Aquatic weeds:
Water waste or water wise?

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Invasive Aquatic Plants and Water

- Importance of aquatic native plant communities
- Overabundant plant growth will adversely affect water quality and quantity
- The benefits of managing aquatic plants for water resources

(Top) Hydrilla mat entangles outboard motor on Lake Gainesville, MS.
(Bottom) Giant salvinia completely covers bayou along Pascagoula River, MS. Photos by W. Robles.

Background Information

CAST

CAST Commentary

QTA2014-1 July 2014

Benefits of Controlling Nuisance Aquatic Plants and Algae in the United States

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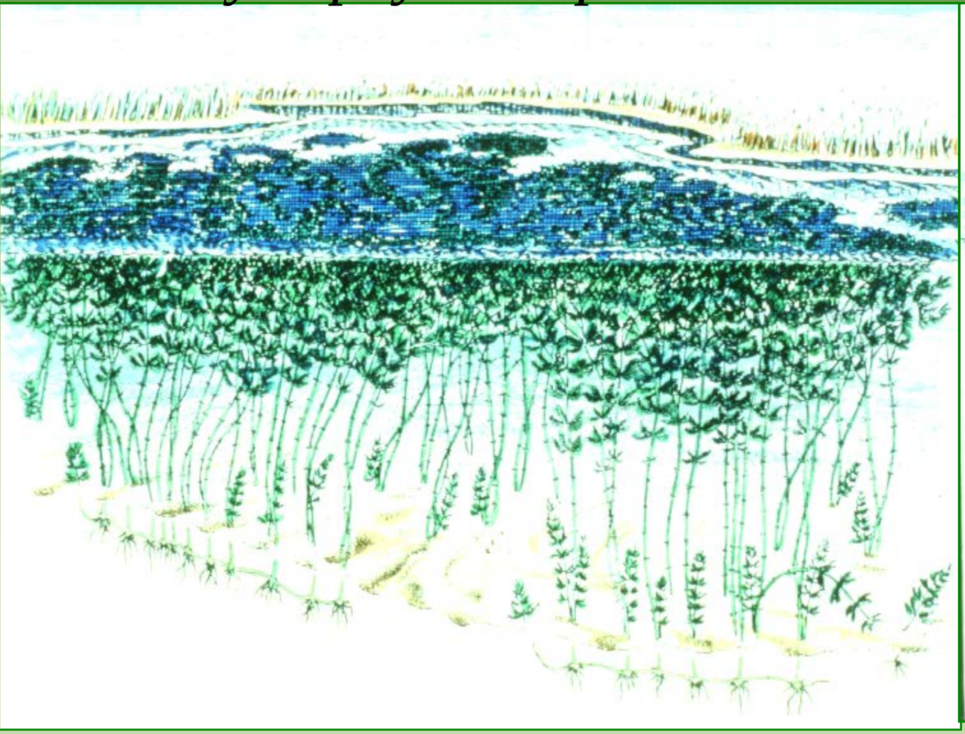
www.cast-science.org

Benefits of Native Aquatic Plants

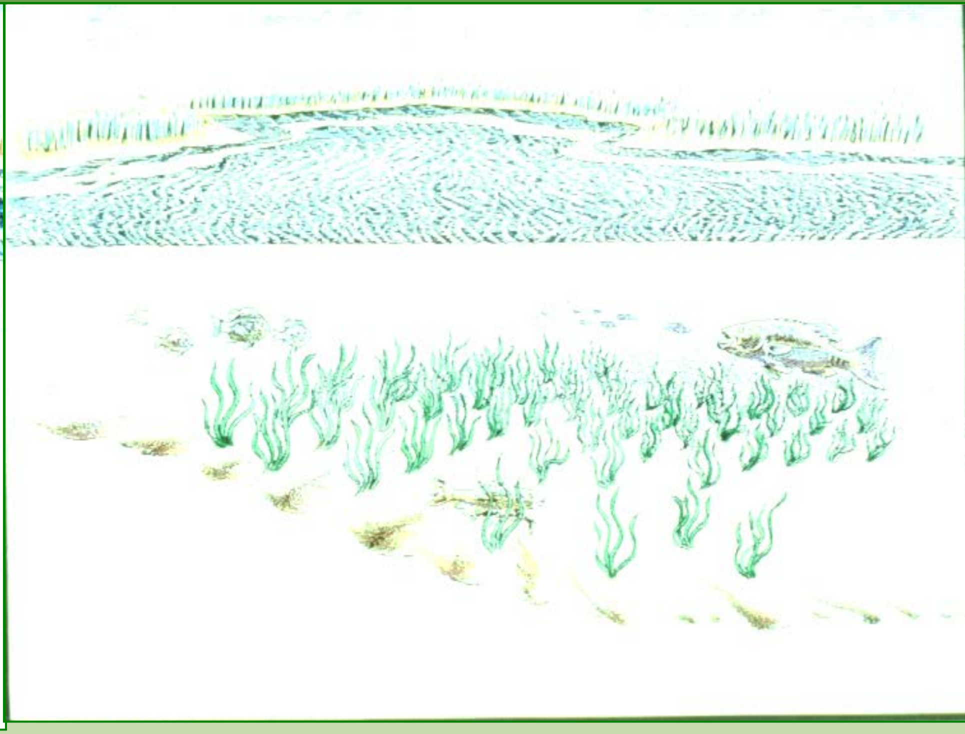
- Stabilize lakes sediments, reducing re-suspension and erosion
- Increase sedimentation, reducing turbidity
- Provide habitat for insects, forage fish, fish spawning and YOY fish
- Provide food for waterfowl, other animals

Invasive vs. Native Community

Eurasian watermilfoil
Myriophyllum spicatum

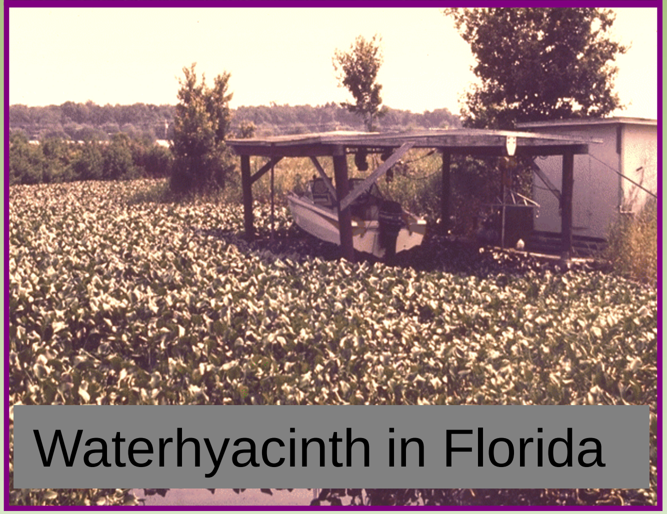


Water celery
Vallisneria americana



Problematic Invasive Aquatic Plant Species

Hydrilla in Lake Guntersville, Alabama



Waterhyacinth in Florida

Eurasian watermilfoil in Lake George, NY

Significant California Aquatic Nuisance Species

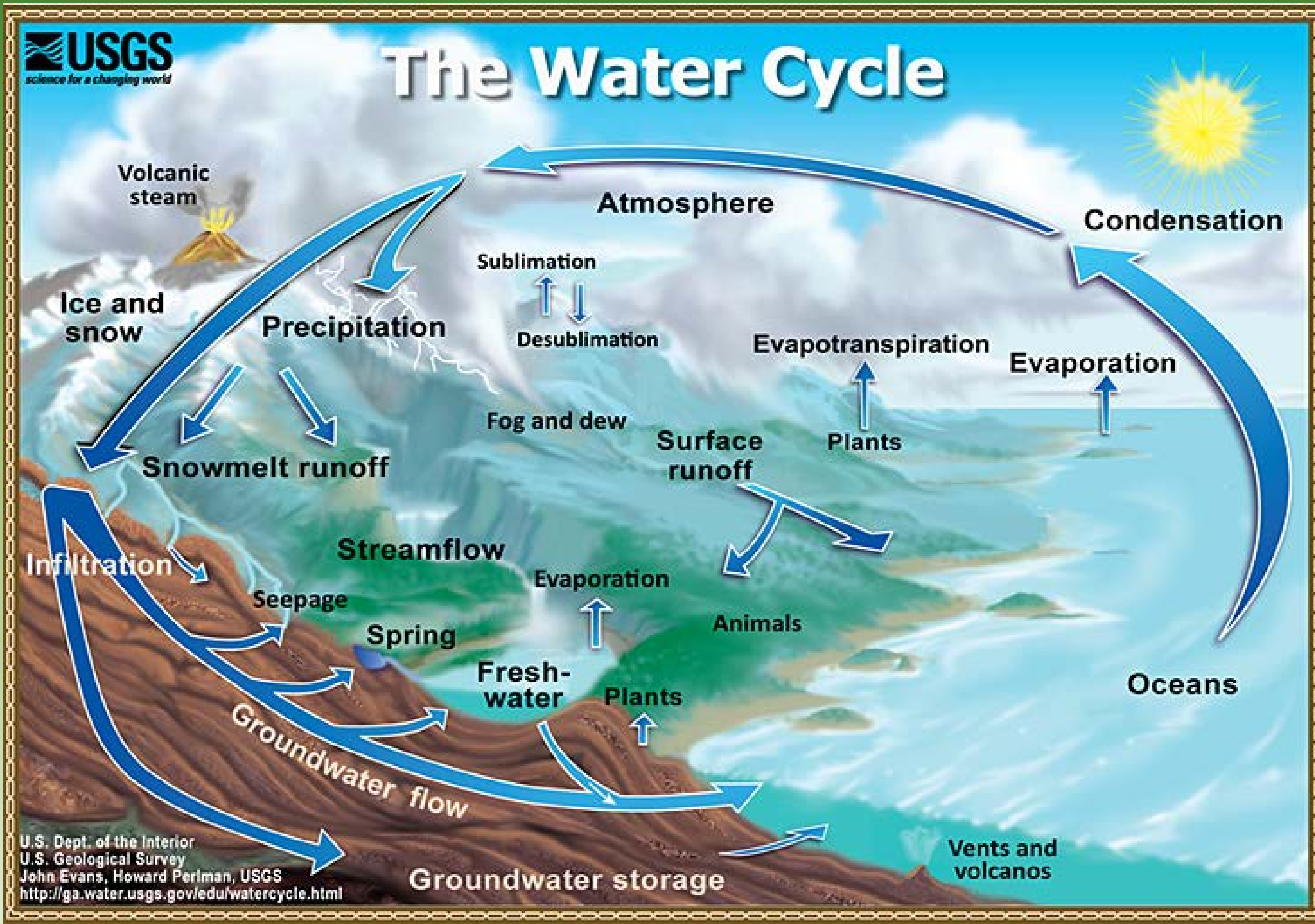
- Waterhyacinth
- Hydrilla
- Eurasian watermilfoil
- Waterprimrose
- Egeria
- See Cal-IPC
    - http://www.cal-ipc.org/

Weeds Adversely Affect Water Loss

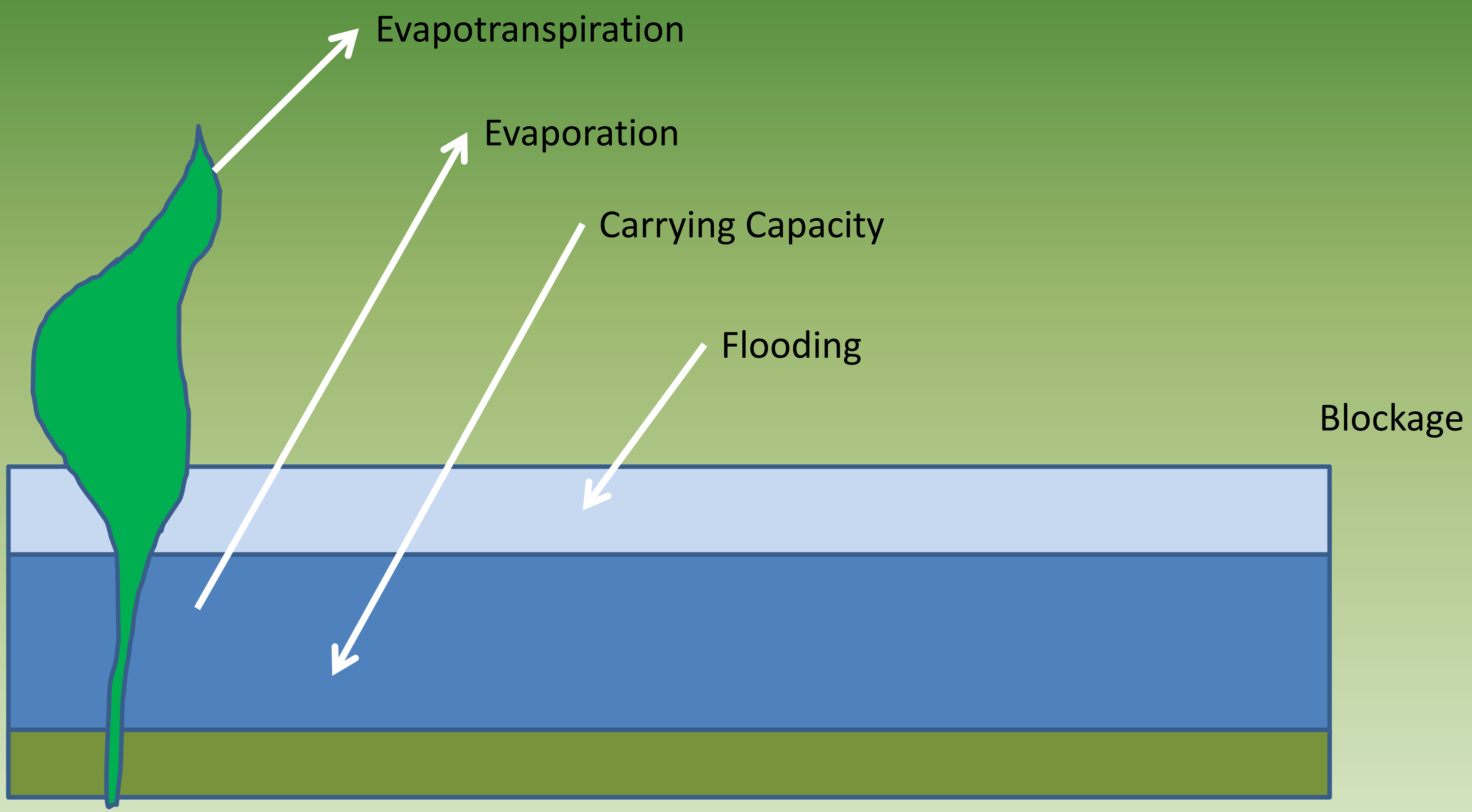
- Evapotranspiration
- Carrying capacity
- Flooding
- Blockage
- Water quality
- Drinking water issues

Madsen on Jefferson Slough, MT. Invasive hybrid cattail and Eurasian watermilfoil have altered the flow pattern to create shallow channel, reduced flow, and increased sedimentation. Reduced flows have encouraged channel widening. Photo by Celestine Duncan.

Hydrologic Cycle

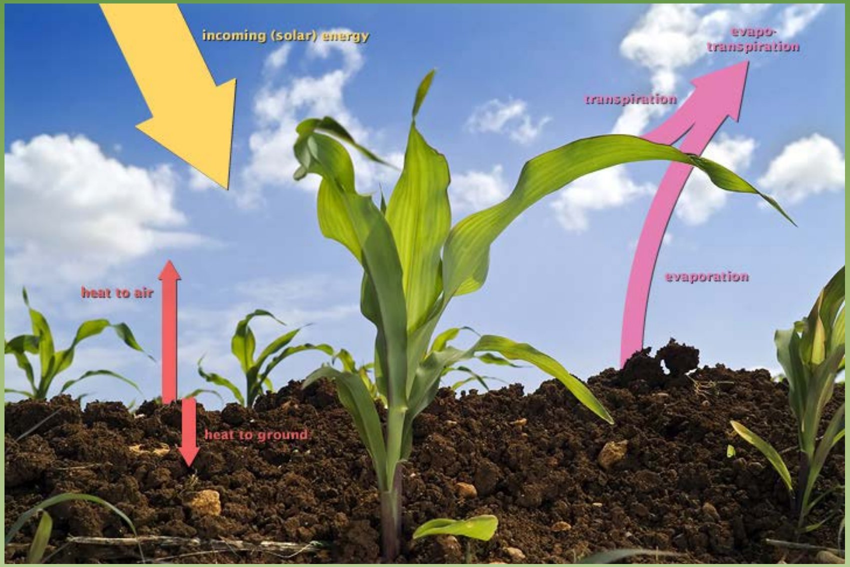


Water Loss Categories



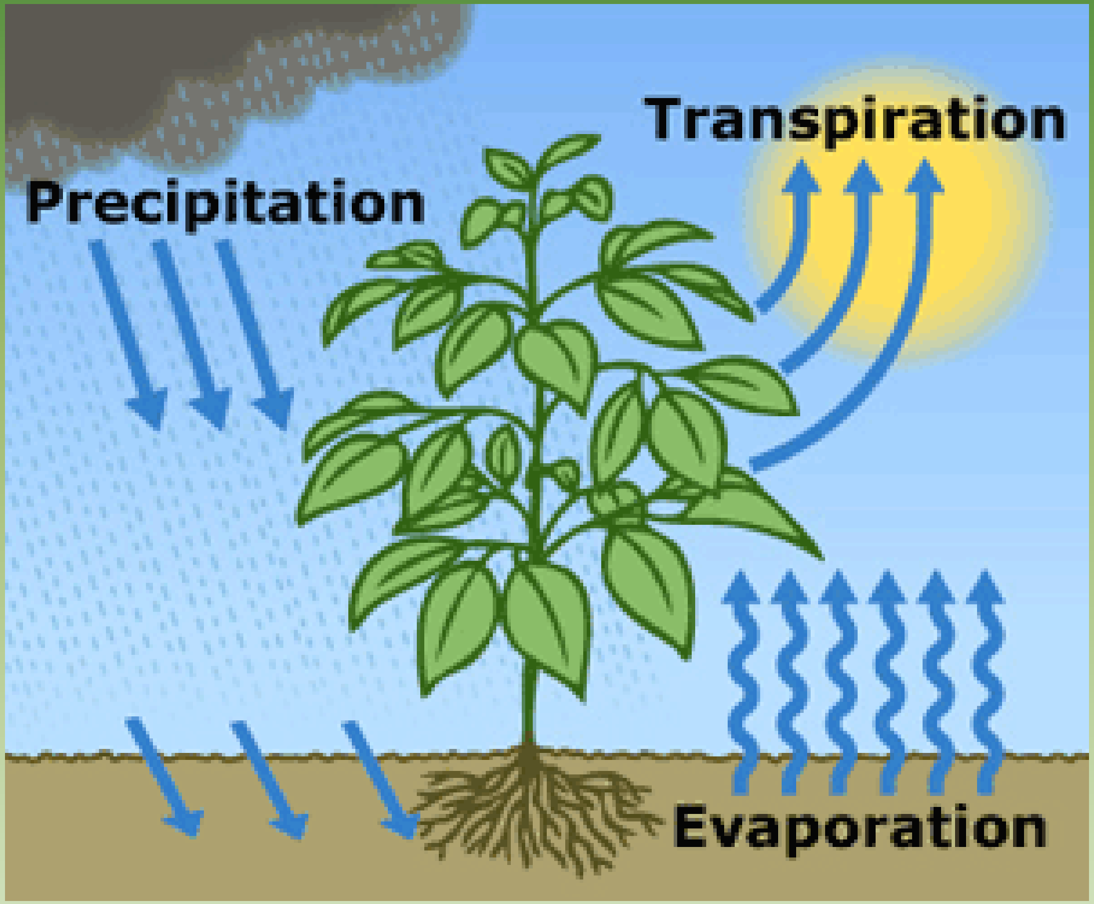
Evapotranspiration

- Water loss from evaporation and transpiration in a plant canopy, as opposed to evaporative water loss from standing water alone.



NASA

Evapotranspiration



Source: US Geological Survey

Evapotranspiration / Evaporation Ratio

Species	Et / Eo	Source (c – cited)
Alligatorweed	1.26	Boyd 1970
Cattail, broadleaf	1.75 – 2.50	Boyd 1970 c
Cattail, broadleaf	1.84	Snyder & Boyd 1987
Cattail, narrowleaf	1.52	Brezny et al. 1973
Duckweed	0.9	Boyd 1970 c
Pickerelweed	1.2	Boyd 1970 c
Softstem bulrush	1.9	Boyd 1970 c
Waterchestnut	0.99	Brezny et al. 1973
Waterhyacinth	1.26 – 1.70	Boyd 1970 c
Waterhyacinth	1.26	Brezny et al. 1973
Waterhyacinth	2.02	Snyder & Boyd 1987
Waterhyacinth	3.67	Timmer & Weldon 1967
Waterlettuce	0.93	Brezny et al. 1973
Watermeal	0.89	Boyd 1970 c
White waterlily	1.0	Boyd 1970 c

Summary of Plants and Evapotranspiration

- Species differ in rates, and environmental factors play a role
- Emergent plants tend to transpire more than just evaporation
- Horizontally-growing free-floating plants transpire equivalent to evaporation
- Submersed plants don’t transpire at all…

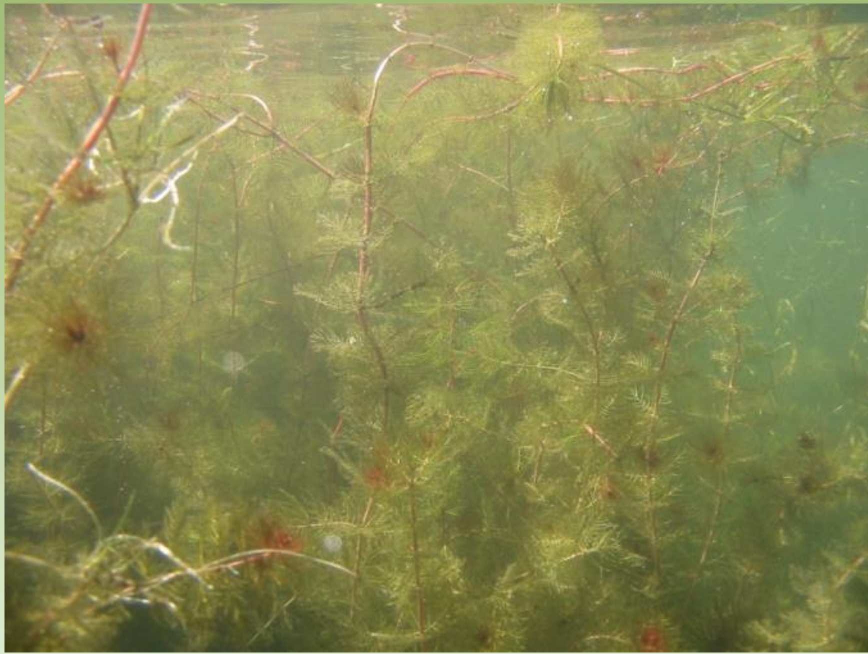
Dissenting Opinions

Evapotranspiration of vegetation of Florida: perpetuated misconceptions versus mechanistic processes. Allen, L. H., Jr.; Sinclair, T. R.; Bennett, J. M.; Proceedings - Soil and Crop Science Society of Florida, 1997, 56, pp 1-10, 2 pp. of ref. Two invasive plant species in Florida, water hyacinth (*Eichhornia crassipes*) and *Melaleuca quinquenervia*, have been attributed with far more water use than native wetland and terrestrial species or open bodies of water. Control programmes for water hyacinth have been proposed based on putative savings of reservoir water supplies. Part of the rationale for eradication of *Melaleuca* in southern Florida is the fear that this tree will "dry up the Everglades." The purpose of this paper is to review the origins of misconceptions concerning "evaporative power" of these species and to explain why all well-watered vegetation in similar climates should have similar evapotranspiration (ET) rates. The ratio of ET to open-water evaporation (E_0) reported for water hyacinth ranges from 12 to 0.87. The large values of ET/E_0 reported in the literature have been caused by growing plants in small containers which expose large peripheral foliage surface areas above the surrounding area, creating a "clothesline effect". Non-emergent, but exposed, floating vegetation has ET/E_0 values of about 0.9. Large areas of emergent aquatic plants should not have ET/E_0 ratios greater than 1.0.

Carrying Capacity

- Aquatic plants can impair the ability of a channel to carry water through:
  - Taking up space (volume / displacement)
  - Reducing flow velocity and "throughput"
  - Increasing hydraulic resistance
  - Encourage sedimentation

(Top) Channel of Pend Oreille River filled with Eurasian watermilfoil. (Bottom) Underwater view of Eurasian watermilfoil. Photos by John Madsen.



Biovolume in Lake Littoral

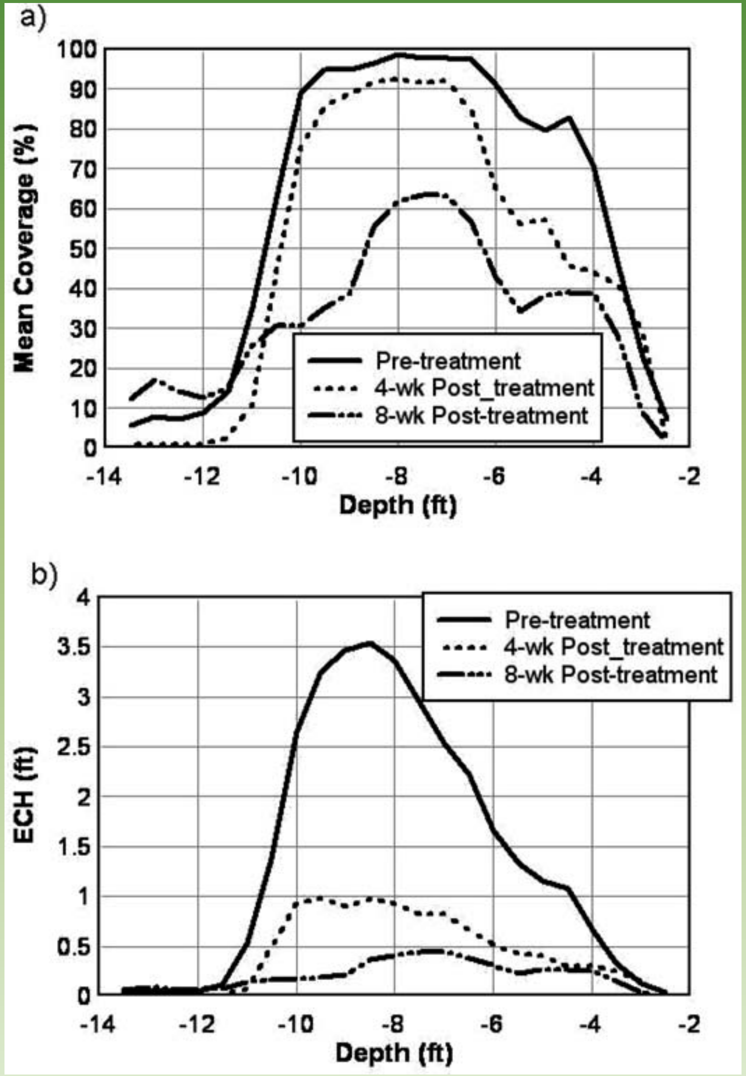


Figure 4. Mean coverage (a) and mean ECH (b) by depth increments of 0.5 ft.

Sabol et al. 2009

Hydroacoustic Transect
Thomas et al. 1990

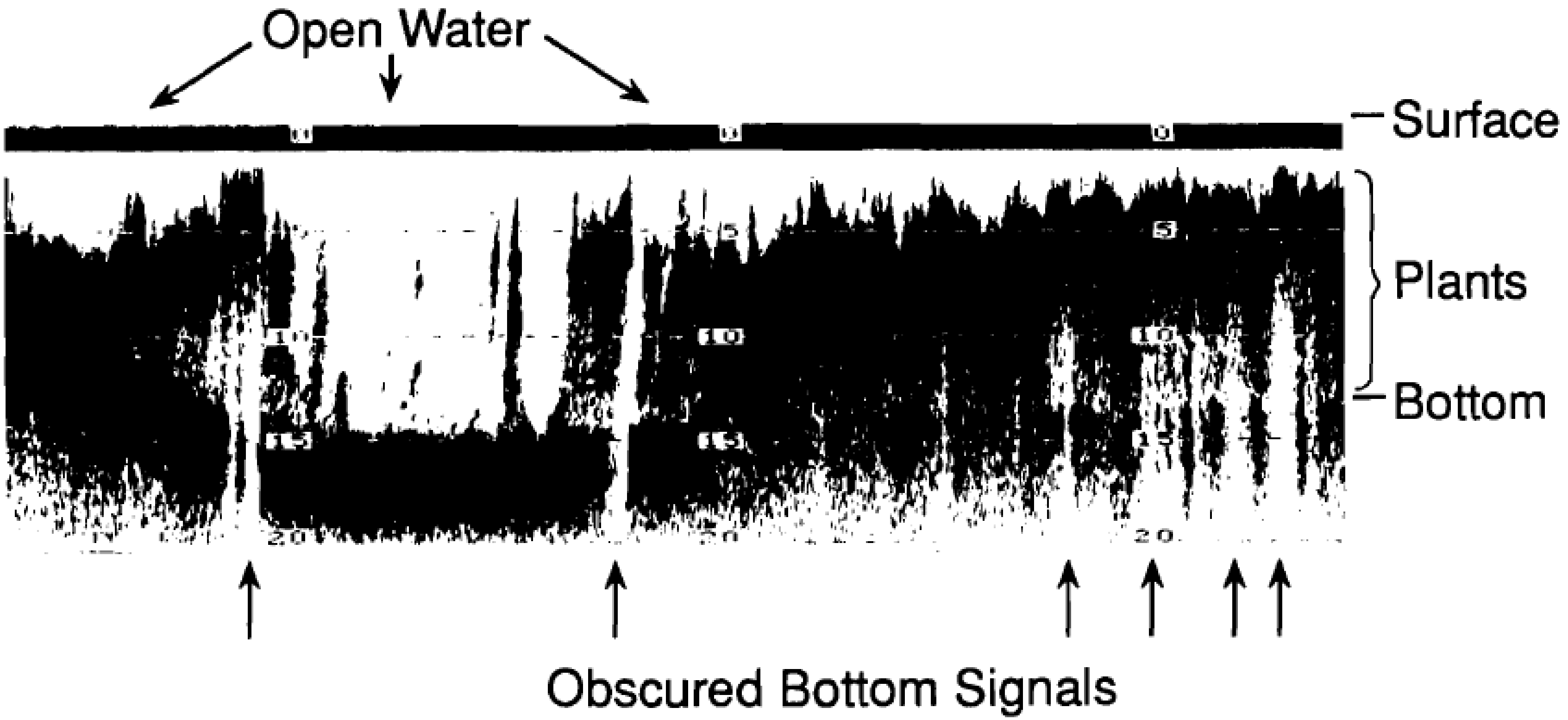


FIG. 2. Echogram showing cross sectional area of water column showing the open water and the water occupied by aquatic plants, and the areas under the plant beds where bottom detection is partially or totally obscured.

Biovolume in Littoral

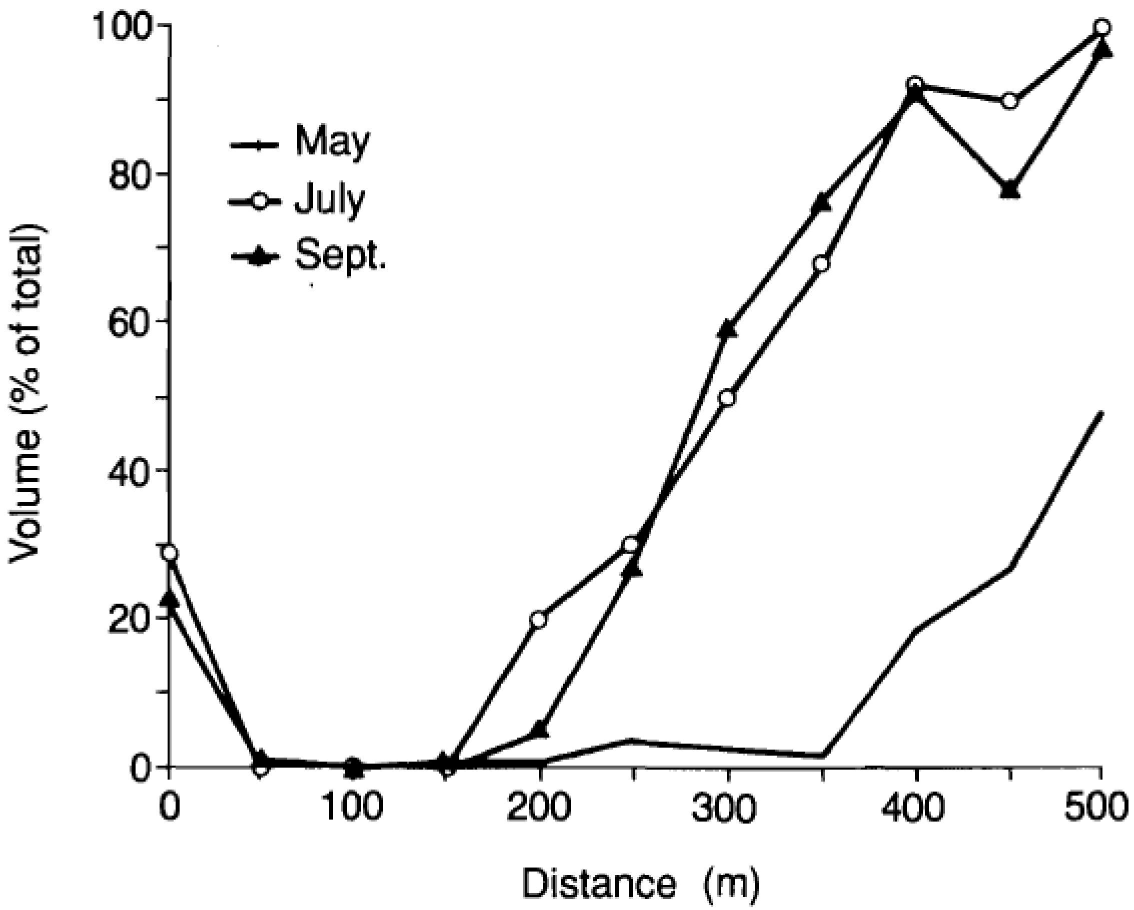


FIG. 5. Distribution of aquatic plants (by percent volume of water column) across Devils Lake in May, July, and September 1986 (Transect 7).

Thomas et al. 1990

Vegetation and Velocity Profile

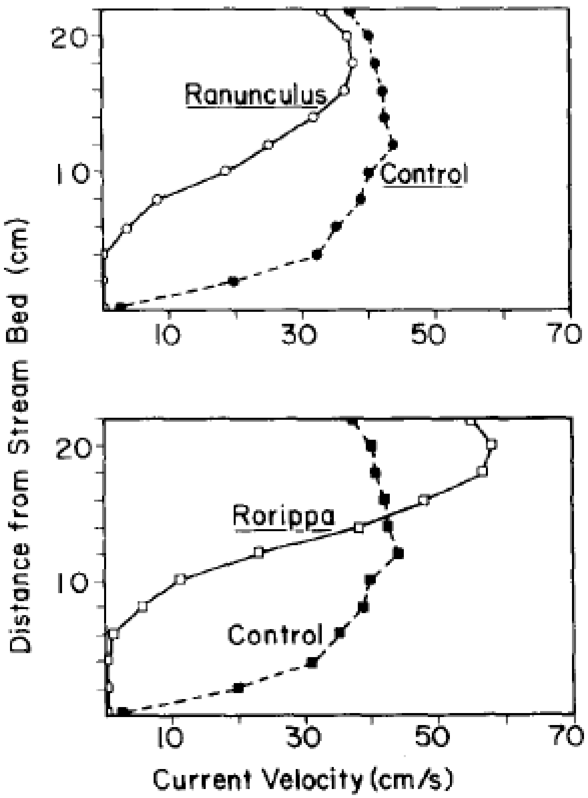


Fig. 2. Mean current velocities at 2 cm intervals over substrate trays from the stream bed to the surface: (a) comparison of current velocities in and over *Ranunculus aquatilis* trays to those over control trays; (b) comparison of current velocities in and over *Rorippa nasturtium-aquaticum* trays to those over the control.

Gregg and Rose 1982

Flow near Aquatic Plants
Nepf 2012

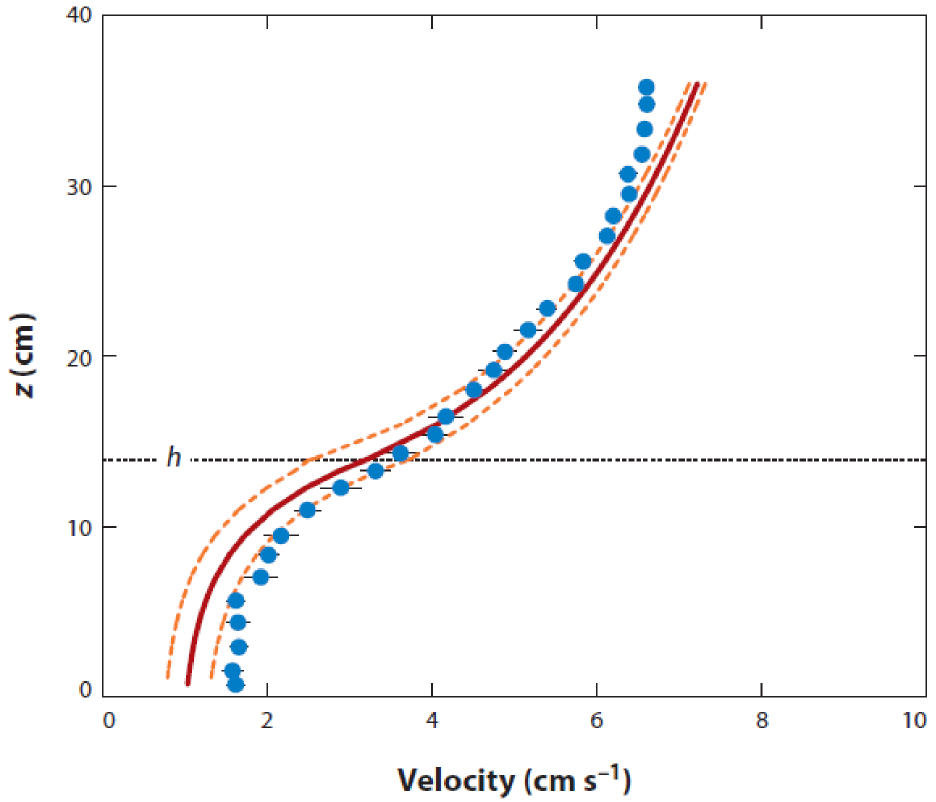


Figure 5

Measured velocity (*dots*) from Ghisalberti (2005). Predicted velocity (*solid line*) with confidence limits (*dashed lines*): $H = 46.7$ cm, $h = 13.9$ cm, $S = 2.5 \times 10^{-5}$, $a = 0.034$ cm^{-1}, and $C_D = 0.77$ (measured). Above the meadow, the velocity is predicted from the logarithmic profile (Equation 12), with $u_* = [gS(H - h)]^{0.5}$, $z_m = h - (1/2)\,\delta_e$ (Equation 13), and $z_o = (0.04 \pm 0.02)a^{-1}$. Inside the meadow, the velocity is predicted from Equations 14 and 15, with U_h taken from logarithmic fit.

Aquatic Plants and Hydraulic Roughness
Bal et al. 2011

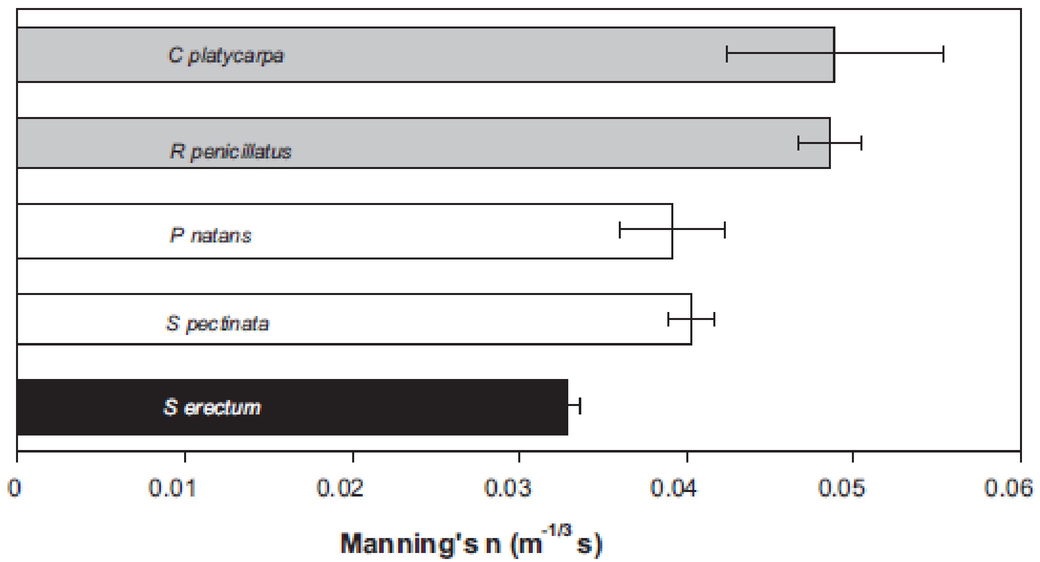
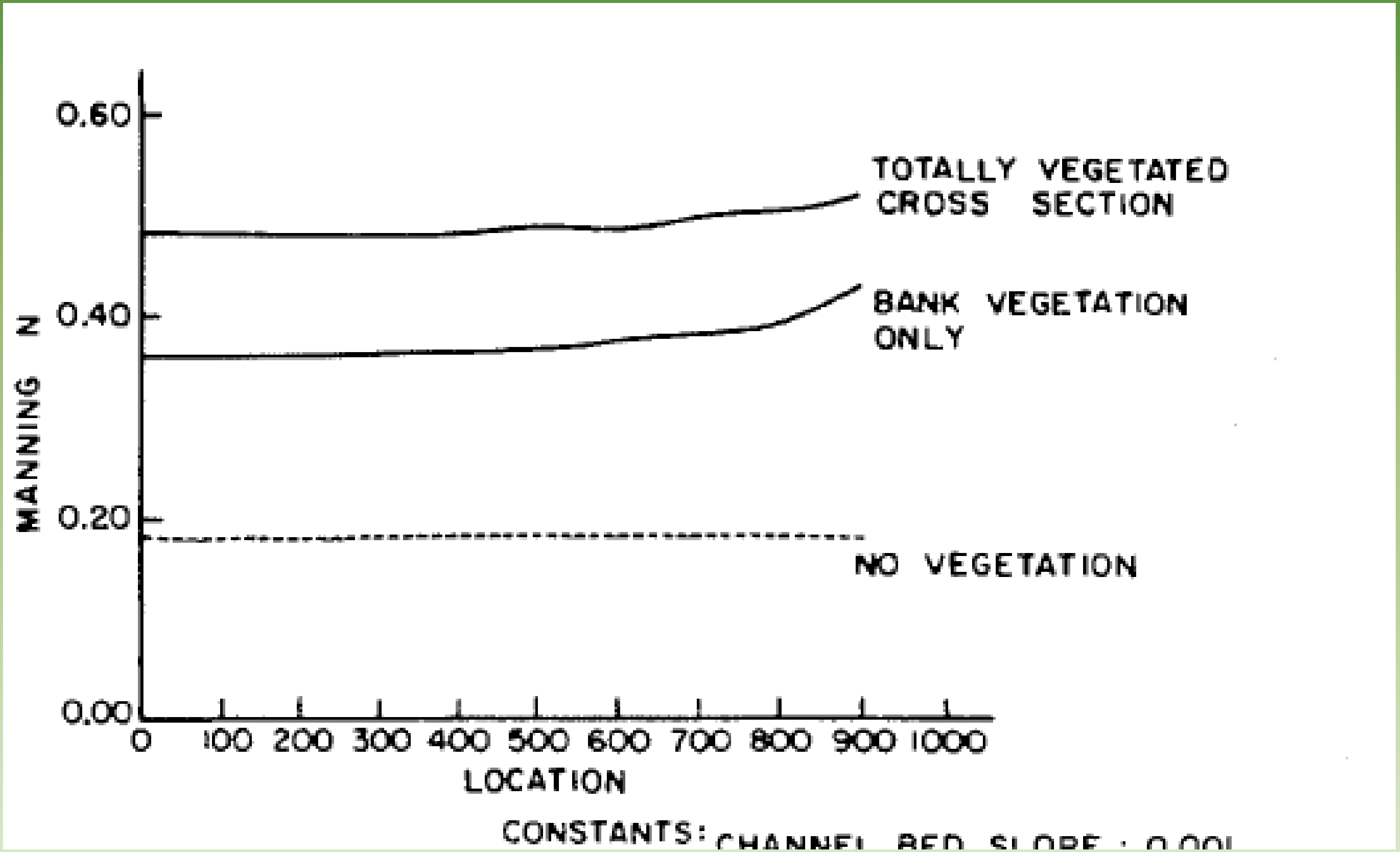


Fig. 3. The average Manning's *n* (averaged for discharge and vegetation distribution pattern) of 5 macrophyte species (*C. platycarpa*, *R. penicillatus*, *P. natans*, *S. pectinatus*, *S. erectum*). Species differing ($p < 0.05$) from each other are shown in different colours.

Vegetation and Irrigation Canals
Manz and Westhoff 1988



Irrigation

- Invasive aquatic plants can reduce the water flow and holding capacity of irrigation canals by 75%
- Weed control in canals is often difficult due to flowing water environment and water use restrictions

CAIP, IFAS

Invasive Weeds and Irrigation Canals

The results of the numerical experiments illustrate that for weed-infested, earth-lined canals without buried membranes, flow characteristics such as depth of flow, average velocity, and channel roughness may be difficult to predict and that weed infestations may seriously complicate the operation of the canal. The increase in depth of flow due to the presence of aquatic weeds and (or) canal operations may cause an increase in seepage losses, reducing the carrying capacity of the channel and also resulting in salinity and (or) waterlogging problems in adjacent lands.

Manz and Westhoff 1988
Numerical analysis of the effects of aquatic weeds on the performance of irrigation conveyance systems

Flood Control

- Invasive aquatic plants increase the amplitude, duration, and probability of flooding
- Aquatic plant control in Florida saves an estimated $300M in potential property damage

CAIP, UFL

Submersed Plant Biomass and Flood Hazard

Higher biomass narrows the margin to hazard and flood stages in a stream with relatively constant flow. Sago pondweed dominant.

Madsen 1993

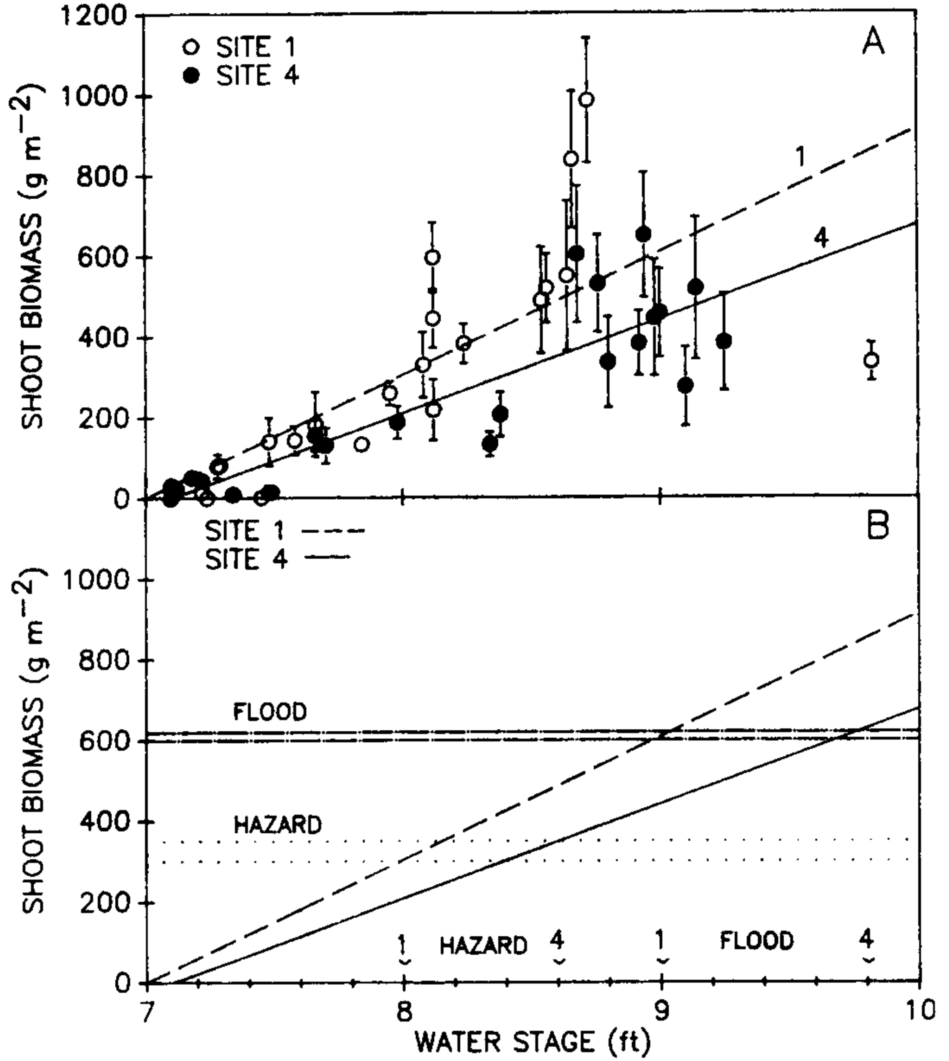


Figure 9.—Water level (or stage, in ft) versus aquatic plant shoot biomass (g m^{-2}) for two sites on Badfish Creek, WI. Mean biomass versus stage for each sample date at the two sites (A); estimation of biomass allowable from known hazard and flood stage water levels (B). Data from Madsen 1986.

Plant Effects on Channels
Gregg and Rose 1982

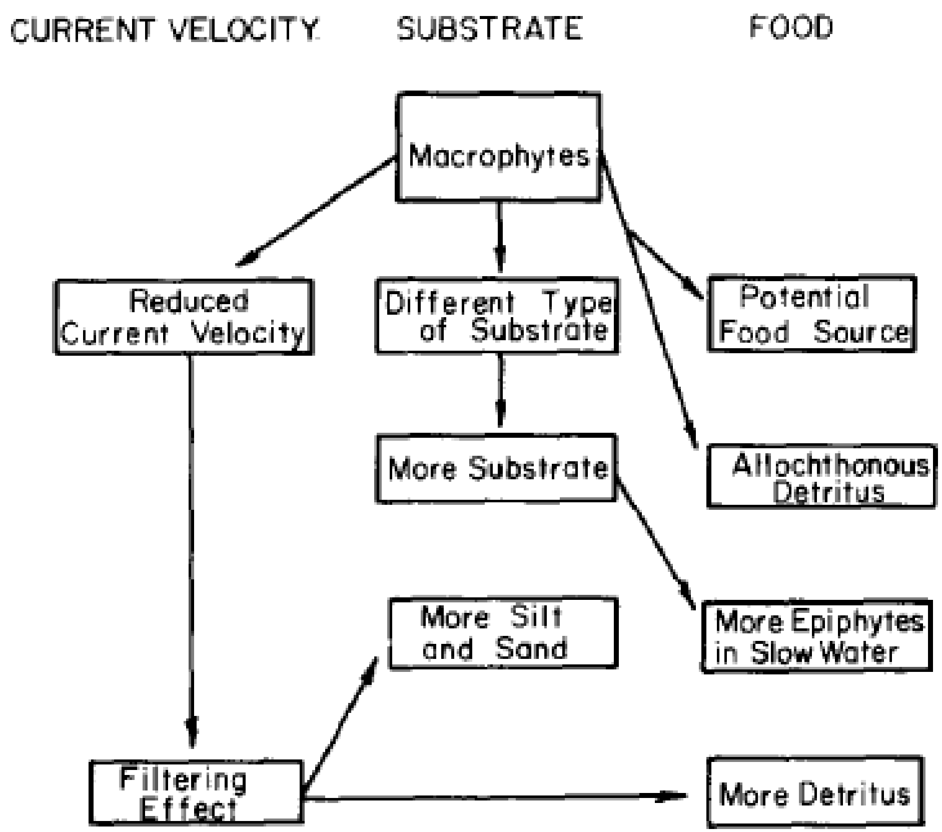


Fig. 3. Diagram of the effects of macrophytes on conditions in the stream microenvironment, with emphasis on current velocity, substrate, and potential food availability. Arrows indicate direct causal relationships.

Blockage

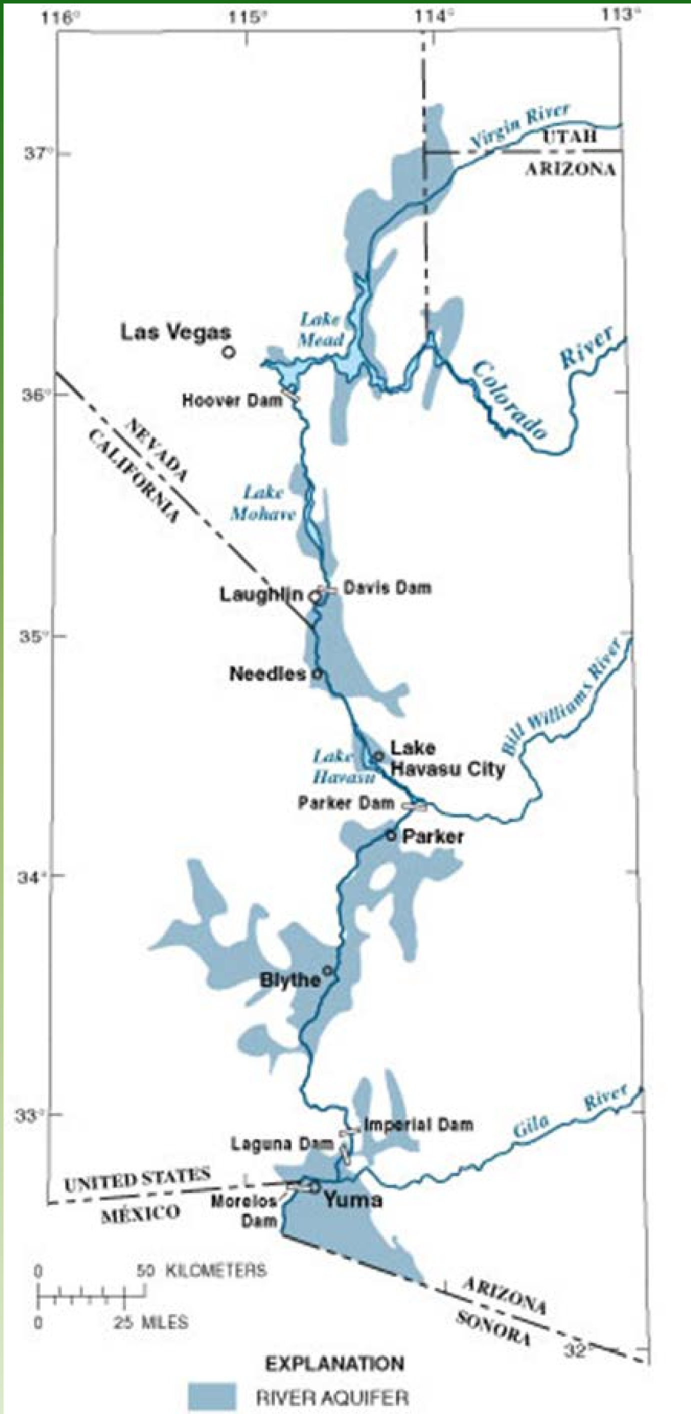
- Aquatic plants can break free, clogging water intakes, narrow areas in channel, and other structures
- May interfere with flow or use of water
- Irrigation, consumption, or cooling applications

Hydropower

- South Carolina spends about $450,000 per year managing invasive aquatic vegetation
- In 1991, an invasion of the aquatic weed hydrilla shut down the St. Stephen hydroelectric plant on Lake Moultrie for weeks, costing $4 million in lost productivity and $526,000 worth of gamefish deaths.

Lake Havasu Background

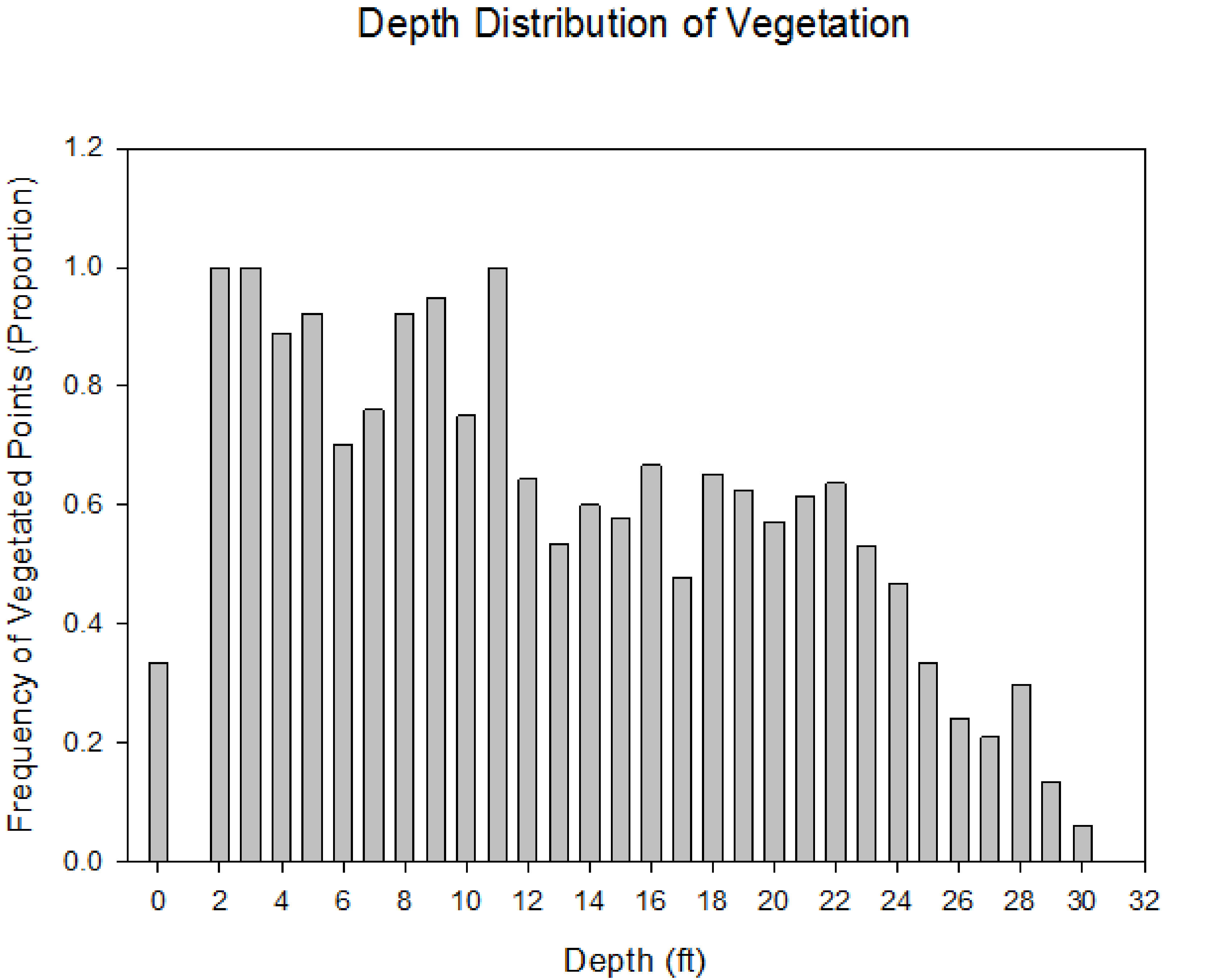
- Lake Havasu is formed by a dam on the Colorado River between California and Arizona
- Constructed in 1938
- 20,000 acres, 45 miles long
- Recreation, water storage, hydropower
- Central Arizona Project pumps water from Lake Havasu for agricultural and domestic use across central and southern Arizona



Problem

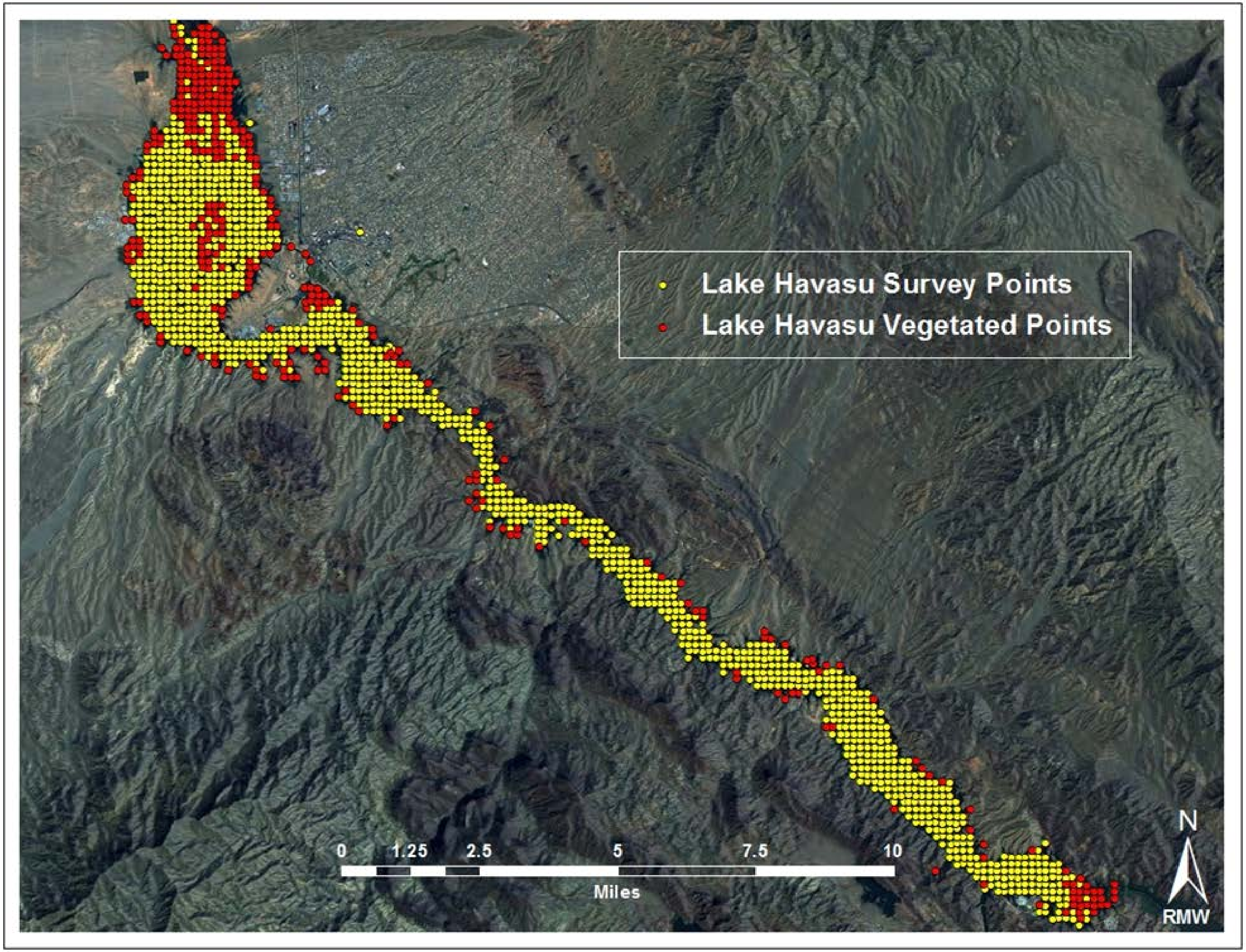
- Quagga mussels invaded in recent years, greatly increasing water clarity
- Predictably, plant growth expanded
- Rafts of native plants break off and clog water intake structure

Problems Created

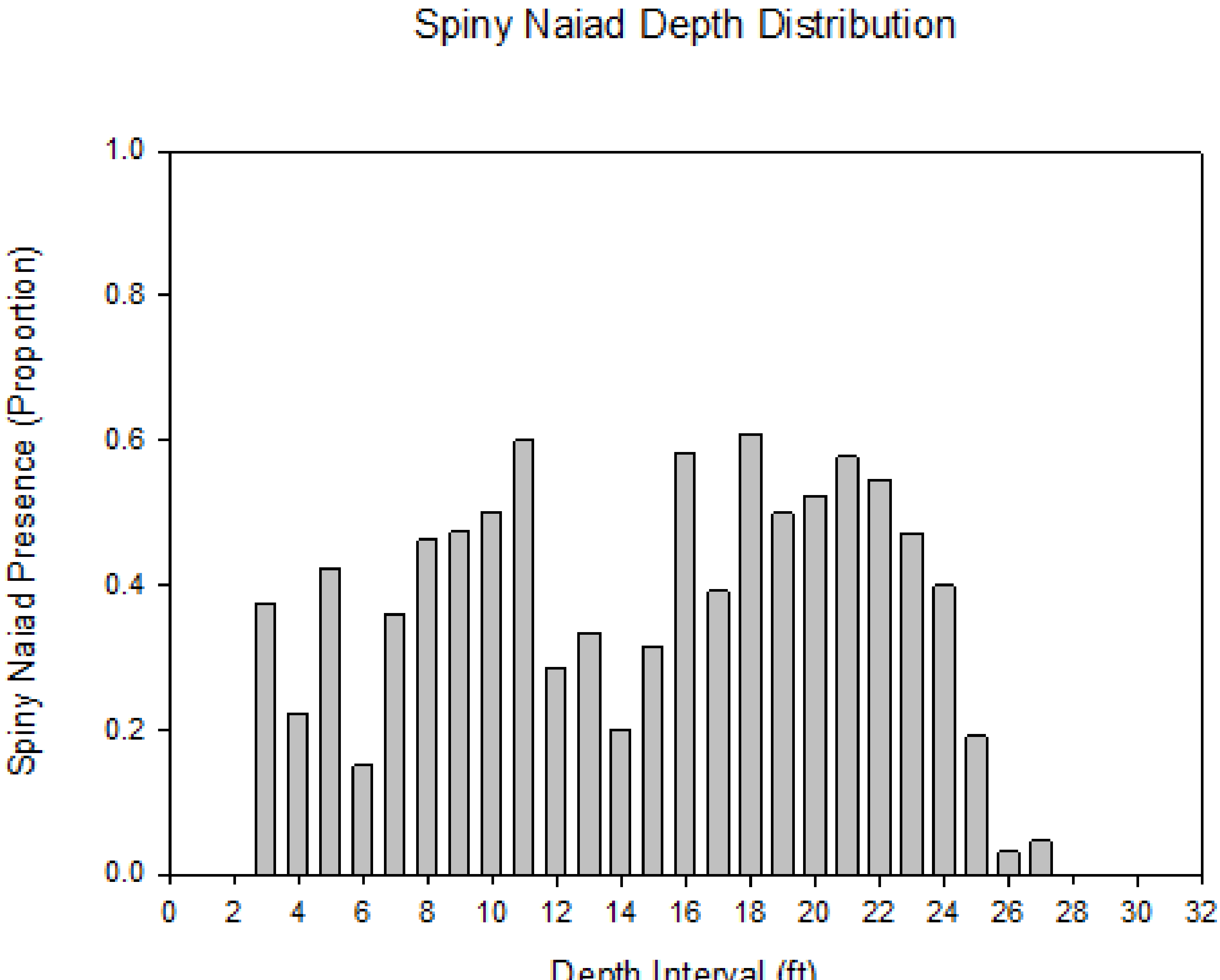


Depth Distribution of Vegetation
Frequency of Vegetated Points (Proportion)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Depth (ft)

Vegetated Area



Spiny Naiad
Najas marina


Spiny Naiad Depth Distribution
Spiny Naiad Presence (Proportion)
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Depth Interval (ft)

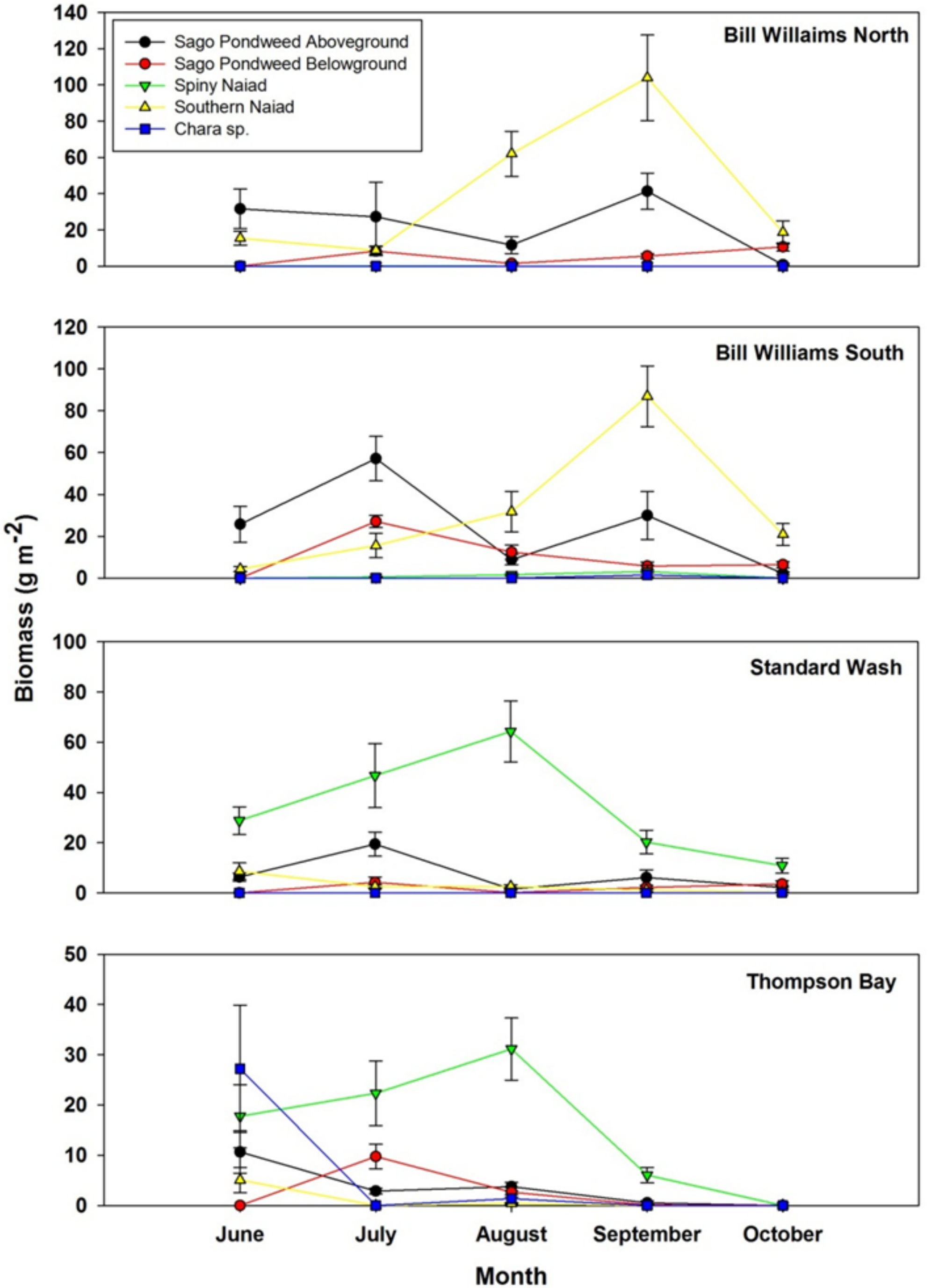
Senesced Mats of Plants

Biomass of Aquatic Plants at Four Sites

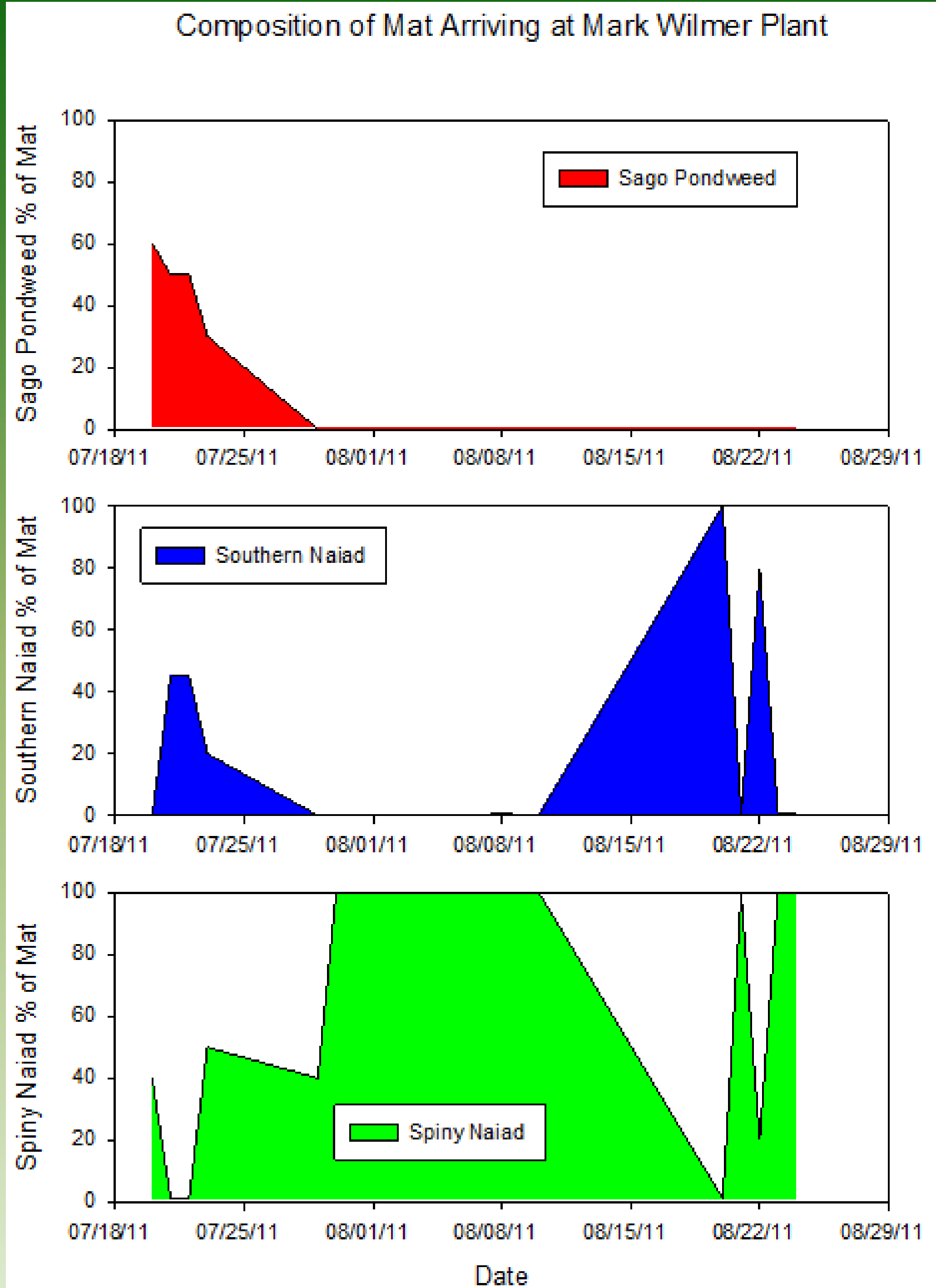
Sago pondweed senesces in August

Southern naiad senesces in September

Spiny naiad senesces in August



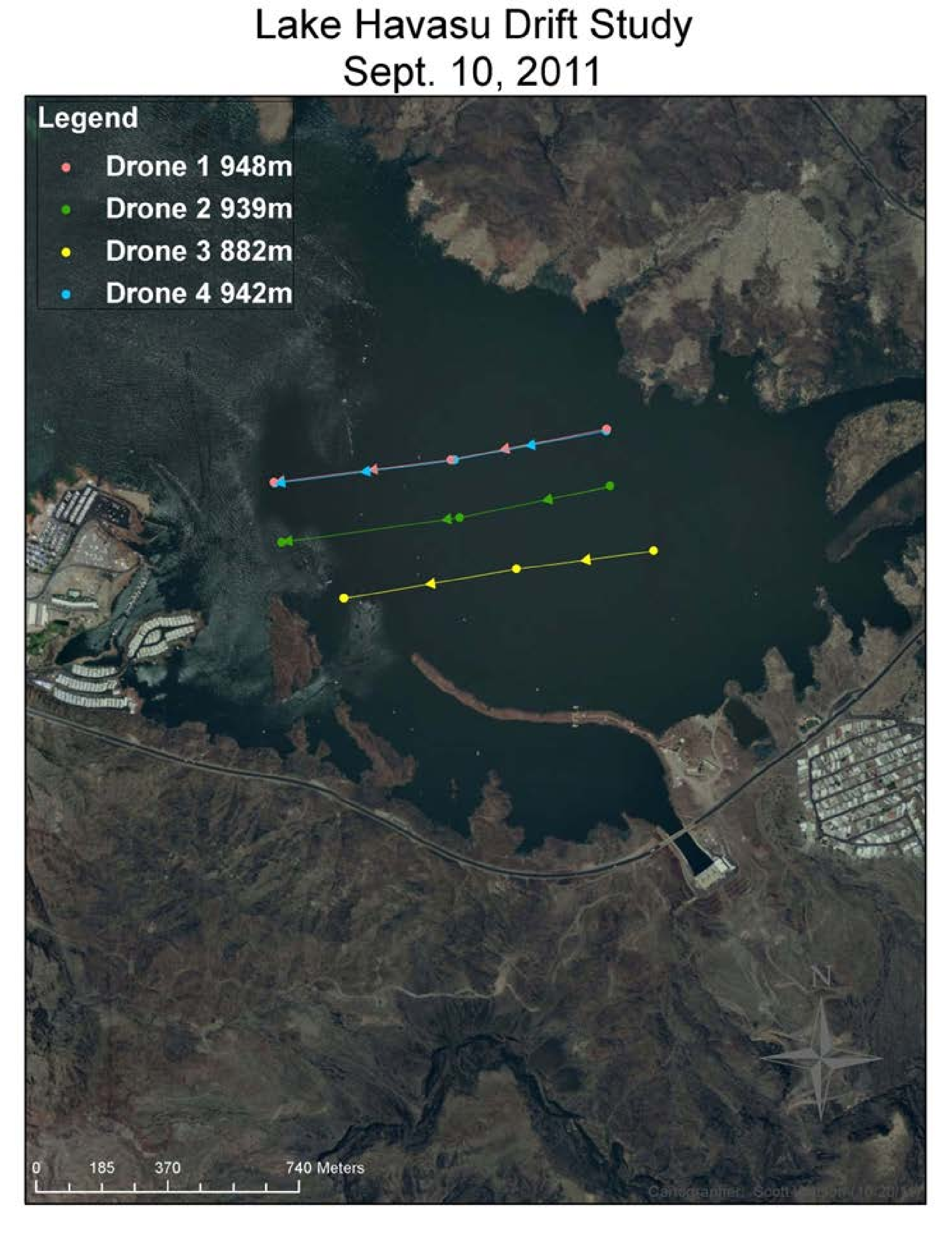
Species Composition of Material Collected at Mark Wilmer Pump Station



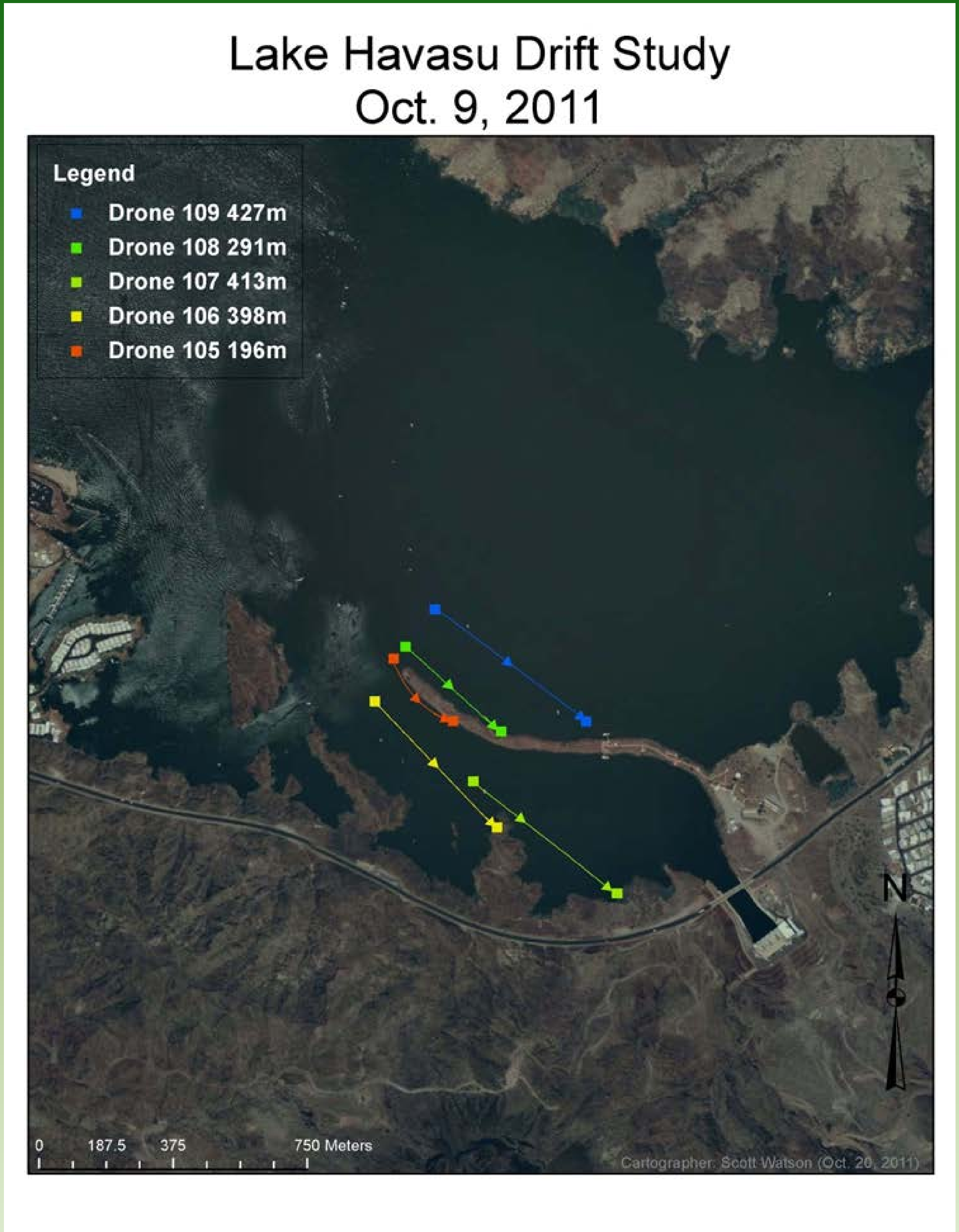
Mat Drift Studies

Mats of senesced plants move quickly from source sites with proper wind direction

Pumping draws plants to the inlet



Drift Study with West Wind



Water Quality

- If aquatic plants alter the quality of water, it may no longer be fitted for its intended or designated purpose.

Recreational Impairment

- Invasive aquatic plants interfere with:
  - Swimming
  - Boating
  - Fishing (both from bank and boat)
- Recreational use of one lake (Lake Tahoe, CA) was estimated at $30-$45M/year
- Benefit/ Cost ratios of management typically are higher than 10:1

Property Value

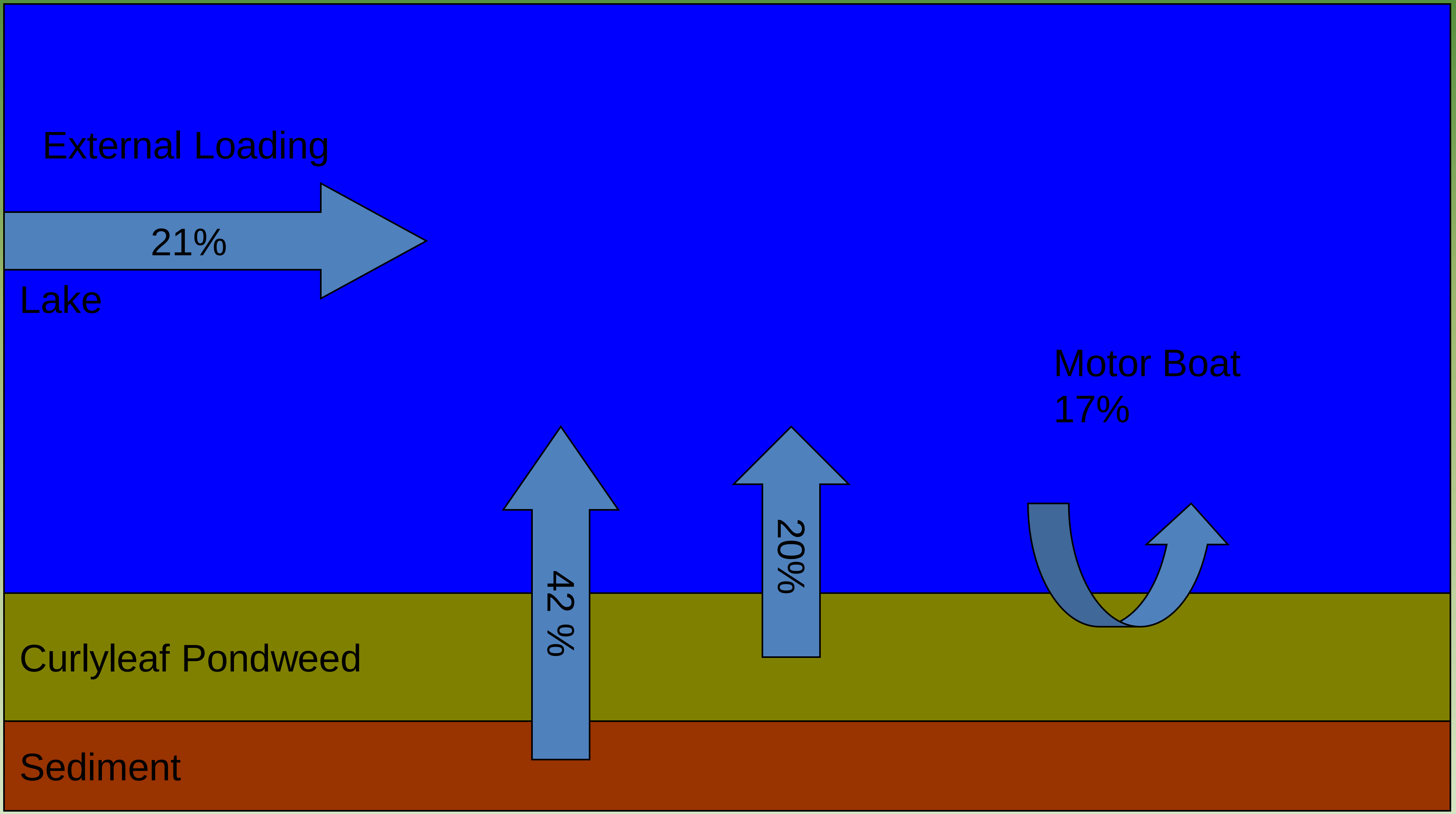
- Invasive aquatic plants reduce the utility of lakeside property, as well as reducing the aesthetic appeal
- One study indicates that property values declined an average of 13% in Wisconsin lakes invaded by Eurasian watermilfoil

Invasive Plants and Water Quality

- Nutrient pump of phosphorus from sediment to water column
- Decomposition releases nutrients
- Reduced oxygen, pH shift can allow release of nutrients from sediment

P Loading

James et al. 2001



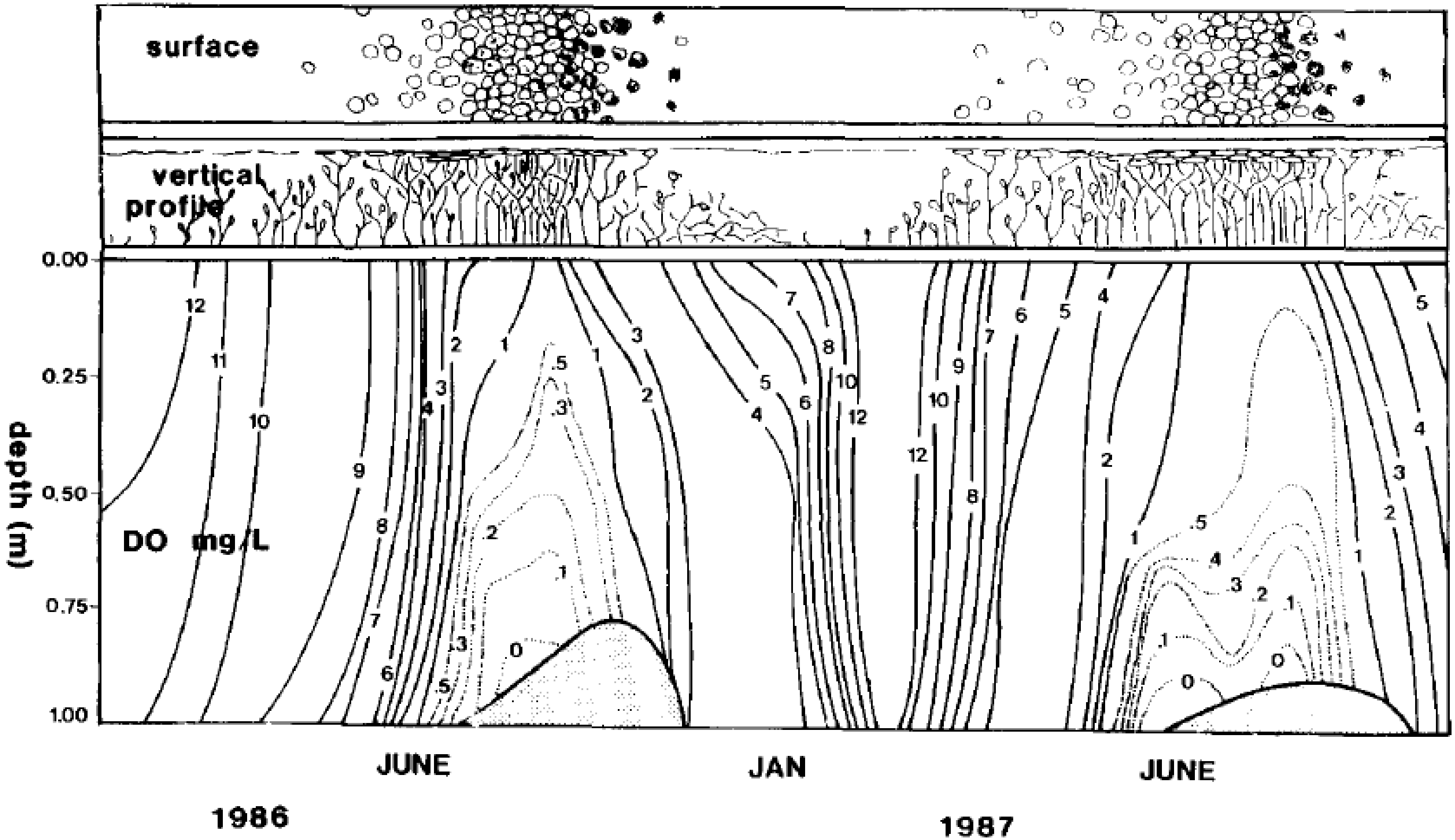


Fig. 3. Dissolved oxygen (mg l^{-1}) isopleths in a dense stand of *B. schreberi* in Keevies Lake from December 1986 to December 1987. The stippled area represents the bottom of the lake during summer low water.

Frodge et al. 1990 – western Washington State

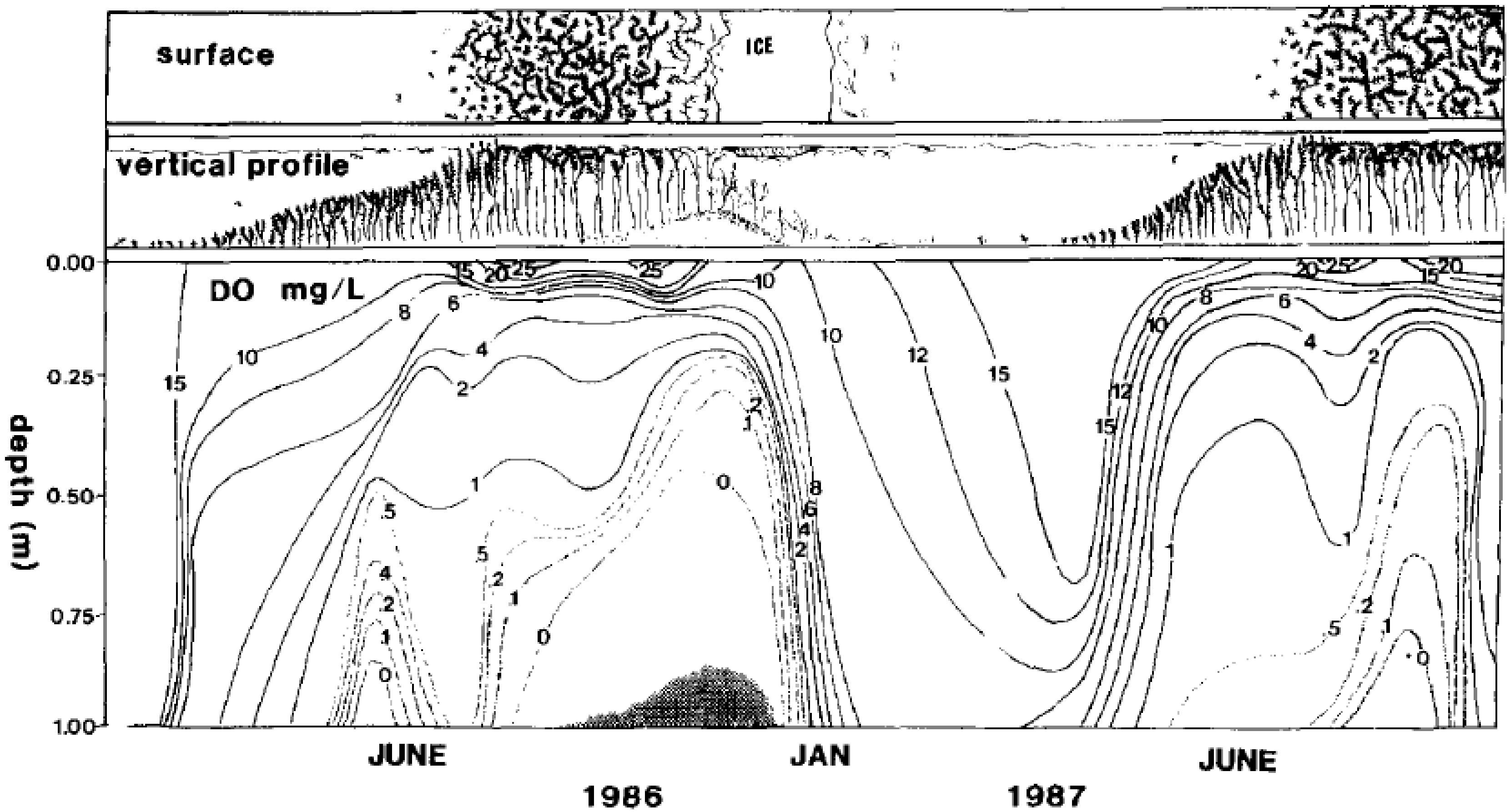


Fig. 7. Dissolved oxygen (mg l^{-1}) isopleths in a dense mixed stand of *C. demersum* and *M. exalbescens* in Bull Lake from March 1986 to December 1987. The stippled area represents the bottom of the lake during summer low water.

Frodge et al. 1990 – eastern Washington State

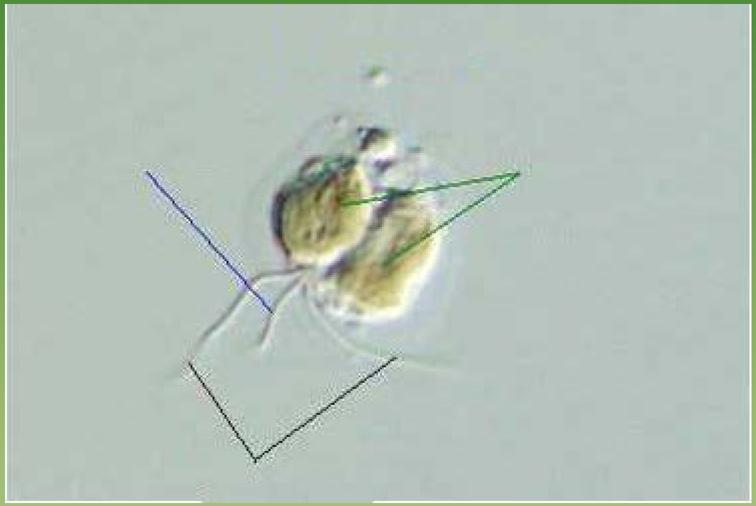
Drinking Water Issues

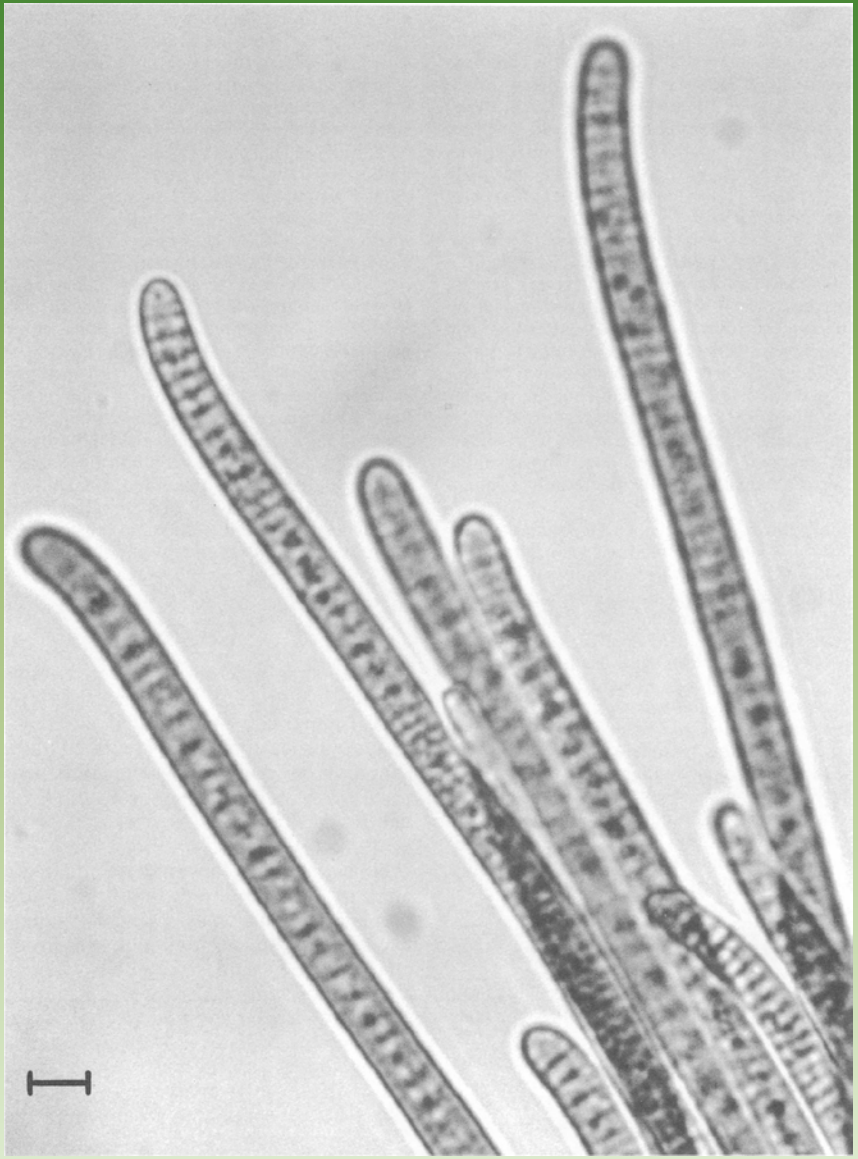
- Taste and odor problems
- Trihalomethane
- Obstructing intakes

Drinking Water

- Invasive aquatic plants contribute to
  - Taste problems
  - Odor problems
  - Increase trihalomethane, a carcinogenic precursor
  - Reduced transport at drinking water intakes

Chrysophytes and Cyanobacteria





Prymnesium parvum (top),
Oscillatoria sp. (right)

Toxin Concentration by Season
Izaguirre et al. 1982

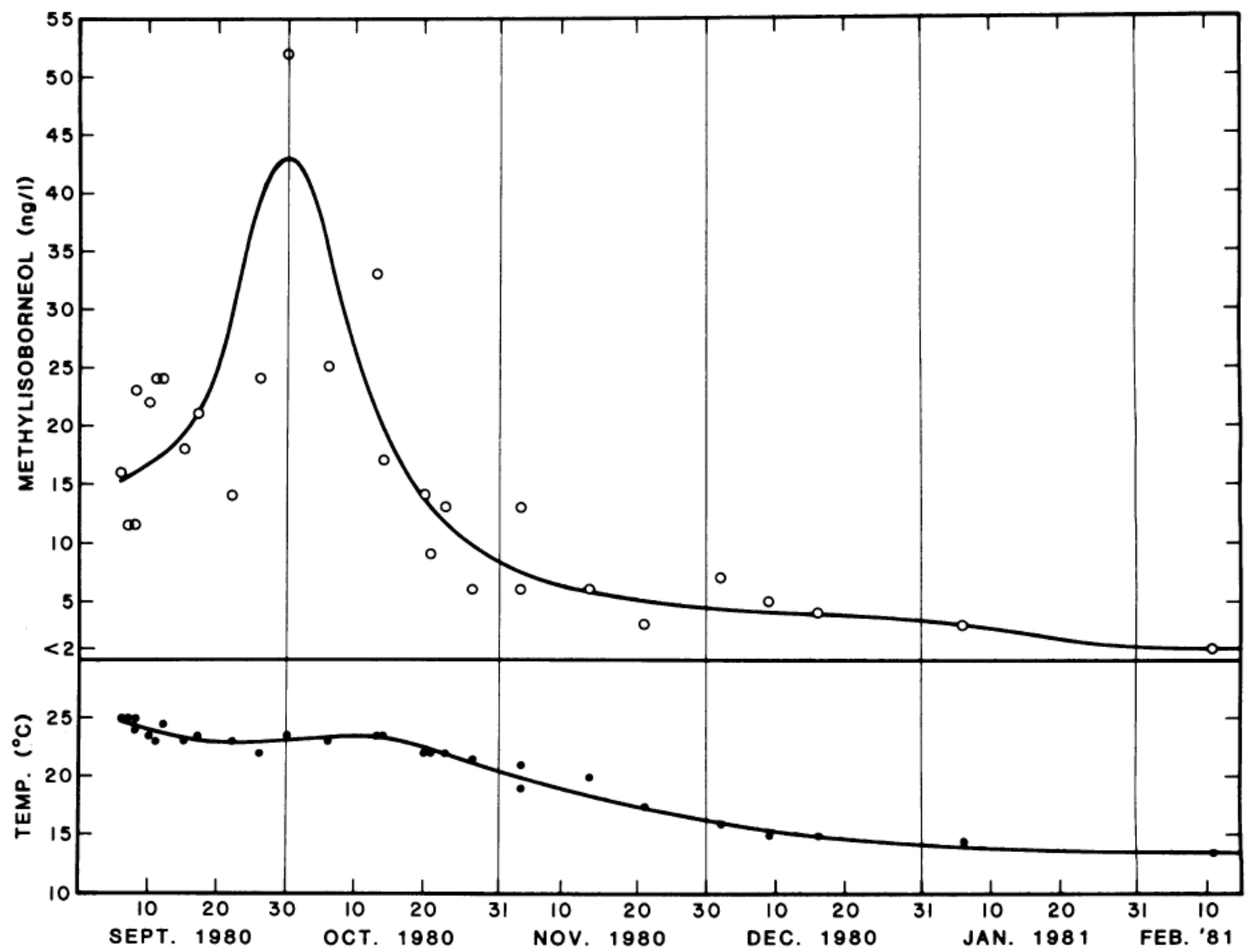


FIG. 3. MIB levels and temperature variation for Lake Mathews effluent.

Methyl-Isoborneol by Season
Westerhoff et al. 2005

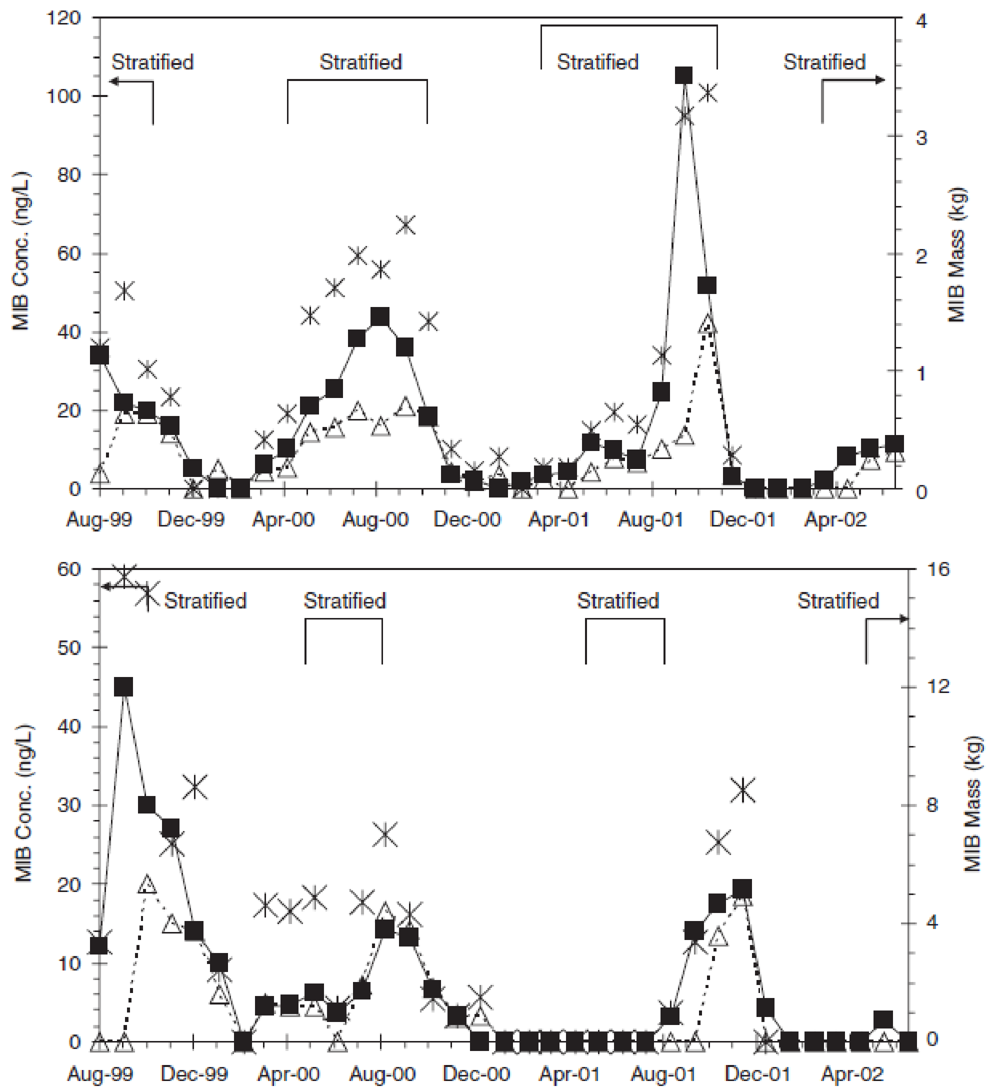


Fig. 5. Concentrations and masses of MIB in Saguaro Lake (upper) and Lake Pleasant (lower). Epilimnion (■) and hypolimnion (△) MIB concentrations are connected with lines, and the total MIB mass in the reservoir (⚹) is also indicated.

Total Phosphorus and Geosmin Smith et al. 2002

tions less than 110 μg·L[-1] throughout the entire lake.

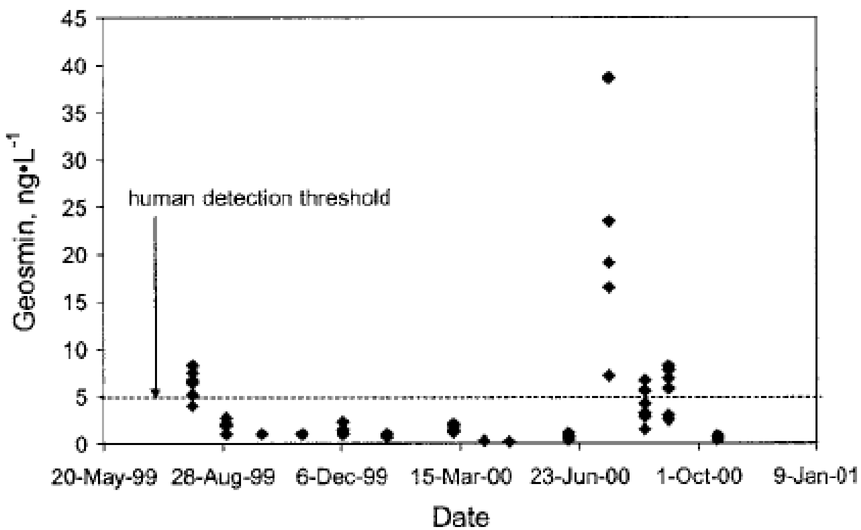


Figure 2.–Trends in geosmin at all six sampling stations in Cheney Reservoir, USA.

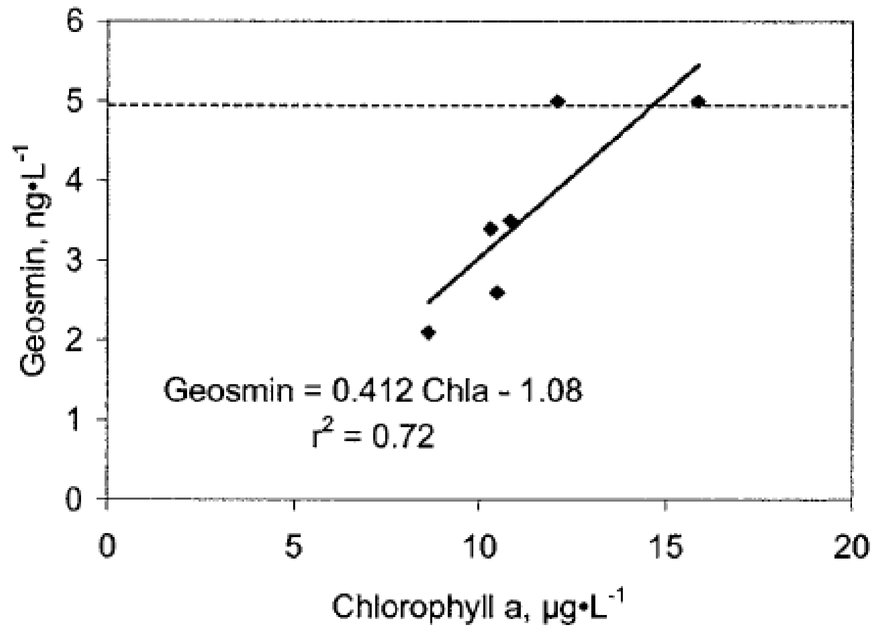
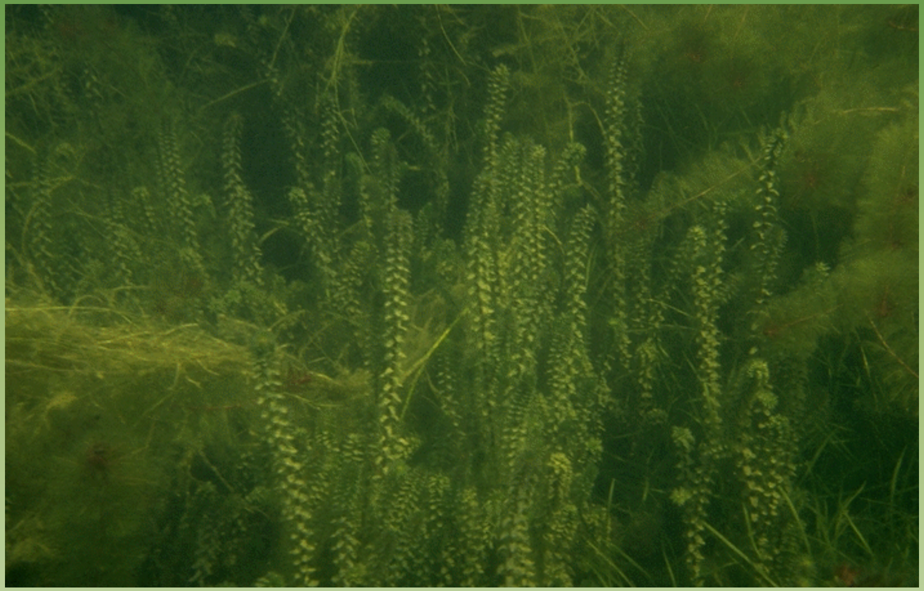


Figure 4.–Relationship between station mean concentrations of geosmin and chlorophyll a in Cheney Reservoir, USA. The horizontal dotted line indicates an approximate threshold concentration of geosmin for human detection of 5 ng·L[-1].

Does Management Do Any Good?

- Reduces dominance of nonnative plant
- Reduces nutrient loading from decomposition
- Allows increased diversity and abundance of native plants

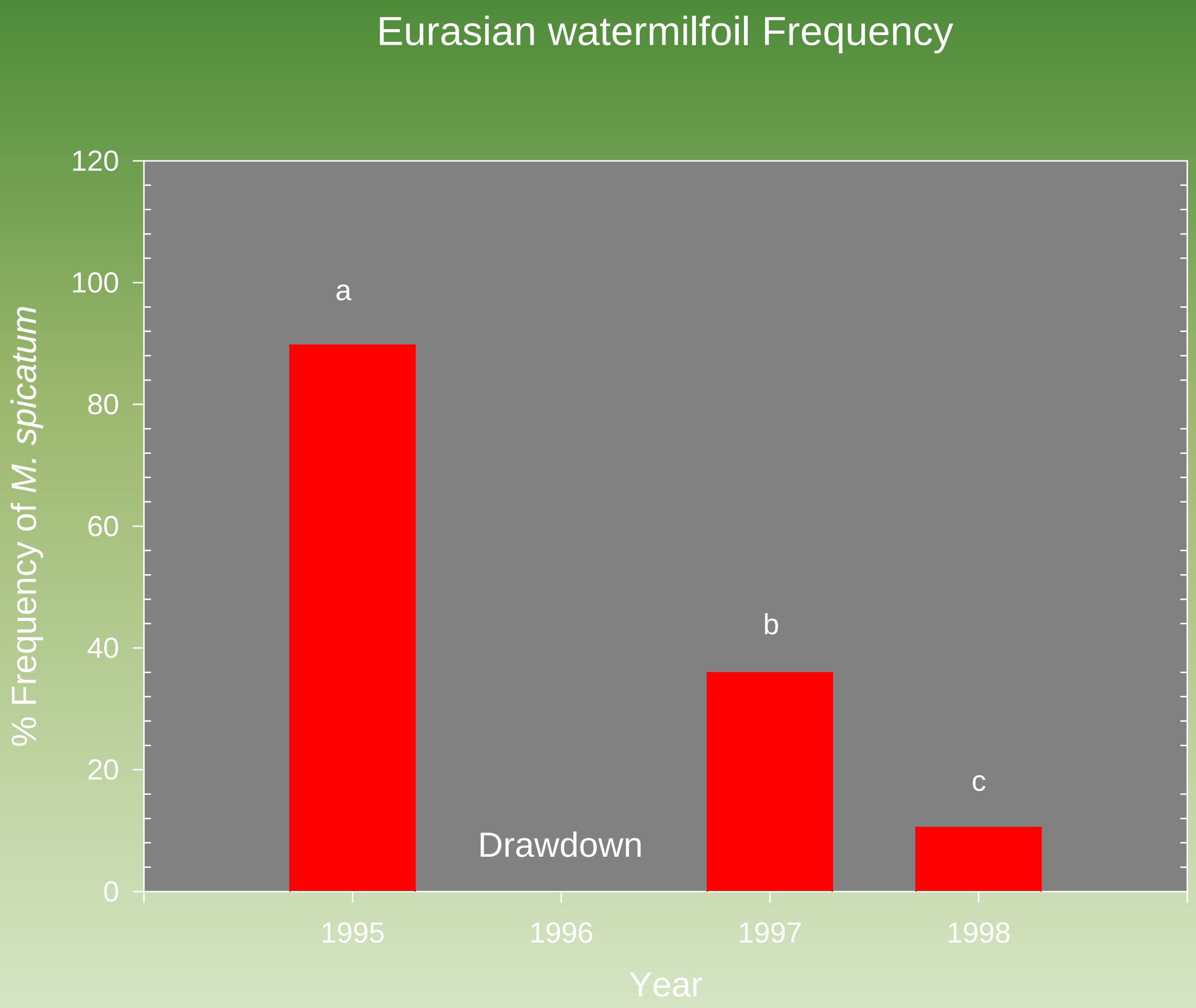


Muskego Lake Project Goals

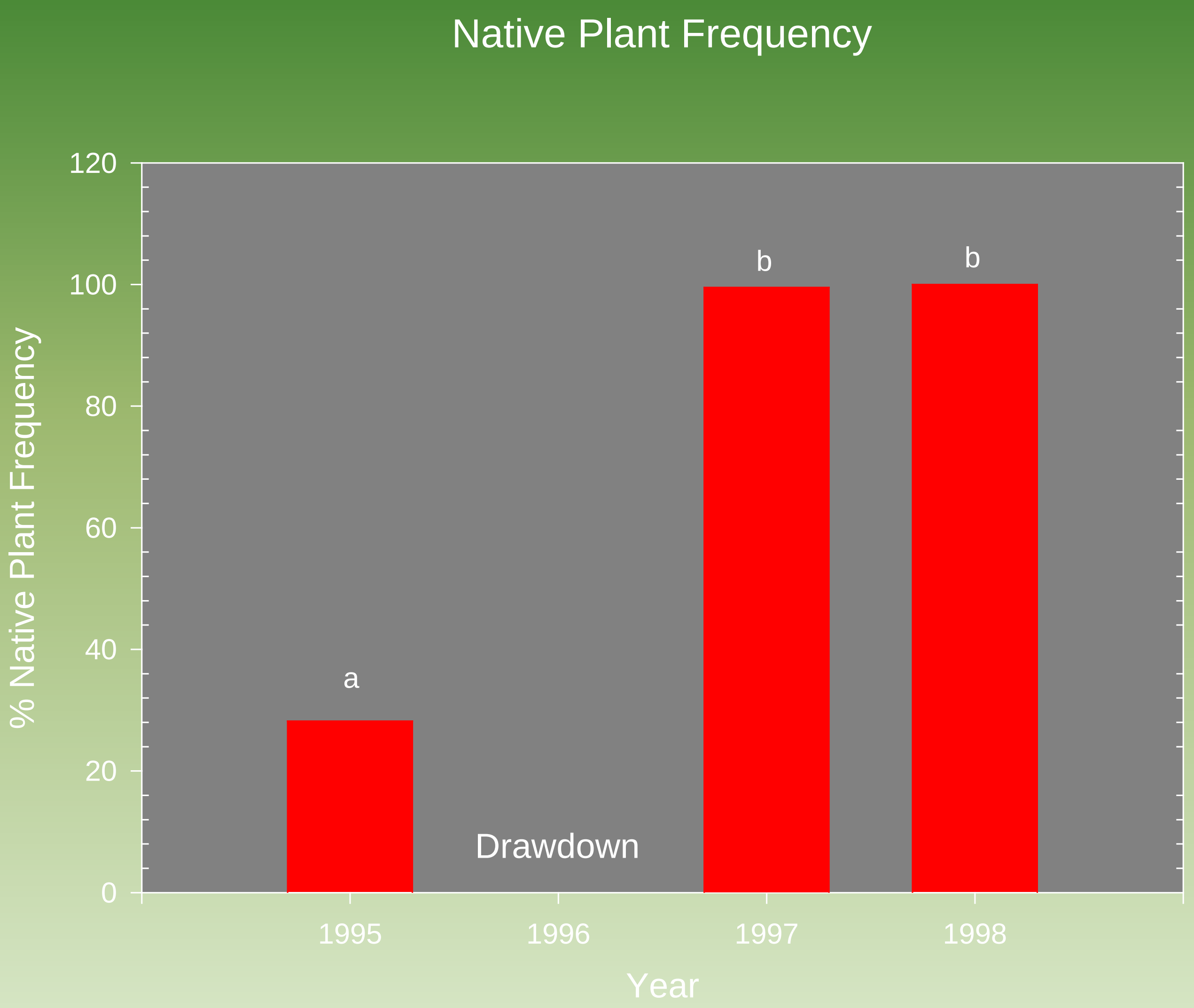
- Monitor changes in aquatic plant community from before drawdown (1995; drawdown in 1996) and two years after drawdown (1997 to 1998)

Eurasian watermilfoil Frequency

Eurasian watermilfoil decreased from 90% of points in 1995, and a dominant; to 36% in 1997 and 11% in 1998



Native Species Cover

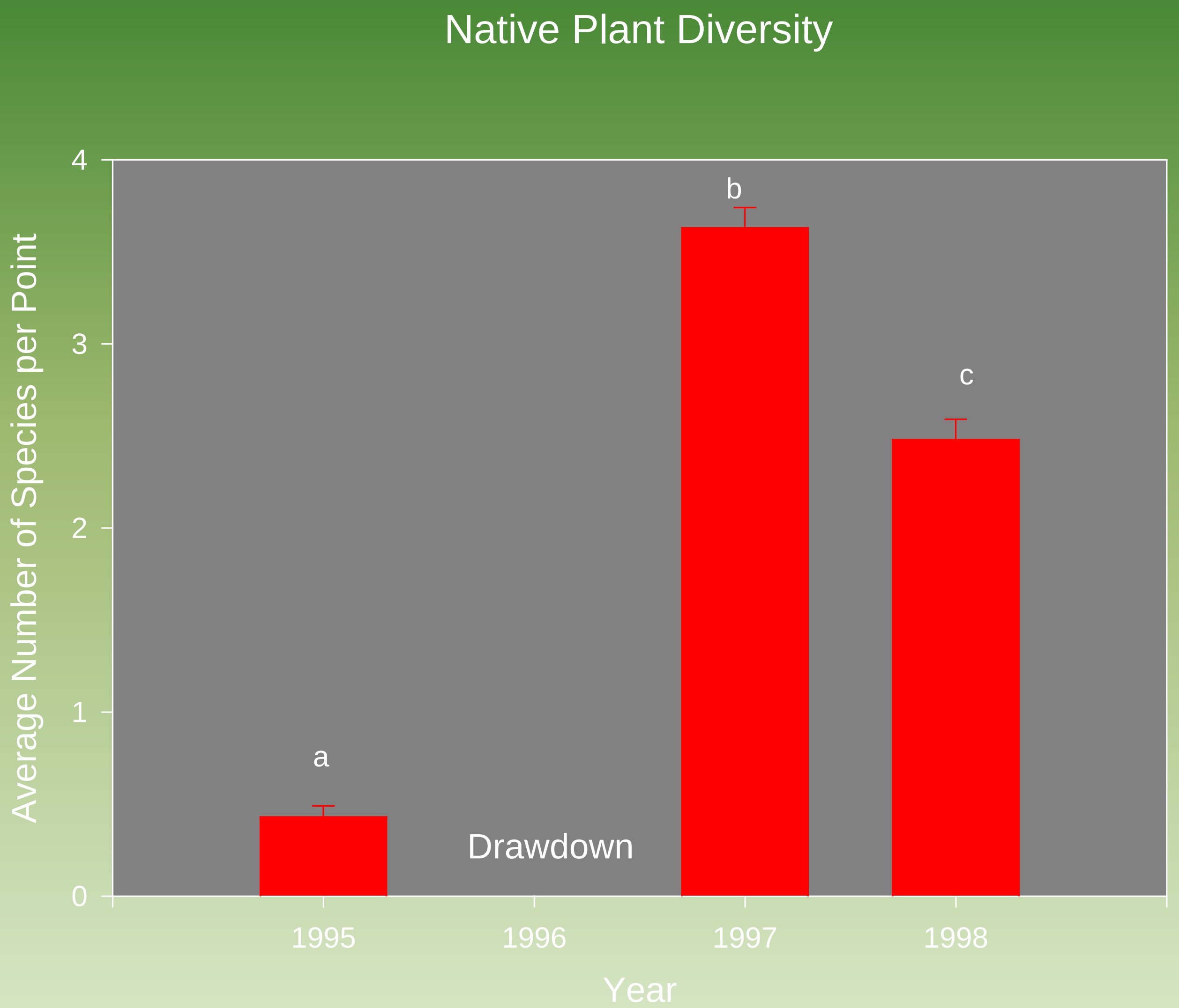


Native plants reestablished in Big Muskego Lake, from 28% of the lake in 1995 to 100% by 1997 and 1998.

A restoration success

Native Plant Diversity

Native plant diversity increased dramatically after drawdown, decreased with interspecific competition in 1998



Aquatic Plant Restoration Goal

Remove invasive plants and restore a diverse community of desirable native plant species

Carsons Bay, MN before treatment

Carsons Bay, MN after treatment

Contact Information

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