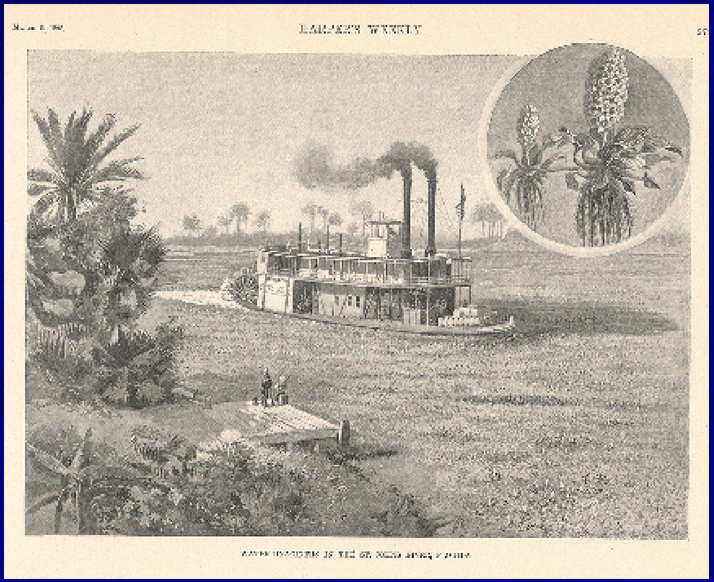
Ecosystem Implications of Invasive Aquatic Plants and Aquatic Plant Control in Florida Springs

Jason M. Evans, PhD
School of Forest Resources and Conservation
University of Florida
January 29, 2008

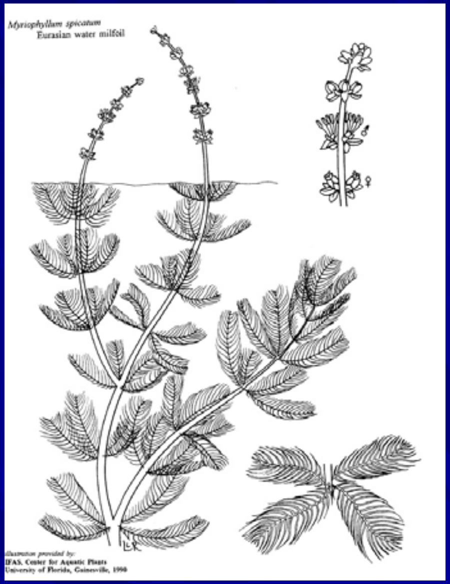
Major Invasive Plants

- Water hyacinth (*Eichhornia crassipes*)
- Water lettuce (*Pistia stratiotes*)
- Hydrilla (*Hydrilla verticillata*)



Other Invasive Plants

- Eurasian milfoil (*Myriophyllum spicatum*)
- Indian Hygrophila (*Hygrophila polysperma*)
- Brazilian Elodea (*Egeria densa*)
- Wild taro (*Colocasia esculenta*)



Aquatic Plant Control: Springs

- Approximately $167,000 spent by DEP for aquatic plant control in spring-fed ecosystems during 2005-2006 fiscal year (BIPM 2007)
  - $64,500: Wakulla River, hydrilla
  - $48,500: Rainbow River, hydrilla
  - $27,400: Weeki Wachee, hydrilla
  - $11,500: Wekiva River, hyacinth and lettuce
  - $8,500: Crystal River, hyacinth and lettuce
  - $2,700: Rainbow River, hyacinth and lettuce
  - $1,600: Silver River, hydrilla

Questions 1a and 1b

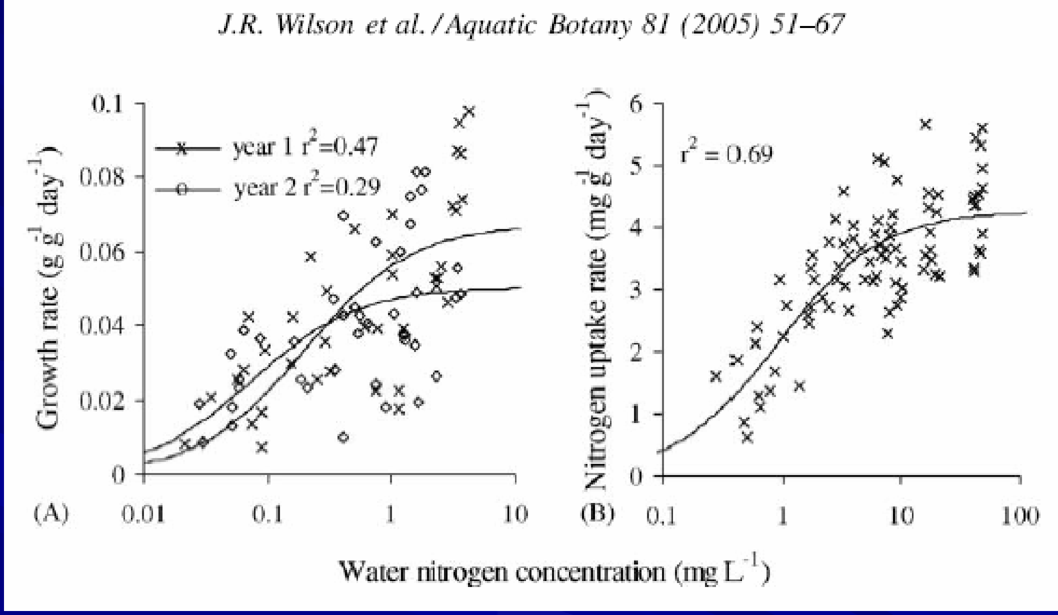
- Does elevated nitrate-nitrogen promote increased growth of invasive plants in springs?

- If so, at what nitrate-nitrogen level would invasive plant growth be limited and/or reduced in springs?

Floating plants

- Water hyacinth and water lettuce show similar growth and uptake response to dissolved nutrients in non-flowing tank experiments (e.g., Aoi and Hayashi 1996)

- General N-limitation for water hyacinth in non-flowing conditions modeled at:
  - N < 1 mg/l *and*
  - N/P < 7-8 (Wilson et al. 2005)



However…

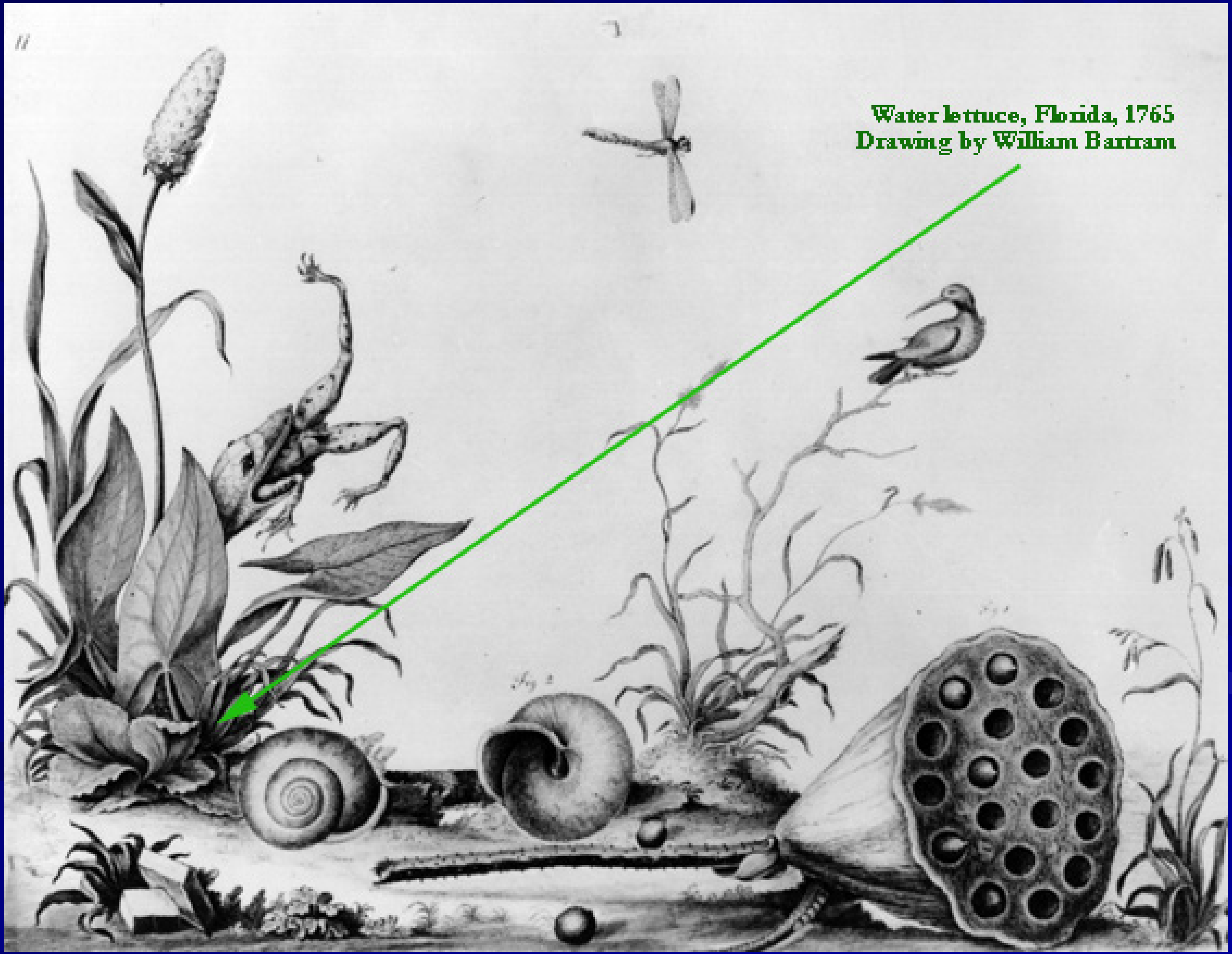
- Maximum growth rate for water hyacinth at:
  - 0.28 mg/l TN and 0.06 mg/l TP (4.67 N/P) in spring-fed St. Marks River (Bartodziej and Leslie 1998)
  - 0.4 mg/l nitrate-nitrogen (both hyacinth and lettuce) at Silver River in 1950s (Odum 1957)
- Nutrients no longer limiting for water hyacinth at 0.16 mg/l TN and 0.02 mg/l TP in Thailand’s Tha-Chin River (Mahujchariyawong and Ikeda 2001)

Historic observations

- 1903 nitrate-nitrogen in Silver River reported at 0.03 mg/l (Munch et al 2006)
  - Stunted water hyacinths in Silver River circa 1890s (Webber 1897)

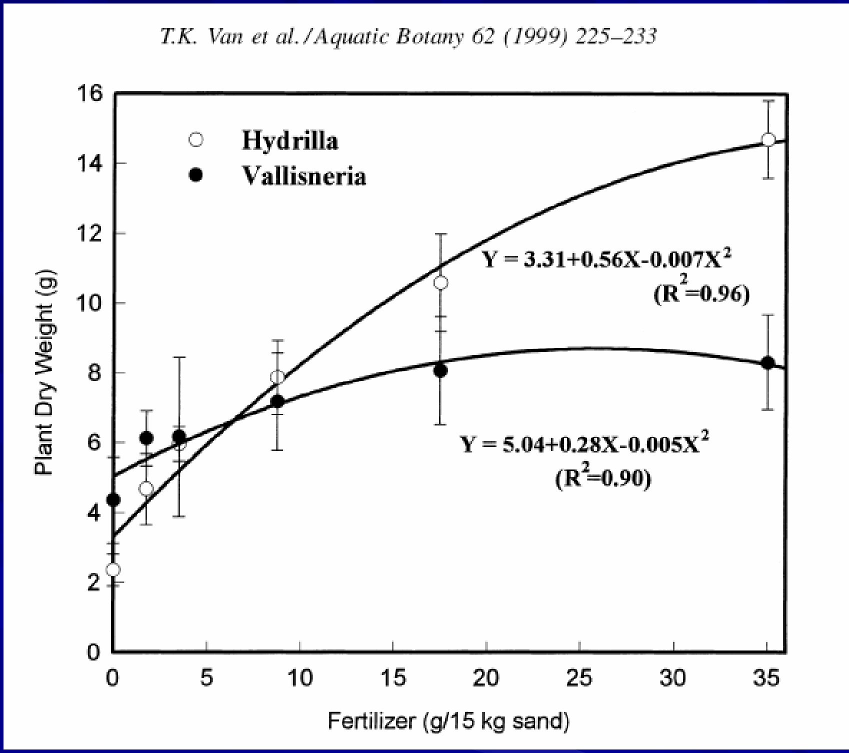
- Large accumulations of water lettuce in Wekiva River circa 1890s (Webber 1897)

Historic observations



Hydrilla

- Nutrient uptake through leaves (dissolved) and roots (sediments) complicates determinations of nutrient limitation
- Higher sediment N correlated with increased competitive displacement of *Vallisneria americana* in non-flowing mesocosms (Smart et al., 1994; Van et al., 1999)
- Terrell and Canfield (1996) concluded that TN reductions to a concentration many times below the observed level of 0.26 mg/l would not effectively reduce hydrilla growth in Kings Bay/Crystal River
  - Nutrient replacement in flowing waters, high light levels, and sediment storages sufficient to sustain maximum growth



Bottom line

- Nitrogen limitation for hyacinth, lettuce, and hydrilla growth only likely to occur at levels near, or perhaps even below, background water quality in most springs

Question 2

- What are potential ecosystem implications of major invasive plants, particularly in terms of “forward shifts” to more algae-dominated springs?

Boom-bust hypothesis

Invasive “boom”:

1. Displaces native plants through higher productivity
2. Results in increased biomass and organic matter accumulation
3. Changes faunal community structure

Catastrophic “bust”

1. Invasive plants subject to population crashes after salinity pulses, floods, aquatic plant control, freezes, other stochastic events
2. Opportunistic algae rapidly fill in ecological “void” and assume dominance after bust

Allelopathy hypothesis

- Powerful algaecides isolated from both water hyacinth (Jin et al 2003) and water lettuce (Aliotta et al 1991)
- Hydrilla shown to allelopathically suppress some other aquatic plants (Kulshresthna and Gopal 1983), but not demonstrated for algae
- Large-scale emissions of novel allelopathic compounds may select for resistant algae and plant taxa (e.g., Gross 2003)

Question 3

- What are the potential ecosystem implications of aquatic plant control operations, particularly in terms of “forward shifts” to more algae-dominated springs?

Control Methods

- Herbicides
  - Endothall (hydrilla, hygrophila)
  - 2-4,D (hyacinth, hygrophila)
  - Glyphosate (hyacinth)
  - Diquat (hydrilla, hyacinth, lettuce)
  - Copper (hydrilla, hyacinth, lettuce)
    - Manatee toxicity concerns (O'Shea 1984)
  - Fluridone (hydrilla, hygrophila)
    - Resistant hydrilla biotypes increasing (Michel et al. 2004)
    - Not suited for flowing water

Other Control

- Physical
  - Mechanical harvest
    - Expense
    - Fragment sprouting, particularly hydrilla
    - Non-target concerns
  - Manual harvest
    - Labor intensive
- Biological
  - Grass carp
    - Can over graze native plants
  - Biocontrol insects
    - Results not immediate
    - Ongoing research and lengthy risk assessments
    - Non-target concerns
    - Perhaps most sustainable over long-term

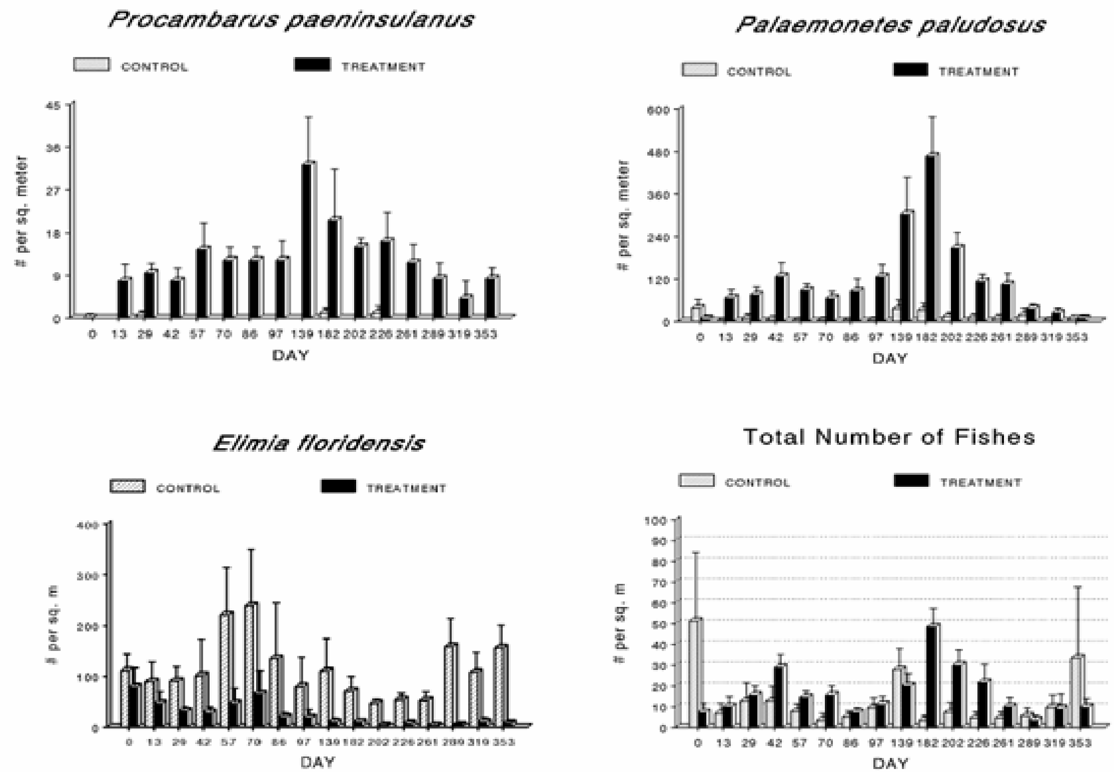
Algal community selection hypothesis

- Herbicides with algaecidal properties may have secondary effect of selecting for resistant algae communities
- Copper and diquat of most concern due to algaecidal action at aquatic plant control concentrations
  - *Lyngbya* sp. and *Oscillatoria* sp. often show evolved resistance to copper herbicide/algaecide formulations (Spencer and Lembi 2005)
  - Diquat generally becomes ineffective for *L. wollei* control after repeat usage (Bayne 2005)
- *Microcystis* sp. recently shown to evolve biotypes resistant to copper (Garcia-Villada et al. 2004) and glyphosate (Lopez-Rodas et al. 2007)

Attractor-Catastrophe hypothesis

- Invasive plants become primary habitat for faunal communities

- Key species are subject to catastrophic losses through non-target toxic effects or general habitat disturbance associated with aquatic plant control activities



Figures 7-10: Ecosystem survey results from St. Marks River (Bartodziej and Leslie 1998).

Control = Strap leaf sag (*Sagittaria kurziana*)

Treatment = Water hyacinth (*Eichhornia crassipes*)

Toxicology

- Copper
  - Severe copper bioaccumulation in manatees attributed to aquatic plant control at Kings Bay/Crystal River during late 1970s and early 1980s (O'Shea 1984)
- Diquat
  - Washington Department of Ecology lists diquat as "very highly toxic" to *Hyalella azteca*, with LC50 as low as 0.048 mg/l diquat (Emmett 2002)
    - *H. azteca* may be an important grazer of *L. wollei* (Comacho and Thacker 2006)
  - "Highly toxic" to apple snail (*Pomacea paludosa*), with LC50 as low as 0.34 mg/l diquat (Emmett 2002)
  - Both species achieve high population densities in water hyacinth and water lettuce in springs (Schmitz et al. 1993; Bartodziej and Leslie 1998; Corrao et al. 2006)

Habitat Disturbance

- Prolonged oxygen sags recorded after aquatic plant control at Wakulla River (DEP 2006) and Wekiva River (Wetland Solutions, Inc. 2006)
- Destruction of habitat due to aquatic plant control suspected as major contributor to apple snail loss in some springs systems (Corrao et al. 2006)

Final Question

- Are there opportunities for adaptive management of invasive aquatic plants in Florida springs?

Perhaps…

- First… monitoring and research to better understand nutrient relationships and ecosystem effects of current control
- Hydrilla biocontrol research (Cuda et al. 2002)
- Floating plant phytoremediation (Mahujchariyawong and Ikeda 2001; SJRWMD 2006)
  - Nutrient removal
  - Faunal recovery
  - Algal displacement
- Hydrilla promoting long-term recovery of submersed native plants (including *Vallisneria americana*) in Potomac River (Rybicki and Landwehr 2007)