Invasive Aquatic Plants: Submerged Plant Biology and Management

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Little Rock, AR, August 9, 2023
Topics

• Submersed invasive aquatic plant
  • Biology
  • Ecology
  • Management

• Species
  • Hydrilla (*Hydrilla verticillata*)
  • Curlyleaf pondweed (*Potamogeton crispus*)
  • Brazilian waterweed (*Egeria densa*)
  • Eurasian watermilfoil (*Myriophyllum spicatum*)
What do plants need?
Community Classification

- Emergent Plants
- Floating-leaf Plants
- Submerged Plants
- Algae

Littoral Zone
A Tale of Two Plants

CO₂, O₂

Nutrients
Water

Emergent, Floating

Removal of Toxic Gases

Submersed
What Plants Need: Requirements for Growth

- **Light**
  - Open sun to shade, or inundation in water

- **Nutrients**
  - Soil is bulk of source for major limiting nutrients (N, P) of rooted plants

- **Water**
  - Water availability is one major limiting factor for terrestrial plants

- **Carbon dioxide**
  - Rate of availability limits photosynthesis

- **Oxygen**
  - Oxygen may be low for respiration, particularly in roots and inundated soils

- **Temperature/Heat**
  - Temperature range (too low or too high) may limit growth
Photosynthesis

6 CO₂ + 6 H₂O → Light energy → C₆H₁₂O₆ + 6 O₂

Carbon dioxide  Water  Photosynthesis  Glucose  Oxygen gas
Plant Nutrition

- Source of Nutrients
  - Water column
  - Sediment
- Low nutrients will limit growth

Essential plant nutrients

<table>
<thead>
<tr>
<th>Structural elements</th>
<th>CO₂</th>
<th>H₂O</th>
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<tr>
<td></td>
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<td>Chlorine, Cl</td>
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<td>Copper, Cu</td>
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<td>Iron, Fe</td>
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<td>Manganese, Mn</td>
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<td>Molybdenum, Mo</td>
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<td>Zinc, Zn</td>
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Ions absorbed by plant

<table>
<thead>
<tr>
<th>NO₃⁻, NH₄⁺</th>
<th>H₂PO₄⁻, HPO₄⁻²</th>
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<tbody>
<tr>
<td>K⁺</td>
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<tr>
<td>Ca⁺²</td>
<td>Mg⁺²</td>
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<tr>
<td>SO₄⁻²</td>
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<tr>
<td>H₂BO₃⁻</td>
<td>Cl⁻</td>
</tr>
<tr>
<td>Co⁺²</td>
<td>Cu⁺²</td>
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<tr>
<td>Fe⁺², Fe⁺³</td>
<td>Mn⁺²</td>
</tr>
<tr>
<td>MoO₄⁻²</td>
<td>Zn⁺²</td>
</tr>
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</table>
Temperature

• For both submersed and floating / emergent plants, growth responds to temperature

• Approximate doubling with every 10 C increase in temperature
Average Daily Productivity
Tucker and DeBusk 1983

Average Air Temperature (C)

Average Productivity (gDW m$^{-2}$ d$^{-1}$)

[Graph showing a positive correlation between average air temperature and daily productivity, with data points and a trend line.]

Figure 18-5. Generalized growth and metabolic patterns for a typical annual aquatic macrophyte. ——— = total biomass; ——— = current gross productivity; ——— = current net productivity; ——— = current respiration rate; ••••• = death losses. (After Westlake, 1965b.)
Eurasian watermilfoil phenology varies geographically, interannually, and between lakes.
Life History and Plant Management

• All plants have a “vulnerable” point in their life history
  • Seed production
  • Propagule production
  • Seasonal stress

• Management can target those vulnerable points
Annual Plant Life Cycle

Seedlings grow to develop leaves, stems, and roots

Plants mature and produce flowers

VEGETATIVE GROWTH

Seedling

FLOWER

SEED

Seeds germinate and grow into a seedling

Flowers produce seeds
Curlyleaf Pondweed (*Potamogeton crispus*)

USAERDC Photos
Curlyleaf Pondweed Life Cycle in Minnesota

- **Plant Height from Lake Bottom to Water Surface (cm)**
- **Flowering and Turion Formation**
- **Plant Senescence**
  - (Only Turions Remain)
- **Turion Sprouting**
- **Ice Cover**
Curlyleaf Pondweed Management

- Early Treatment with contact herbicides to prevent turion formation
- Late treatment with herbicides or drawdown to control sproutling?
- Research was needed to test for herbicide efficacy in cold water

Figure 6. Curlyleaf pondweed turion and seedhead production measured on June 18, 1998 following endothall applications on March 31 (18°C water temperature) and May 15 (25°C water temperature). Letters above the bars represent significant differences between treatments according to an LSD test (α = 0.05, n = 5). Error bars indicate + 1 standard error of the mean.

Netherland et al. 2000
Whole-lake curlyleaf pondweed treatments

Figure 7.- Mean curlyleaf turion abundance (Oct, turions/m²) in littoral sediments (≤4.6 m) of treated lakes (by years of treatment) and untreated reference lakes (by calendar year). Error bars represent ±2 SE. Horizontal lines represent the 4-year mean (solid) and 95% CI (dashed) for untreated reference lakes.
Aquatic Plant Management Techniques

• Biological Control
• Chemical Control
• Mechanical Control
• Physical Control
The Arkansas Big 4?

- Eurasian watermilfoil
- Brazilian waterweed
- Hydrilla
- Curlyleaf pondweed
Biological Control

- Insects (Classical or Naturalized)
- Grass carp*
- Pathogens (Classical or Naturalized)
Grass Carp

• **Advantages**
  • Effective
  • Inexpensive
  • Long-term

• **Disadvantages**
  • “All-or-none” response
  • Not selective
  • Cannot control feeding sites
  • Cannot stop fish
  • Difficult to contain
  • Reproduction?
  • Won’t eat some species (e.g., Eurasian watermilfoil)
  • Regulations
Classical Insect Control

• Advantages
  • Public perception
  • Low cost after R&D
  • Long-term
  • Works well for some species in some areas

• Disadvantages
  • No agents for several target invasive plants
  • Long time for R&D
  • Unpredictability of results
  • Limited distribution of effectiveness
  • None available operationally for submersed plants
<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Product</th>
<th>Registrant</th>
<th>Contact or Systemic</th>
<th>Emergent or Submersed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td>Various</td>
<td>Various</td>
<td>Systemic</td>
<td>Both</td>
</tr>
<tr>
<td>Bispyrubic-Sodium</td>
<td>Tradewind</td>
<td>Nufarm</td>
<td>Systemic</td>
<td>Both</td>
</tr>
<tr>
<td>Carfentrazone-Ethyl</td>
<td>Stingray</td>
<td>SePRO</td>
<td>Contact</td>
<td>Both</td>
</tr>
<tr>
<td>Copper Complexes</td>
<td>Various</td>
<td>Various</td>
<td>Contact</td>
<td>Submersed</td>
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<tr>
<td>Diquat</td>
<td>Various</td>
<td>Various</td>
<td>Contact</td>
<td>Both</td>
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<tr>
<td>Dimethyl-alkylamine salt of Endothall</td>
<td>Hydrothol 191, others</td>
<td>United Phosphorus</td>
<td>Contact</td>
<td>Submersed</td>
</tr>
<tr>
<td>Endothall – Potassium salt</td>
<td>Aquathol K, others</td>
<td>United Phosphorus</td>
<td>Contact</td>
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</tr>
<tr>
<td>Flumioxazin</td>
<td>Clipper</td>
<td>Nufarm</td>
<td>Contact</td>
<td>Both</td>
</tr>
</tbody>
</table>

See [www.aquatics.org](http://www.aquatics.org) or BMP for more details
Aquatic Herbicide Active Ingredients (II of II)

<table>
<thead>
<tr>
<th>Active ingredient</th>
<th>Product</th>
<th>Registrant</th>
<th>Contact or Systemic</th>
<th>Emergent or Submersed</th>
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</thead>
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<tr>
<td>Fluridone</td>
<td>Sonar AS and others</td>
<td>SePRO and others</td>
<td>Systemic</td>
<td>Submersed</td>
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<tr>
<td>Glyphosate</td>
<td>Various</td>
<td>Various</td>
<td>Systemic</td>
<td>Emergent</td>
</tr>
<tr>
<td>Imazamox</td>
<td>Clearcast</td>
<td>SePRO</td>
<td>Systemic</td>
<td>Both</td>
</tr>
<tr>
<td>Imazapyr</td>
<td>Various</td>
<td>Various</td>
<td>Systemic</td>
<td>Emergent</td>
</tr>
<tr>
<td>Penoxsulam</td>
<td>Galleon SC</td>
<td>SePRO</td>
<td>Systemic</td>
<td>Both</td>
</tr>
<tr>
<td>Peroxides*</td>
<td>Various</td>
<td>Various</td>
<td>Contact</td>
<td>Algae*</td>
</tr>
<tr>
<td>Topramezone</td>
<td>Oasis</td>
<td>SePRO</td>
<td>Systemic</td>
<td>Both</td>
</tr>
<tr>
<td>Triclopyr</td>
<td>Various</td>
<td>Various</td>
<td>Systemic</td>
<td>Both</td>
</tr>
</tbody>
</table>

Is it really an herbicide? Some products labeled, others not:

| Dye               | Various          | Various        | NA                  | Submersed             |

See [www.aquatics.org](http://www.aquatics.org) or BMP for more details
Herbicide Risk

• People
• Environment
  • Fish
  • Wildlife
Opposition to Glyphosate

“Thank goodness the tide against these highly toxic chemicals is turning. The original testing for this chemical was designed by Monsanto¹ with no long-term studies and rubber stamped by regulators plucked from the industry². The evidence on the broad toxicity of Glyphosate as an ecosystem disruptor in terms of fueling harmful algal blooms³, destroying soil bacteria⁴ and human health in terms of disruption of gut bacteria and cancer⁵ is at least substantial enough to question the dousing of food crops with this poison⁶.” Comment on LinkedIn, Name withheld by me
In the words of Jedi Master Luke Skywalker:

AMAZING. EVERY WORD OF WHAT YOU JUST SAID WAS WRONG.
Herbicides are applied to water, and plants take up herbicide from water.

Water movement, residence time, and concentration are critical for effective treatment.

K. Getsinger, USAERDC
The Label is the Law

• Products must be labeled for use in aquatic sites
• Products may be labeled for specific application techniques, or may specifically exclude some application techniques
• The label will have specific water use restrictions for herbicide-treated water
• Read the label before purchasing a product, and before applying – read the label ON THE CONTAINER
• Why, you ask? Fines, imprisonment, potential damage to people and the environment, and possibly even a zombie apocalypse
• (well, maybe not a zombie apocalypse)
Which Herbicide To Use?

• Plant susceptibility to specific herbicides
• Compatibility with proposed use
• Water use restrictions
• Selectivity
• Concentration / exposure time for submersed applications

Underwater photo of Eurasian watermilfoil in Pend Oreille Lake, Idaho, 2017
Plant Susceptibility to Herbicide

- Examine a subset of species and herbicides as an example
- Information from small-scale and field testing
- Listing on a label does not necessarily mean that it has been tested on the species or that it will work well
Herbicide susceptibility for four Arkansas submersed plants based on empirical testing.

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Trade Name*</th>
<th>Brazilian waterweed ((Egeria densa))</th>
<th>Curlyleaf pondweed</th>
<th>Eurasian watermilfoil</th>
<th>Hydrilla</th>
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</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td>Various</td>
<td>P</td>
<td>E</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Bispyrabic-sodium^</td>
<td>Tradewind</td>
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</tr>
<tr>
<td>Carfentrazone-ethyl^</td>
<td>Stingray</td>
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<td></td>
<td>F</td>
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<tr>
<td>Copper complexes</td>
<td>Various</td>
<td>E</td>
<td>E</td>
<td>P</td>
<td>E</td>
</tr>
<tr>
<td>Diquat</td>
<td>Reward&amp;</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>Endothall, Dimethylalkylamine Salt</td>
<td>Hydrothol 191&amp;</td>
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<td>E</td>
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<td>E</td>
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<tr>
<td>Endothall, Dipotassium salt</td>
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<td>E</td>
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<td>Florpyrauxifen-benzyl^</td>
<td>ProcellaCOR</td>
<td>P</td>
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<td>Clipper</td>
<td>P</td>
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<td>P</td>
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<td>Peroxides</td>
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<tr>
<td>Triclopyr</td>
<td>Various</td>
<td>P</td>
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Make one for our submersed plants

John Madsen, 2023-08-02T00:53:33.021
## Herbicide Application Rate and Plant Response Time

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<th>Chemical</th>
<th>Plant Response</th>
<th>Maximum Application Rate</th>
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<tr>
<td>2,4-D</td>
<td>7-10 days</td>
<td>0.5 gal/acre</td>
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<tr>
<td>Carfentrazone-ethyl</td>
<td>7-14 days</td>
<td>0.2 lb ai/acre</td>
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<tr>
<td>Diquat</td>
<td>7 days</td>
<td>2 gal/acre</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>Up to 4 weeks</td>
<td>2 gal/acre</td>
</tr>
<tr>
<td>Imazapyr</td>
<td>Up to 8 weeks</td>
<td>.75 gal/acre</td>
</tr>
<tr>
<td>Triclopyr</td>
<td>Up to 2 weeks</td>
<td>6 lb ae/acre</td>
</tr>
</tbody>
</table>
Water use restrictions

• Herbicides may have specific water use restrictions after treatment in following categories:
  • Human consumption (e.g., drinking)
  • Human contact (e.g., swimming)
  • Fish consumption
  • Animal drinking water source
  • Turf irrigation
  • Forage Crop irrigation
  • Food crop irrigation

• Concern is for both food residues and direct damage to nontarget organisms and humans
## Water Use Restrictions

Water use restrictions, in days, for waters treated with selected U.S. EPA-approved aquatic herbicides. See the current herbicide label for specific provisions or exemptions. An asterisk indicates a specific concentration provision.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Human</th>
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<th>Animal</th>
<th></th>
<th>Irrigation</th>
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<td>Drinking</td>
<td>Swimming</td>
<td>Fish Consumption</td>
<td>Drinking</td>
<td>Turf</td>
<td>Forage</td>
<td>Food Crops</td>
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<tr>
<td>Triclopyr</td>
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<td>0</td>
<td>120</td>
<td>120</td>
<td>0</td>
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Mechanical Control

- Hand pulling
- Cutting
- Harvesting
- Diver-operated suction harvesting
- Rotovating
Hand Harvesting

• Most widely used technique in the world

• Hand pulling weeds from water, or using a simple implement

• Bag up pulled plants

• Very effective if labor is inexpensive and laborers can identify the plants

• Works best on scattered plants
Cutting

- A boat or implement (usually a sickle bar) that severs the plant stem from the root, but no effort is made to remove the plant matter.
Harvesting

• Using a machine or implement to simultaneously cut plants and collect the biomass.

• Subsequent step offloads plants for disposal
Summary of direct effects of 1982 mechanical harvesting on juvenile largemouth bass (*Micropterus salmoides*).

<table>
<thead>
<tr>
<th></th>
<th>Collection date 8/13/1982</th>
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<tbody>
<tr>
<td></td>
<td>Site #1</td>
</tr>
<tr>
<td><strong>Total # of fish removed</strong></td>
<td>11</td>
</tr>
<tr>
<td><strong># fish removed / ha</strong></td>
<td>220</td>
</tr>
<tr>
<td><strong>Fish standing crop estimate (#/ha)</strong></td>
<td>1,894</td>
</tr>
<tr>
<td><strong>% standing crop removed</strong></td>
<td>11.6</td>
</tr>
</tbody>
</table>

Site #1 was previously harvested in June 1982. Site #2 was previously unharvested.
Physical Control

- Dredging
- Drawdown
- Benthic Barrier
- Shading
- Nutrient Inactivation
Drawdown

• De-watering a water body in either summer or winter to dehydrate or freeze aquatic plants

• Must have a water level control structure or mechanism to remove water

• Refugia for fish
I strongly recommend:

- Biology and Control of Aquatic Plants
- Free download
- [http://www.aquatics.org/bmp.html](http://www.aquatics.org/bmp.html)
Contact Information:

Dr. John D. Madsen
PO Box 81
Eads, TN 38028

john.d.madsen86@gmail.com

Ph. 662-722-0157

Quail plantation hunt in the Southeast. No lawyers were harmed at this event (Sorry, VP Cheney).