New locations and species at risk from Avian Vacuolar Myelinopathy (AVM)

Susan Wilde, John Maerz, Sonia Hernandez, Brigette Haram, Garon Brandon, Vanessa Kinney, and Susan Williams

1994/95 DeGray Lake, Arkansas

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"

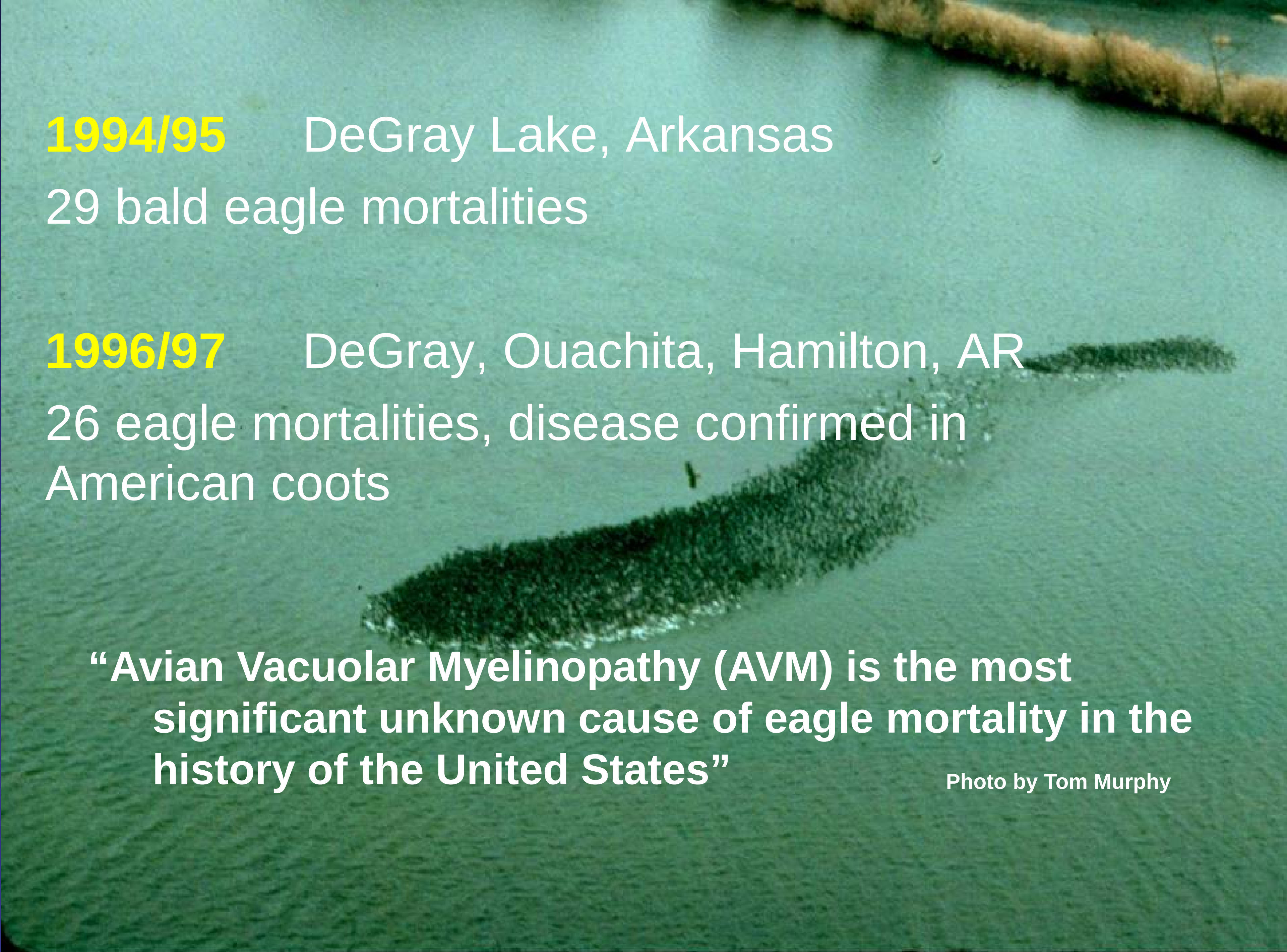
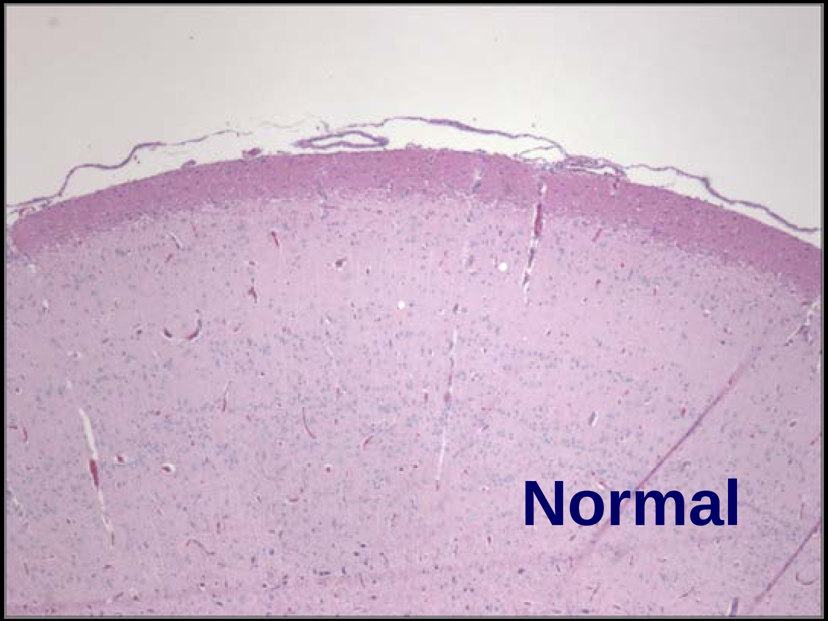
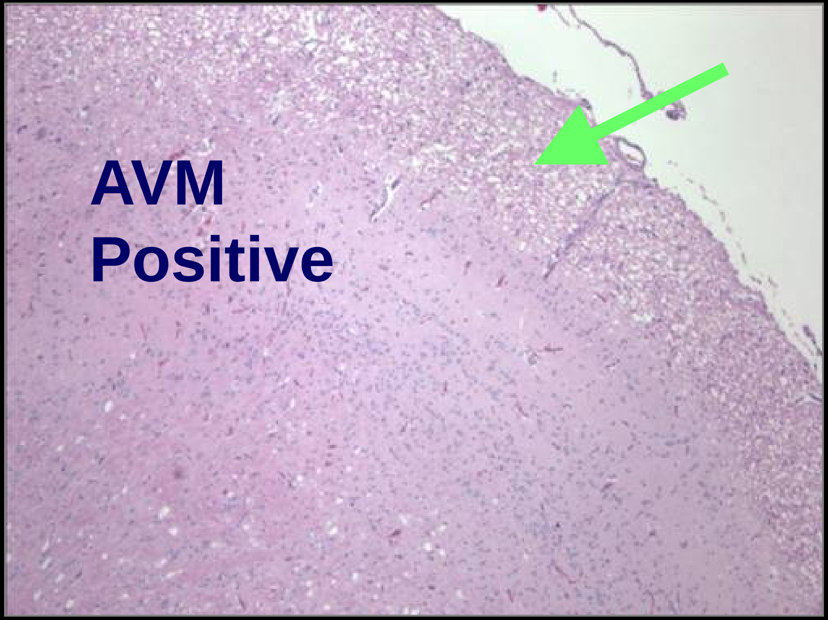


Photo by Tom Murphy

Vacuolar Myelinopathy



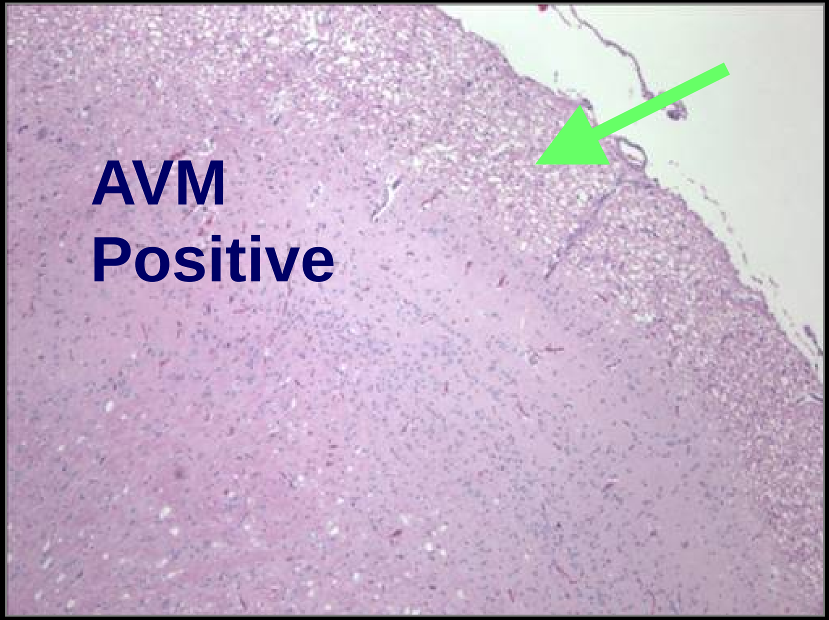


- 1994-1996, large die offs of Bald Eagles in Arkansas. Confirmed they had Vacuolar Myelinopathy.
  - Also confirmed in American Coots

- 1997, eagles started dying on Lake J. Strom Thurmond.

Lesions: white matter of the central nervous system, specifically an intramyelinic edema

Vacuolar Myelinopathy



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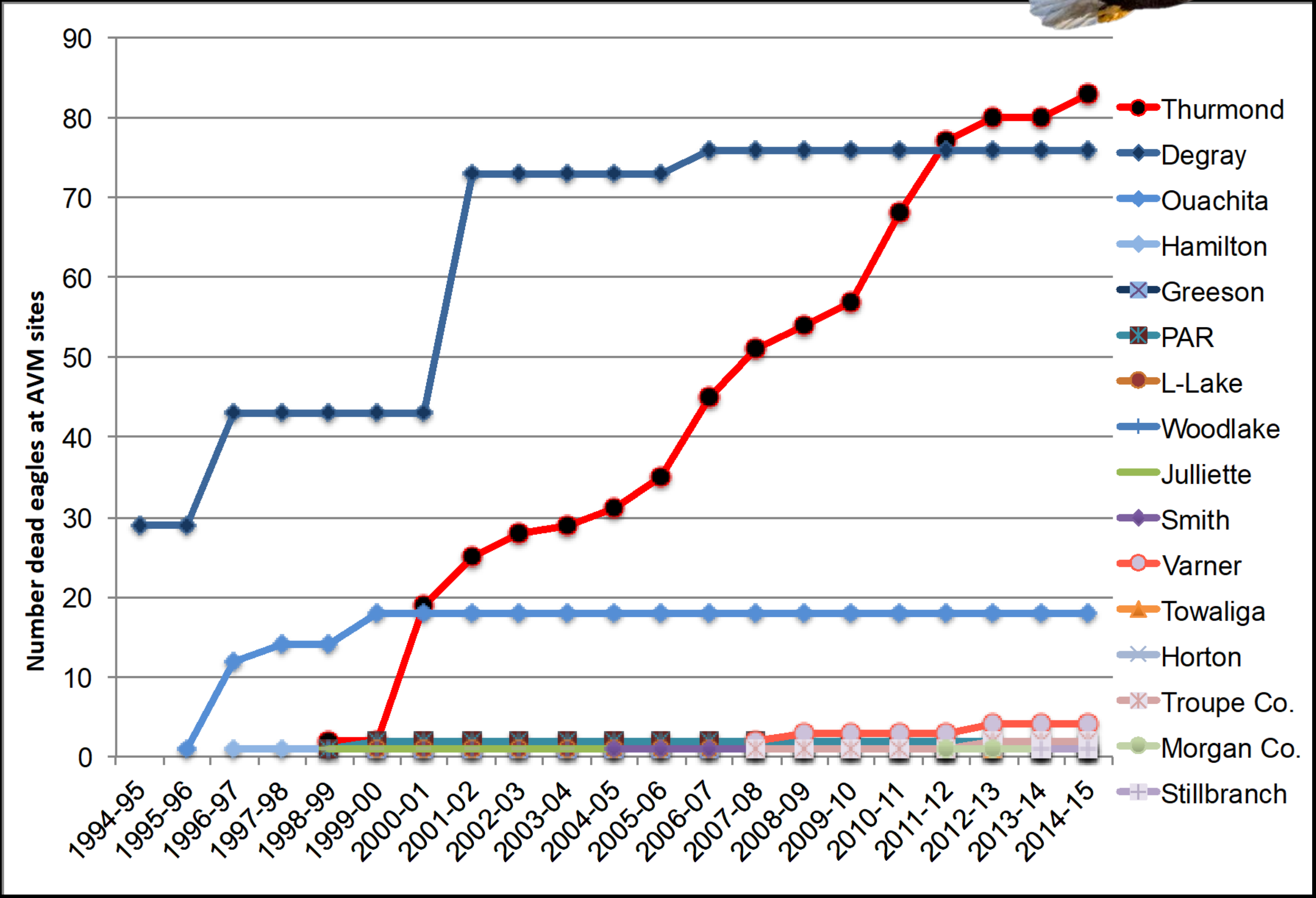
- 1997, eagles started dying on Lake J. Strom Thurmond.

Lesions: white matter of the central nervous system, specifically an intramyelinic edema

Animals become neurologically impaired including “drunken” gait and inverted swimming.

“Avian” Vacuolar Myelinopathy

- 1998, eagles started dying on Lake J. Strom Thurmond



- Also affected are Mallards, Ring-necked ducks, Buffleheads, American wigeon, Canada geese, Great Horned owls, and Killdeer

How can you tell that a coot has AVM?

Aquatic Plant Invasions

- Aquatic systems including freshwater wetland, ponds and lakes are prone to invasion
- Generally, plant invasions are a nuisance, but effects on wildlife are mixed, often benign.
- Effects can be direct, bottom up effects via water quality or resource availability; or…
- indirect via effects on habitat structure and species interactions.
- Plant invasions can facilitate the spread of other invasive species.
- Examples of direct negative effects from consumption of nonnative plant species are rare.

Aquatic Plant Invasions

Functional Ecology 2005
19, 970–975

Can secondary compounds of an invasive plant affect larval amphibians?

J. C. MAERZ,†‡ C. J. BROWN,‡ C. T. CHAPIN§* and B. BLOSSEY‡
‡Ecology and Management of Invasive Plants Program, Department of Natural Resources, Cornell University,

Freshwater Biology
Freshwater Biology (2010) 55, 1694–1704 doi:10.1111/j.1365-2427.2010.02404.x

Does detritus quality predict the effect of native and non-native plants on the performance of larval amphibians?

Ecological Applications, 22(1), 2012, pp. 218–228

Traits, not origin, explain impacts of plants on larval amphibians

Jillian S. Cohen,[1,3] John C. Maerz,[2] and Bernd Blossey[1]
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Abstract. Managing habitats for the benefit of native fauna is a priority for many government and private agencies. Often, these agencies view nonnative plants as a threat to wildlife habitat, and they seek to control or eradicate nonnative plant populations. However, little is known about how nonnative plant invasions impact native fauna, and it is unclear whether managing these plants actually improves habitat quality for resident animals. Here, we compared the impacts of native and nonnative wetland plants on three species of native larval amphibians; we also examined whether plant traits explain the observed impacts. Specifically, we measured plant litter quality (carbon : nitrogen : phosphorus ratios, and percentages of lignin and soluble phenolics) and biomass, along with a suite of environmental conditions known to affect larval amphibians (hydroperiod, temperature, dissolved oxygen, and pH). Hydroperiod and plant traits, notably soluble phenolics, litter C:N ratio, and litter N:P ratio, impacted the likelihood that animals metamorphosed, the number of animals that metamorphosed, and the length of larval period. As hydroperiod decreased, the likelihood that amphibians achieved metamorphosis and the percentage of tadpoles that successfully metamorphosed also decreased. Increases in soluble phenolics, litter N:P ratio, and litter C:N ratio decreased the likelihood that tadpoles achieved metamorphosis, decreased the percentage of tadpoles metamorphosing, decreased metamorph production (total metamorph biomass), and increased the length of larval period. Interestingly, we found no difference in metamorphosis rates and length of larval period between habitats dominated by native and nonnative plants. Our findings have important implications for habitat management. We suggest that to improve habitats for native fauna, managers should focus on assembling a plant community with desirable traits rather than focusing only on plant origin.

Key words: Anaxyrus americanus; *benthic environment; central and western New York, USA; detrital food web; ecological impact; invasive species;* Lithobates palustris; Lithobates sylvaticus; *litter quality; stoichiometry; tadpole.*

Introduction

Managing habitats for the benefit of native fauna is a key priority for agencies such as the U.S. Fish and Wildlife Service, the National Park Service, state departments of conservation, and many non-governmental organizations. Invasions by nonnative species are recognized as a major force of ecological change, a force that could degrade habitat and threaten native fauna (Clinton 1999, Mack et al. 2000). As such, there is considerable interest in understanding and mitigating the impacts of invasions. Despite increasing attention to biological invasions, scientists rarely elucidate the mechanisms behind nonnative species' impacts, making it difficult to predict how ecosystems will respond when these species invade (Levine et al. 2003, Ricciardi and Atkinson 2004, Miller et al. 2007). This is particularly true for studies of impacts of plant invasions on animals (Levine et al. 2003, Gerber et al. 2008). A fundamental assumption underlying invasive plant management is that removing nonnative species and replacing them with native species will improve ecosystem function; but if we do not understand the mechanisms behind invasive species impacts how can we know that removing the invader is the right course of action? Further, how will we know which native plants are the most appropriate to replace the invader? Understanding the mechanisms underlying the impacts of plant invasions will help environmental managers to make more targeted, informed decisions regarding invasive plant management and will facilitate development of more successful strategies to mitigate negative impacts.

Plants are a critical basal resource in many food webs, and plant nutritional quality plays an important role in determining the fate of plant production within an ecosystem (Cebrian 1999). In freshwater ecosystems, where terrestrial plant litter is a key resource (Wallace et al. 1997, Cole et al. 2006, Rubbo et al. 2006), plant invasions could impact fauna by altering the quality of litter inputs (Kennedy and Hobbie 2004, Zedler and Kercher 2004). Larval amphibians are among the many taxa that maybe affected, as they respond strongly to changes in plant species composition (Skelly et al. 2002, Rubbo and Kiesecker 2004, Williams et al. 2008, Stohler

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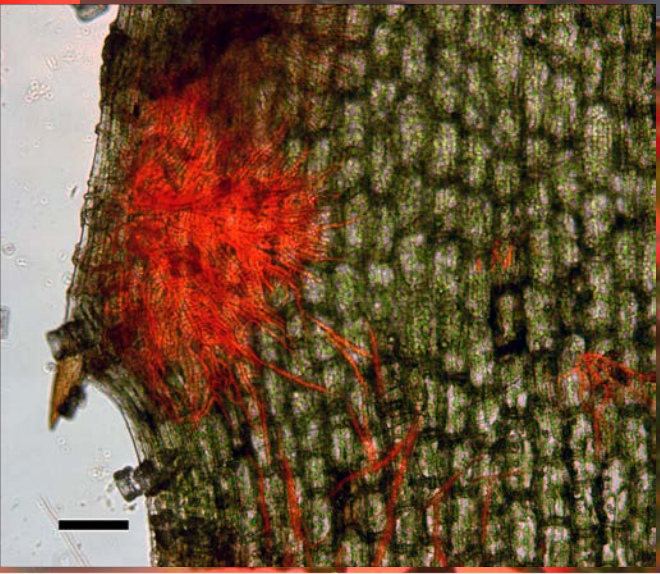
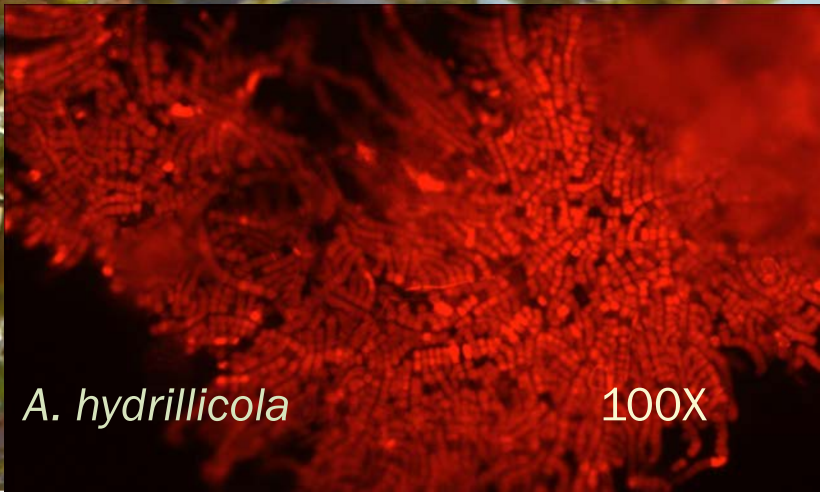
- Aquatic systems including freshwater wetland, ponds and lakes are prone to invasion
- Generally, aquatic plant invasions are a nuisance, but effects on wildlife are mixed.
- Effects can be direct, bottom up effects via water quality or resource availability; or…
- indirect via effects on habitat structure and species interactions.
- Plant invasions can facilitate the spread of other invasive species.
- Examples of direct negative effects from consumption of nonnative plant species are rare.

- *Aetokthonos hydrillicola*
  - Previously undescribed cyanobacterium
  - Grows as an **epiphyte on hydrilla** and other invasive exotic aquatic plants in ALL AVM SITES
  - Neurotoxin production
    - (uncharacterized)





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Aetokthonos hydrillicola gen. et sp. nov.: Epiphytic cyanobacteria on invasive aquatic plants implicated in Avian Vacuolar Myelinopathy

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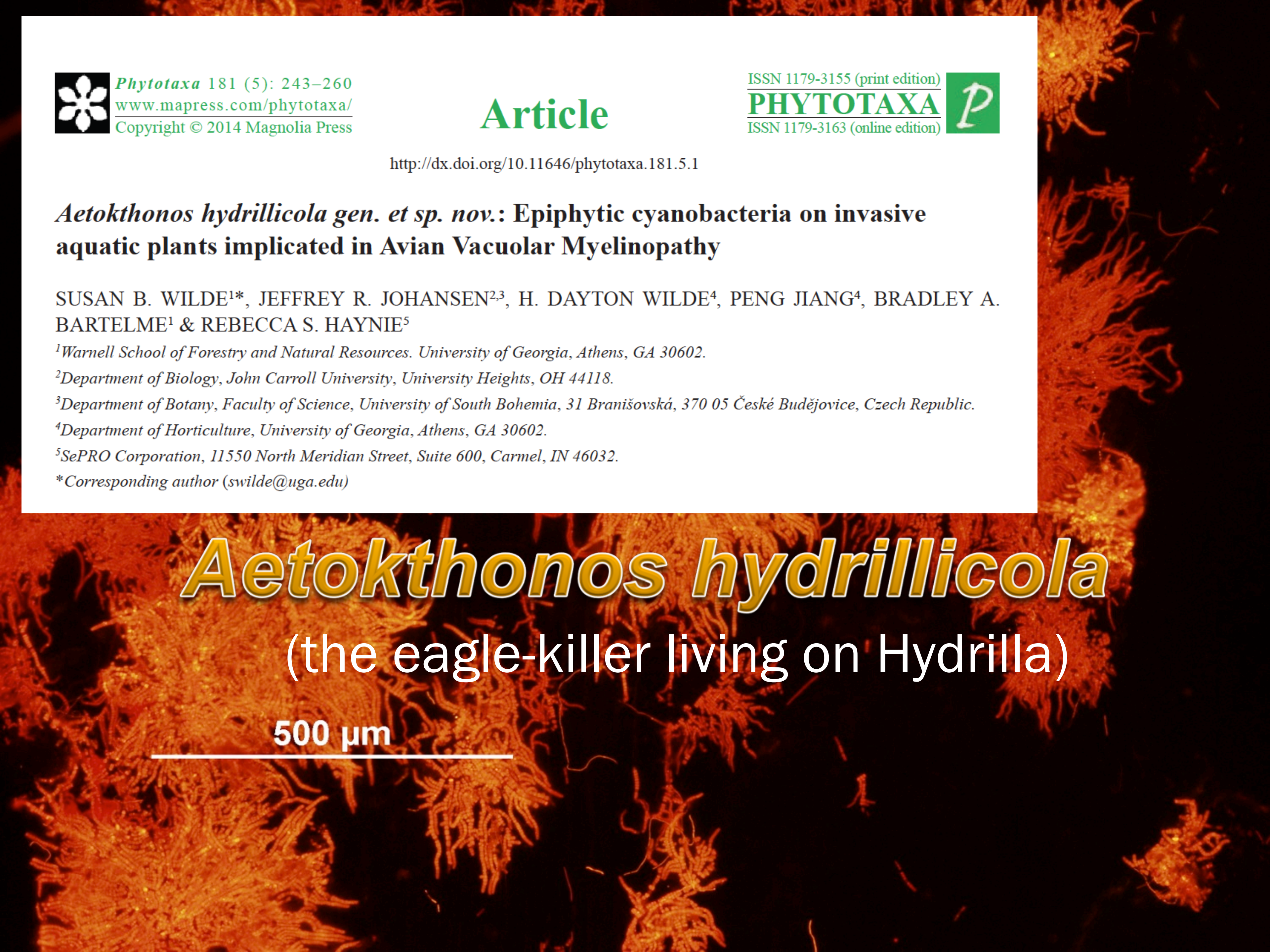
**Corresponding author (swilde@uga.edu)*



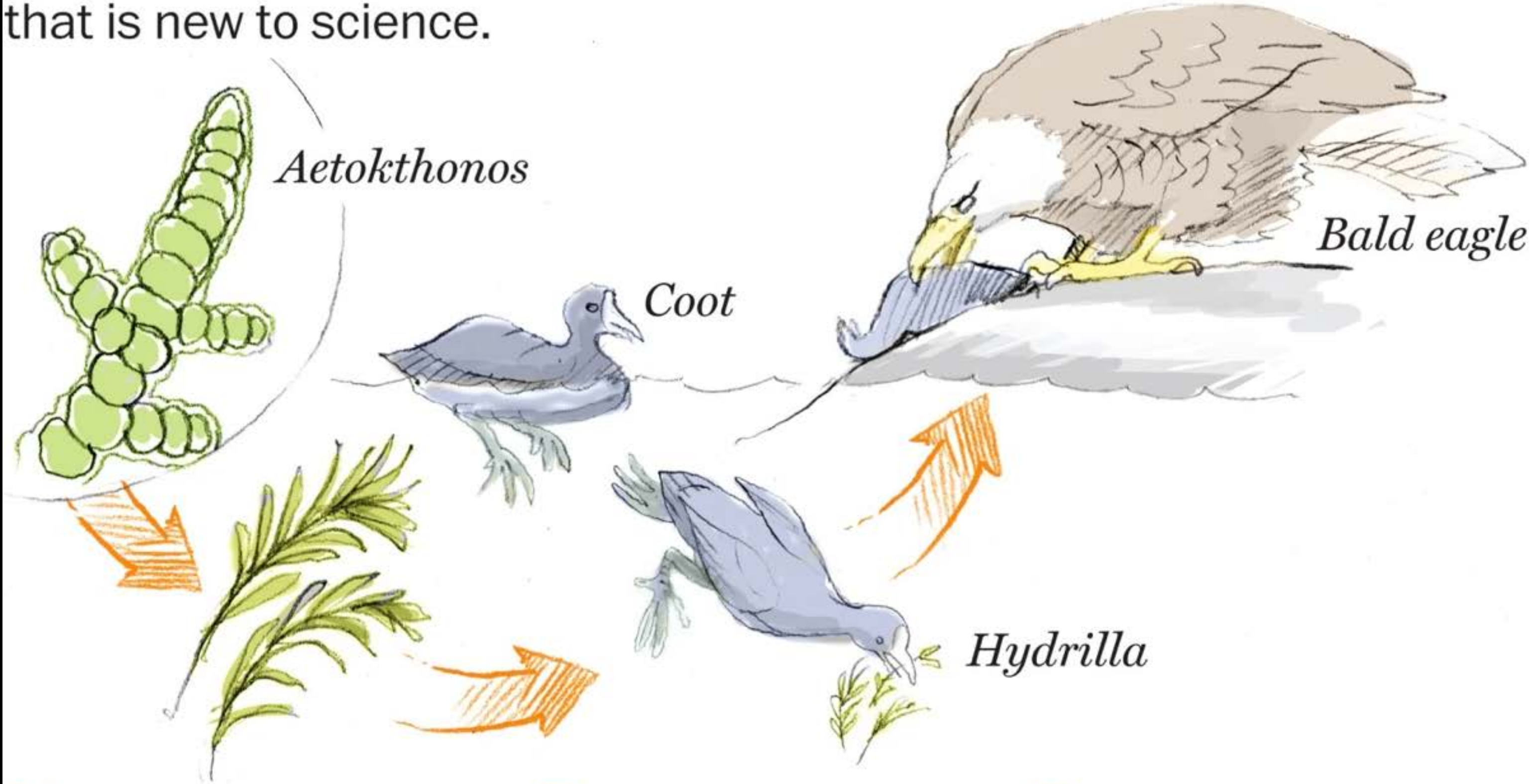
Bald eagles are starting to flourish again — but hold the confetti

by Darryl Fears February 18, 2015

http://www.washingtonpost.com/news/energy-environment/wp/2015/02/18/the-eagle-killer-the-name-of-a-new-scary-red-bacteria-is-well-earned/

Novel cyanobacterium killing eagles

Bald eagles across the Southeastern U.S. are succumbing to a neurotoxin generated by a blue-green algae that is new to science.

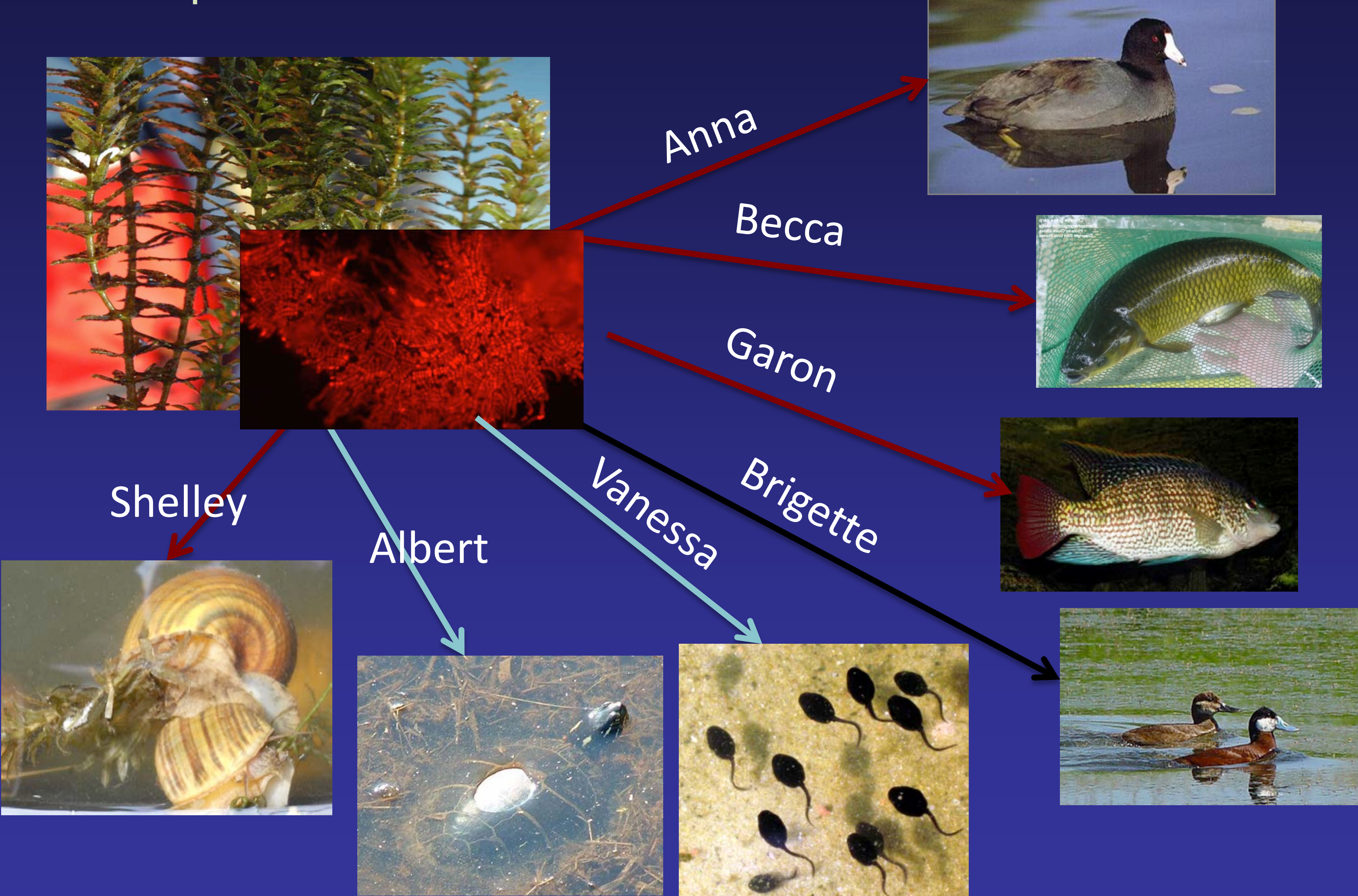


1. *Aetokthonos hydrillicola* grows on the underside of the leaves of *Hydrilla,* an exotic invasive aquatic plant.
2. Coots eat *Hydrilla* and accumulate cyanobacterium neurotoxins in their tissue.
3. An eagle feeding on a dead coot might consume the neurotoxins and develop a deadly neurological disease.

Source: Phytotaxa

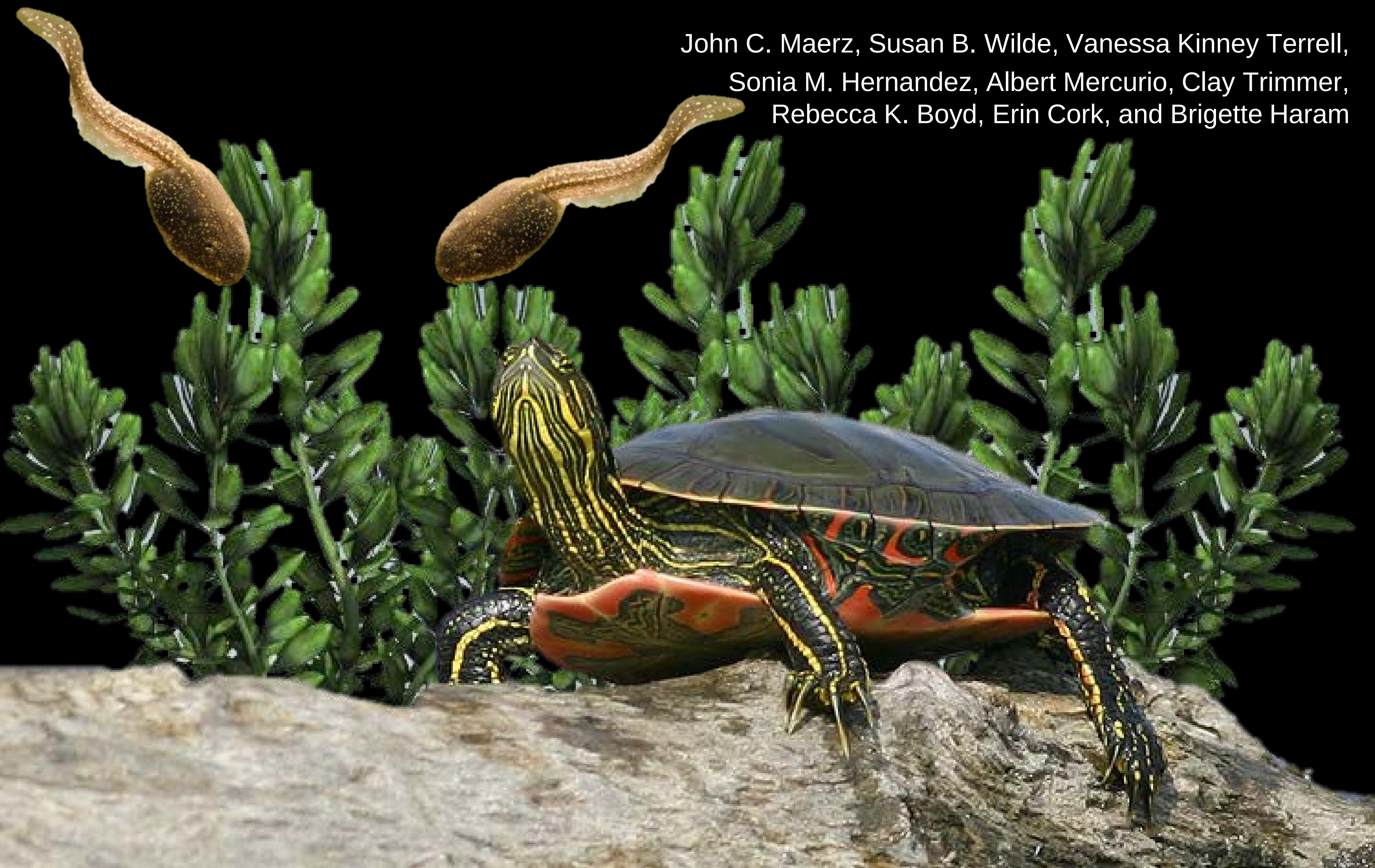
PATTERSON CLARK/THE WASHINGTON POST

- Can the AVM toxin effect other herbivores and transferred to their predators?



Amphibian and Reptile Vulnerability to *Hydrilla* Invasions and the Spread of *Aetokthonos hydrillicola*

John C. Maerz, Susan B. Wilde, Vanessa Kinney Terrell,
Sonia M. Hernandez, Albert Mercurio, Clay Trimmer,
Rebecca K. Boyd, Erin Cork, and Brigette Haram



Vacuolar Myelinopathy

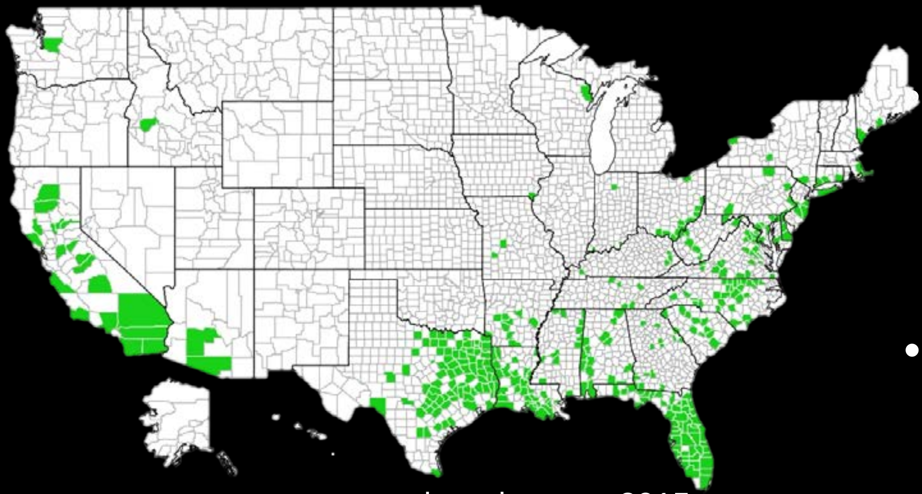
Established that food linkage between herbivores and predators.

As part of intensive surveys and monitoring beginning in 2001, noted dense aquatic macrophytes associated with sites.

- Three most abundant species were all nonnative.
- Most abundant plant at all sites was non-native *Hydrilla verticillata*.
- Heavily colonized by epiphytic algae.

Hydrilla verticillata

- Introduced to US in 1950s from Asia or Africa.
- Has broad distribution in U.S., but densest populations currently concentrated in the southeastern U.S.
- Forms dense mats of submerged vegetation



invasives.org 2015

hydrilla
***Hydrilla verticillata* (L. f.) Royle**

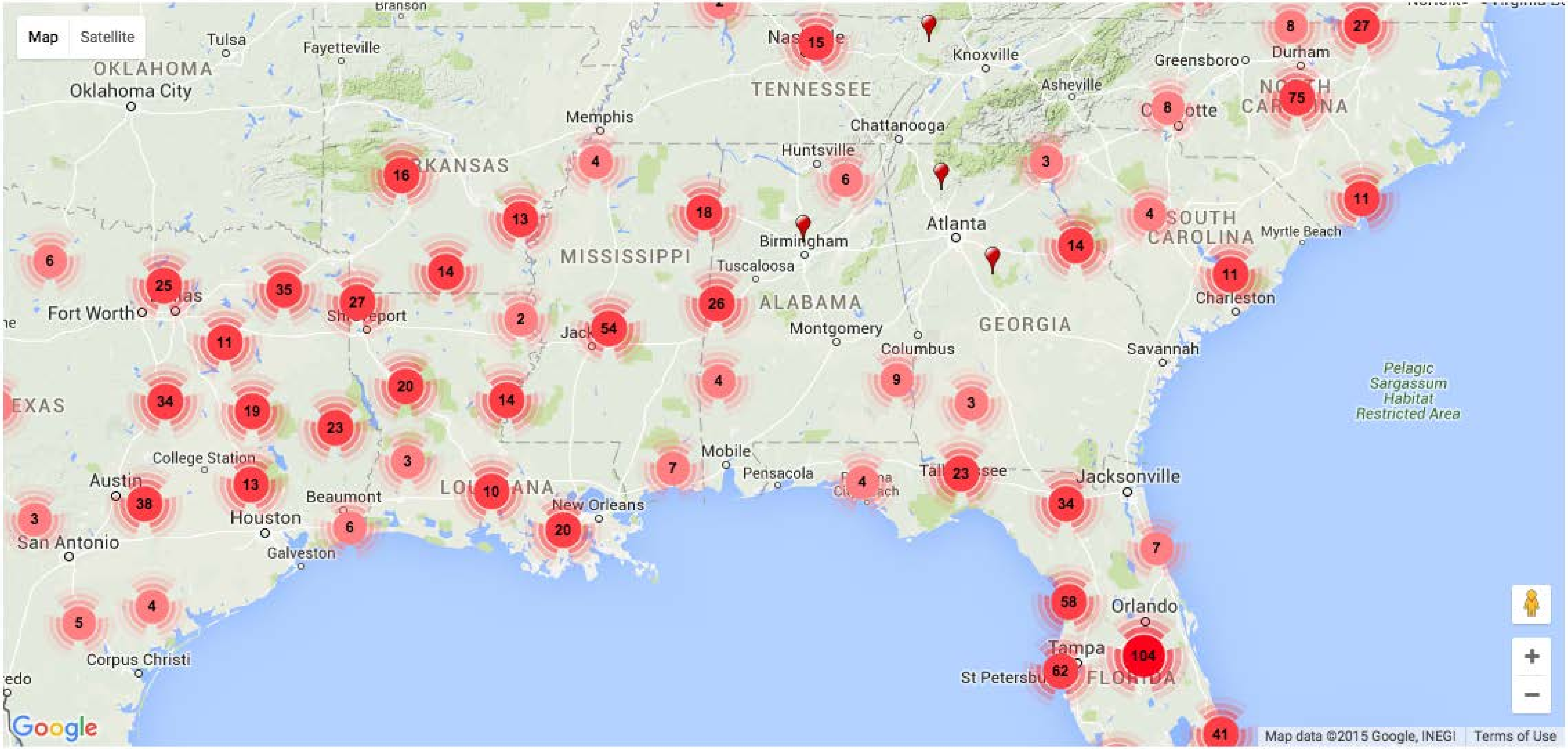
USDA PLANTS Symbol:HYVE3
Invasive Plant Atlas
Species Information

States Counties **Points** GIS List

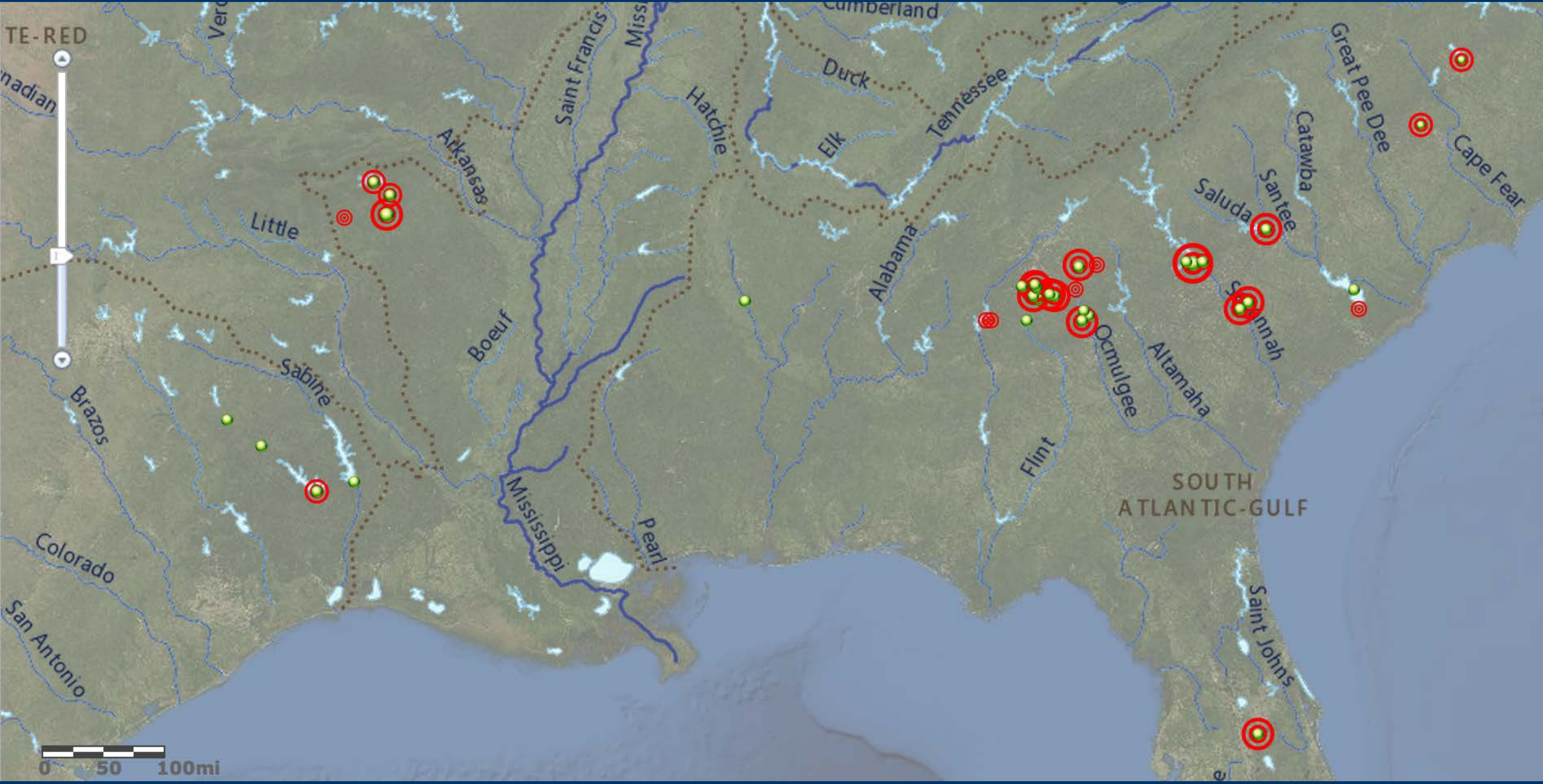
XLS KML GPX Shapefile

1407 points

Zoom to My Location Share Flag Fullscreen



Avian Vacuolar Myelinopathy 2014



30 sites (+5 FL)

Hydrilla &
Aetokthonos hydrillicola

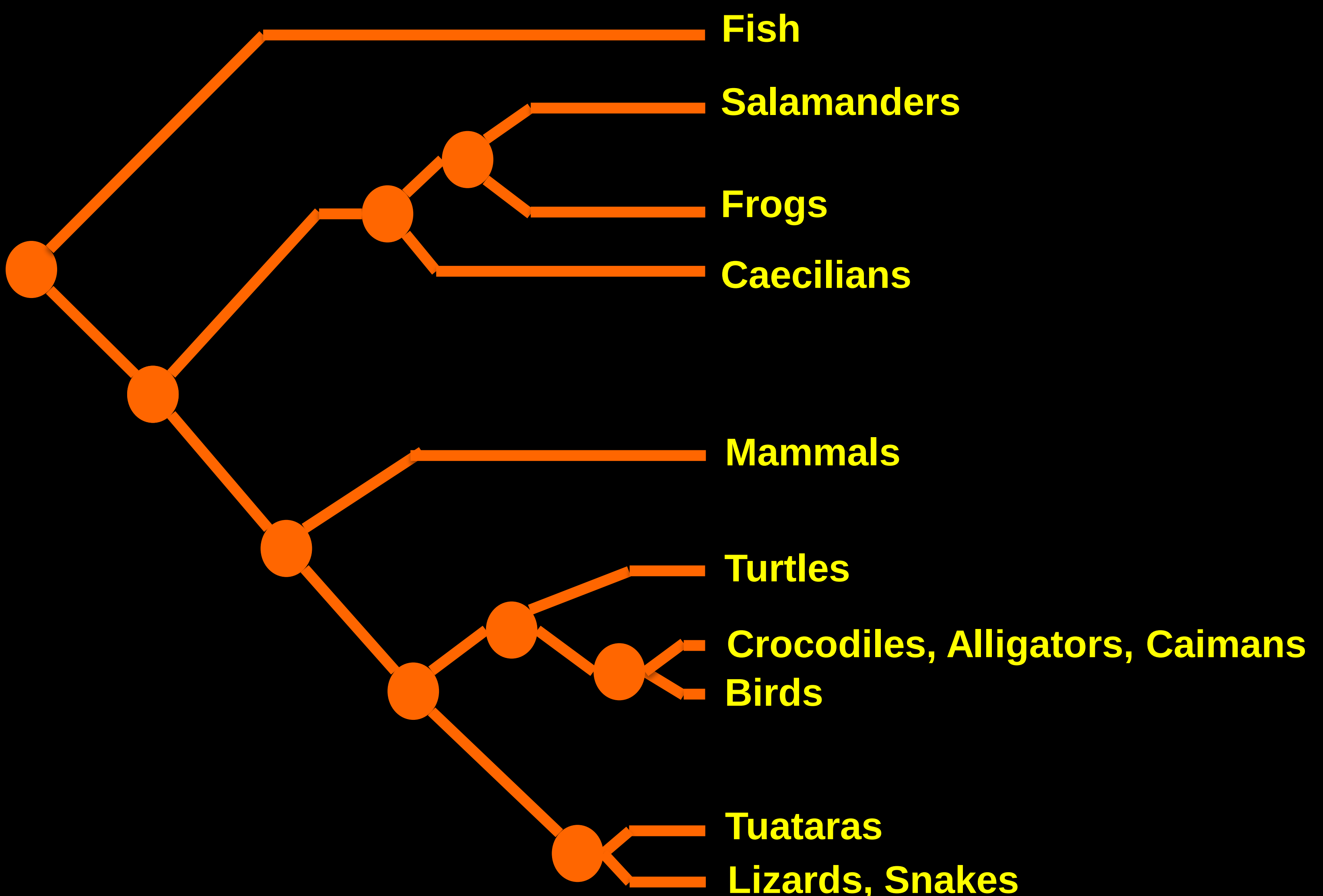
166 eagles

AVM confirmed birds

20 sites

AVM+, Hydrilla &
A. hydrillicola

Taxa affected by ingesting *Aetokthonos* positive *Hydrilla*



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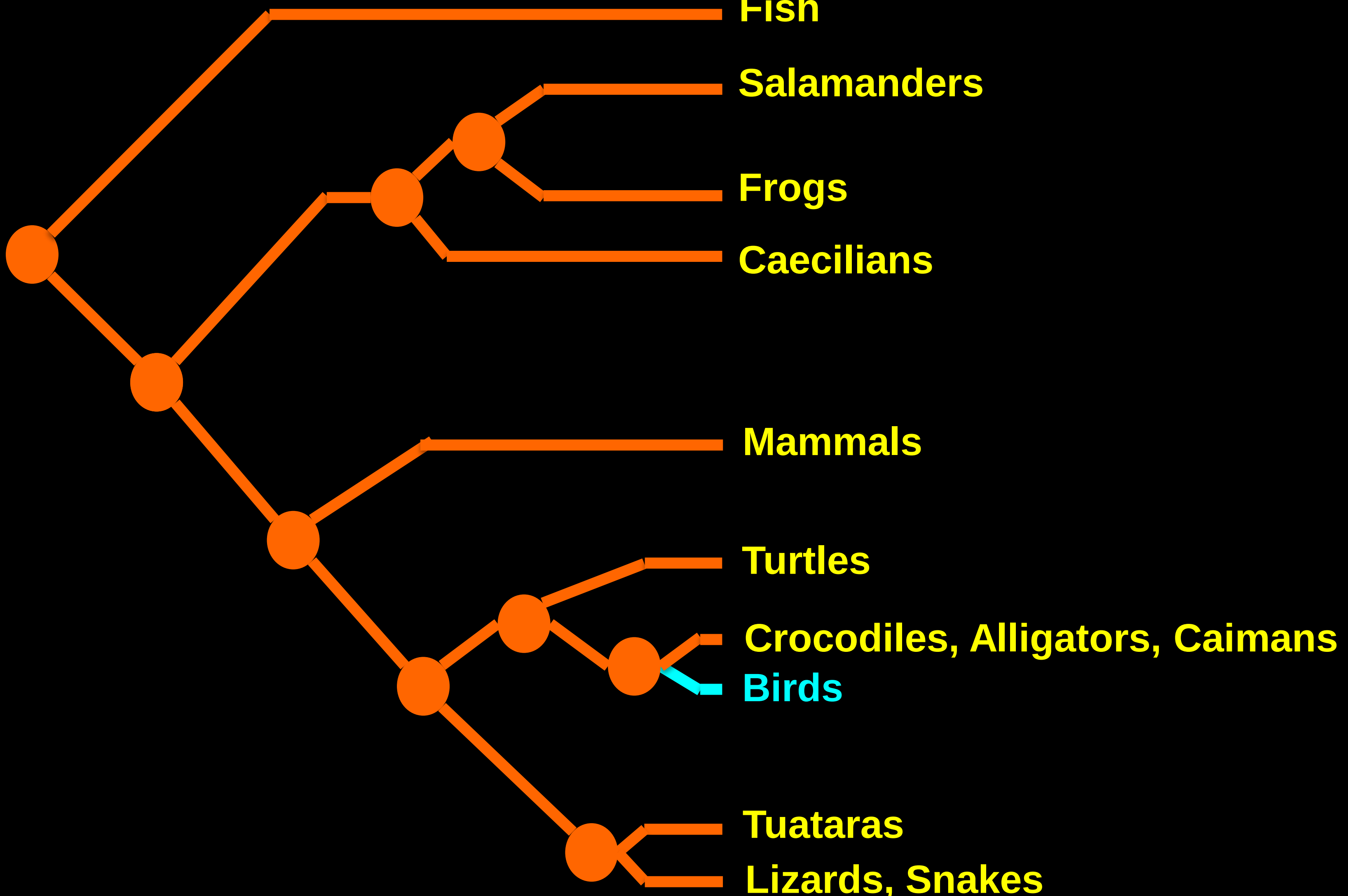

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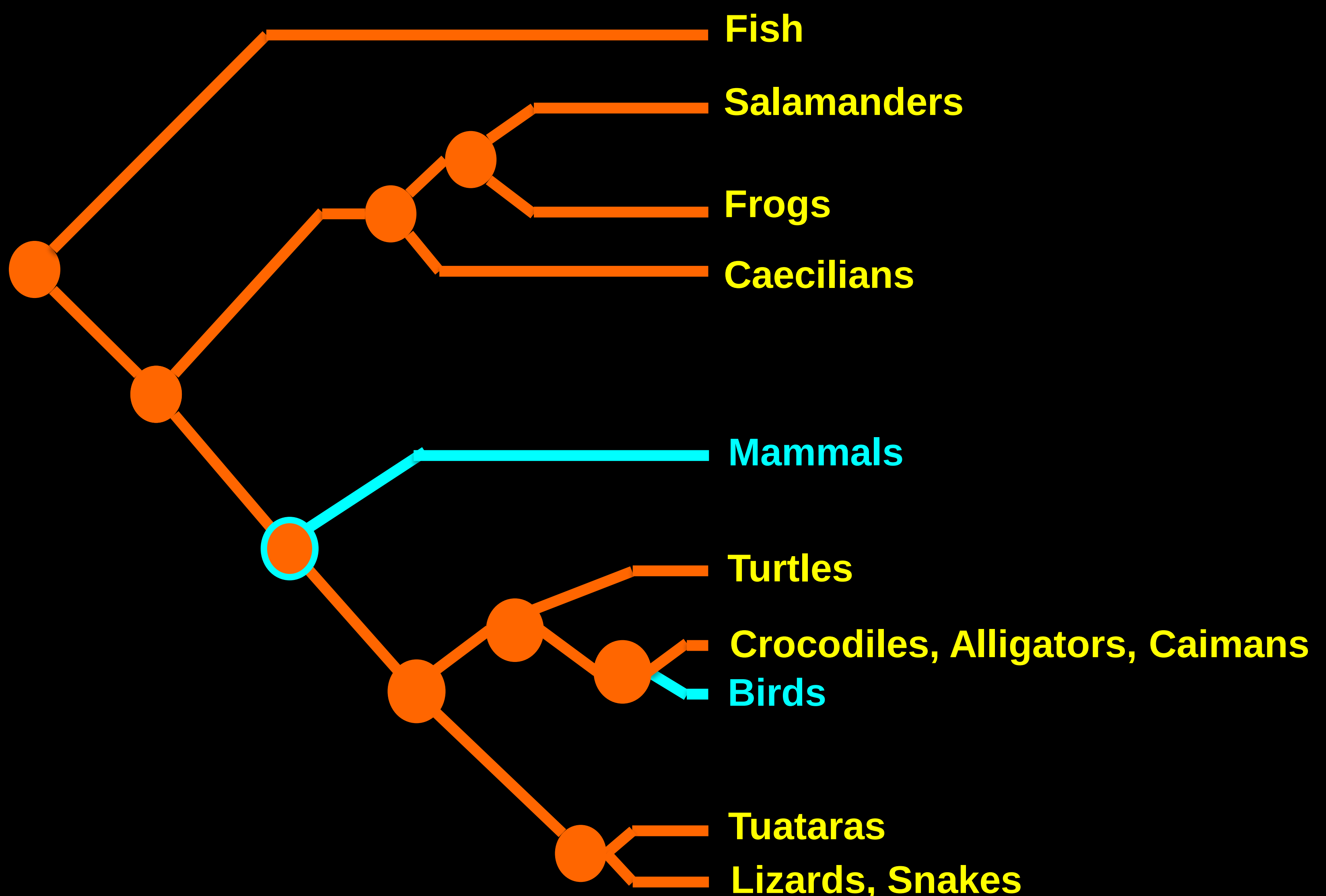

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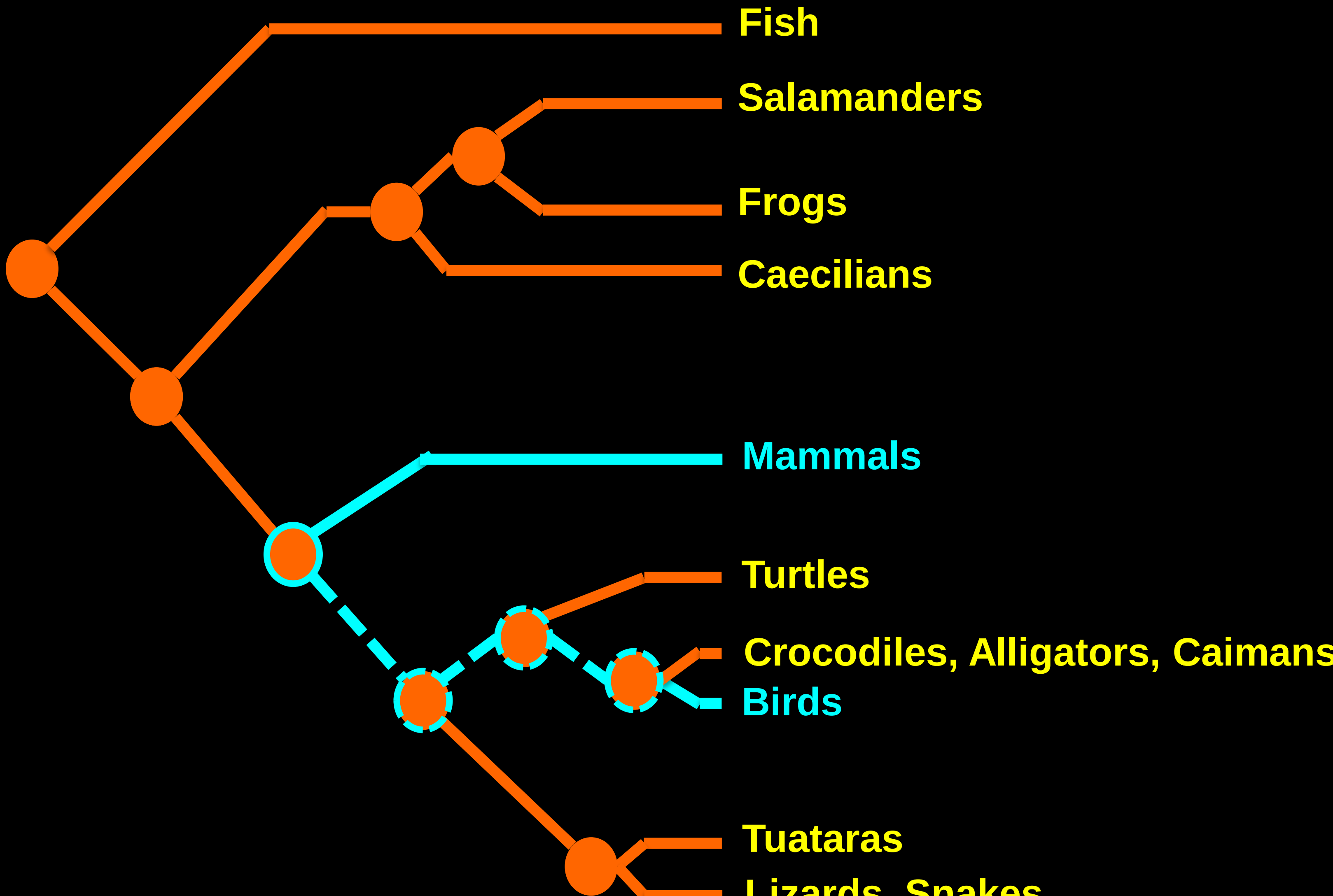

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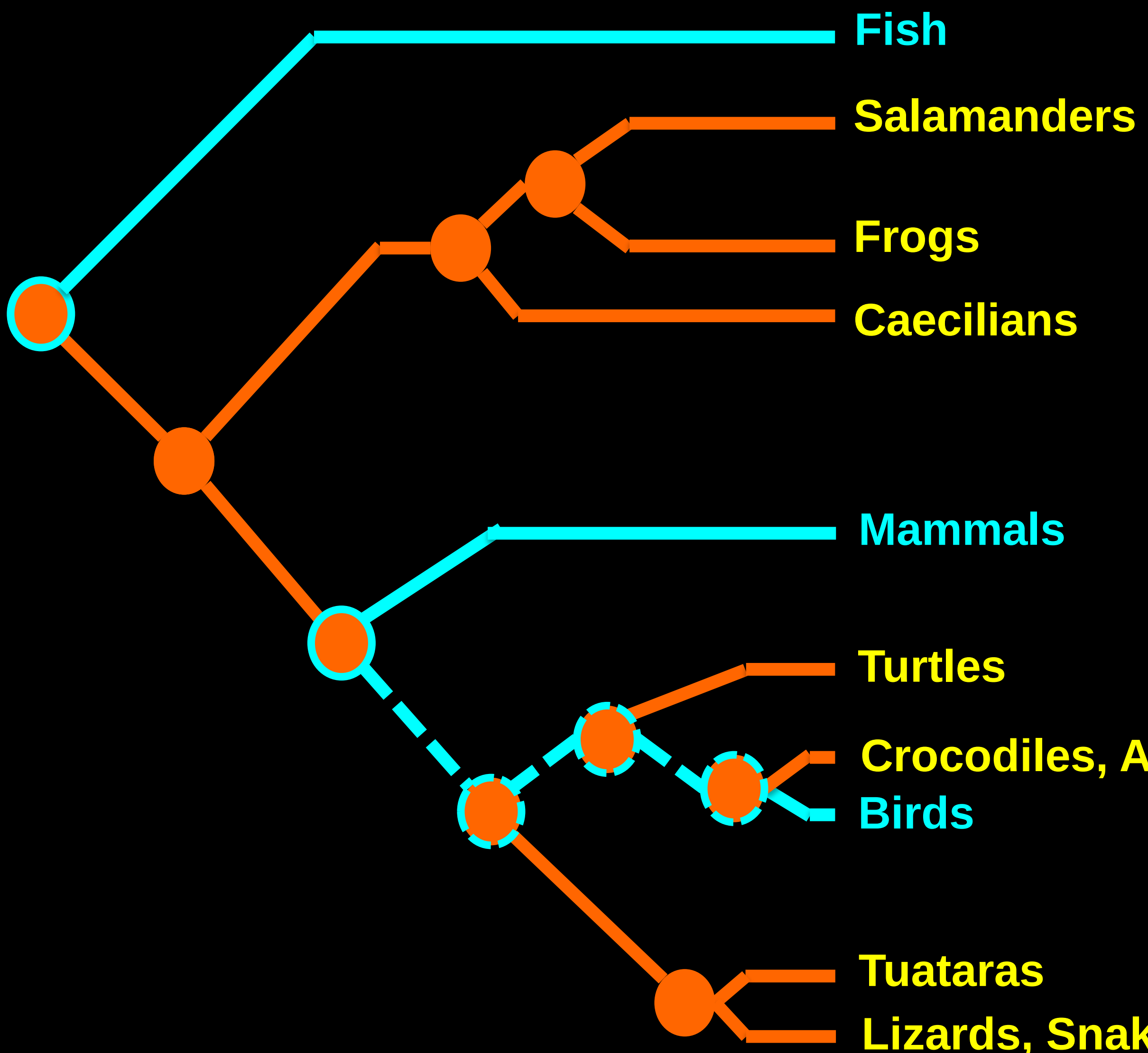
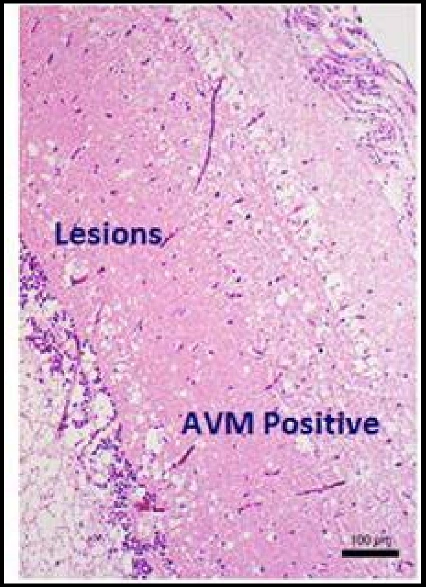
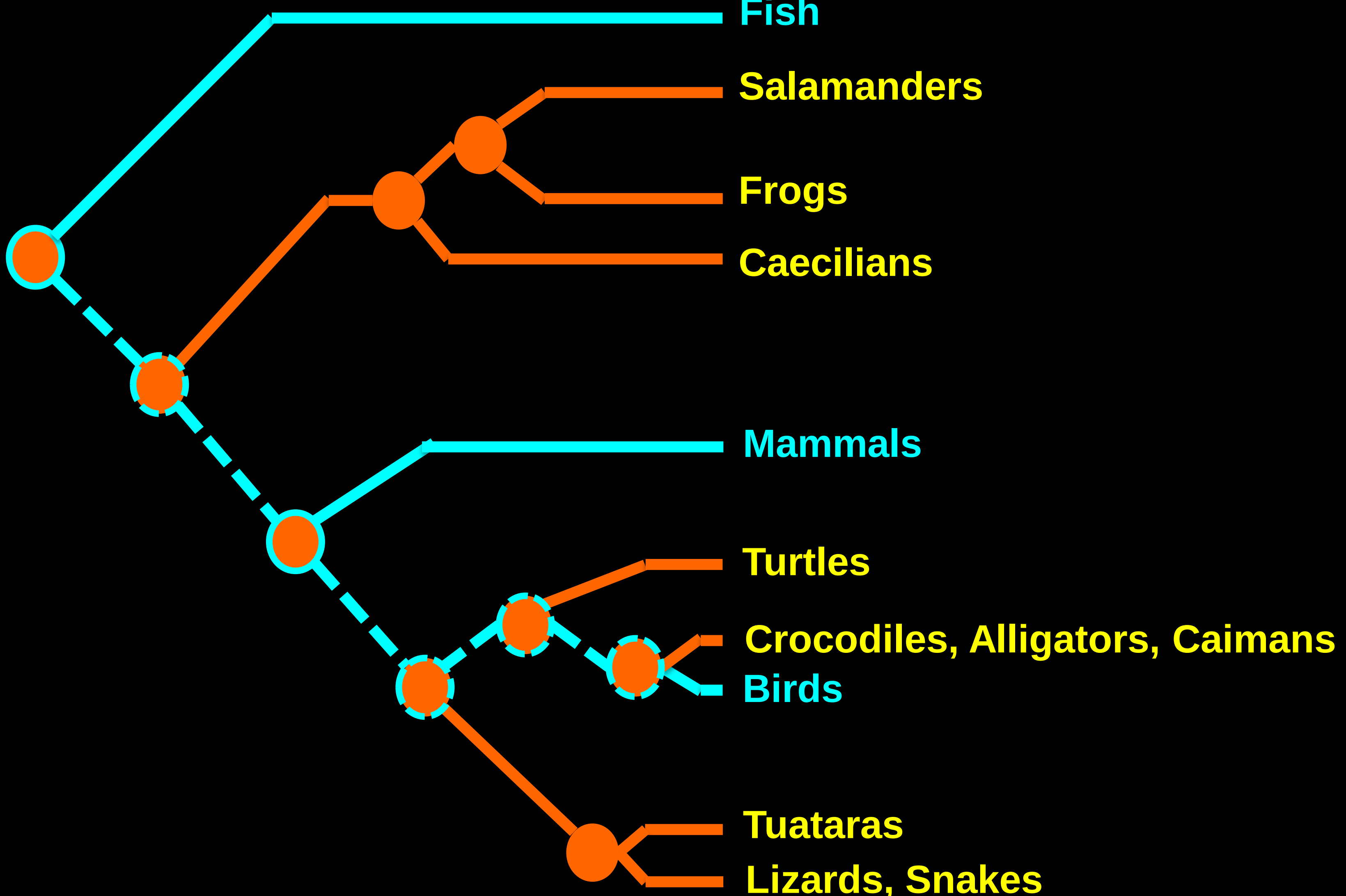




(Haynie, et al 2013)

Taxa affected by ingesting *Aetokthonos* positive *Hydrilla*



- Southeastern U.S. is a global hot spot of freshwater turtle diversity.
- Most species are omnivorous or herbivorous.
  - ~85% of adult diets are composed of aquatic plants and algae.
  - Hydrilla commonly reported as a dominant plant in turtle diets in SE US.

Methods

- Ten turtles from a local pond
  - 5 treatment, 5 control
- Maintained at Whitehall Herpetology Laboratory
  - Standard husbandry protocols (Johnson 2004)
- *Hydrilla* offered in two forms for 90 days
  - Gelatin capsules
  - Floating *Hydrilla*
  - Supplemented diet with Reptomin
- Monitored 2X/day for neurologic signs and general well-being
- Performed a complete physical and neurologic workup every 10 days

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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]

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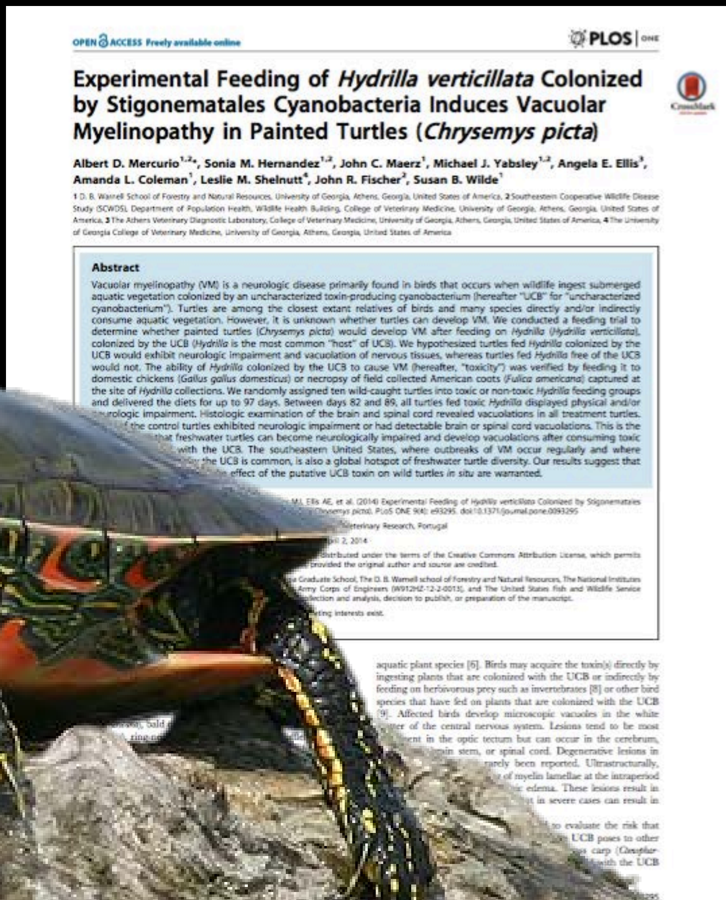
Abstract

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 ...urologic impairment. Histologic examination of the brain and spinal cord revealed vacuolations in all treatment turtles. ...f the control turtles exhibited neurologic impairment or had detectable brain or spinal cord vacuolations. This is the ... that freshwater turtles can become neurologically impaired and develop vacuolations after consuming toxic ... with the UCB. The southeastern United States, where outbreaks of VM occur regularly and where ... the UCB is common, is also a global hotspot of freshwater turtle diversity. Our results suggest that ... effect of the putative UCB toxin on wild turtles *in situ* are warranted.

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

Methods

- Humanely euthanized and performed a complete necropsy
- Organs in 10% formalin
- ½ brain stored in EM fixative
- Histology on major organs
- Electron microscopy on CNS



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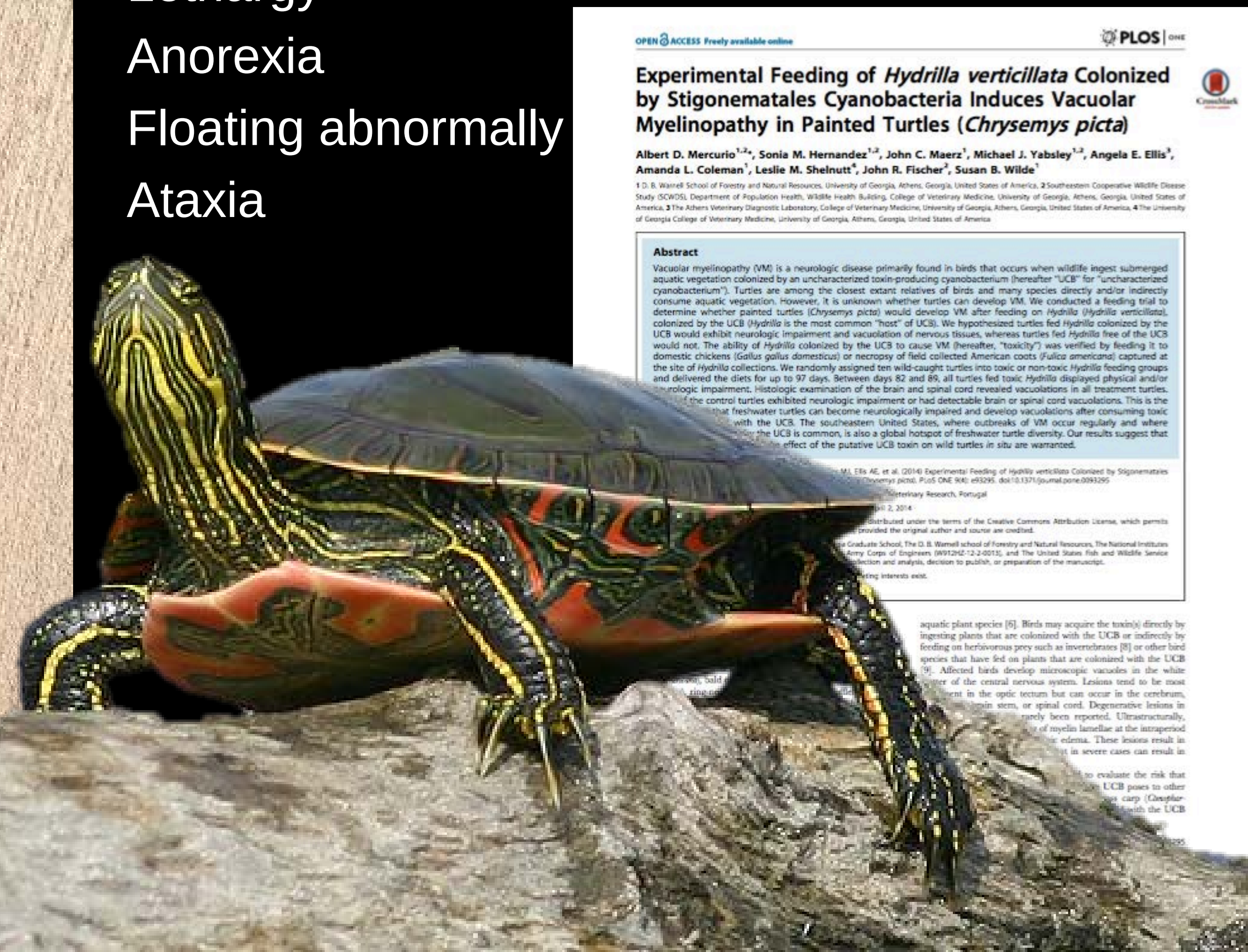
Key Findings

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

- Weakness
- Lethargy
- Anorexia
- Floating abnormally
- Ataxia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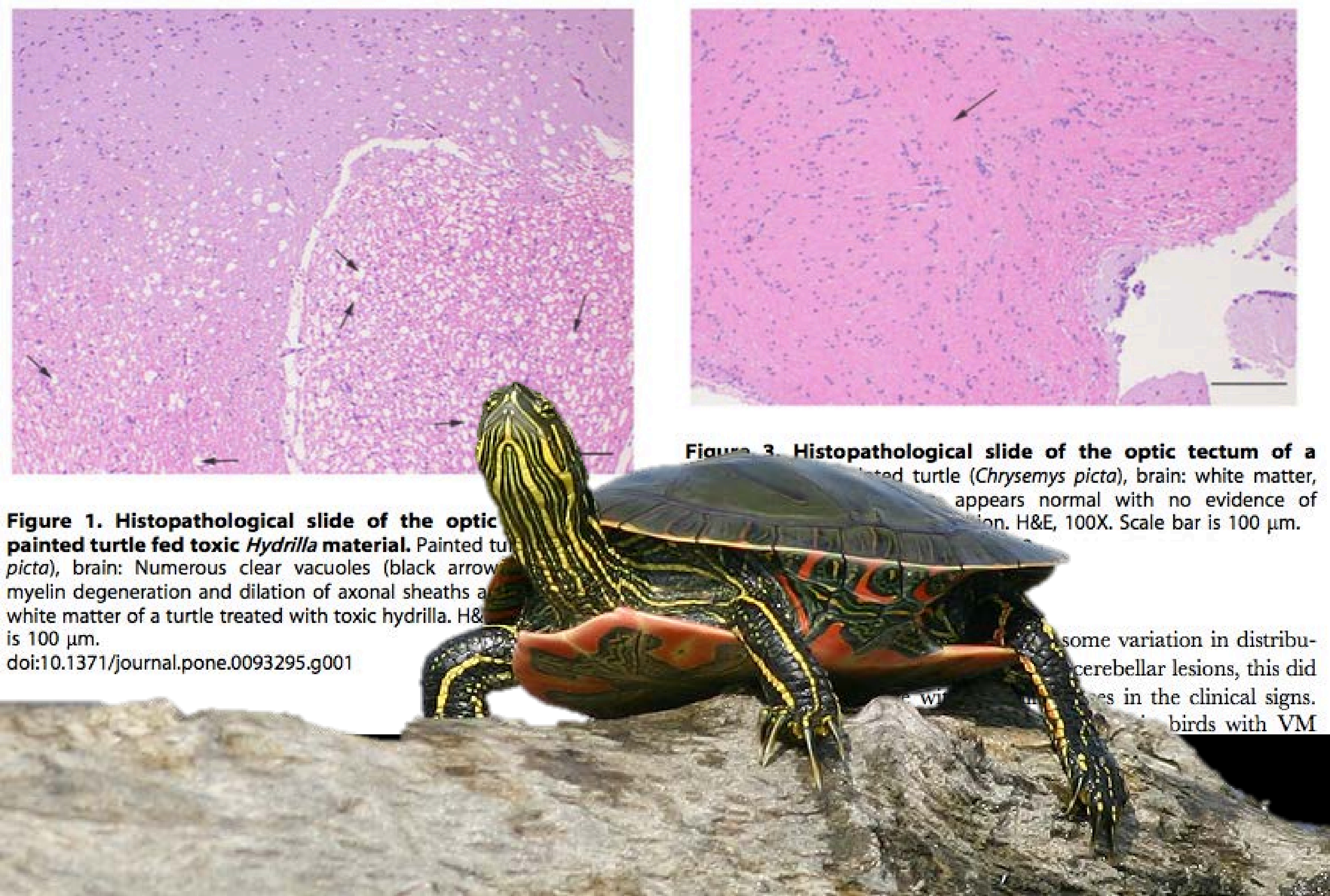
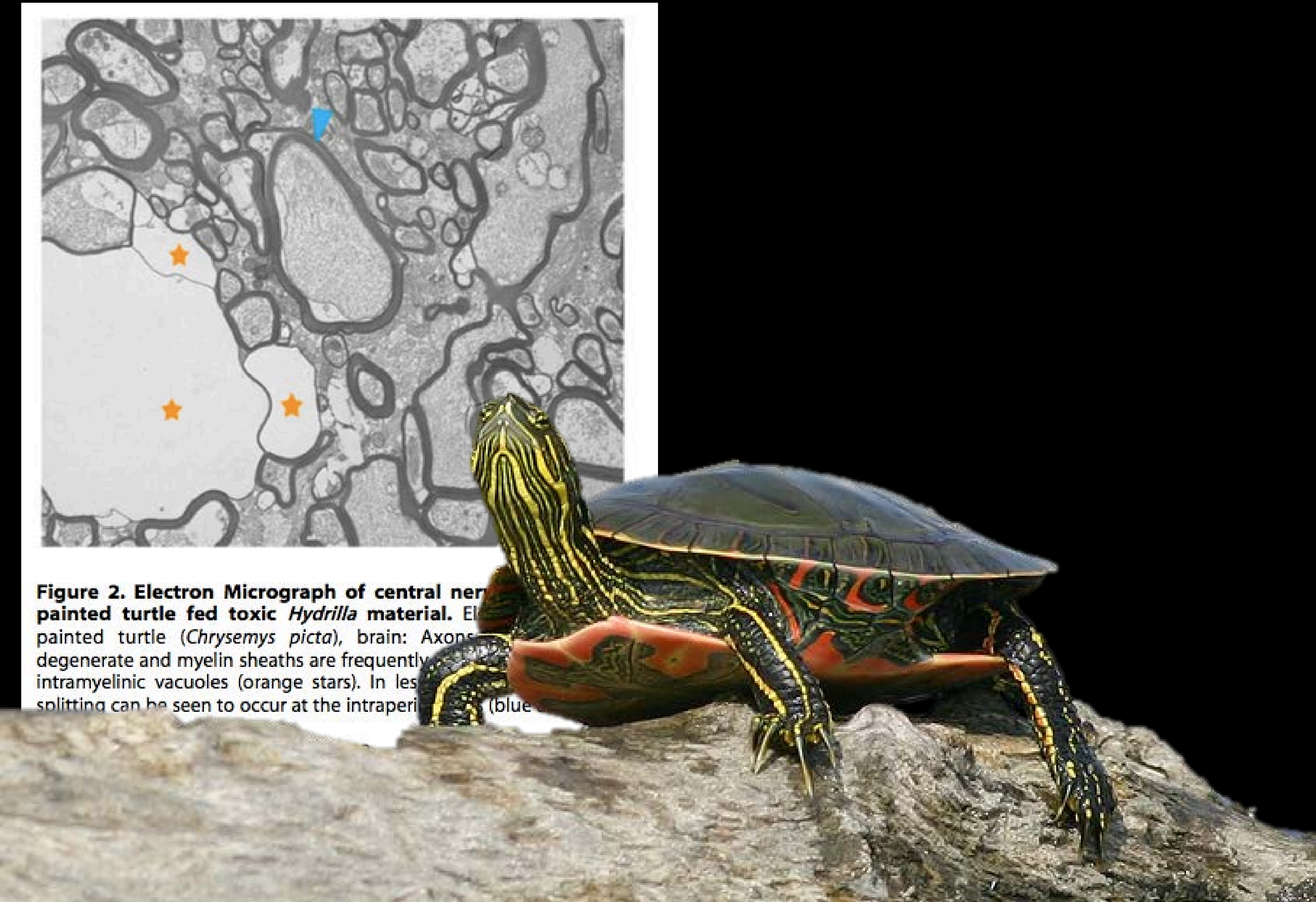


Figure 1. Histopathological slide of the optic
painted turtle fed toxic *Hydrilla* material. Painted tu
picta), brain: Numerous clear vacuoles (black arrow
myelin degeneration and dilation of axonal sheaths a
white matter of a turtle treated with toxic hydrilla. H&
is 100 µm.
doi:10.1371/journal.pone.0093295.g001

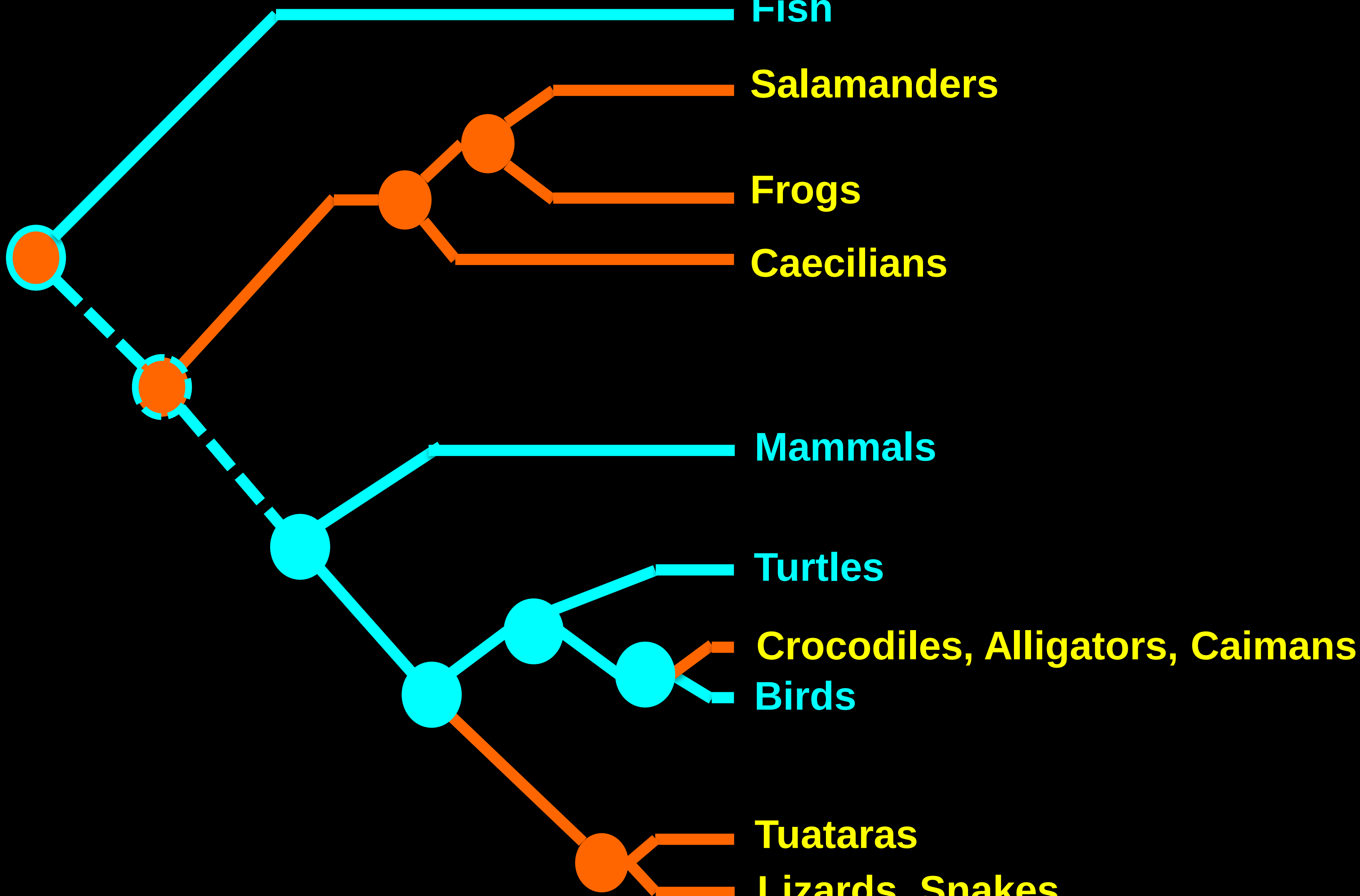
3. Histopathological slide of the optic tectum of a
turtle (*Chrysemys picta*), brain: white matter,
appears normal with no evidence of
on. H&E, 100X. Scale bar is 100 µm.

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

Key Findings



Taxa affected by ingesting *Aetokthonos* positive *Hydrilla*

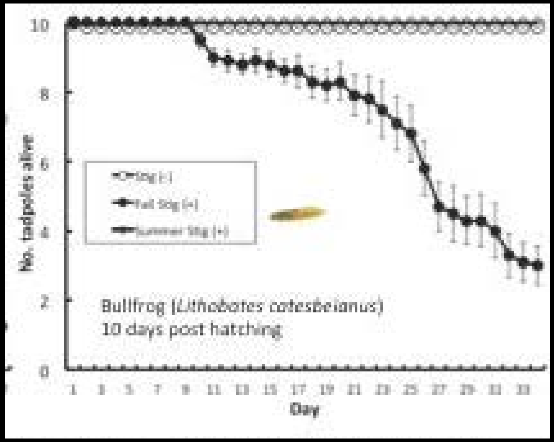


- Southeastern U.S. has a rich diversity of amphibians.
- Species breed in a range of water bodies including ponds and the littoral zones of lakes.
- Anuran [frogs and toads] have an aquatic tadpole stage that feeds on epiphytic biofilms on aquatic plants.

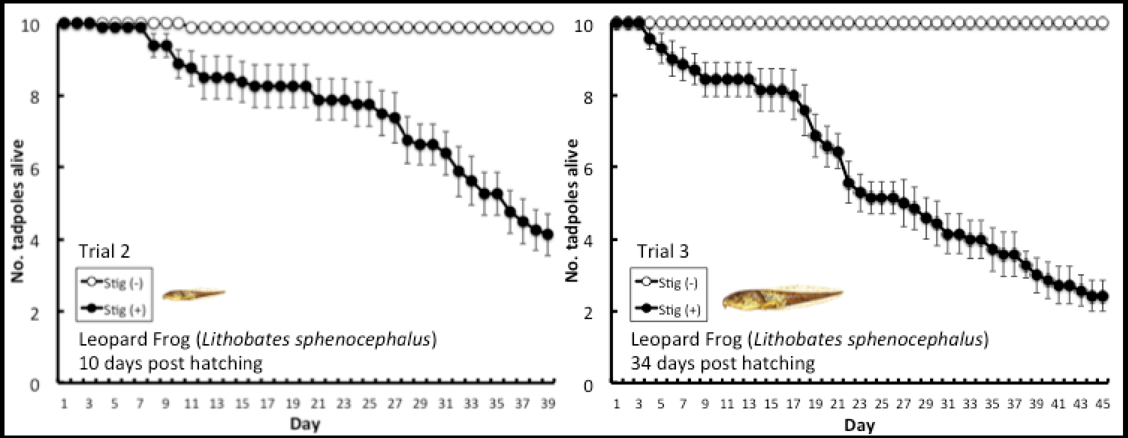
Methods

- 7-10 replicate aquaria containing 5-10 tadpoles [depending on size]
- Tested three species at various stages using fall collected *Aetokthonos* positive or negative *Hydrilla*
- Monitored survival and behavior daily

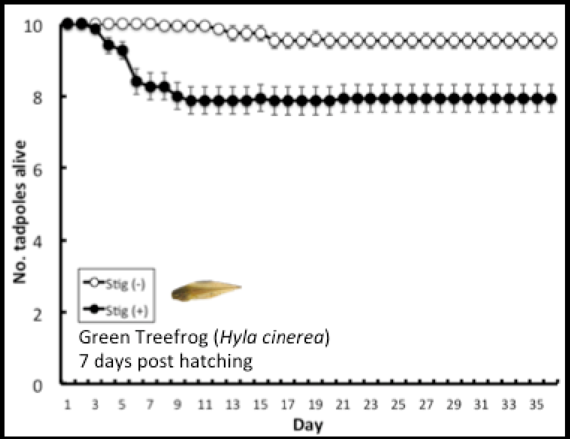
Results



No. tadpoles alive
Stig (-)
Fall Stig (+)
Summer Stig (+)
Bullfrog (*Lithobates catesbeianus*)
10 days post hatching
Day

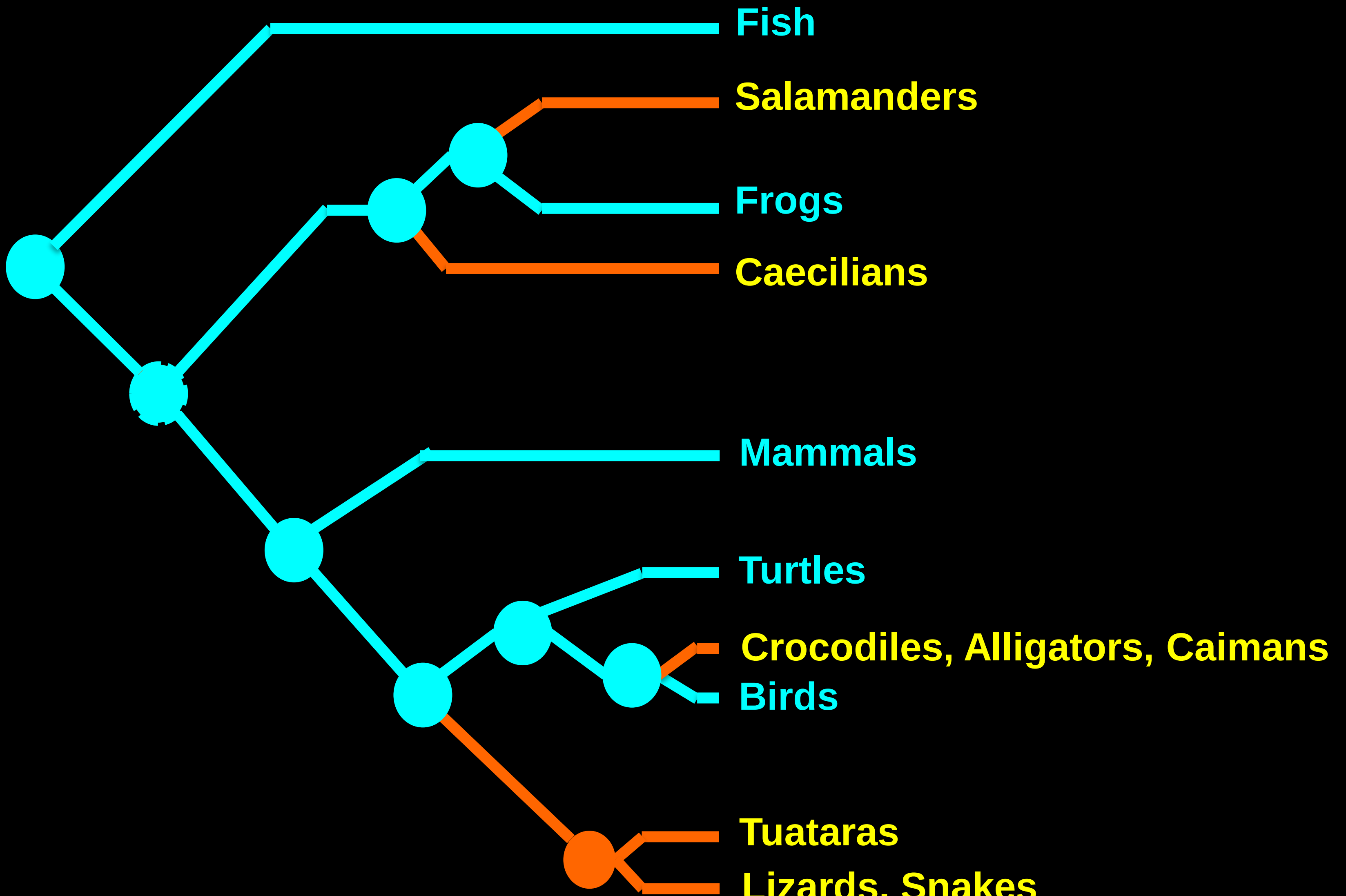


No. tadpoles alive
Trial 2
Stig (-)
Stig (+)
Leopard Frog (*Lithobates sphenocephalus*)
10 days post hatching
Day
Trial 3
Stig (-)
Stig (+)
Leopard Frog (*Lithobates sphenocephalus*)
34 days post hatching
Day

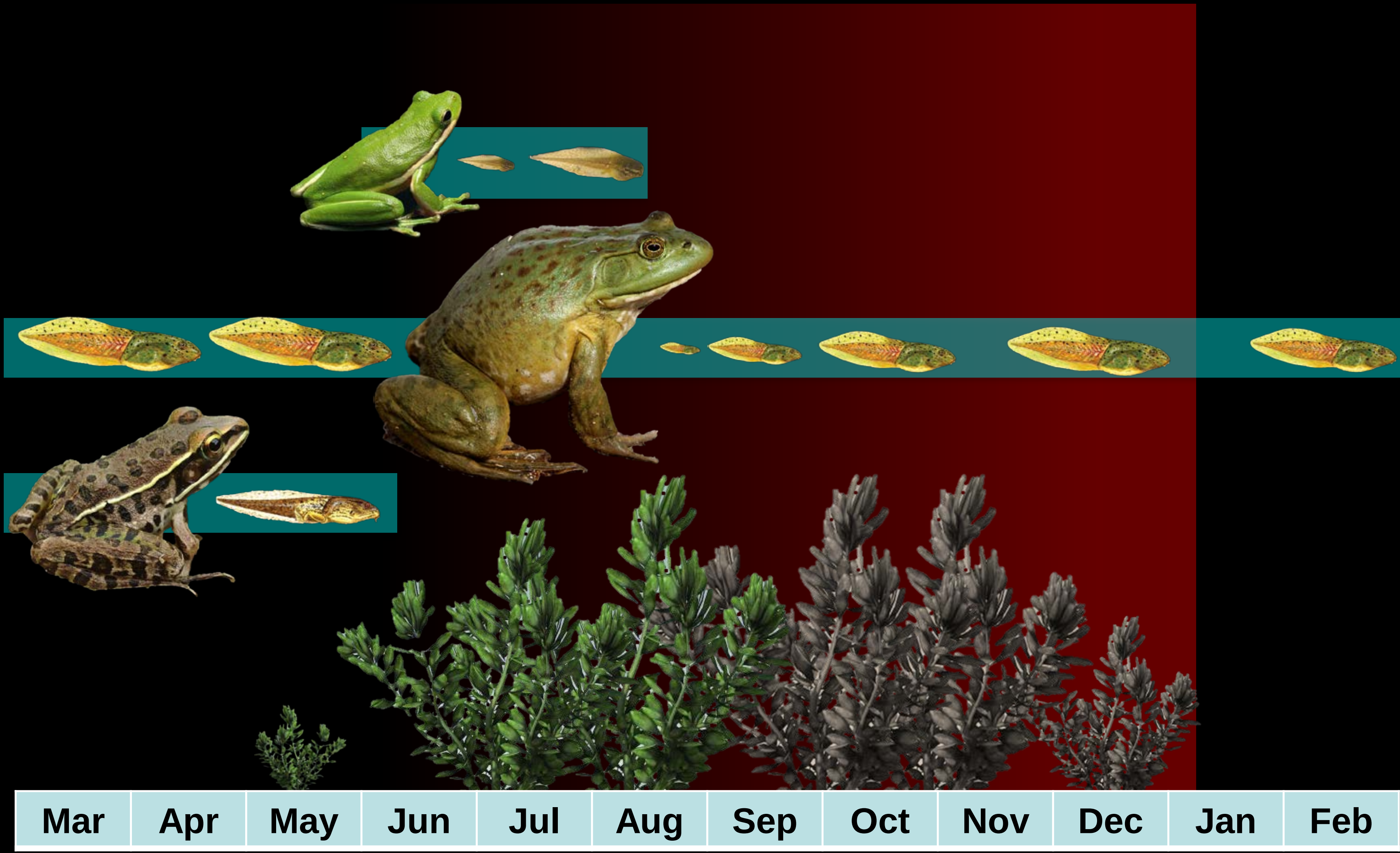


No. tadpoles alive
Stig (-)
Stig (+)
Green Treefrog (*Hyla cinerea*)
7 days post hatching
Day

Taxa affected by ingesting *Aetokthonos* positive *Hydrilla*



Risk = Sensitivity + Exposure



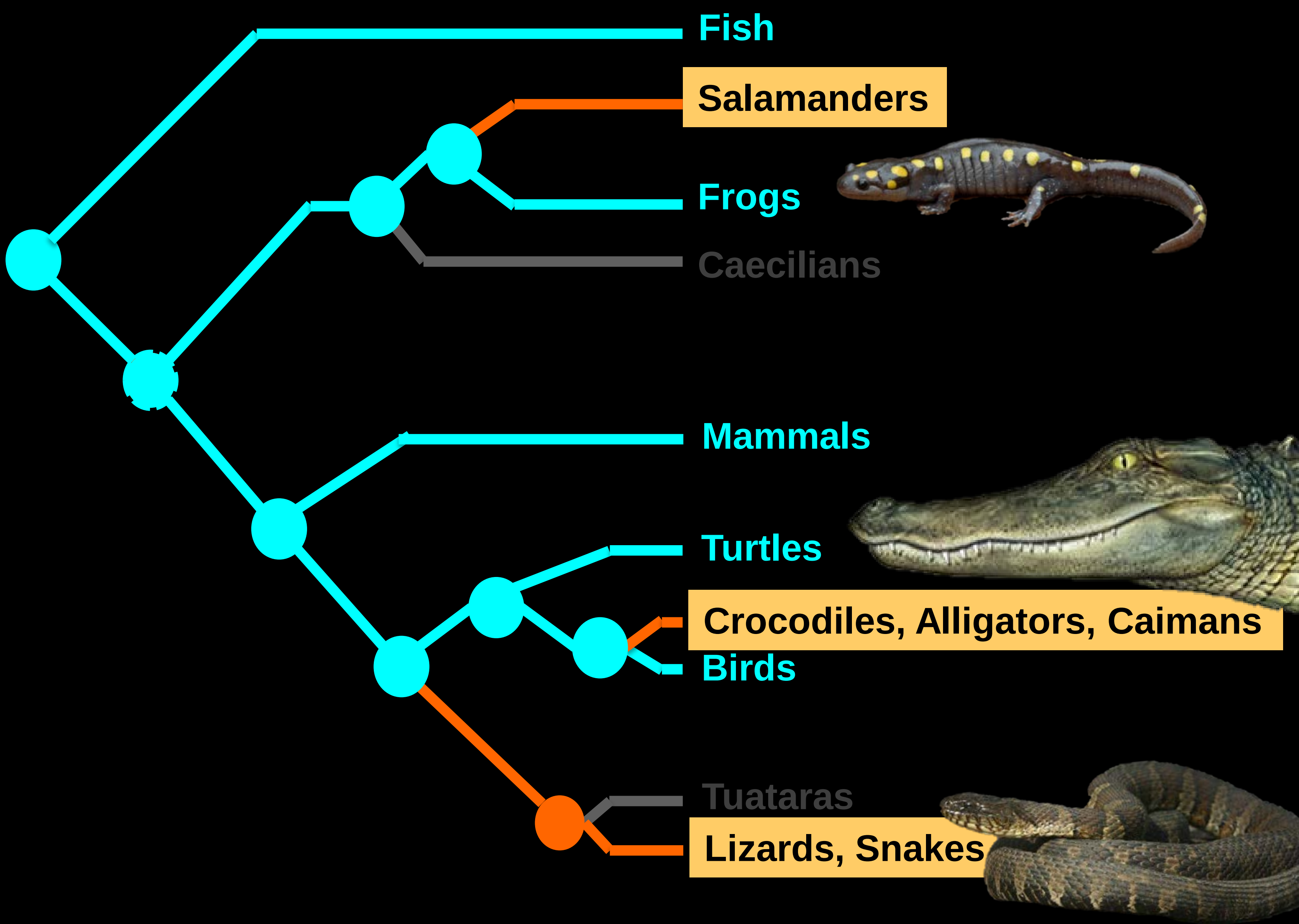
So, what now? What next? Is it all bad?

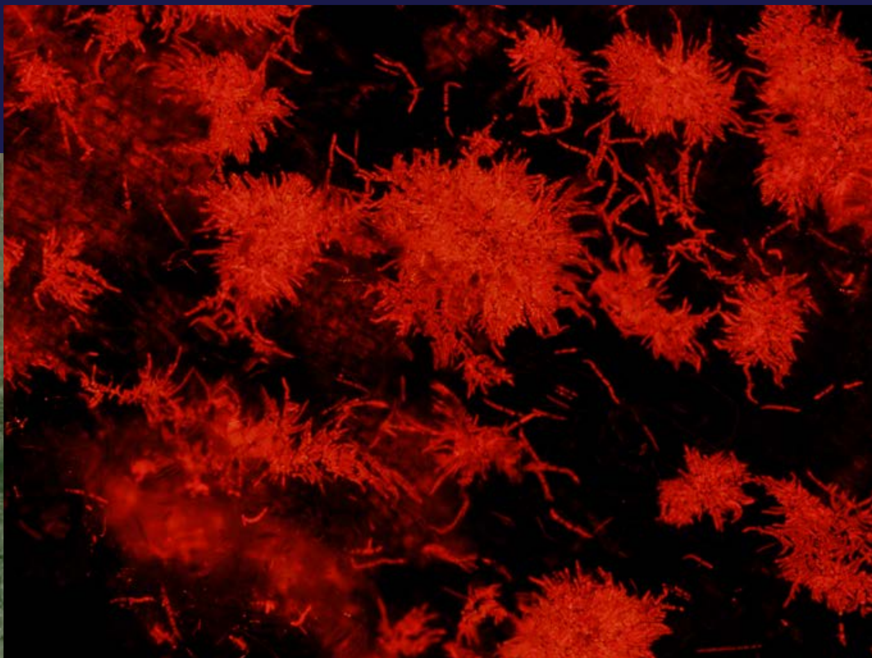
Najas guadalupensis

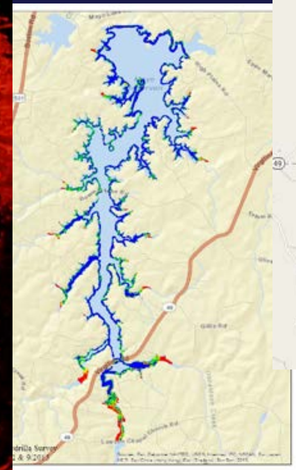
- What are effects of *Aetokthonos* positive *Hydrilla* exposure on turtle fitness? Can they tolerate or recover?

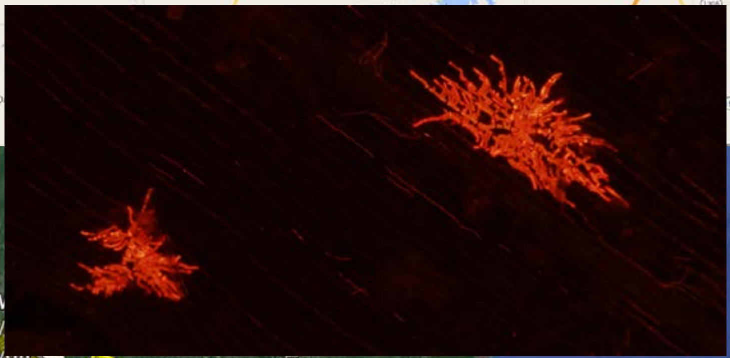
- Do effects of *Aetokthonos* positive *Hydrilla* exposure carry over to terrestrial amphibian stages among surviving tadpoles?

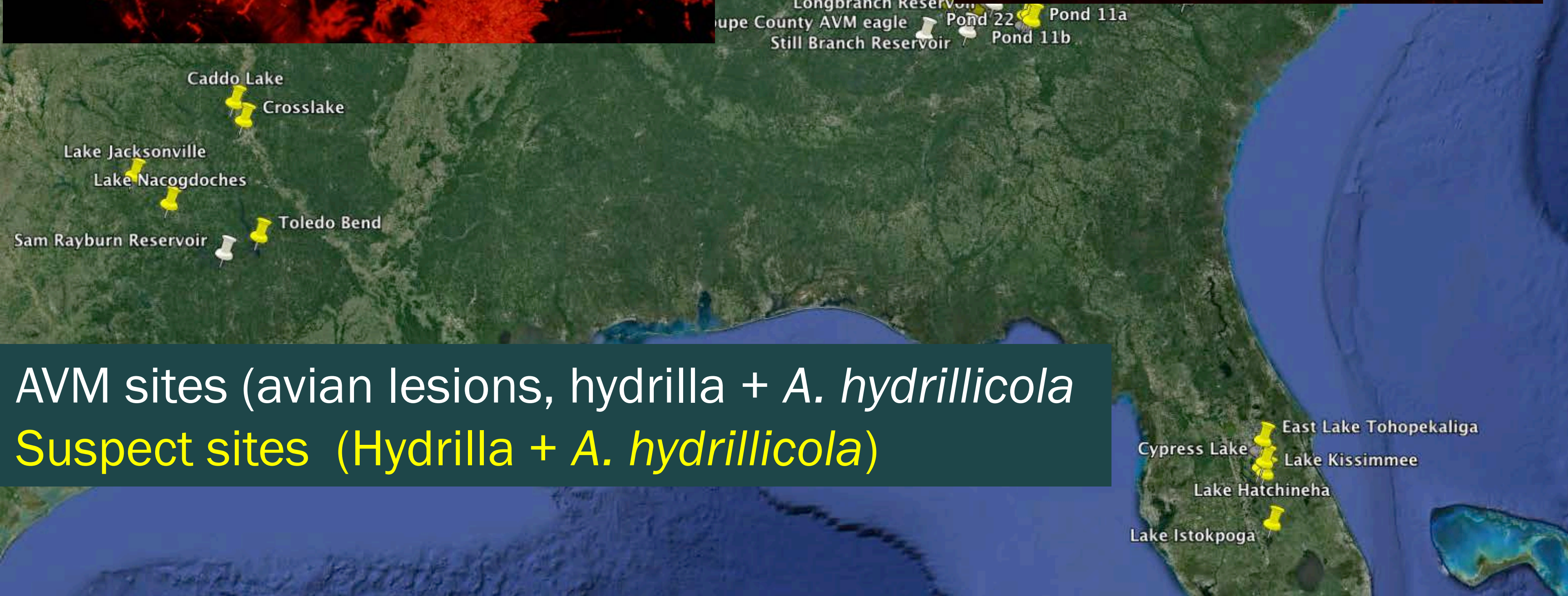
So, what now? What next? Is it all bad?





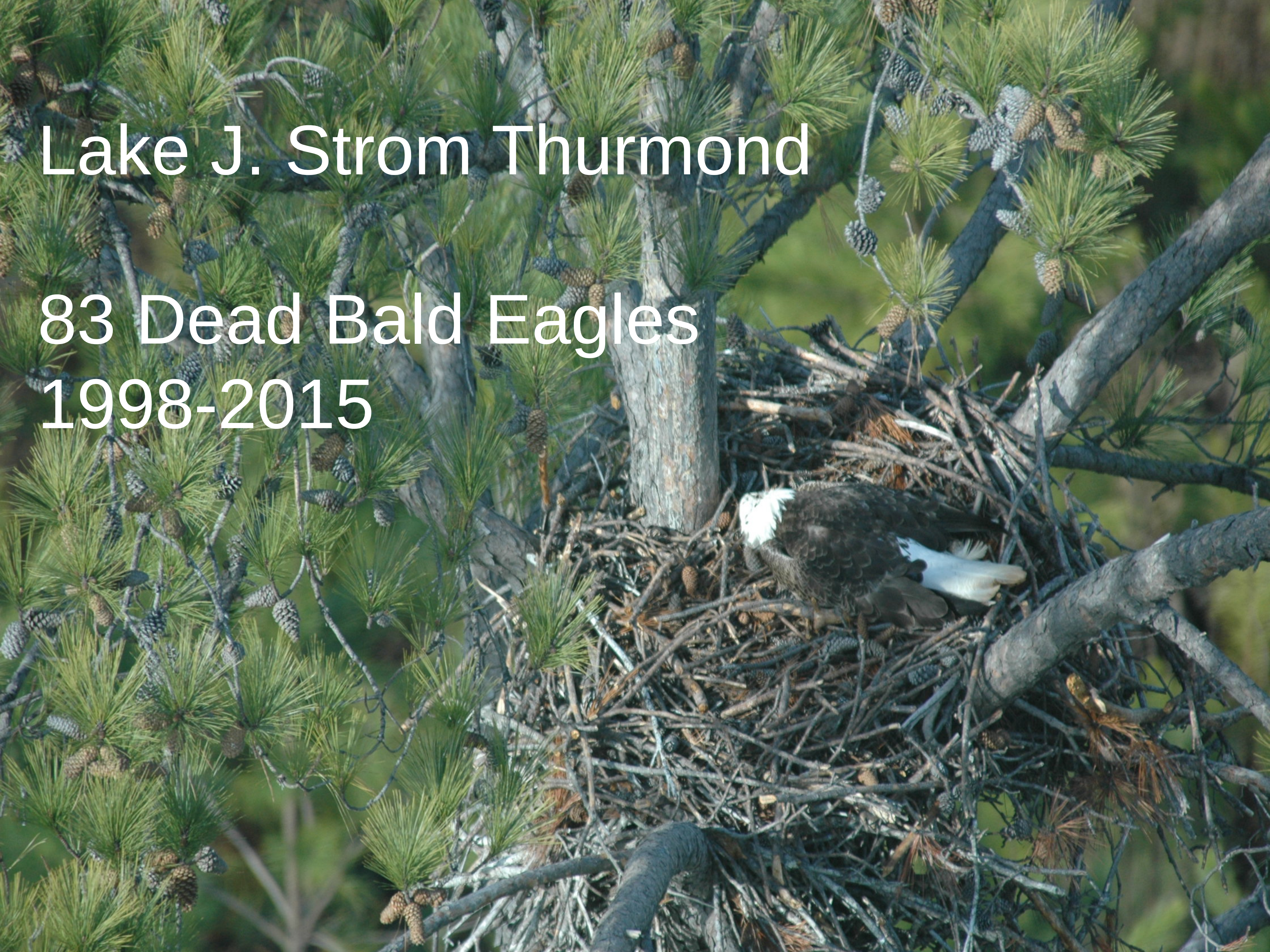


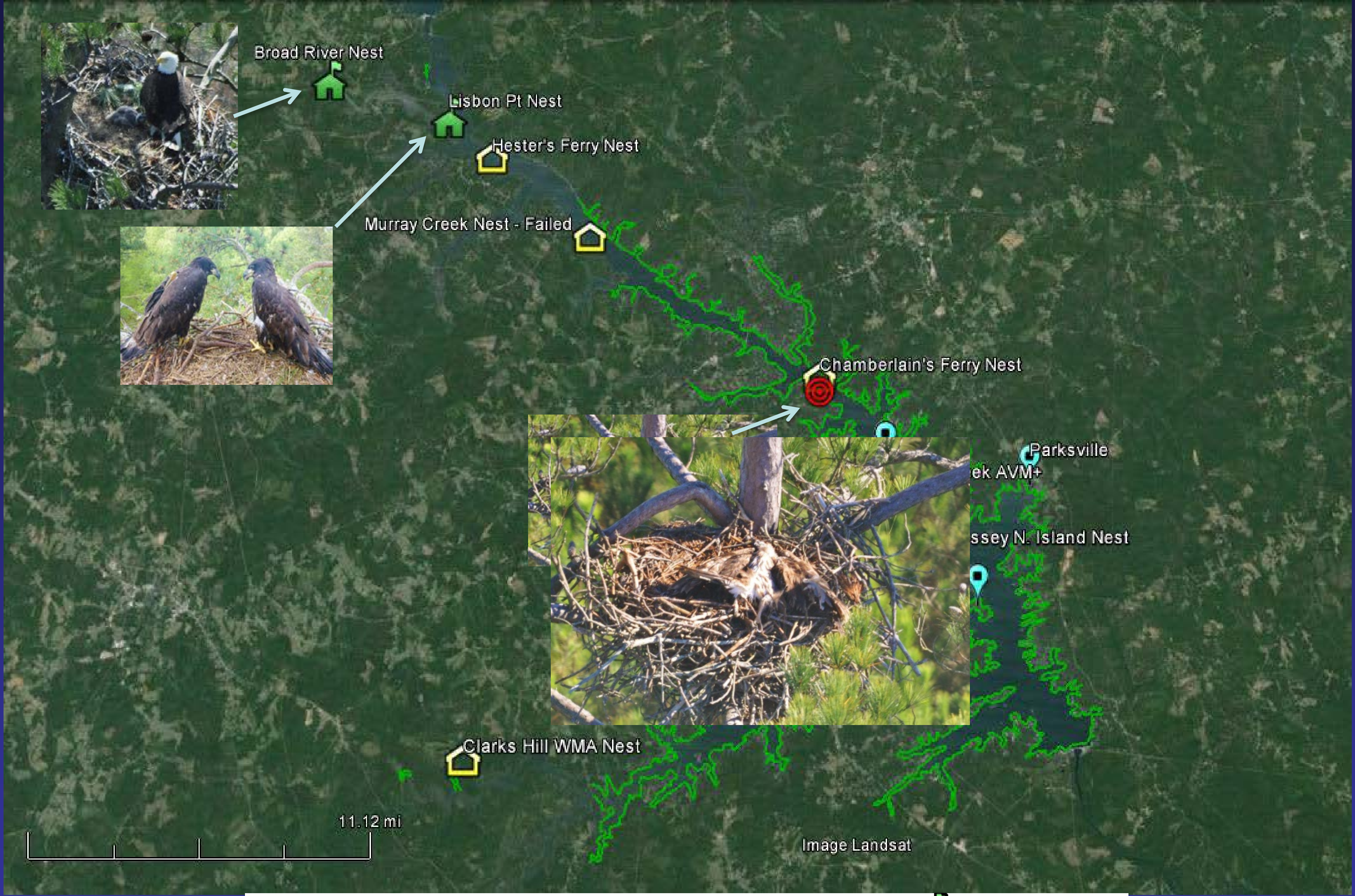




AVM sites (avian lesions, hydrilla + *A. hydrillicola*

Suspect sites (Hydrilla + *A. hydrillicola*)


Lake J. Strom Thurmond
83 Dead Bald Eagles
1998-2015



J. Strom Thurmond Reservoir. Green shoreline with hydrilla, active nest, inactive nest, trap site, roost site, eagle mortality

The CENTER for CONSERVATION BIOLOGY

Thurmond nestling April 3, 2015

Libby Mojica

Craig Koopie

Brigette Haram photo

- Solar powered PTT/GPS 70g units (Microwave Telemetry Inc)
- Transmit to Argos
- Programmed for the winter risk period (Nov-Jan) and sends a UHF signal during daylight hours

Thurmond Juvenile Eagle Locations; October 6, 2015

Are Fish susceptible to AVM?

Triploid Chinese Grass Carp:

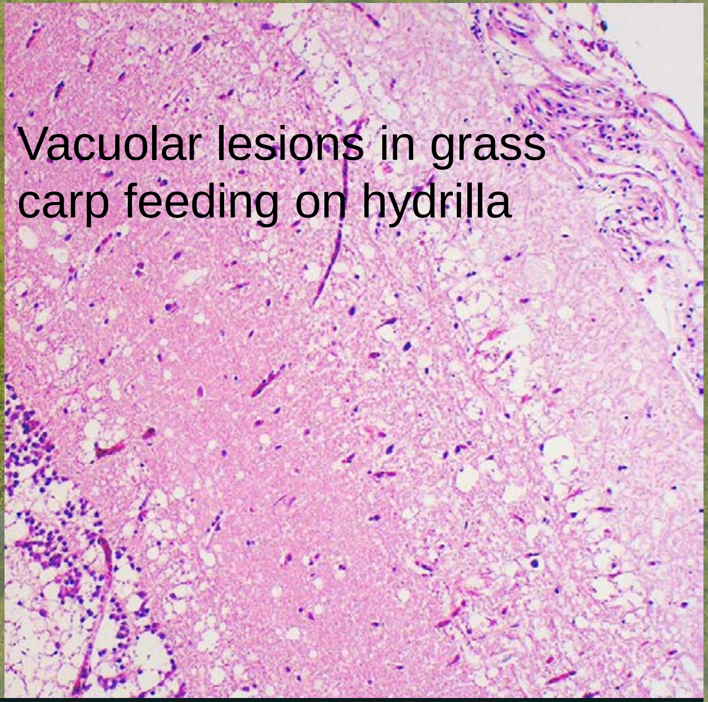
- Effective control of submerged aquatic plants
- Disease susceptibility?
- Vector potential?

Davis Pond Field Trial

Photo: Larry McCord

Triploid Chinese Grass Carp:

- Effective control of submerged aquatic plants Yes
- Disease susceptibility? Yes
- Vector potential? No



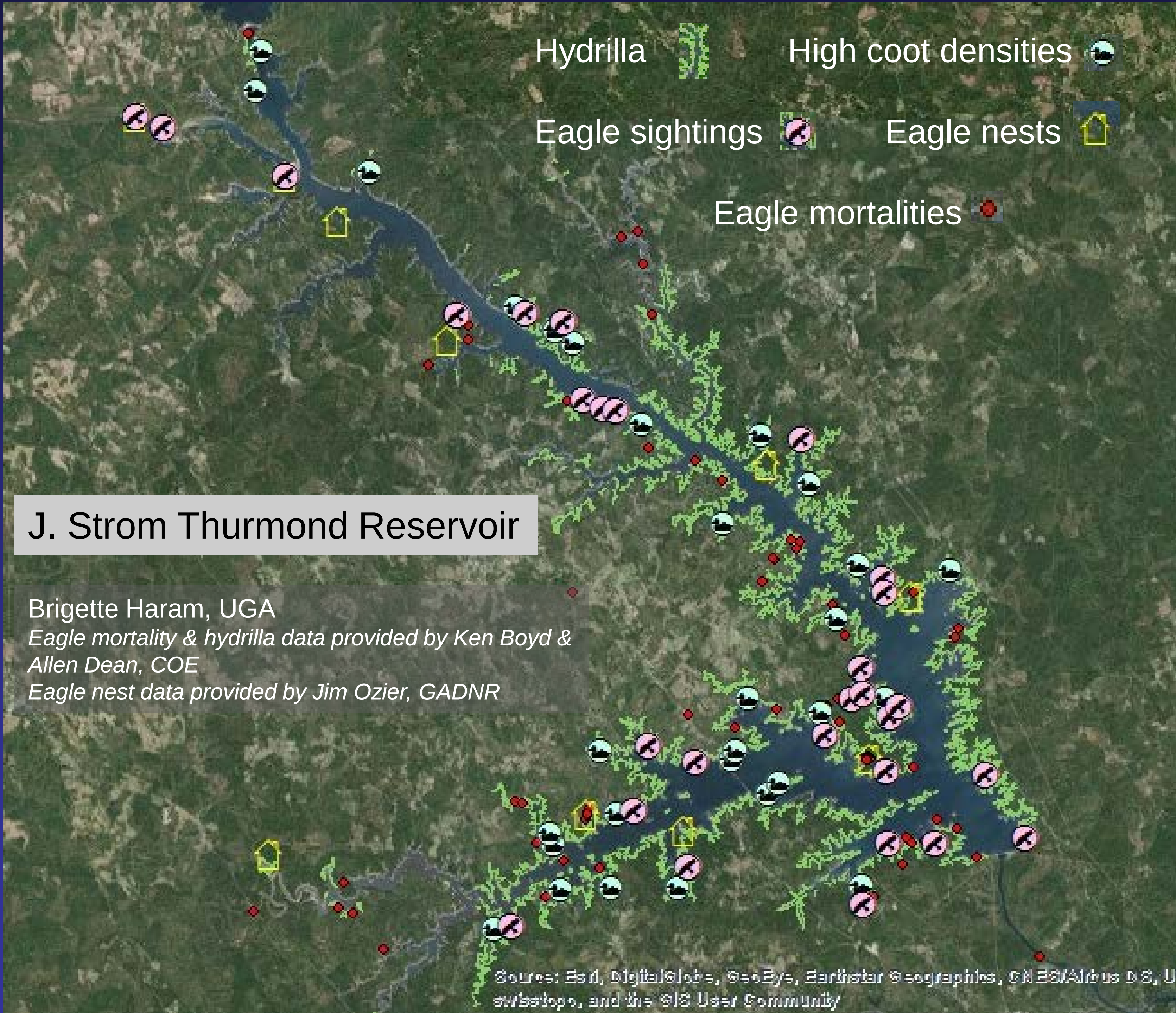
Haynie, R.H., Bowerman, W.W., Williams, S.K. Morrison, J.R. Grizzle, J.R. Fischer, J.R. & Wilde S.B. (2013) Are triploid grass carp suitable for aquatic vegetation management in systems affected by Avian Vacuolar Myelinopathy? Journal of Aquatic Animal Health 25: 252–259.

Sentinel birds
Fall 2012

All sentinels with access to hydrilla-- AVM positive

w/o Hydrilla: AVM negative

Sentinel Mallard: Longbranch Reservoir December 2012



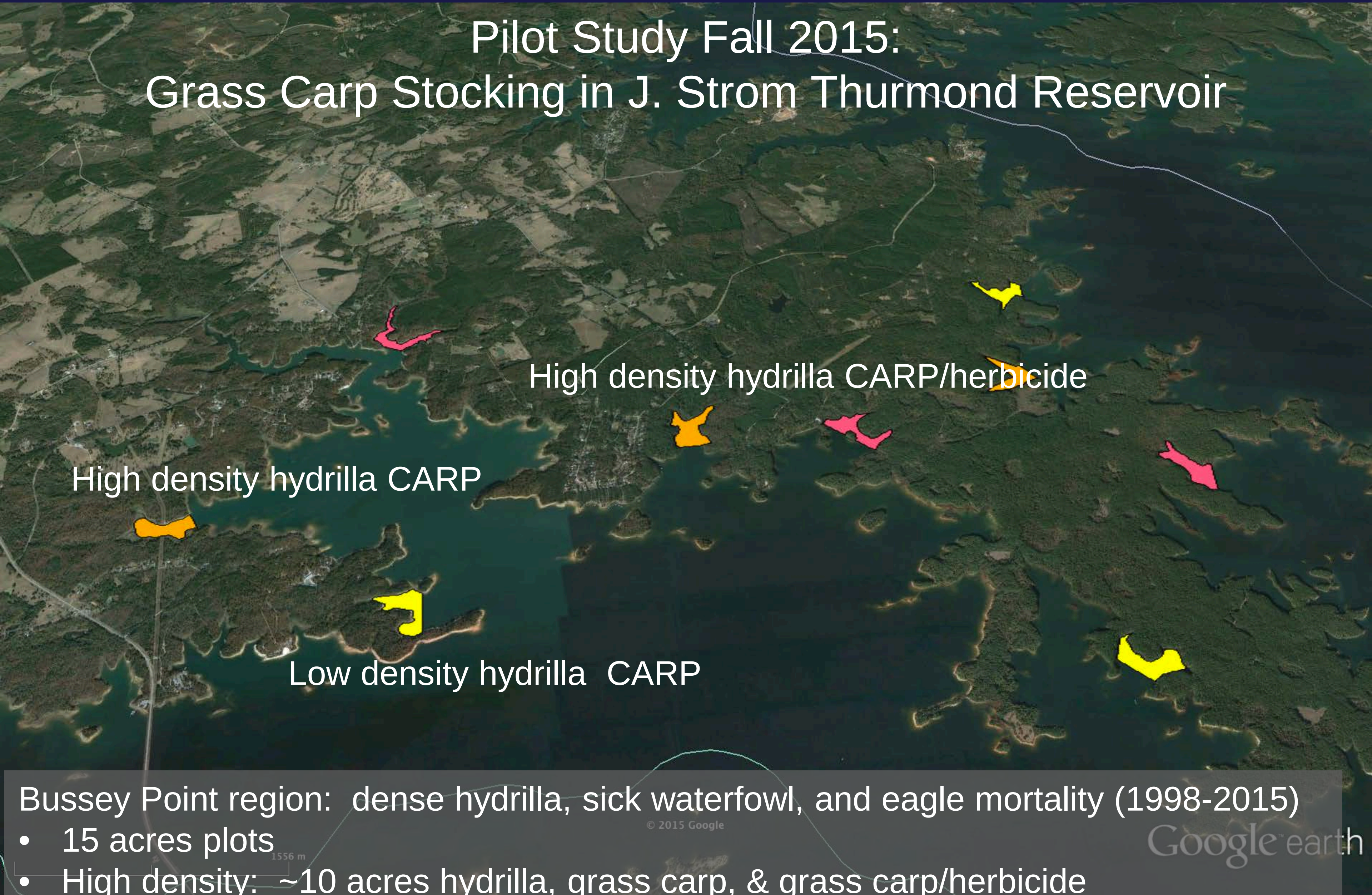
J. Strom Thurmond Reservoir

Brigette Haram, UGA

Eagle mortality & hydrilla data provided by Ken Boyd & Allen Dean, COE

Eagle nest data provided by Jim Ozier, GADNR

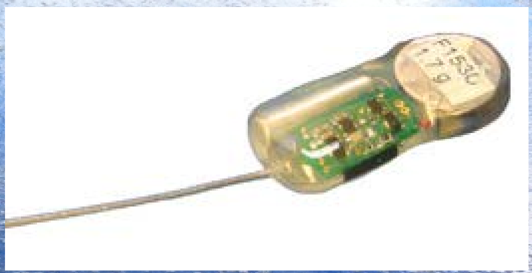
Pilot Study Fall 2015:
Grass Carp Stocking in J. Strom Thurmond Reservoir



Bussey Point region: dense hydrilla, sick waterfowl, and eagle mortality (1998-2015)

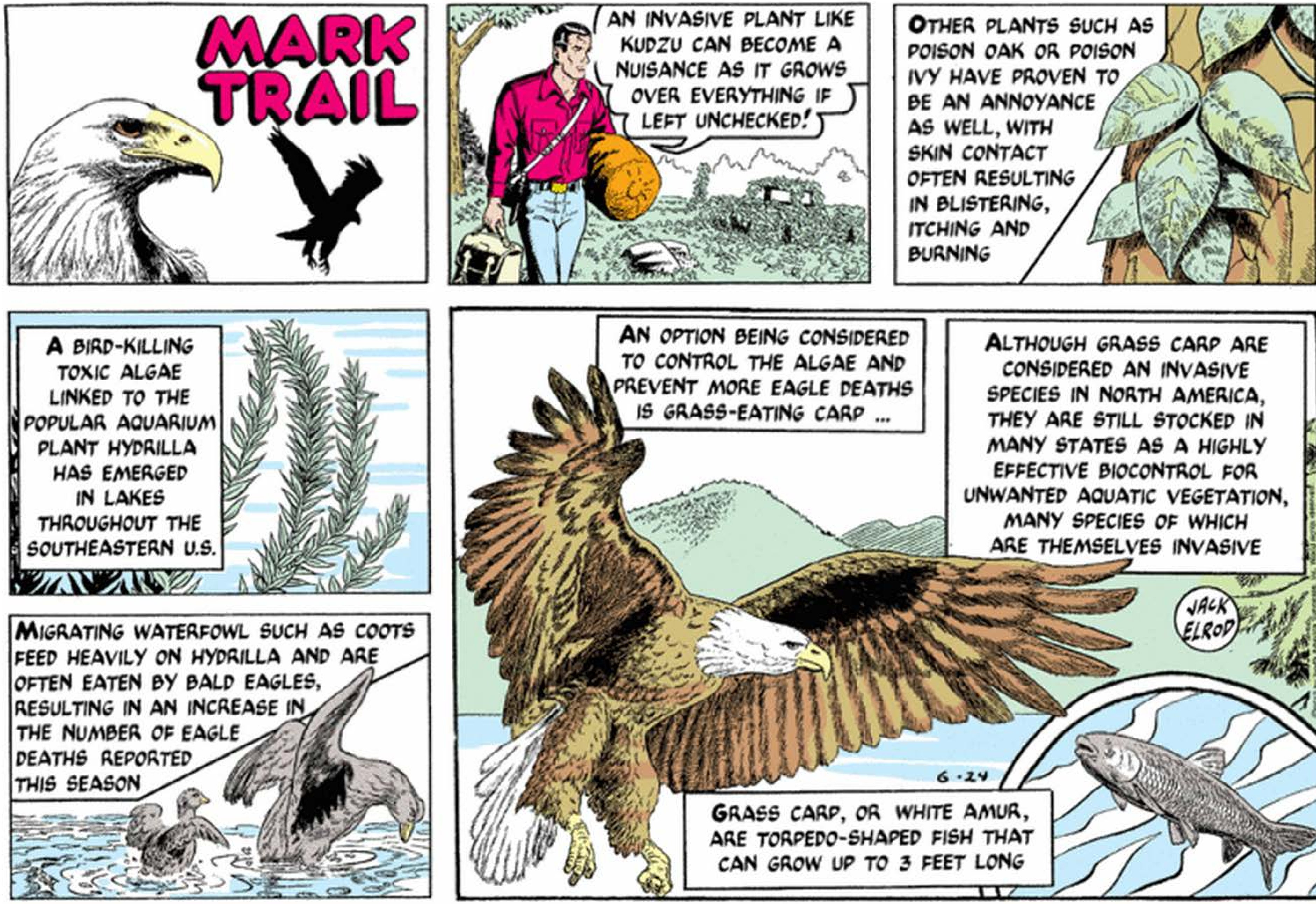
- 15 acres plots
- High density: ~10 acres hydrilla, grass carp, & grass carp/herbicide
- Low density ~5 acres hydrilla

Pilot Study Fall 2015:
Grass Carp Stocking in J. Strom Thurmond Reservoir



- 24 grass carp will be fitted with body implant radio transmittors to assess movement.

- We will use electroshocking boat to collect a small subset of stocked grass carp and other fish species for:
  - Health assessments (including vacuolar lesions)
  - Laboratory feeding trials (to test for risk of AVM toxin transmission)



by Jack Elrod

U.S.
FISH & WILDLIFE
SERVICE
DEPARTMENT OF THE INTERIOR

GULF & SOUTH ATLANTIC
REGIONAL PANEL
ON AQUATIC INVASIVE SPECIES

Gulf & South Atlantic Regional Panel On Aquatic Invasive Species

GULF STATES MARINE FISHERIES COMMISSION