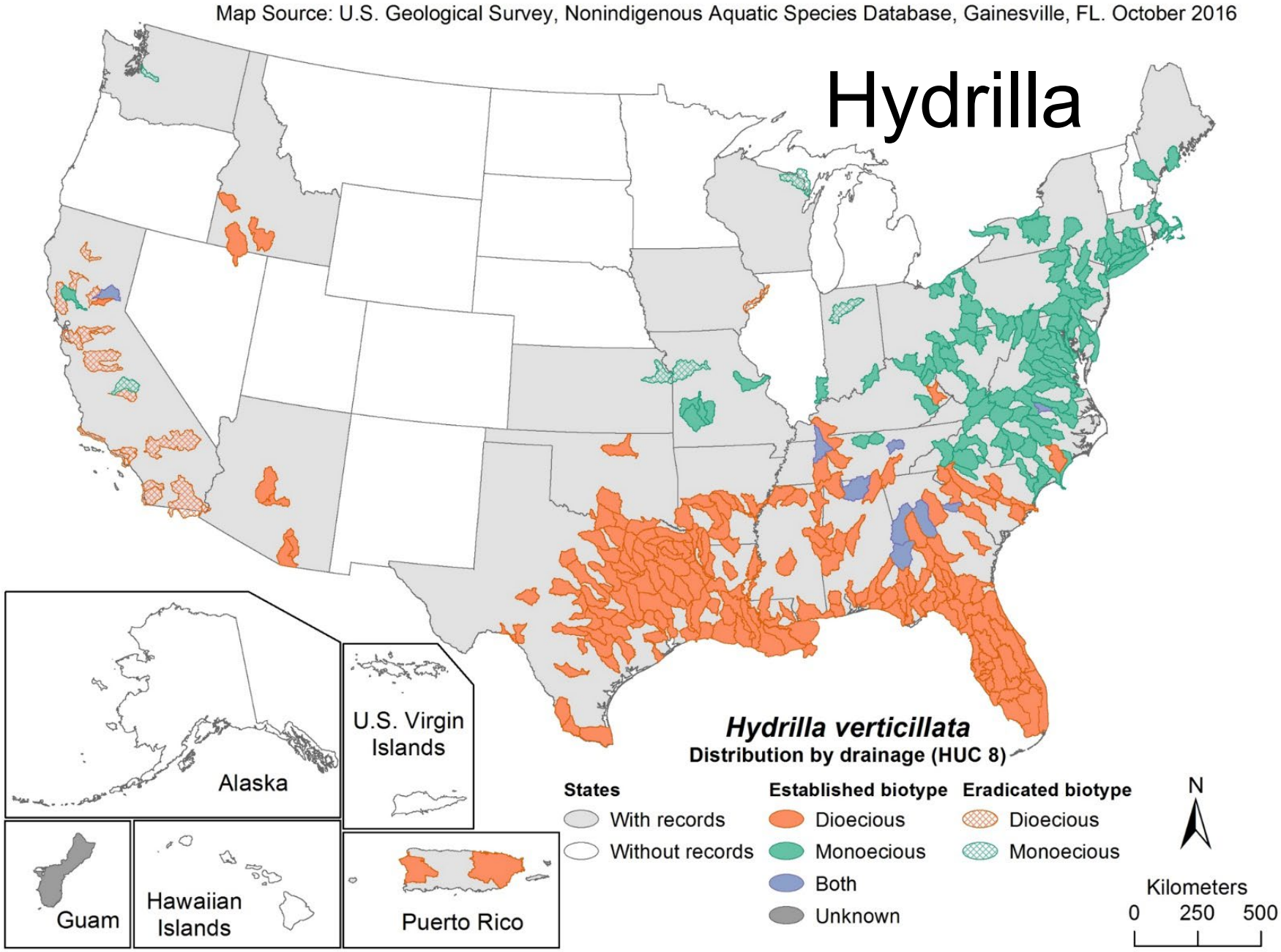
Aquatic plants and epiphytic algae are primary food source for coots

Sick waterfowl are consumed by Bald Eagles

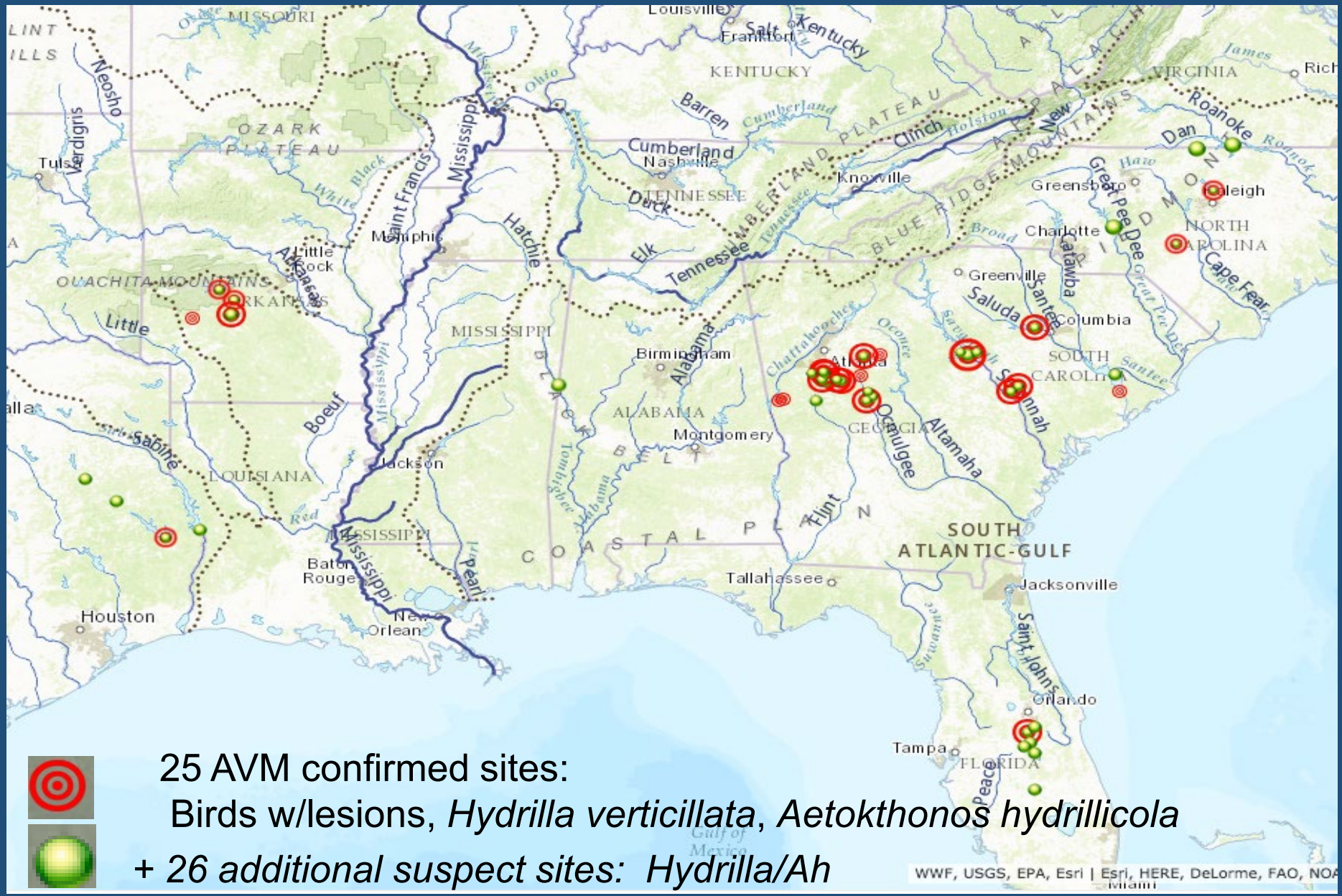
Harmful cyanobacteria growing on invasive aquatic plants-- AVM sites



Wilde SB, Johansen JR, Wilde HD, Jiang P, Bartleme BA, Haynie RS. 2014. Aetokthonos hydrillicola gen. et sp. nov.: Epiphytic cyanobacteria associated with invasive aquatic plants and implicated in bird deaths from Avian Vacuolar Myelinopathy. Phytotaxa 181:243-260.


Map Source: U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL. October 2016
Hydrilla
Alaska
U.S. Virgin Islands
Guam
Hawaiian Islands
Puerto Rico
Hydrilla verticillata
Distribution by drainage (HUC 8)
States
With records
Without records
Established biotype
Dioecious
Monoecious
Both
Unknown
Eradicated biotype
Dioecious
Monoecious
N
Kilometers
0 250 500

“Avian” Vacuolar Myelinopathy 2021



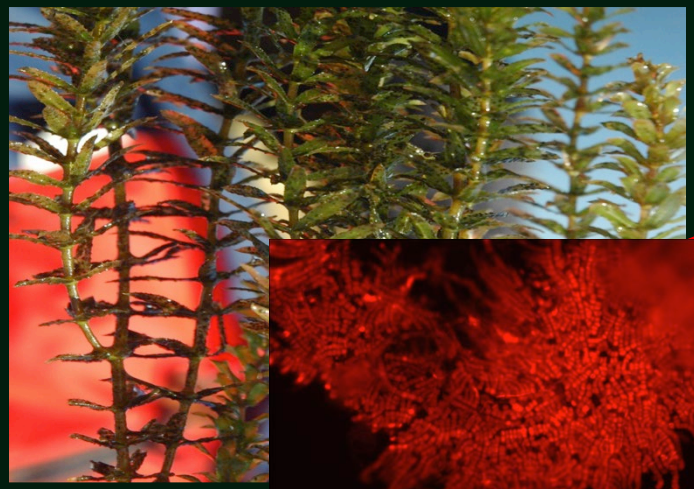
25 AVM confirmed sites:

Birds w/lesions, *Hydrilla verticillata*, *Aetokthonos hydrillicola*

+ 26 additional suspect sites: Hydrilla/Ah

Expanding Food Chain

More aquatic animals at risk



Birrenkott 2004

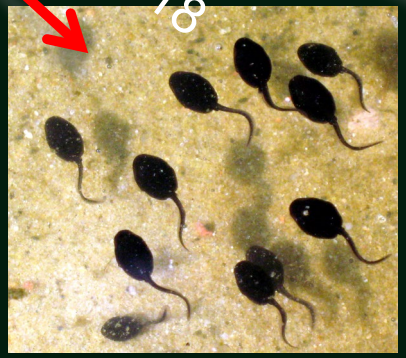
Haynie 2013

Haram et al submitted

Maerz, et al 2018

Mercurio 2014

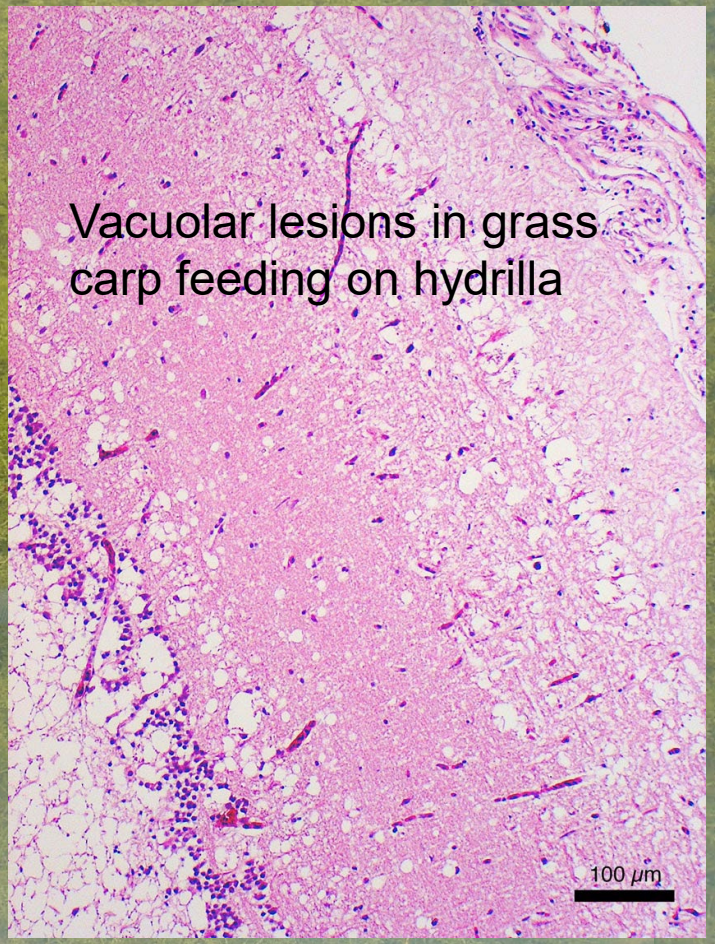
Dodd 2016



Management solutions

Triploid Chinese Grass Carp

- Effective control of submerged aquatic plants
- Develop vacuolar lesions, but survive
- Did not induce lesions in birds



Taylor & Francis

Journal of Aquatic Animal Health

ISSN: 0899-7659 (Print) 1548-8667 (Online) Journal homepage: http://www.tandfonline.com/loi/uahh20

Triploid Grass Carp Susceptibility and Potential for Disease Transfer when used to Control Aquatic Vegetation in Reservoirs with Avian Vacuolar Myelinopathy

Rebecca S. Haynie , William W. Bowerman , Sarah K. Williams , John R. Morrison , John M. Grizzle , John M. Fischer & Susan B. Wilde

- First AVM study with grass carp (field and lab trials)
- No mortality or abnormal behavior found in treatment or control fish in laboratory study
- Chickens consuming grass carp did not develop AVM lesions.

Exposure type	*n*	Fish with lesions
Lab Treatment	20	11
Lab Control	20	0
Field	23	7

Consistent histology, Vacuolar myelinopathy

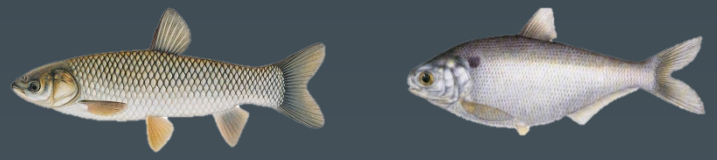
Grass Carp VM Lesions

J. Strom Thurmond
Hydrilla + *Aetokthonos hydrillicola*

Control
Hydrilla

Dr. Alvin Camus, UGA Veterinary Pathologist

VM Confirmed



Fish

Salamanders

Frogs

Mammals

Turtles

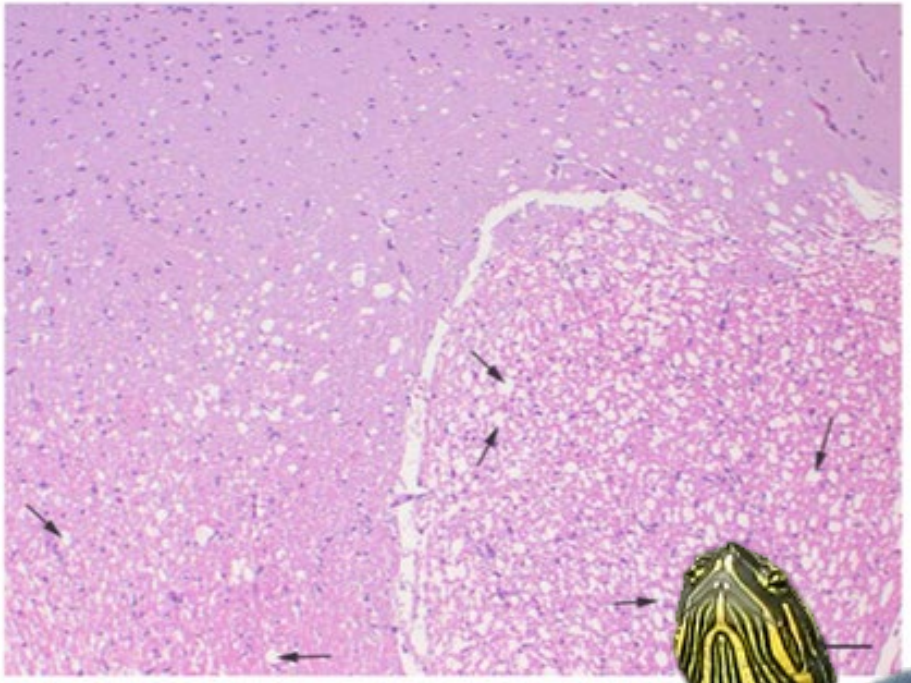
Alligators

Birds

Snakes

Diagram provided by
Dr. John C. Maerz

Key Findings



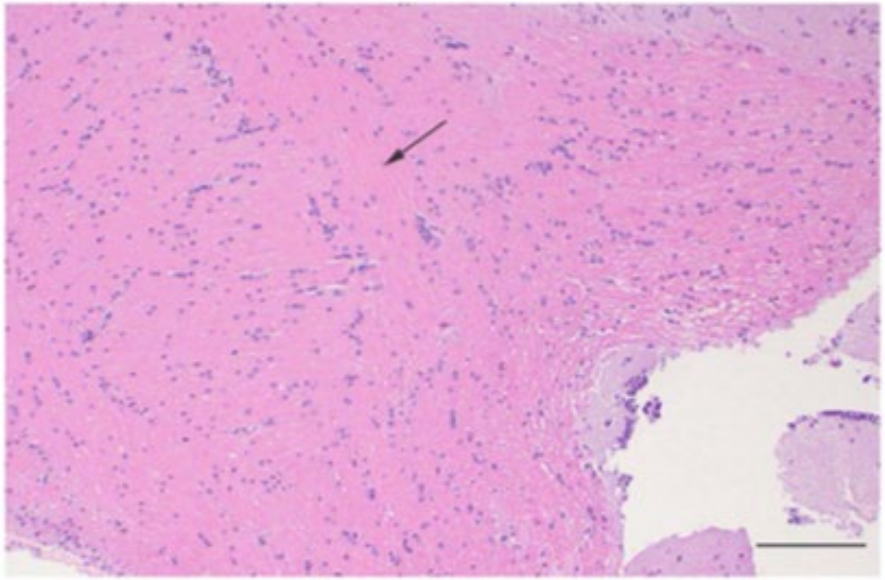


Figure 1. Histopathological slide of the optic … painted turtle fed toxic *Hydrilla* material. Painted tu… *picta*), brain: Numerous clear vacuoles (black arrow… myelin degeneration and dilation of axonal sheaths a… white matter of a turtle treated with toxic hydrilla. H&… is 100 μm.
doi:10.1371/journal.pone.0093295.g001

Figure 3. Histopathological slide of the optic tectum of a …ted turtle (*Chrysemys picta*), brain: white matter, … appears normal with no evidence of …ion. H&E, 100X. Scale bar is 100 μm.

…some variation in distribu- …cerebellar lesions, this did …es in the clinical signs. … birds with VM

Consistent clinical impairment

80-90 days, all turtles fed Aetokthonos positive Hydrilla exhibited associated clinical signs of VM

Off balance swimming, floating

Weakness

Lethargy

Anorexia

Ataxia

OPEN ACCESS Freely available online

PLOS ONE

Experimental Feeding of *Hydrilla verticillata* Colonized by Stigonematales Cyanobacteria Induces Vacuolar Myelinopathy in Painted Turtles (*Chrysemys picta*)

Albert D. Mercurio[1,2]*, Sonia M. Hernandez[1,2], John C. Maerz[1], Michael J. Yabsley[1,2], Angela E. Ellis[3], Amanda L. Coleman[1], Leslie M. Shelnutt[4], John R. Fischer[2], Susan B. Wilde[1]

1 D. B. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, Georgia, United States of America, 2 Southeastern Cooperative Wildlife Disease Study (SCWDS), Department of Population Health, Wildlife Health Building, College of Veterinary Medicine, University of Georgia, Athens, Georgia, United States of America, 3 The Athens Veterinary Diagnostic Laboratory, College of Veterinary Medicine, University of Georgia, Athens, Georgia, United States of America, 4 The University of Georgia College of Veterinary Medicine, University of Georgia, Athens, Georgia, United States of America

Abstract

Vacuolar myelinopathy (VM) is a neurologic disease primarily found in birds that occurs when wildlife ingest submerged aquatic vegetation colonized by an uncharacterized toxin-producing cyanobacterium (hereafter "UCB" for "uncharacterized cyanobacterium"). Turtles are among the closest extant relatives of birds and many species directly and/or indirectly consume aquatic vegetation. However, it is unknown whether turtles can develop VM. We conducted a feeding trial to determine whether painted turtles (*Chrysemys picta*) would develop VM after feeding on *Hydrilla* (*Hydrilla verticillata*), colonized by the UCB (*Hydrilla* is the most common "host" of UCB). We hypothesized turtles fed *Hydrilla* colonized by the UCB would exhibit neurologic impairment and vacuolation of nervous tissues, whereas turtles fed *Hydrilla* free of the UCB would not. The ability of *Hydrilla* colonized by the UCB to cause VM (hereafter, "toxicity") was verified by feeding it to domestic chickens (*Gallus gallus domesticus*) or necropsy of field collected American coots (*Fulica americana*) captured at the site of *Hydrilla* collections. We randomly assigned ten wild-caught turtles into toxic or non-toxic *Hydrilla* feeding groups and delivered the diets for up to 97 days. Between days 82 and 89, all turtles fed toxic *Hydrilla* displayed physical and/or neurologic impairment. Histologic examination of the brain and spinal cord revealed vacuolations in all treatment turtles. [illegible] of the control turtles exhibited neurologic impairment or had detectable brain or spinal cord vacuolations. This is the [illegible] that freshwater turtles can become neurologically impaired and develop vacuolations after consuming toxic [illegible] with the UCB. The southeastern United States, where outbreaks of VM occur regularly and where [illegible] the UCB is common, is also a global hotspot of freshwater turtle diversity. Our results suggest that [illegible] effect of the putative UCB toxin on wild turtles *in situ* are warranted.

M.L. Ellis AE, et al. (2014) Experimental Feeding of *Hydrilla verticillata* Colonized by Stigonematales [illegible] *Chrysemys picta*). PLoS ONE 9(4): e93295. doi:10.1371/journal.pone.0093295

[illegible] Veterinary Research, Portugal

April 2, 2014

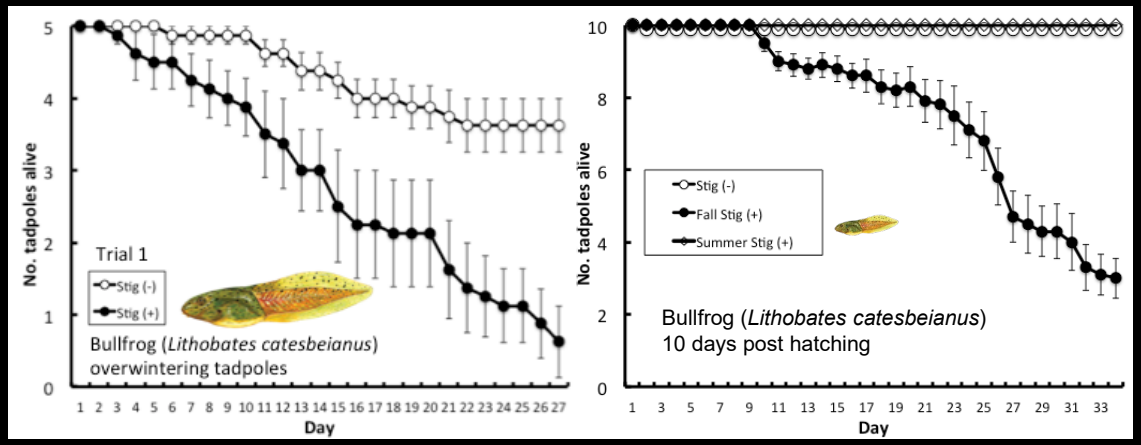
[illegible] Graduate School, The D. B. Warnell School of Forestry and Natural Resources, The National Institutes [illegible] Army Corps of Engineers (W912HZ-12-2-0013), and The United States Fish and Wildlife Service [illegible] collection and analysis, decision to publish, or preparation of the manuscript.

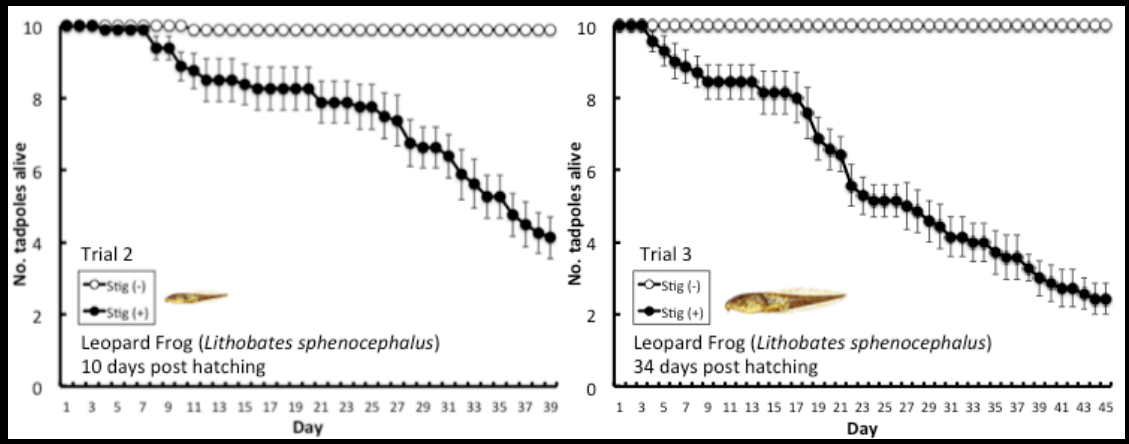
[illegible] ting interests exist.

aquatic plant species [6]. Birds may acquire the toxin(s) directly by ingesting plants that are colonized with the UCB or indirectly by feeding on herbivorous prey such as invertebrates [8] or other bird species that have fed on plants that are colonized with the UCB [9]. Affected birds develop microscopic vacuoles in the white [illegible] of the central nervous system. Lesions tend to be most [illegible] ent in the optic tectum but can occur in the cerebrum, [illegible] brain stem, or spinal cord. Degenerative lesions in [illegible] rarely been reported. Ultrastructurally, [illegible] of myelin lamellae at the intraperiod [illegible] ic edema. These lesions result in [illegible] t in severe cases can result in [illegible] to evaluate the risk that [illegible] UCB poses to other [illegible] carp (*Ctenopha-* [illegible] with the UCB

Amphibians

Impairment, mortality, VM lesions

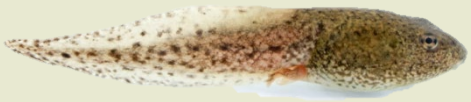




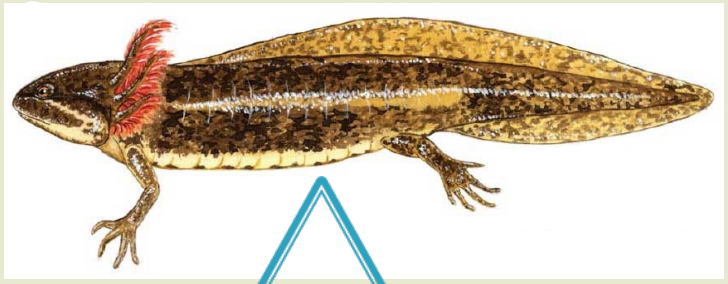
Trophic Transfer of *Aetokthonos hydrillicola* in Mole Salamanders (*Ambystoma talpoideum*)

Hunter Smith

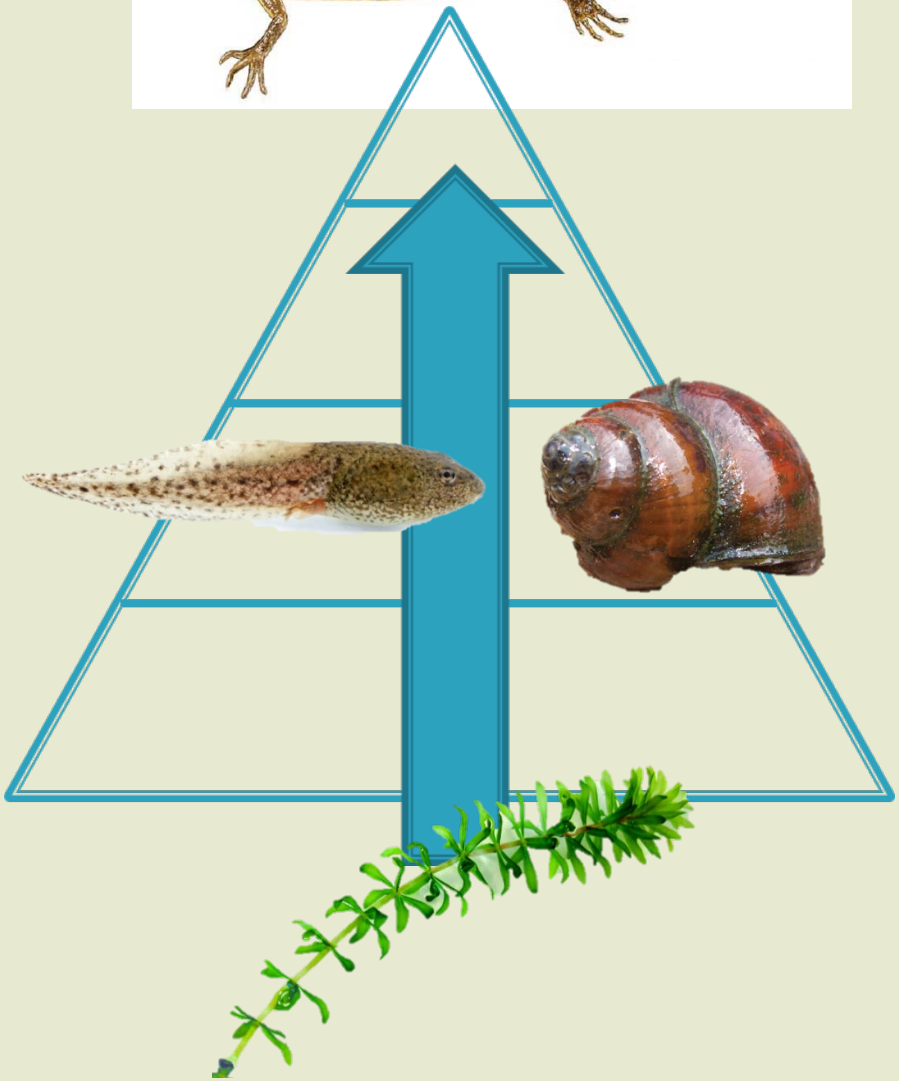
John Maerz and Susan Wilde



Objectives



- Determine whether paedomorphic mole salamanders are affected by *Ah* by consumption of an Ah+ gut-loaded intermediate food source.



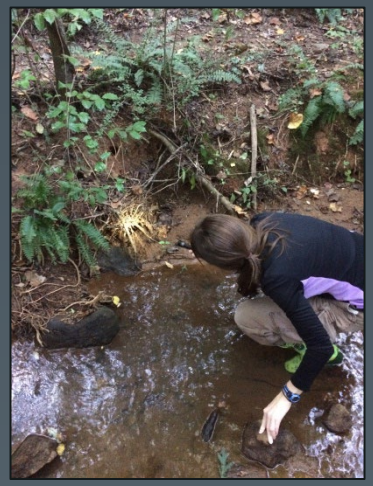
Righting Response Results

Other signs noticed:

- Seizures
- Total paralysis
- Partial paralysis
- Head twitching
- Muscle atrophy

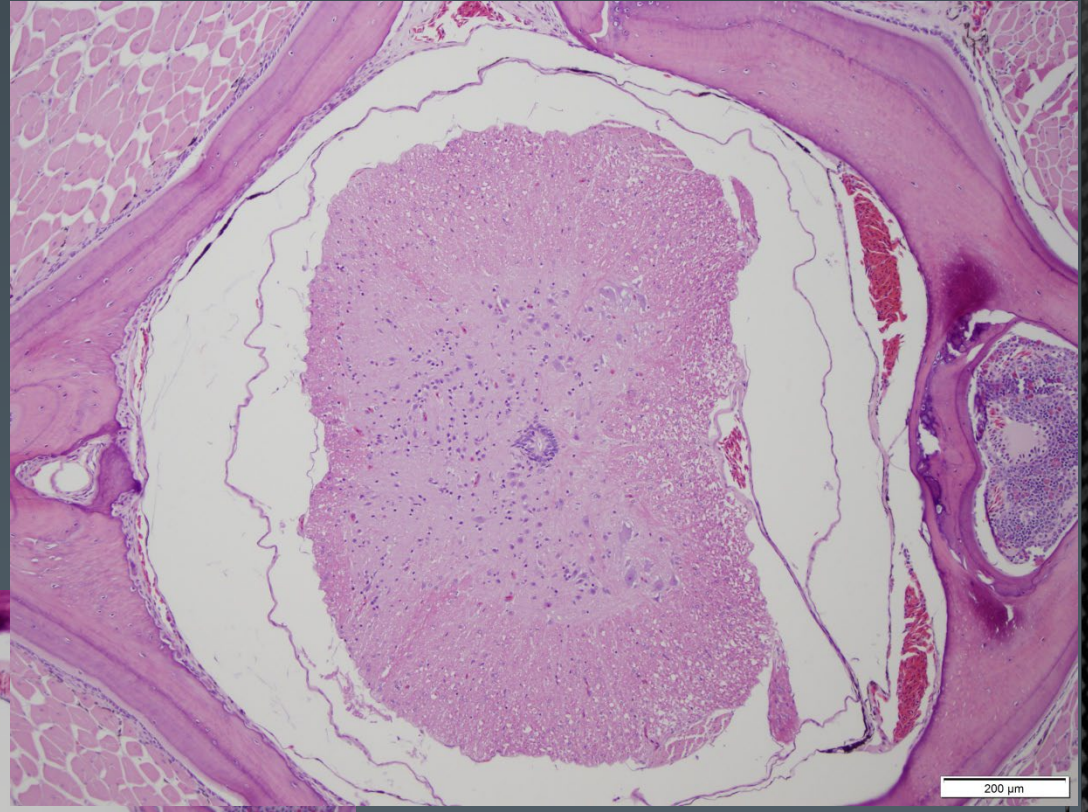
Trophic transfer; Water snakes (*Nerodia spp.*)

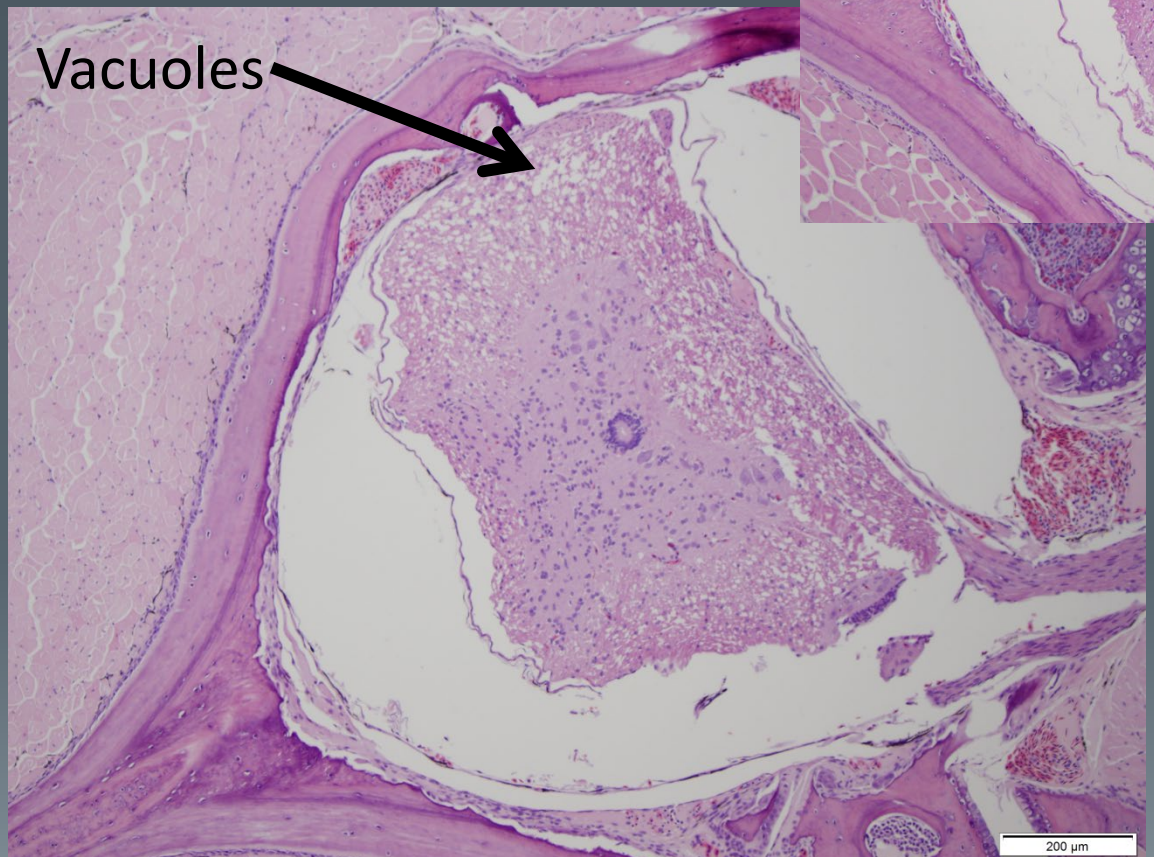
Melissa Martin, Audrey , Heather Fenton



Results-Histology

Ah - ⟶

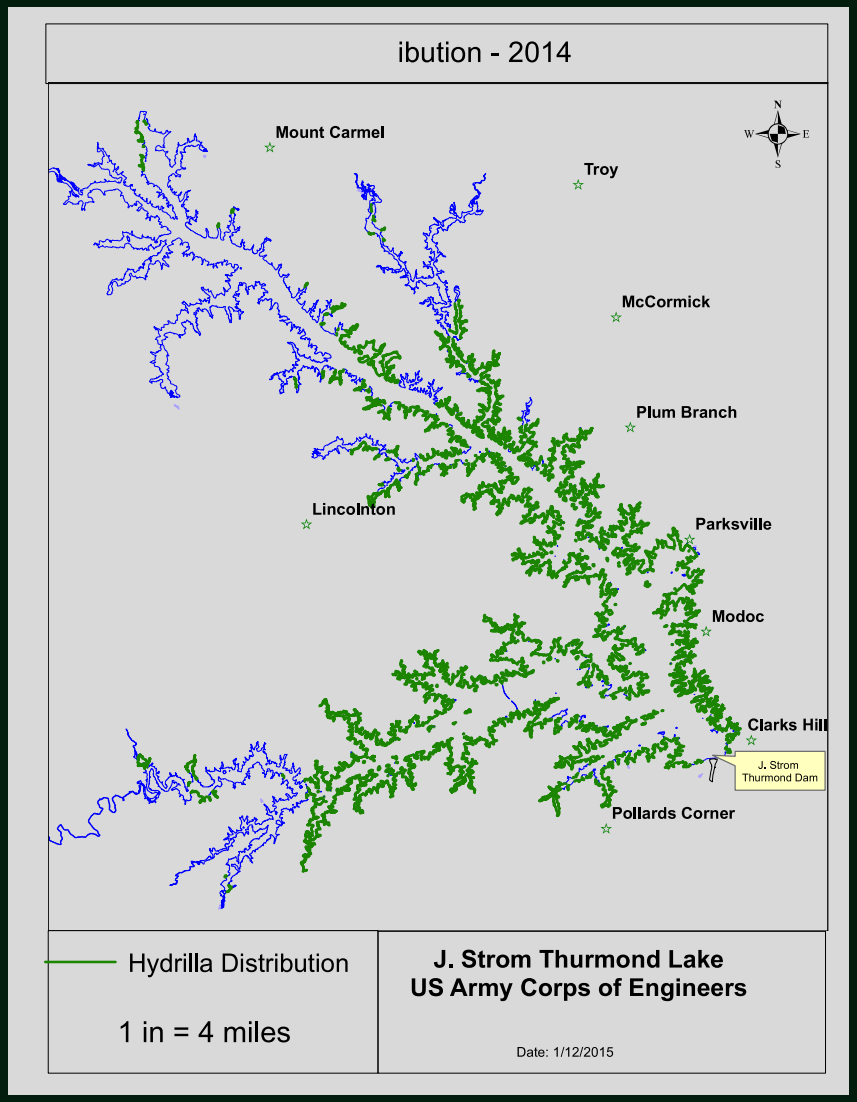




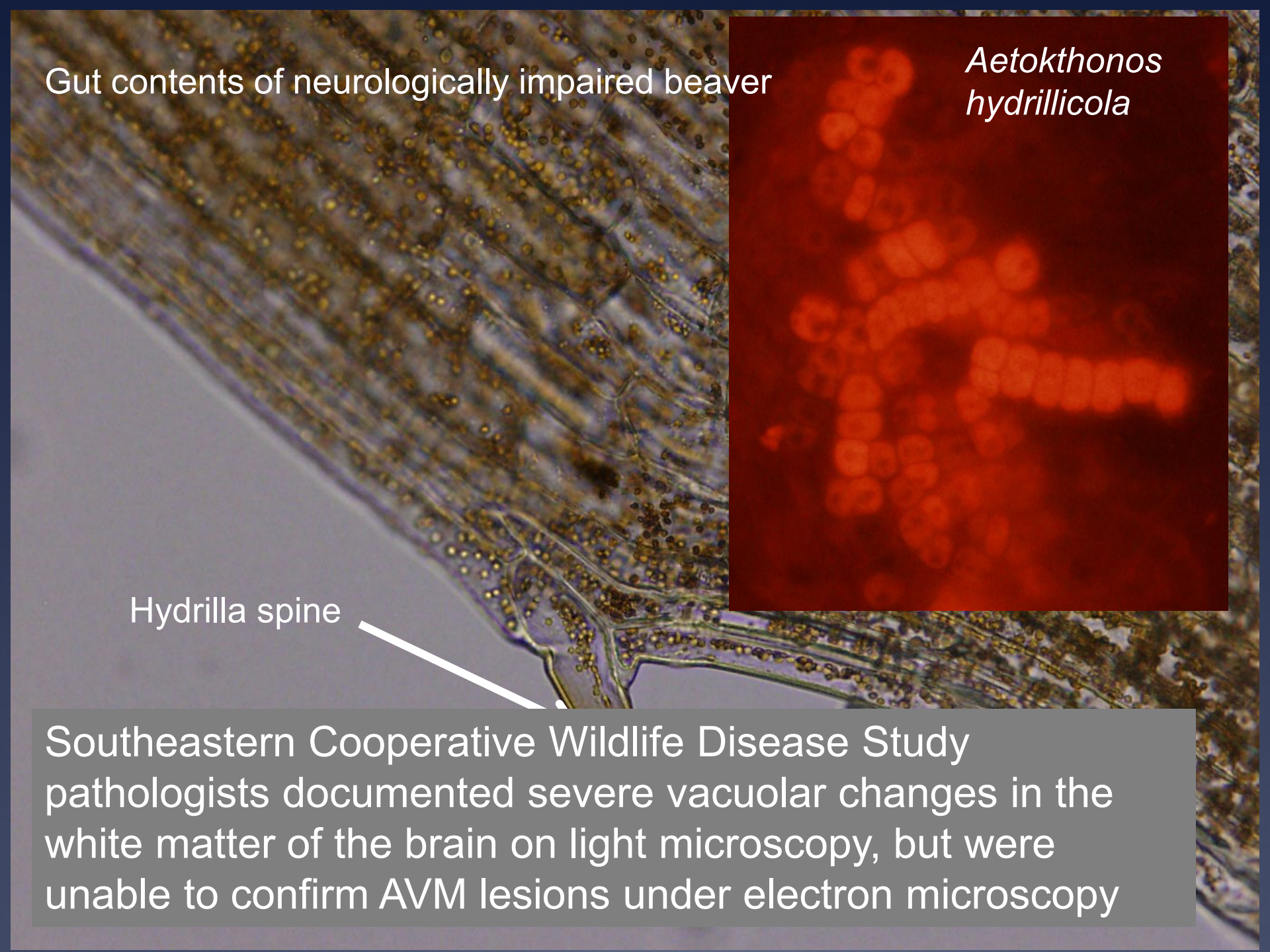
⟵ Ah +

Expanding Food Chain

Lethargic beaver recovered from AVM positive site during late fall

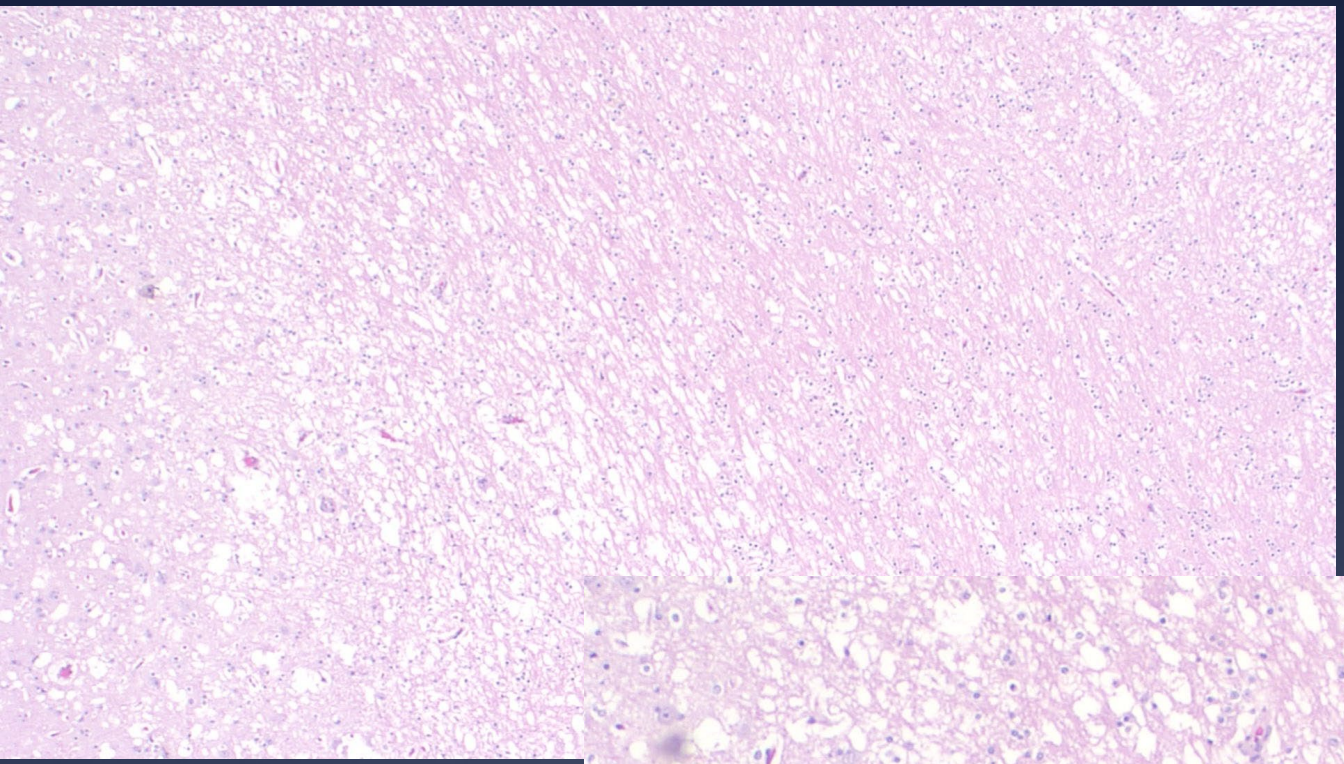


J. Strom Thurmond Reservoir

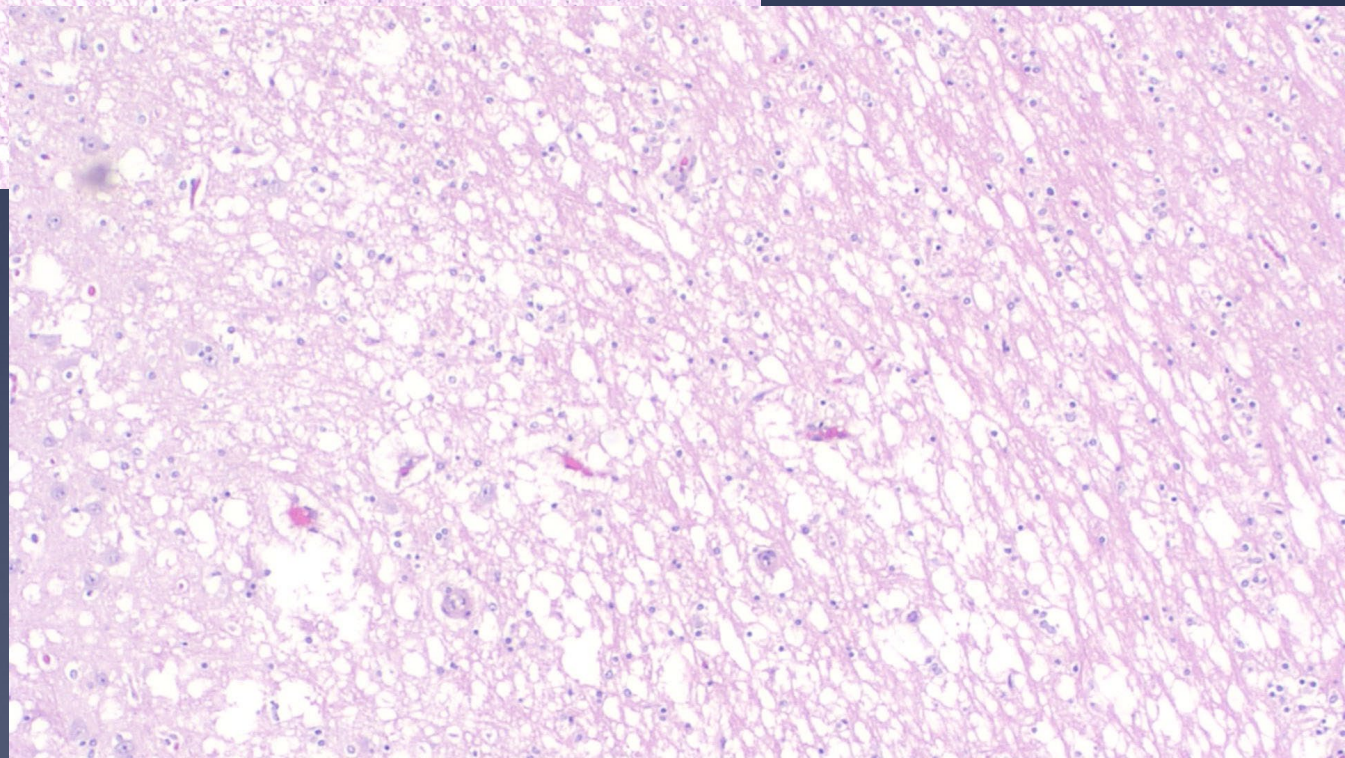


Southeastern Cooperative Wildlife Disease Study pathologists documented severe vacuolar changes in the white matter of the brain on light microscopy, but were unable to confirm AVM lesions under electron microscopy

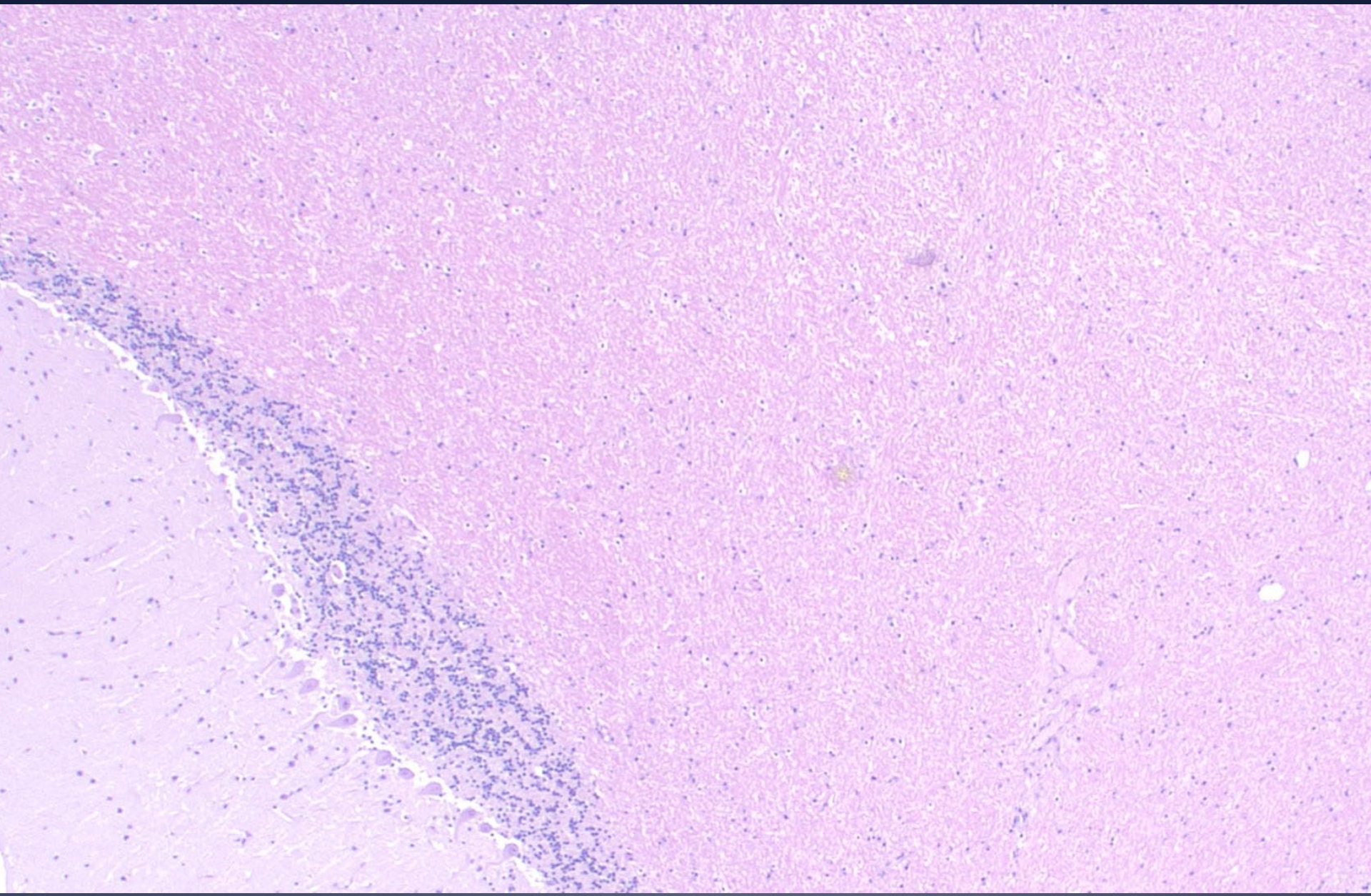
White matter vacuolation



cerebrum



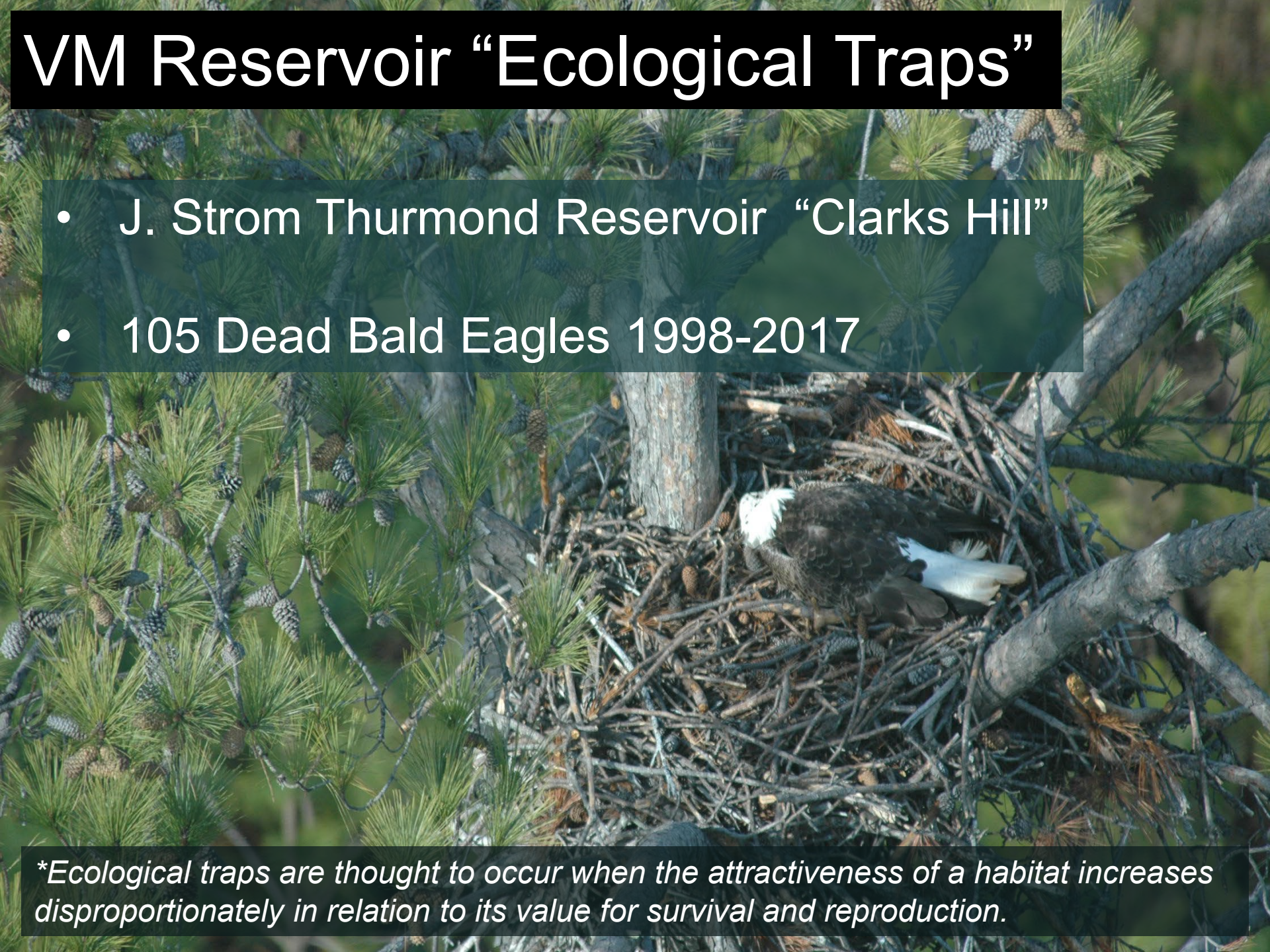
cerebellum



Normal beaver histology cerebrum

VM Reservoir “Ecological Traps”

- J. Strom Thurmond Reservoir “Clarks Hill”
- 105 Dead Bald Eagles 1998-2017

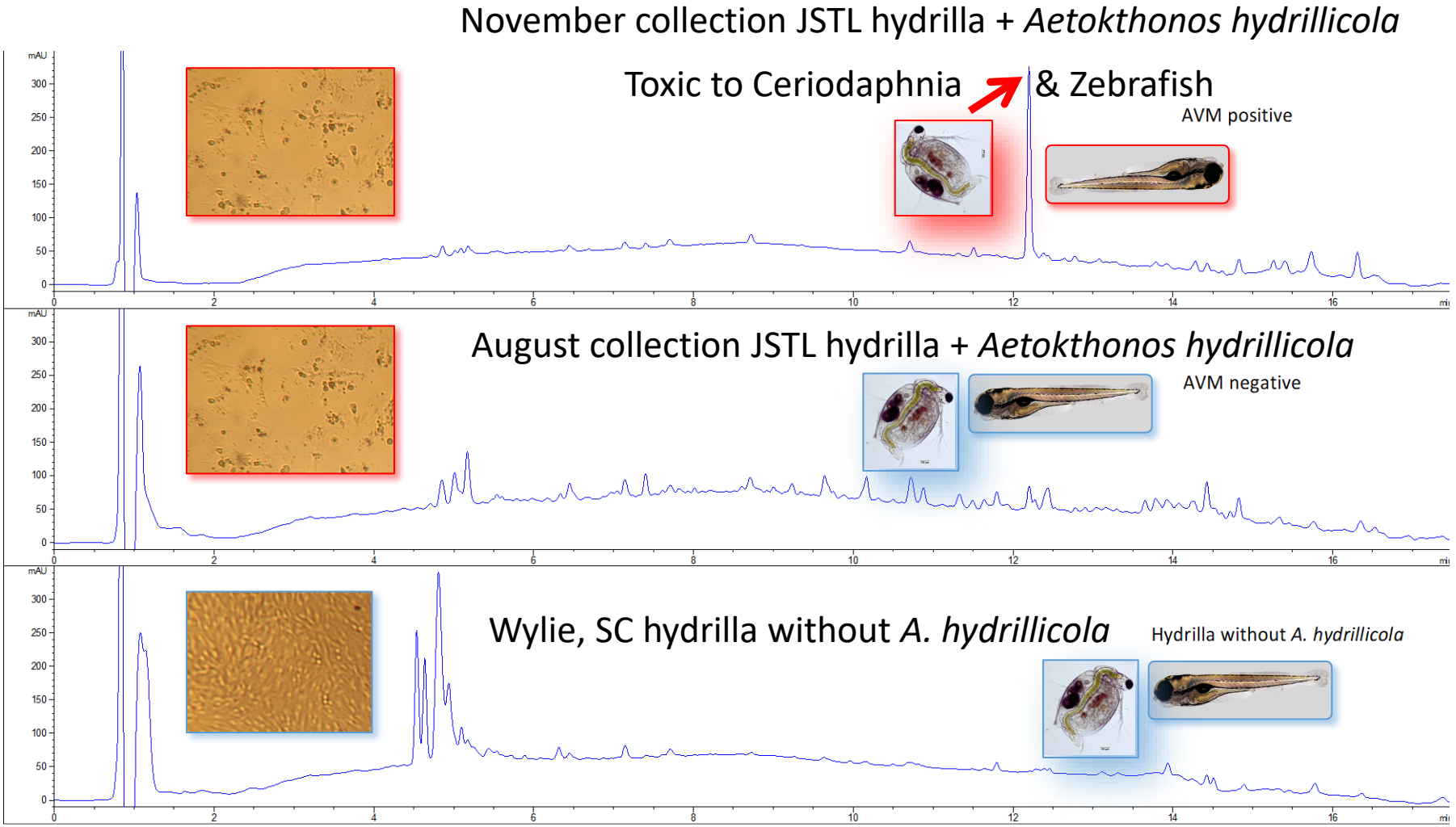


**Ecological traps are thought to occur when the attractiveness of a habitat increases disproportionately in relation to its value for survival and reproduction.*

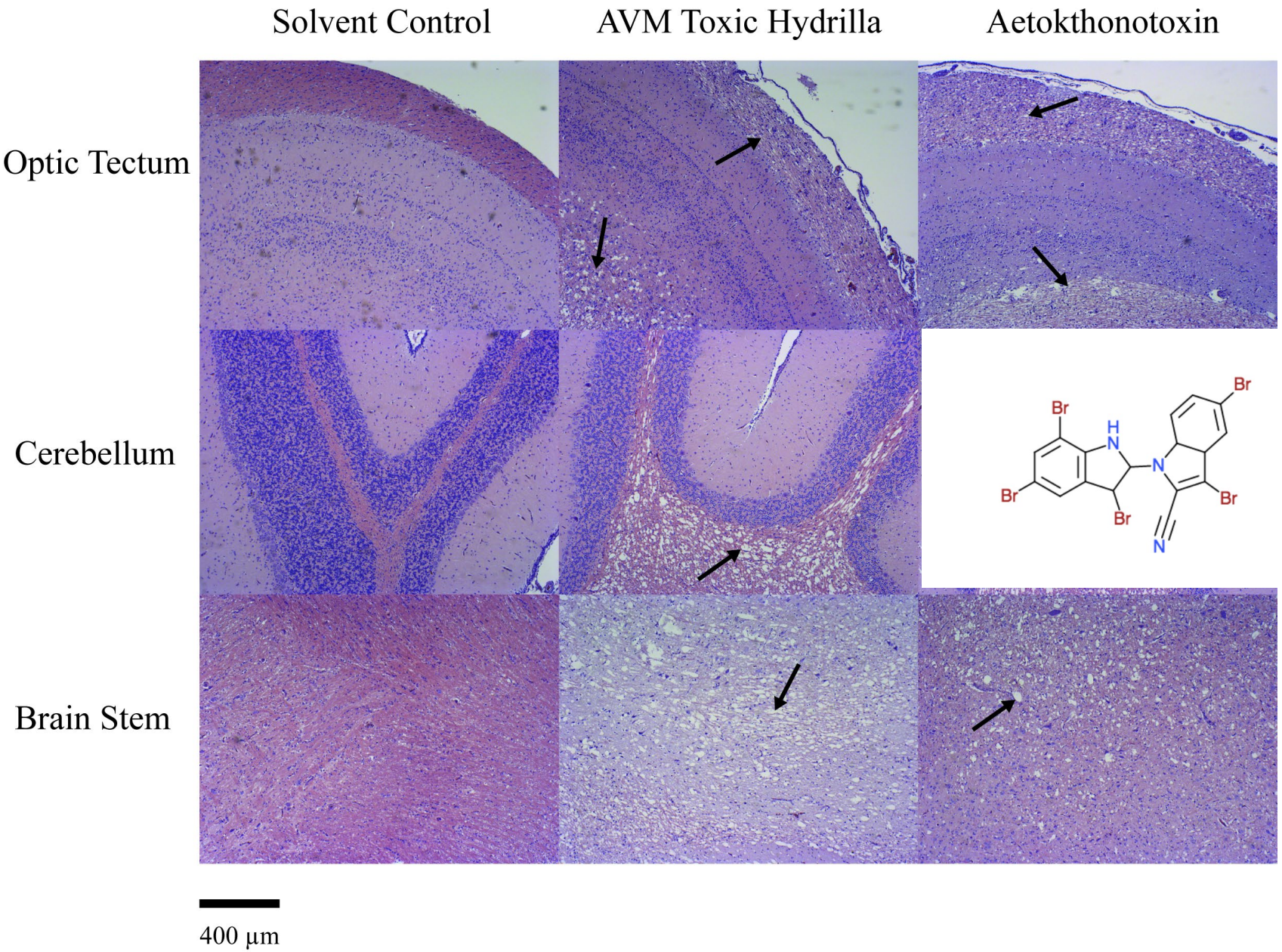
Human health effects?

HPLC chromatograms (UV detection at 210 nm) methanol extracts

↗ unique peak shown in the top panel



Histology results: May 2019 chicken gavage trial



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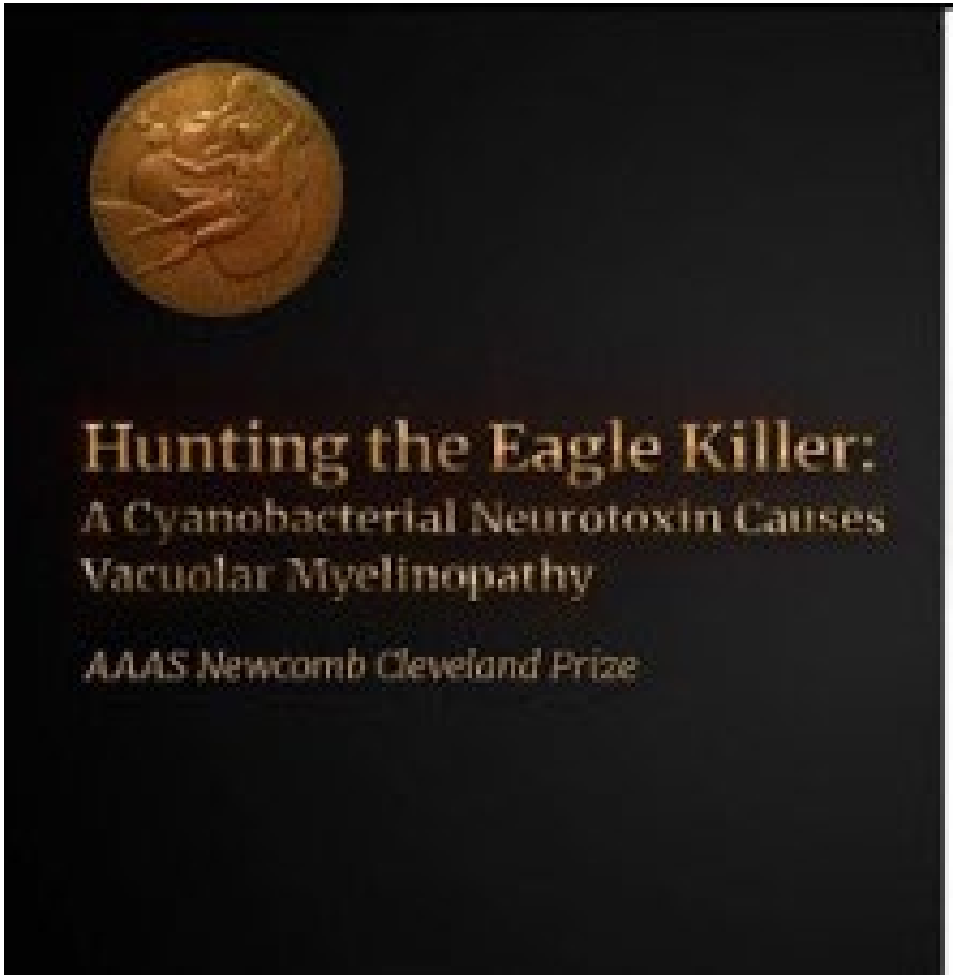
DEADLY CASCADE



Hunting the Eagle Killer:

A Cyanobacterial Neurotoxin Causes Vacuolar Myelinopathy

AAAS Newcomb Cleveland Prize

RESEARCH ARTICLE SUMMARY

Hunting the eagle killer: A cyanobacterial neurotoxin causes vacuolar myelinopathy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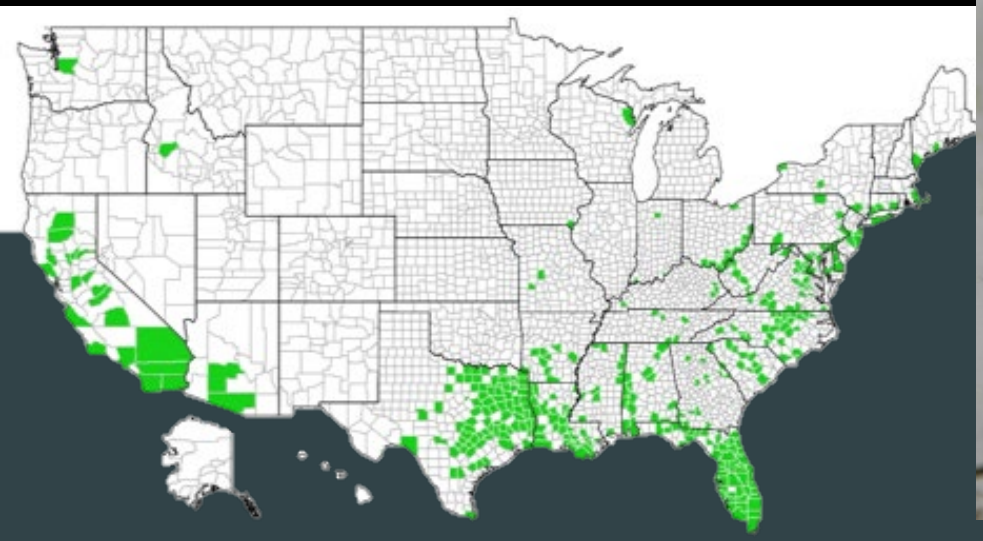

- Please help expand AVM survey efforts
- Send hydrilla for screening during October-December
- Email swilde@uga.edu for collection and shipping information

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