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

WAR NELLE SCHOOL OF FORFETRY AND NATURAL RESOURCE

SCHOOL OF FORESTRY AND NATURAL RESOURCES THE UNIVERSITY OF GEORGIA

DeGray Lake, Arkansas 29 bald eagle mortalities

1996/97 DeGray, Ouachita, Hamilton, AR26 eagle mortalities, disease confirmed inAmerican coots

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

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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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

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 (2010) 55, 1694-1704

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

doi:10.1111/j.1365-2427.2010.02404.:

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Publishing Ltd

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Traits, not origin, explain impacts of plants on larval amphibians	
JILLIAN S. COHEN, ^{1,3} JOHN C. MAERZ, ² AND BERND BLOSSEY ¹	
¹ Department of Natural Resources, Cornell University, Fernow Hall, Ihaca, New York 14853 USA ² Warnell School of Forestry and Natural Resources, University of Georgia, Athens, Georgia 30502 USA	
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 wildlift habitat, and they seek to control or eradicate normative 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 phenolos) and biomass, along with a suis of environmental conditions known to affect larval amphibians (hydroperiod, temperature, dissolved oxygen, and pH). Hydroperiod and plant traits, notably soluble phenolis, litter CN 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 cereased, the likelihood	

and pris), Hydropenod and paint trains, nodindy southe pnenoics, inter C.N. ratio, and inter NP ratio, impacted the likelihood that atimists metamorphiosed, the number of animals that metamorphosed, and the length of larval period. As hydroperiod decreased, the likelihood that amphibinas achieved metamorphosis and the percentage of tadpoles that successfully metamorphosed also decreased. Increases in soluble plenoics, litter NP ratio, and litter CNP 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. Interestingly, we found no difference is suggest that to improve habitats for native fuura, managers should focus on assembling a plant community with desirable traits rather than focusing only on plant origin.

Kry words: Anaxyrus americanus; benkic environment; central and western New York, USA; derital food web; ecological impact; broasive species; Lithobates palustris; Lithobates sylvaticus; litter quality; riotichimetry; 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

Manuscript received 15 January 2011; revised 23 May 2011; accepted 15 July 2011; final version received 9 August 2011. Corresponding Editor: T. W. J. Garner. ³ E-mail: jsc74@cornell.edu that removing nonnative species and replacing them with native species will improve cocystem 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 miligate negative impacts.

Plants are a critical basal resource in many food weby, 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 funan by altering the quality of litter inputs (Kennedy and Hobbie 2004, Zedler and Kercher 2004). Larval amplithas 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

218

- 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.

Ecology 2005

19,970-975

Aetokthonos hydrillicola

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

A. hydrillicola

100X

http://dx.doi.org/10.11646/phytotaxa.181.5.1

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

SUSAN B. WILDE^{1*}, JEFFREY R. JOHANSEN^{2,3}, H. DAYTON WILDE⁴, PENG JIANG⁴, BRADLEY A. BARTELME¹ & REBECCA S. HAYNIE⁵

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 * Corresponding author (swilde@uga.edu)

Aetokthonos hydrillicola (the eagle-killer living on Hydrilla)

500 µm

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

Darryl Fears February 18, 2015

http://www.washingtonpost.com/news/ener gy-environment/wp/2015/02/18/the-ender killer-the-name-of-a-new-scary-red-bacterio 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 A

Aetokthonos hydrillicola grows on the underside of the leaves of Hydrilla, an exotic invasive aquatic plant. Coots eat *Hydrilla* and accumulate cyanobacterium neurotoxins in their tissue. 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

hydrilla Hydrilla verticillata (L. f.) Royle

Points

USDA PLANTS Symbol: HYVE3 **Invasive Plant Atlas** Species Information

📧 XLS 🔜 KML 🔜 GPX 🎇 Shapefile

Counties States

GIS List

1407 points

Avian Vacuolar Myelinopathy 2014

Hydrilla & Aetokthonos hydrillicola

AVM confirmed birds

AVM+, Hydrilla & *A. hydrillicola*

 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.

<u>Methods</u>

- 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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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. Maerz¹, Michael J. Yabsley^{1,2}, Angela E. Ellis³, Amanda L. Coleman¹, Leslie M. Shelnutt⁴, John R. Fischer², Susan B. Wilde¹

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Abstract

Vacuolar my opathy (VM) is a neurologic disease primarily found in birds that occurs when 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 insume aquatic vegetation. However, it is unknown whether turtles can develop VM. We conducted a feeding trial to termine whether painted turtles (Chrysemys picto) would develop VM after feeding on Hydhillo (Hydhillo verticiliata), alanized by the UCB (Hydrilla is the most common "host" of UCB). We hypothesized turtles fed Hydrilla cale UCB would exhibit neurologic impairment and vacuolation of nervous tissues, whereas turtles fed Hyo would not. The ability of Hydrilla colonized by the UCB to cause VM (hereafter, "toxicity") was verified by fe stic chickens (Gallus gallus damesticus) or necropsy of field collected American coats (Fulica flections. We randomly assigned ten wild-caught turtles into toxic or non-toxic red the diets for up to 97 days, Between days 82 and 89, all turtles fed toxic Hydnilla dis impairment. Histologic examination of the brain and spinal cord revealed vacuolations rol turtles exhibited neurologic impairment or had detectable brain or spinal cord va th the UCB. The southeastern Unit ed States, where outbreaks of VM occur regularly and whe on, is also a global hotspot of freshwater turtle diversity. Ou e tir Rice fect of the outative UCB toxin on wild turtles in situ are warranted

> M. Elis AE, et al. (2014) Experimental Reeding of Hydrillo verticibato Colonized by Solgonematale Of Neuropy pictus, PLoS ONE 901: e33295. doi:10.1371/journal.pone.0093295 Verterlary Research, Portugal

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> > to evaluate the risk that we UCB poses to other loss carp (Grouplart with the UCB

<u>Methods</u>

- Humanely euthanized and performed a complete necropsy
- Organs in 10% formalin
- $\frac{1}{2}$ brain stored in EM fixative
- Histology on major organs
- Electron microscopy on CNS

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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. Maerz¹, Michael J. Yabsley^{1,2}, Angela E. Ellis³, Amanda L. Coleman¹, Leslie M. Shelnutt⁴, John R. Fischer², Susan B. Wilde¹

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Abstract

Vacuular myelinopathy (MK) is a neurologic disease primarily found in briefs that occurs when widtile ingest submerged anautic vegetation colonized by an uncharacterized toxinoproducing synaphotechrom (herewiter "UCB" of "uncharacterized cyanobacterium"). Turties are among the closest extant relatives of bries and many species directly and/or indirectly consume aquatic vegetation. Indiverse, it is unknown whether turties can develop (MK vecnolated a feeding trial to determine whether painted turties (Chystemys picta) would develop VM after feeding on Ajdolla (Myddila verticilitat). Colonized by the Wood exhibit neurologic impairment and vacuolation of neurosus tissues, wherease turties feel Ajdolla forealized by the UCB would entitle feel (Myddila is neurosus) and avacuolation of neurosus tissues, wherease turties feel Ajdolla forealized by the UCB would entitle result of the CLB is cause. WM hereafter, "taxicity", wai serified by feeding it to domestic chickens (Galus galus domesticus) on neuropsy of field callected American costs /fulica menticanel captured at the site of Ajdolla collections. We result called turties into taxic or neurosus (Hybriel desting) around and include) (Empainteent, Instocoje camanitation of the taxic and spanic and revealed vacuolations in all breakent turties, include) taxies eshibited neurologic impairment on hold detectable brain response cand even advacuolations in all breakent turties. The control turties eshibited neurologic impairment on hold detectable brain response cand developily. We occur singularly and where here the UCB is common, is also a global hotspat of freshwater turties, in the averanted.

> MJ, Elis AE, et al. (2014) Experimental Reeding of Hydrilla verticiliata Colonized by Solgonematale Officiency planti, PLoS ONE Sol; e33295. doi:10.1371/journal.pone.0093295 Veterlaay Resourch, Portugal

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or Conducts School, THN D. B. Warrell school of Foresty and Natural Instances, The National Institutes Army Corps of Engineers (W12942-12-3-0015), and The United States Fish and Wildlife Senice Solution and analysis, decisions to publish, or apreparation of the manuscipt.

interests exist.

aquate plant species (6). Brief may acquire the twisty directly by ingering plants that are colonized with the UCB are directly by forging the behaviorus pery such as invertebrates [8] or other bird forging the base of an plant that are colonized with the UCB (9). Methed birds develop microscopic vancels in the white ther of the entrum hereva ayters. Lesions tend to be most ent in the specie totum but can occur in the oreburns, new years of the ore reported. Ultratructurally, of repeties landle are instagered in the instagered in the specie totum but can occur in the carborns, new years reported. Ultratructurally, of repeties landle are the instagered in these reports are read in in the species of the

> to evaluate the risk that the UCB poses to other use carp (Omphetowith the UCB

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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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. Maerz¹, Michael J. Yabsley^{1,2}, Angela E. Ellis³, Amanda L. Coleman¹, Leslie M. Shelnutt⁴, John R. Fischer², Susan B. Wilde¹

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Abstract

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> MJ, Elis AE, et al. (2014) Experimental Feeding of HypNila verticiliara Colonizer by Sigonematale Ovversys pictol. PloS DNE SNE e93295. doi:10.1371/journal.pone.0099285 Veterinary Resourch, Portugal

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or Conducts School, THA D. B. Warrell school of Foreity and Natural Instrument. The National Institution Army Corps of Engineers (MOVI2024): 22-20013, and The Valuatio States (shi and Wildlife Sensice splection and analysis, decision to publish, or preparation of the manuscript.

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> > to evaluate the risk that the UCB poses to other gas carp (Complert with the UCB

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 inted turtle (*Chrysemys picta*), brain: white matter, appears normal with no evidence of ion. H&E, 100X. Scale bar is 100 µm.

> some variation in distribucerebellar lesions, this did es in the clinical signs. birds with VM

Key Findings

Figure 2. Electron Micrograph of central ner painted turtle fed toxic *Hydrilla* material. El painted turtle (*Chrysemys picta*), brain: Axons degenerate and myelin sheaths are frequently intramyelinic vacuoles (orange stars). In les splitting can be seen to occur at the intraperi

- 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.

<u>Methods</u>

- 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

7 days post hatching

3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35

Day

0

1

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)

East Lake Tohopekaliga Cypress Lake Lake Kissimmee Lake Hatchineha

Lake Istokpoga 7

Lake J. Strom Thurmond

83 Dead Bald Eagles 1998-2015

The CENTER for CONSERVATION BIOLOGY

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

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

HydrillaHigh coot densitiesEagle sightingsEagle nests

Eagle mortalities 4

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

> Source: Estl, DigitalSloke, SeoEye, Earinstar Seographics, CNES/Alibus DS, US swisstopo, and the SIS User Community

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

High density hydrilla CARP/herbicide

Googleearth

High density hydrilla CARP

Low density hydrilla CARP

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. Stron

urmond 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)

Gulf & South Atlantic Regional Panel On Aquatic Invasive Species

