GREAT LAKES HYDRILLA COLLABORATIVE

Linderman Creek
Cayuga Inlet NY (before management)

Management of Monoecious Hydrilla with Aquatic Herbicides

Technical Considerations and Future Outlook

Linderman Creek
Cayuga Inlet NY (after management)

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February 12, 2018

Management Principles

- It is **complex effort** needing **diverse expertise** and **clear picture of objectives, benefits, and risks**.
- **When first detected**, the main goals of treatment are to **remove the problem, physically or via chemical treatment**.
- **Chemical treatment** is usually the only way to **treat populations that have spread beyond the area of initial introduction**.
- **Specific treatment protocols** have been developed through **careful scientific experiments** to **ensure the safest and most effective care**.

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Management Principles

- Using **combinations of different chemical treatments** may help **eliminate the original detected population** and, at the same time, **eliminate individuals elsewhere in the system, even when there is not yet detection**.
- **Even when eradication is impossible**, **long-term impacts can often be relieved** with treatment that **improves quality** of the system**.**

MERCK MANUAL

Principles for cancer treatment

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Seminar Overview

- Monoecious Hydrilla…biology summary for management
- Aquatic herbicides for monoecious hydrilla management
- Technical considerations of an integrated program utilizing herbicides
- Future outlook on managing this invasive species

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AIS Management

- **Prevention**
  - Proactive, Cost Efficient, Education
- **Monitoring**
  - Consistent, Scalable, Sensitive, Quantitative
- **Early Detection and Rapid Response (EDRR)**
  - Rapid means Rapid…Fund and Be Ready
- **Control**
  - Biological, Mechanical, Chemical… Integrated as feasible
  - Eradication, or Containment / Maintenance
- **Restoration**
  - Re-Vegetation, Native Dominance, Maintenance

Hydrilla verticillata

'The Worst Aquatic Weed'

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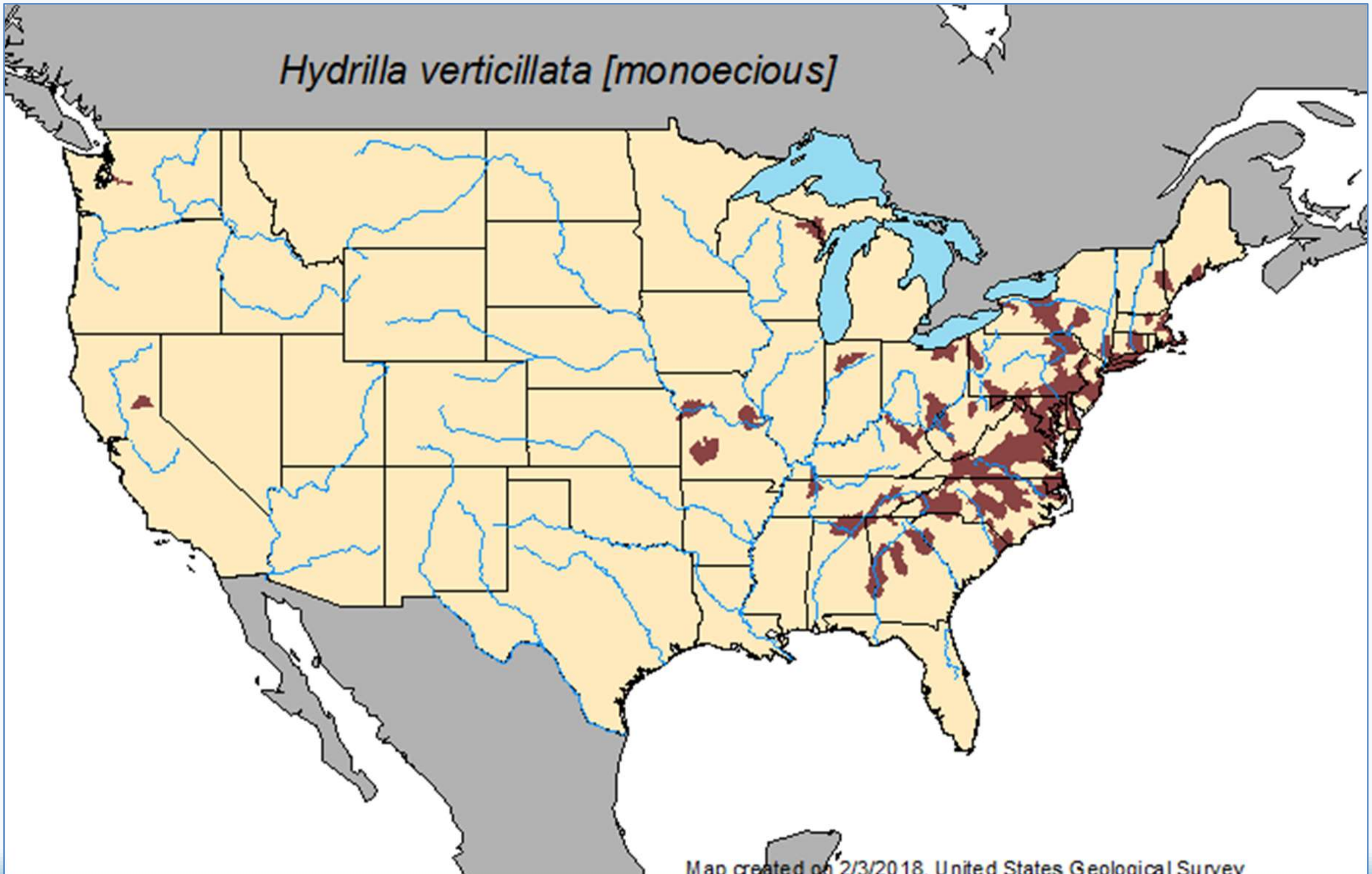
Hydrilla verticillata [monoecious]
Map created on 2/3/2018. United States Geological Survey

Control Methods for Hydrilla

- **Physical / Mechanical**
  - *Dredge or Fill*, Hand-Pull, Barriers, (Harvest – NO)
    - scale limited and expensive (at least low $1,000s / acre)
  - Seasonal Drawdown…acceptable/achievable?

- **Biocontrol**
  - Non-Selective and low cost: Sterile Triploid Grass Carp
  - Selective: No operational success to date
- **Chemical**
  - Aquatic Herbicides are predictable with better selectivity than carp and reasonable economics
    - $200 - $1,000/A + Application
  - Should be integrated (IPM) wherever feasible
  - Public perception…education
  - Limited technologies for hydrilla management

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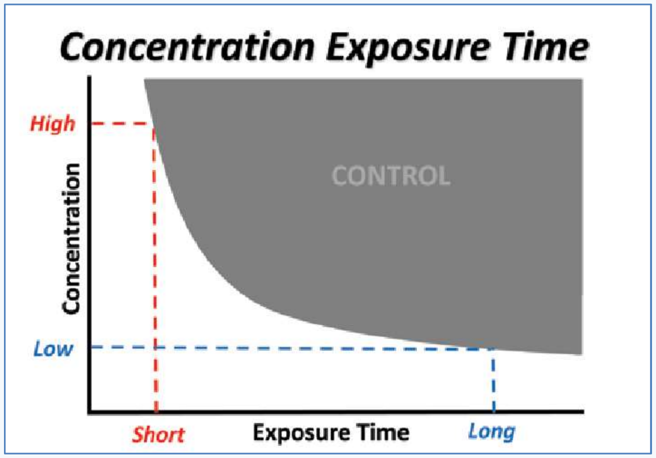
Aquatic Herbicides – Terminology

- **Concentration and Exposure Time** (Corps APCRP)
  - RATE NEEDED AND FOR HOW LONG TO ACHIEVE CONTROL
  - 80's – 90's research developed many CETs but refinement continues
  - Fundamental principle for characterizing in-water use
    - High rate with short exposure v. low rate with long exposure
  - CET relationships are unique by herbicide and by plant



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Aquatic Herbicides – Terminology

- **Short-term versus long-term control**
  - Short-term
    - removal of aboveground foliage or 'burndown'
    - high potential for recovery from belowground tissues within a few weeks
    - Require repeat treatments for season-long management
    - Typically short exposure (hours) with 'contact' herbicides
  - Long-term
    - Full control of root systems of target plants
    - Typically intermediate to long exposure (days to weeks) with 'systemic' herbicides

Aquatic Herbicides for Hydrilla

- **Registered herbicides <u>not used</u> for hydrilla**
  - Auxin-mimic herbicides
    - **2,4-D** (Navigate®, DMA®4, Sculpin®) and **triclopyr** (Renovate®)
    - Long-standing selective herbicides for control of Eurasian watermilfoil
  - **glyphosate** (Rodeo® FAS)
  - **imazapyr** (Habitat ®) (ALS)

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Aquatic Herbicides For Hydrilla

- **‘Contacts’ for short-term control or ‘burndown’**
  - **copper**
    - broad-spectrum contact herbicide for spot treatment of hydrilla
    - most common algaecide **$CuSO_4$** but more commonly **chelated copper** herbicides (e.g., Komeen®, Nautique®)
    - Chelated products show less, product-specific, non-target toxicity than $CuSO_4$ (e.g., Closson and Paul 2014)
    - Granular versus liquid delivery (granular examples: Komeen Crystal and Harpoon® Granular)
  - **diquat** (Reward®)
    - Broad-spectrum, affected by water quality
    - Commonly combined with copper for better, more consistent activity
  - PPO inhibitors - **carfentrazone-ethyl** (Stingray®) and **flumioxazin** (Clipper®)
    - Newer mode of action
    - less effective in higher pH waters due to hydrolysis and better in high light
    - Limited use in combination with diquat

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Aquatic Herbicides for Hydrilla

- **‘Systemic’ or long-term control options**
  - **<u>Short to intermediate exposure requirements</u> (days)**
    - **endothall** (Aquathol® – dipotassium salt)
    - **florpyrauxifen-benzyl** (**ProcellaCOR™**)**
  - **<u>Extended exposure requirements</u> (weeks to months)**
    - **fluridone** (Sonar®)
    - Other herbicides with hydrilla activity but no current use on monoecious hydrilla

      <u>ALS herbicides</u>
      - **penoxsulam** (Galleon®)
      - **bispyribac-sodium** (Tradewind®)
      - **imazamox** (Clearcast®) – unique growth regulation

      <u>HPPD inhibitor</u>
      - **topramezone** (Oasis) – good selectivity in lake-wide treatments

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Aquatic Herbicides for Hydrilla

- **endothall**
  - Registered 1960
  - Serine/threonine protein phosphatase inhibitor (Bajsa et al 2012)
  - Recent translocation findings with longer exposures (up to 8 days) (Colorado State - Ortiz et al. 2018 in prep)
  - Formulations
    - Liquid (Aquathol K - 4.23 lbs active as salt) or granular (Aquathol Super K – 63% active as salt)
      - Amine salt of endothall (Hydrothol®) is more toxic and less commonly used
  - 2 – 4 ppm use rates on hydrilla (rates as dipotassium salt) with exposures of 12 – 96 hours (Poovey and Getsinger 2010, Wood 2017 (UF Masters thesis with MD Netherland))
    - Indications of slightly extended exposure requirements for monoecious vs. dioecious

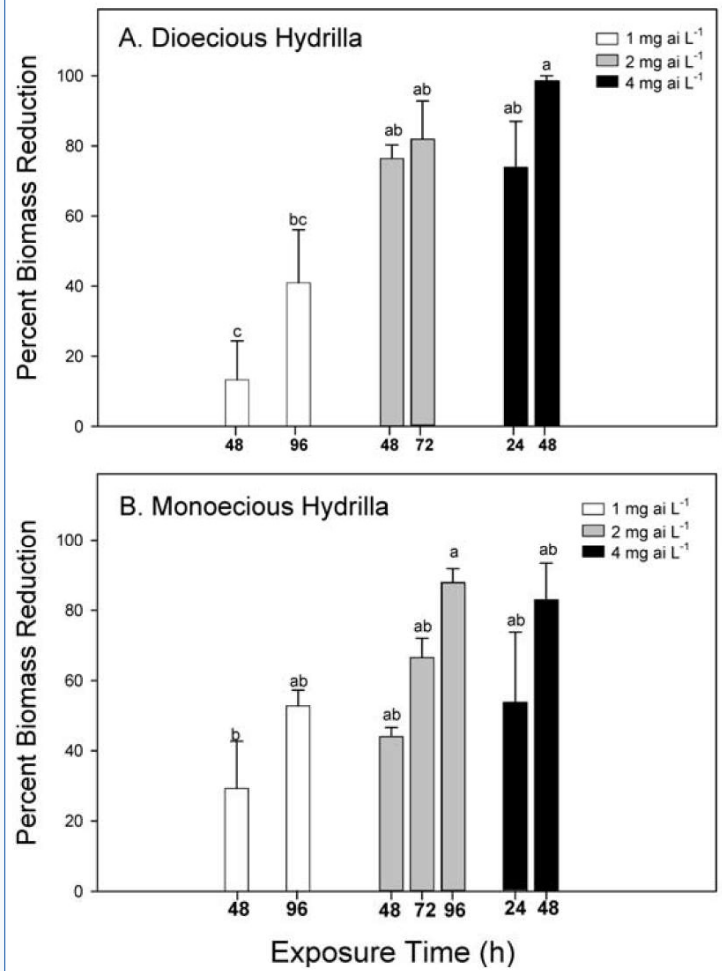
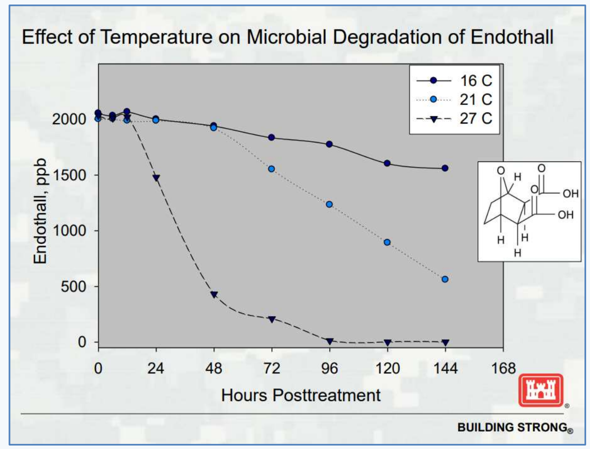
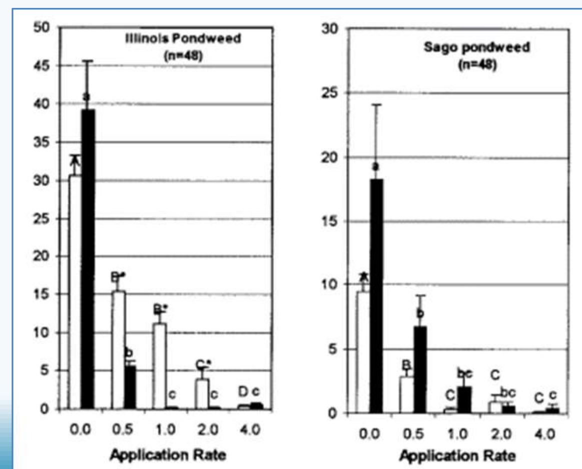


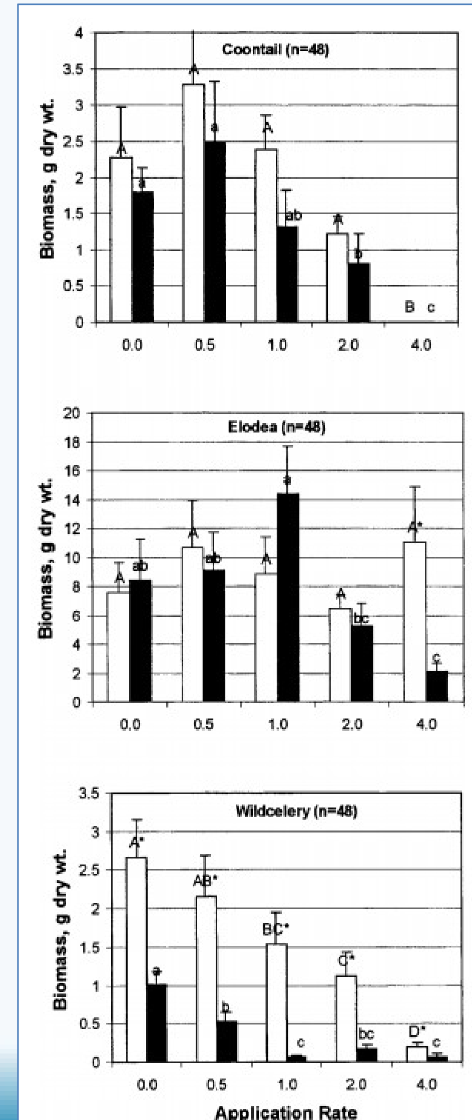
Figure 2. Percent biomass reduction of (A) dioecious and (B) monoecious hydrilla propagated from tubers 6 weeks following endothall applications of 1, 2, and 4 mg ai L^{-1} under various exposure periods (24, 48, 72, and 96 h). Means are ±1 SE ($n = 3$). Treatments different letters are significantly different for each biotype (S-N-K; $p \leq 0.05$). **(from Poovey and Getsinger 2010)**

Aquatic Herbicides for Hydrilla

- **endothall**
  - Microbially degraded and better activity in colder water
  - Partial selectivity depending on non-target species, CET, site conditions and use pattern
    - Skogerboe and Getsinger 2002
  - Combination use with several other herbicides





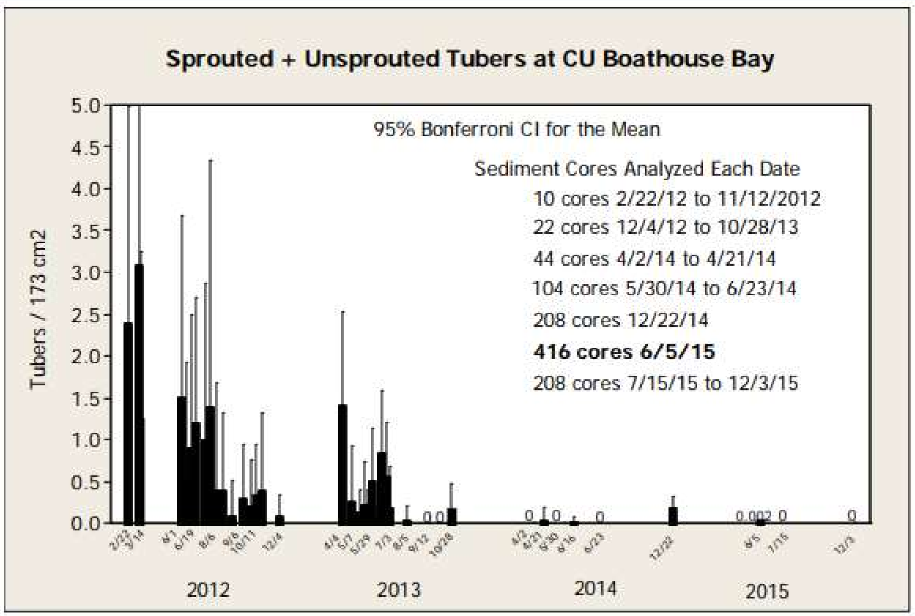


Plant response figures from Skogerboe and Getsinger 2002

Endothall project examples

Sequenced with Sonar (fluridone) for successful management in Cayuga Inlet (Cayuga Lake NY) 2012 – 2015

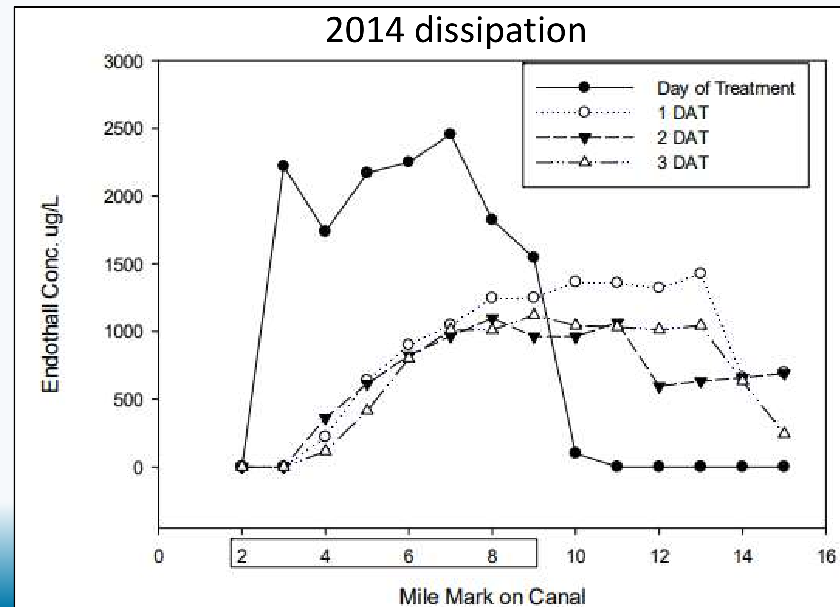
- http://ccetompkins.org/environment/invasive-nuisance-species/aquatic-invasives/hydrilla/fighting-hydrilla-in-the-cayuga-lake-watershed



Endothall project examples

Boat applications to Erie Canal – Tonowanda USACE-Buffalo, APCRP 2014 - ongoing

- http://erie.cce.cornell.edu/invasive-species/wny-hydrilla-project



Endothall – Erie Canal

- Excellent hydrilla control with tuber density reductions near 99% in heavily-infested areas following multiple seasons of treatment.
- Initial 2014 application produced strong native plant reductions but improved selectivity in subsequent, reduced intensity treatments.
- Stubborn small patches persist in several areas and additional strategies to attack those locations planned in 2018.

Native Plant Frequency of Occurrence

	Jul 2014	Sep 2014	Jul 2015	Sep 2015
Native submersed macrophytes (% Frequency of Occurrence)				
coontail (Ceratophyllum demersum)	35	4	5	7
wild celery (Vallisneria americana)	63	8	7	7
water star-grass (Zosterella dubia)	14	4	1	2
fragrant water-lily (Nymphaea odorata)	11	4	6	8
elodea (Elodea canadensis)	0.1	0.2	4	8
Potamogeton species (Potamogeton)	0	0	0.4	2
Number of sample points	1389	1793[1]	1439	1245

Species Richness Increased from 2014 to 2015

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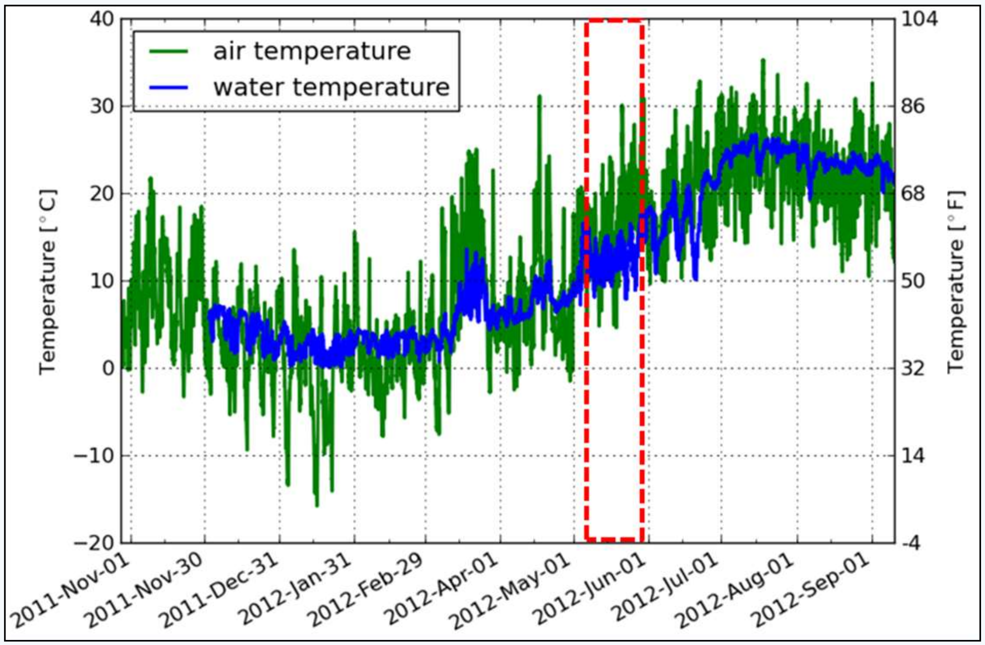
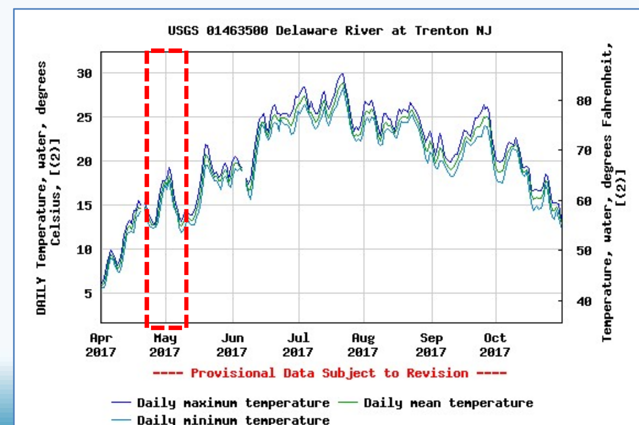
Aquatic Herbicides for Hydrilla

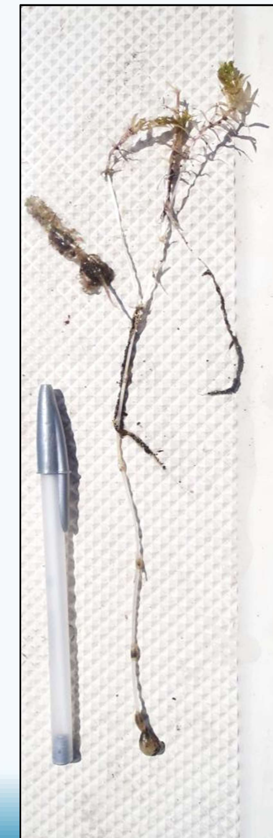
- **fluridone (Sonar®)**
  - Large-scale / whole lake / pond / partial management of Hydrilla, Eurasian watermilfoil, curly-leaf pondweed, others
  - Focus of monoecious hydrilla eradication programs since 1990s (e.g. CDFA)
- **mode of action**
  - PDS Inhibition ('bleacher')
- **target concentration**
  - 1 – 3 ppb: early-stage treatment (Netherland 2015: EC90 >2 ppb)
  - 3 - 5 ppb: mature biomass reduction
    - rate and speed of control correlated but threshold response much above 5 ppb.
- **exposure for control of monoecious hydrilla**
  - 6 – 12 weeks depending on rate, establishment and conditions
  - Season-long, low-dose exposure most common use pattern today
    - addresses 'indiscriminate' tuber germination (4+ week 'tuber-to-tuber' cycle)
  - Extended release pellet formulations (One 5% ai and Sonar H4C 2.7% ai) efficiently maintain low-level exposure in target zone

Monoecious hydrilla management using Sonar (fluridone)

- Initial germination ~15C is optimal start time







Example of Sonar pellet use
Deep Creek Lake, MD

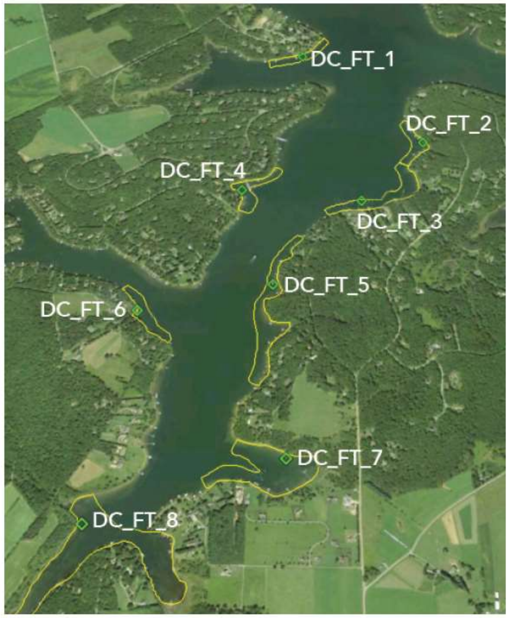


Figure 3. Deep Creek Lake treatment areas and FasTEST® sampling stations.

	ppb Sonar							
	18-Jun	**25-Jun**	**10-Jul**	**16-Jul**	**30-Jul**	**5-Aug**	**25-Aug**	**15-Sep**
DC_FT_1	<1	<1	1.1	<1	<1	<1	<1	<1
DC_FT_2	<1	<1	1.4	1.3	<1	1.1	1.4	1.5
DC_FT_3	<1	<1	1.8	1.1	1.2	1.0	1.1	1.7
DC_FT_4	<1	<1	<1	1.1	1.4	1.0	1.0	1.2
DC_FT_5	<1	1.1	1.0	<1	1.8	1.2	1.6	1.4
DC_FT_6	<1	1.0	1.5	2.1	1.7	1.4	1.1	1.7
DC_FT_7	<1	1.2	1.8	1.3	1.8	2.3	2.4	1.8
DC_FT_8	<1	1.0	1.3	1.5	1.7	2.1	1.5	1.4

Treatment dates: June 11, July 2, July 21, August 11, September 3

Table 1: FasTEST analytical results for eight sampling stations sampled during the 2014 Deep Creek Lake Sonar treatment. Samples were collected one foot off the bottom at locations ranging from 5 - 8 feet deep.

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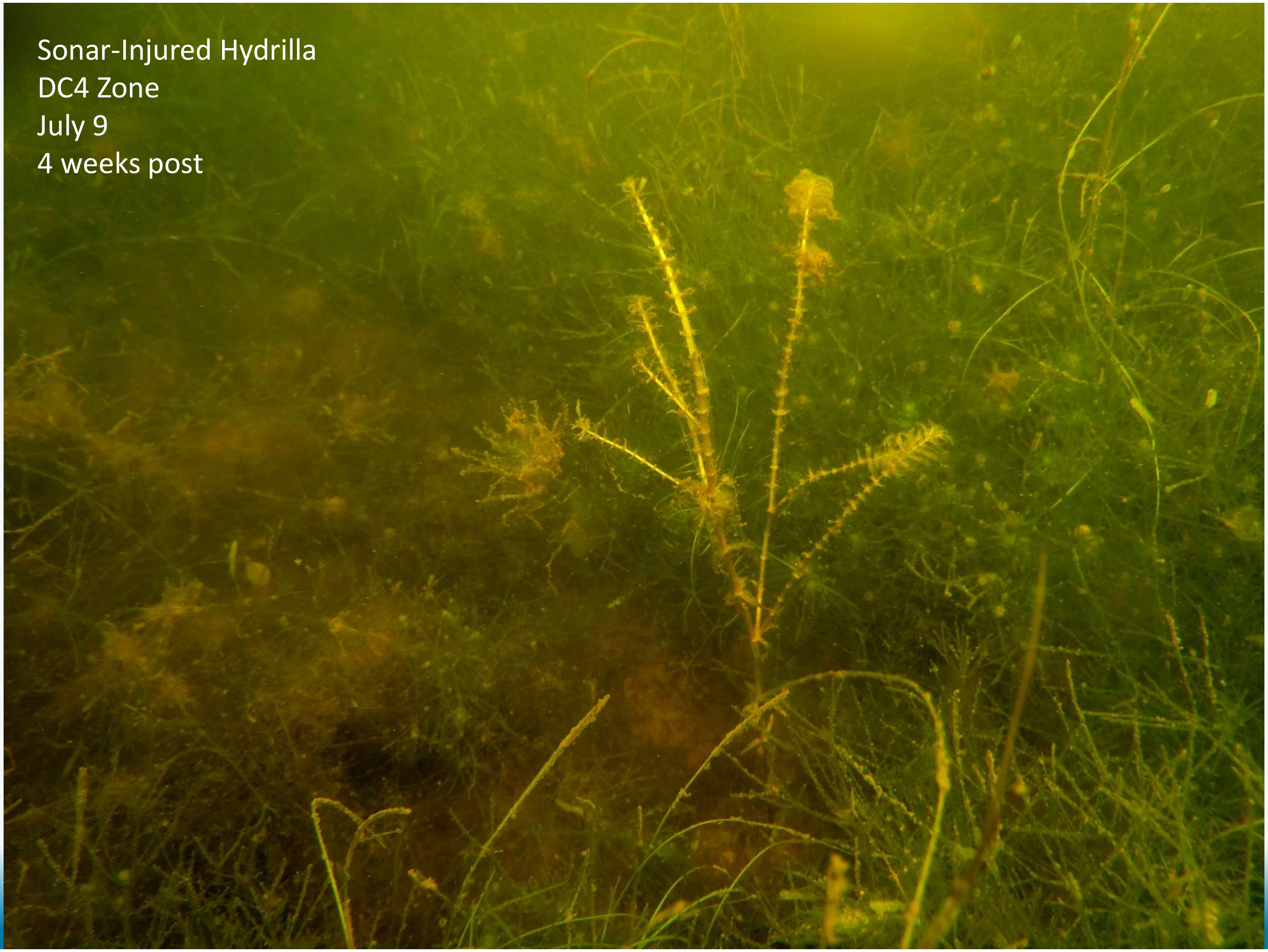
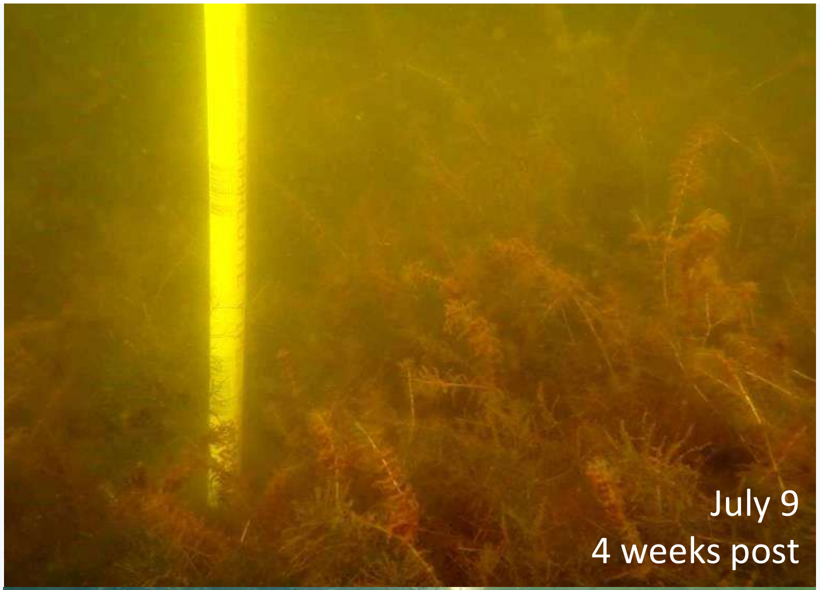
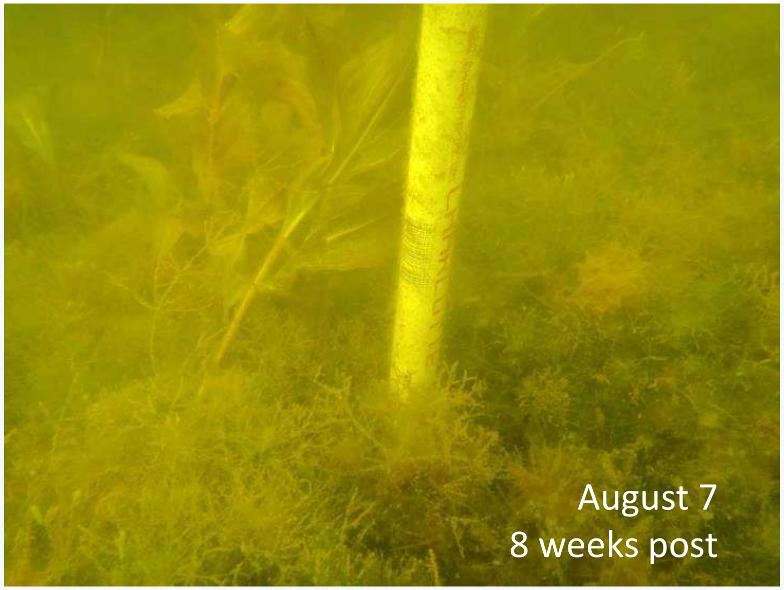

Sonar-Injured Hydrilla
DC4 Zone
July 9
4 weeks post





Progression of Deep Creek hydrilla control with Sonar pellets showing selectivity to native aquatic vegetation (tolerant large leaf pondweed)


Large Leaf Pondweed Canopy (7 ft plants)
Deep Creek Hydrilla Site
September 22
14 Weeks Post

Representative selectivity data: low-rate, season-long Sonar pellet use (Silver Lake, Waushara Cty, WI)

Lake-wide management example

86 acre littoral band of 360 total lake acres treated to maintain 1 – 2 ppb season-long concentrations for difficult hybrid Eurasian watermilfoil control

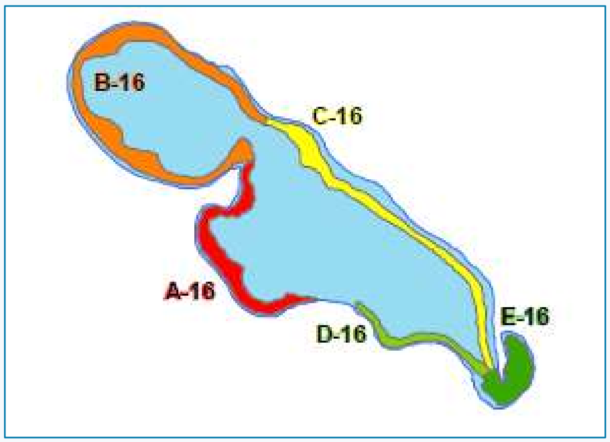
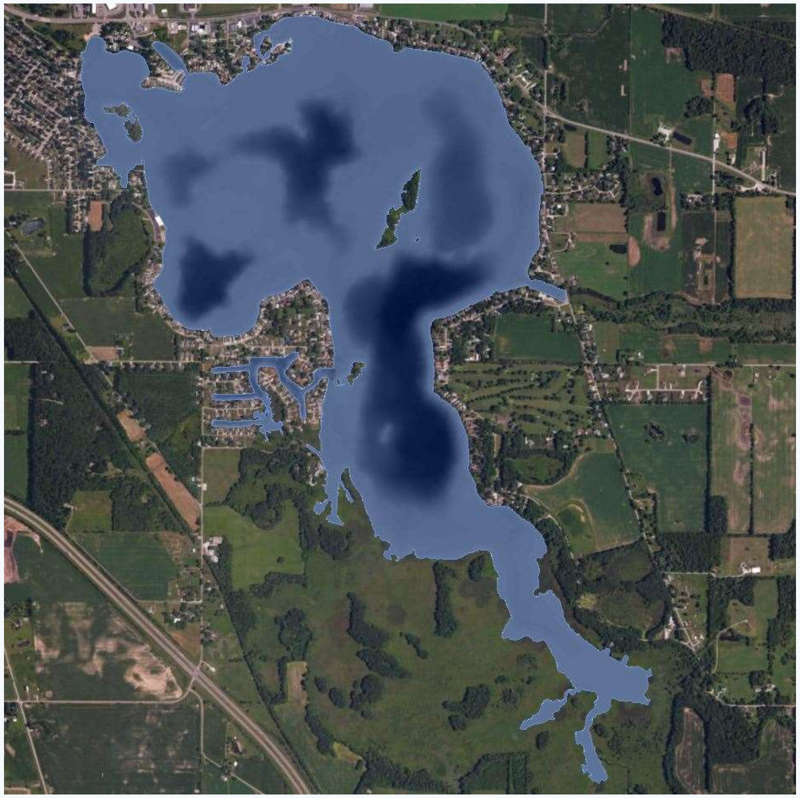


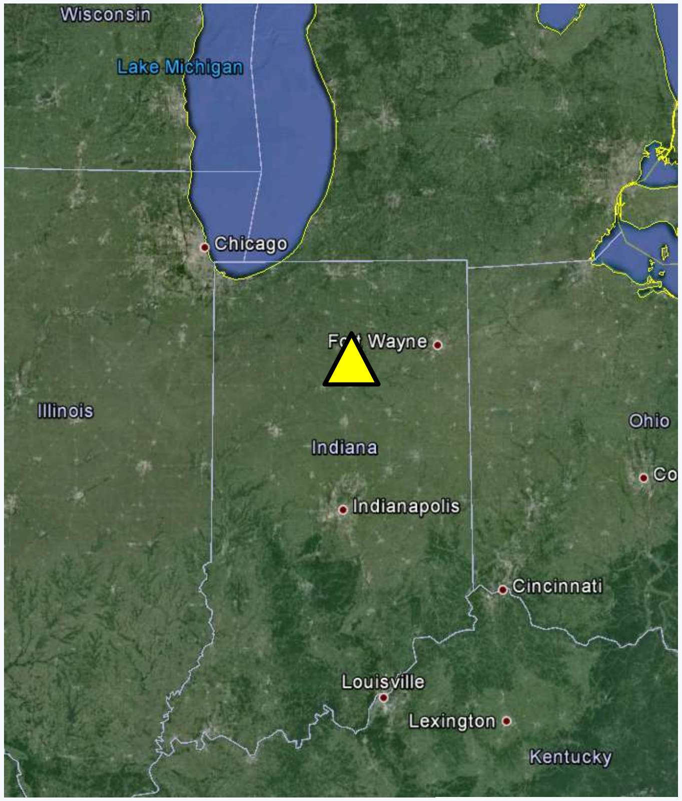
Table 1. Silver Lake Chi Square Analysis.

	Scientific Name	Common Name	LFOO (%) 2012	2013	2014	2015	2017	2015-2017 % Change	Direction
Dicots	*Myriophyllum spicatum*	Eurasian w atermilfoil	25.3	33.6	7.8	20.0	0.2	-98.9	▼
	Ceratophyllum demersum	Coontail	32.9	32.9	42.5	36.3	20.2	-44.3	▼
	Myriophyllum sibiricum	Northern w atermilfoil	0.6	5.4	0.7	0.2	0.0	-100.0	▼
	Bidens beckii	Water marigold	0.0	0.0	0.2	0.0	0.4		▲
	Ranunculus aquatilis	White w ater crow foot	0.0	0.0	0.2	0.4	0.0	-100.0	▼
	Ceratophyllum echinatum	Spiny hornw ort	0.0	0.0	0.0	0.0	0.2		▲
	Nymphaea odorata	White w ater lily	0.2	0.0	0.0	0.0	0.0		-
Non-dicots	*Potamogeton crispus*	Curly-leaf pondw eed	0.2	0.0	0.0	0.2	1.1	400.0	▲
	Chara spp & Nitella spp.	Muskgrasses & stonew o	33.8	25.1	30.0	23.9	25.7	7.3	▲
	Chara spp.	Muskgrasses	28.7	15.9	19.2	17.4	22.2	27.5	▲
	Elodea canadensis	Common w aterw eed	27.8	35.1	28.2	19.1	0.0	-100.0	▼
	Najas guadalupensis	Southern naiad	24.7	21.3	22.6	16.5	3.7	-77.6	▼
	Vallisneria americana	Wild celery	11.0	8.9	11.6	12.4	9.8	-21.1	▼
	Potamogeton gramineus	Variable-leaf pondw eed	20.7	13.6	10.7	11.1	3.5	-68.6	▼
	Nitella spp.	Stonew orts	8.0	9.4	11.4	8.5	3.7	-56.4	▼
	Stuckenia pectinata	Sago pondw eed	6.5	5.1	6.5	8.9	7.4	-17.1	▼
	Potamogeton friesii	Fries' pondw eed	2.1	3.4	2.2	11.7	4.6	-61.1	▼
	Filamentous algae	Filamentous algae	7.0	2.2	3.8	13.3	1.1	-91.8	▼
	Fissidens spp. & Fontinalis spp.	Aquatic Moss	5.5	10.1	7.4	4.8	0.0	-100.0	▼
	Potamogeton praelongus	White-stem pondw eed	4.6	4.0	8.5	4.8	1.5	-68.2	▼
	Potamogeton zosteriformis	Flat-stem pondw eed	1.5	2.2	2.0	2.6	6.1	133.3	▲
	Potamogeton illinoensis	Illinois pondw eed	4.6	2.7	4.7	5.4	1.5	-72.0	▼
	Potamogeton pusillus	Small pondw eed	0.0	2.0	2.2	4.8	3.5	-27.3	▼
	Najas flexilis	Slender naiad	3.2	1.8	3.8	3.0	0.0	-100.0	▼
	Potamogeton foliosus	Leafy pondw eed	3.6	0.2	2.9	0.7	1.7	166.7	▲
	Heteranthera dubia	Water stargrass	0.6	0.2	0.2	0.0	2.4		▲
	Potamogeton strictifolius	Stiff pondw eed	0.0	0.0	0.0	0.0	1.5		▲
	Potamogeton natans	Floating-leaf pondw eed	0.0	0.7	0.4	0.9	0.0	-100.0	▼
	Eleocharis acicularis	Needle spikerush	0.0	0.0	0.2	0.7	0.4	-33.3	▼
	Potamogeton amplifolius	Large-leaf pondw eed	0.6	0.0	0.7	0.0	0.0		-
	Spirodela polyrhiza	Greater duckw eed	0.0	0.0	0.0	0.0	0.4		▲
	Potamogeton spirillus	Spiral-fruited pondw eed	0.0	0.0	0.0	0.0	0.4		▲
	Elodea nuttallii	Slender w aterw eed	0.0	0.4	0.0	0.0	0.0		-
	Freshwater sponge	Freshw ater sponge	0.2	0.0	0.0	0.0	0.0		-

Data courtesy of Onterra LLC

Extended adaptive eradication: Manitou IN





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Extended adaptive eradication: Manitou IN

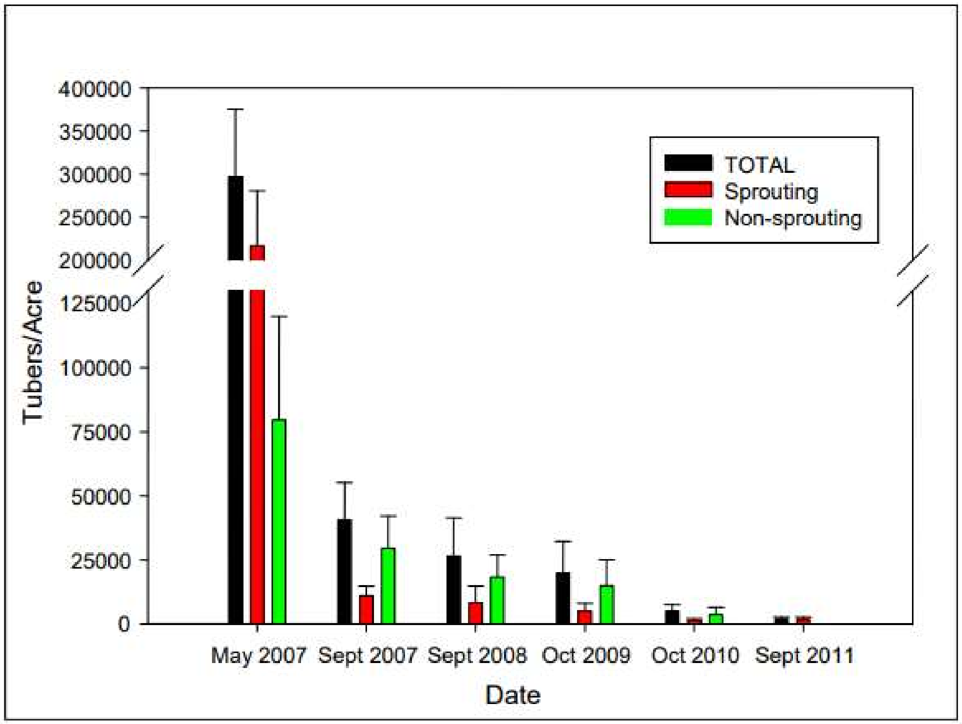
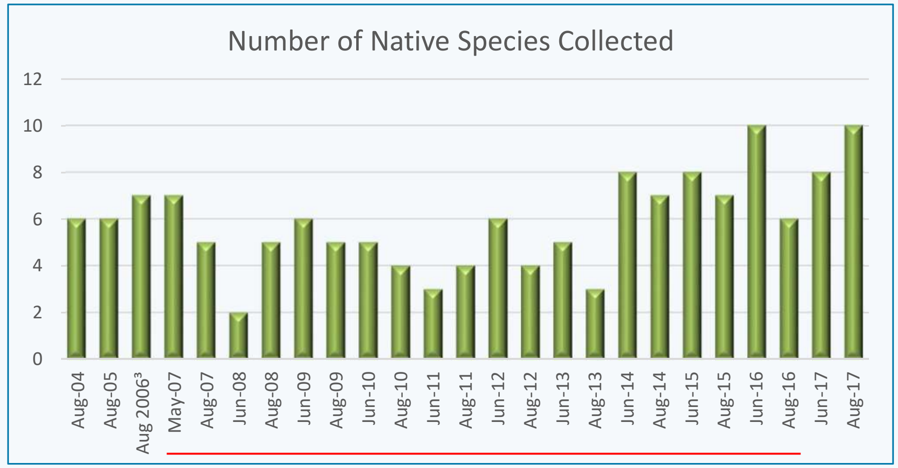
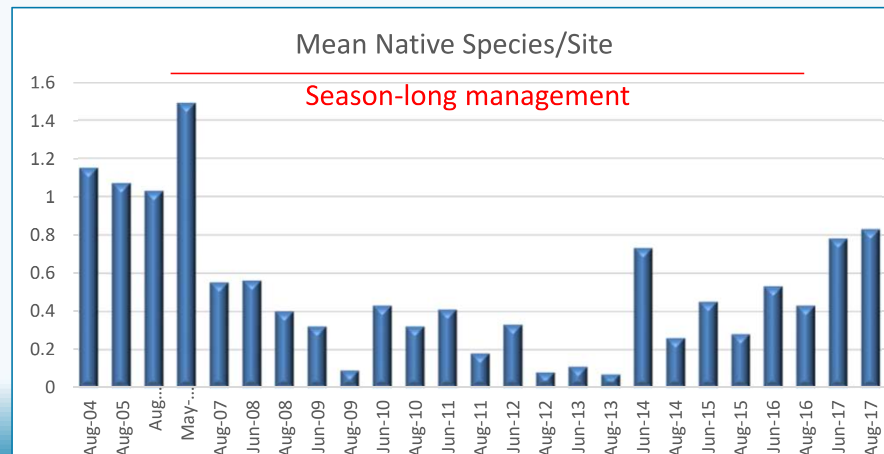


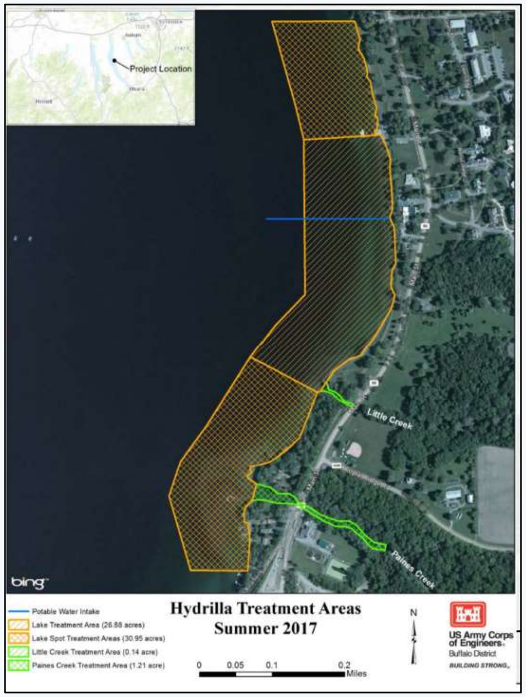
Chart 2.2.1. Overall changes in monoecious hydrilla tuber abundance in Lake Manitou following five consecutive years of Sonar treatments (spouting + non-sprouting = total).

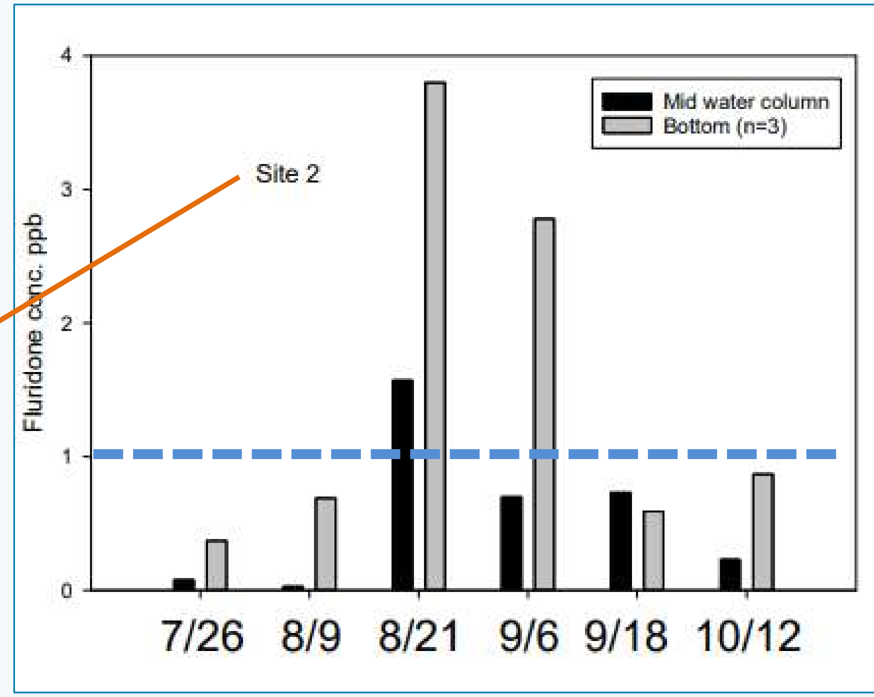




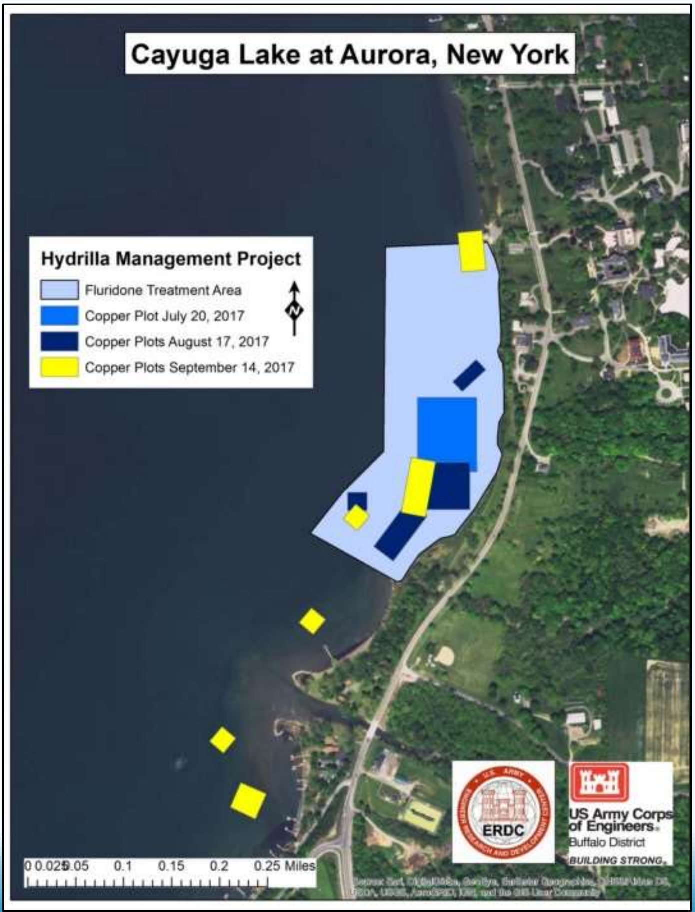
Diver surveys detect hydrilla through 2013; treatments continued through 2016

Localized hydrilla management (USACE Buffalo) Cayuga Lake (Aurora) - 2017





Aurora NY pelleted fluridone (Sonar H4C 2.7% ai) plus spot chelated granular copper (Komeen Crystal)



- <u>Sept 2016 to Sept 2017</u>
  96% reduction in hydrilla coverage
  (57% FOO to 2.4% FOO)
- Good diversity and biovolume of native plants
- 93% reduction in hydrilla tuber density from late June to mid Sept with no new tubers collected

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Liquid fluridone (Sonar Genesis) injection in flowing systems

- Examples: Eno River NC, Croton River NY, Delaware & Raritan Canal NJ

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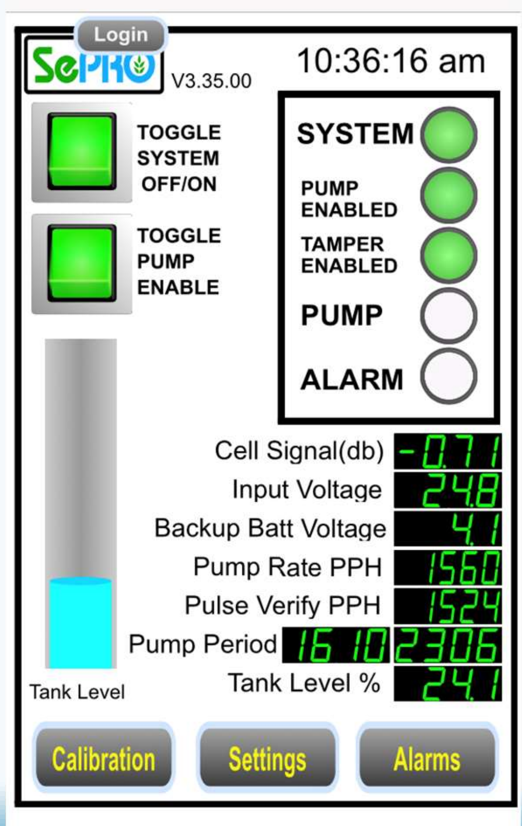
Cellular-controlled injection systems



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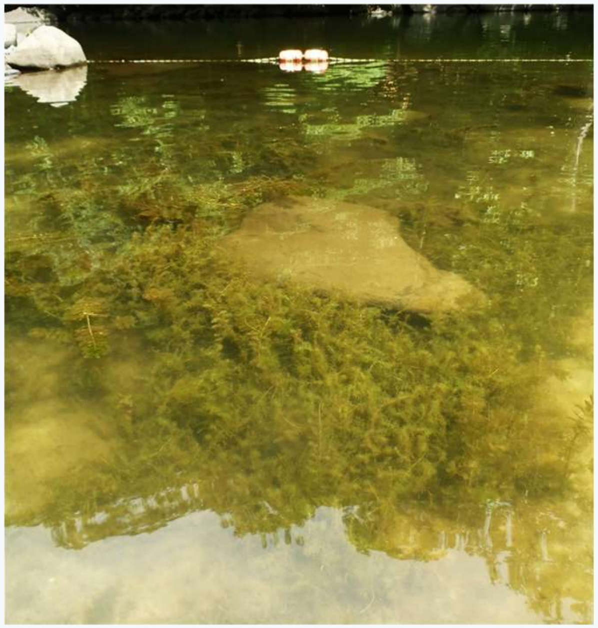
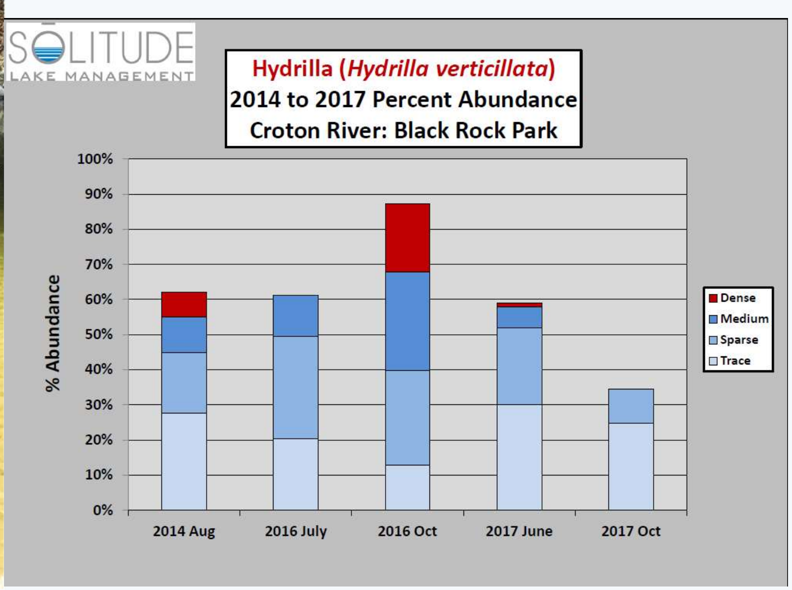
Sonar injection example: Croton River NY

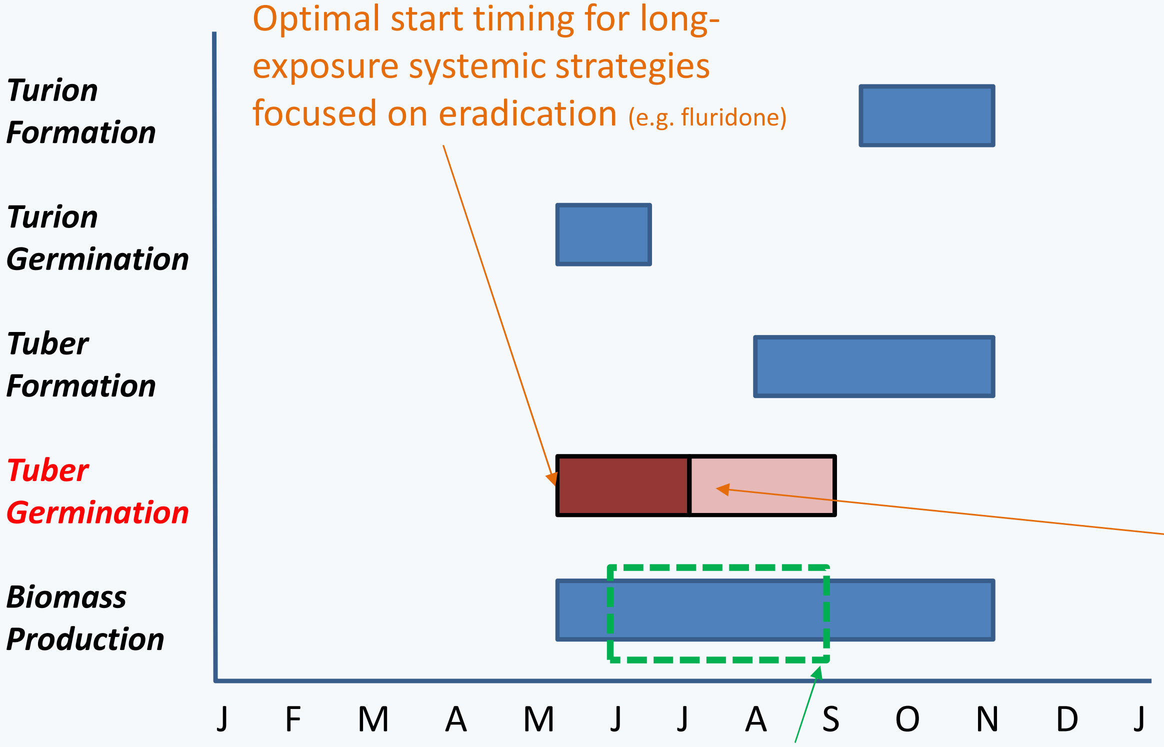




GREAT LAKES HYDRILLA COLLABORATIVE

Monoecious hydrilla tuber eradication

Phenological Considerations (Great Lakes/Northern US)



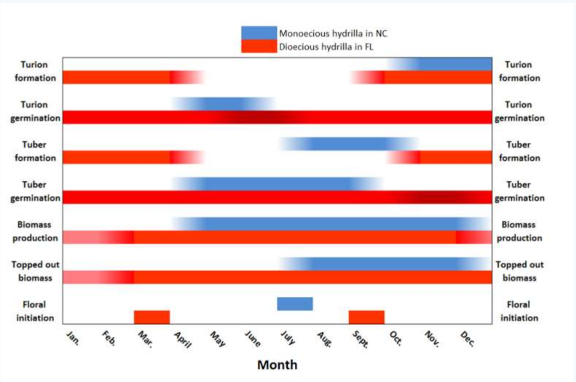


Figure 5. A comparison of monoecious hydrilla phenology in North Carolina to dioecious hydrilla phenology in Florida.

Modified from Meadows et al 2016

Monoecious hydrilla tuber eradication

Phenological Considerations (Great Lakes/Northern US)

- Timing considerations
  - Early-season start with fluridone
    - Suppress growth with lower rates and shorter exposure needed (6 vs. 12 weeks)
    - Minimal biomass development strongly decreases risk of vegetative spread
    - High flow conditions in the spring can challenge maintenance of concentrations
  - Mid-season or delayed start: knockdown with contact / endothall f/b fluridone
    - ProcellaCOR (florpyrauxifen-benzyl) will be a future selective option
  - Late-season find: knockback with contacts to minimize turion/tuber formation as feasible

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Hydrilla Management Approach

- **<u>Strategies based on General Site Characteristics</u>**
  - *High Retention Sites*
    - Systemic, season-long management (Sonar/fluridone)
  - *Spring Low Retention / Summer High Retention*
    - Partial treatment with fluridone pellets
    - Contacts/endothall/Procellacor f/b Sonar
  - *Tributary Infestation (low – moderate discharge)*
    - Herbicide Injection to manage entire area of infestation
  - *Major Waterway (high discharge)*
    - Possible herbicide injection transitioning to limited spot management of public access areas to reduce spread risk
    - Possible protection/restoration of key habitat areas

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Other Aquatic Herbicide Use Considerations

- **Eradication and containment**
  - **The challenge of scale: ‘whack a mole’ versus ‘whack an elephant’**
- **Water uses**
  - Potable, swimming, recreation, irrigation—see labels
- **Integration with low-rate triploid carp in contained sites**
  - Small pond management?
  - Reduce tuber bank first with selective herbicides and stock much lower carp rate
- **Education and Outreach: Science v. Perception**

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Conclusions and Future Outlook

- **AIS such as monoecious hydrilla are cancers of our lakes, and management should approach them with that mindset.**
- **EDRR must be well implemented.**
- **Eradication of early-stage infestations has clear economic and ecological value** and should be first consideration with **solid maintenance control as second option**.
- **Aquatic herbicides are a valuable component of integrated management.**

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- NC State University
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- Maryland DNR
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- Multiple private applicators
- Multiple other university cooperators

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GREAT LAKES HYDRILLA COLLABORATIVE

Questions?

Croton River, NY
Fall 2015 before herbicide treatment

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Fall 2017 after treatment