Avian Vacuolar Myelinopathy (AVM) Research Update

Gulf- and South Atlantic Regional
Panel on Invasive Aquatic Species

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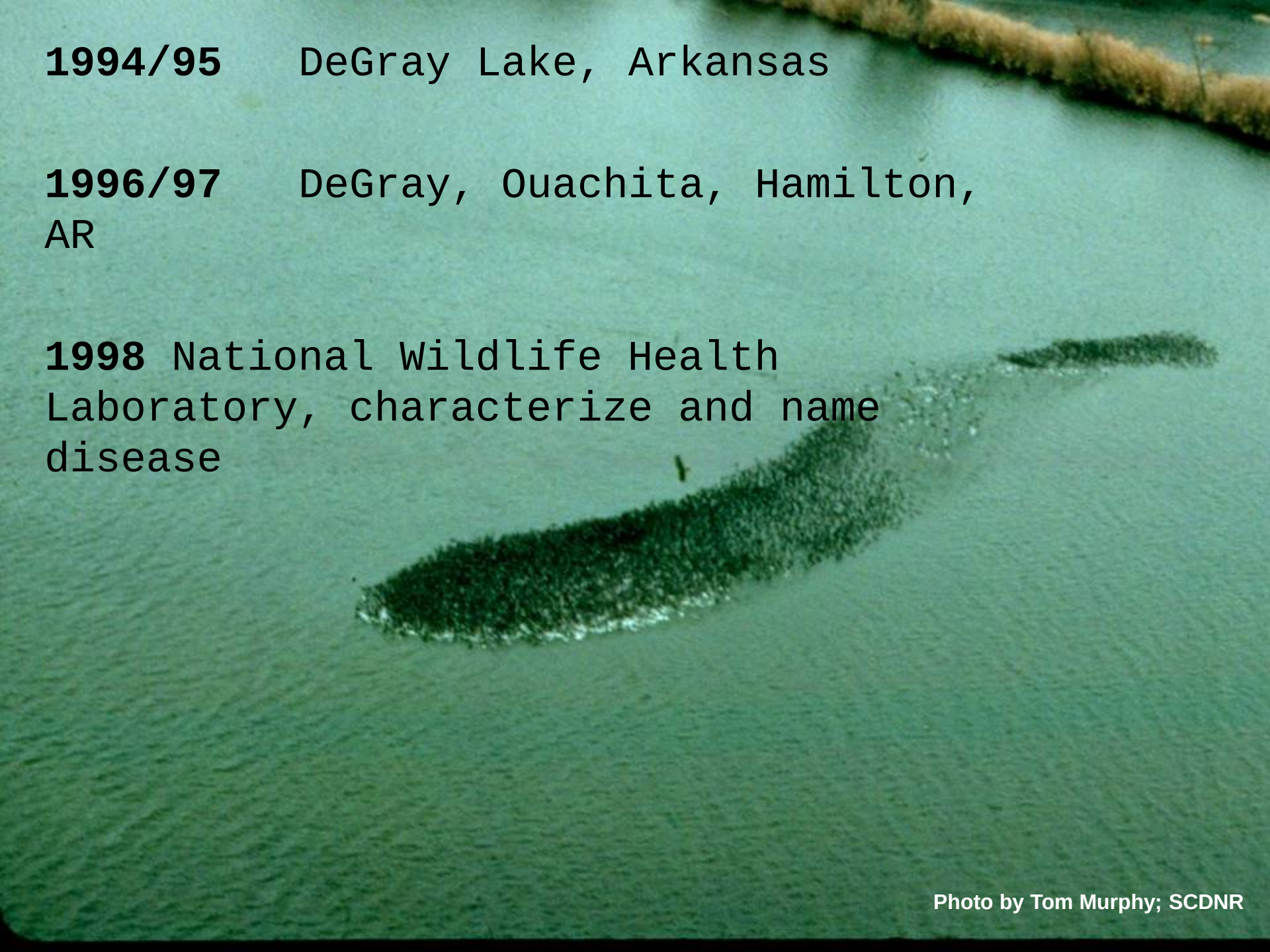
- History
- Role of aquatic vegetation
- Current research projects
- Toxin identification

AVM is a neurologic disease that affects waterbirds and their avian predators.



1994/95 DeGray Lake, Arkansas

1996/97 DeGray, Ouachita, Hamilton, AR

1998 National Wildlife Health Laboratory, characterize and name disease

Photo by Tom Murphy; SCDNR

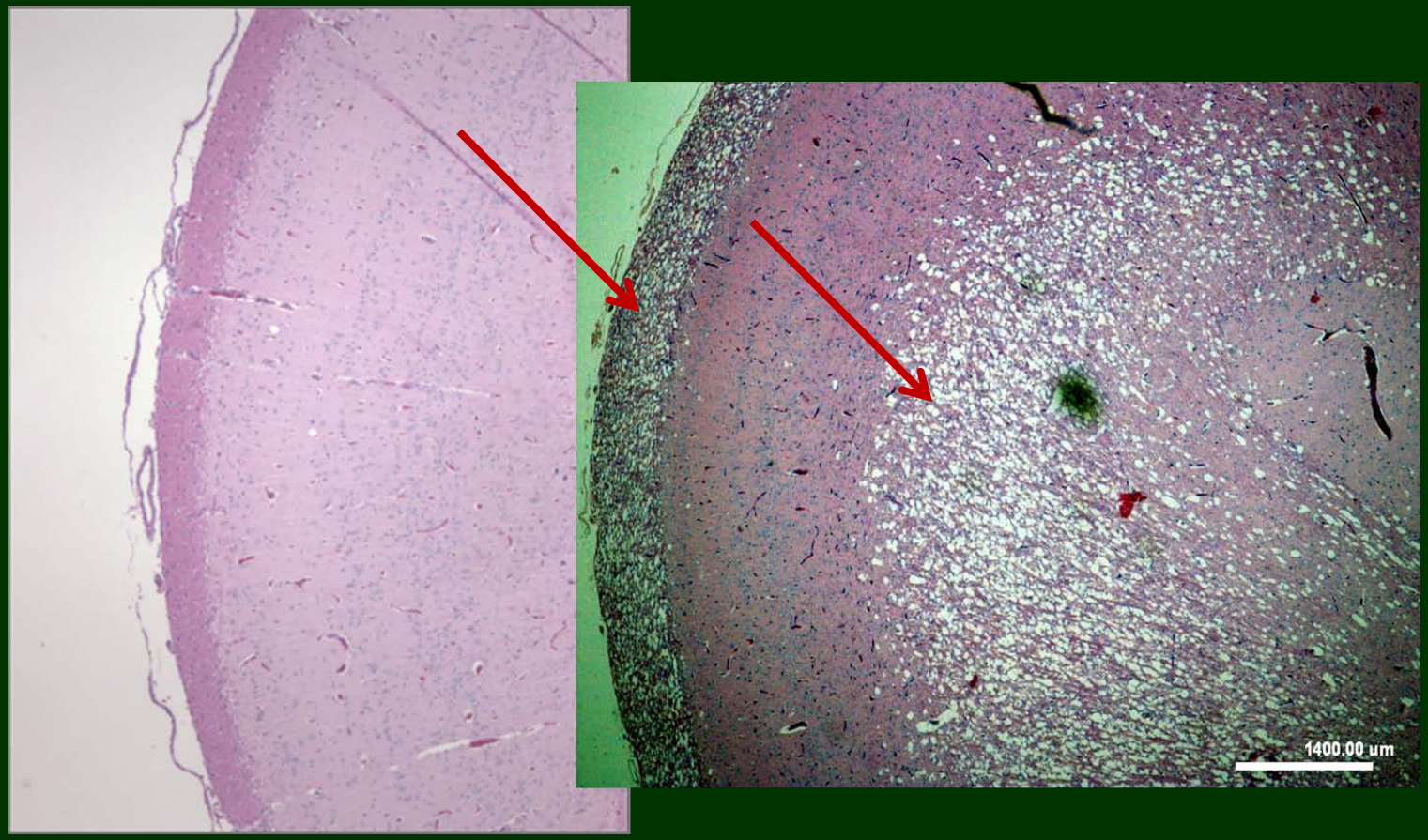

AVM confirmed in birds from reservoirs across the South
IL
IN
KY
VA
AR
TN
NC
SC
TX
MS
AL
GA
LA
FL
Coachman's Trail
Woodlake
Lake Ouachita
Lake Hamilton
Lake Greeson
DeGray Lake
Lake Murray
Lake Varner
Lake Thurmond
Emerald Lake
Lake Horton
Davis Pond
Smith Reservoir
L Lake
Par Pond
Lake Juliette
Sam Rayburn Reservoir
Miles
0
125
250
500
N

Body Count: Mallards, Ring-necked ducks, Buffleheads, American wigeon, Canada geese, Great Horned owls, and Killdeer

Clinical symptoms

- Staggering gait
- Ascending paralysis
- Loss of righting reflex
- General incoordination

Pathology



Only consistent finding: unique lesion in white matter CNS, intramyelinic edema (Thomas et al. 1998)

The culprit?

Anthropogenic compounds that elicit this type of myelinopathy:

hexachorophene, triethyltin, bromethalin (Thomas et al. 1998; Dodder et al. 2003)

Quickly ruled out- could the source of the toxin be environmental?

Field, Laboratory Investigations

- Disease is site-specific, seasonal (late fall-winter)
- Rapid onset (<5 days)
- Transmission is dietary:
  - Primary intoxication, etiologic agent associated with plant material (Rocke et al. 2002, Fischer et al.
  - Secondary intoxication, agent retained in digestive tract

Rocke et al. 2002, 2005; Augspurger et al, 2003; Lewis-Weis et al 2004; Fischer et al. 2002, 2006

S. Wilde Lab
Reservoir Surveys, Spring 2001

- Water quality: Temperature, DO, pH
- Whole Water: Nutrient chemistry
  Algal identification
- Sediment: Algal identification
- Aquatic Plants, primarily submerged aquatic vegetation (SAV):
  Epiphytic algal identification
  (abundant!)

#1 *Hydrilla verticillata*

ARKANSAS
DeGray Lake
Lake Ouachita

TEXAS
Sam Rayburn Reservoir

SOUTH CAROLINA/GEORGIA
Lake Murray
Davis Pond
J. Strom Thurmond Reservoir
Lake Juliette
Emerald Lake
Lake Horton
Smith Reservoir
Lake Varner

NORTH CAROLINA
Coachmans Trail
Woodlake

Photo: T. Murphy

13/17

#2 Brazilian waterweed (*Egeria densa*)

ARKANSAS
DeGray Lake
Lake Ouachita

GEORGIA
Lake Juliette

#3 Eurasian watermilfoil (*Myriophyllum spicatum*)

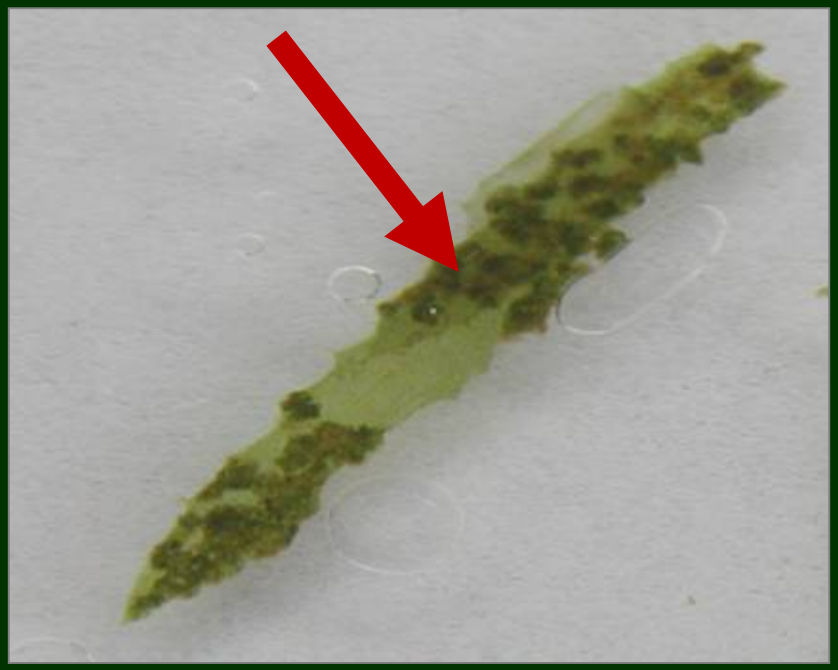
ARKANSAS
Lake Hamilton

SOUTH CAROLINA
Savannah River Site (SRS):
L Lake, Par Pond

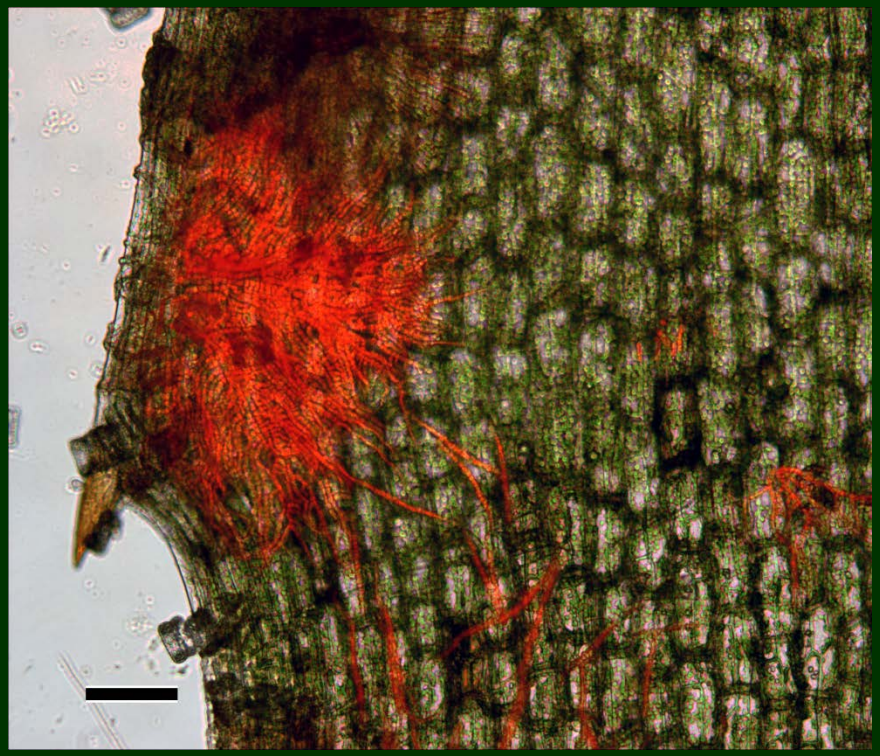
GEORGIA
Lake Juliette

Nonindigenous, invasive SAV dominate AVM sites

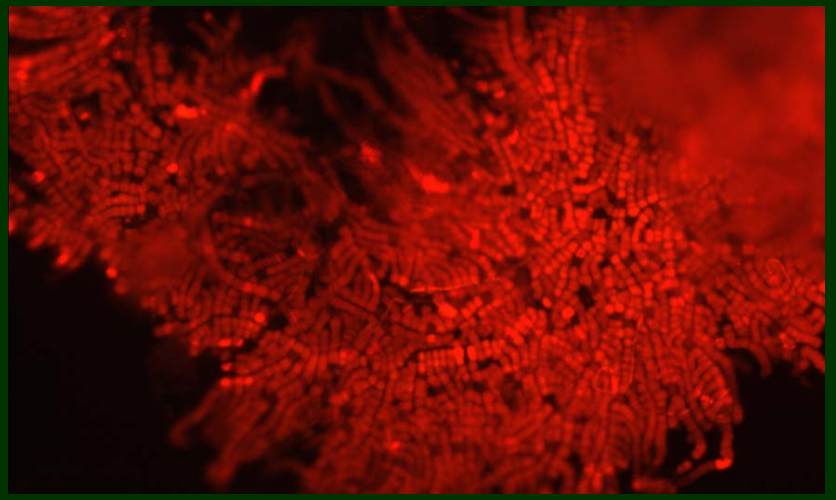
Previously undescribed cyanobacterium, order Stigonematales (“Stig”), ABUNDANT on vegetation (Wilde et al 2005, Williams et al 2007)



- Dominant epiphyte on SAV from affected reservoirs
- Rare or absent on SAV from unaffected reservoirs (Wilde et al 2005)
- PCR analysis confirms morphologic identification (Williams et al 2007)

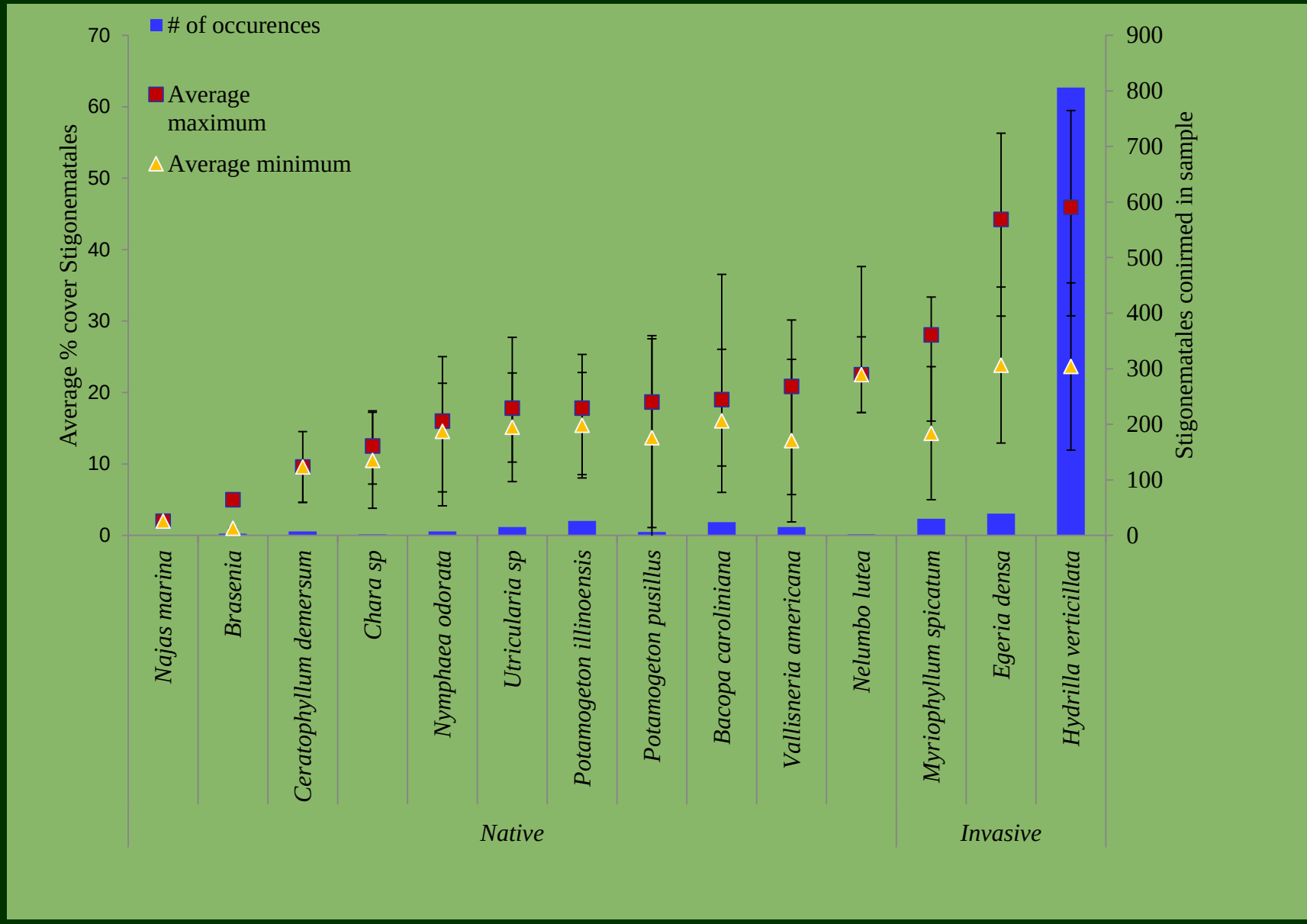


UCB on hydrilla leaflet, 50X



UCB culture 100X
Epifluorescence,
Rhodamine filter

Associated with invasive nonindeginous SAV



Confirmed AVM sites, relative Stig density

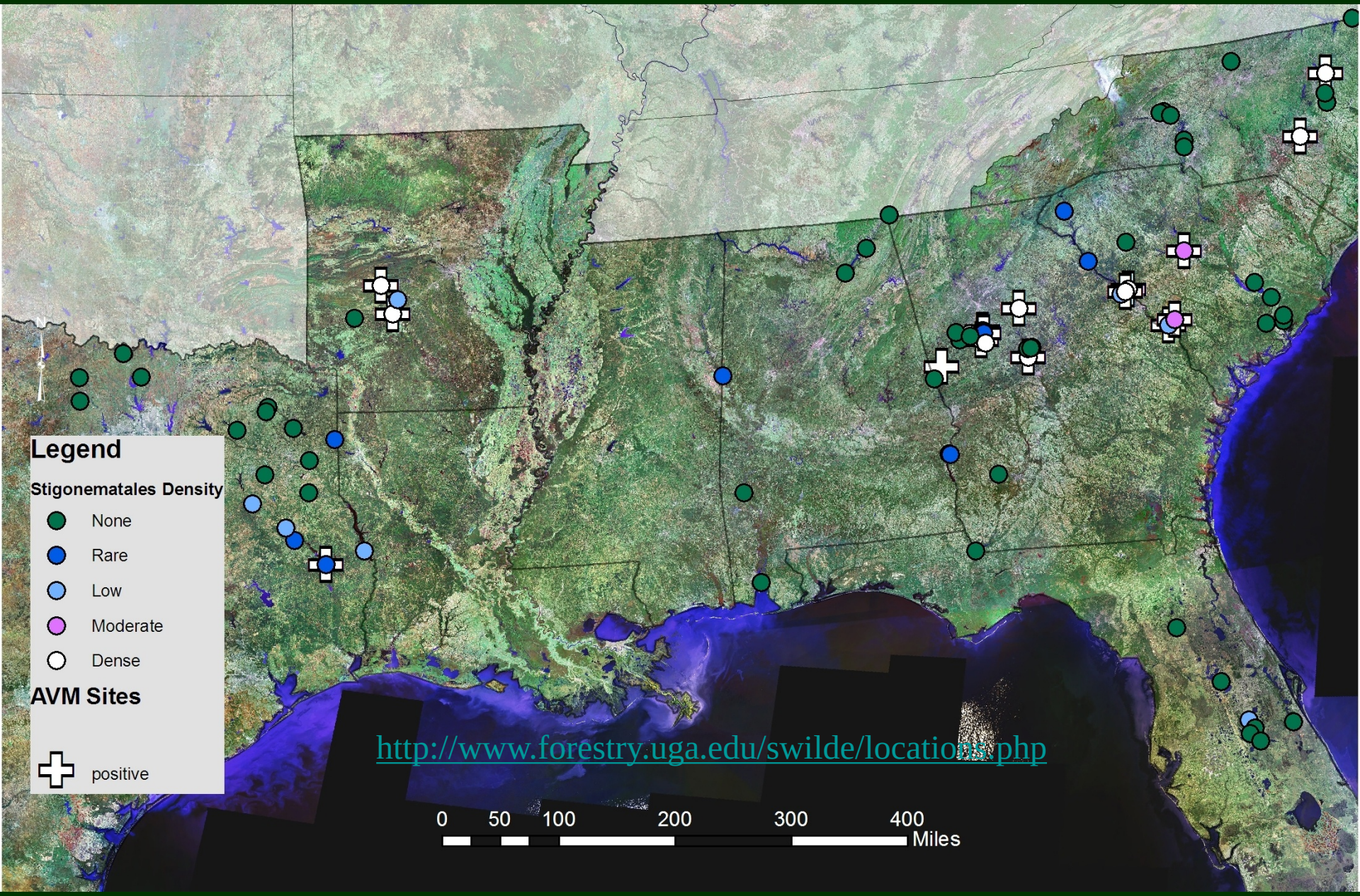



Photo: S Wilde

Stig (toxin-producing cyano) – SAV complex

Toxin consumed by herbivirous waterbirds


Photo: T Murphy

Affected waterbirds consumed by raptors

Birrenkott et al 2004; Wilde et al 2005; Wiley et al 2007; Haynie 2008

Toxin isolation, identification

- Methanol extract, derived from Stig-SAV complex, caused AVM in mallards
- Toxin is a stable, polar compound

(Wiley et al. 2008)

Current research, Wilde Lab UGA

- Environmental parameters conducive to Stig growth

- Invertebrate bioassay development

(M. Hook, MS University of South Carolina, J. Herrin, MS student)

Current research, Wilde Lab UGA

- Environmental parameters conducive to Stig growth
- Bioassay development (B. Harem, MS student)
- Cell-line assay refinement (Dr. F. Wiley, Augusta State University)

Current research, Wilde Lab UGA

- Alternative toxin transfer pathway (S. Robertson, MS Student)
  - Invertebrate vector: invasive island apple snail (*Pomacea insularum*)
  - Threats to endangered raptors- Snail kite (*Rhostrhamus socialibilis*)
- Distribution, impacts in GA, Maxent model predict potential range

Current research, Wilde Lab UGA

USFWS Avian Health Initiative:

- Evaluate management of invasive SAV as to mitigate impacts of AVM
- Evaluate paired “AVM” reservoirs with and without SAV management (grass carp)

Current research, Wilde Lab UGA

Idiopathic neurodegenerative diseases: genetic predisposition, environmental trigger?

o Brian Popko

Director, University of Chicago Center for Peripheral Neuropathy

Mammalian suceptibility

o R. Bidigare, S. Christensen

University of Hawaii, Center for Marine Microbial Ecology and Diversity, University of Hawaii, Honolulu, Hawaii

Investigate involvement of known human neurotoxin

Excitotoxins

- Kainate
- Domoic acid
- BMAA (β-n-methylamino-L-alanine)

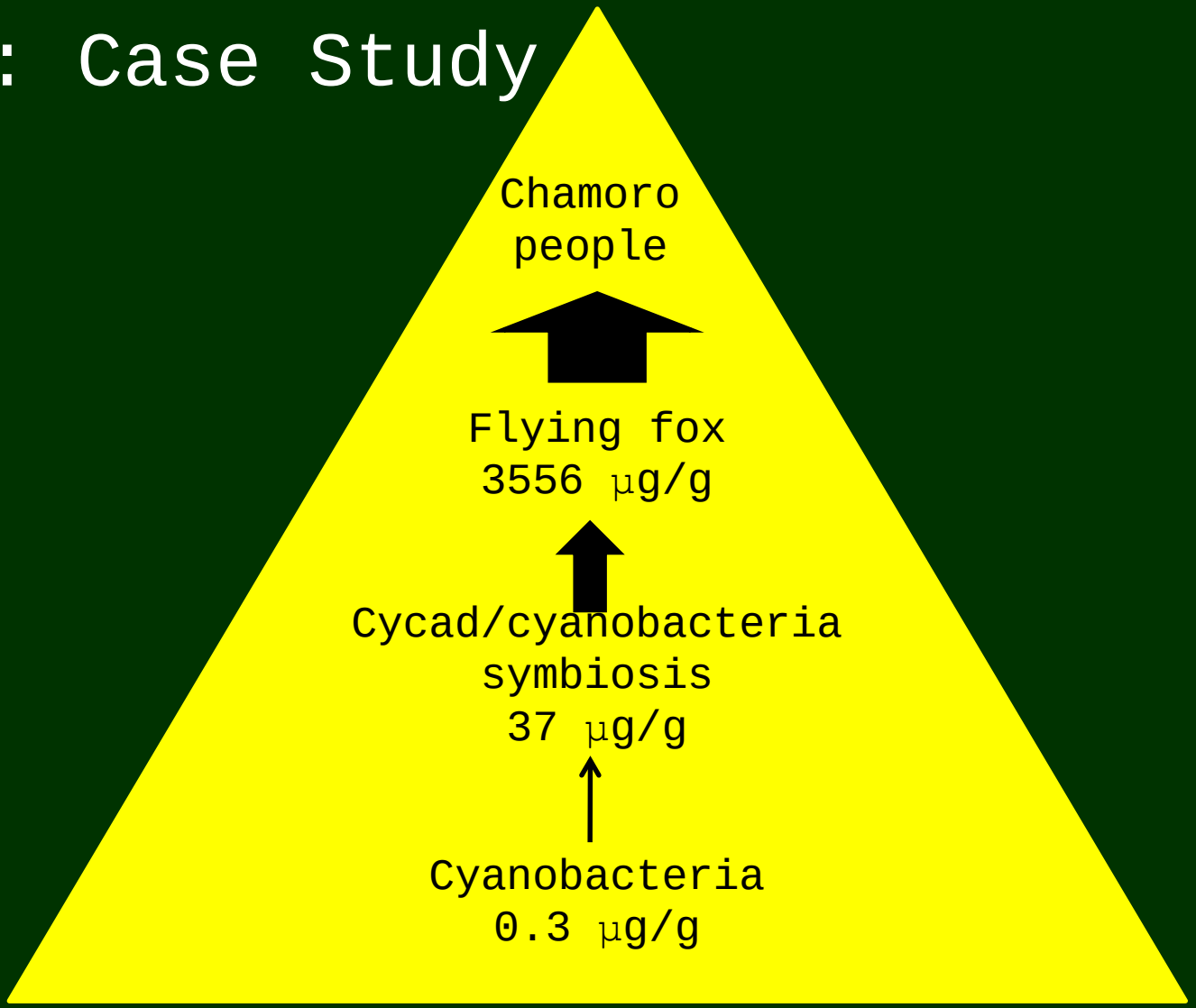
- Source: Marine and freshwater alga
- Mode of action: Glutamate agonists
- Ultimate toxicity: neurodegeneration

BMAA: Case Study

- 1950’s- Chamorro people of Guam

Amyotrophic Lateral Sclerosis/Parkinson–Dementia complex (ALS-PDC) 50-100 times any other known population

BMAA: Case Study



BMAA accumulates in ascending levels of the Guam ecosystem(Cox et al. 2003).

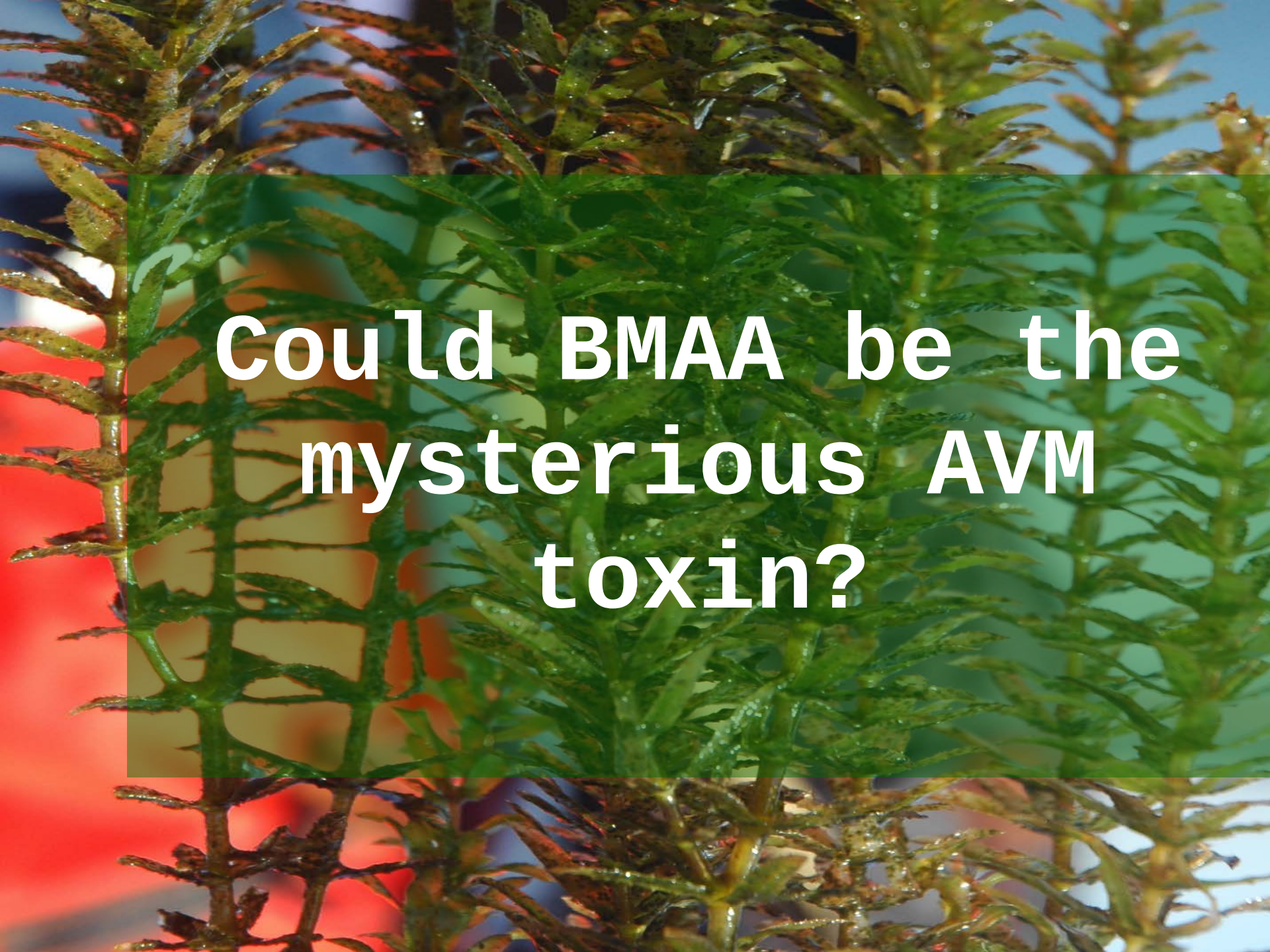
BMAA: Case Study

Free BMAA found in brains of Canadian Alzheimer's patients (Cox et al. 2003; Murch et al. 2004)

Cyanobacterial strains that produce BMAA represent all 5 morphological sections

(Cox P. A., et.al. 2005)

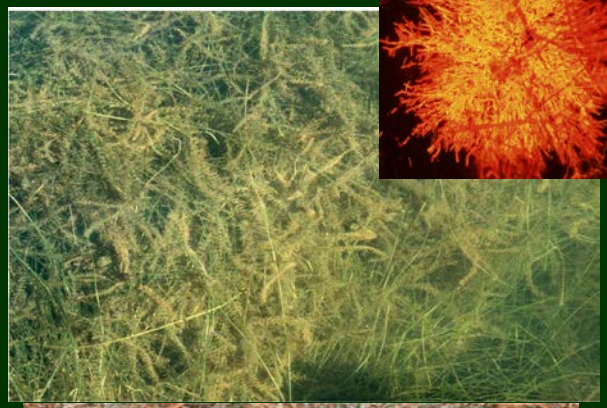
Is the biomagnification of this cyanotoxin unique to the Guam case study or can it occur elsewhere?


Could BMAA be the mysterious AVM toxin?

Toxin Similarities

(Murch et al. 2004)

Origin:
Cyanobacteria-
vegetation
complex



Secondary
predator

Tertiary
predator

Similar clinical symptoms?

In birds: ***Yes***

Ascending paralysis, head retraction, staggering gait, loss of righting reflex

Whiting 1988c, Vega et al. 1968

Similar clinical symptoms?

In mammals: Unknown

AVM: none observed

BMAA: Dragging, unsteady gait, weakness and convulsions, ataxia, inability to stand- in mice and rats (Smith and Meldrum 1990; Polsky et al. 1972)

Similar pathology?

In birds: Unknown

In mammals: ***Yes***

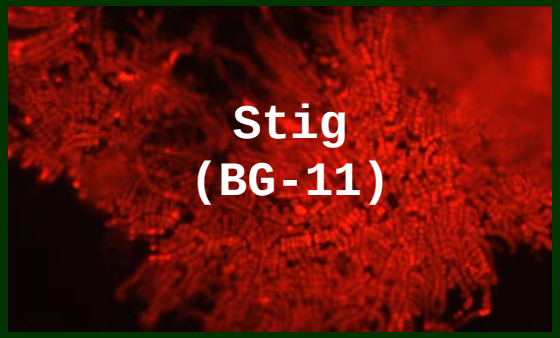
BMAA: Damage to hippocampal neurons in young mice (Buenz and Howe 2007)

AVM: suspected damage to hippocampal neurons in young rats (Wiley et al. 2008)

Could BMAA be the mysterious AVM toxin?

- Screen laboratory culture, field collected cyano-SAV and birds for presence of BMAA

Methods: BMAA detection



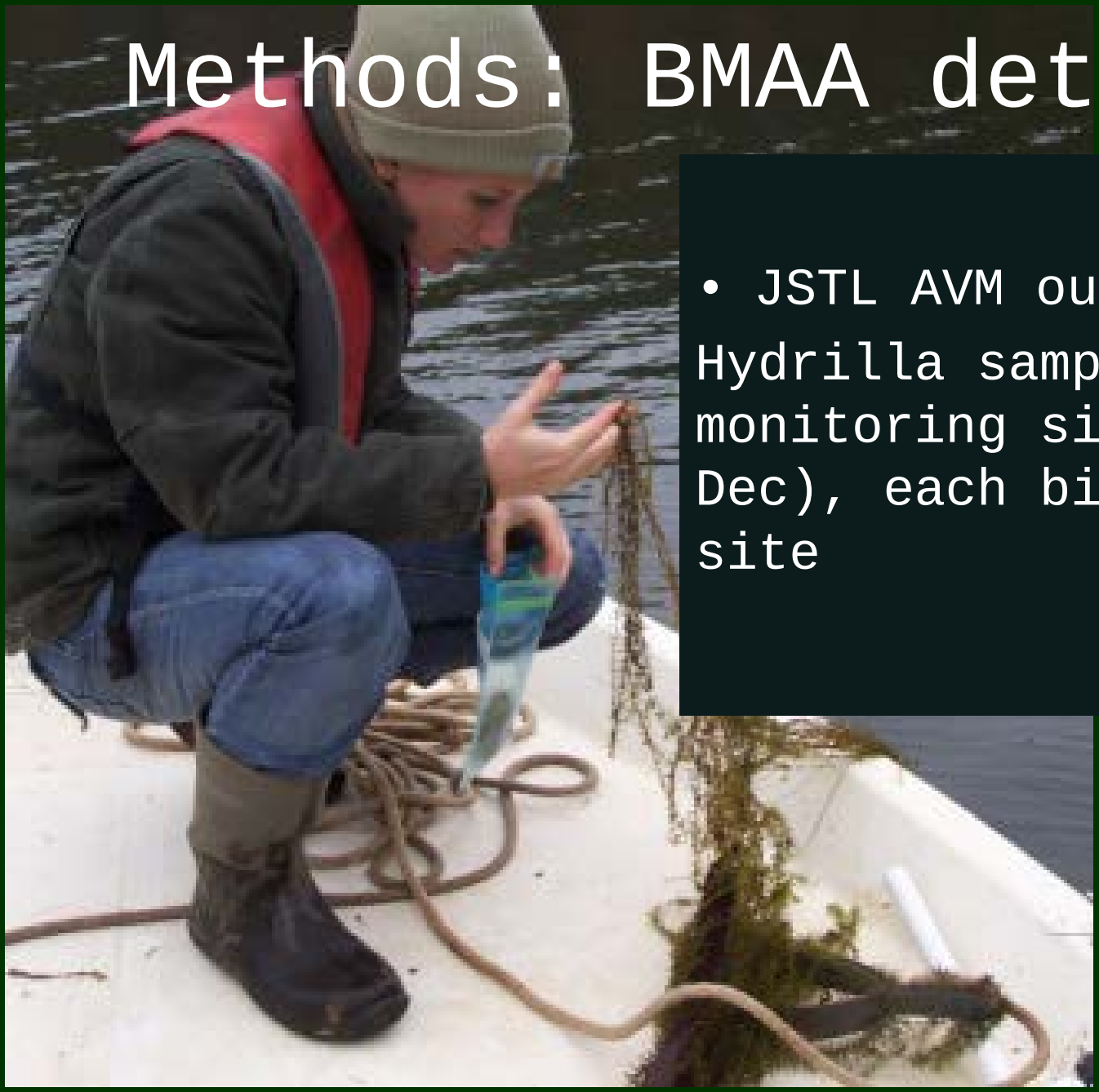
Methods: BMAA detection

November 2010:

AVM outbreak at J. Strom Thurmond Lake (JSTL; 33°40'3.20"N, 82°12'38.79"W)

Collect coots (n=18) with clinical symptoms

Methods: BMAA detection



- JSTL AVM outbreak:

Hydrilla sample from monitoring sites (Sept-Dec), each bird collection site

Methods: BMAA detection

- Tissues prepared for BMAA analysis:

Muscle, liver, kidney, brain, crop/GI tract

- Subset (n=7) brains reserved for AVM analysis

Methods: BMAA detection

- Analyzed using high performance liquid chromatography/fluorescence detection (HPLC/FD)
- BMAA identification confirmed by liquid chromatography/

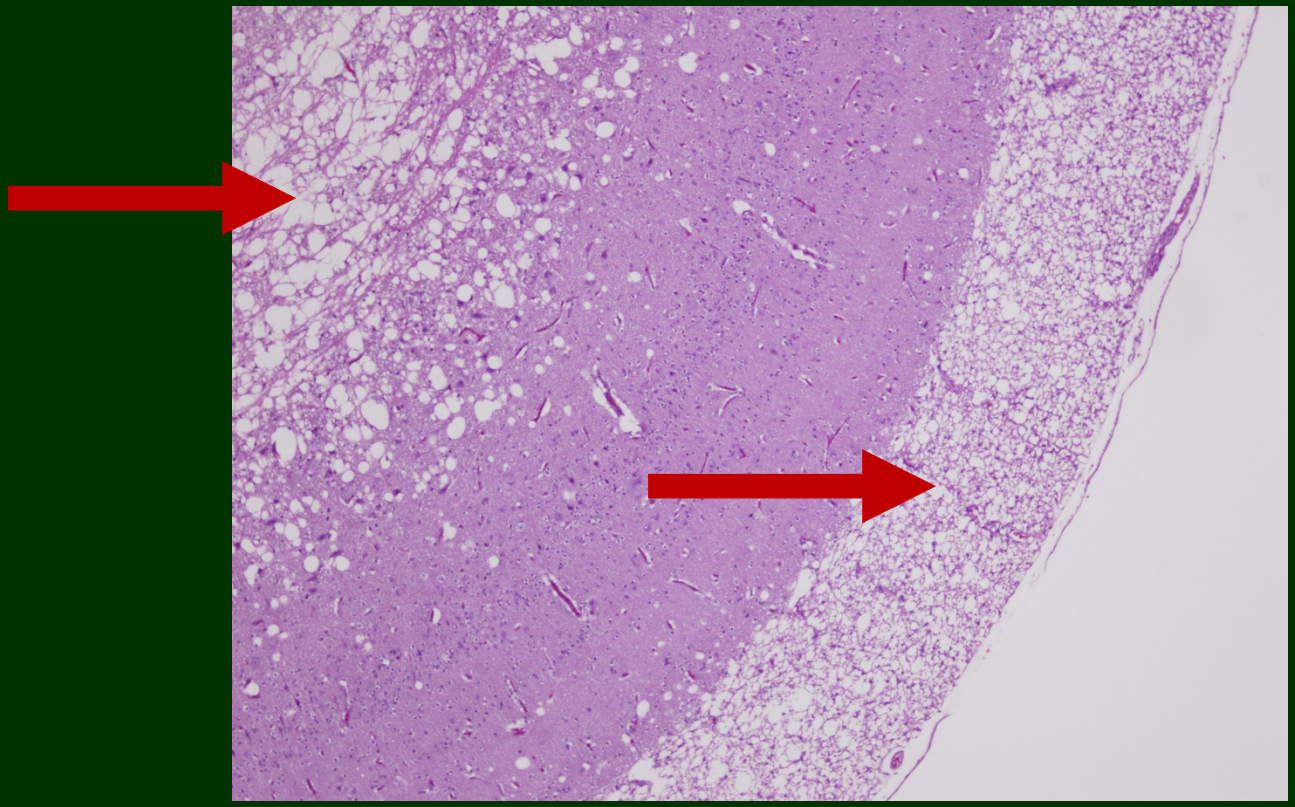
  mass spectrometry (LC/MS)
- Center for Marine Microbial Ecology and Diversity, University of Hawaii, Honolulu, Hawaii

Results: BMAA detection

(Bidigare RR, Christensen SJ, Wilde SB and Banack SA. 2009)

Results: AVM confirmation

- AVM confirmed in all (7/7) coots



Results: BMAA detection

- BMAA below detection limit in all coot tissue samples (n=79)
- Hydrilla-Stig samples:
  - *Results pending*

Discussion

- BMAA *may not* be the AVM toxin
- Anecdotal evidence: adaptation to BMAA-tainted food source, ability to metabolize and/or depurate toxin?
- Strengthen conclusions: BMAA detection results in hydrilla samples collected with coots

Discussion

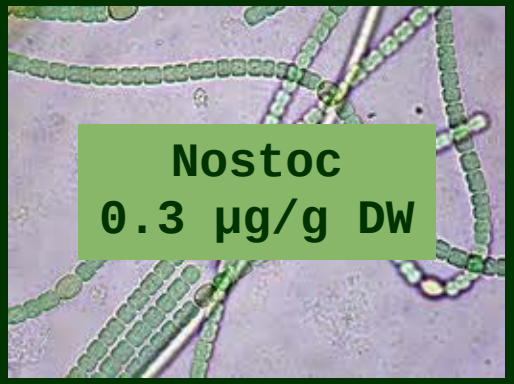
Species/strain	Habitat	Origin	Free BMAA (µg/g)
Microcystis PCC 7806*	Freshwater	The Netherlands	4
Lyngbya majuscule*	Marine	Zanzibar	32
Anabaena variabilis*	Freshwater	USA	35
Chlorogloeopsis PCC 6912*	Soil	India	758
Stigonematales	Freshwater	USA	30

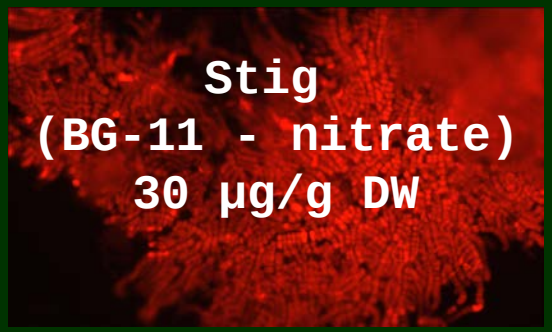
**Cox et al. 2005*

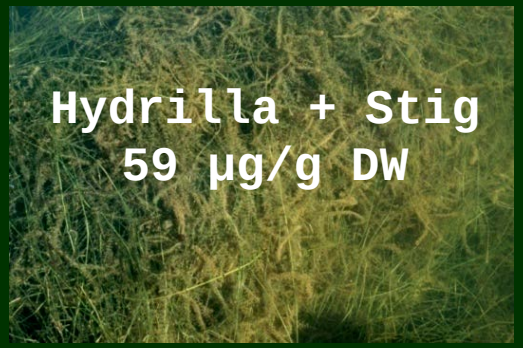
Human health concern: 7000 µg/g
Damage to (mammalian) neurons: 10-30 nMol

Discussion

Plant-cyano symbiosis = increase BMAA







Discussion

- BMAA: Clinical symptoms in mammals- was this an “environmentally relevant” dose?
- Ability to incorporate BMAA into proteins = “slow toxin”
- 30+ years in Chamorro people

Implications

Wildlife- dire

Human health?- unclear

Photo : Jim Ozier, GADNR

Conclusions

- Management of invasive aquatic vegetation imperative
- Prevalence, severity cyanoblooms increasing
    - Increased awareness, improved management practices to prevent, reduce cyanoblooms

Works Cited

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Thank you GASRP!
Questions?