

Monoecious Hydrilla Biology and Implications for Management

Rob Richardson

Professor and Extension Specialist

NC STATE UNIVERSITY

Aquatic Plant Management

NC STATE

EXTENSION



Hydrilla

Hydrilla verticillata



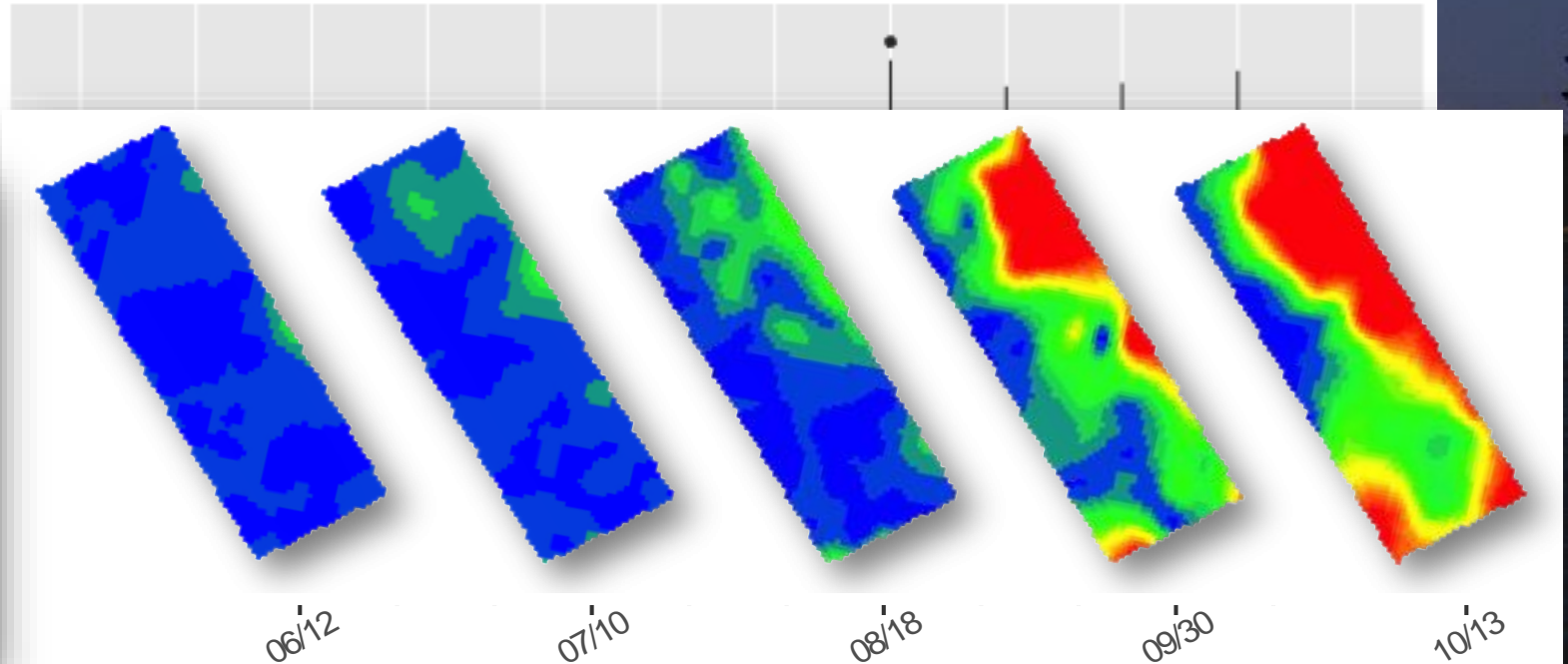
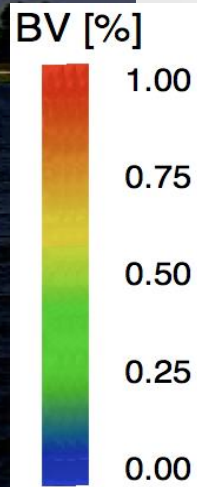
Hydrilla

- Called the “perfect aquatic weed” (Langeland 1996)
- #1 aquatic weed in U.S.
- Leaves in whorls of 3-10+
- Serrated leaf margins
- Tubers can remain in sediment for over 7 years
- Very shade tolerant
- Rapid growth: 262 ft of linear shoot tissue in 35 days (Glomski Netherland, 2012)

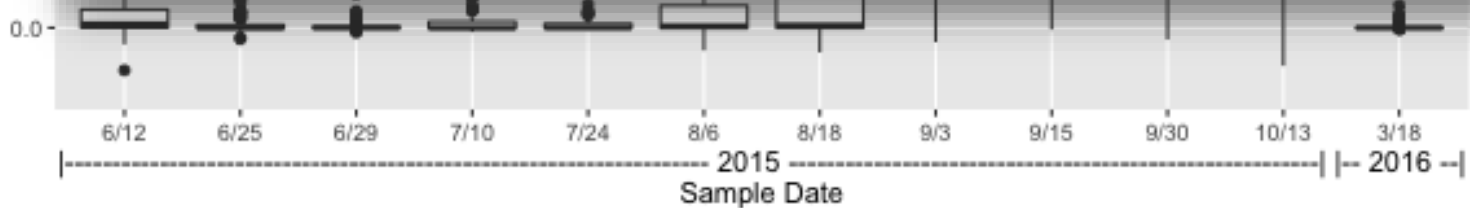


Temporal Development

Shearon Harris Temporal Development -- Plot 1



Sample Date



Hydrilla Biotypes

- US:
 - Female triploid dioecious (FL and warm climates)
 - Triploid monoecious (NC and temperate climates)
 - Worldwide:
 - 9 biotypes in Japan (Nakamura and Kadono 2000)
 - Benoit (2011) theorized cryptic speciation
 1. Indian/Nepal (US dioecious) species*
 2. Japan/Korean/European species
 3. Indonesian/Malaysian species (AU/NZ)*
- *US monoecious perhaps hybrid

Neighbor Joining Analysis

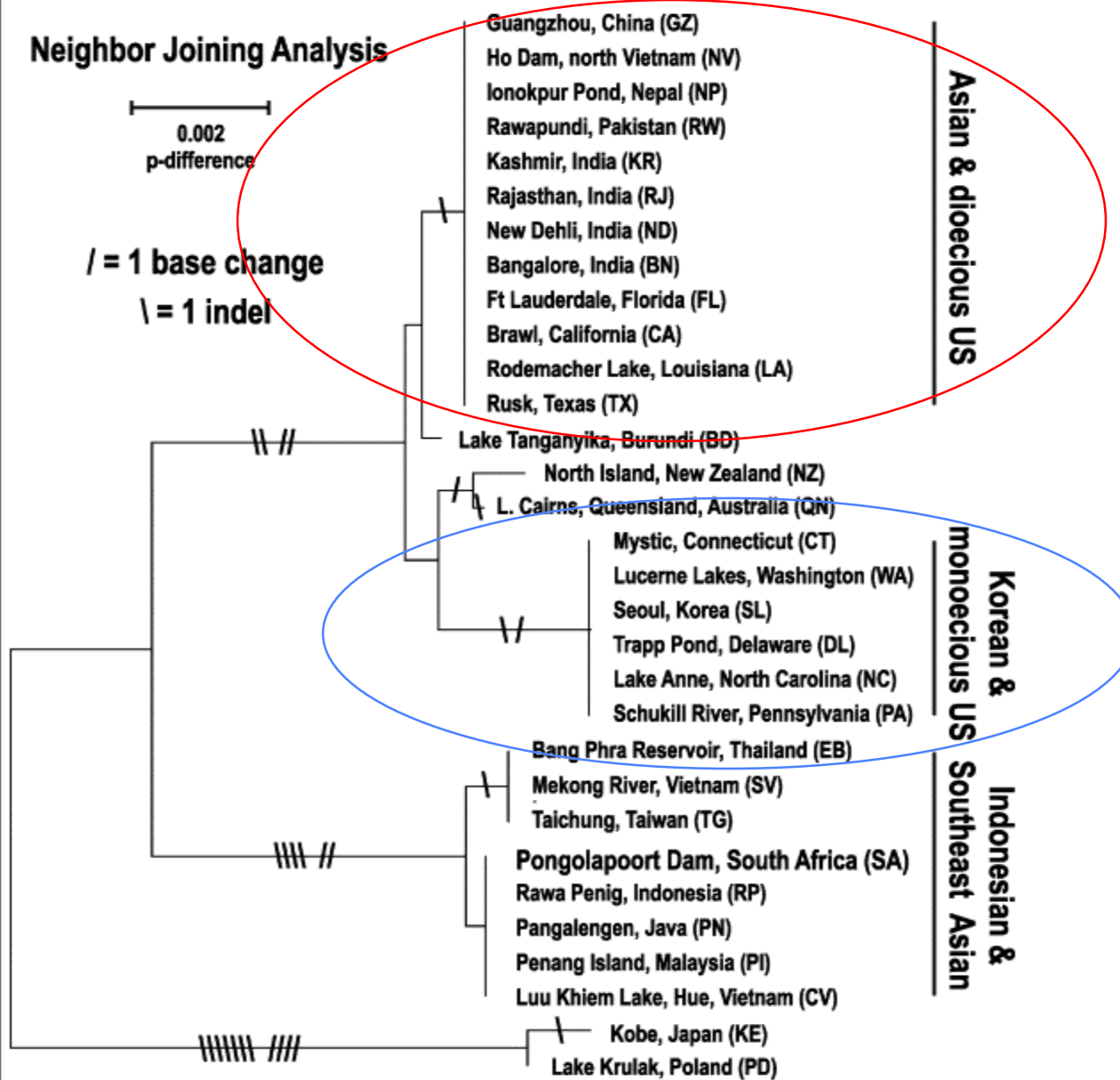


Fig. 1. Neighbor joining analysis of the chloroplast *trnL* intron and *trnL-F* spacer sequences for 34 worldwide samples of *Hydrilla verticillata*. The Pongolapoort dam, South Africa sequence represents four samples. Nine unique sequences were discovered. Identical sequences are presented with a vertical line at the end of a terminal branch. The sequence divergence metric is *p*-difference (transversion, transition, and indel costs are identical). Ten base changes [|] and sixteen indels [—] are presented on the branches where the changes occurred. Three major clusters are identified in the figure.



U.S. dioecious

U.S. monoecious



Seoul

Kashmir

Guangzhou

Other clusters

Bangalore



Biotypes - Summary

- Monoecious
 - Linked to Korea
 - Introduced mid 70's
 - Invading NC & north
 - Less robust
 - Herbaceous perennial
 - May produce seed??
 - Tubers:
 - Formed June – Nov.
 - Weight 76 to 139 mg
 - 430 – 1,700 / m²
- Dioecious
 - Linked to China, India
 - Introduced 1950's
 - Invaded SC & south
 - More robust
 - Root crown persists
 - No seed production
 - Tubers:
 - Formed Oct. – April
 - Weight 188 to 290 mg
 - 60 – 900 / m²

Tuber Weight

Biotype	Tuber weight (mg)	Situation	Citation
Dioecious	63-91	Mesocosm	Sutton et al. (1992)
	160-386	Mesocosm	Spencer et al. (1987)
	42-44	Mesocosm	Van (1989)
	188-290	Field, lake	Miller et al. (1976)
Monoecious	42-53	Mesocosm	Sutton et al. (1992)
	117-202	Mesocosm	Spencer et al. (1987)
	33-34	Mesocosm	Van (1989)
	5-320	Field, lake	NCSU

Tuber Weight

- Why would monoecious tubers be smaller?
 - Less longevity
 - Seed size somewhat correlated to seed longevity
 - Not that much difference in size between biotypes
 - Insufficient documentation to support or refute

Oenothera biennis
Evening primrose
Viable >70 years



Nelumbo nucifera
Sacred lotus
Viable >1,000 years



Tuber Weight

- Why would monoecious tubers be smaller?
 - Less longevity ???
 - Allow for greater quantities
 - Differential initial growth strategies

Tuber Densities

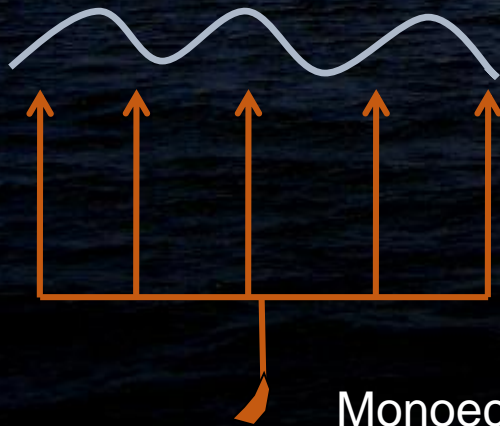
Biotype	Tuber density	Situation	Citation
Dioecious	2,153	Mesocosm, 12 mo.	Steward and Van (1987)
	2,293	Mesocosm, 7 mo.	Steward (1980)
	257	Field, ponds	Haller and Sutton (1975)
	293-605	Field, lake	Miller et al. (1976)
	62-900	Field, ponds	Steward (1980)
Monoecious	2,099-9,053	Mesocosm, 16-28 mo	Steward and Van (1987)
	910-2,985	Mesocosm, 2 mo	Poovey and Kay (1998)
	189-1,312	Field, 3 lakes	Harlan et al. (1985)
	430-1,700	Field, 4 lakes	Nawrocki (2009)

Tuber Weight

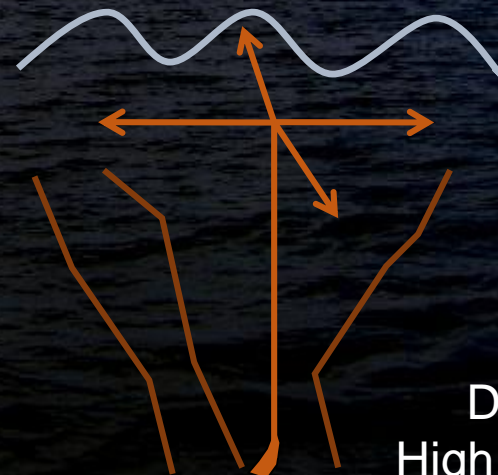
- Why would monoecious tubers be smaller?
 - Less longevity ???
 - Allow for greater quantities ✓
 - Differential initial growth strategies

Tuber Weight

- Why would monoecious tubers be smaller?
 - Less longevity ???
 - Allow for greater quantities ✓
 - Differential initial growth strategies ✓



Monoecious:
Low intraspecific competition at sprouting



Dioecious:
High intraspecific
competition at sprouting



Monoecious Hydrilla History in NC?

Hydrilla specimen

Dec. 9 1980

NCSU
herbarium

Monoecious

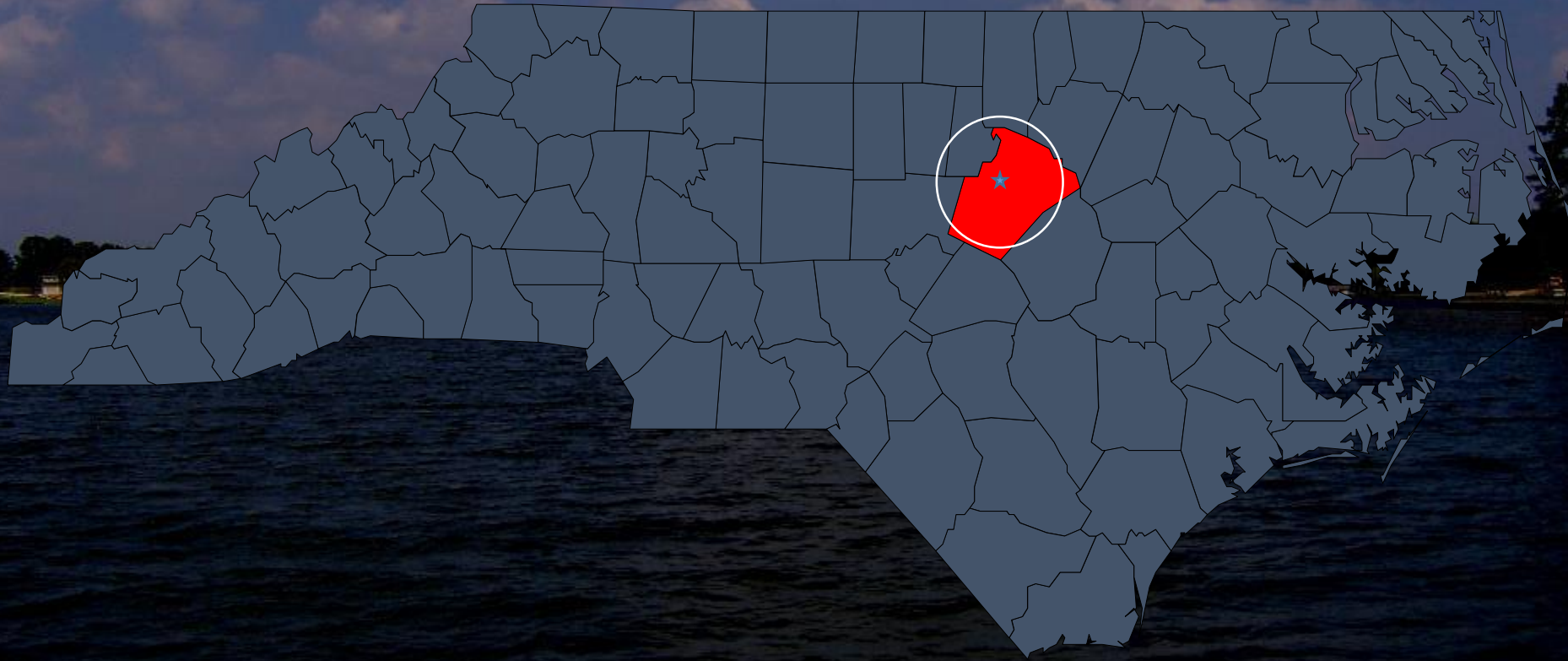


 Danger! This specimen is a Federal Noxious Weed. Safeguard to prevent the dissemination of viable propagules.
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

HERBARIUM
NCSU
98299
NORTH CAROLINA STATE UNIVERSITY

Herbarium of North Carolina State University
PLANTS OF NORTH CAROLINA
County: Wake
HYDRILLA VERTICILLATA (L.f.) Caspary
Pond at Umstead Park
D. J. DeMont Dec. 9, 1980

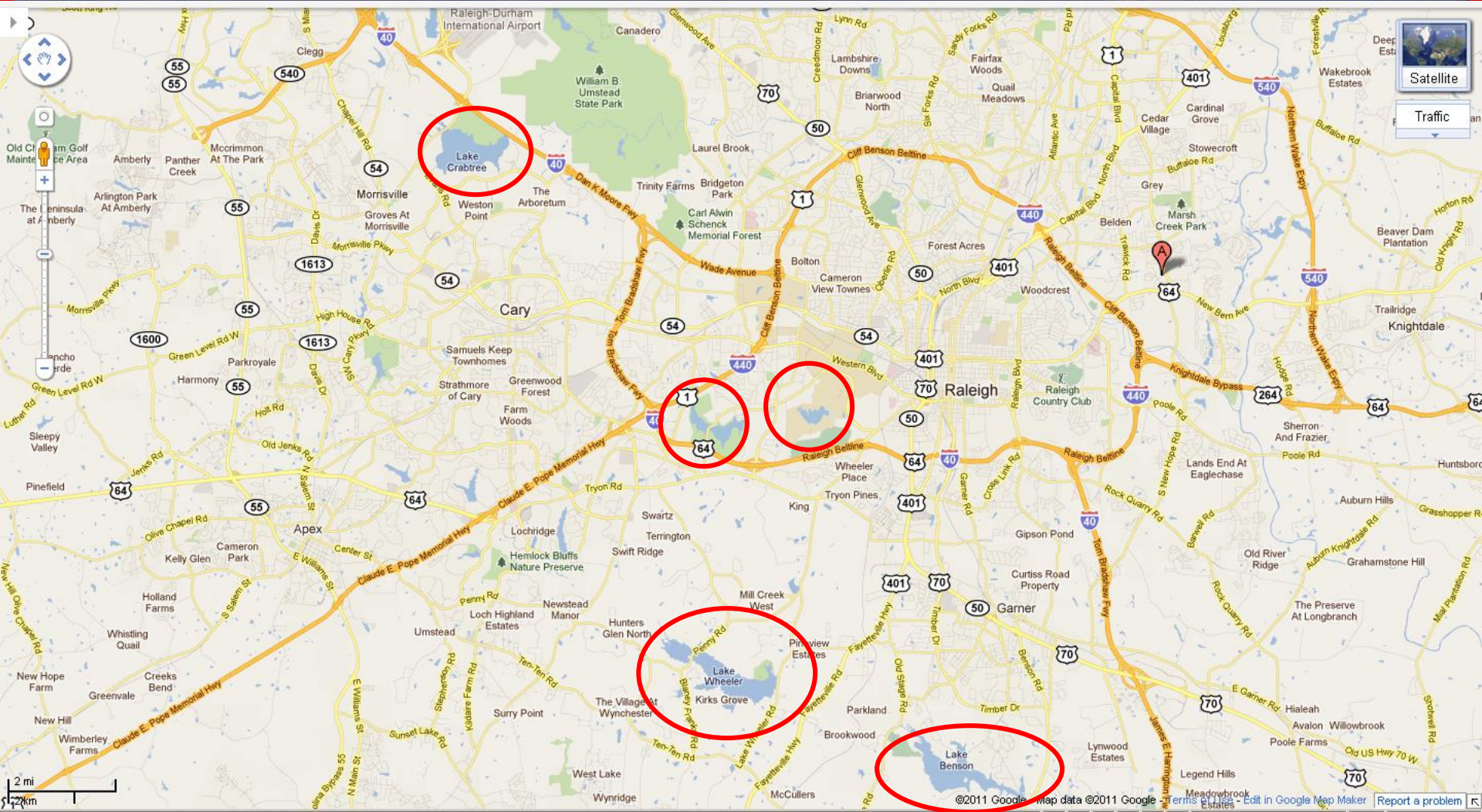
1981



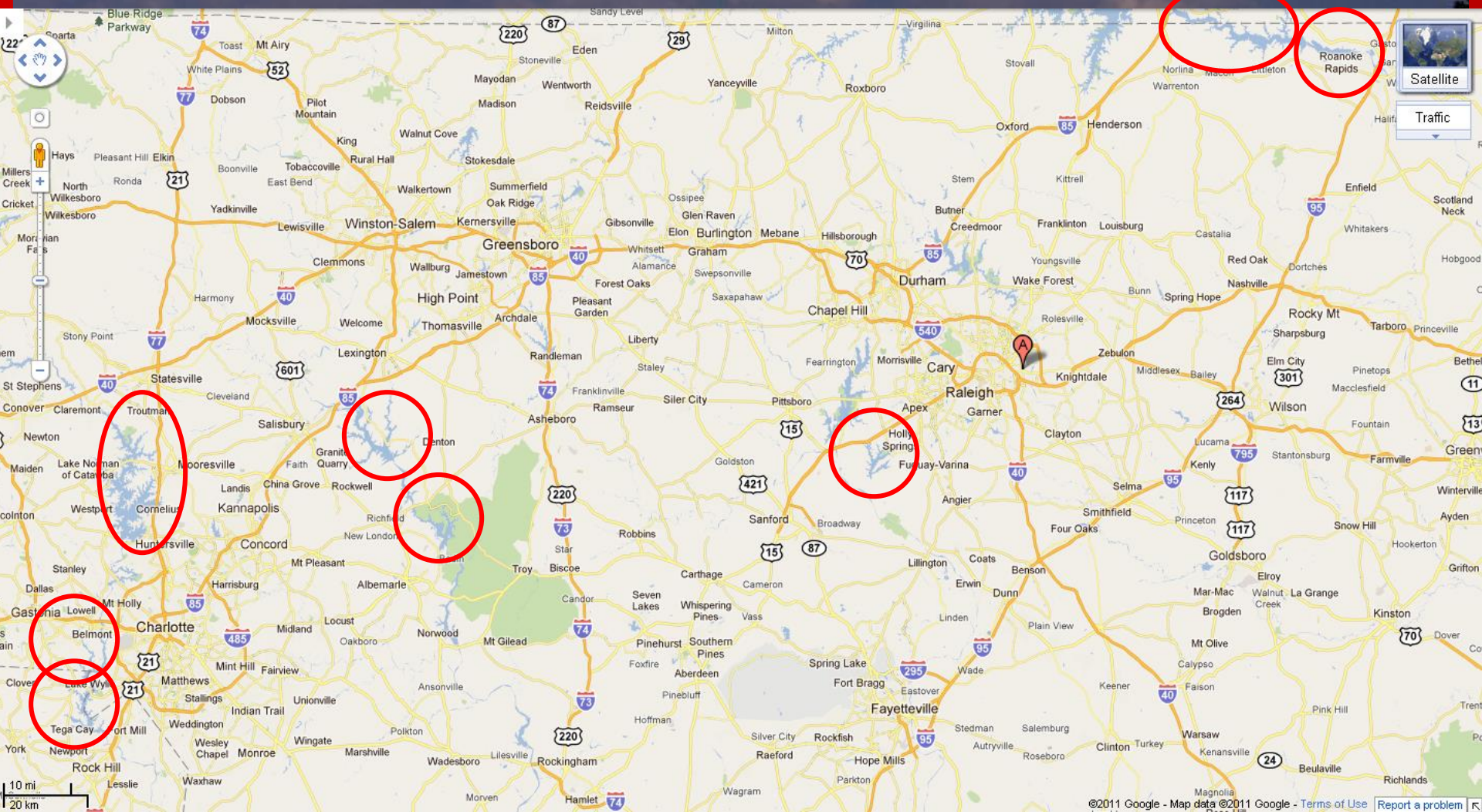
NC STATE

EXTENSION

Stage 1: Ponds and Small Lakes Around Wake Co.



Stage 2: Piedmont Reservoirs



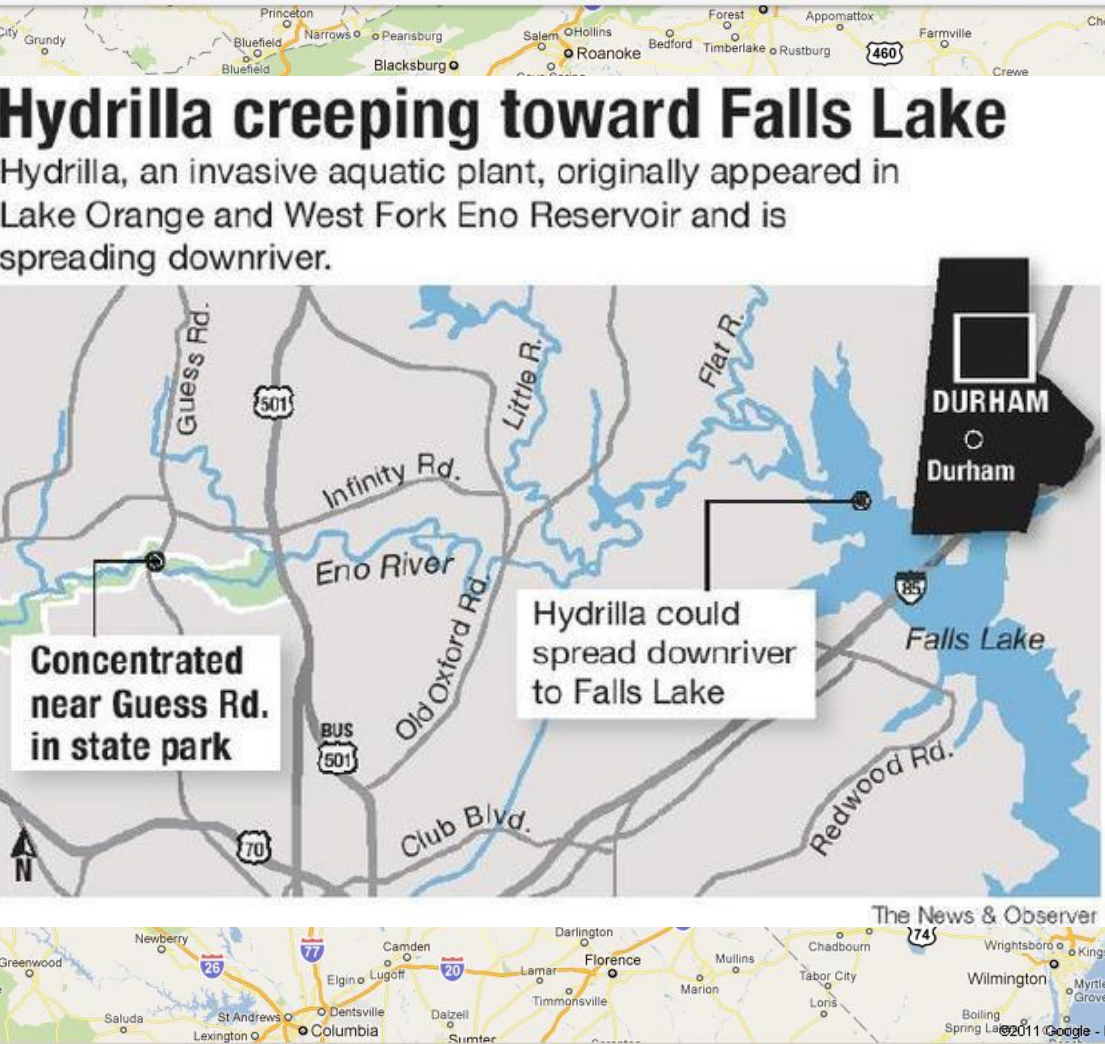
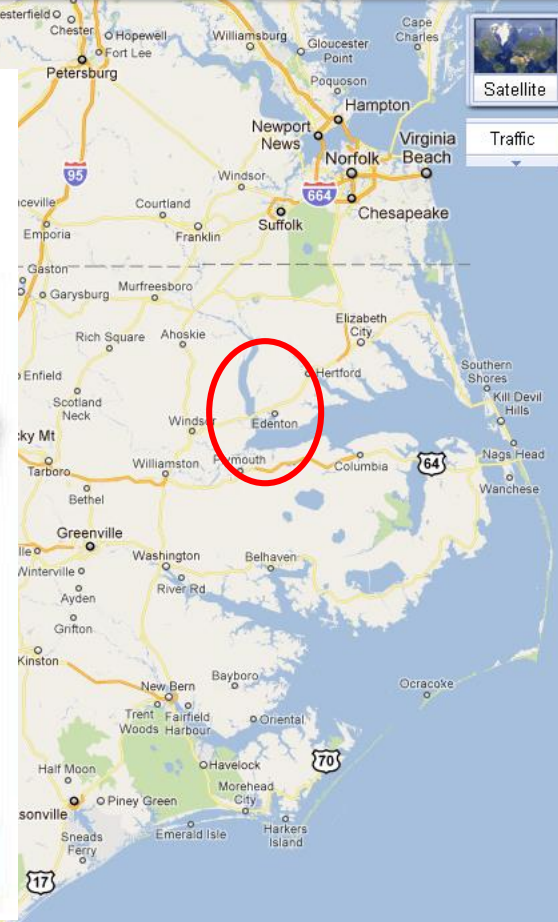
Stage 3: Everything Else?

Hydrilla creeping toward Falls Lake

Hydrilla, an invasive aquatic plant, originally appeared in Lake Orange and West Fork Eno Reservoir and is spreading downriver.

Concentrated near Guess Rd. in state park

Hydrilla could spread downriver to Falls Lake

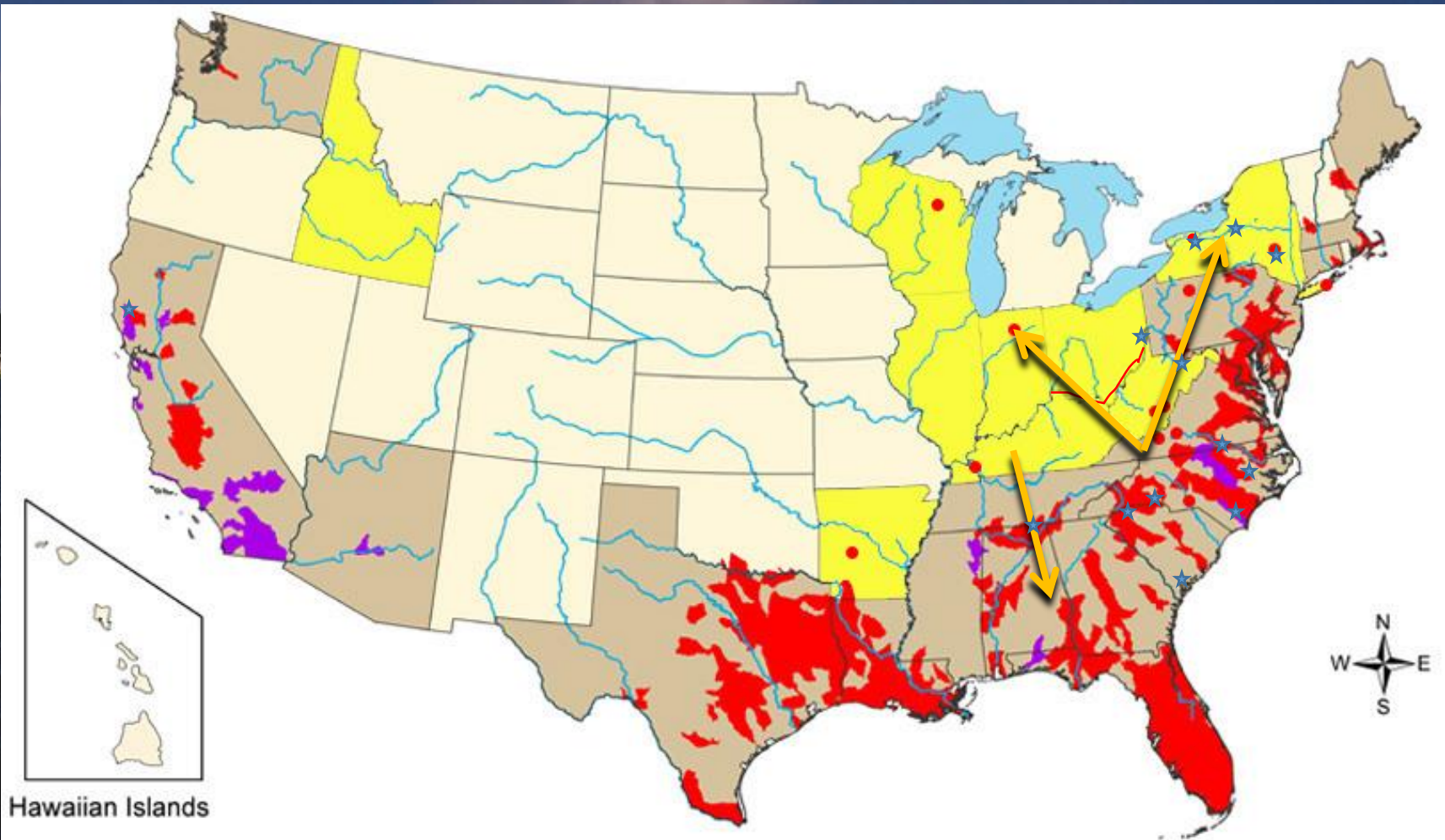


Hydrilla creeping toward Falls Lake

Hydrilla, an invasive aquatic plant, originally appeared in Lake Orange and West Fork Eno Reservoir and is spreading downriver.



Continuing Spread of Hydrilla



Hawaiian Islands

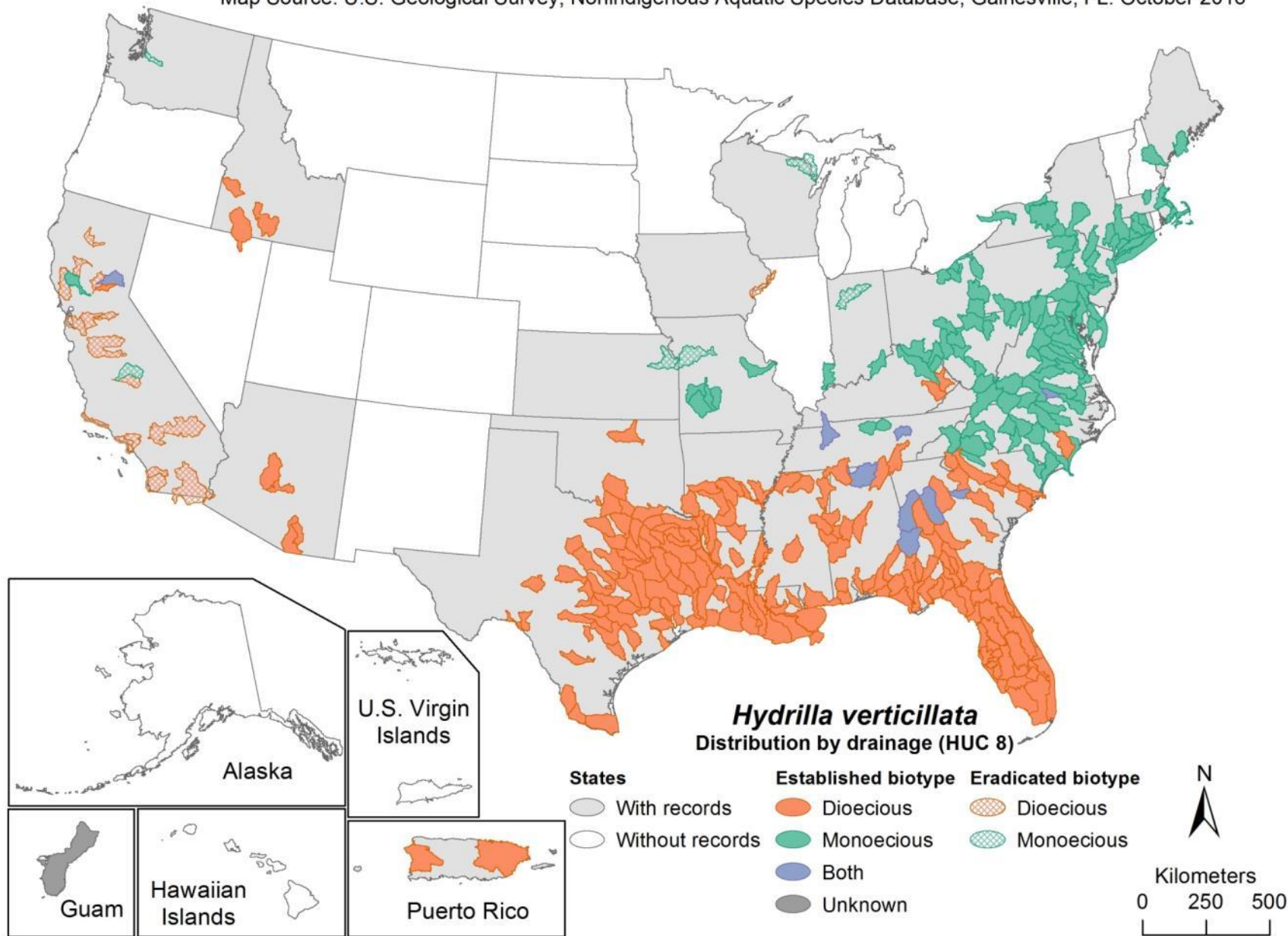
Hydrilla verticillata

- drainages where recorded
- drainages where eradicated



September 2003

ON



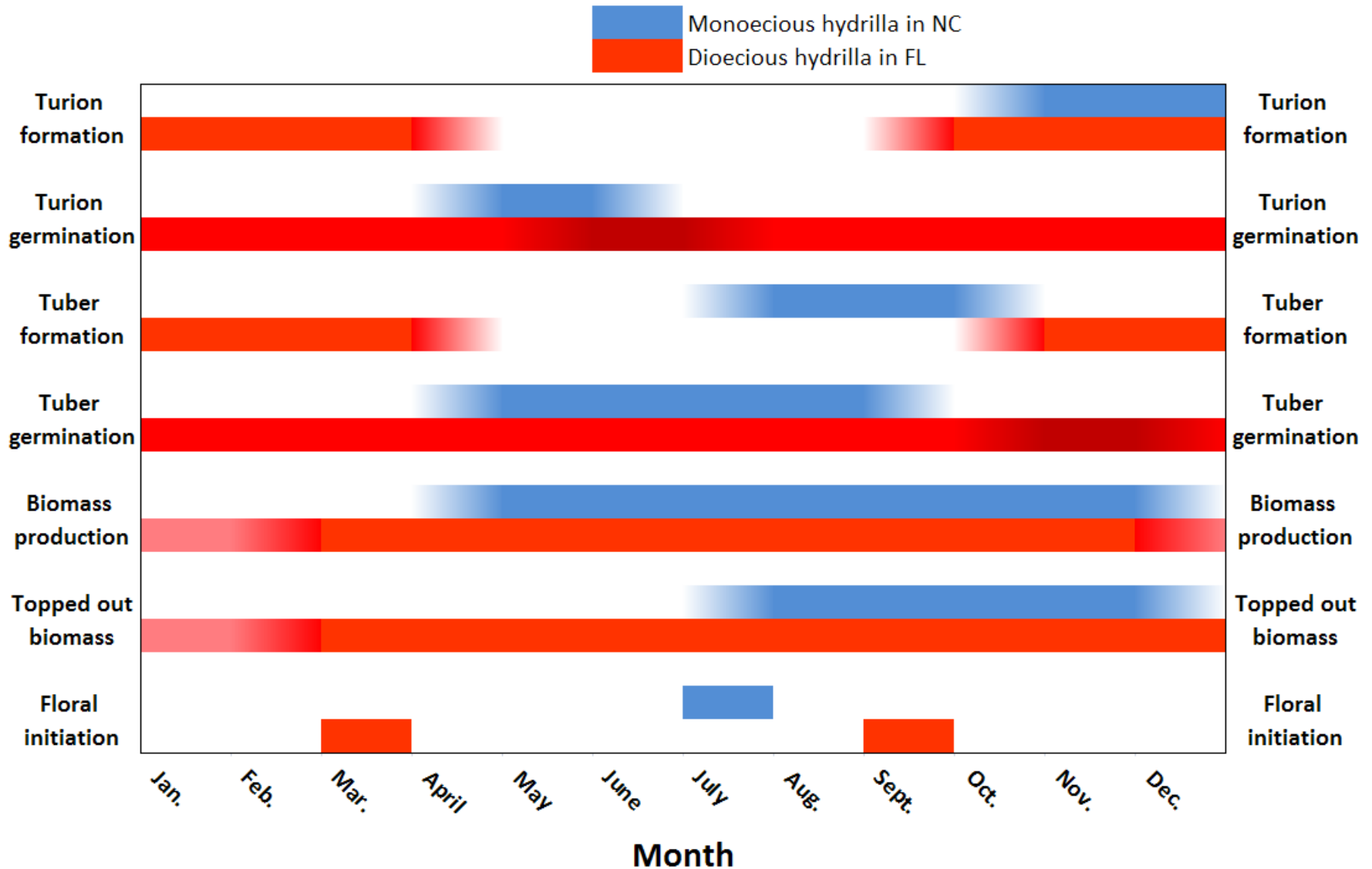
Hydrilla Turions

- Form main challenge to management
- Turion – an overwintering bud structure
- Hydrilla forms both axillary turions and subterranean turions (tubers)
- Tuber longevity estimated to be 5+ years, but turions only ~6-8 months
- Long-term management plans must consider and monitor the tuber bank



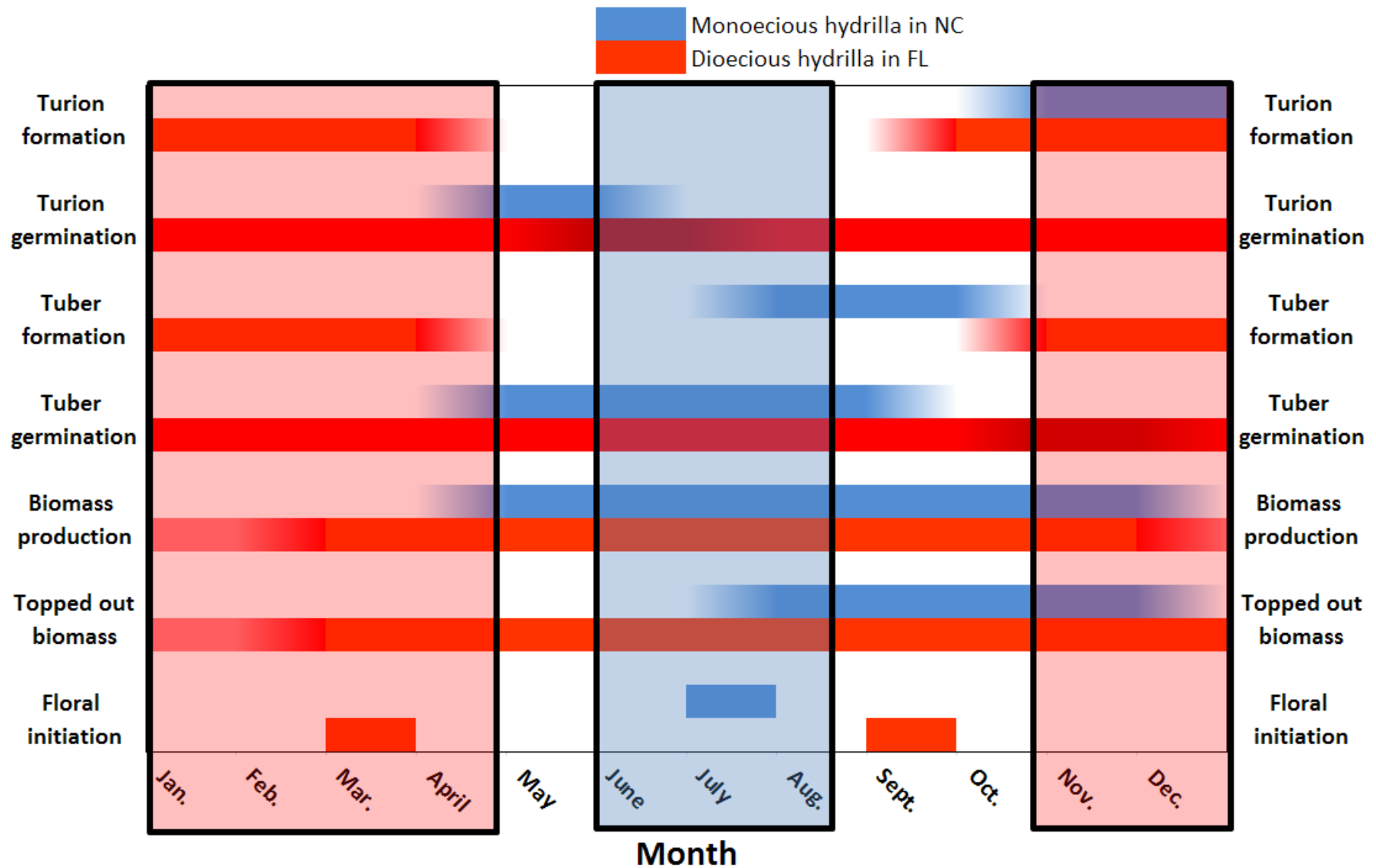
STATE EXTENSION

Biotype Phenology



Modified from Harlan et al. (1985. J. Aquat. Plant Manage. 23:68-71).

Timeframe for Management



Hydrilla Research

Series of Research Questions that
Influence Management Decisions



How Long Do you Have to Manage Monoecious Hydrilla?

Core Sampling Methods

- Soil core sampler, 4” diameter, 6 ft long
- Permanent sampling stations were established based on finding 2 to 3 tubers in first sample
- Tubers and turions were sifted from soil through screens
- The number of samples taken were based on tuber density per Spencer (1993)
 - Varied from 10 to 200 (increased sampling with decreasing tuber #'s)





Tar River Reservoir Tuber Bank Attrition

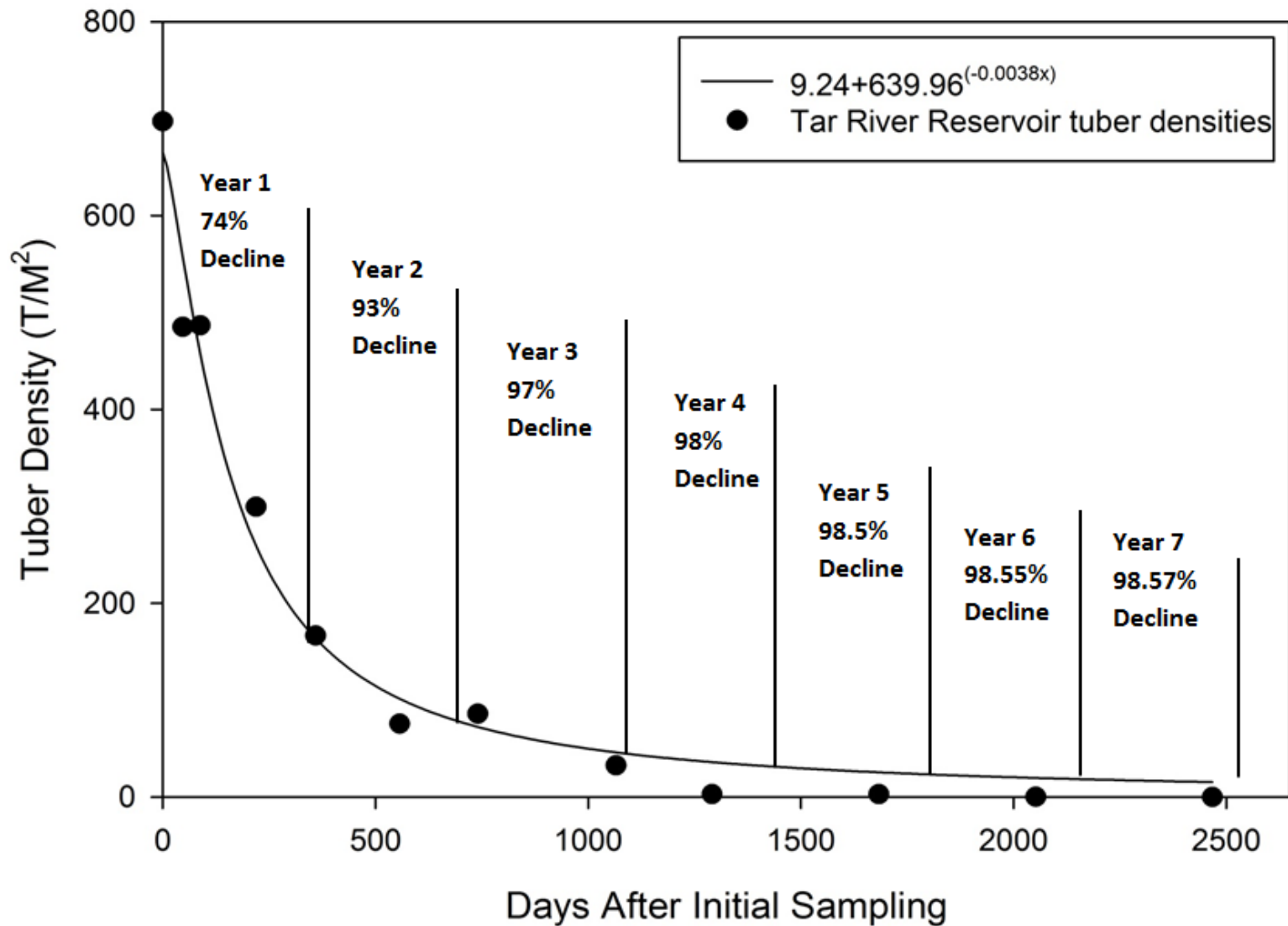


Figure 4. Observed and predicted decline of the averaged tuber bank density in the Tar River reservoir.

Key Insights From NY Tuber Sampling - Mike Netherland

- >92% sprouting observed in June Sampling
 - SYNCHRONOUS SPROUTING !!
- Tubers emerge in late June to early July
 - Lag between sprouting and growth (temperature related)
- No new sprouting observed in Aug and Sept.
 - Implications for use of contact herbicides
- Latitudinal impact on sprouting of monoecious hydrilla tubers



Hydrilla Tuber Attrition – Assuming 92% sprouting

Year	Tubers/acre	Tubers/sq. ft
0	1,000,000	22.9
1	80,000	1.8
2	6,400	0.15
3	512	0.012 1 per 90 sq ft
4	41	.0009 1 per 1100 sq ft
5	3	.00006 ~ 2 per acre



Courtesy Mike Netherland



Year 3 Assuming Different Tuber Attrition (starting from 1 million/acre)

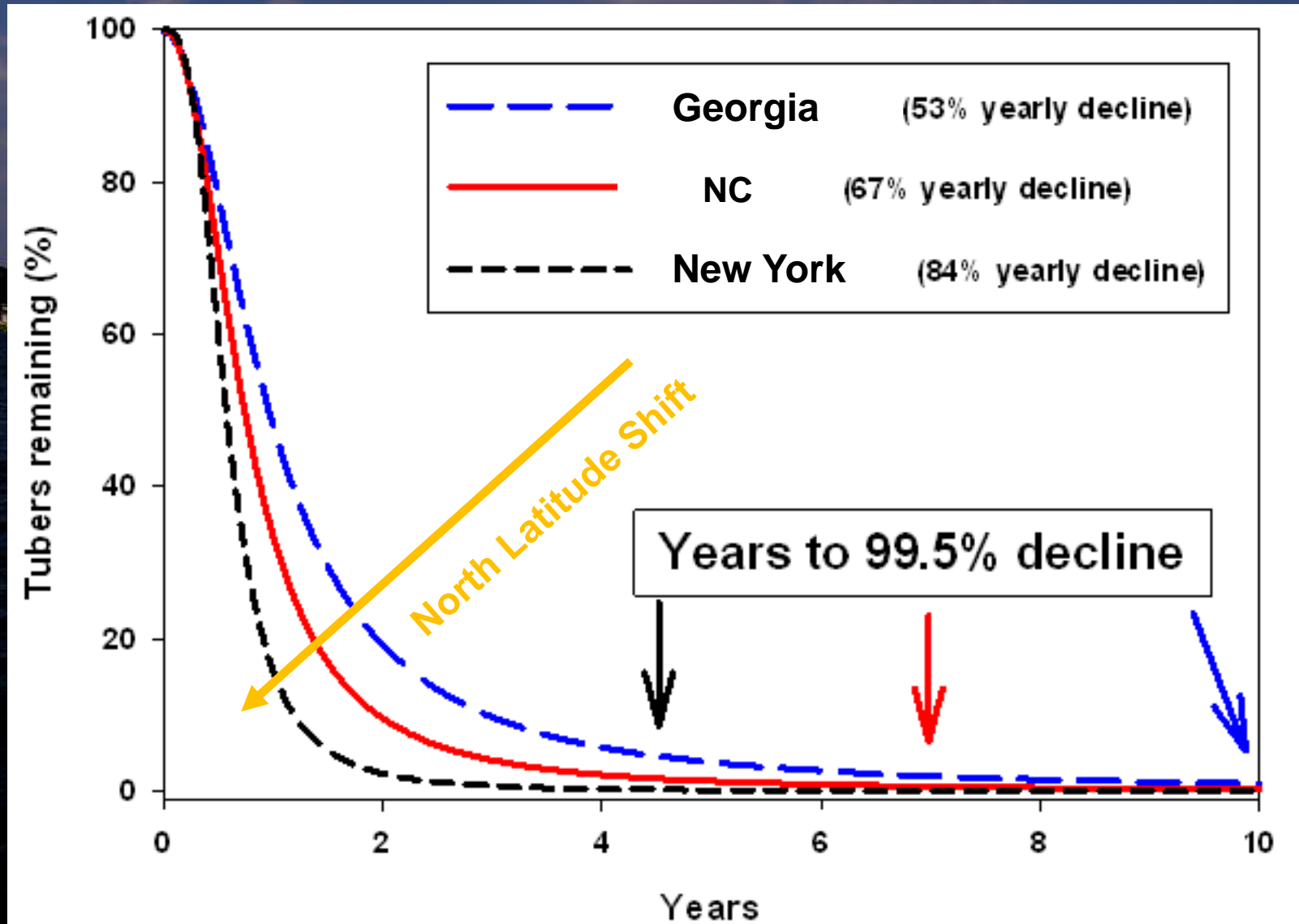
- 92% ~ 500 tubers / acre (Erie Canal)
 - 50% ~ 125,000 tubers /acre
 - 25 % ~421,875 tubers / acre (GA Power)
-
- Big difference in the sprouting dynamics of northern and southern populations
 - ▶ Is encouraging for Northern managers



Courtesy Mike Netherland

ERDC

Hypothetical Tuber Longevity





Can You Take a Year Off From Management?

NC STATE

EXTENSION

Treatment Comparison

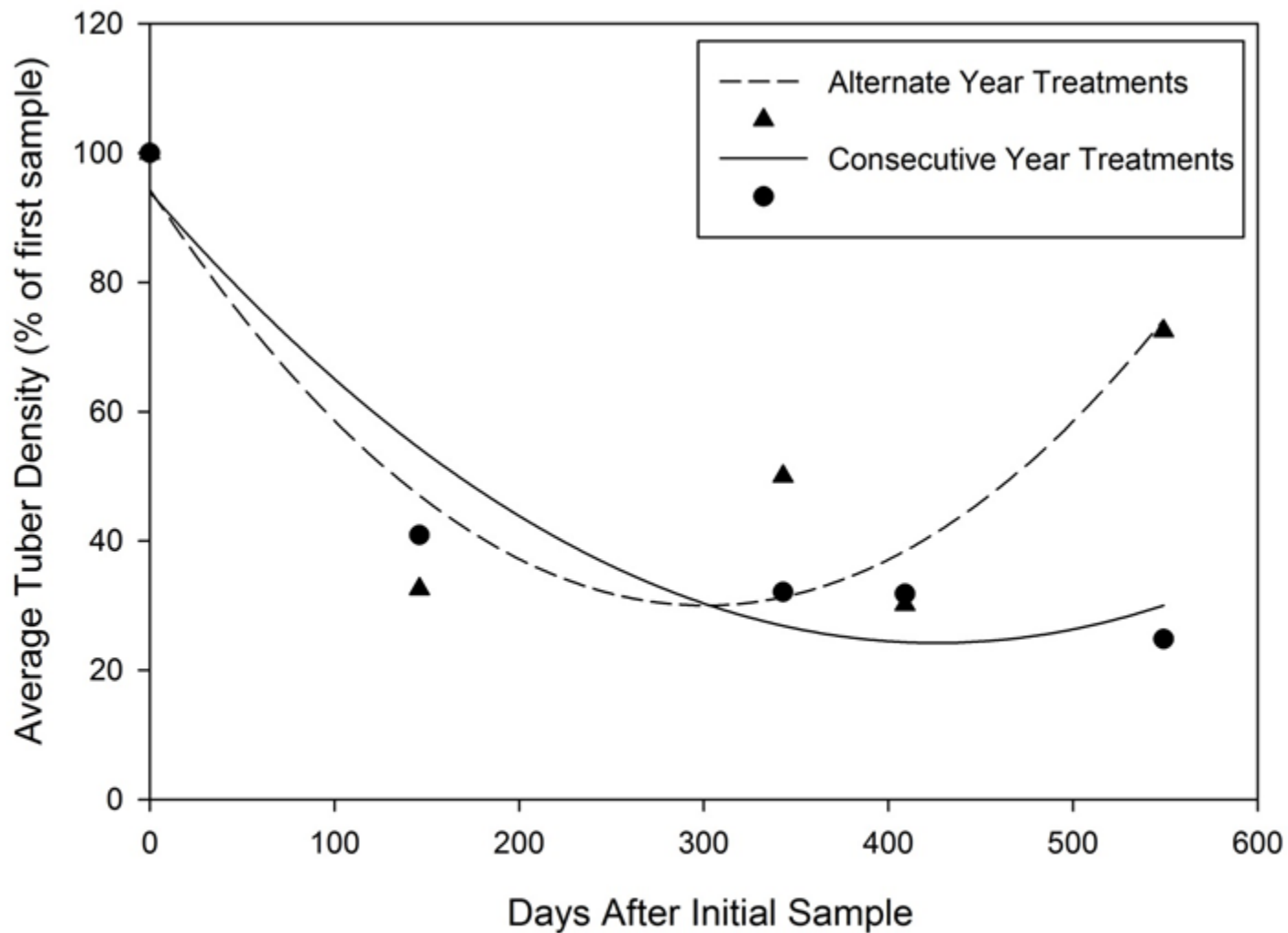


Figure 5. Quadratic regression models and averaged values of tuber densities for alternate year ($R^2=0.91$; $P=0.043$) treatment and consecutive year ($R^2=0.99$; $P=0.031$) treatment sites on Lake Gaston.

Treatment Comparison

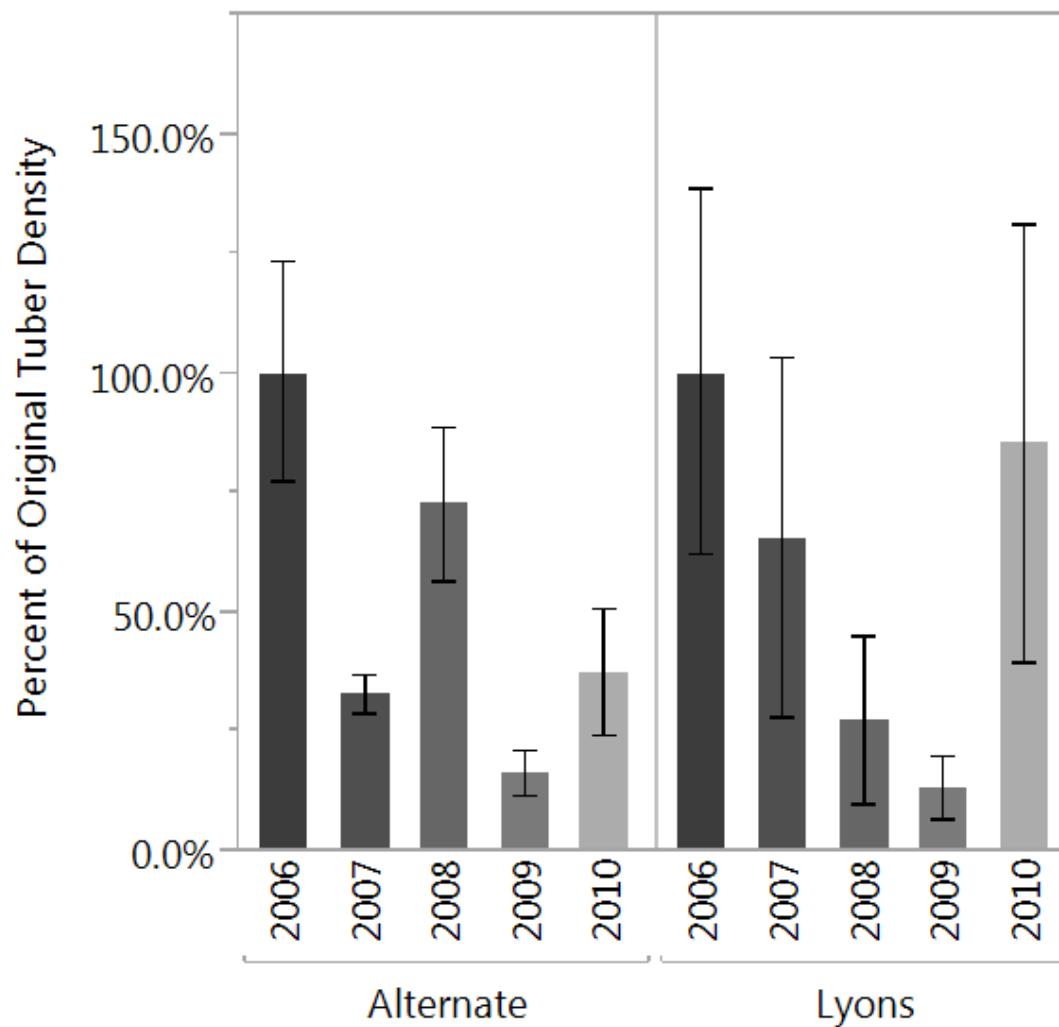


Figure 6. Tuber density means and standard errors for alternate year treatment sites (Cold Springs, Hawtree, and Poe), which received treatments in 2007 and 2009 and the consecutively treated site Lyons, which received treatment from 2007-2009.

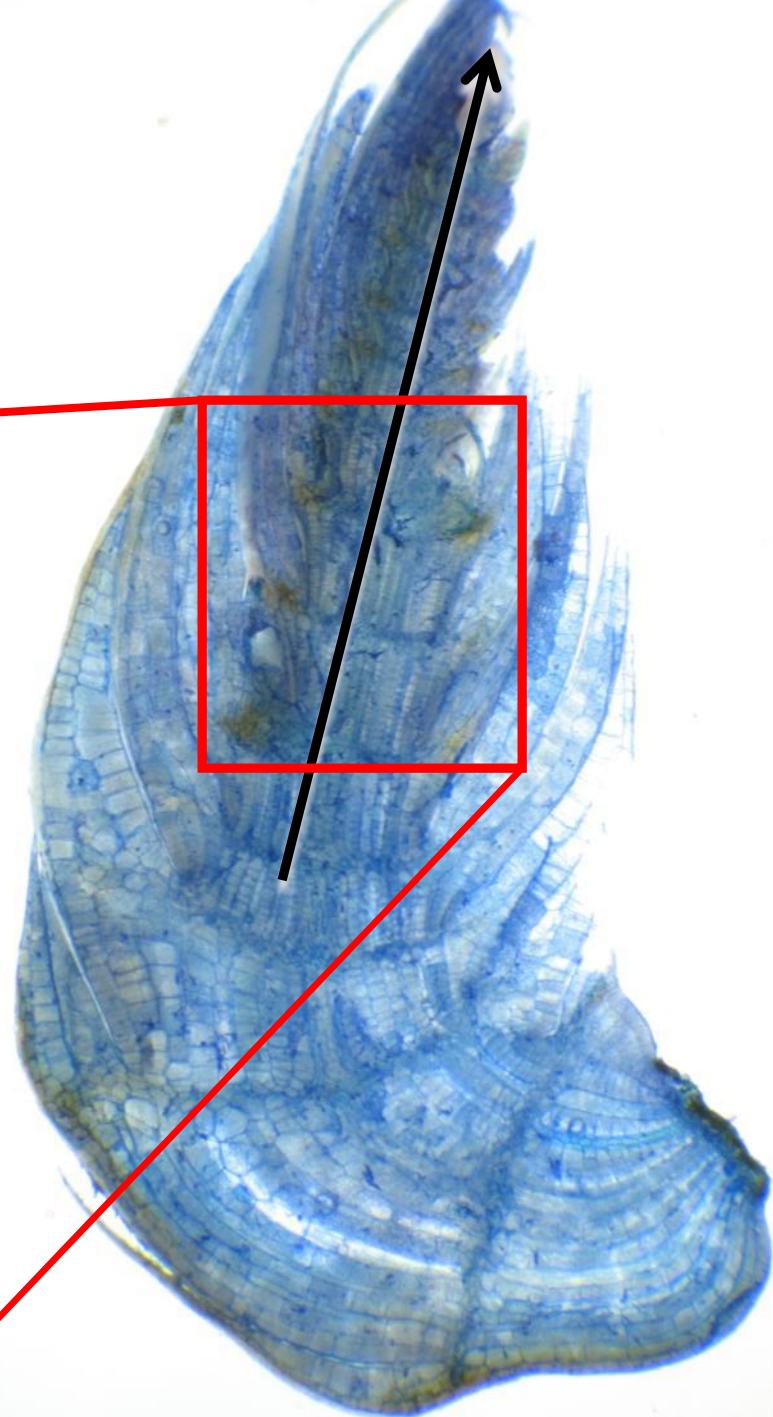
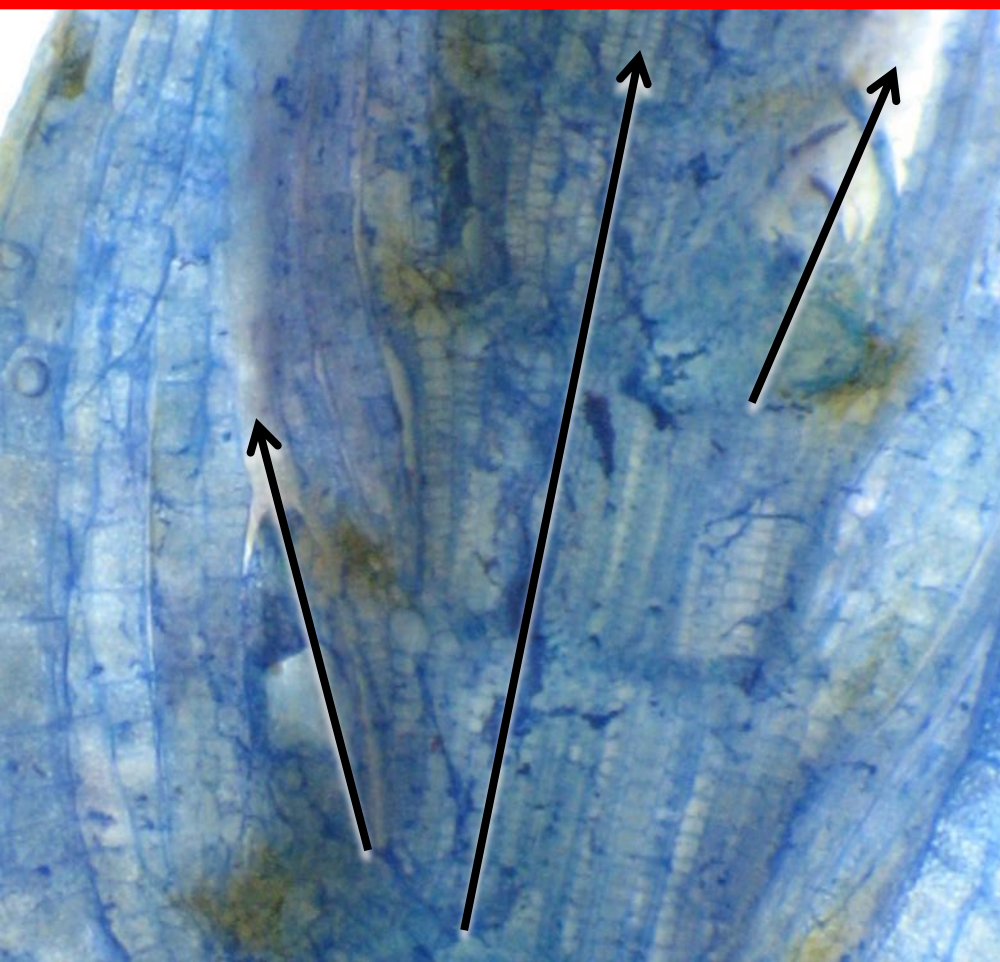


**If You Kill A Hydrilla
Shoot, Have You Killed
the Original Tuber?**

**How many
shoots?**



**How many
shoots?**





Let's Clip the Sprouts and...



Watch Them Sprout...



**Shoot
Removed From
Tuber**



Triploid Grass Carp



Practical Implications



Mechanical Harvesting

Monitoring Grass Carp Effect



NC STATE

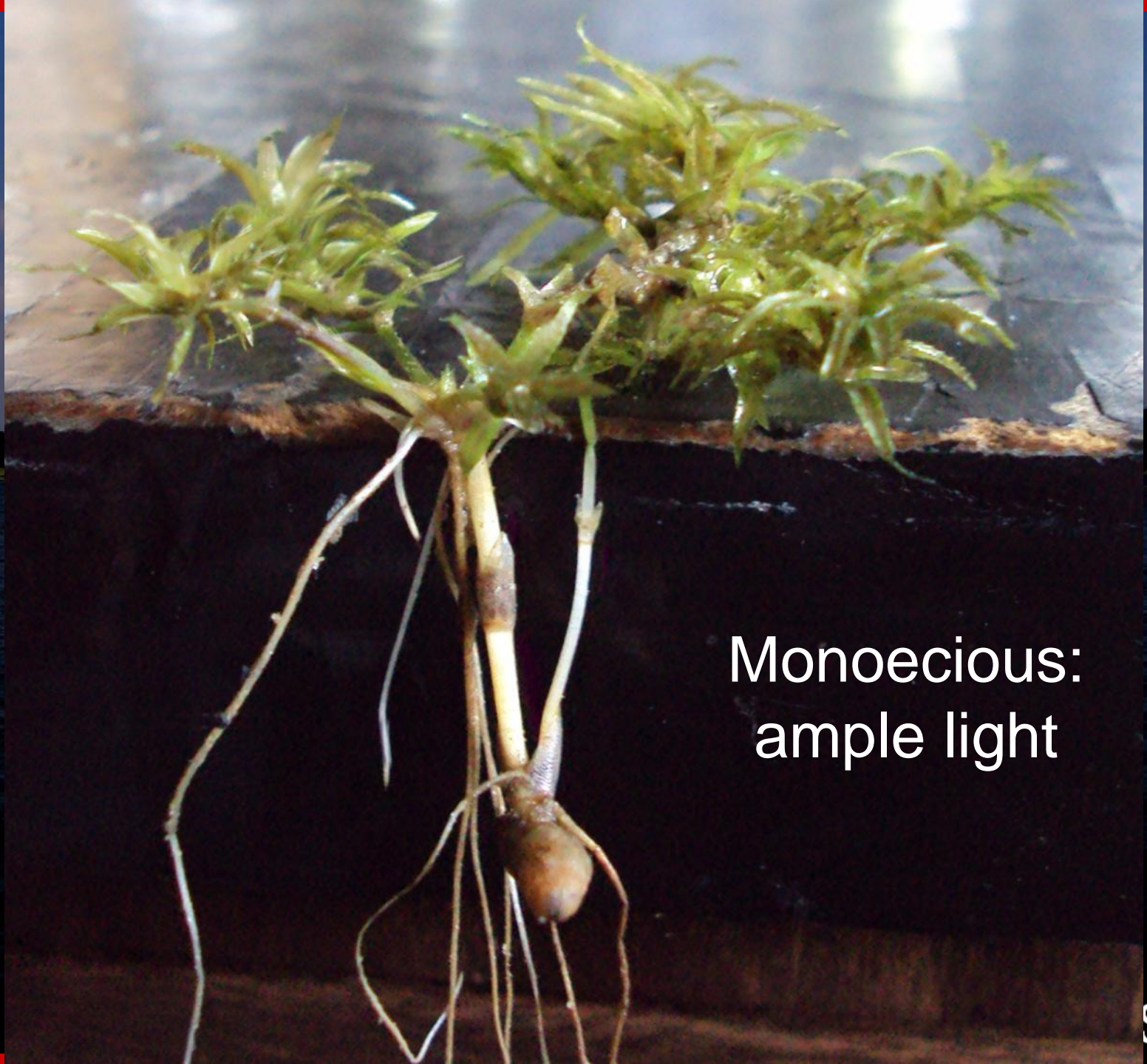
EXTENSION

Monoecious:
Various
planting
depths

25 cm

4 Weeks After Planting





Monoecious:
ample light

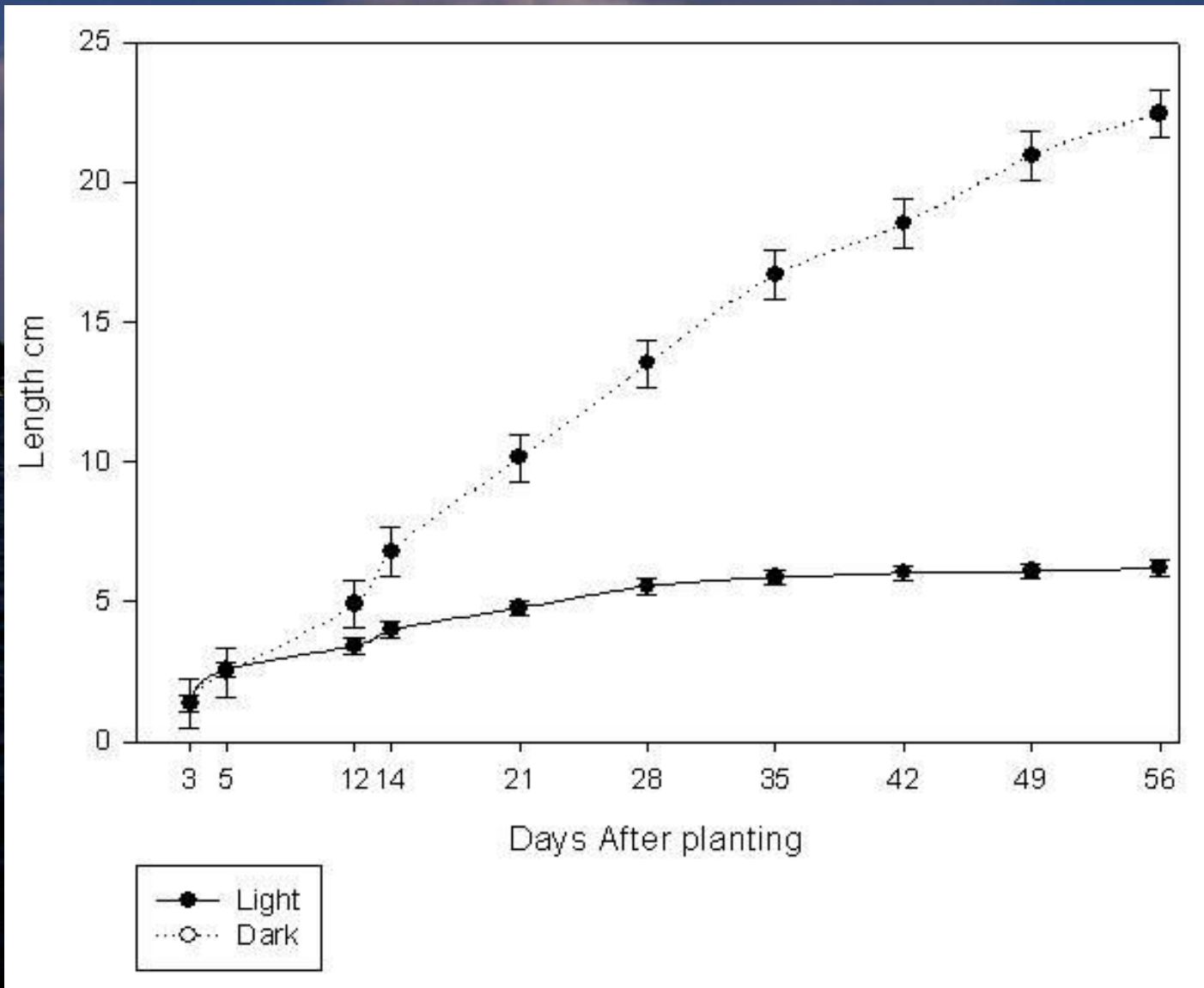


Can You Manage Hydrilla By Shading It?

NC STATE

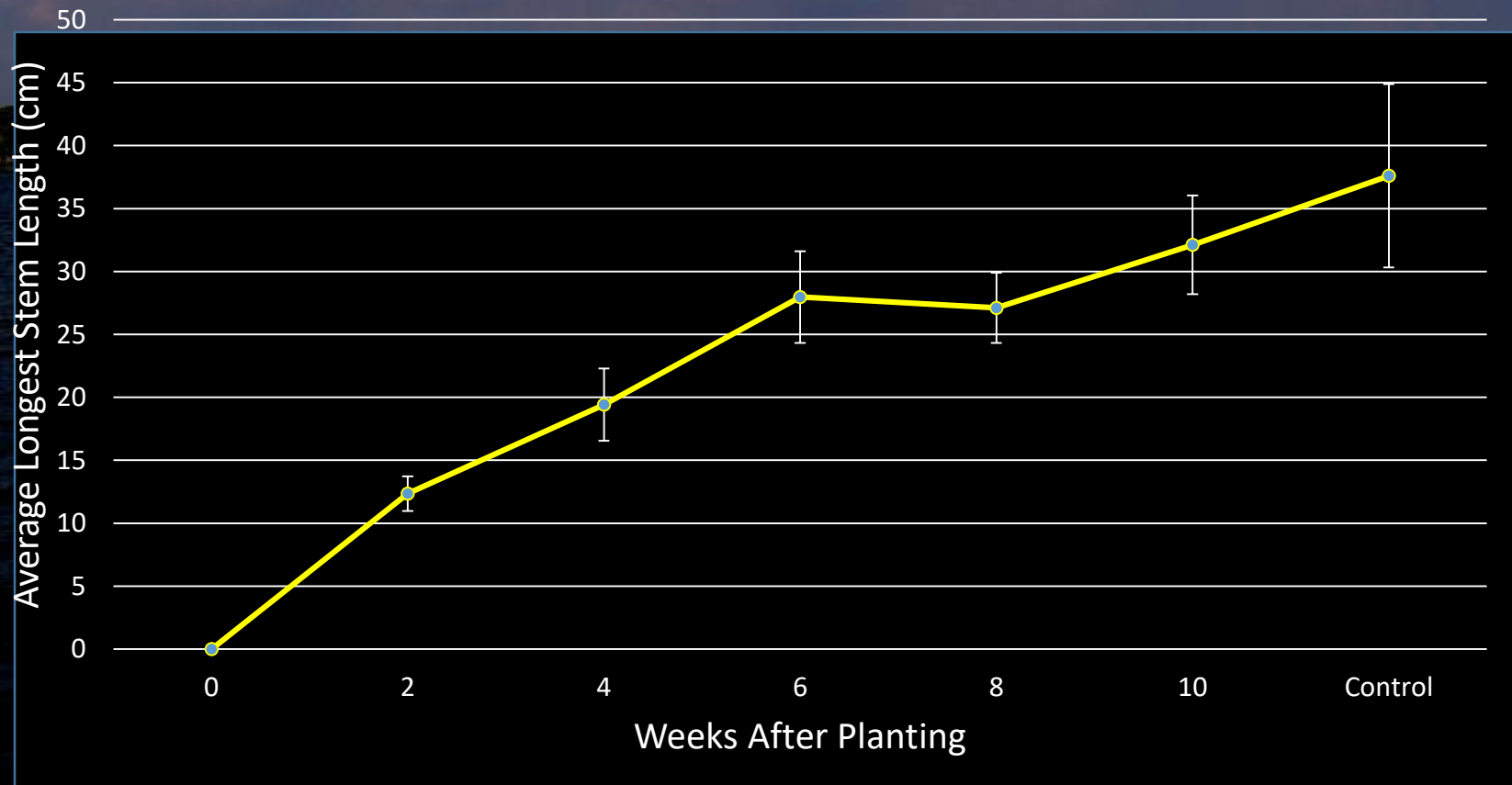
EXTENSION

Hydrilla Growth: Light vs Dark

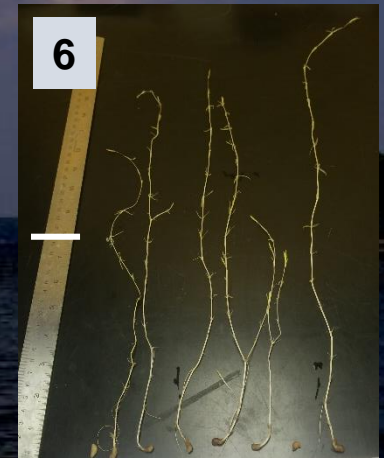
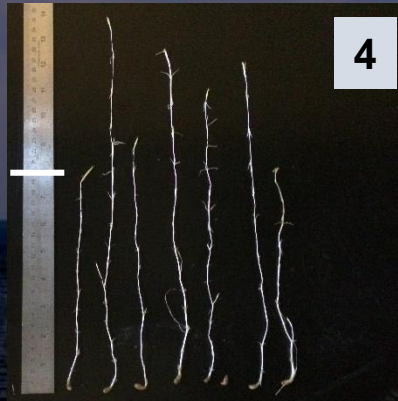


Change in the length of the longest shoot

Change in Plant Size Over Time



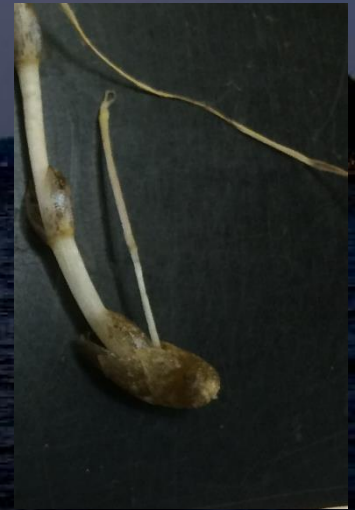
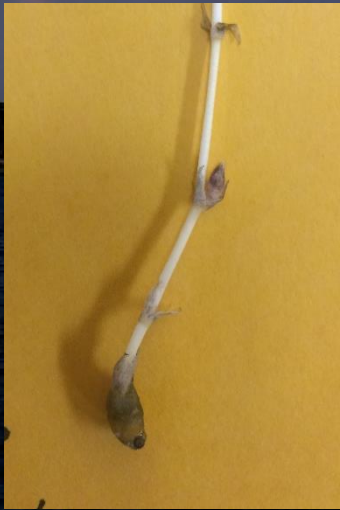
Change in the length of the longest shoot



Control



Reproduction in darkness?!



Tuber Growth and Development in Darkness Results Cont.



Light or no light
after 1 and 6 wk





What About Water pH?

NC STATE

EXTENSION

5.5

6.0

7.0

7.5

6.5

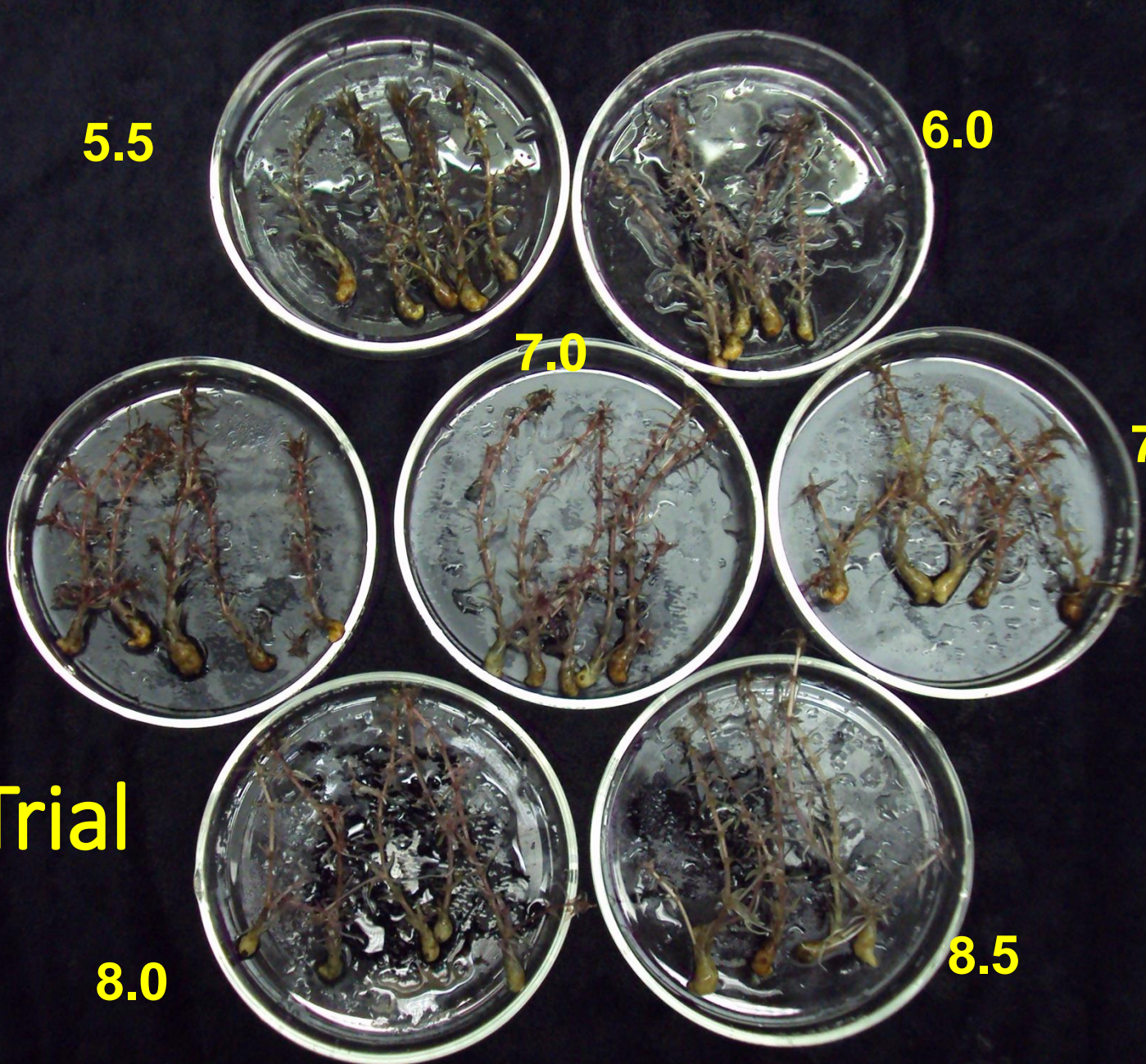
pH Trial

8.0

8.5

NC STATE

EXTENSION



Final Thoughts

- Monoecious hydrilla is usually identified 2+ years after invasion; tuber bank established
- Growth habit is fairly well suited for many northern lakes...it may not directly compete with Eurasian watermilfoil or curly leaf pondweed
- It may not be considered as big a nuisance as EWM in some northern states, but it could invade more systems than EWM
- Monoecious hydrilla would be much worse in NC if not for grass carp; management in diverse systems is not easy, but can be done



Before
Treatment

After
Treatment

NC STATE

EXTENSION

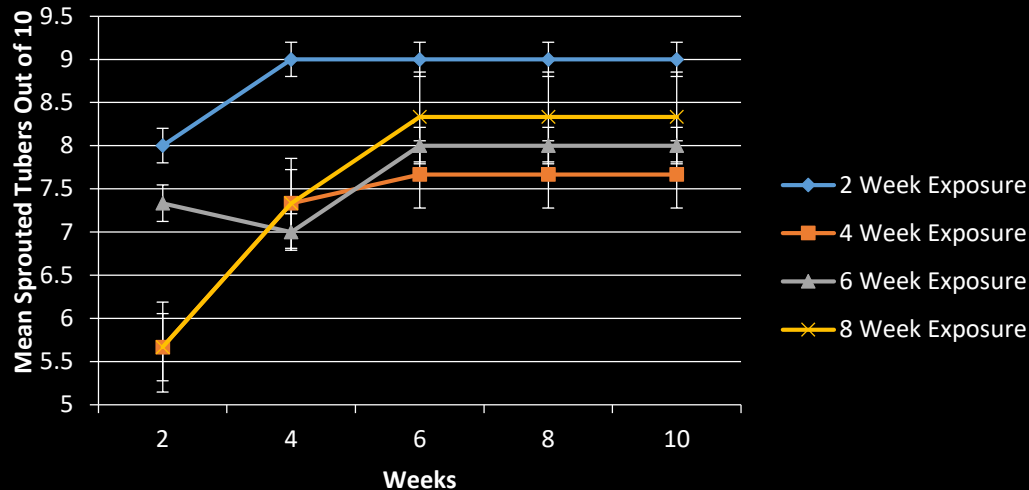
Questions?



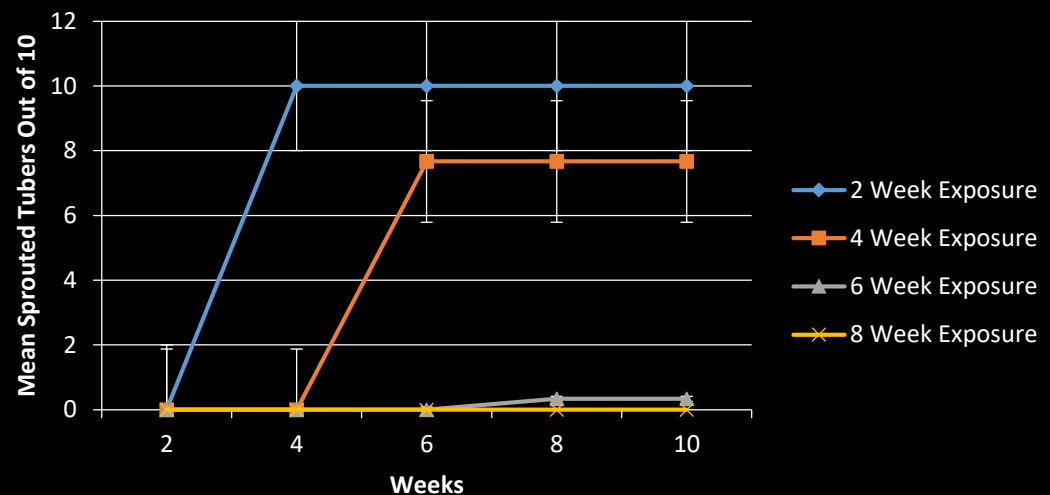
Sunrise over a 4,100A Cooling Pond for a 900MW Nuclear Reactor

Short Term Salinity Exposure

12 ppt



18 ppt

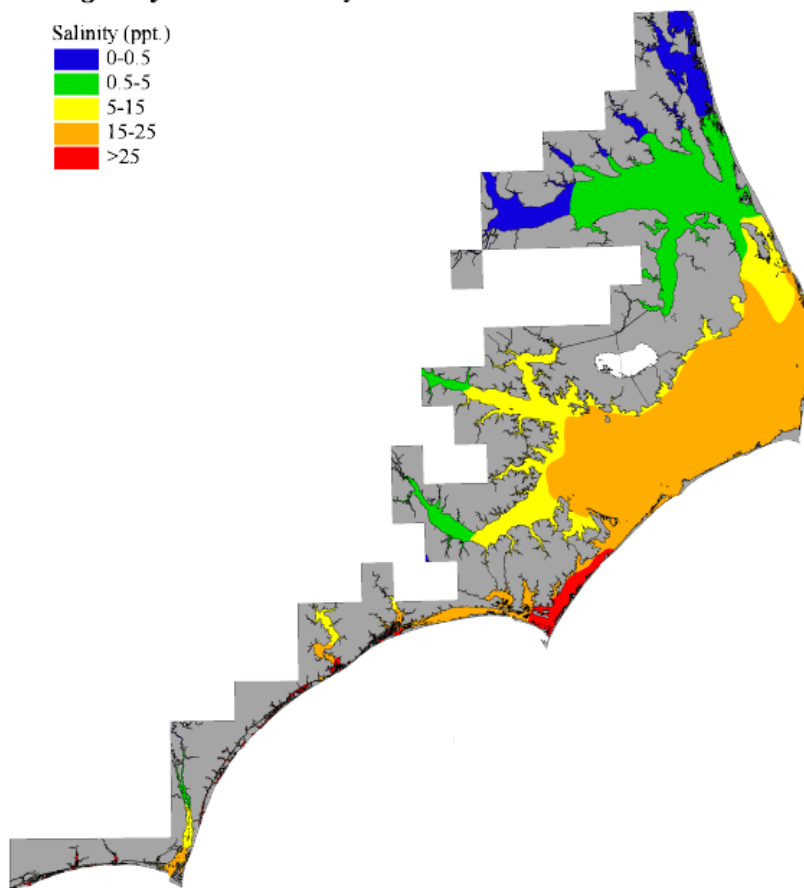


- Carter et al. 1987 found salinities of 5-9 ppt resulted in 4-20% of tubers sprouting and >9 ppt none sprouted in monoecious hydrilla
- Steward and Van 1987 found growth was severely suppressed above 13 ppt for both dioecious and monoecious hydrilla

Salinity Conclusions

- Salinity
 - 12 ppt 5.67 ± 0.7 tubers sprouted with 4 wk exposure
 - 18 ppt 2 and 4 wk exposure time resulted in an increased rate of sprouting when compared to 6 and 8 wk exposure
 - Tubers were able to sprout at 24 ppt but numerous died due to extended exposure
 - No tubers sprouted in 36 ppt

*North Carolina Estuaries:
Biologically-Based Salinity Zones*



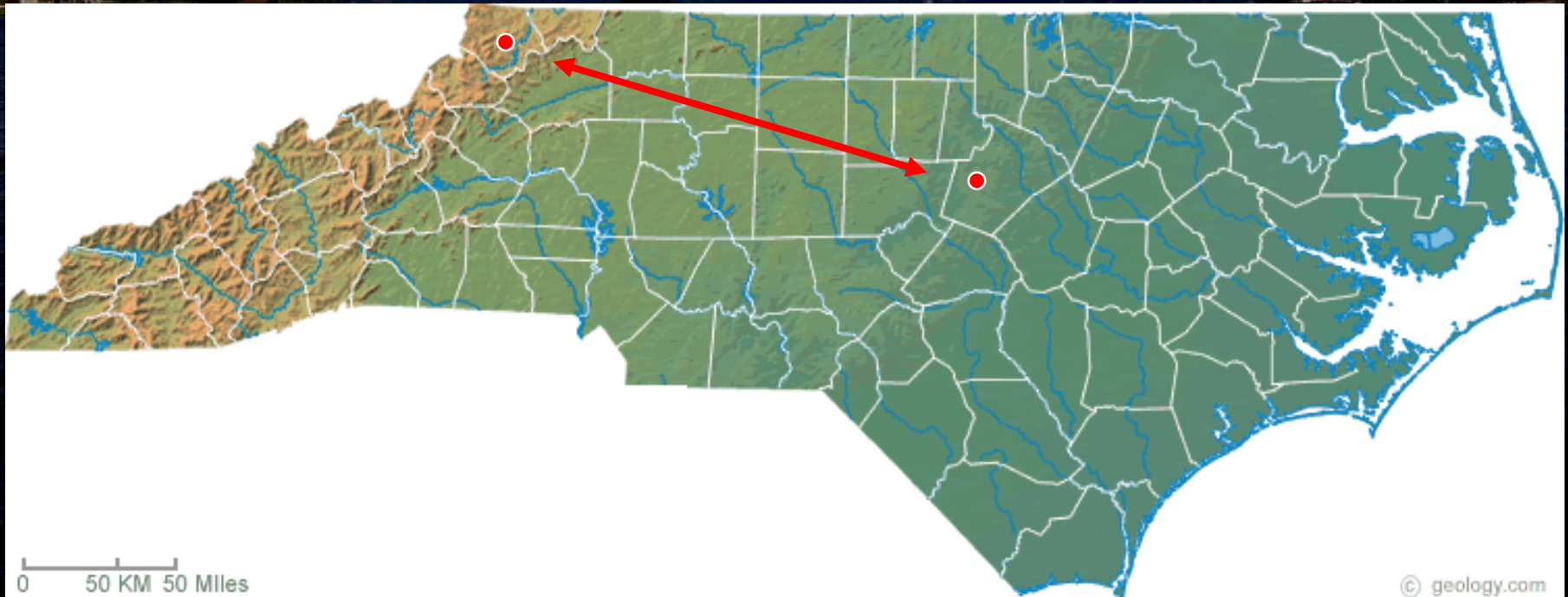
Climate Comparisons

Laurel Springs

- 2,750 feet above sea level

Raleigh

- 350 feet above sea level



Tuber Production

Tubers Collected

Harvest	Month	Raleigh	Laurel Springs
1	April	224 a	89 c
2	May	216 a	81 c
3	June	217 a	103 bc
4	July	209 a	85 c
5	August	205 a	86 c
6	September	192 ab	173 abc

Turions Collected

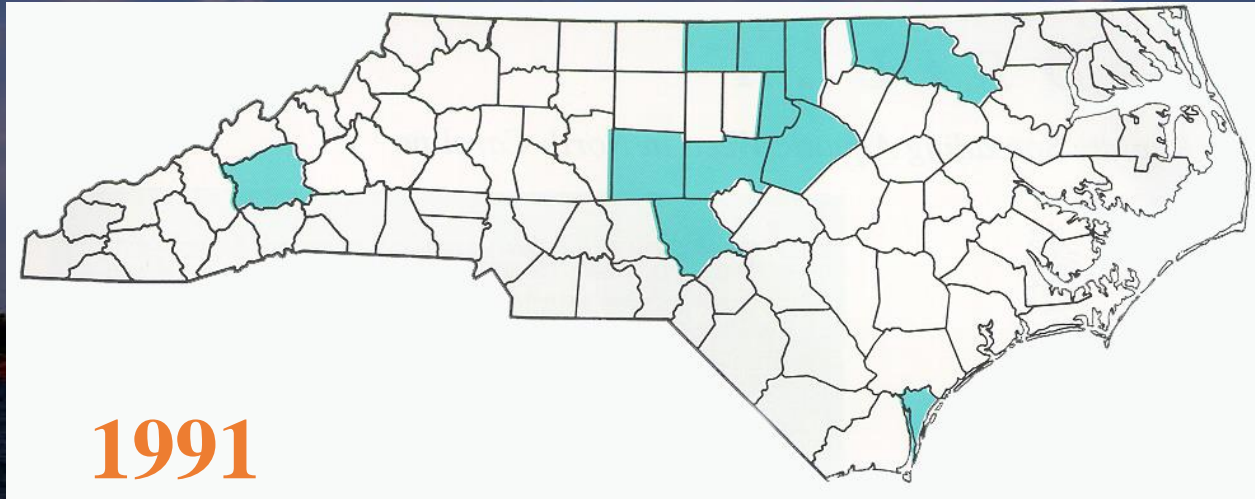
Harvest	Month	Raleigh	Laurel Springs
1	April	80 a	59 a
2	May	49 a	64 a
3	June	38 a	44 a
4	July	56 a	34 a
5	August	41 a	43 a
6	September	29 a	70 a

Propagule Cold Tolerance

Tuber Viability Rate			
Temperature	Location	Mean Viability Rate	
4° C	Raleigh	62.83%	b
	Laurel Springs	89.45%	a
0° C	Raleigh	0.00%	b
	Laurel Springs	19.58%	a
-3° C	Raleigh	0.00%	a
	Laurel Springs	0.00%	a

Turion Viability Rate			
Temperature	Location	Mean Viability Rate	
4° C	Raleigh	40.65%	b
	Laurel Springs	78.49%	a
0° C	Raleigh	0.00%	a
	Laurel Springs	0.46%	a
-3° C	Raleigh	0.00%	a
	Laurel Springs	0.00%	a

Hydrilla Spread





And Another Consideration...

NC STATE

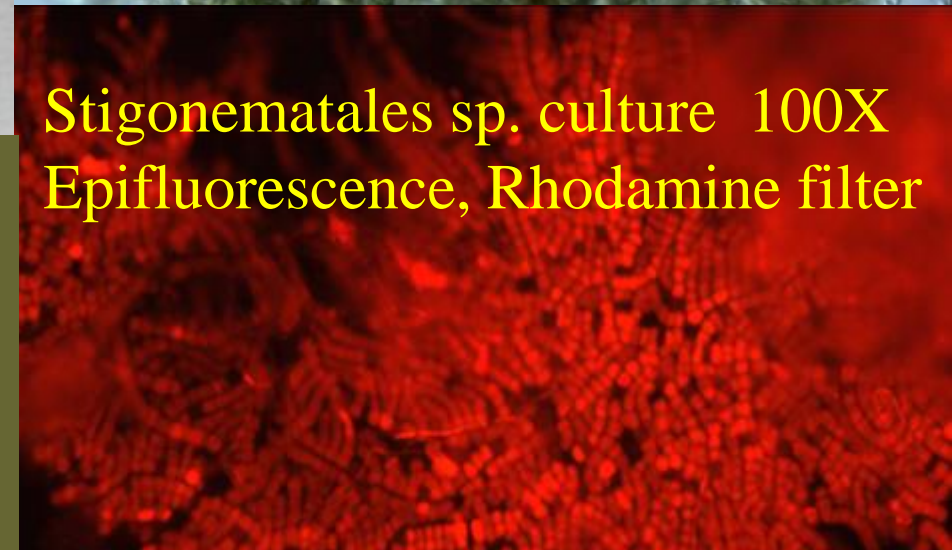
EXTENSION

Avian Vacuolar Myelinopathy

- Disease complex associated with death of coots, bald eagles, and other birds
- Coots die within 5 days of first symptoms
- Bioaccumulates in birds
- Believed to be connection between hydrilla, cyanobacteria, and waterfowl
- Documented throughout southeastern US
- No long-term impact on grass carp



Stigonematales sp. culture
100X Light



Stigonematales sp. culture 100X
Epifluorescence, Rhodamine filter

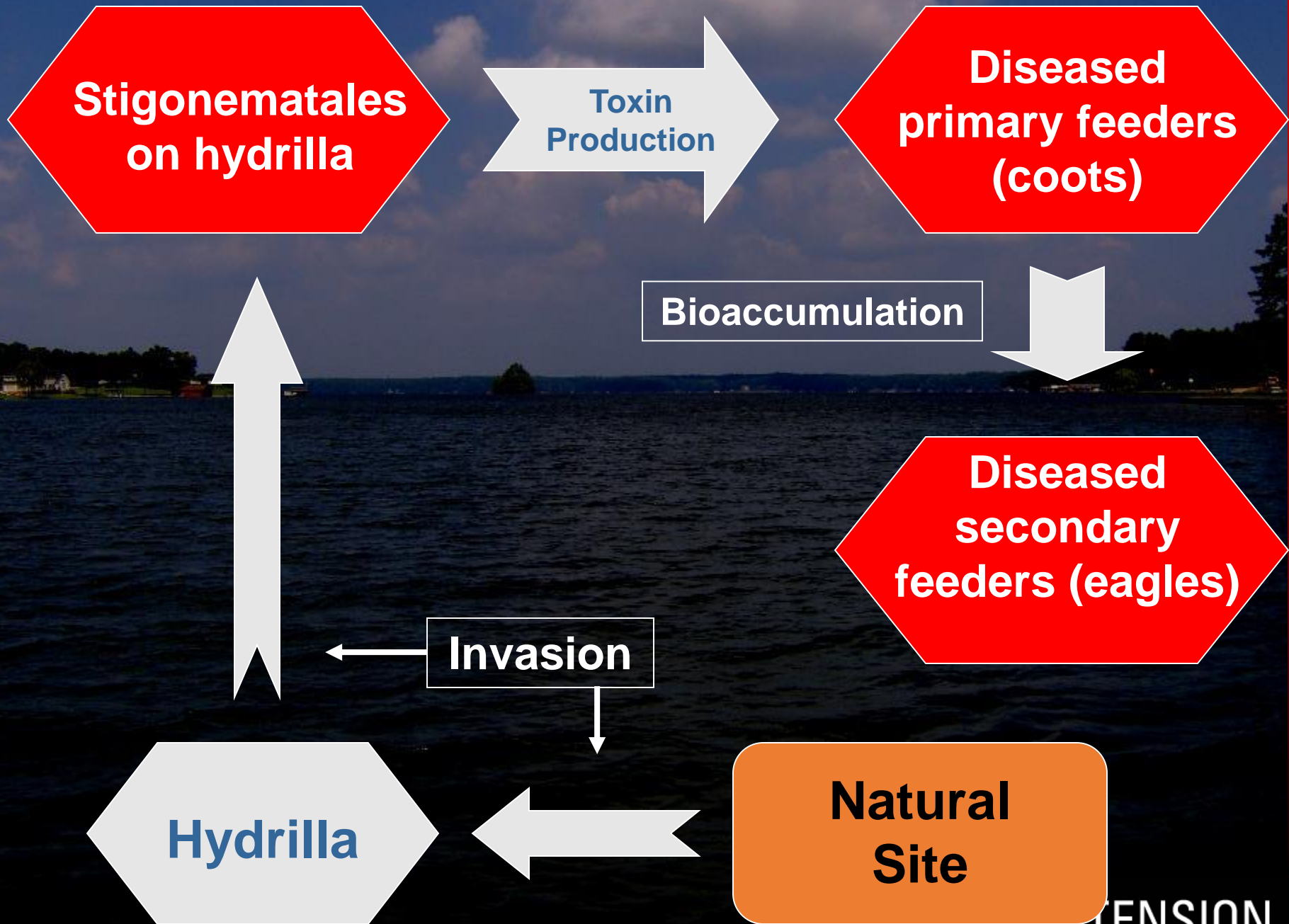
--Culprit--

Stigonematales species--

Morphologically similar to 3 genera:

Hapalosiphon, *Fisherella*, or
Thalpophila

Williams, S.K., S.B. Wilde, J. Kempton, and Alan J. Lewitus. A novel epiphytic cyanobacterium associated with reservoirs affected by Avian Vacuolar Myelinopathy. To be submitted to *Phycologia*.



Effect of Planting Depth and Soil Type on Tuber Germination

	Planting Variables	% Germination
Soil Type	Clay	51 b
	Sand	59 ab
	Organic	69 a
Planting Depth (cm)	0	42 b
	2	60 a
	4	59 a
	8	69 a
	16	57 a
	30	59 a

Letters represent differing LSD values, different letters are significantly different



20 ° C



25 ° C



30 ° C



35 ° C

3 Days After Planting

VISION