Invasive Aquatic Plants: Submersed Plant Biology and Management

John D Madsen PhD

Consulting Scientist

USDA ARS, Retired

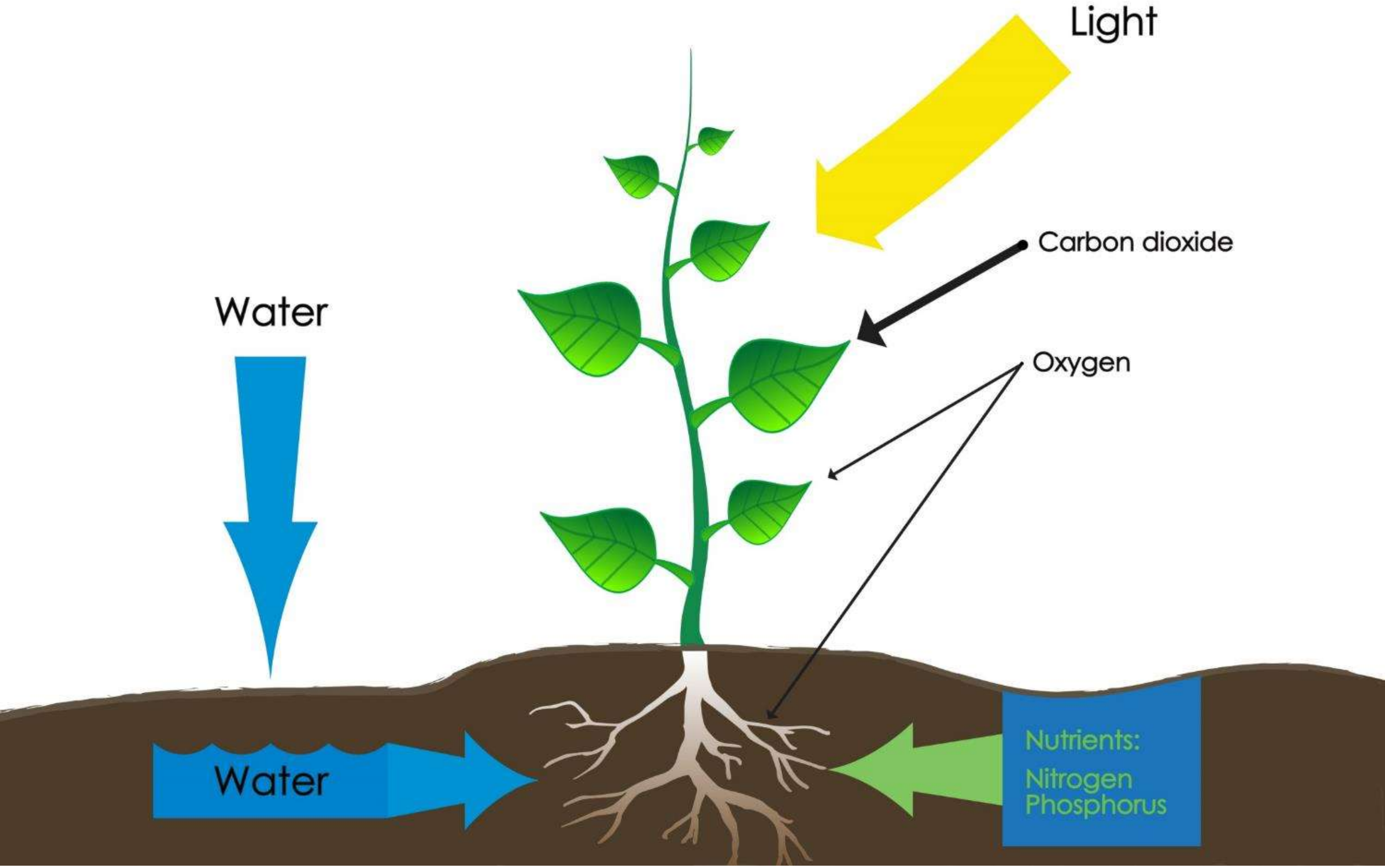
john.d.madsen86@gmail.com

Invasive Aquatic Plant Workshop, Arkansas Chapter of the AFS
Little Rock, AR, August 9, 2023

Topics

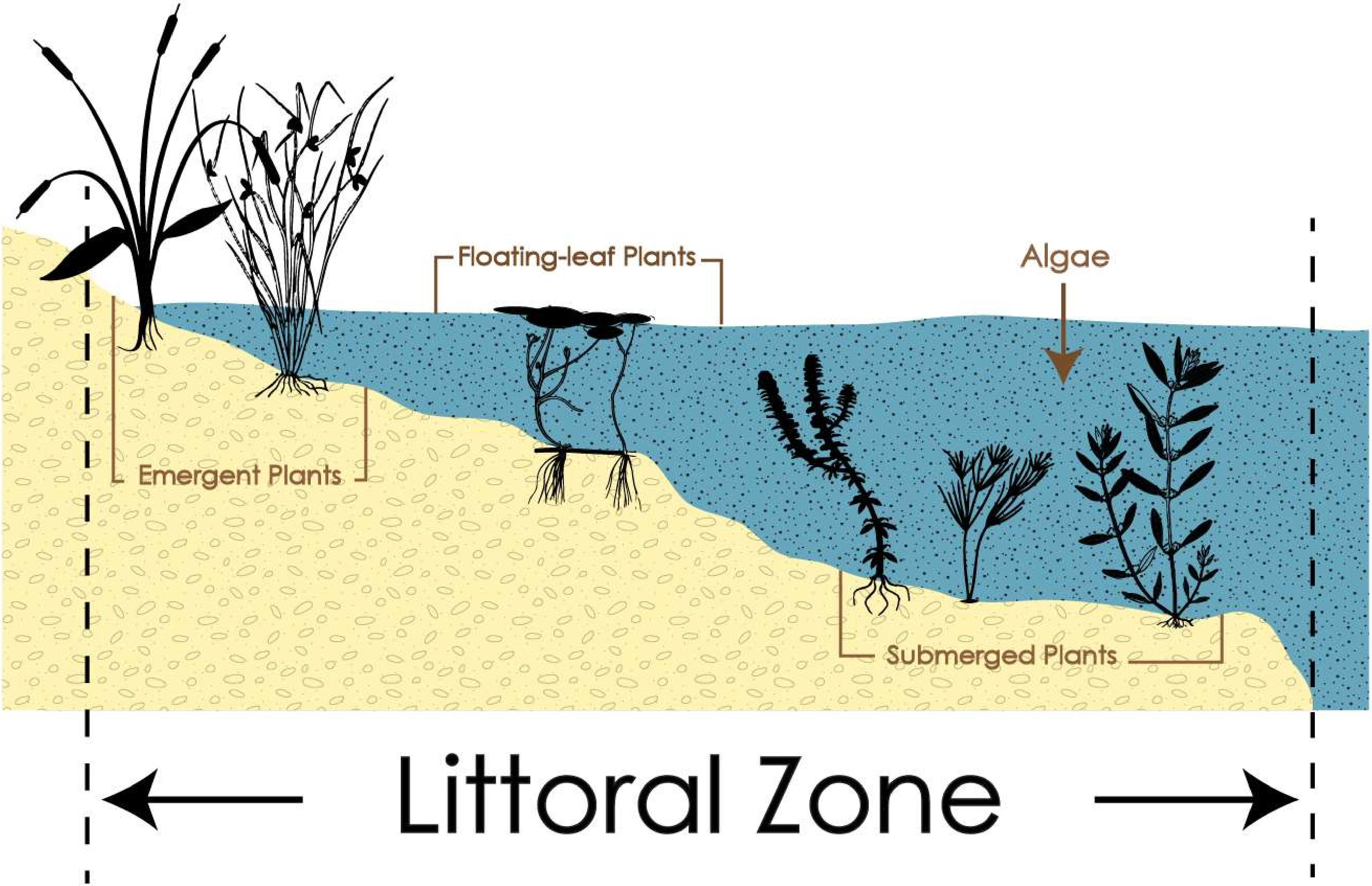
- Submersed invasive aquatic plant
    - Biology
    - Ecology
    - Management
- Species
    - Hydrilla (*Hydrilla verticillata*)
    - Curlyleaf pondweed (*Potamogeton crispus*)
    - Brazilian waterweed (*Egeria densa*)
    - Eurasian watermilfoil (*Myriophyllum spicatum*)

What do plants need?

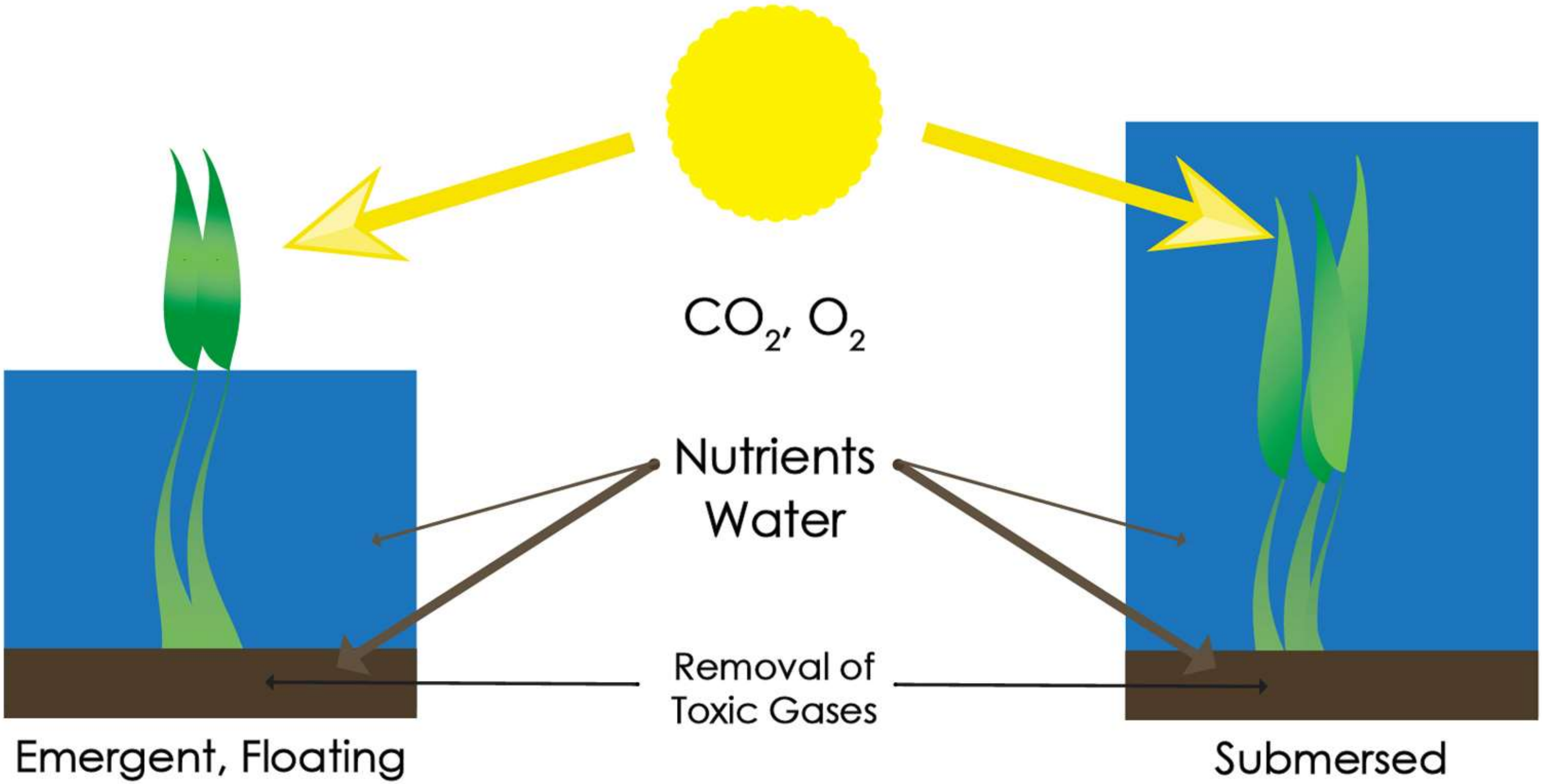


Revised from MDNR 1994

Community Classification



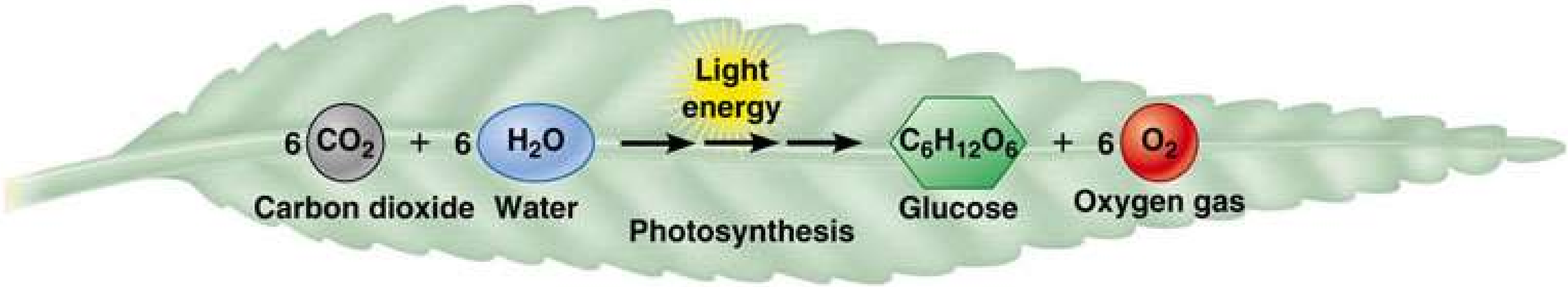
A Tale of Two Plants



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



Plant Nutrition

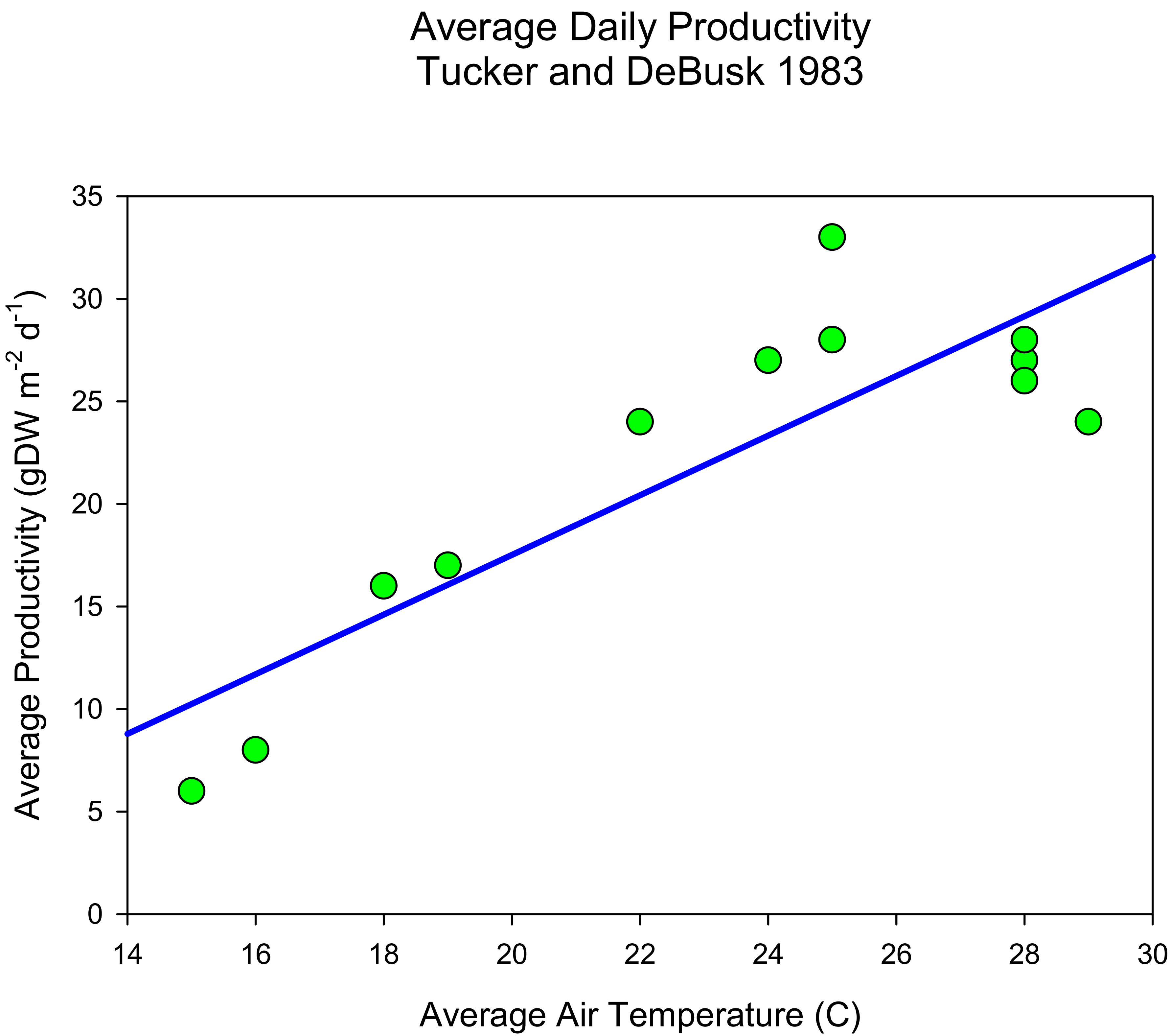
- Source of Nutrients
  - Water column
  - Sediment
- Low nutrients will limit growth

Essential plant nutrients

Structural elements	ions absorbed by plant
Carbon, C	CO_2
Hydrogen, H	H_2O
Oxygen, O	O_2
Primary nutrients	
Nitrogen, N	NO_3^-, NH_4^+
Phosphorus, P	$H_2PO_4^-$, HPO_4^{-2}
Potassium, K	K^+
Secondary nutrients	
Calcium, Ca	Ca^{+2}
Magnesium, MG	Mg^{+2}
Sulfur, S	SO_4^{-2}
Micronutrients	
Boron, B	$H_2BO_3^-$
Chlorine, Cl	Cl^-
Ccbalt, Co	Co^{+2}
Copper, Cu	Cu^{+2}
Iron, Fe	Fe^{+2}, Fe^{+3}
Manganese, Mn	Mn^{+2}
Molybdenum, MO	MoO_4^{-2}
Zinc, Zn	Zn^{+2}

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 Productivity (gDW m-2 d-1)
Average Air Temperature (C)
0
5
10
15
20
25
30
35
14
16
18
20
22
24
26
28
30

Annual Growth Cycles

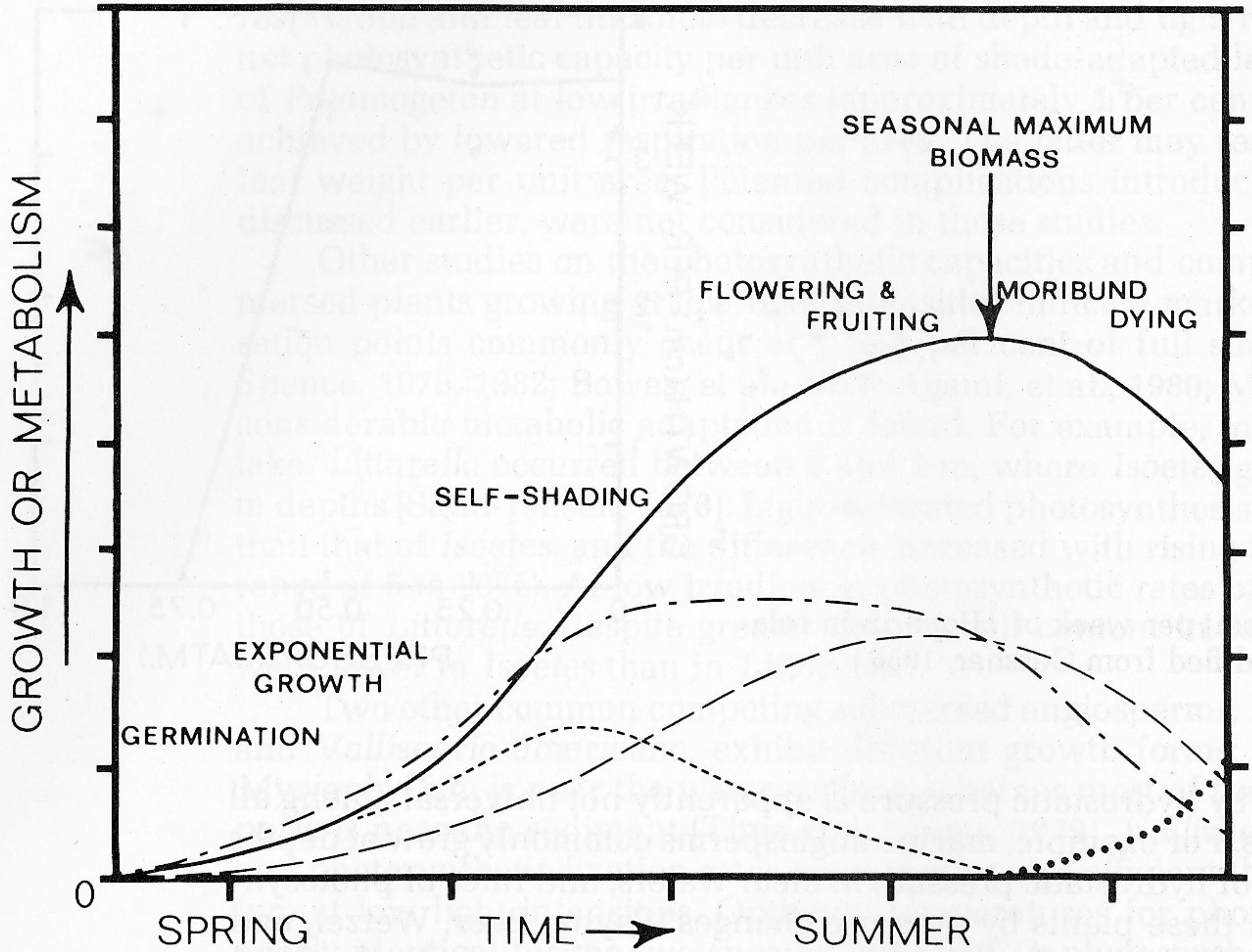
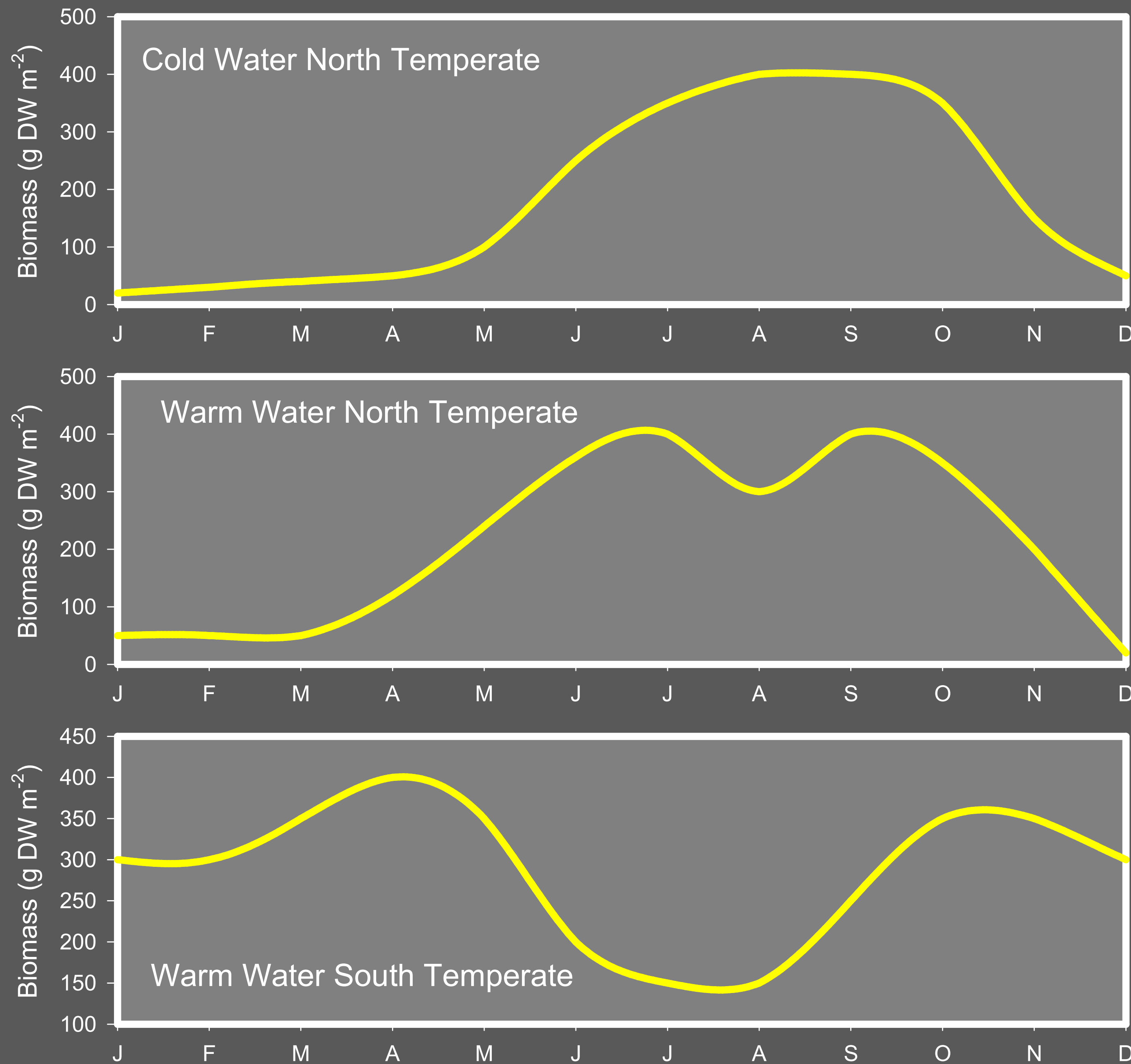


Figure 18–5. Generalized growth and metabolic patterns for a typical annual aquatic macrophyte. ——— = total biomass; — - — - = current gross productivity; - - - - = current net productivity; — — — = current respiration rate; · · · · · = death losses. (After Westlake, 1965b.)

Wetzel 1983

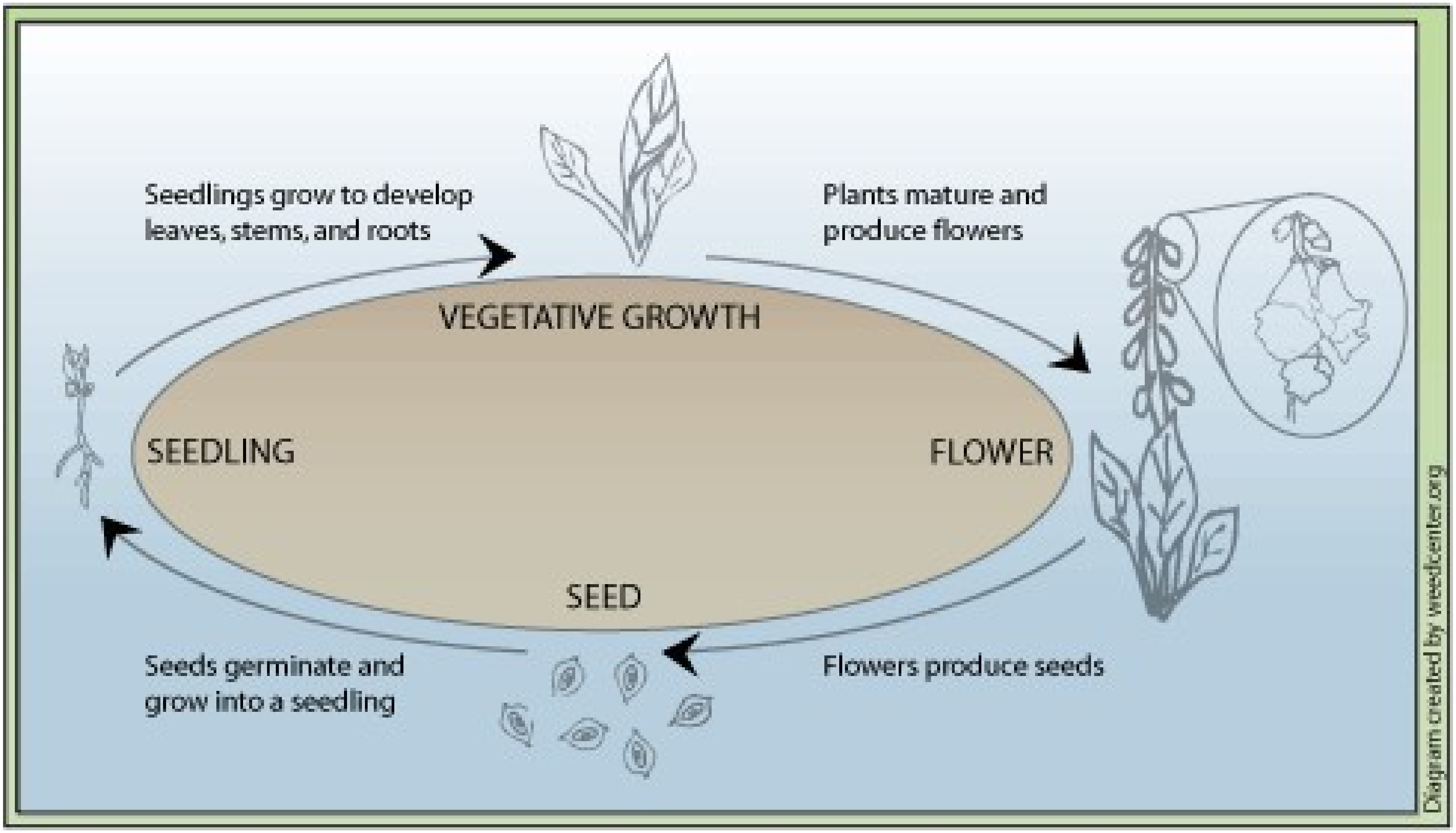
Eurasian watermilfoil phenology varies geographically, interannually, and between lakes



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

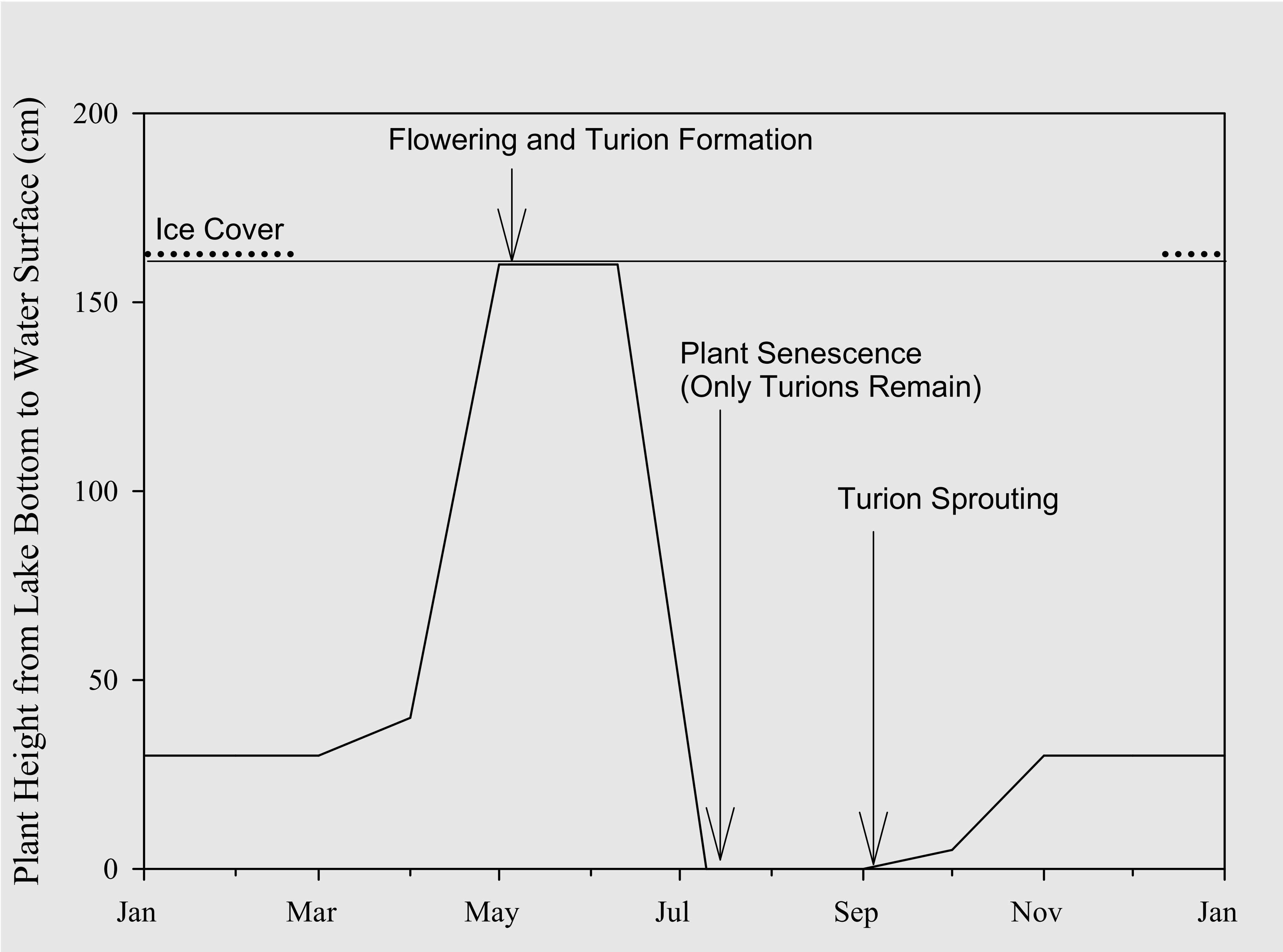
Annual Plant Life Cycle



Curlyleaf Pondweed (*Potamogeton crispus*)

USAERDC
Photos

Curlyleaf Pondweed Life Cycle in Minnesota



Curlyleaf Pondweed Management

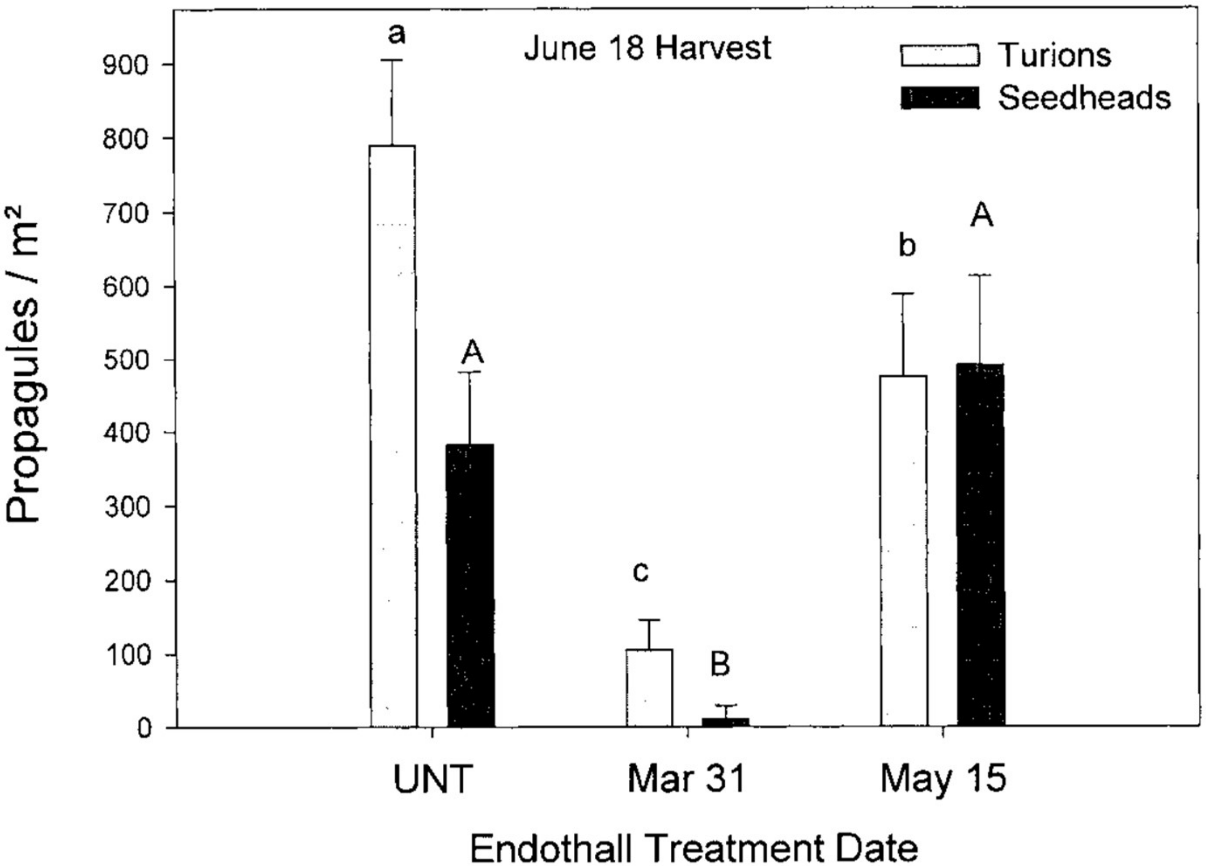


Figure 6. Curlyleaf pondweed turion and seedhead production measured on June 18, 1998 following endothall applications on March 31 (18C water temperature) and May 15 (25C water temperature). Letters above the bars represent significant differences between treatments according to an LSD test (α = 0.05,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

- 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

Netherland et al. 2000

Whole-lake curlyleaf pondweed treatments
Johnson et al. 2012. LRM28:346-363.

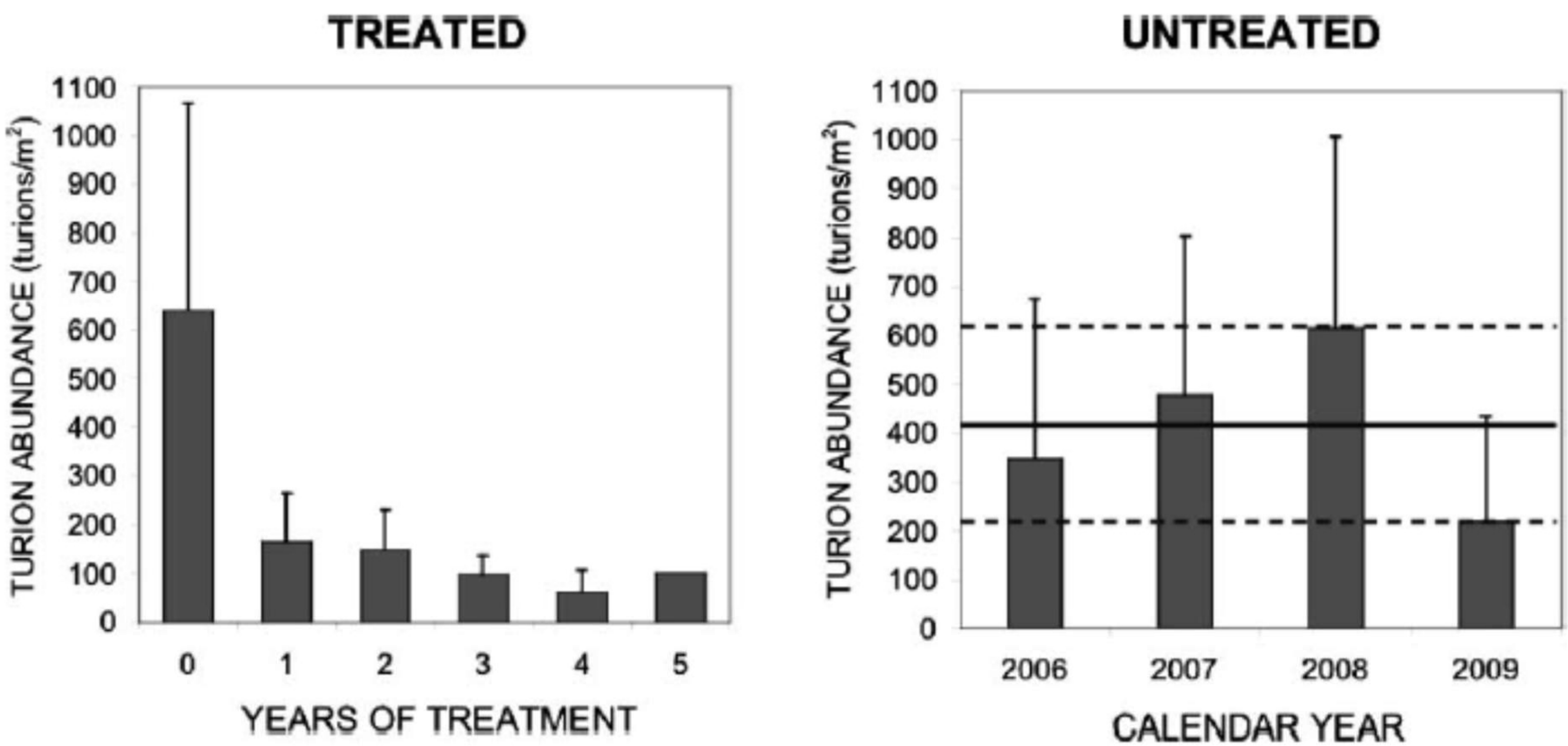
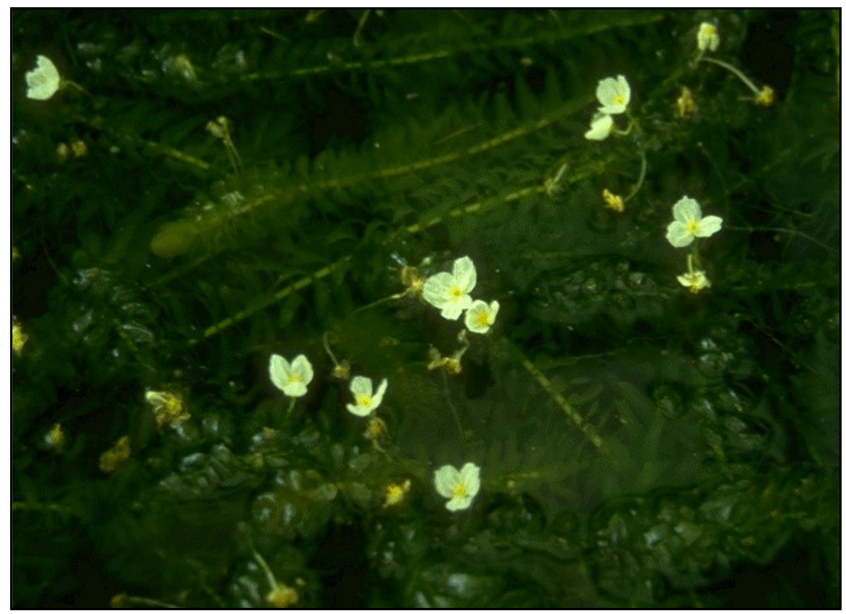


Figure 7.-Mean curlyleaf turion abundance (Oct, turions/m^2) in littoral sediments ($\leq$4.6 m) of treated lakes (by years of treatment) and untreated reference lakes (by calendar year). Error bars represent +2 SE. Horizontal lines represent the 4-year mean (solid) and 95% CI (dashed) for untreated reference lakes.

Aquatic Plant Management Techniques

- Biological Control
- Chemical Control
- Mechanical Control
- Physical Control



The Arkansas Big 4?

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

Aquatic Herbicide Active Ingredients (I of II)

Active Ingredient	Product	Registrant	Contact or Systemic	Emergent or Submersed
2,4-D	Various	Various	Systemic	Both
Bispyrabic-Sodium	Tradewind	Nufarm	Systemic	Both
Carfentrazone-Ethyl	Stingray	SePRO	Contact	Both
Copper Complexes	Various	Various	Contact	Submersed
Diquat	Various	Various	Contact	Both
Dimethyl-alkylamine salt of Endothall	Hydrothol 191, others	United Phosphorus	Contact	Submersed
Endothall – Potassium salt	Aquathol K, others	United Phosphorus	Contact	Submersed
Flumioxazin	Clipper	Nufarm	Contact	Both

See www.aquatics.org or BMP for more details

Aquatic Herbicide Active Ingredients (II of II)

Active ingredient	Product	Registrant	Contact or Systemic	Emergent or Submersed
Fluridone	Sonar AS and others	SePRO and others	Systemic	Submersed
Glyphosate	Various	Various	Systemic	Emergent
Imazamox	Clearcast	SePRO	Systemic	Both
Imazapyr	Various	Various	Systemic	Emergent
Penoxsulam	Galleon SC	SePRO	Systemic	Both
Peroxides*	Various	Various	Contact	Algae*
Topramezone	Oasis	SePRO	Systemic	Both
Triclopyr	Various	Various	Systemic	Both
Is it really an herbicide? Some products labeled, others not:				
Dye	Various	Various	NA	Submersed

See www.aquatics.org or BMP for more details

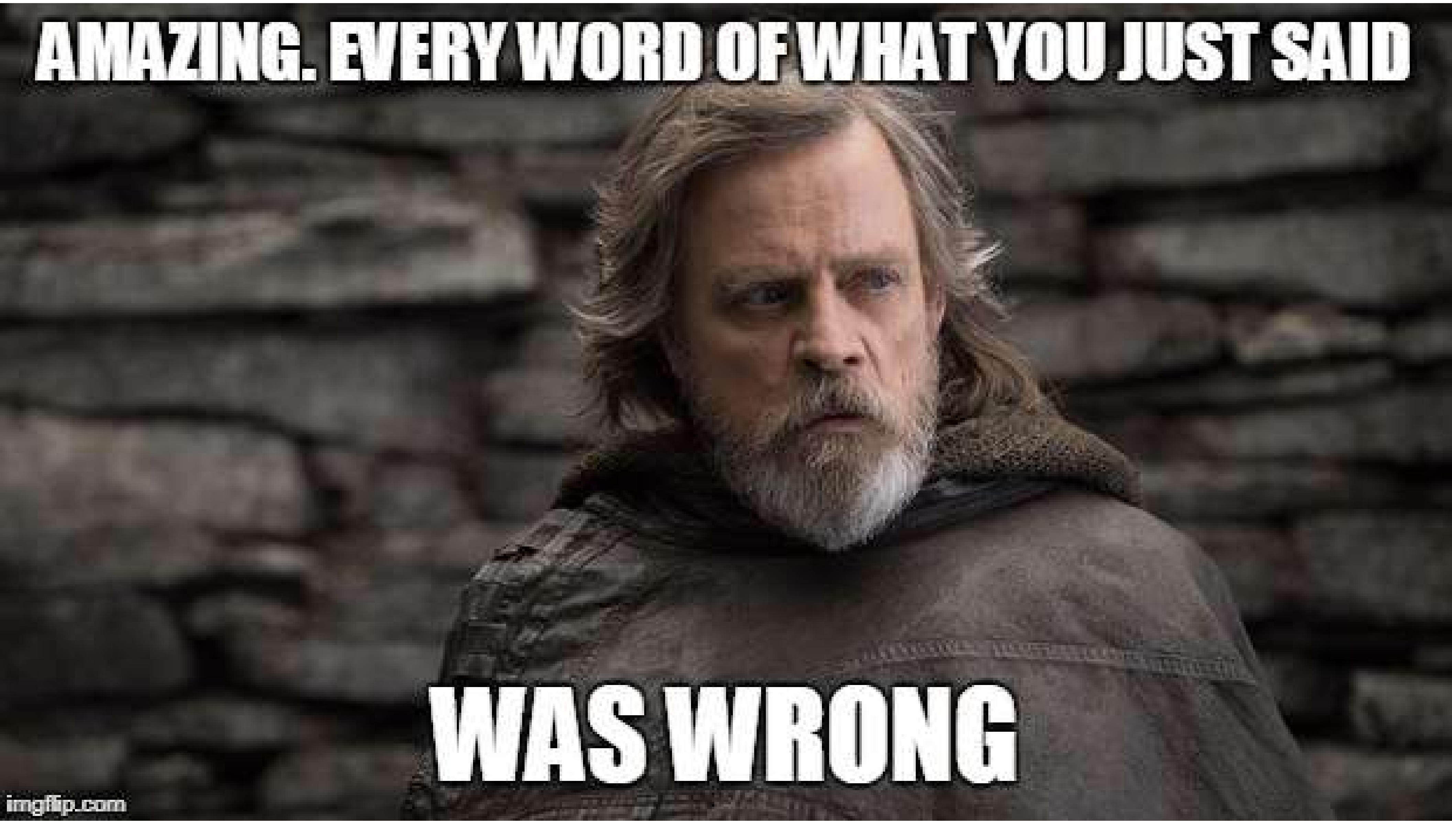
Herbicide Risk

- People
- Environment
  - Fish
  - Wildlife

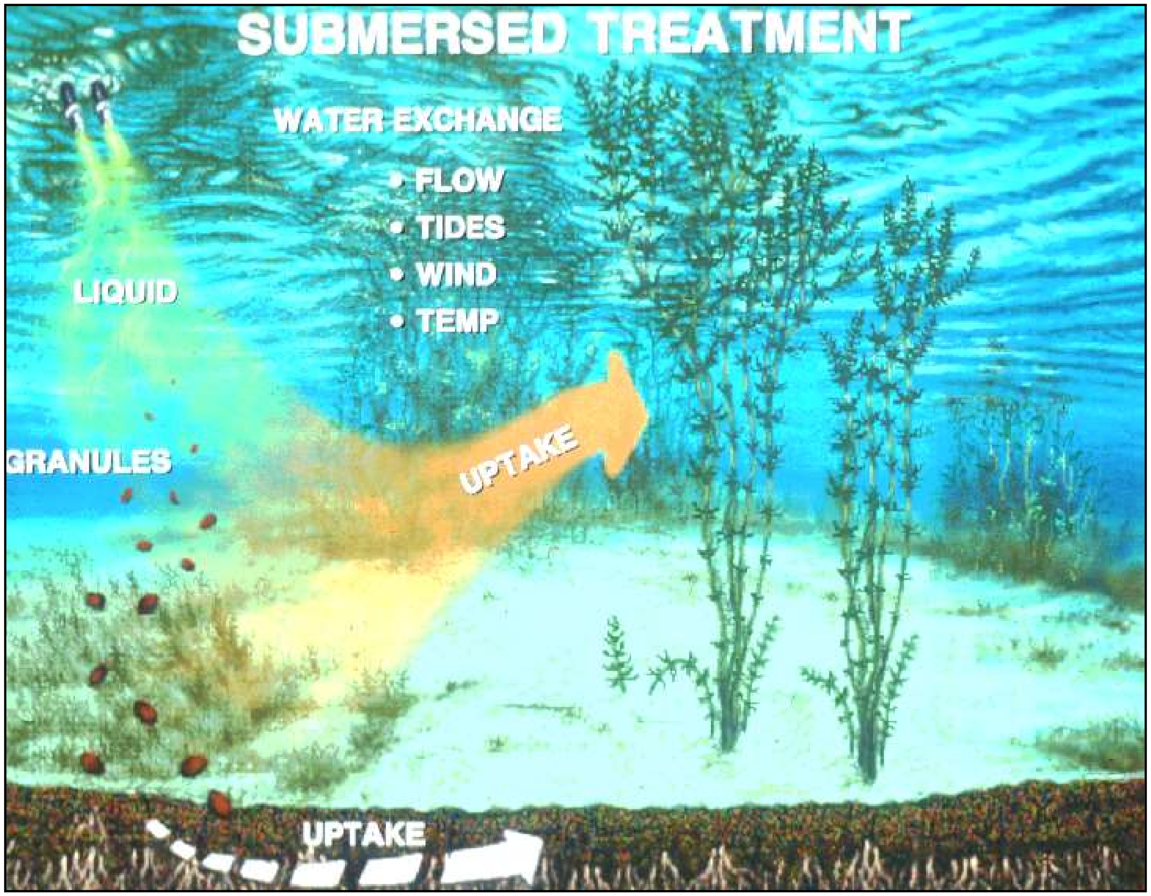
Opposition to Glyphosate

"Thank goodness the tide against these highly toxic chemicals is turning. The original testing for this chemical was designed by Monsanto[1] with no long-term studies and rubber stamped by regulators plucked from the industry[2]. The evidence on the broad toxicity of Glyphosate as an ecosystem disruptor in terms of fueling harmful algal blooms[3], destroying soil bacteria[4] and human health in terms of disruption of gut bacteria and cancer[5] is at least substantial enough to question the dousing of food crops with this poison[6]." *Comment on LinkedIn, Name withheld by me*

In the words of Jedi Master Luke Skywalker:



Submersed Plant Herbicide Applications



K. Getsinger, USAERDC

- Herbicides are applied to water, and plants take up herbicide from water
- Water movement, residence time, and concentration are critical for effective treatment

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

Eurasian watermilfoil test

Reference Aquathol 24h Aquathol 12 h 2,4-D

JM0

Herbicide susceptibility for four Arkansas submersed plants based on empirical testing.					
Active Ingredient	Trade Name*	Brazilian waterweed (*Egeria densa*)	Curlyleaf pondweed	Eurasian watermilfoil	Hydrilla
2,4 - D	Various	P		E	P
Bispyrabic-sodium^	Tradewind				
Carfentrazone-ethyl^	Stingray			F	
Copper complexes	Various	E	E	P	E
Diquat	Reward&	E	E	E	E
Endothall, Dimethylalkylamine Salt	Hydrothol 191&	E	E	E	E
Endothall, Dipotassium salt	Aquathol K&	P	E	E	E
Florpyrauxifen-benzyl^	ProcellaCOR	P		E	E
Flumioxazin^	Clipper	P			
Fluridone	Sonar&	E	G	E	E
Glyphosate#	Various				
Imazamox	Clearcast&	P	E	P	
Imazapyr#	Various				
Penoxsulam^	Galleon SC	P			
Peroxides	Various				
Topramezone^	Oasis				
Triclopyr	Various	P		E	

Slide 33

JM0 Make one for our submersed plants

John Madsen, 2023-08-02T00:53:33.021

Herbicide Application Rate and Plant Response Time

Chemical	Plant Response	Maximum Application Rate
2,4-D	7-10 days	0.5 gal/acre
Carfentrazone-ethyl	7-14 days	0.2 lb ai/acre
Diquat	7 days	2 gal/acre
Glyphosate	Up to 4 weeks	2 gal/acre
Imazapyr	Up to 8 weeks	.75 gal/acre
Triclopyr	Up to 2 weeks	6 lb ae/acre

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							
	Treated Water Use Restriction (days)						
	Human			Animal	Irrigation		
Chemical	Drinking	Swimming	Fish Con-sump-tion	Drinking	Turf	Forage	Food Crops
2,4-D	21	0	0	0	21	21	21
Carfentrazone-ethyl	1	0	0	1	14	14	14
Diquat	1-3	0	0	1	1-3	5	5
Glyphosate	0	0	0	0	0	0	0
Imazapyr	2	0	0	0	120	120	120
Triclopyr	*	0	0	0	0	120	120

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

Fish Impact: Largemouth Bass

Mikol, G.F. 1985. J Aquat. Plant Manage. 23:59-63.

Summary of direct effects of 1982 mechanical harvesting on juvenile largemouth bass (*Micropterus salmoides*).			
	Collection date 8/13/1982		
	Site #1	Site #2	Combined
Total # of fish removed	11	7	18
# fish removed / ha	220	56	103
Fish standing crop estimate (#/ha)	1,894	1,894	1,894
% standing crop removed	11.6	3.0	5.4
Site #1 was previously harvested in June 1982. Site #2 was previously unharvested			

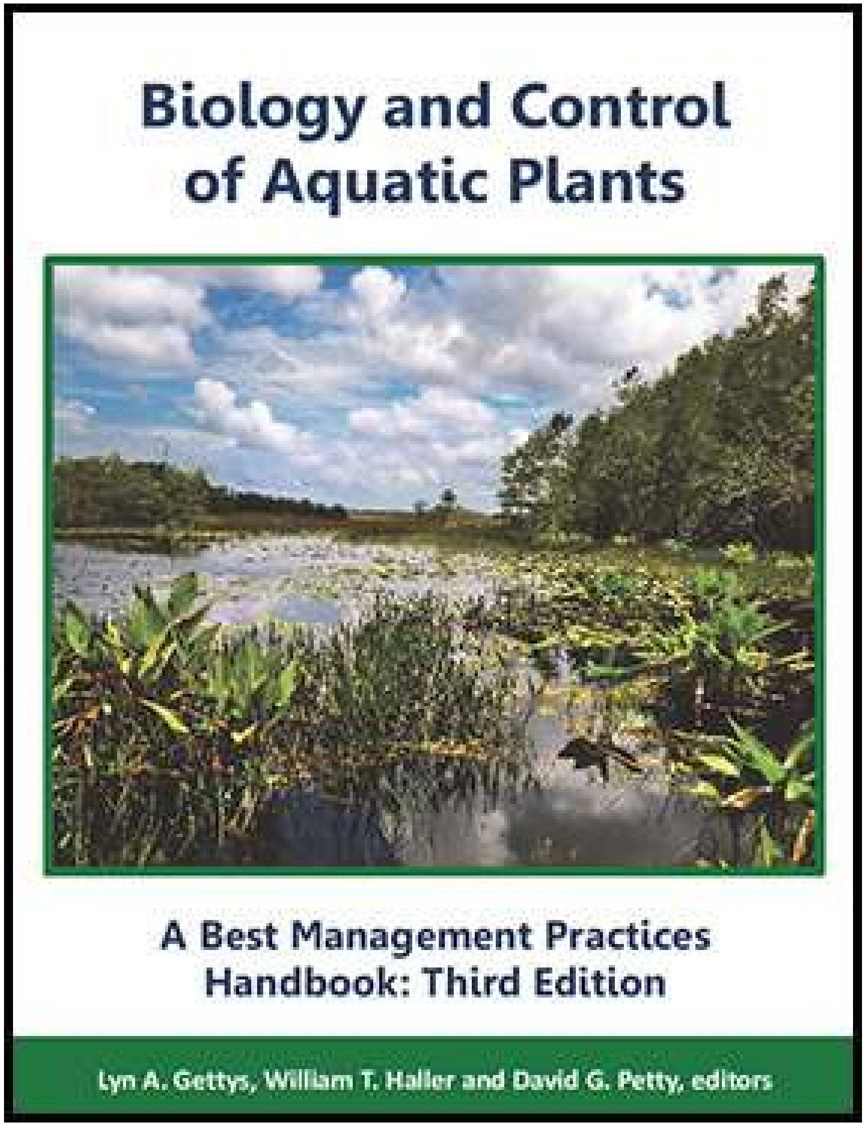
Physical Control

- 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

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).