Ecological Effects of Whole-Lake Fluridone Treatments for Eurasian Watermilfoil Control

Summary of Available Data

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Integrated Science Services, Fisheries and Aquatic Sciences
Outline

• Background on fluridone
• Results of our national technical review on efficacy and additional ecological effects
• What happened in the 4 Wisconsin treatments?
• What happened in Houghton Lake, MI?
• Preliminary data on the Madison lakes
Fluridone Overview

• Marketed as Sonar® and Avast!®
• Systemic herbicide
• Kills plants in 60-90 days (6 ppb)
• Whole-lakes or coves, partial treatments possible
• Semi-selective control of Eurasian Watermilfoil and Hydrilla
Recent interest in WI for whole-lake treatments

- The WDNR has authority over the use of chemical treatment in public waters (but does not initiate chemical treatments or apply chemicals – permit approval)

- Detailed regulatory procedures are outlined in Ch. NR 107, Wis. Adm. Code. Includes DNR’s legal responsibility to understand effectiveness of chemical treatments not only as a tool for nuisance relief, but also potential ecosystem effects* before approving permit applications.

Q: So what’s the big deal with fluridone?
A: Spatial scale!

Whole lake treatment = Whole ecosystem manipulation
Need to be reasonably certain that “the proposed treatment” will NOT:

(3)(d) …result in a hazard to humans, animals or other nontarget organisms;

(3)(e) …result in a significant adverse effect on the body of water;

(3)(g) …significantly injure fish, fish eggs, fish larvae, essential fish food organisms or wildlife, either directly or indirectly through habitat destruction;

(4) New applications will be reviewed with consideration given to the cumulative effect of applications already approved for the body of water…

(Wisconsin Administrative Code, NR 107.05)

Why do we care?

Plants  Nutrient uptake, erosion control, habitat (fish, birds, wildlife, invertebrates)

Too much algae  Poor water clarity, aesthetics (odors), health, affect fish

Fish  Important component of ecosystem, important to WI economy and legacy
Questions

1) What are the primary and secondary ecological effects (both intended and unintended)?
   - Vegetation (exotic and native)
   - Water quality (algae)
   - Fisheries

2) What has been done already to address those questions?

- Anecdotal accounts
- Technical review of DATA N > 1, generalize effects
Fluridone Use in U.S.

- FL ~ 75-80 y\(^{-1}\)
- MI ~ 20 y\(^{-1}\)
- MA > 40-50 treatments
- WA ~ 27
- MN ~ 10 (2) (+2 for CLP expt.)
- IA ~ 6

Whole-lake treatments, public waterbodies > 30 acres

- WI 4 (2)
- VT ~ 4
- IN ~ 4 (2)
- OR ~ 2
- ME 1 (hydrilla)
- CA 0

States with no State monitoring or permitting requirements: KY, MO, VA
States contacted with no reply: AR, CO, NC, NJ, NV, OH, PA, TX, LA, AL, GA, SC, IL, NY
Fluridone Studies

- Despite widespread use in some states, very few peer-reviewed papers (3 on vegetation, 0 on water quality, 4 on fish)
- Army Corps technical reports
- Michigan has published information as well as reliable unpublished data
- Minnesota DNR shared data from research lakes
- Additional data from WI, VT, WA, NY, IN, ME, OR

*Most studies focus on vegetation*
Limitations of Data

1) Study length often only 1-2 years post-treatment

2) Methods vary
   - Sampling design, data collection, statistics

3) Inadequate sampling frequency or timing
   - Early spring or late fall vegetation samples

4) Lack of pretreatment data or reference lakes
   (effect of treatment vs interannual variation?)
Data Reliability

• Plant and Water Quality Data
  – Include at least one year pre-treatment data or reference lake
  – Sampling during peak biomass or at least two samples per year
  – Had to be quantitative

• Fish Data
  – Limited to specific examples due to lack of information
National Plant Results

\[ n \geq 4 \text{ WHOLE LAKE TREATMENTS} \]
\[ \text{Had to be initially present at } >10\% \text{ frequency (or } 10\% \text{ cumulative cover – MI data)} \]
\[ \text{Change} = >10\% \text{ difference in frequency of occurrence from pretreatment data} \]

Tables indicate the \% of cases in which the species increased or decreased by at least 10\% (not the magnitude)

<table>
<thead>
<tr>
<th>Species</th>
<th>Year</th>
<th>% of Decreases</th>
<th>% of Increases</th>
<th>% w/ No Change</th>
<th>( n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eurasian watermilfoil</td>
<td>1</td>
<td>98</td>
<td>2</td>
<td>0</td>
<td>54</td>
</tr>
</tbody>
</table>

**EWM**
- Decrease in 98\% of cases
- Large decrease, regardless of dosage (see next slide)
- Always returns, often rapidly (see next slide)
Long-term effects on EWM (3+ year data sets):

Most commonly, 1-2 seasons of nuisance relief, followed by rapid rebound

*Cumulative cover – indicates coverage and density of plants in lake
Native WI species listed as susceptible by SePro

Floating plants
- Duckweed
- Watermeal
- Pond-lilies
- Water-lilies

Emergent
- Northern water-plantain
- Cattail species
- Spike rush species
- Reed-canary grass*

Submerged
- Watermilfoil species
- Coontail
- Waterweed
- Bladderwort species
- Southern water naiad
- Sago pondweed
- Curly-leaf pondweed*
- 6 Potamogeton pondweed species
- Horned pondweed

DNR has all WI species information (susceptible, tolerant, or unknown) available to anyone upon request, including species listed on label, laboratory studies, and field studies.
### Short-term effects on native plants:

**-Susceptible species:**

<table>
<thead>
<tr>
<th>Species</th>
<th>Year</th>
<th>% of Decreases</th>
<th>% of Increases</th>
<th>% w/ No Change</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern milfoil</td>
<td>1</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Slender naiad</td>
<td>1</td>
<td>90</td>
<td>0</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Elodea (waterweed)</td>
<td>1</td>
<td>85</td>
<td>0</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Clasping leaf pondweed</td>
<td>1</td>
<td>67</td>
<td>0</td>
<td>33</td>
<td>9</td>
</tr>
<tr>
<td>Thin leaf pondweed</td>
<td>1</td>
<td>54</td>
<td>8</td>
<td>38</td>
<td>24</td>
</tr>
<tr>
<td>White-stem pondweed</td>
<td>1</td>
<td>60</td>
<td>0</td>
<td>40</td>
<td>5</td>
</tr>
<tr>
<td>Water crowfoot</td>
<td>1</td>
<td>57</td>
<td>0</td>
<td>43</td>
<td>7</td>
</tr>
<tr>
<td>Coontail</td>
<td>1</td>
<td>50</td>
<td>5</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>Variable pondweed</td>
<td>1</td>
<td>43</td>
<td>0</td>
<td>57</td>
<td>7</td>
</tr>
<tr>
<td>Large leaf pondweed</td>
<td>1</td>
<td>41</td>
<td>9</td>
<td>50</td>
<td>22</td>
</tr>
<tr>
<td>Bulrush</td>
<td>1</td>
<td>33</td>
<td>0</td>
<td>67</td>
<td>6</td>
</tr>
<tr>
<td>Illinois pondweed</td>
<td>1</td>
<td>33</td>
<td>7</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td>Pond lily - Nuphar spp.</td>
<td>1</td>
<td>28</td>
<td>8</td>
<td>64</td>
<td>25</td>
</tr>
<tr>
<td>Cattail</td>
<td>1</td>
<td>27</td>
<td>0</td>
<td>73</td>
<td>11</td>
</tr>
</tbody>
</table>

Decreases in 30% – 100% of the cases

Response dependent on dose and duration
Long-term effects on susceptible native plants (common, abundant species):

- Potential large decreases, regardless of dosage
Short-term effects on native plants:

-Tolerant species:

<table>
<thead>
<tr>
<th>Species</th>
<th>Year</th>
<th>% of Decreases</th>
<th>% of Increases</th>
<th>% w/ No Change</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern naiad</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>White water lily</td>
<td>1</td>
<td>8</td>
<td>8</td>
<td>84</td>
<td>25</td>
</tr>
<tr>
<td>Fern pondweed</td>
<td>1</td>
<td>0</td>
<td>20</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>Common bladderwort</td>
<td>1</td>
<td>0</td>
<td>20</td>
<td>80</td>
<td>5</td>
</tr>
<tr>
<td>Wild celery</td>
<td>1</td>
<td>25</td>
<td>20</td>
<td>55</td>
<td>20</td>
</tr>
<tr>
<td>Chara spp.</td>
<td>1</td>
<td>8</td>
<td>33</td>
<td>59</td>
<td>49</td>
</tr>
<tr>
<td>Flat-stem pondweed</td>
<td>1</td>
<td>18</td>
<td>35</td>
<td>47</td>
<td>17</td>
</tr>
<tr>
<td>Water stargrass</td>
<td>1</td>
<td>11</td>
<td>42</td>
<td>47</td>
<td>19</td>
</tr>
<tr>
<td>Sago pondweed</td>
<td>1</td>
<td>22</td>
<td>44</td>
<td>33</td>
<td>18</td>
</tr>
</tbody>
</table>

Mixed results - no change or mixed increases/decreases
Long-term effects on tolerant native plants:

- Potential large increases, mixed results
Another exotic – curly leaf pondweed

-May inhibit recreation
-May contribute to degraded water quality due to unique biology – dies off in early summer, can fuel algal growth

<table>
<thead>
<tr>
<th>Species</th>
<th>Year</th>
<th>% of Decreases</th>
<th>% of Increases</th>
<th>% w/ No Change</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curly-leaf pondweed</td>
<td>1</td>
<td>35</td>
<td>35</td>
<td>29</td>
<td>17</td>
</tr>
</tbody>
</table>

Curly-leaf pondweed (poor timing for monitoring)
- Cook et al. 2005 - Often increases
- Don’t trade one exotic for another - needs concurrent management
Overall long-term effects on plants:

**EWM**
Most often, 2 seasons of nuisance relief (1-4)

**Natives**
Dependent on:
1) Plant community
   -% of natives susceptible to chemical vs tolerant species
   -Reproductive strategy (seed producers return more often)

2) EWM response
   With 2+ seasons of EWM relief certain species sometimes increase (chara, sago), until EWM returns
Effects on Algae / Water Clarity

-Since they compete for nutrients, trade-off between plants and algae
-Plant decay also provides nutrients for algal growth, resuspension of sediments

**Alternative States in Shallow Lakes:**

<table>
<thead>
<tr>
<th>Clear-Water, Aquatic Plant State</th>
<th>Turbid Algal State</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Clear water</td>
<td>• Turbid green water</td>
</tr>
<tr>
<td>• Aquatic plants abundant</td>
<td>• Aquatic plants sparse</td>
</tr>
<tr>
<td>(with high biodiversity?)</td>
<td>• Bottom sediment resuspension &amp; phosphorus recycling high</td>
</tr>
<tr>
<td>• Bottom sediment resuspension &amp; phosphorus recycling low</td>
<td>• Algae densities high</td>
</tr>
<tr>
<td>• Algae densities low</td>
<td>(high blue-green algal toxins?)</td>
</tr>
<tr>
<td>• Carp densities low, low planktivores</td>
<td>• Carp densities high, high planktivores</td>
</tr>
</tbody>
</table>

From R. Lathrop (WDNR)
-Reductions in secchi depth in 80% of treated lakes ($P = 0.003$) due to increased algae (late summer samples, 1 yr pretreatment vs averaged year of treatment and 1 year post)
-Long term effects?
Overall effects on algae/water clarity:

Depends on the lake:
- Biomass of susceptible vegetation
- External and internal nutrient loads
- Morphology and bathymetry of lake (% of lake area that is vegetated)

Shallow, eutrophic lake with high biomass of EWM, coontail, and elodea throughout vs Deep, oligotrophic lake with some EWM, and high biomass of tolerant natives
From a Fisheries Standpoint:

- Submersed aquatic vegetation provides services to multiple fish species at multiple life stages
  - Game fish – sunfish, largemouth bass, northern pike, muskellunge
  - Nongame fish – darters, minnows, killifishes
- Losses to fish recruitment are probable with loss of habitat
- Extent of impact depends on the lake (fish, plants, physical characteristics, water quality)

From Valley et al. 2004
National Fish Results

• No acute or chronic toxic effects on Trout, Bluegill, Catfish, Fathead Minnows, Sheepshead Minnows\(^1\), or fry of Walleye, SMB, and LMB\(^2\)

\(^1\)Hamelink et. al 1986, \(^2\)Paul et. al 1994

• Secondary effects of vegetation removal (recruitment, growth, condition, mortality)?
  – Population structure\(^1-6\)
  – Behavior\(^2,5\)
  – Reproduction\(^6\)

\(^1\)Pothoven et al. 1999, \(^2\)Pothoven 1996 (gray), \(^3\)Valley and Bremigan 2002, \(^4\)Schneider 2000 (gray), \(^5\)Welling et. al 1997 (gray), \(^5\)Sammons et. al 2003, \(^6\)Schneider 2000

• Long-term effect on fisheries? Need data!
Summary

Deciding whether a whole-lake treatment is appropriate:

1) **Quantify the perceived problem! Data, data, data…**

2) **Set reasonable expectations (ecological and economical)**
   - Whole lake treatments generally do not eradicate EWM, repeat treatments would probably be requested
   - Usually provide 2 seasons of nuisance relief, need to manage in interim
   - Can incur unintended ecological effects – need to evaluate data lake by lake (physical features, plants, algae/water clarity, fisheries)

3) **Weigh the benefit with the risks**

4) **Recognize that managing invasives is a long-term commitment with any tool (action based on data)**
What happened in WI lakes?

4 lakes treated
30-200 acres
>95% littoral
1997-2001
6-16 ppb
Fall or spring

- Clear Lake, Sawyer
- Bughs Lake, Waushara
- Random Lake, Sheboygan
- Potter Lake, Walworth
Effect on exotics:

- 1-4 seasons significant reduction
- Concurrent small-scale treatments
- Rapid return
- Potter retreated in 2004 and 2005
- Random retreated in 2005
Effect on natives:

- Elodea, coontail, slender naiad, and water-thread pondweed decreased
- Where present, chara and sago increased until EWM returned
  *In Clear Lake, additional natives increased
Effect on water clarity:

*Bughs Lake – no data, aerator installed because of crashes in dissolved oxygen
What happened in Houghton lake, MI?

Size = 8100 ha
Primarily forested watershed
Mean depth < 3 m
Near 100% littoral
54% EWM
Volume (treated) = 200 million m³
$1.4 million to SePro for chem. and app.
Additional annual costs
Riparian owners assessed $200/yr (per lakeshore unit) for 3 yrs, then reduction

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>HOUGHTON LAKE PLANT CONTROL HISTORY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sonar® (acres treated)</td>
</tr>
<tr>
<td>2002</td>
<td>20,044</td>
</tr>
<tr>
<td>2003</td>
<td>32</td>
</tr>
<tr>
<td>2004</td>
<td>44</td>
</tr>
</tbody>
</table>

Data and figures from Progressive AE
Effect on plants:

Figure 4. Population changes in common Houghton Lake species, 2001 - 2004.

Data from Progressive AE
Total % Frequency of Occurrence: Native Species on Houghton Lake

Data from Progressive AE
Houghton Lake Summary

• Four seasons EWM control (with additional efforts)
• Significant Decreasers – 8 native species
  – 5 species still less abundant in 2005 than pretreatment:
    Elodea, Richardson’s pondweed, Vallisneria, coontail, nitella
  – 3 species exhibited initial decrease with rebound:
    Thin leaf pondweed, naiad, whitestem pondweed
• Significant Increasers – 6 native species
  – Chara, flatstem pondweed, variable-leaf pondweed, Illinois pondweed, ribbon leaf pondweed
• Undesirable species increased
  – Curly leaf pondweed, co-managed by herbicides/harvesting
  – Spirogyra (filamentous algae, from 0 to 4%)

Data from Progressive AE
## Madison lakes – preliminary data

<table>
<thead>
<tr>
<th>Lake</th>
<th>Surface Area (ha)</th>
<th>Volume (million m$^3$)</th>
<th>Max Depth (m)</th>
<th>Flushing Rate (yr$^{-1}$)</th>
<th>% Littoral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendota</td>
<td>3,985</td>
<td>505</td>
<td>25.3</td>
<td>0.22</td>
<td>18</td>
</tr>
<tr>
<td>Monona</td>
<td>1,326</td>
<td>110</td>
<td>22.6</td>
<td>0.91</td>
<td>30</td>
</tr>
<tr>
<td>Waubesa</td>
<td>843</td>
<td>40</td>
<td>11.6</td>
<td>3.2</td>
<td>35</td>
</tr>
<tr>
<td>Kegonsa</td>
<td>1,299</td>
<td>67</td>
<td>9.8</td>
<td>2.2</td>
<td>50</td>
</tr>
</tbody>
</table>

Madison lakes watershed - primarily URBAN & AGRIC.

Used the 4 m contour as proxy, may overestimate for lower lakes.
Madison lakes bathymetry

-Mendota
Madison lakes bathymetry

-Monona
Madison lakes bathymetry

-Waubesa

(Correction from Dick Lathrop 3/22/06–2 m contour may be more accurate)
Madison lakes bathymetry

- Kegonsa

(Correction from Dick Lathrop 3/22/06–2 m contour may be more accurate)
Every season a greenish-yellow scum occurs...are collected into fleecy masses, and driven ashore..., forming a slimy scum which quickly putrifies, giving off a very disagreeable odor..."

- Occasionally prevented boating
- Noticeable odor within 1-2 blocks from lake

Source:
# Madison lakes – preliminary data

## Biology – History of algae and/or “weed” problems:

### MENDOTA

<table>
<thead>
<tr>
<th>Year</th>
<th>Max depth of plant growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1912-1920</td>
<td>about 5.5 m (25% of lake area!)</td>
</tr>
<tr>
<td>1951</td>
<td>about 4.8 m</td>
</tr>
<tr>
<td>1966</td>
<td>4.0 m</td>
</tr>
<tr>
<td>1980</td>
<td>3.0 m</td>
</tr>
<tr>
<td>1984</td>
<td>plants sparse between 2 and 3 m</td>
</tr>
<tr>
<td>1989</td>
<td>3.5-4m</td>
</tr>
</tbody>
</table>

### MONONA

<table>
<thead>
<tr>
<th>Year</th>
<th>Max depth of plant growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920'S</td>
<td>3.0m (&gt;20% of lake area, continuous belt around lake) (sewage effluent caused a lot of algae)</td>
</tr>
<tr>
<td>1925</td>
<td>3-5.5 (increased clarity due to extensive chemical treatment for planktonic algae)</td>
</tr>
<tr>
<td>'48 &amp; '51</td>
<td>1.7 m (planktonic algae treatments discontinued)</td>
</tr>
<tr>
<td>1961</td>
<td>1.8m</td>
</tr>
<tr>
<td>1984</td>
<td>3.0m</td>
</tr>
</tbody>
</table>

### UPPER MUD

<table>
<thead>
<tr>
<th>Year</th>
<th>Max depth of plant growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1887</td>
<td>dense growths</td>
</tr>
<tr>
<td>1930</td>
<td>no submersed macrophytes (loss probably caused by algae caused by sewage effluent)</td>
</tr>
</tbody>
</table>

### WAUBESA -- Sago was the only important species through 1936, before that, wild celery had been abundant.

<table>
<thead>
<tr>
<th>Year</th>
<th>Max depth of plant growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1939</td>
<td>0.6-1.5m (&lt;3% of lake) (sewage effluent discharge began in 1936)</td>
</tr>
<tr>
<td>1951</td>
<td>1.2m</td>
</tr>
<tr>
<td>1955 + '61</td>
<td>very little macrophyte growth</td>
</tr>
<tr>
<td>'72-'75</td>
<td>milfoil growth abundant; &quot;a nuisance&quot;</td>
</tr>
<tr>
<td>1976</td>
<td>dramatic decline in plant growth (dense algae blooms)</td>
</tr>
<tr>
<td>1987</td>
<td>extensive growth of EWM; high density</td>
</tr>
</tbody>
</table>

-Data from *Fisheries of the Yahara Lakes*
- EWM made up the largest component of the vegetation in 1960s
- Levelled off lakewide over recent decade
- Provides historical perspective – not to minimize nuisance for homeowners or discourage discussion on alternative management
### Madison lakes - preliminary data

- Data from UW-LTER

<table>
<thead>
<tr>
<th>Species</th>
<th>Mendota</th>
<th>Monona</th>
<th>Waubesa</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWM</td>
<td>27</td>
<td>33</td>
<td>60</td>
</tr>
<tr>
<td>Coontail</td>
<td>27</td>
<td>36</td>
<td>10</td>
</tr>
<tr>
<td>Elodea</td>
<td>19</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Northern milfoil</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Clasping leaf pw</td>
<td>3</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Illinois pw</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Sago pw</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>White water lily</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat-stem pw</td>
<td>0.2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Wild celery</td>
<td>11</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Water stargrass</td>
<td>9</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Curlyleaf pw</td>
<td>1</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Filamentous algae</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

60-80% of plant community susceptible
40-50% of native plant species richness likely affected
CLP/Filamentous algae/Sago/other spp. may increase
Rake fullness is reflective of milfoil density.

247 Sampling Points
156 Acres
Madison lakes - preliminary data

Potential to support toxic blue-green blooms exists:
Need to balance recreational use with other uses, in addition to human health aspect

Dog dies after swimming in Kegonsa
11:08 PM 6/10/04
Beth Williams Wisconsin State Journal

Wisconsin teen's death a wake-up call about toxic algae
Posted on Wed, Feb. 11, 2004
BY RAMSEY CAMPBELL AND ROBERT SARGENT
The Orlando Sentinel
-Golf course pond

State monitoring lakes for toxic blue-green algae
By TOM HELD
theld@journalsentinel.com
Last Updated: Aug. 7, 2003
-Wingra and Monona
Summary

- All ecosystem components are interrelated, major change in vegetation affects all aspects of lake ecology
  
  Because of spatial scale, whole lake herbicide treatments need to be evaluated lake by lake

- We have several tools for managing invasive aquatic plants (see table), each with its own benefits and drawbacks

- We don’t yet know how to eradicate aquatic invasives (any approach requires long-term commitment)

- Adaptive management approach – evaluate success/drawbacks scientifically (employ good monitoring designs)