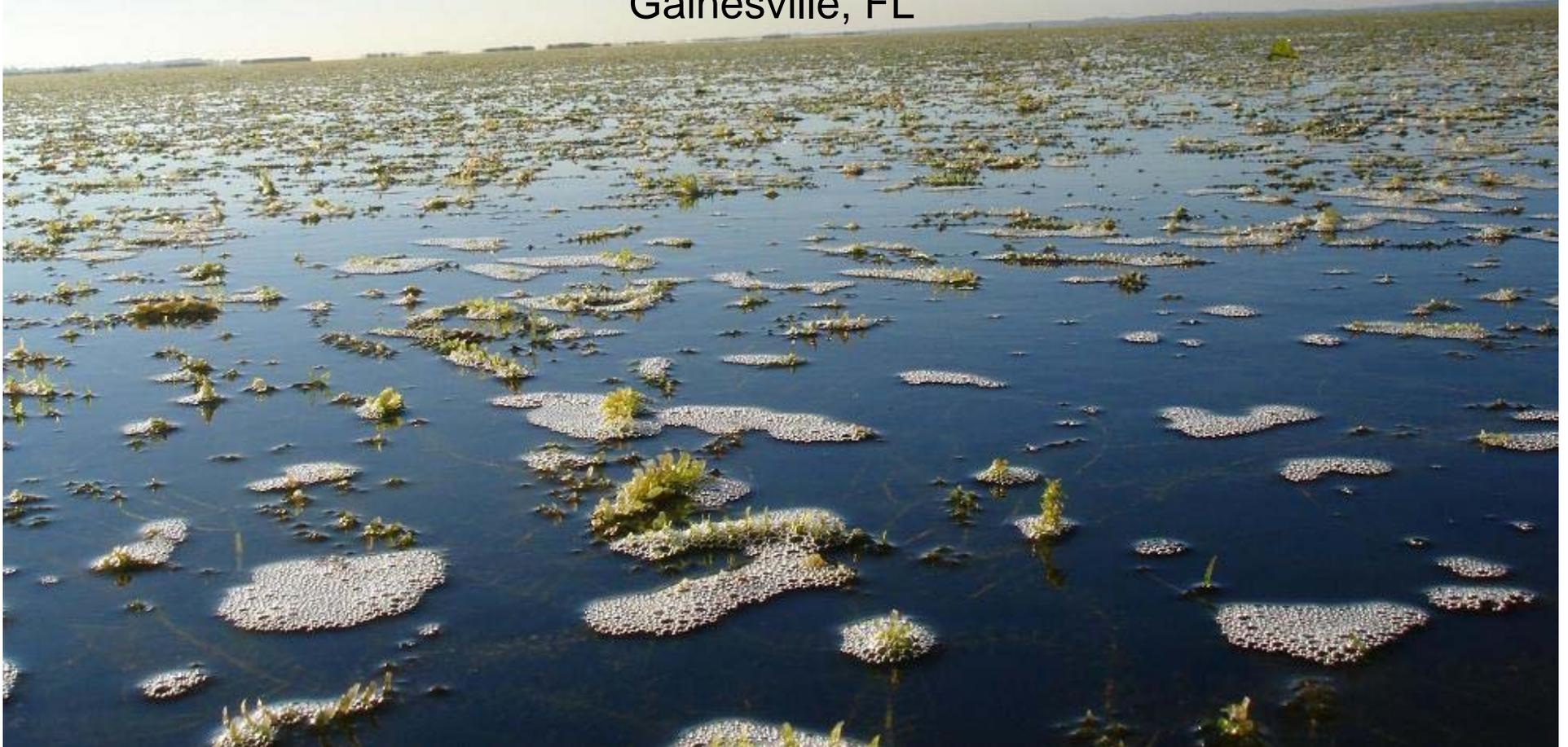


The 5th Wave of Hydrilla Invasion in the US

Michael D. Netherland

US Army Engineer Research and Development Center
Gainesville, FL



Does Hydrilla Pose a Greater Threat to NE Waters Than Other Invasive Submersed Plants ?



Hydrilla



Eurasian Milfoil



Curlyleaf Pondweed



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Not My First Rodeo

a.k.a. “the chicken little of hydrilla”

- Michigan Great Lakes Invasive Conf. 2004
- FL Hydrilla Workshops – 2004-05, 2009, 2011
 - ▶ Fluridone resistance - White Paper w/ recommendations 04 & 05
- Midwest APMS – 2007
 - ▶ Special session on Hydrilla
- APMS 50th Anniv. – 2010 and 51st Mtg. in 2011
 - ▶ Organized Special Session on Hydrilla
 - ▶ Organized Special Session on Ecological Services and Hydrilla
- BASS Conservation Directors – 2012 – “They love hydrilla”
- MO DEC – Invasive Threats – last week



Overview

- The 5th wave of invasion
- Hydrilla as the perfect weed
 - ▶ Biology, biotypes, and constraints
- Recent trends - **Monoecious Hydrilla**
- Unintended consequences of hydrilla
- A worldwide perspective on hydrilla



4 Distinct Waves of Invasion

- Florida invasion
 - ▶ profound impacts on how people view hydrilla
- Southeast and Texas – Reservoir invasion
 - ▶ Very limited number of natural lakes
 - ▶ Grass Carp Option
- California and West Coast
 - ▶ Rapid response and Eradication Approach
- Mid-Atlantic States
 - ▶ Monoecious hydrilla (distinct biotype)



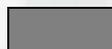
The 5th Wave –

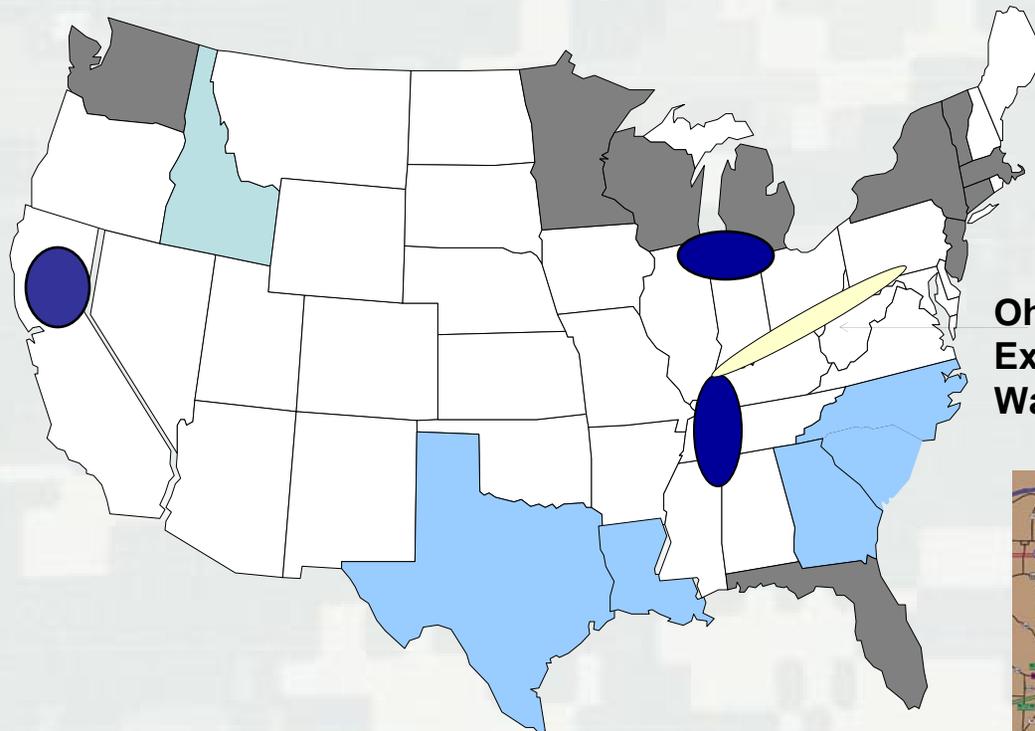
Monoecious Coming to a Northern Tier State Near You ?

- Glacial Lakes of the NE and upper MW
 - 1000's of lakes with potential to support hydrilla
- State policies are mixed
 - Precautionary principle – we don't want to know how bad hydrilla can get (eradicate)
 - We don't know how bad hydrilla can get (wait & see)
- 5 to 10 years from now, what will we say?
 - We saw the early stages of a major new invasion
 - What was all the fuss about ?



Significant Milfoil or Hydrilla

-  Natural Lakes
-  Reservoirs



Ohio River – Hydrilla
Expanding where no SAV
Was previously noted



**High Energy Reservoirs /
Turbid with water level fluctuations
Generally not conducive to SAV (Monoecious hydrilla ?)**



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Progression of Hydrilla Spread

Year	Number of States	States
1960 – 1969	1	FL (1953 ?)
1970 –1979	6	AL, CA, DE, GA, LA
1980 – 1989	13	CT, MD, MS, NC, SC, TX, VA
1990 – 1999	17	AR, PA, TN, WA
2000 – 2011	29	ID, IN, KY, MA, ME, NJ, OK, WI, WV, NY, KS, OH

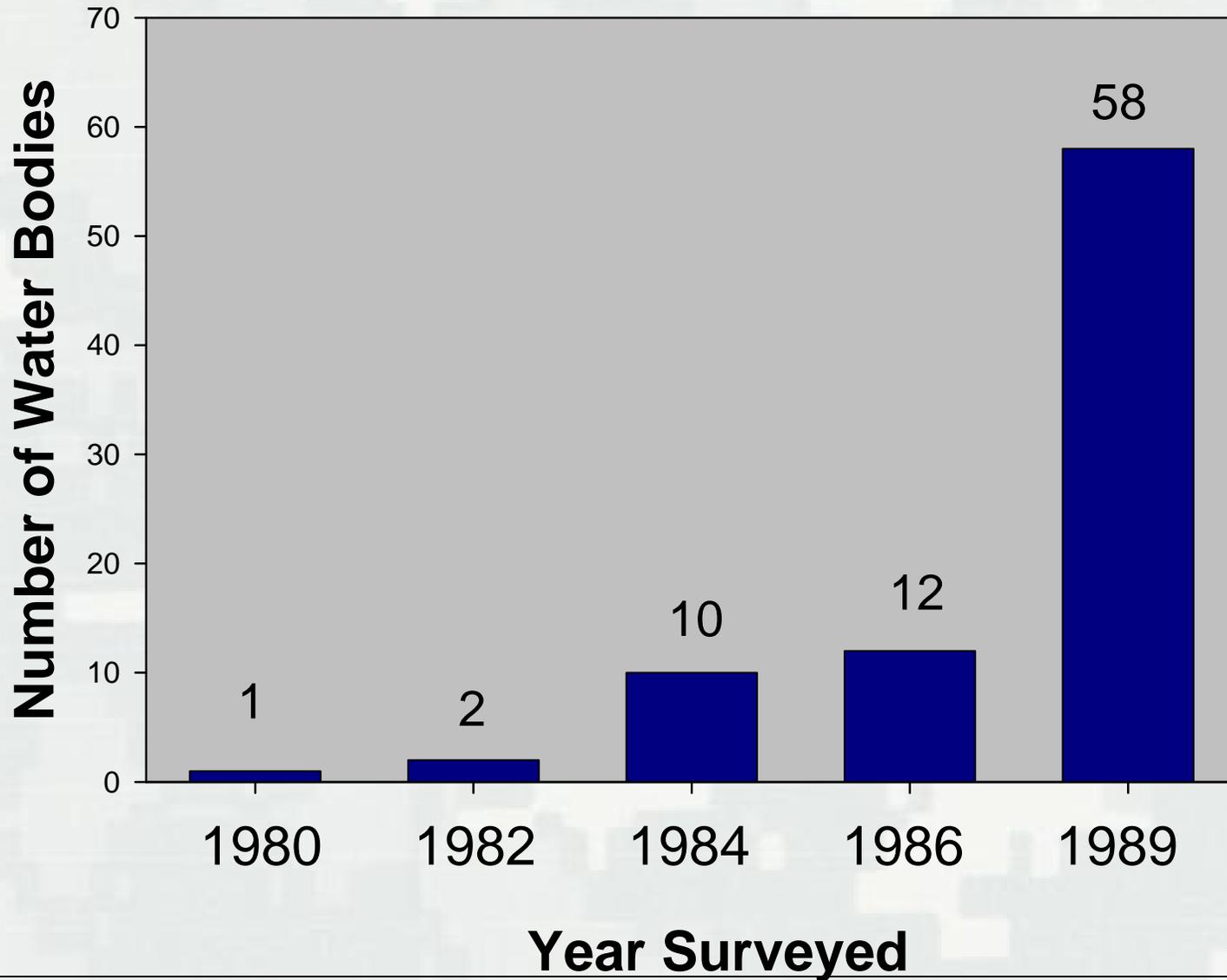


Spread of Monoecious Hydrilla

Year	Number of States	States
1970 – 1979	1	DE
1980 – 1989	6	CA, (CT ?), MD, NC, VA
1990 – 1999	8	PA, WA
2000 – 2011	21	IN, KY, MA, ME, NJ, WI, WV, NY, OH, (KS ?) SC, TN, GA, AL



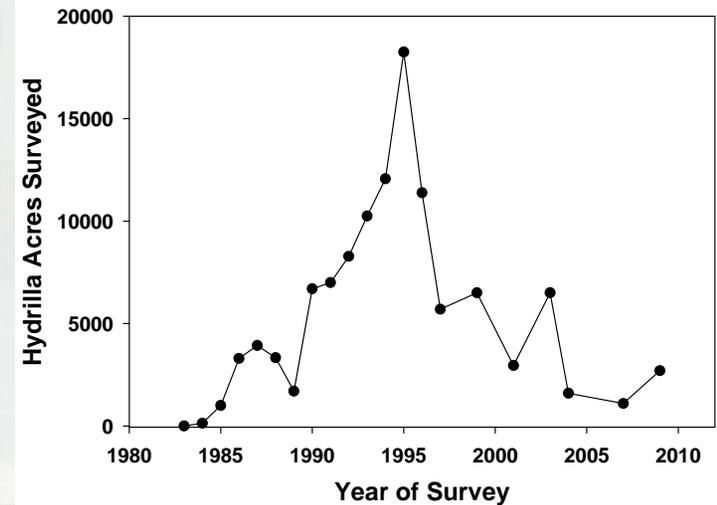
Water Bodies in Wake County, NC with Hydrilla



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Hydrilla Movement in FL

- Introduction in the 1950's
- Canals and small waters in 1960's
- Urban Lakes in 1970's
- Large Central Florida Lakes in 1980's
 - 20+ year lag from introduction
- Boom- Bust – Boom in numerous lakes



Lake Kissimmee





Hydrilla - “The Almost Perfect Weed”

- * Ability to cover thousands of contiguous acres
- * propagates by fragments, turions, tubers, crowns
 - tubers can remain quiescent for years (seed)
- Low light and CO₂ compensation points
 - C₄-like photosynthesis
- * Clonal plant - but high genetic diversity



Hydrilla verticillata L.f. Royle

- Hydrilla is a monocot - Hydrocharitaceae family
 - ▶ Elodea, Egeria, and Vallisneria
 - ▶ Early detection ?
- Native to tropical SE Asia
 - ▶ Found on 6 Continents (Poland)
 - ▶ Multiple Biotypes and Cryptic speciation
- **Dioecious** and **Monoecious** Biotypes
 - ▶ Separate Introductions to the US
 - ▶ Worldwide – Monoecious is tropical and Dioecious is temperate

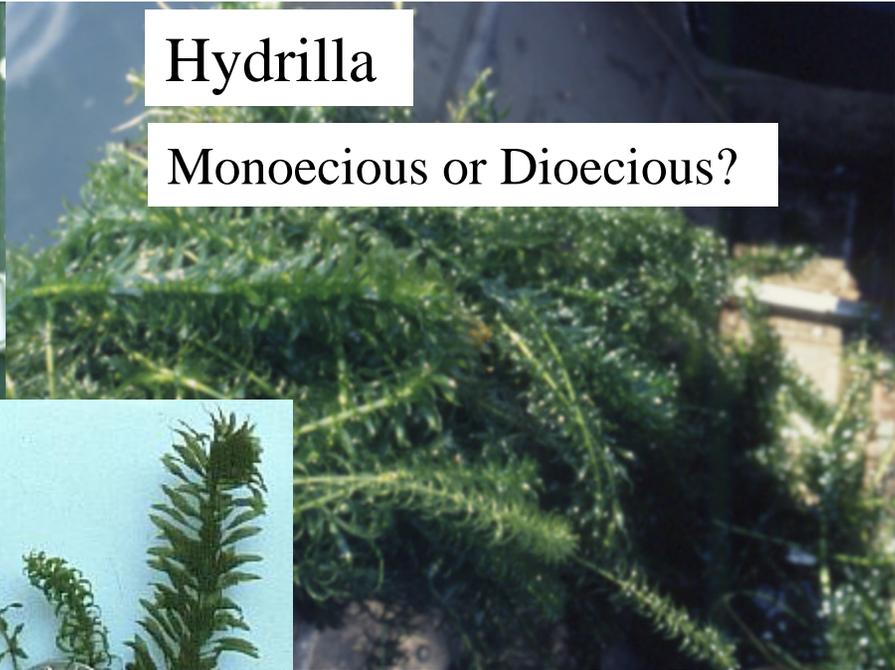


Egeria



Hydrilla

Monoecious or Dioecious?



ANACHARIS
159/bunch



Elodea

Mixed Natives



Dioecious Hydrilla

- Southern Distribution in the US
 - ▶ Clonal female population
- Tubers produced - day length < 12 hr
 - ▶ Fall production (short window in North)
 - ▶ May switch to axillary turions in North (rapid process)
- Rapid Canopy formation
 - ▶ Internodes measured in feet
- Fluridone Resistant Populations limited to FL

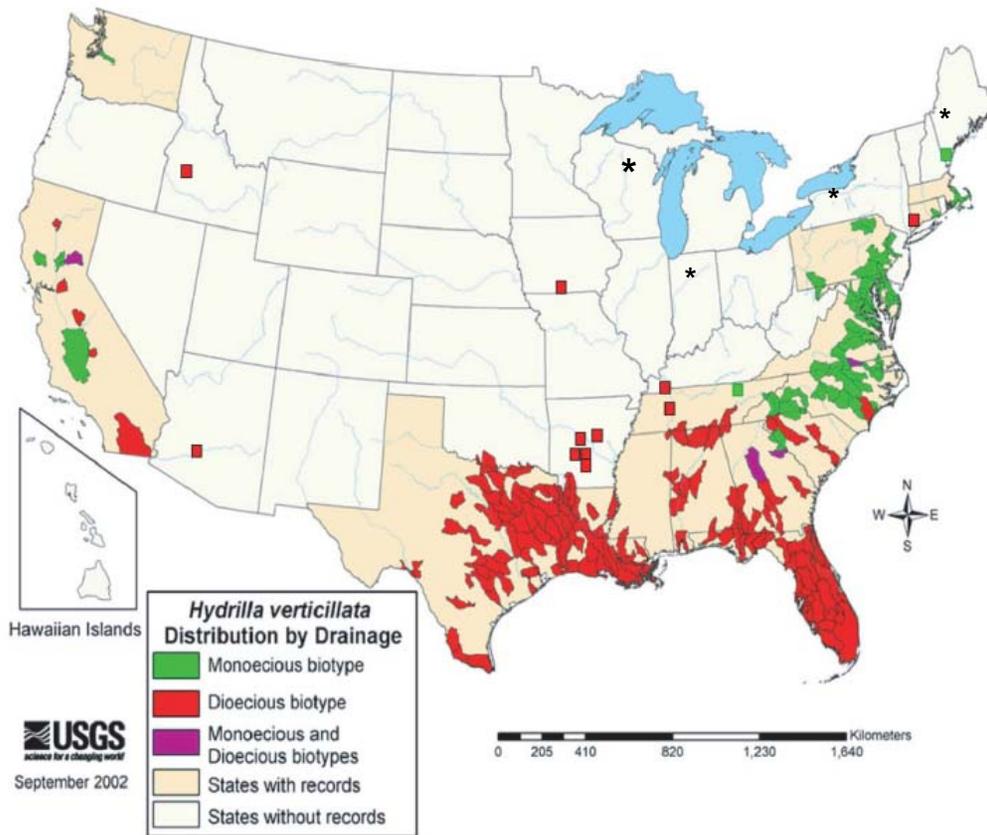


Monoecious Hydrilla

- Northern Distribution in the US
- Longer period of tuber production
- More synchronous tuber sprouting
- Dies Back in Winter (relies on propagules)
- Rapid lateral expansion
 - ▶ Competitive interactions not documented
- Multiple Eradication Programs Ongoing



Hydrilla Biotypes in the U.S.



	Monoecious	Dioecious
Sex	Staminate & pistillate flowers present on same plant	Plants with pistillate flowers only
Above Ground Stem Duration	Annual	Perennial
Habit	Plants first spread along hydrosoil and then grow upward	Plants grow upward and branch forming dense canopy near water surface
¹ Leaf Length	12 ± 2.05 mm	16.1 ± 1.45 mm
Internode Length	14 – 16.1 ± 0.82 – 1.45 mm	11 – 12 ± 0.82 – 2.05 mm
Turion Production	More	Less
Tuber Size	Smaller (≤10 mm)	Larger (14-18 mm)
Tuber Color and Surface	Brown with pronounced leaf scales	White with smooth surfaces
Tuber Production	More	Less

¹Other features such as plant texture, degree of toothiness on margins and midrib, and plant color are often related to water chemistry.

Modified from USGS

Is Monoecious Hydrilla the “Wimpy Cousin of the Dioecious Biotype ?

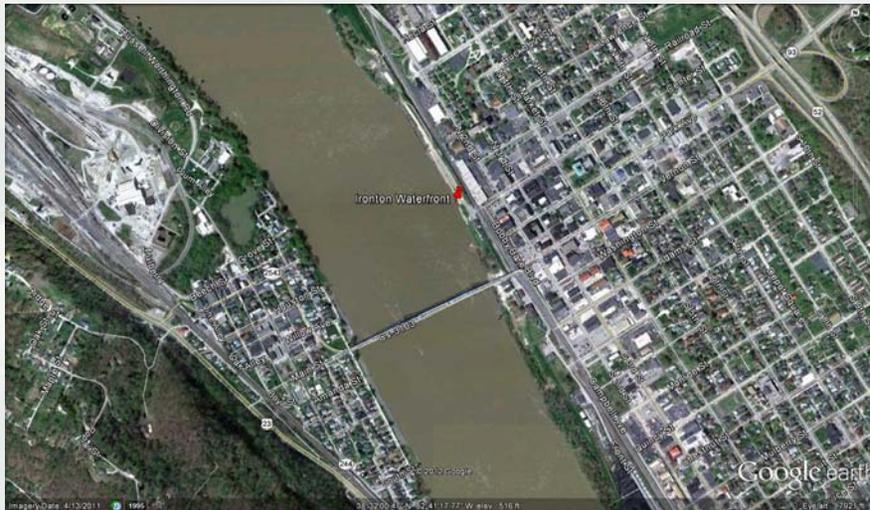


OR

Is Monoecious Hydrilla the Tortoise and Dioecious Hydrilla the Hare ?



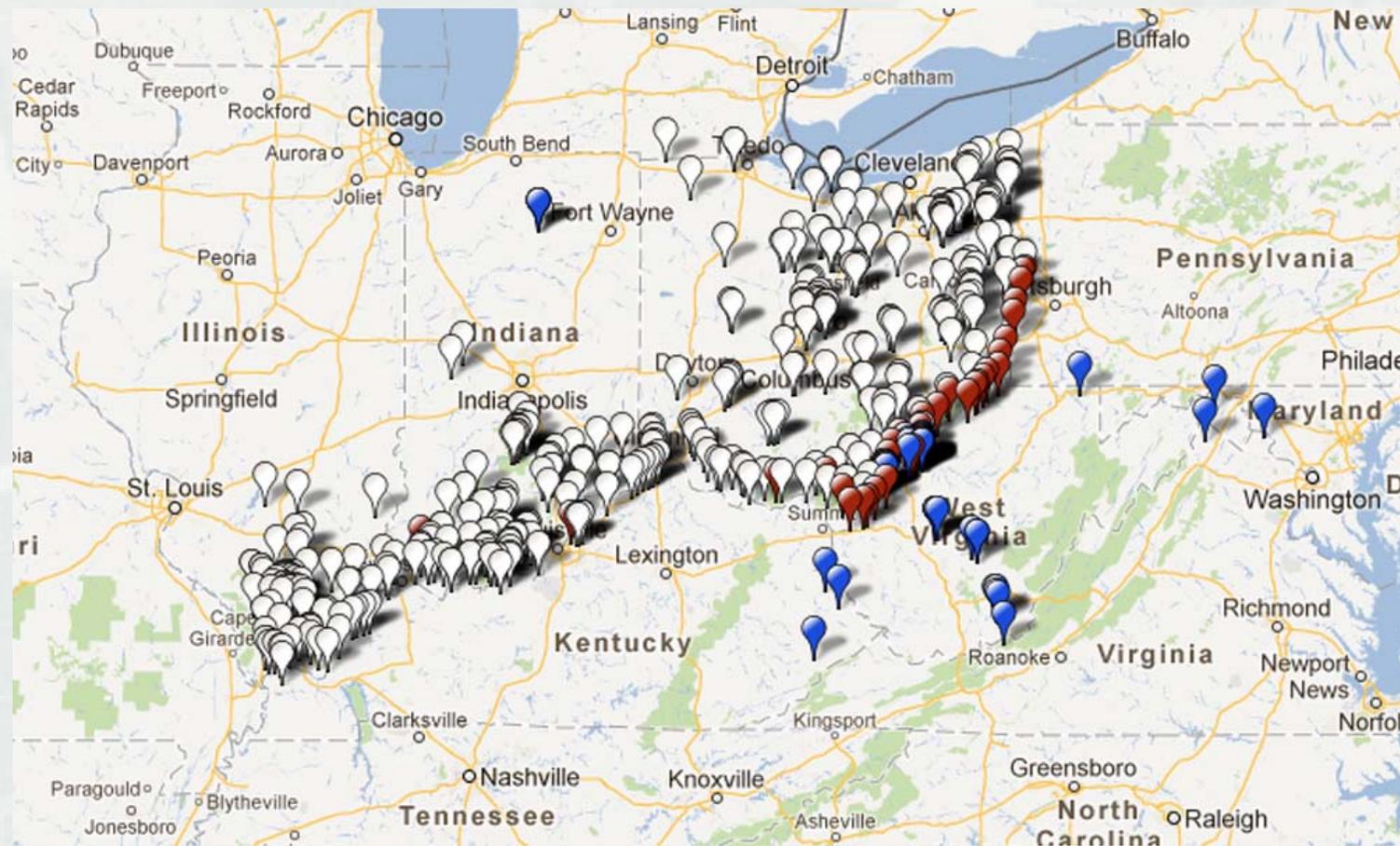
Monoecious Hydrilla on the Ohio River



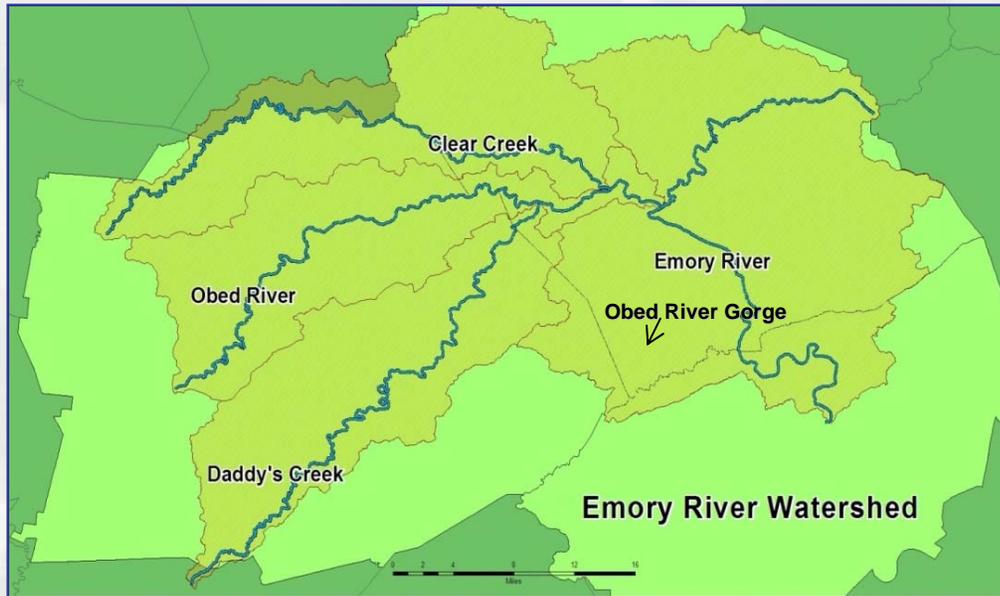
“The entire river has not been mapped for hydrilla, but hydrilla grows in thin patches along most of the river shoreline in Ohio to at least 4 ft deep with occasional thick dense populations”



Central Hardwoods Invasive Plant Network (CHIP-N) Joint Aquatic Invasive Species Survey



Monoecious Hydrilla



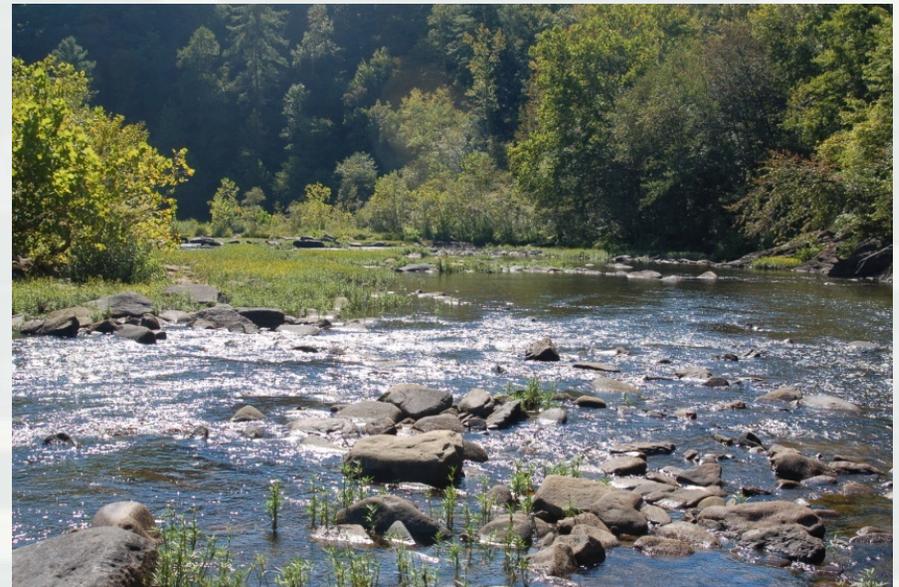
- **Obed Wild and Scenic River (OWSR)**
 - ▶ National park located along the Cumberland Plateau
 - ▶ Morgan and Cumberland Counties
- **Protects ~ 42.5 river miles of the Emory River Watershed (ERW)**



Locations

Wild and Scenic Rivers in TN and NC

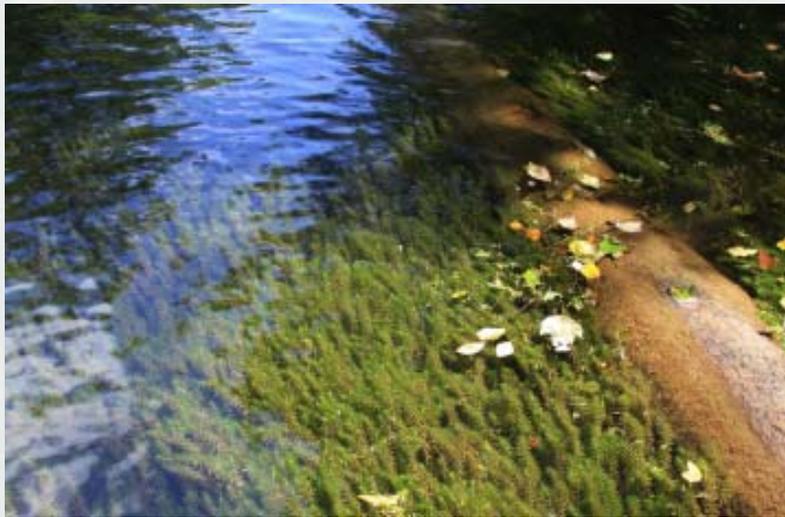
- Considered a threat to unique macroinvertebrate and fish communities



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Hydrilla in odd places

- **Identified infested areas within the ERW**



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Results: Substrate & Water Depth

- ***Hydrilla* grows well in a variety of substrate types – found in 54 River miles**
 - ▶ **Best adapted to cobble, sand and detritus**
 - ▶ **Poorly adapted to bedrock and large slabs**
 - ▷ Rooted between large boulders in sand-filled crevices
- ***Hydrilla* withstands a variety of water depths**
 - ▶ **Abundance varied in water depth**
 - ▷ **Commonly observed waters a few inches to 8 feet**



BUILDING STRONG®

Colonized unique stream habitat

High quality river system

Large boulders and high gradient

Fast-flowing water (100,000+ cfs)

Numerous whitewater rapids



Monoecious Hydrilla – A Reservoir Specialist ?

- Significant infestation of reservoirs in SC, NC, and VA (TN, KY)
- If it is so bad – why don't we hear more about it ?
 - ▶ Heavy use of GRASS CARP – (e.g. Duke Energy)
- Well adapted to drawdowns
 - ▶ Displacing dioecious hydrilla in TVA systems



Monoecious Hydrilla as Habitat

- Aggressive Expansion in Chesapeake Bay and Abermarle Sound
 - ▶ Expansion restricted by salinity
 - ▶ Taking advantage of aggressive growth traits
 - ▶ Helps recruit other native SAV
 - Sediment Stabilization and water clarity
 - ▶ Limited or no Management
 - ▶ Numerous Lake treatments slated for Delaware this year



Disturbance Specialist ?

- Monoecious Biotype
 - ▶ Tolerates much higher disturbance
 - ▶ Tuber sprouting synchronized with favorable growth conditions
 - Reduced flow/fluctuation and clear water
 - ▶ We know much less about monoecious hydrilla biology ?
 - So..... “wimpy cousin” or insidious invader ?



Why Should NY and NE Be Concerned ?

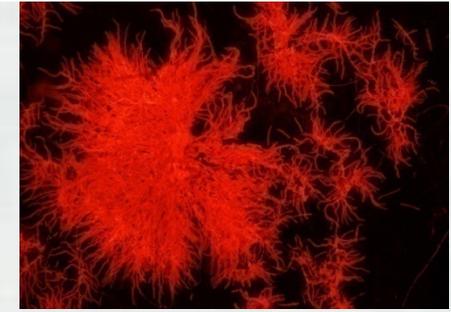
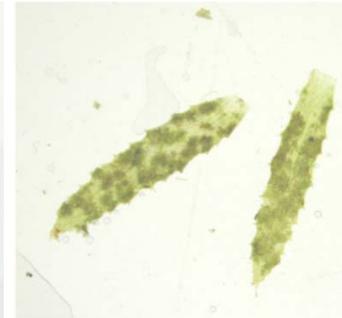
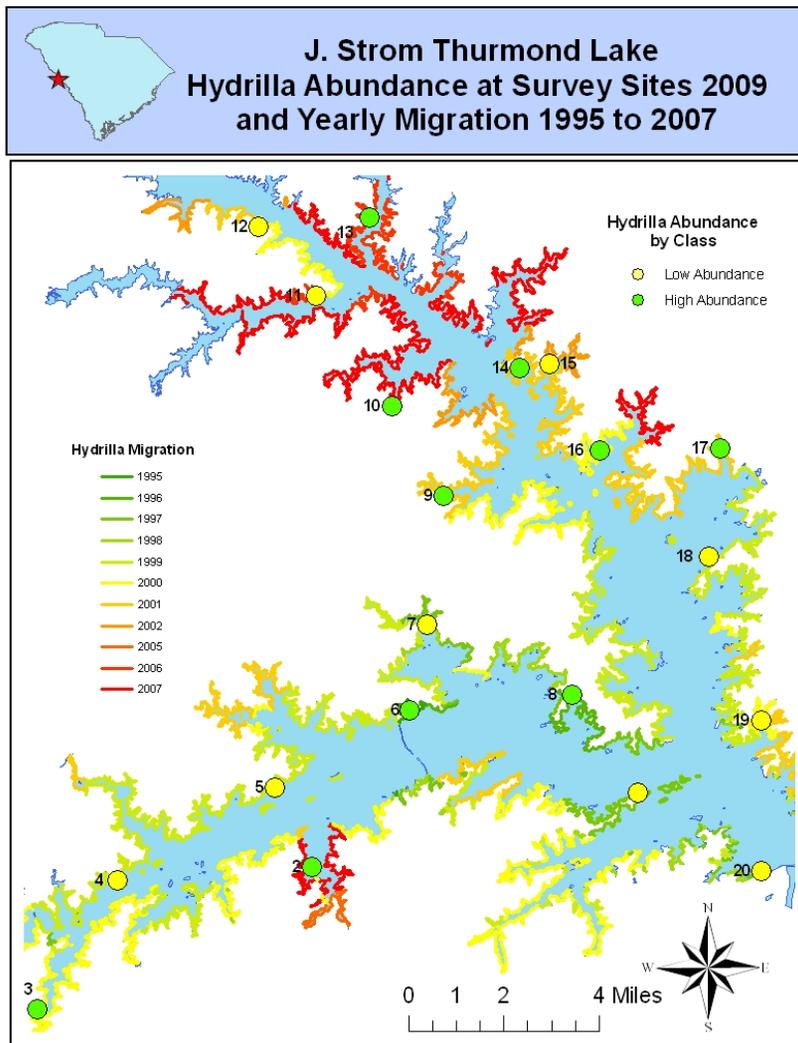
- Reliance on Grass Carp – Highly unlikely
- Performance in glacial lakes
 - ▶ Major Unknown
- Eradication Programs = 5+ years
- Disjunct Introductions are common/likely
 - ▶ Cayuga was just the lottery winner
- Riverine Establishment = > chance of natural lake introduction



Unintended Consequences of Hydrilla Growth



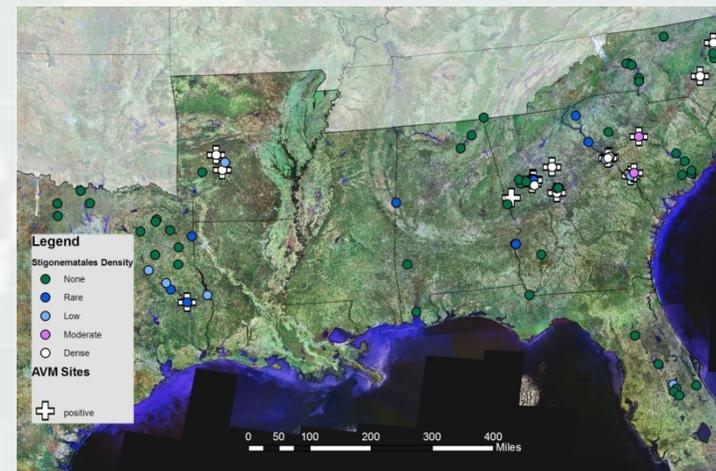
Unintended Consequences of Hydrilla Growth



Stignematalan algae – produces a novel toxin



8 eagle deaths in 2012



Water Birds Feeding on Hydrilla –

What happens if you get a serious toxic Stig bloom ?

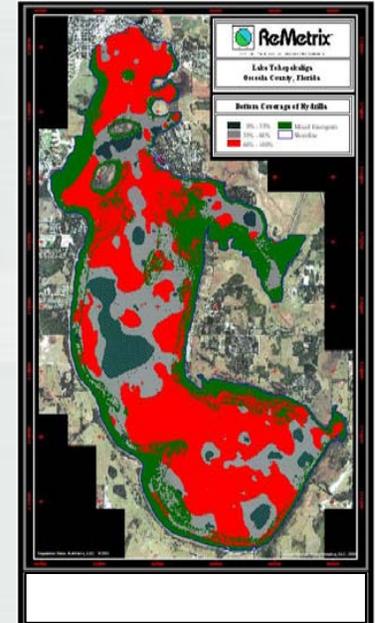




Kissimmee Chain of Lakes

- Headwaters- C&SF Flood Control Project
- Extensive hydrilla management

Photo by Rob Bennetts



**In a cruel twist of irony –
Florida DEP recently declared Lake
Toho impaired for Excessive
Macrophyte Growth (Hydrilla)**



Hydrilla in US

- Two separate introductions
 - ▶ Monoecious – Korean lineage (38th parallel)
 - Adapted to Northern Latitudes ?
 - ▶ Dioecious – Indian lineage – Southern strain
- Both are polyploids
- Both exhibit heterosis (hybrid vigor)
- “Might as well be two different species”



Hydrilla in China

- Recent proliferation of articles on hydrilla are being published by Chinese
- Lori Benoit (CT) – PhD Dissertation
 - ▶ Hydrilla in China is highly invasive but genetically distinct and highly differentiated from both US populations
 - ▶ Research Relevance to Monoecious Biotype ?
- Irony – Chinese are using hydrilla for vegetation restoration projects (Metals)



Hydrilla in Europe

- Single introduction of a diploid plant
- Not an “Aggressive Invader”
- Valued, but “rare component” of aquatic plant community
- European Literature would not be highly useful in predicting behavior of US polyploids



Lessons Learned in Life

- Aquatic Plant Scientists from New Zealand DO NOT appreciate it when you question their competence

- ▶ “Response of Hydrilla in New Zealand to the Herbicide Fluridone”

- ▶ They concluded that fluridone does not work on hydrilla at the rates used in the US.



Unknowns for Hydrilla in NE

- What is the greatest environmental constraint to hydrilla growth in NE waters ?
 - Seasonal Extremes (temp, flow, etc.)
 - Sediment Composition, Water Clarity
 - Remember – Variable Milfoil and Cabomba are southern imports
- Can hydrilla colonize, compete & proliferate in deep NE Lakes ?
 - Will it spread to unvegetated areas (e.g. FL ?)
- Will Monoecious Hydrilla be competitive ?





Only YOU can prevent the Spread of Hydrilla

The Hydrilla Warrior - Pulled from the Depths of a Maine Lake during Hydrilla Tuber Sampling for an Eradication Project



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Research

Past, Present, and Future



Monoecious Hydrilla

- Search of the UF Center for Aquatic and Invasive Plant Library
 - ▶ “Hydrilla” = 5099 records
 - ▶ “Monoecious Hydrilla” = 197 records
 - > 80 % are titles from Presentations
- Bottom Line
 - ▶ Very few published articles focusing on the Monoecious biotype in US



Past Research on Monoecious

- Florida – Steward, Van, Sutton - retired
 - CA – Spencer, Ryan, Anderson – retired?
 - MS – Barko – retired
 - NCSU – active program on Monoecious – Richardson
-
- Photoperiod differences, Tuber formation, Competition, Biotypes via DNA

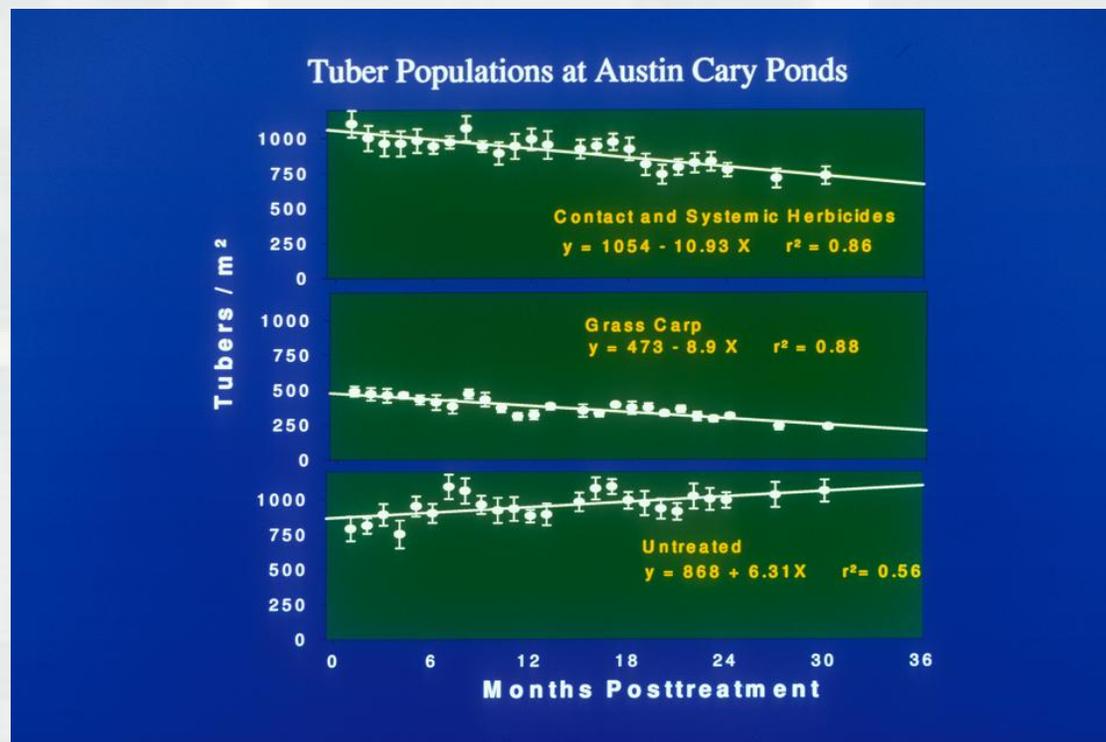


Sprouting Dynamics of Monoecious Hydrilla in the North –

- **KEY UNKNOWN**

Highly Relevant to Management

- **Synchronous = good** **Asynchronous = bad**



Northern Expansion ?

(Limited Information)

- Northern Expansion of Hydrilla (biotype considerations)
 - ▶ Van, Spencer, MacFarland, Langeland (No consensus)
- Peterson et al. 2003 – Predictive model – low invasive potential for hydrilla in MW & NE
 - ▶ Dioecious ?
- Maki & Galatowitz 2008 (MN) – turion survival
- Recent genetic work - Benoit 2012
 - ▶ Cryptic speciation = high variability



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Competition

- TVA - large-scale system with dioecious, monoecious, and Eurasian WM
- No studies under “Northern conditions”
 - ▶ Current trial at NCSU – funded by APMS

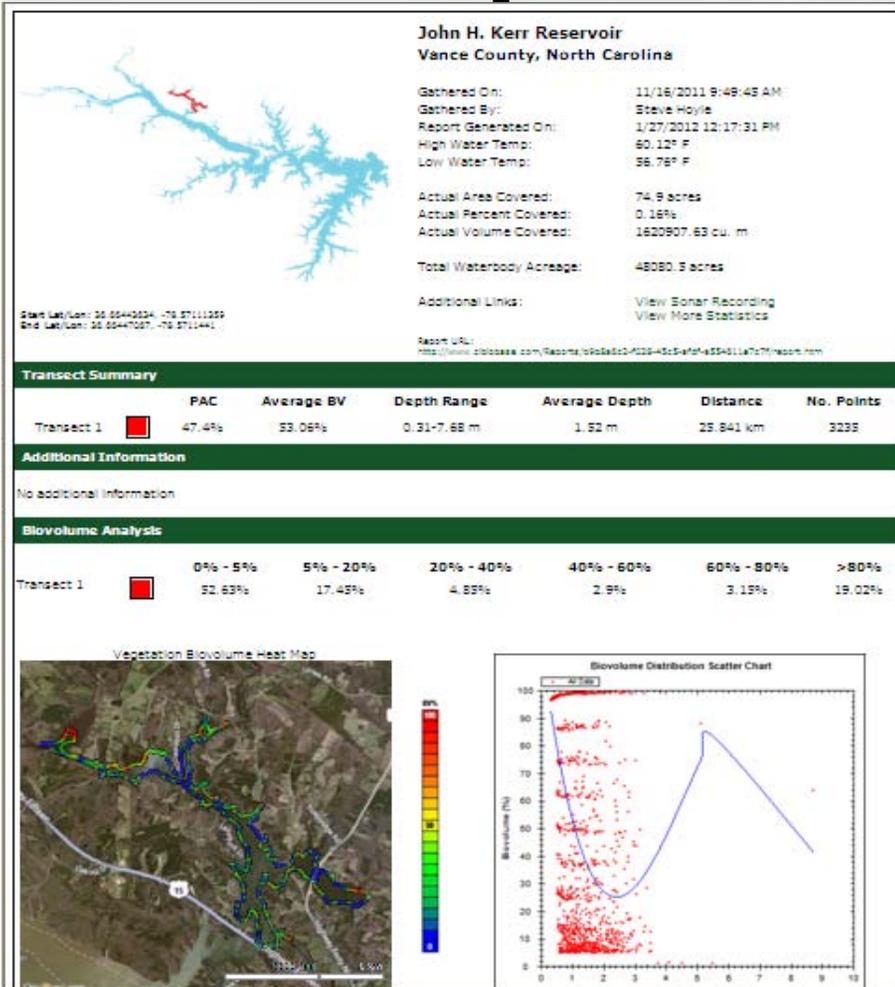


Herbicide Research

- 1 publication on diquat
- 1 publication on endothall
- 0 publications on fluridone – main tool for eradication
- 0 publications – newly registered herbicides
- Lake Gaston – fluridone- high exchange areas
 - ▶ Clear Lake – treat 5 acres around each find



Hydrilla Mapping – Lake Kerr – Corps Reservoir in NC/VA



- Mapped 900+ miles of Shoreline
- Mgmt. to be decided



Why Plant Biology Matters ?

What is it about Hydrilla that
Allows it to Grow to Such
Abundance ?

50+ years following hydrilla
introduction to FL – we are still
asking questions



DOES HYDRILLA GROW AN INCH PER DAY ?

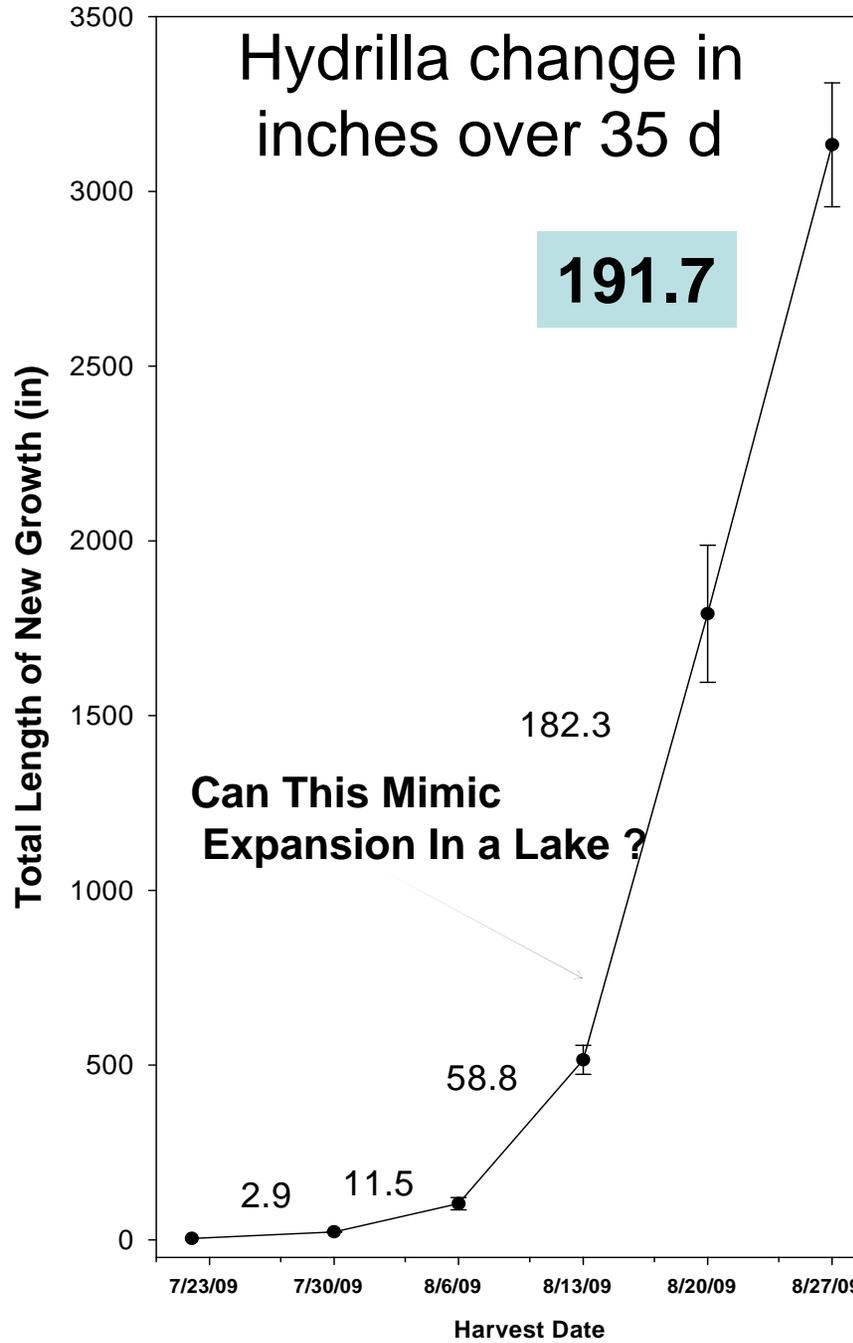
Field Observation – Rapid Change in Coverage (2 to 3 wks)

Single 4 inch stem planted – Growth measured for 35 day.
Plants were harvested weekly & measured for total length

Initiated in June – Favorable sediment nutrition



Hydrilla change in inches over 35 d



	Week 1	Week 2	Week 3	Week 4	Week 5
Laterals	2 ± 2	13 ± 6	43 ± 11	109 ± 29	127 ± 38
New Stems	2 ± 0	6 ± 1	34 ± 13	71 ± 16	110 ± 63
Runners	0 ± 0	1 ± 1	3 ± 2	9 ± 6	35 ± 20

- A single 4 inch shoot = over **3200 inches** of growth in 5 weeks

Illinois Pondweed = 277 inches

Vallisneria = 107 inches



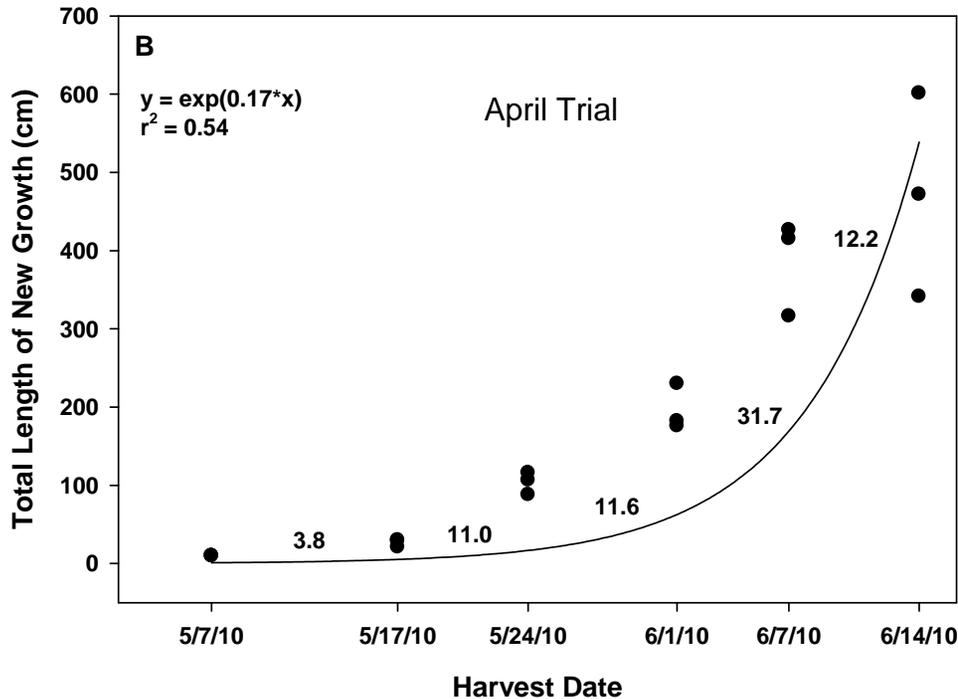
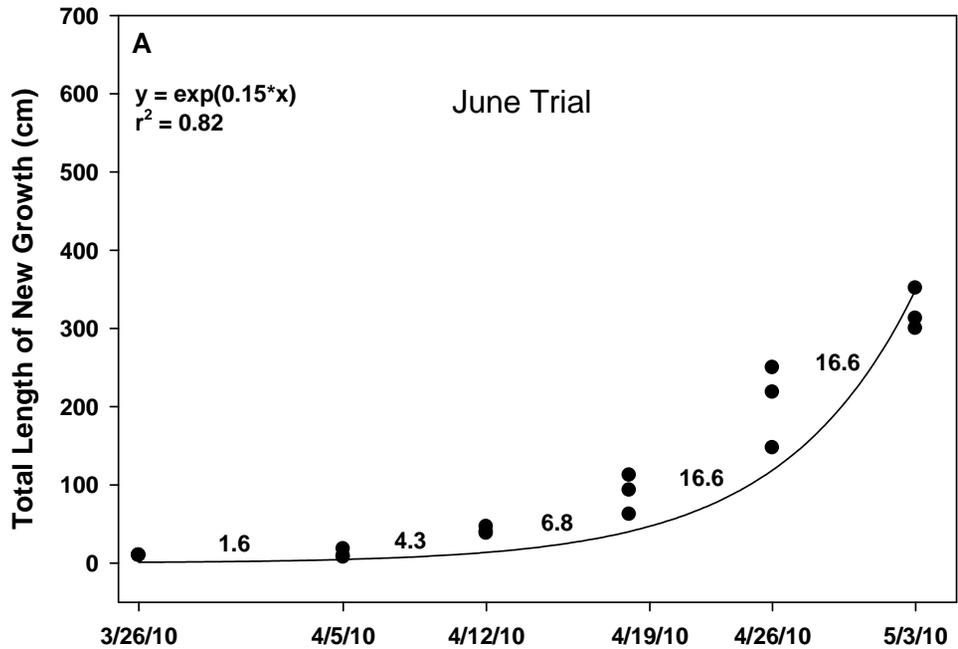
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Hydrilla

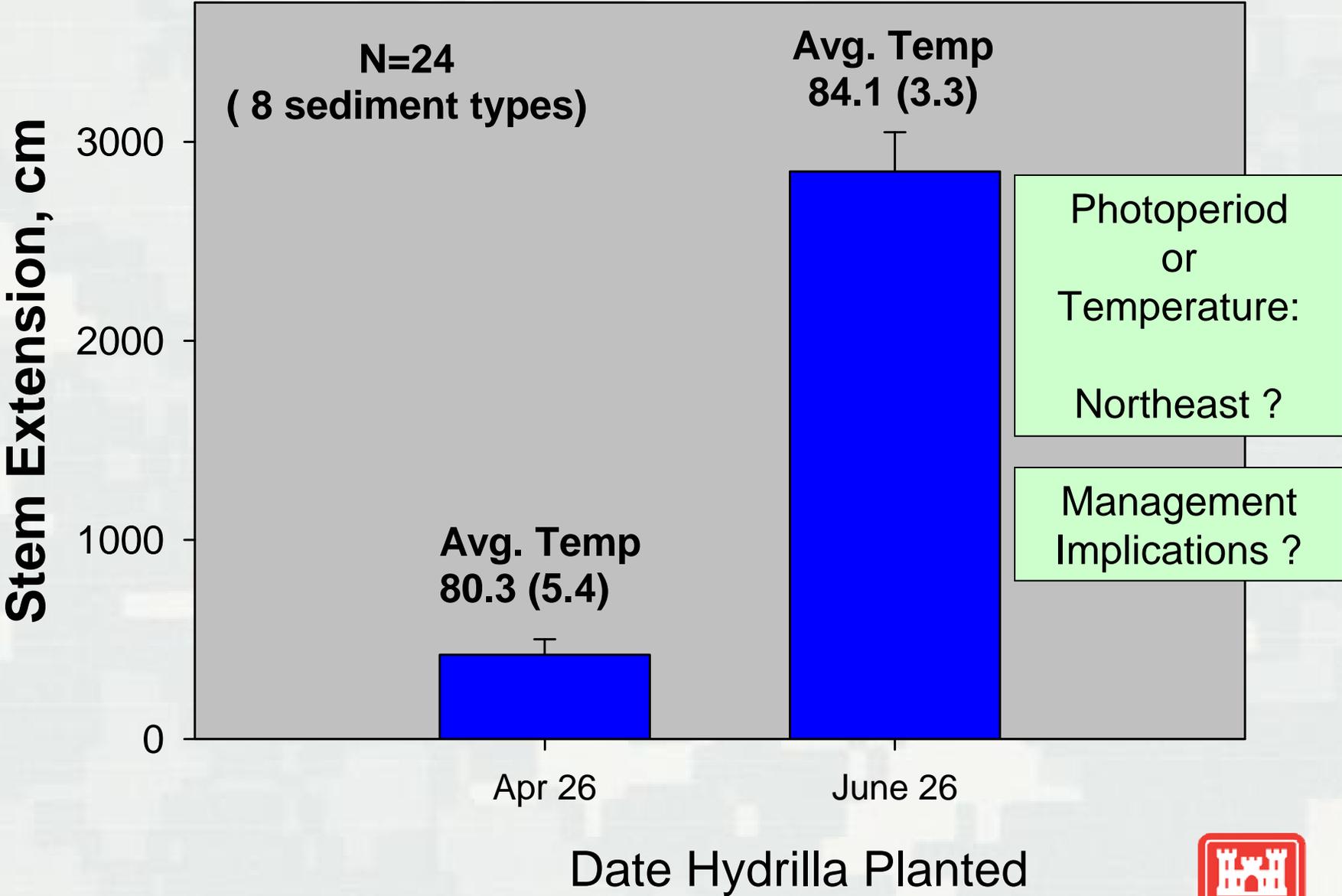


Eurasian Watermilfoil Growth 484 inches in 35 days

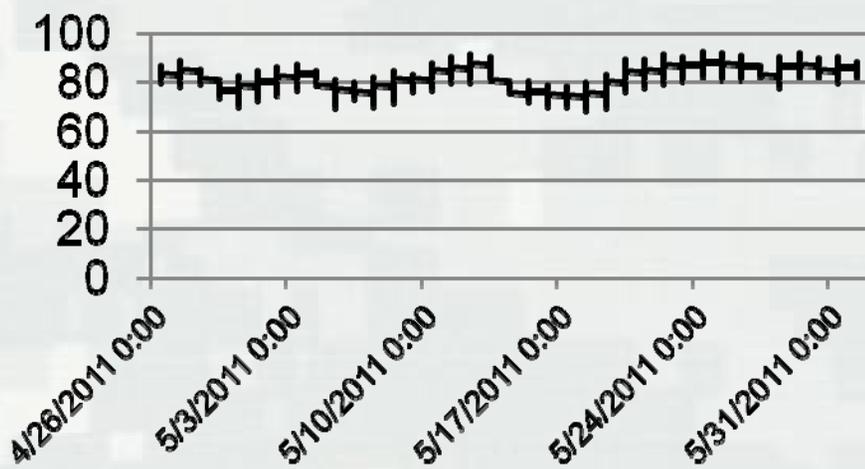
Order of Magnitude Less than
Hydrilla ? - Canopy former



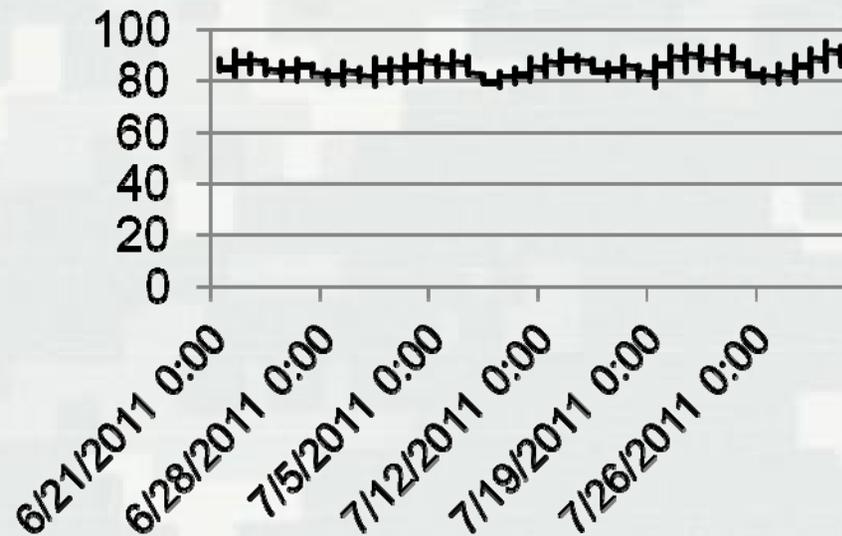
Growth of Hydrilla Over a 35 Day Period

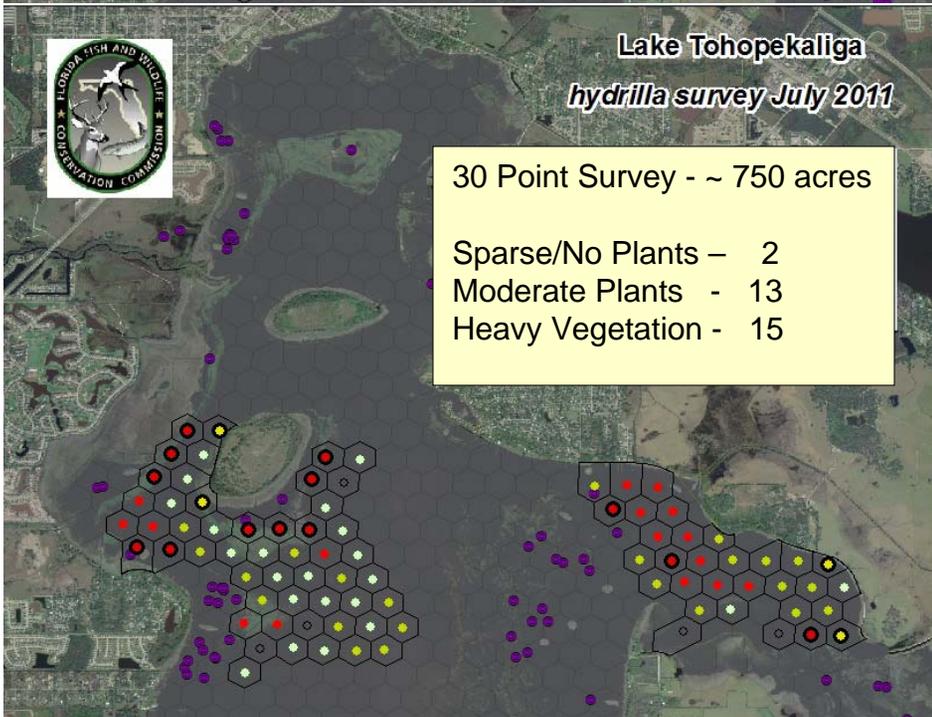
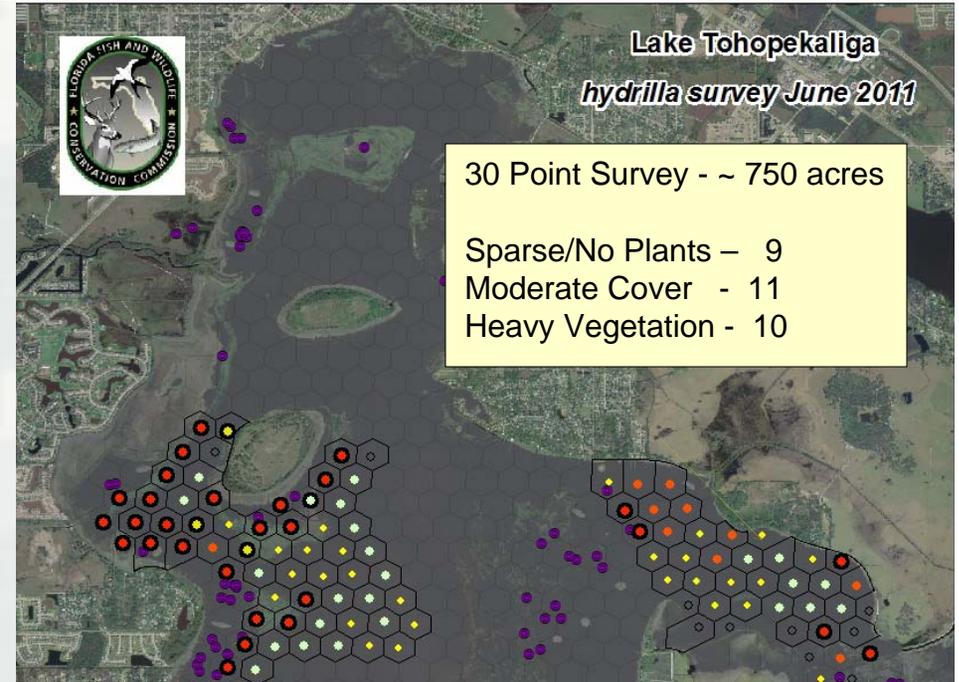
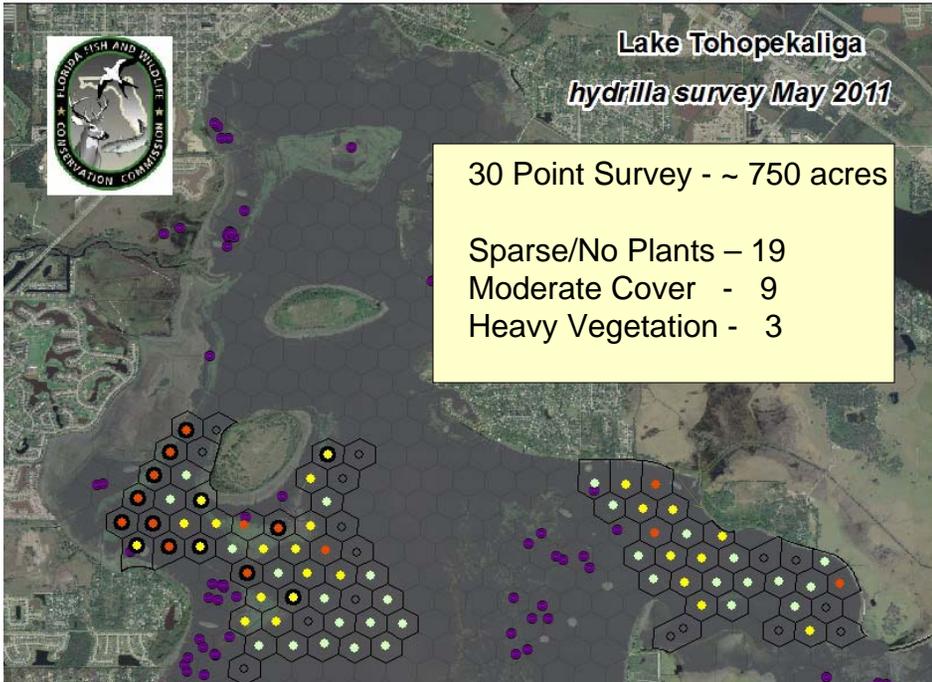


Study 1 – 80.3 ± 5.4



Study 2 - 84.1 ± 3.3





May 11 – 36 % Cover (Moderate to Dense)

June 11 – 70% Cover (Moderate to Dense)

July 11 - 94% Cover (Moderate to Dense)

August – 77% Dense Cover (26/30 sites)

10, 33, 50, 87



Research Points

- Many of the monoecious growth studies – FL and CA
 - ▶ **Conflicting information**
- Biocontrol – Hydrellia – may need overwintering biomass
- Limited herbicide information outside of fluridone – whole-lake



What Limits Hydrilla Growth ?

- “It’s the light”, stupid
 - ▶ Algal turbidity, suspended sediments
- Poor Sediment quality or nutrition
- Cyanobacteria blooms – toxins ?
- Herbivores – general and specialists
 - ▶ Grass carp, snails, etc.
- Consistent Management ?
 - ▶ Setting back the clock



Hydrilla Summary

- Eradication Plans
 - ▶ Limiting the Biomass is Most Critical Component in Preventing Spread
- Educate the Fisheries Groups NOW !
 - ▶ If mindset that hydrilla promotes fisheries prevails – We will be able to answer the question of hydrilla competitiveness
- Multiple sources of introduction are now likely



Is Eradication a Reasonable Strategy ?

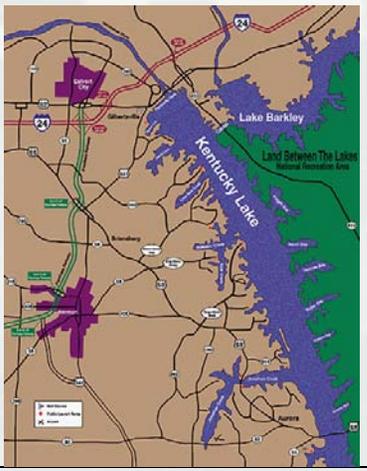
Lake Gaston, NC



Plants move from large to small water bodies and vice versa



Small Landscape Pond



Hydrilla in Wisconsin Pond – Response by DNR

Positive i.d. in fall of 07



Completely drained pond for
winter drawdown



Spring 08- refilled and
treated with fluridone



Why such a strong response ?
Where did the hydrilla come from ?

California – Eradication Policy

- Ongoing Eradication efforts for 30+years
 - ▶ concern = agricultural irrigation
- Aggressive and Immediate Action
- Clear Lake (~ 40,000 acres)
 - ▶ Eradication policy
 - ▶ Treat 5 acres around individual plant finds
 - ▶ Poor Economics on an acre basis / Good overall Policy ?
- Nationwide Eradication projects > 6 years



Management Options Are Limited

Selective Biocontrol



Cross-Country 25 Reservoir



Environmental Extremes

