Aquatic Weeds:

Subversive and Stealthy Drivers of Water Quality

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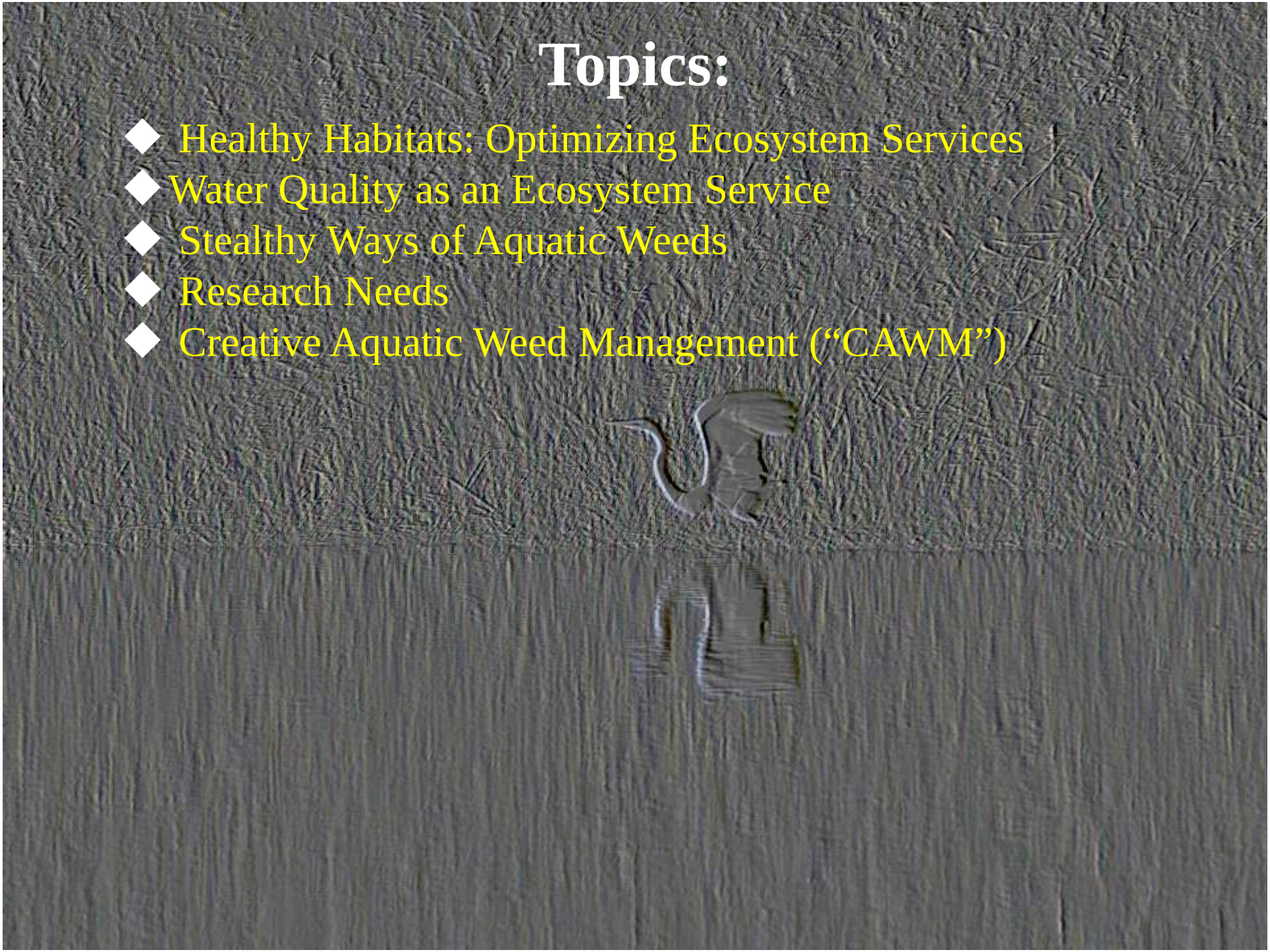
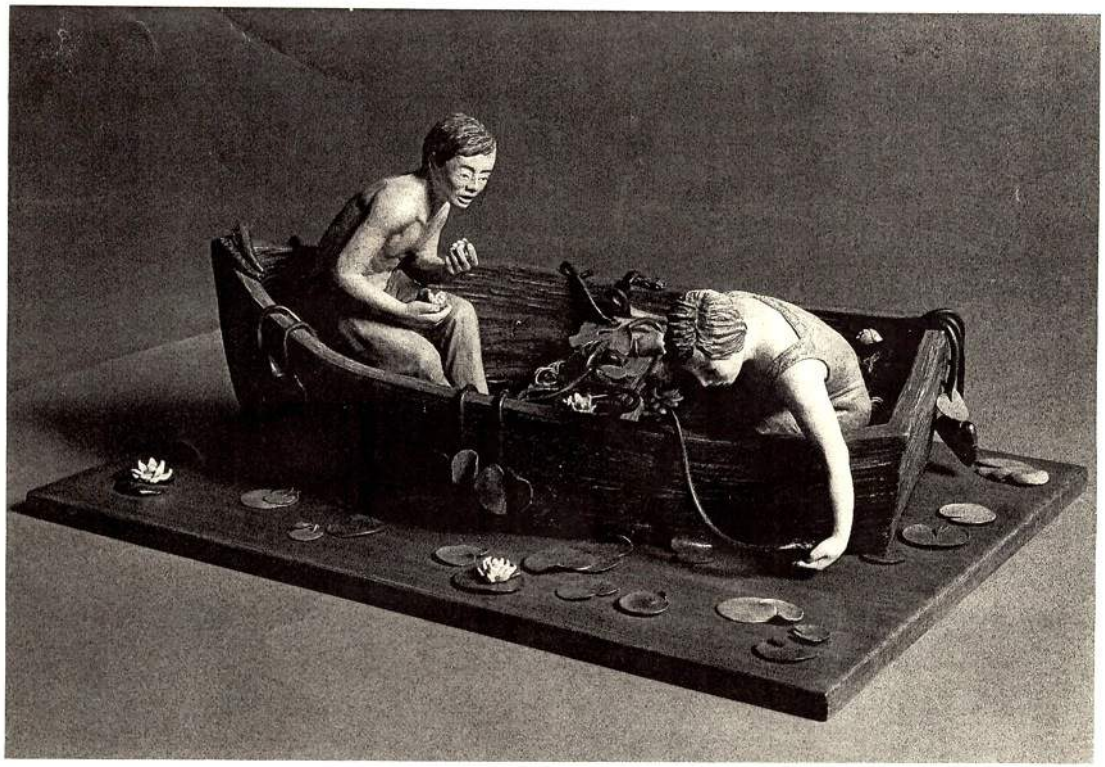
Waterweed*Solutions*
Inverness, CA

Topics:

- Healthy Habitats: Optimizing Ecosystem Services
- Water Quality as an Ecosystem Service
- Stealthy Ways of Aquatic Weeds
- Research Needs
- Creative Aquatic Weed Management (“CAWM”)





MIRIAM DAVIS • VISUAL ARTIST

Your face peers up from under the lily pads:
you've pushed them apart as you rose,
slipped through the eels of the roots, touched
the pond-silt grainy with pebbles,

slick with algae underfoot. Now the sun
flashes its swords in your eyes as the lily pads
slide away, each one obscuring,
as it goes, a circle of subaqueous light,

What are Ecosystem Services? *

- *Provisioning Services* : **FOOD**, crops**, AQUACULTURE**, ***WATER***, minerals, pharmaceuticals, natural products, ***Energy***

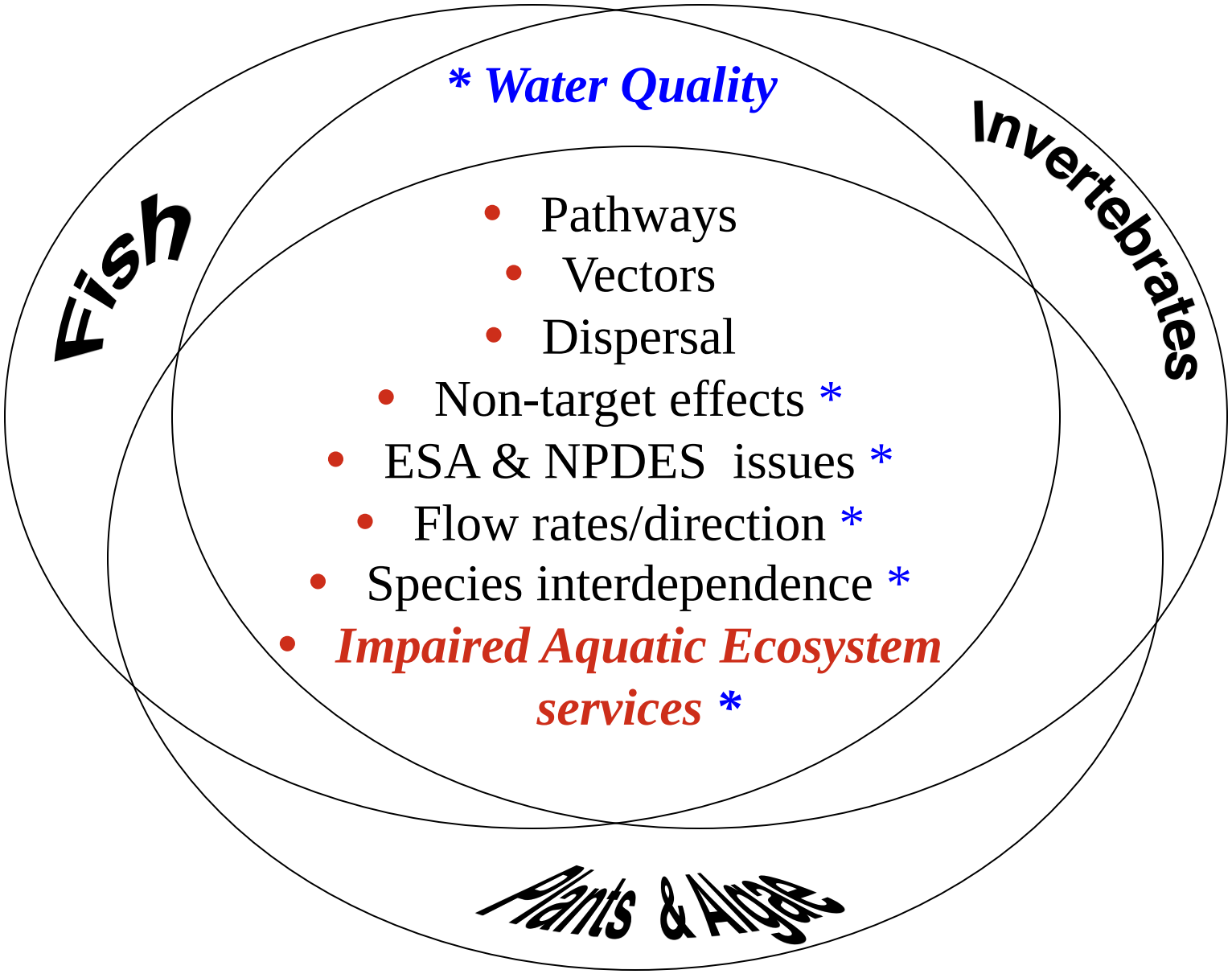
- *Regulating Services* : **CARBON SEQUESTRATION**, climate, waste decontamination and detoxification, purification of water, air, crop pollination, ***PEST*** and **DISEASE CONTROL**.

- *Supporting Services* : **NUTRIENT DISPERSAL and CYCLING**, seed dispersal**, *PRIMARY PRODUCTION***.

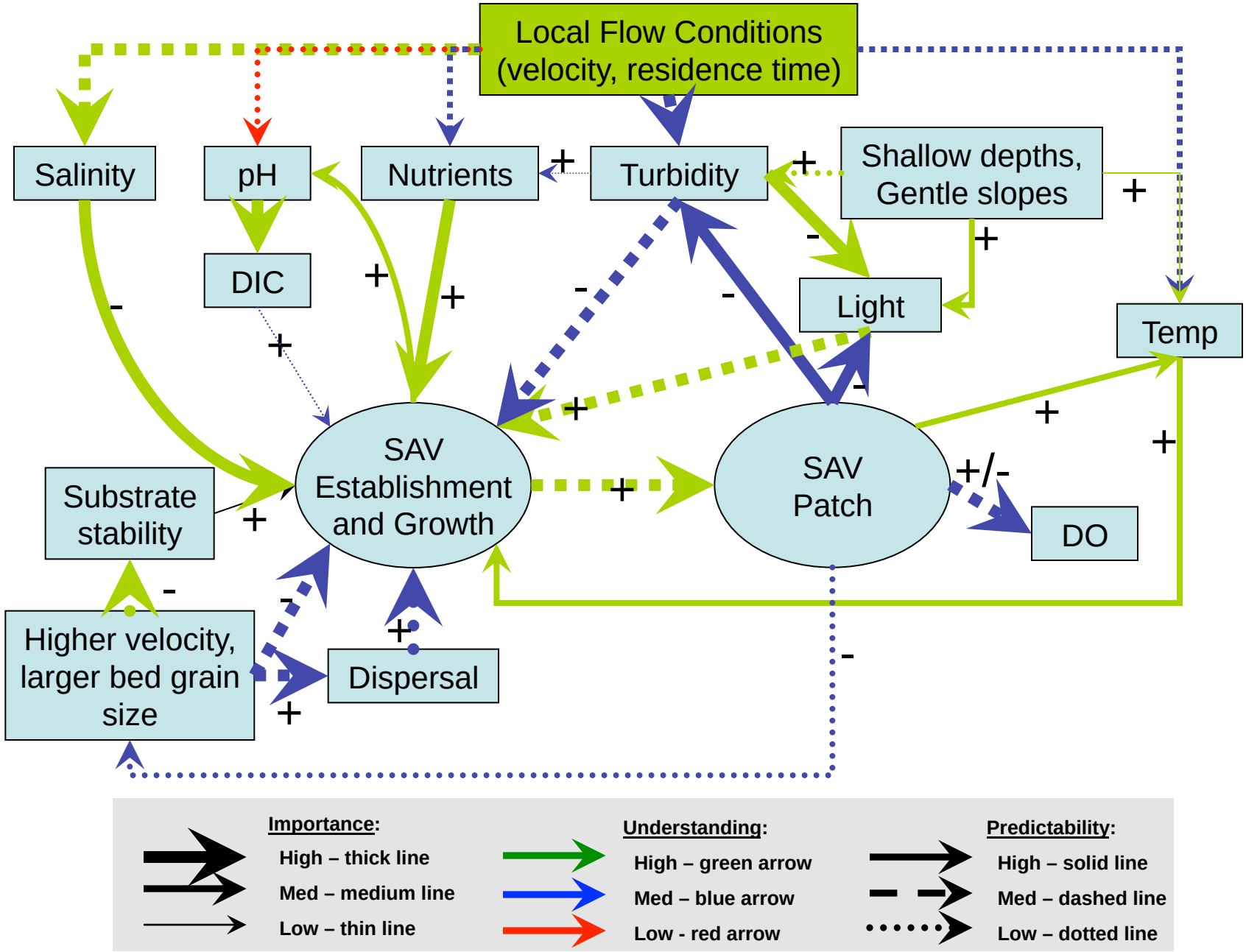
- *Cultural Services* : ***RECREATIONAL EXPERIENCES*****, SCIENTIFIC DISCOVERY,** cultural, intellectual, spiritual inspiration: ***"AESTHETICS"***

*Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-Being: Synthesis Island Press, Washington.

AIS Management Issues

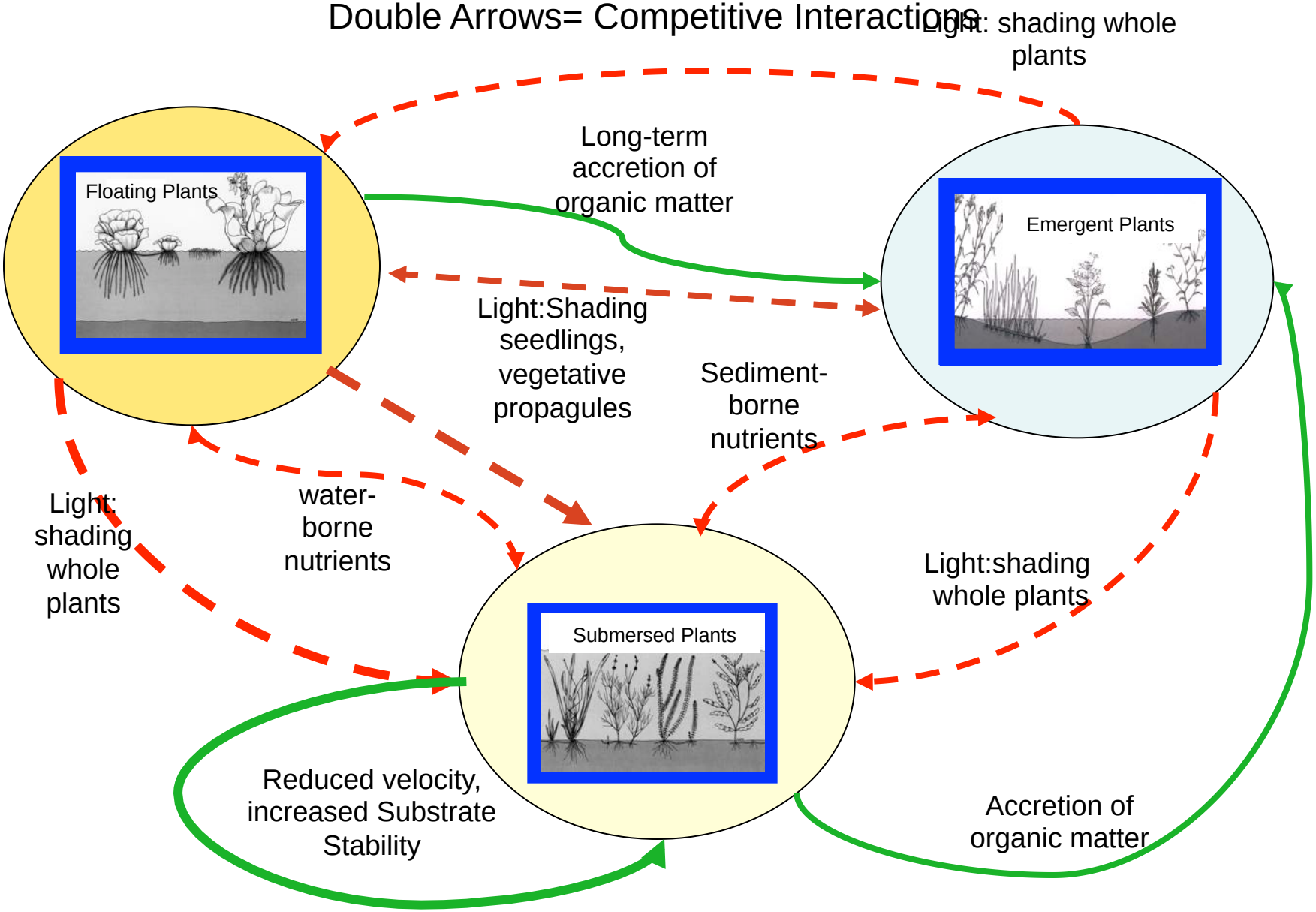


1B) Physical Environment Feedback Sub Model to SAV

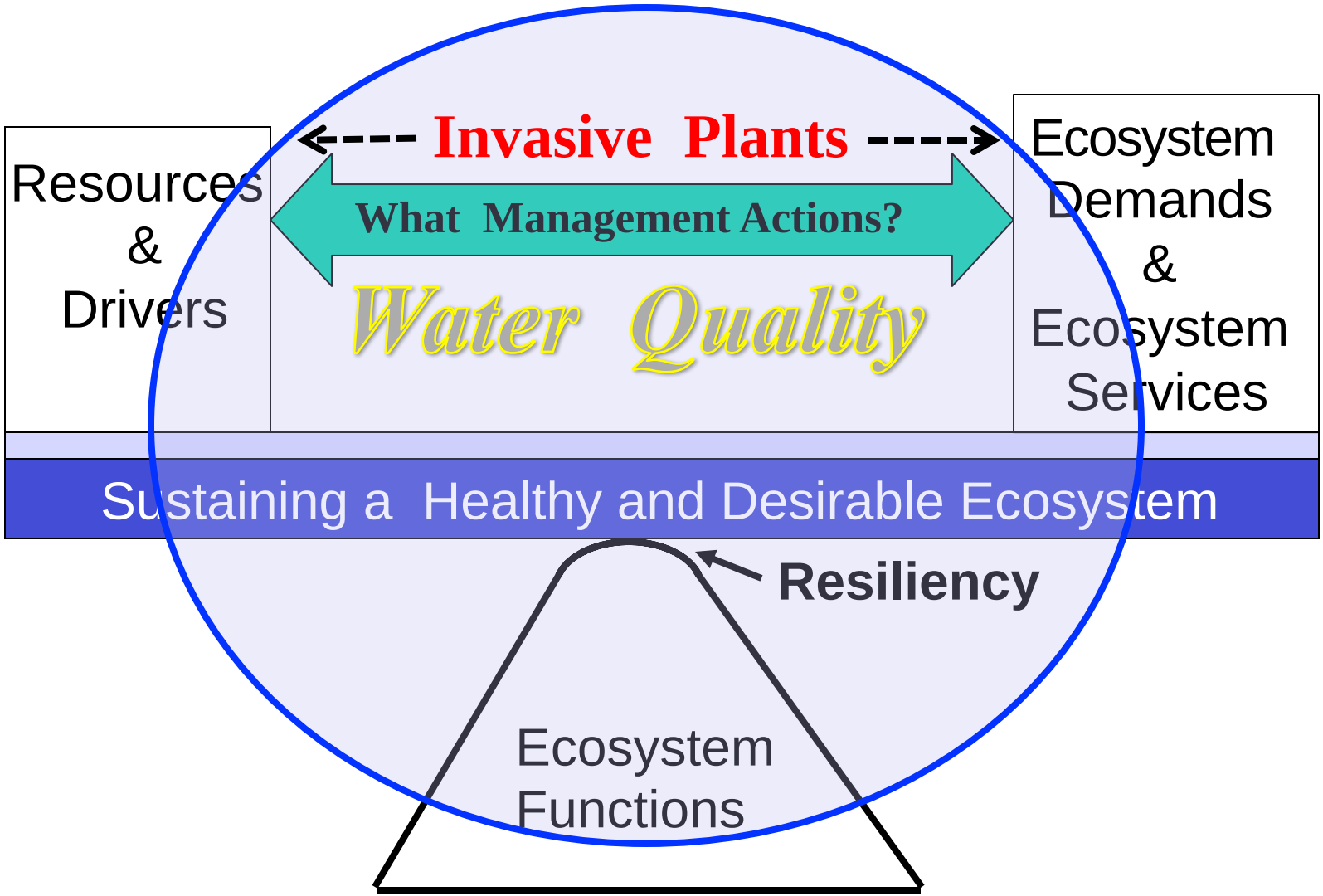


Interactions Between SAV, FAV and EAV Affecting Establishment and Growth

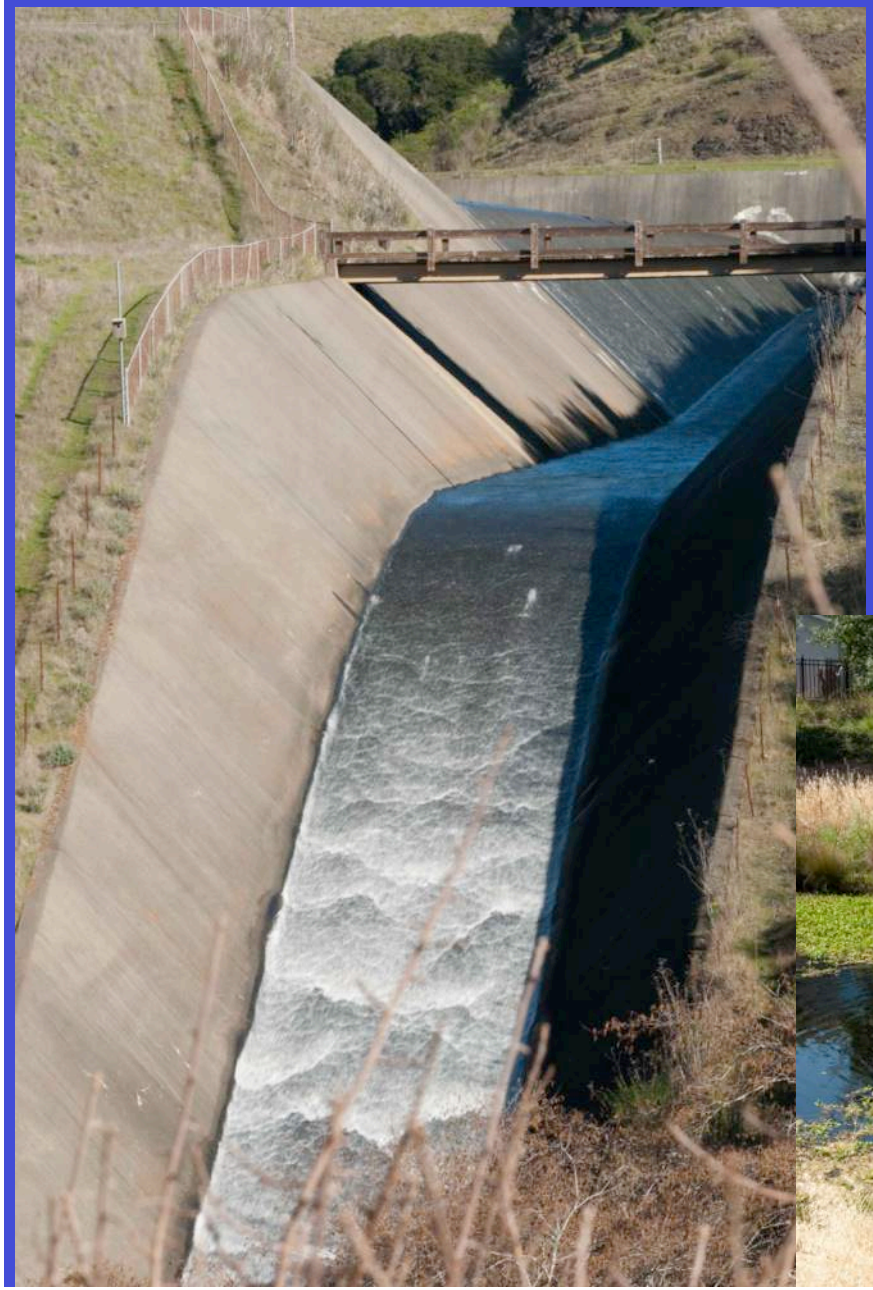
Red (dashed)=Negative effect (causes reduced growth
Green (solid)=Positive effect (more growth)
Double Arrows= Competitive Interactions

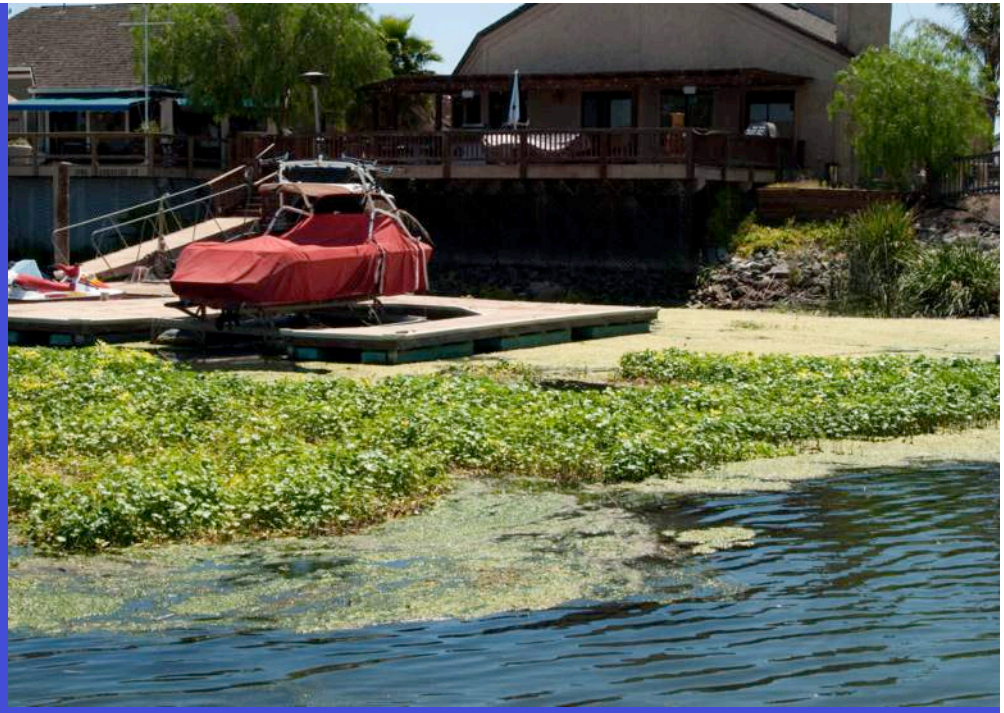


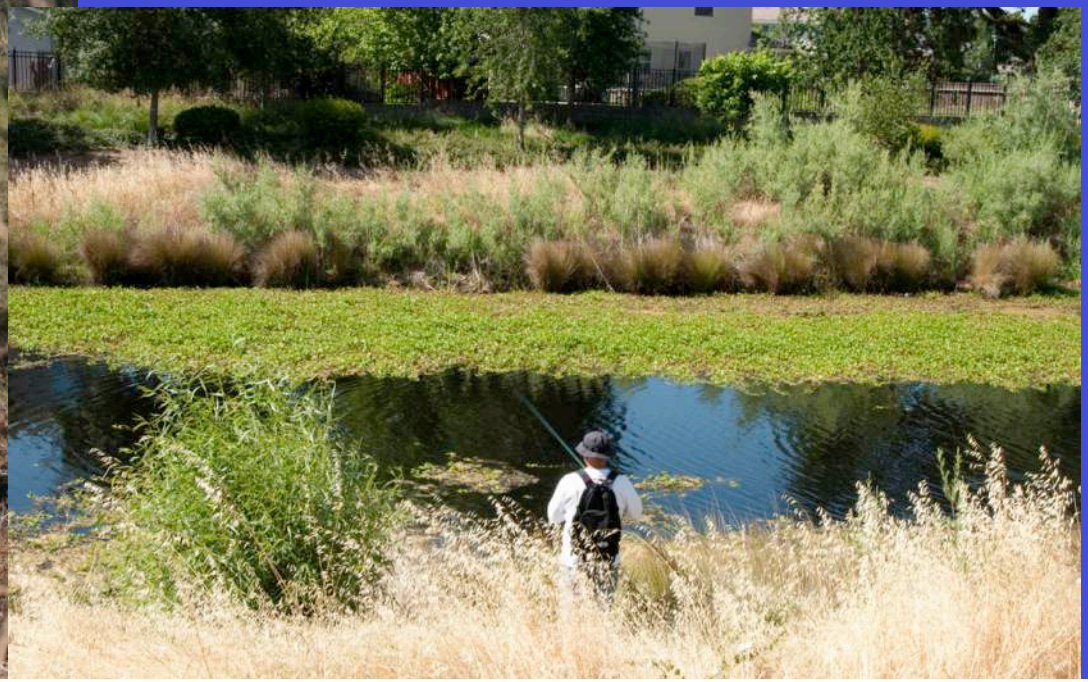
Balancing Risks and Benefits



WATER: Ecosystem Services

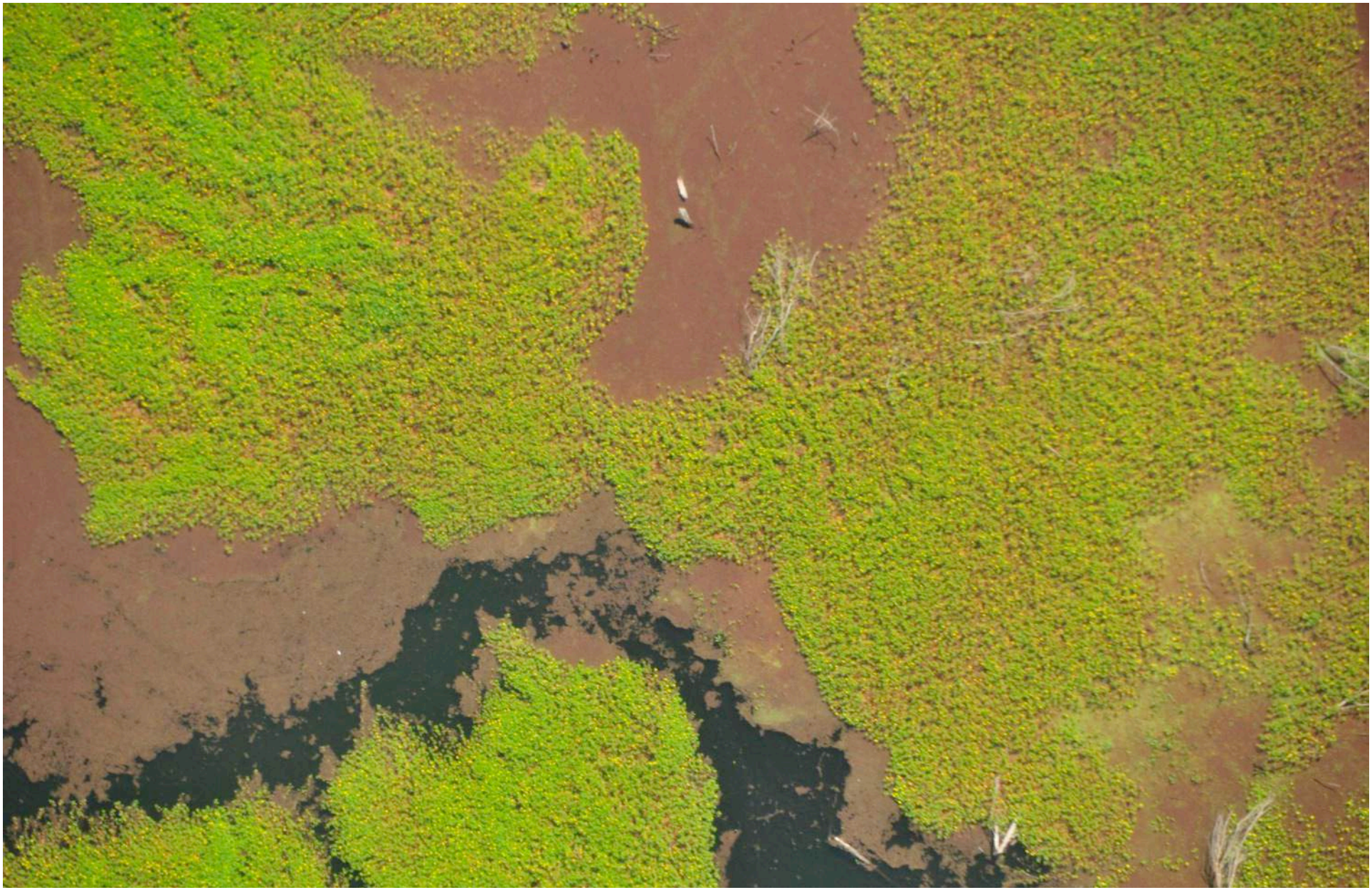




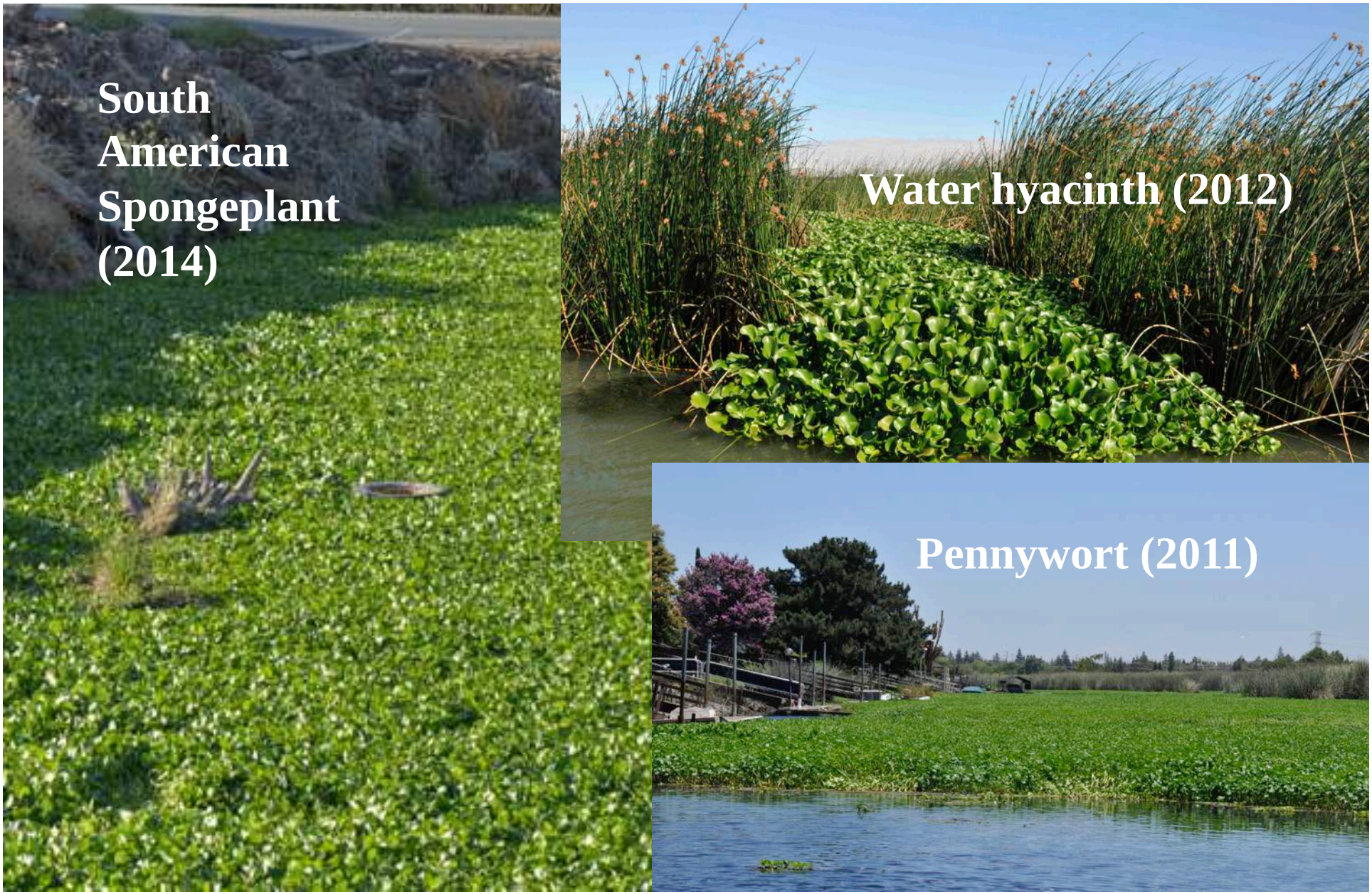


Sacramento- San Joaquin Delta:
Egeria densa + Algae + Sinking Board> Water Quality?

Ludwigia & Azolla: Prospect Isl. CA
(From 1,500 ft up!)



Floating Plant Canopies:
Sacramento-San Joaquin Delta



Macrophytes and Sources and Sinks

(Carpenter and Lodge 1986)

Effects of submersed macrophyte stands on concentrations of selected materials in lake water. "Source" means that there was a net flux from the plant beds to the water during the course of the study; "sink" means that there was a net flux from the water to the plant beds

Material	Effect	Reference
Coarse particulate organic matter	Sink	Dawson, 1980
Suspended solids	Sink	Bulthuis et al., 1984
Particulate phosphorus	Sink	Bulthuis et al., 1984
Particulate phosphorus	Sink	Adams and Prentki, 1982
Particulate silica	Sink	Bulthuis et al., 1984
Dissolved organic carbon	Source	Mickle and Wetzel, 1978
Dissolved organic carbon	Sink	Prentki et al., 1979
Dissolved calcium	Sink	Mickle and Wetzel, 1978
Dissolved magnesium	No effect	Mickle and Wetzel, 1978
Dissolved potassium	Sink	Mickle and Wetzel, 1978
Dissolved inorganic nitrogen	Sink	Mickle and Wetzel, 1978
Dissolved phosphorus	Source	Prentki et al., 1979

Sink and Source Links

(Barko et al. 1991)

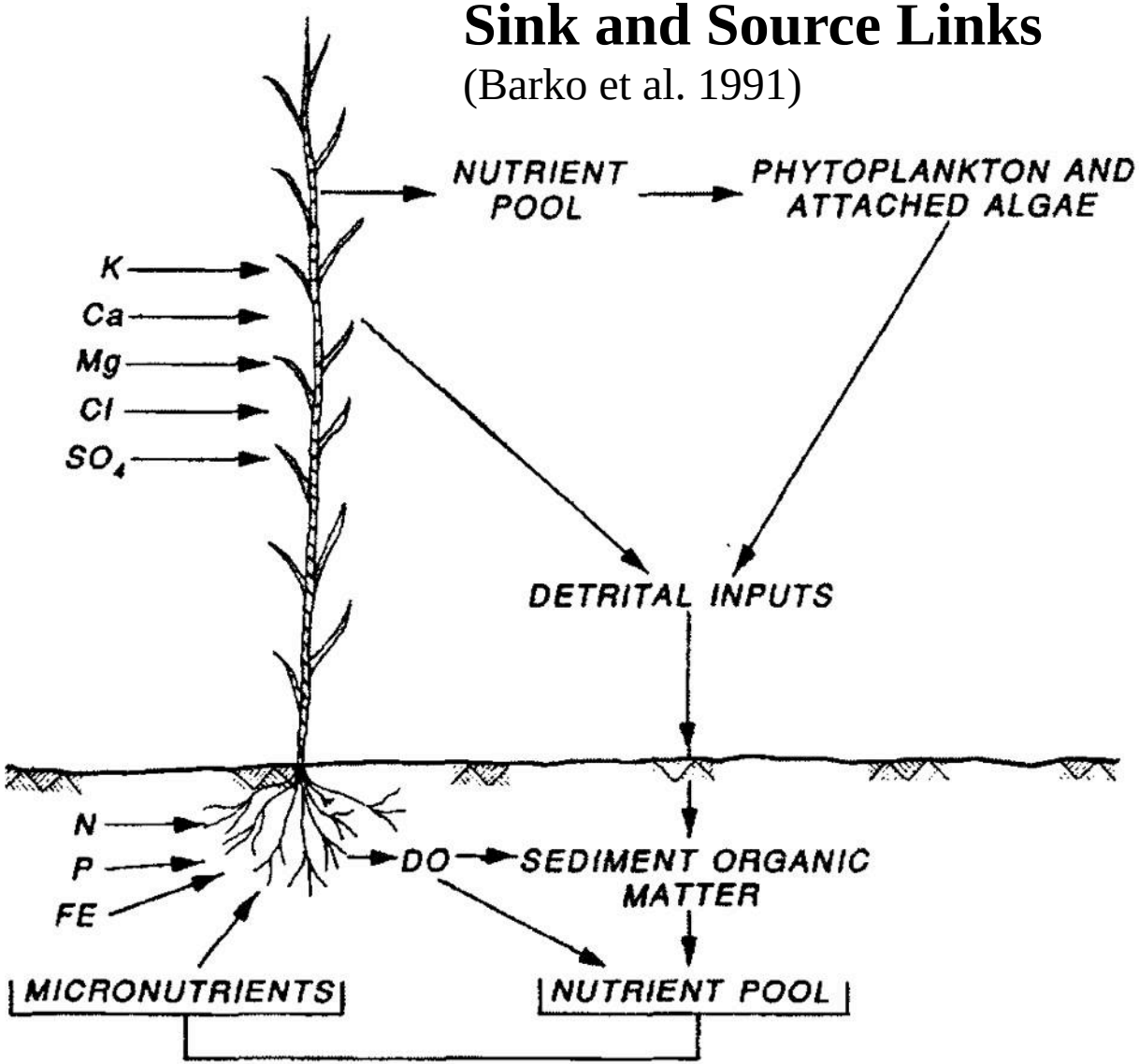
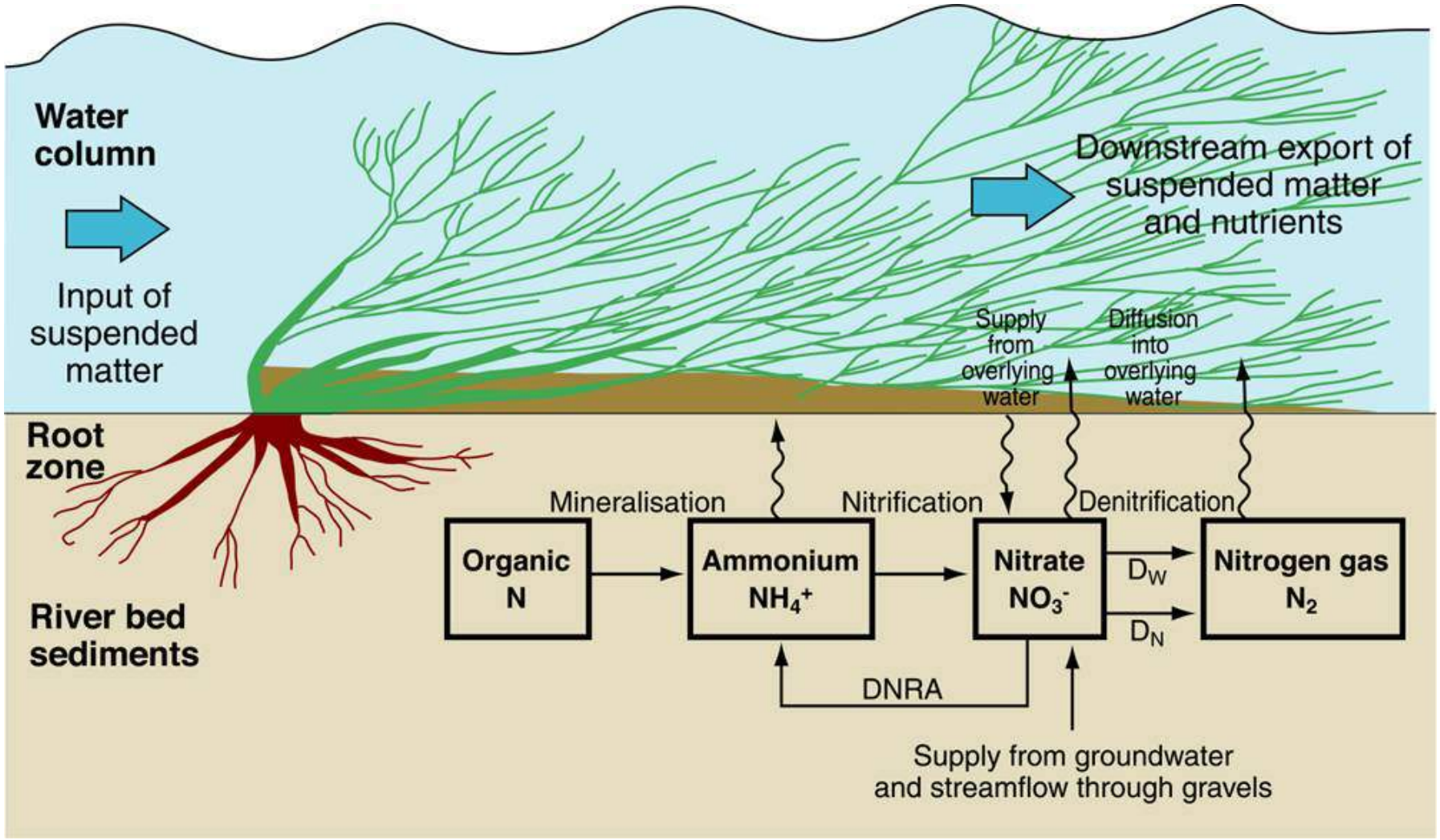


Fig. 6. Major linkages between aquatic macrophytes and bottom sediments in littoral systems. These linkages apply to all life forms of rooted aquatic macrophytes, and are based on information obtained from a variety of sources (see text).

Flowing System and Inputs to Water Quality



Relative Metal Uptake Ability for Macrophytes

(Srivastava et al. 2008)

Table 3 Removal of metal ions by some common aquatic macrophytes

Common macrophytes	Metal/s	Removing efficiency (%)	References
Eichhornia cressipes	Fe → Cu → Zn→ Cd	80.0	Sahu et al. (2007), Schneider et al. (1999), Prakash et al. (1987)
Azolla spp.	Hg	93.0	Kamal (2004)
Ceratophyllum demersum	Pb → Zn → Cu	80.0	Keskinkan et al. (2004)
Ipomoea aquatica	Hg	90.0	Götheberg et al. (2002)
Lemna spp.	Pb	90.0	Gazi and Steven (1999)
Ludwigia repens	Hg	99.8	Pilon-smith and Pilon (2002)
Pistia stratiotes	Cd → Hg → Cr	85–90.0	Maine et al. (2001)
Potamogeton spp.	Pb → Zn	70.0	Schneider et al. (1999)
Salvinia herzogii	Cr	70.83	Maine et al. (2004)

(→) Symbolize the preference of removal, Removal efficiency is based on the total possible removal of metals from given treatment, Metals mentioned are reported in the literature however; these plants are able to take up other metals too

Commonly Recognized Aquatic Weed Impacts on Water Quality

- Temperature gradients (depth, diurnal, seasonal)
- Dissolved oxygen (spatial and diurnal)
- Carbon availability (CO_2? HCO_3?)
- pH (spatial and diurnal)
- Physical structure: Flow velocity and Directions
- Vertical mixing (*nutrient cycling*)
- Sedimentation rates and locations
- Turbidity

These Also Affect ESA Listed Species !

Effect of Plant Canopy on DO: Floating leaf vs. Subersed leaf types

(From Frodge et al. 1990)

DO (mg/l)	Open Water	*P. natans*	*B. schredberi*
Jan-April	8.4	Nd	7.5
May-June	5.7	6.8	7.1
July	5.1	7.4	1.7
Aug.	4.8	4.9	1.4
Sept	3.6	8.8	0.7
Oct-Dec	4.3	6.5	6.5

Seasonal Effect of *Brasenia schreberi* on DO

(Frodge et al. 1990)

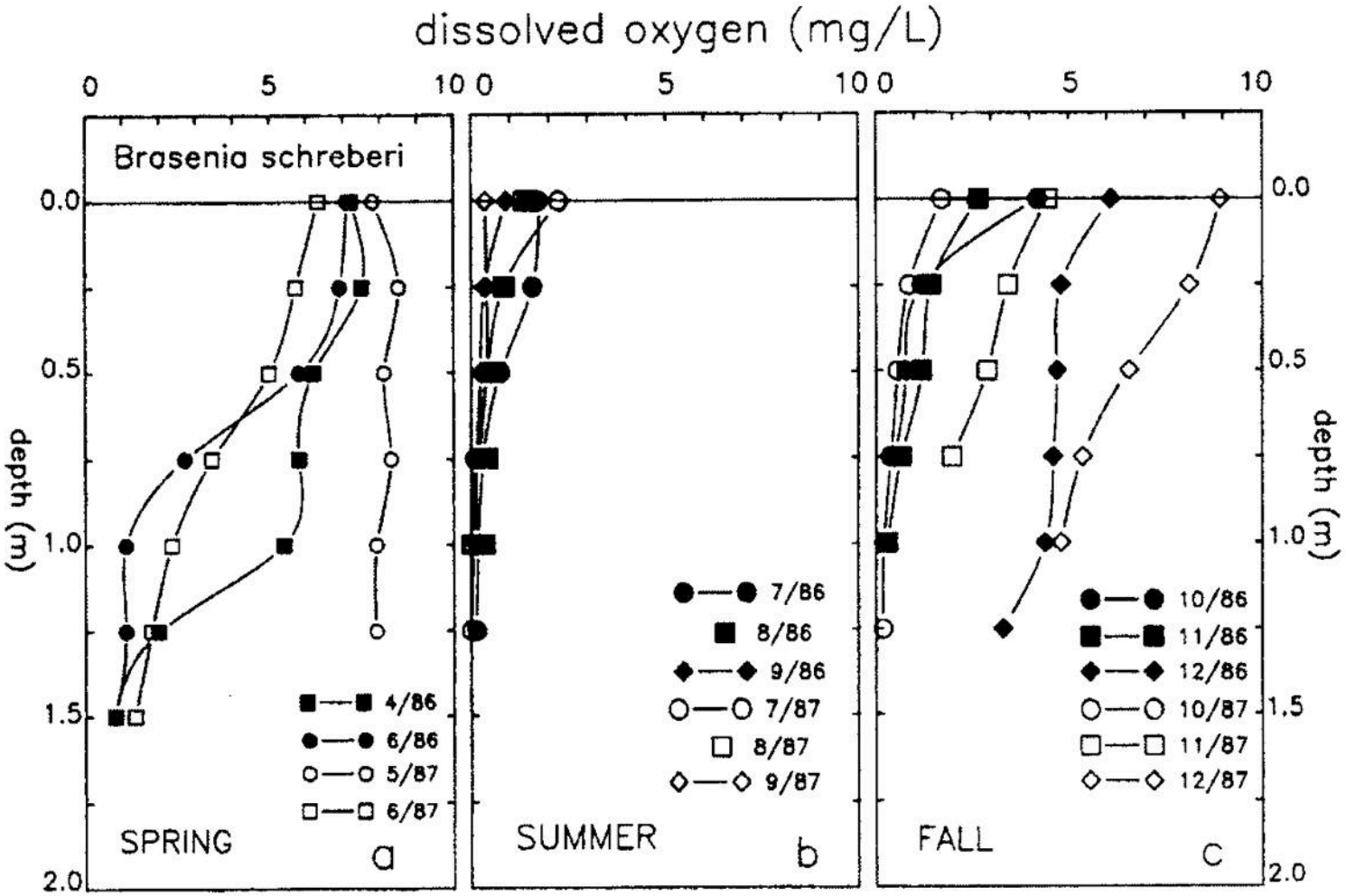


Fig. 4. Mean dissolved oxygen by depth ($n \geq 15$) in beds of *B. schreberi* in Keevies Lake for: (a) spring (January–June); (b) summer (July–September); (c) fall (October–December), 1986–1987.

Effect of *P. natans* and *E. canadensis* on DO

(Frodge et al. 1990)

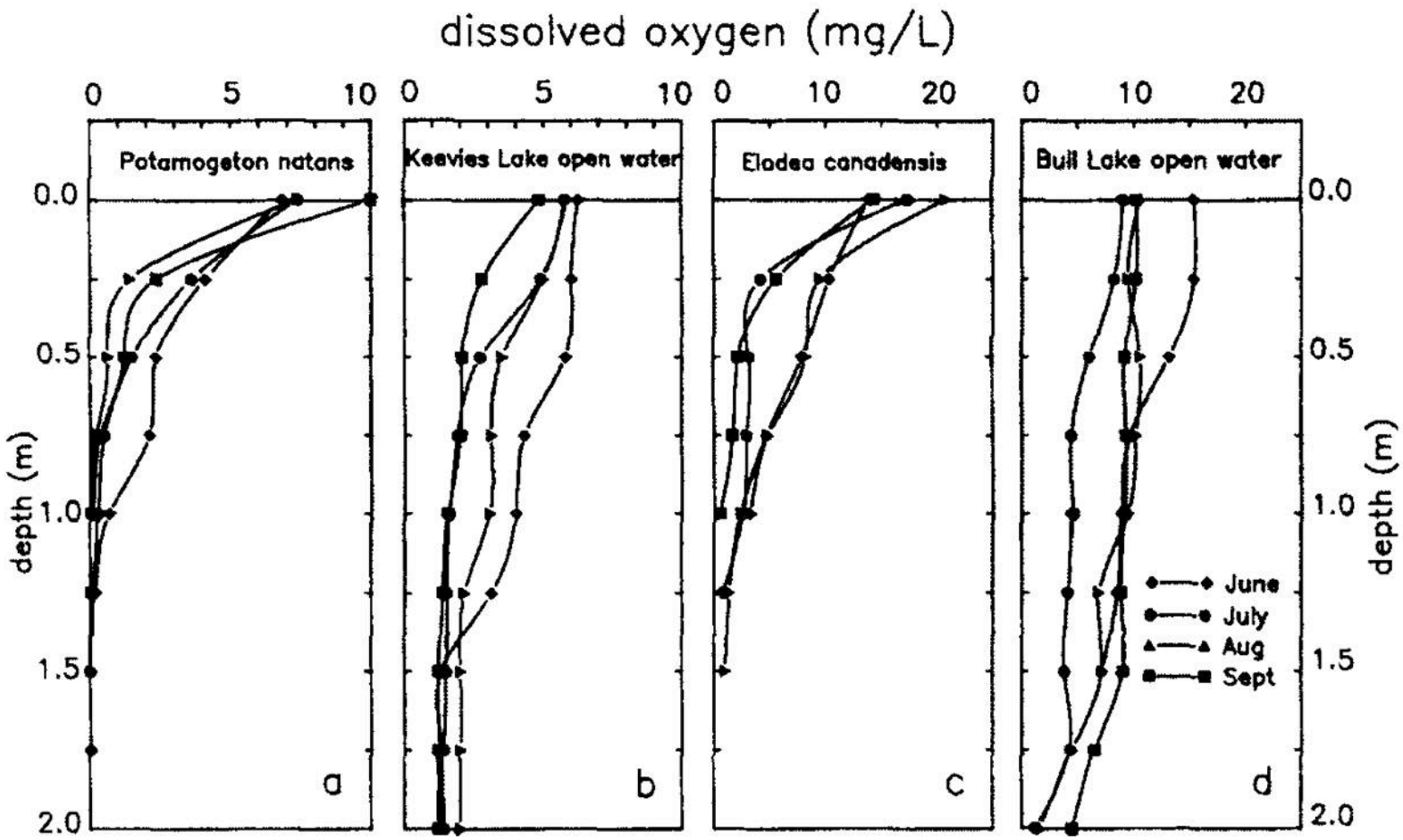


Fig. 5. Mean dissolved oxygen by depth ($n \geq 15$) during June through September, 1986–1987 for: (a) *P. natans* sites in Keevies Lake; (b) open-water sites in Keevies Lake; (c) *E. canadensis* sites in Bull Lake; (d) open-water sites in Bull Lake.

Effect of Water hyacinth Removal on DO (Hours/day that DO below 25% Saturation)

(Perna & Burrow 2005) (Australia)

Table 1

Number of hours per day where DO levels fell below 25% saturation at Gorizia's and Payard's Lagoons, before and after weed removal

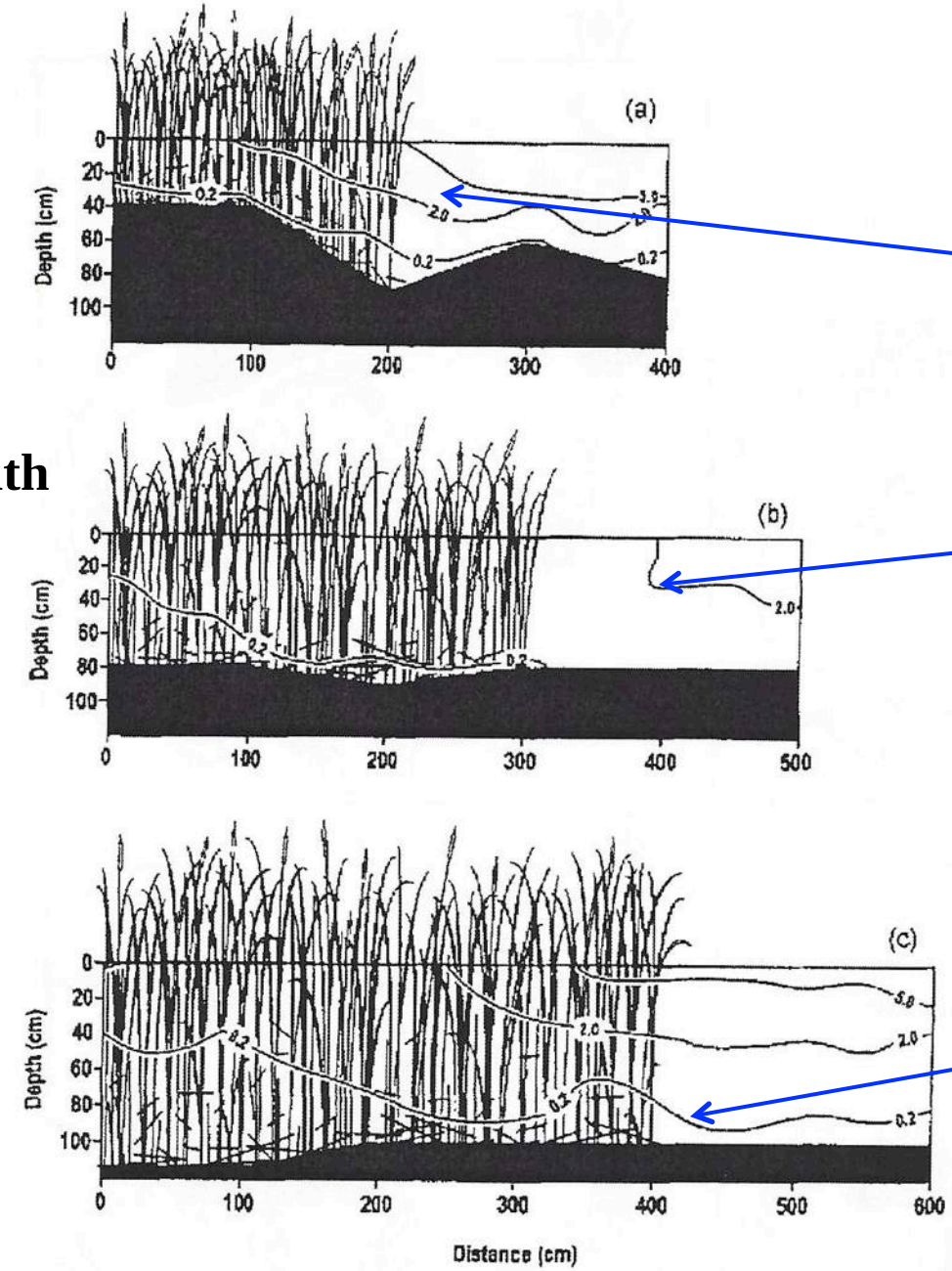
Site	Mean no. hours (S.E.)		*T* value	*p*
	Pre-removal	Post-removal		
No. days logging	22	30		
Payard's Lagoon inlet	0.40 ± 0.4	0.00 ± 0	1.03	0.31
Payard's Lagoon outlet	10.81 ± 2.42	2.5 ± 0.56	4.07	0.00***
No. days logging	13	13		
Gorizia's Lagoon inlet	16.62 ± 2.84	17.92 ± 0.92	−0.44	0.67
Gorizia's Lagoon outlet	21.62 ± 1.19	7.69 ± 2.37	5.24	0.00***

*** Significance of 0.001.

Effect of Emergent Plants on DO

(Rose & Crumpton 1996)

- **Low DO assoc. with dense shoreline stands**
- **Canopy reduced light to <2% of ambient**



DO Isopleth Lines

“Stealthy” Aquatic Weed Impacts on Water Quality

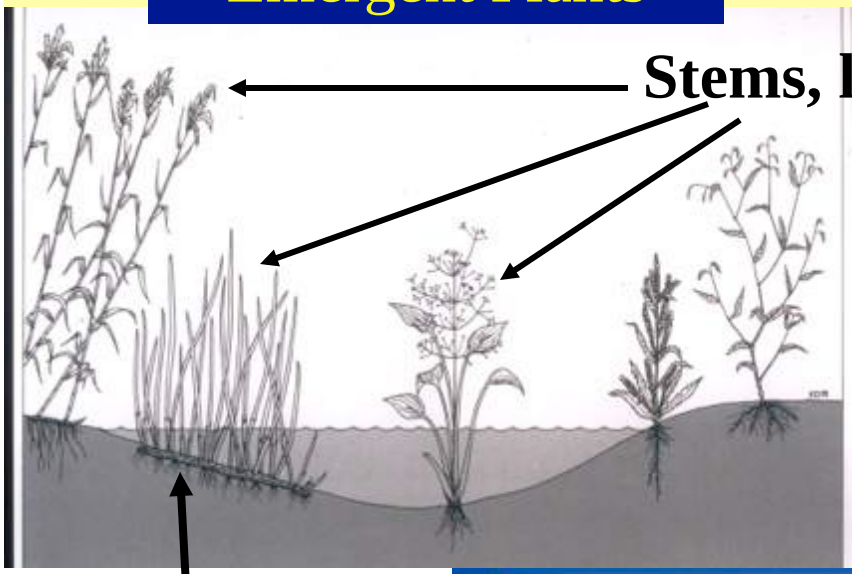
- Increased *VARIATION* and *INSTABILITY*
- Hystoresis (or Historesis)> System Stable States
- Epiphyte Community Diversity and Function
- Microbial Community Diversity and Function
- Pore Water Quality (nutrients, redox, OM, toxins)
- DOM and POM (microbial communities)
- Degradation of axenic contaminants
- Allelochemicals (stability, movement)
- Plant-Plant interactions (e.g. competition)
- Herbicide/Algaecide Efficacy

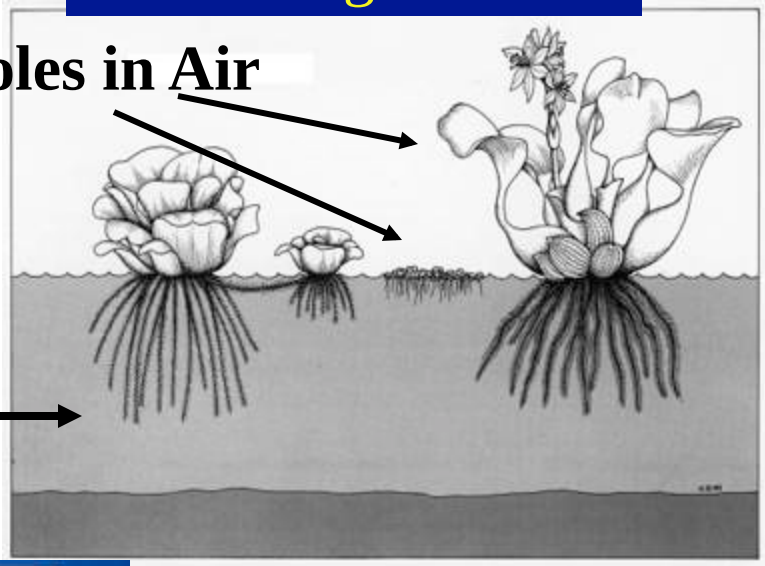
These Also Affect ESA Listed Species !

General Types of Aquatic Plant Growth Forms:

Emergent Plants

Floating Plants

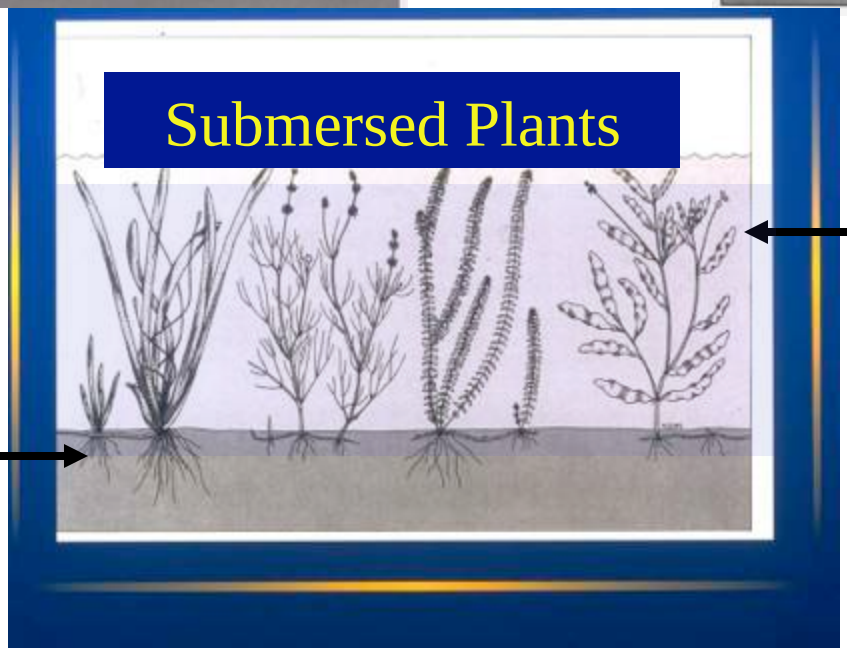




Stems, leaves, petioles in Air

Roots in Water

Submersed Plants

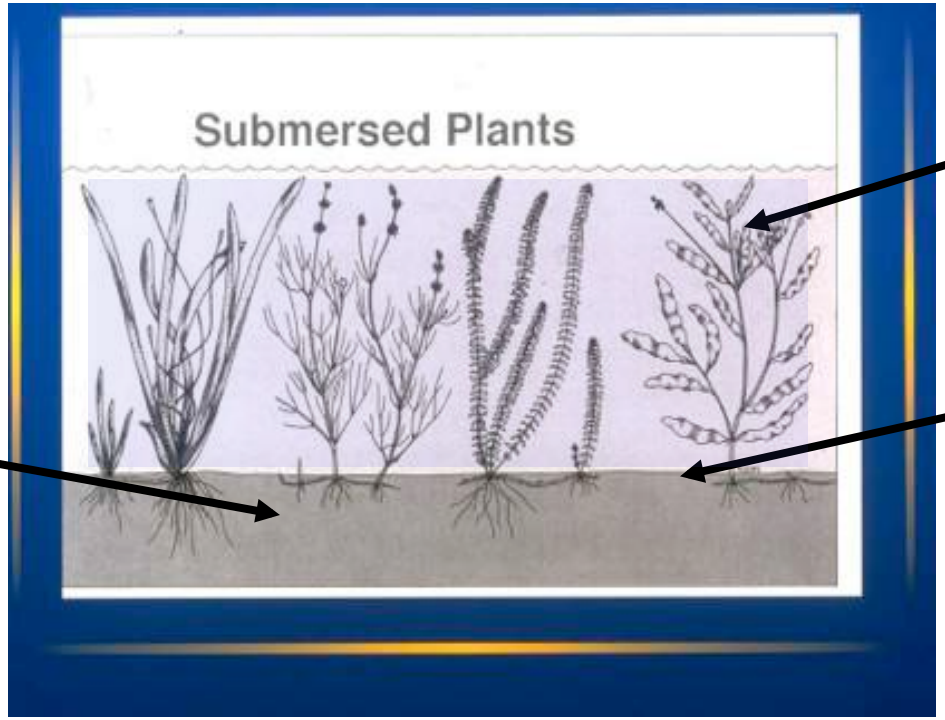


Roots and Rhizomes in the Sediment

Stems/Leaves in Water

Submersed Plant Influence on Water Quality

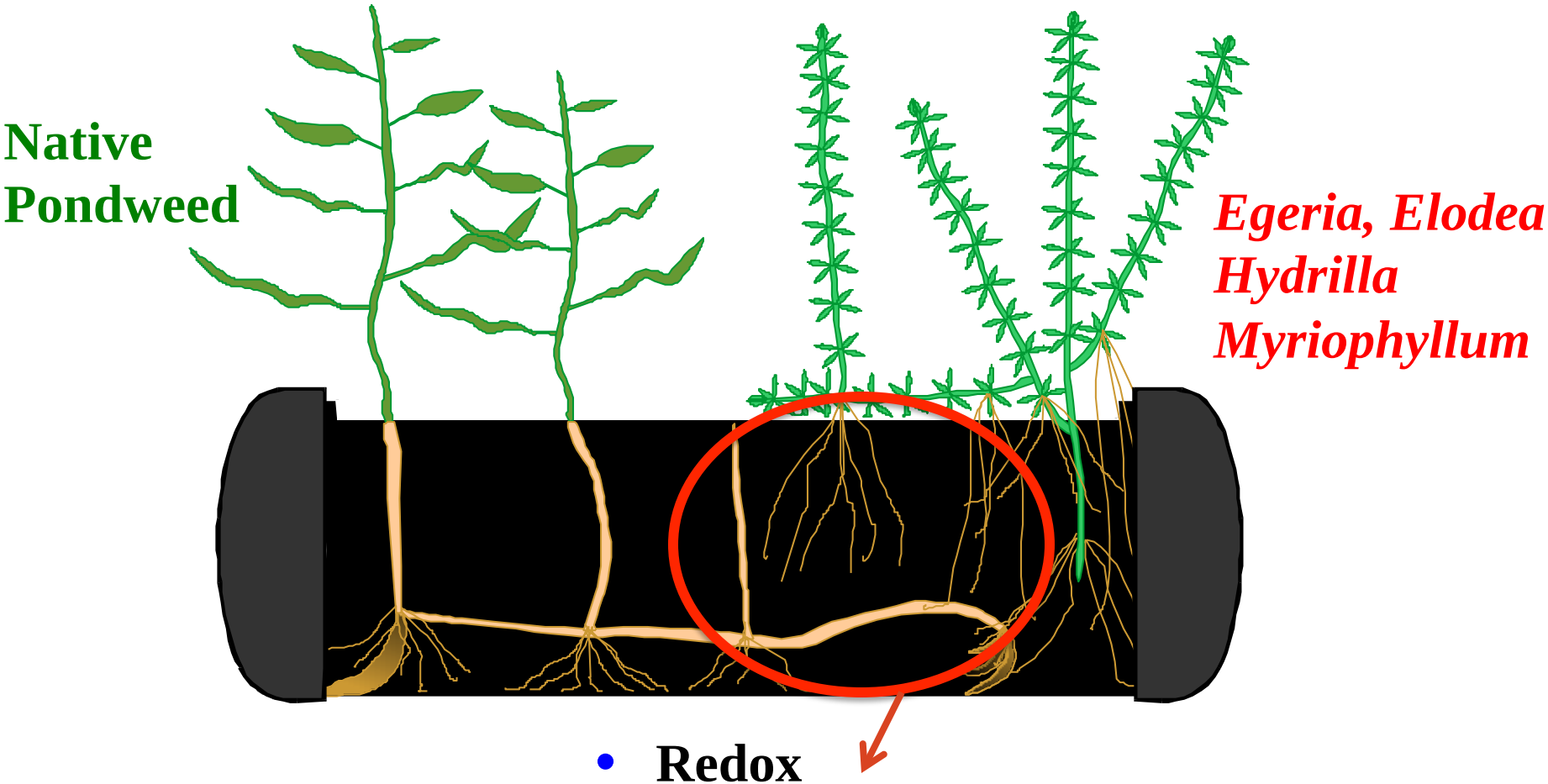
***Sediment*:**
>Pore Water
>Microorganisms
>Allelochemicals
>Infauna
>Redox



Water Column:
>Temperature
>pH, DO, Turb.

Water/Sediment Interface:
>Exchange
>POM
>Epifauna

Rhizosphere Interactions: Pore Water Quality?



- **Redox**
- **Nutrient solubility**
- **Metals (ionic states; eg. MeHg)**
- **Microbial populations**

Eurasian watermilfoil

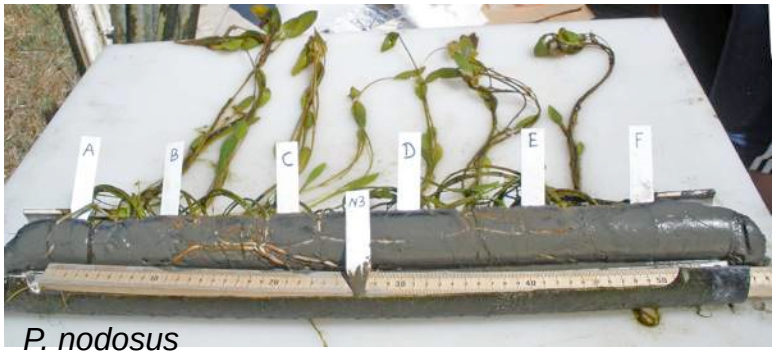
Exampling of PVC- Grooved Pipe

M. Spicatum-planted end

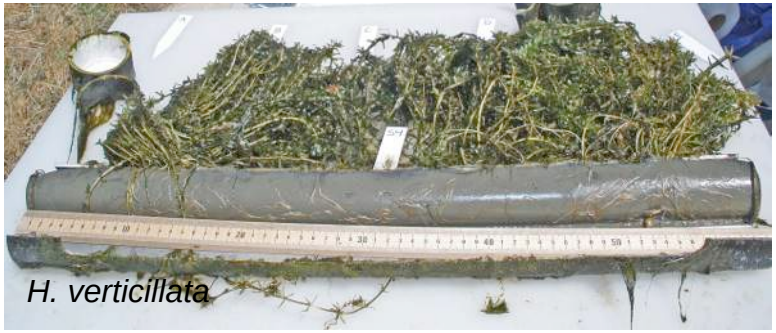
P. nodosus-planted end

Rhizosphere-Associated Sediment Sampling: PVC Grooved Tube

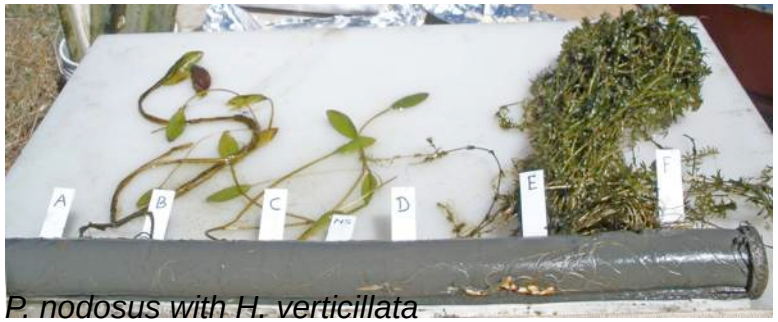
DGGE gel: Interaction between *P. nodosus* and *H. verticillata*



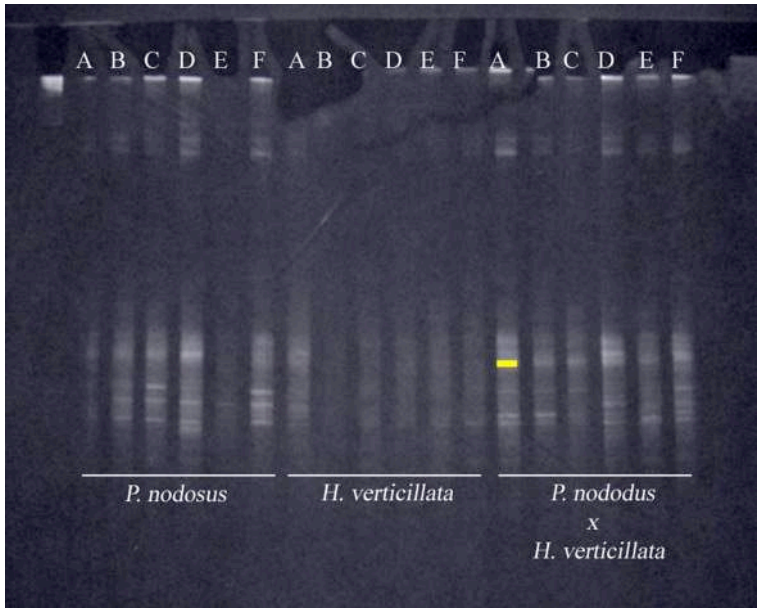
P. nodosus



H. verticillata



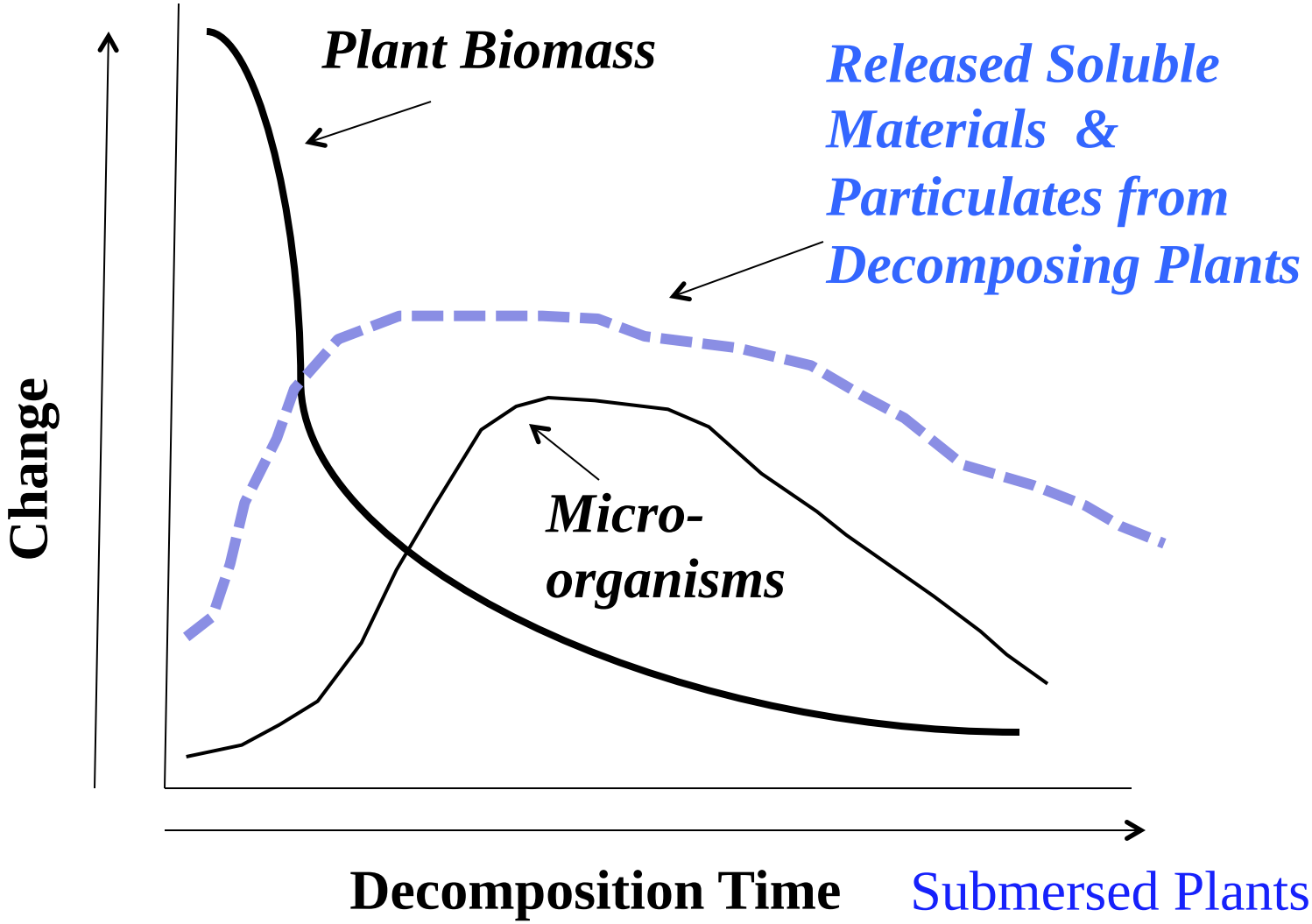
P. nodosus with H. verticillata



Indicates band in *P. nodosus* x *H. verticillata* not detectable in *P. nodosus* or *H. verticillata*

(Faint bands in *H. verticillata* lands suggest low levels of DNA from sed. samples)

Aquatic Plants as Sources: Senesncence
(Modified from Barko et al. 1991)



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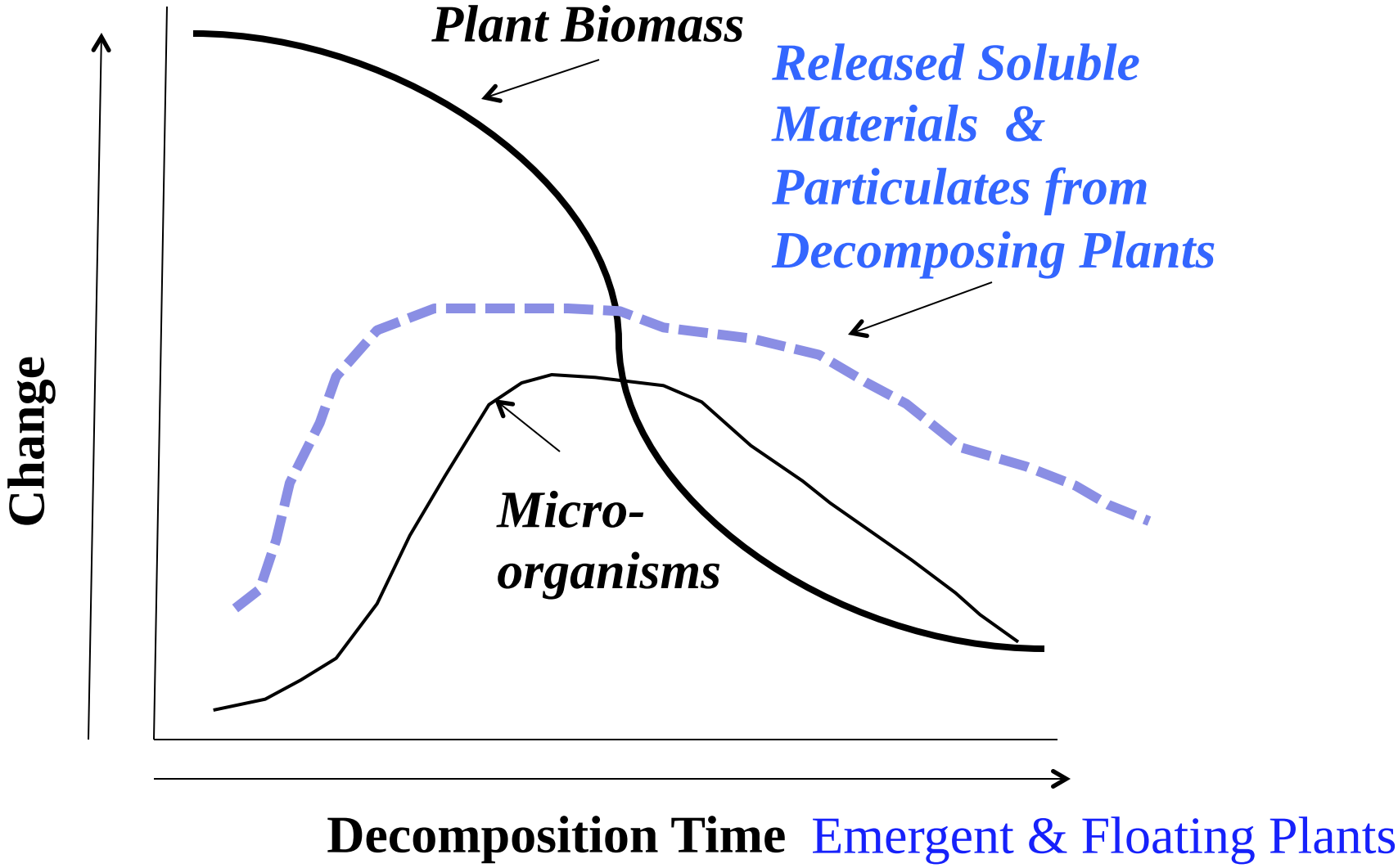


Decompositin of *Callitriche* and Release of Nutrients

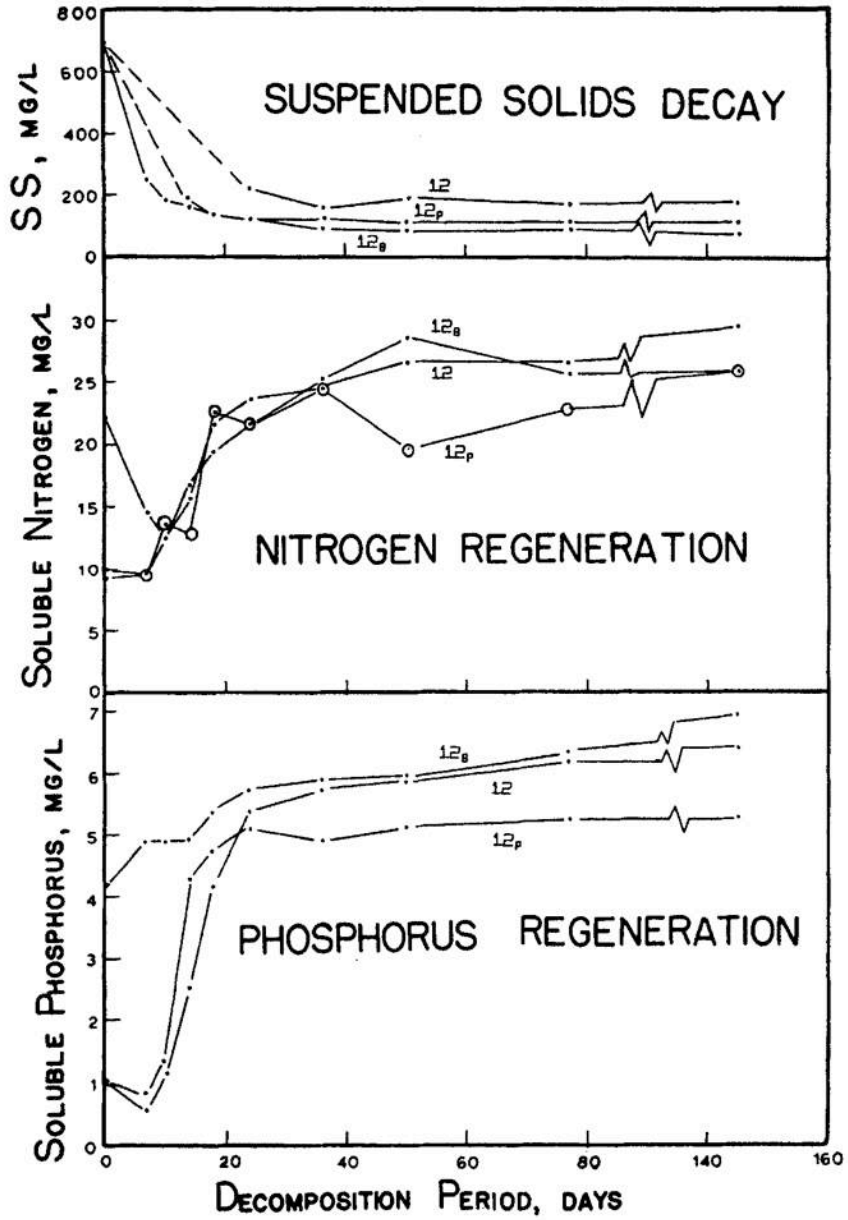
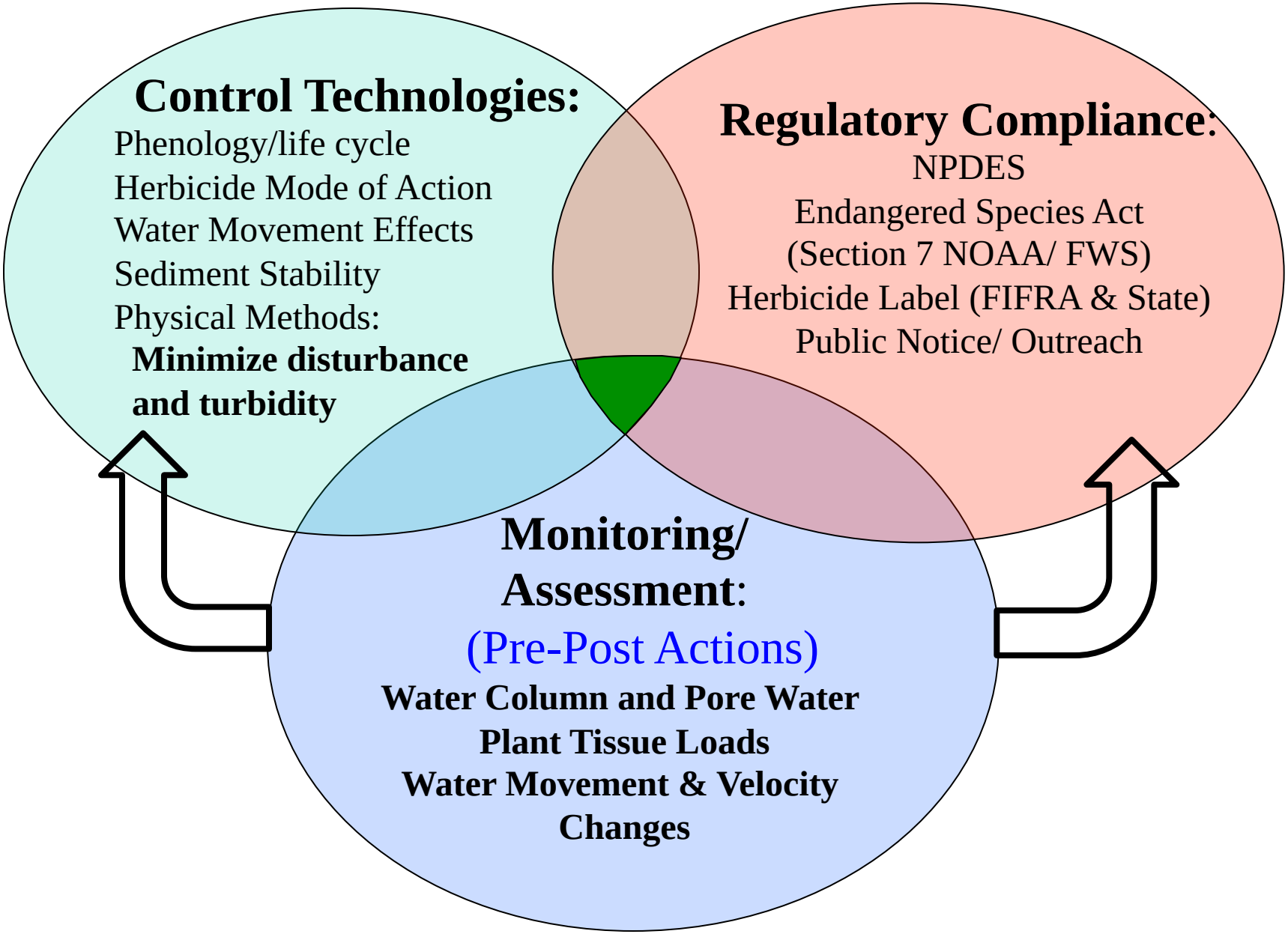


FIGURE 1.—Change in mass and soluble nutrient concentrations during the decay of *Callictriche* sp. (Sample 12) prepared in three conditions: 12_p, unaltered from natural conditions; 12, cut into 1-in. (2.54-cm) segments; and 12_B, blended.

(Jewel, 1971)

Integrating Water Quality and Aquatic Weed Management



***Summary*:**

- Macrophytes are sinks, repositories and sources for nutrients and organic matter that affect water quality
- Macrophytes create water quality “micro-zones”
- All management methods affect water quality in the water column *AND* in pore water
- Excessive macrophyes biomass leads *to increased variations* in constituents that determine water quality
- More detailed assessments of water quality constituents should be included in pre- and post management actions- NOT just “minimal compliance” with NPDES

Thank you…
and what's your water quality?