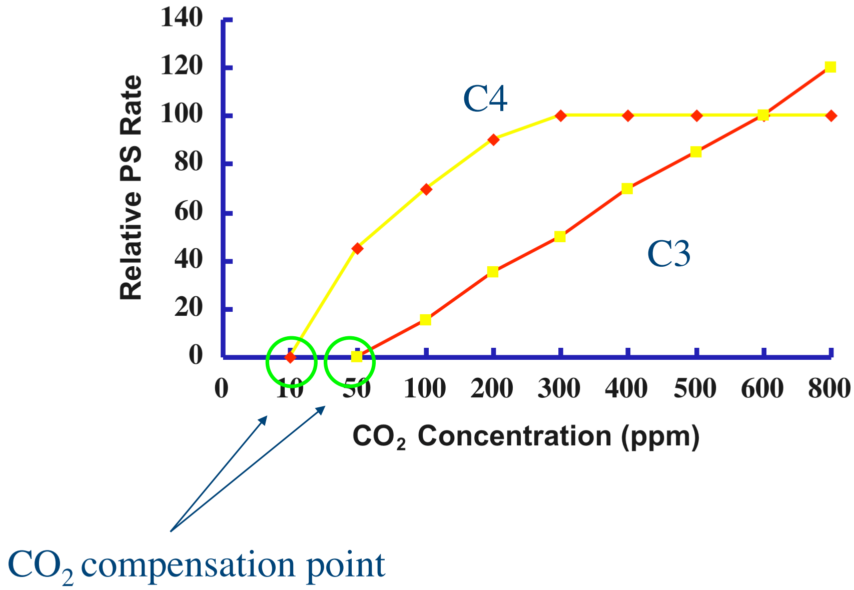
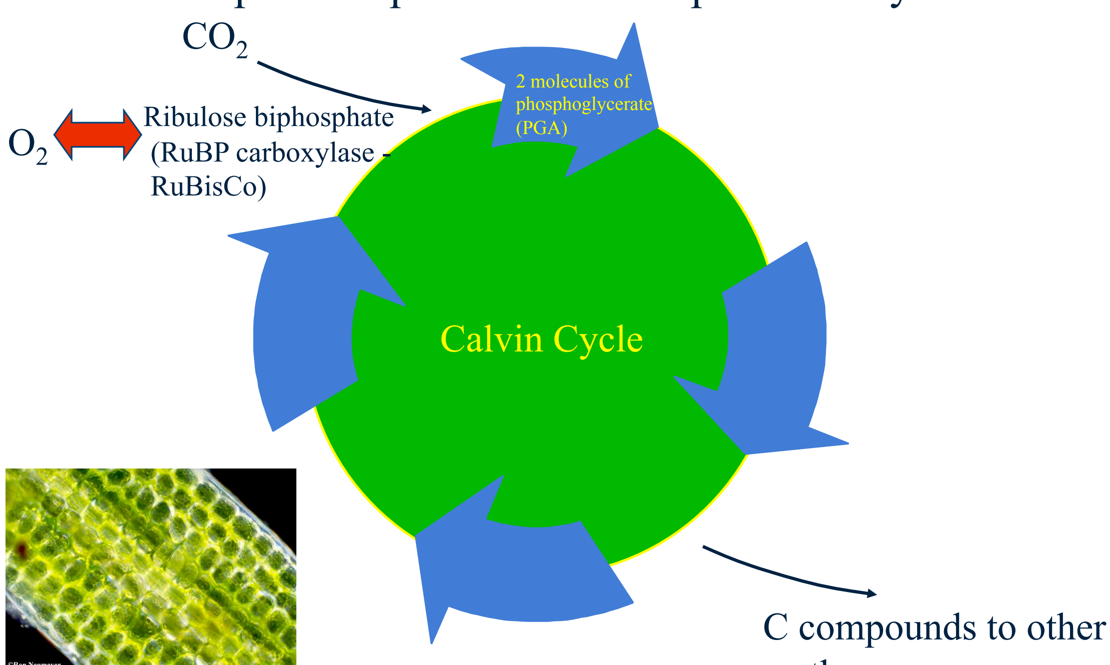
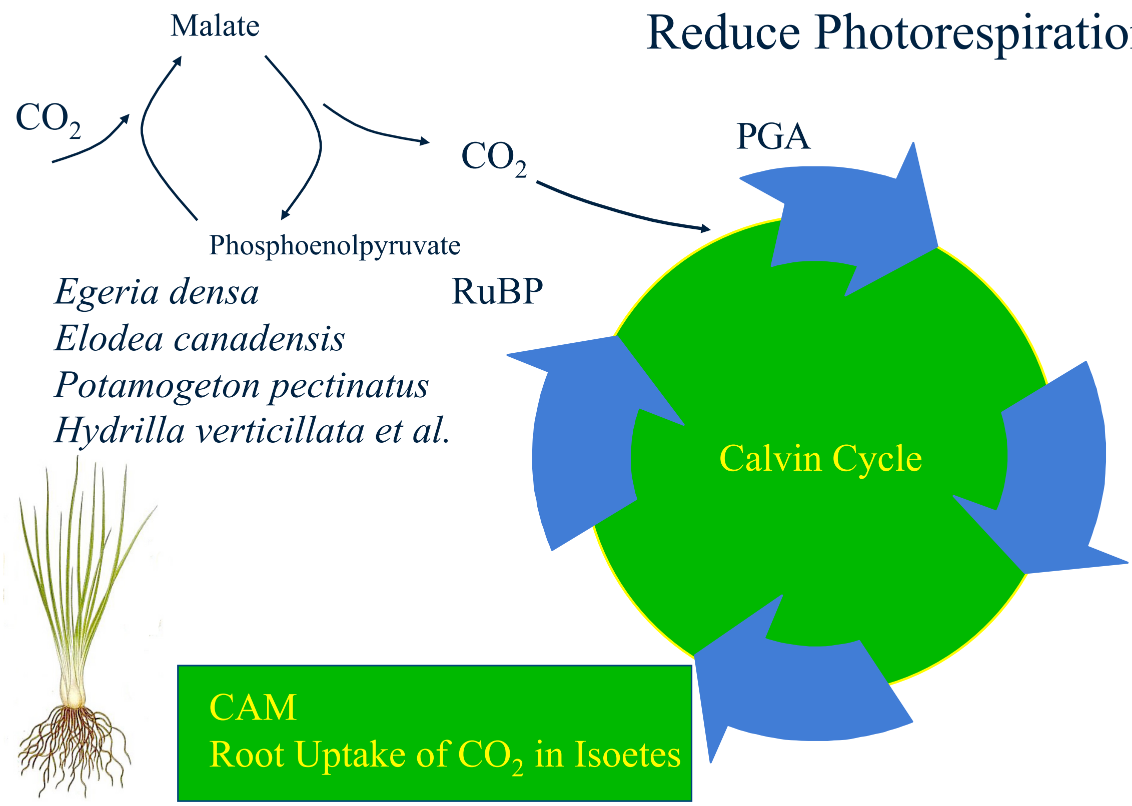


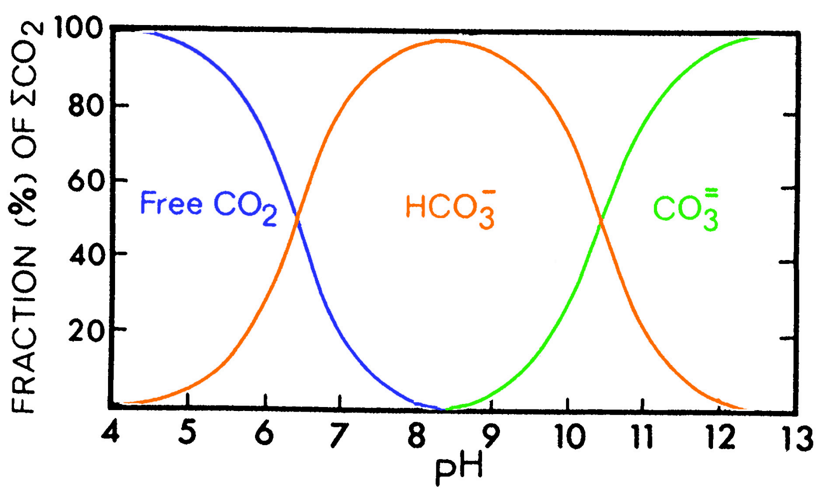
Boundary layer effect leads to low CO_2 and high O2 concentrations at leaf surface and photorespiration reduces productivity



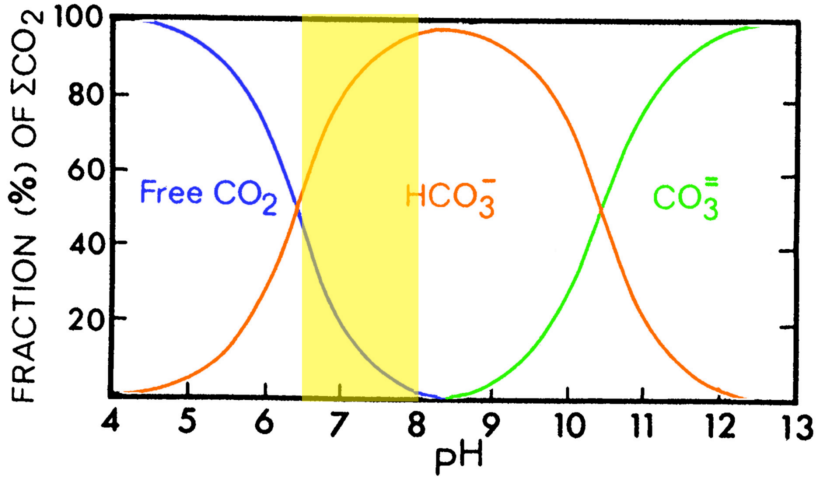
Carbon Concentrating Adaptations Reduce Photorespiration



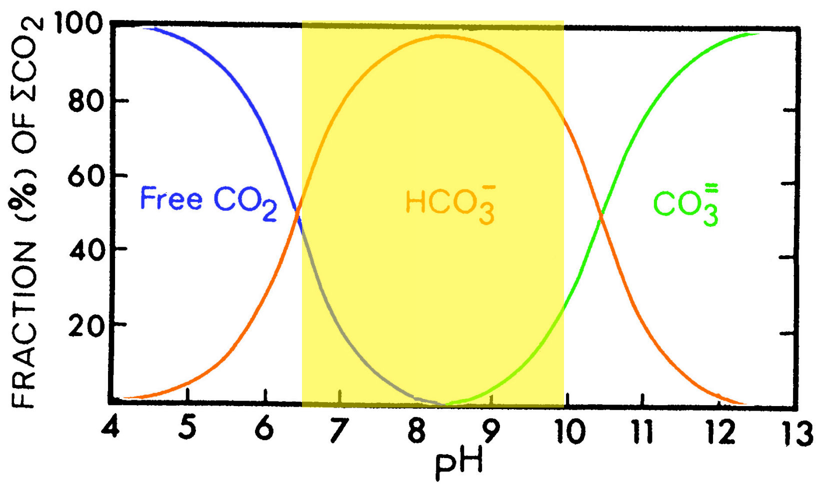
The proportions of the different carbon forms are highly pH-dependent



Typical pH range in lakes

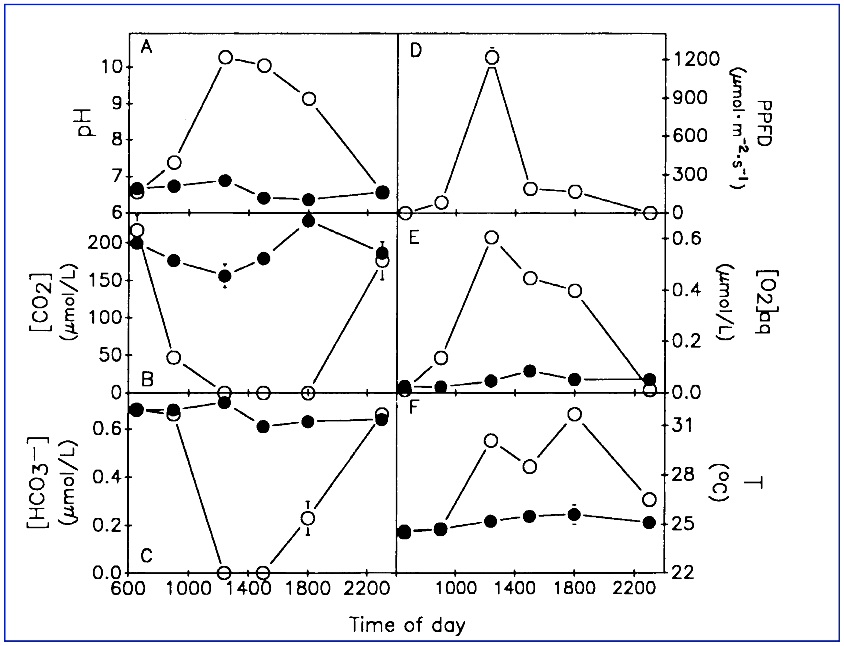


Bicarbonate users can drive up pH and "starve" obligate CO_2-users



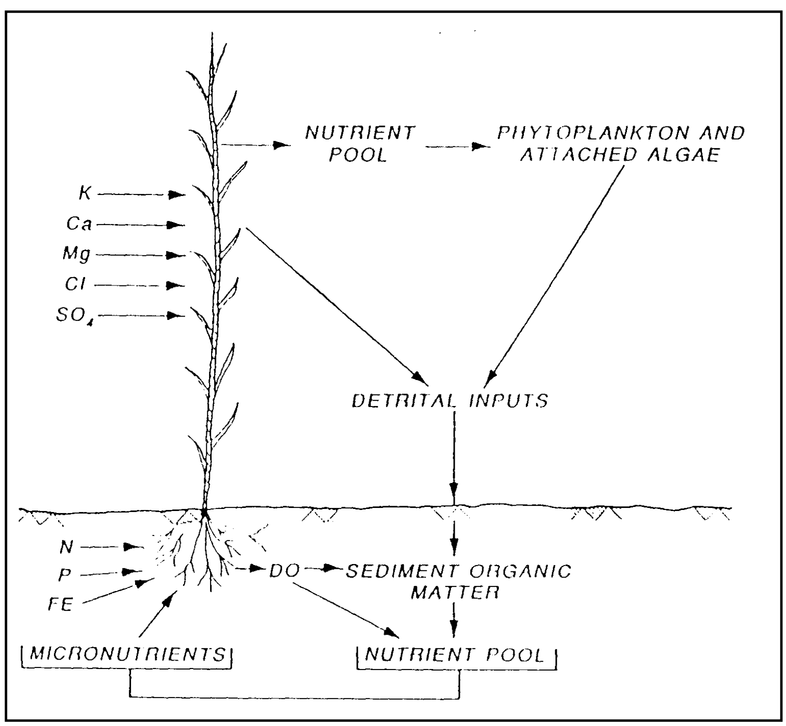
Physical and Chemical Impacts

Diurnal changes within and outside hydrilla mat
(Spencer et al. 1994)



Effect on nutrient cycling and mobilization of sediment N and P

Rooted plants and phytoplankton have access to different N and P pools than phytoplanton and floating species



Effect of changes in rooted macrophyte abundance on phytoplankton, waterfowl, and fish populations in a shallow lake in southern Sweden - multiple stable states

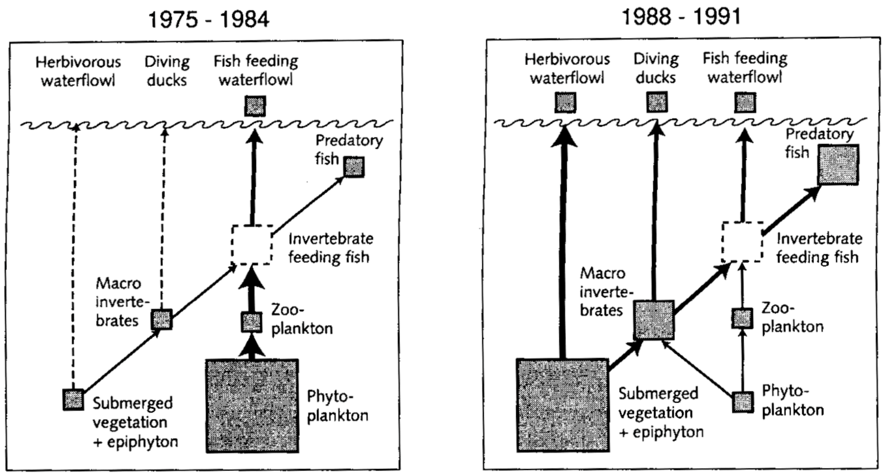
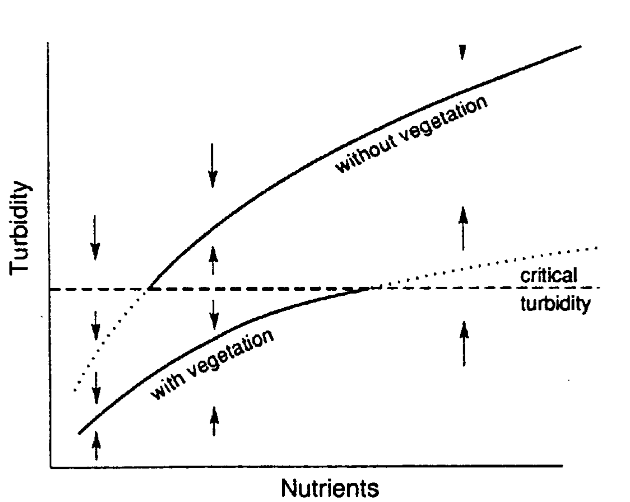


Fig. 5.10 Schematic description of the trophic web before (1975–1984) and after (1988–1991) the shift from a turbid to a clear state in the Swedish Lake Krankesjön. Boxes represent biomass, arrows represent energy flow. The estimation of invertebrate-feeding fish is uncertain. From Hargeby *et al.* (1994).

Dual stable states in lakes

Fig. 4. Alternative equilibrium turbidities related to the presence and absence of aquatic vegetation[6]. Equilibrium turbidity increases with rising nutrient level, but as vegetation reduces turbidity, two different relations apply depending on the presence or absence of vegetation. Vegetation presence itself, however, also depends on turbidity. Light limitation prevents growth below a (turbidity-dependent) depth, and since shallow lakes are often rather homogeneous in depth, the response of the vegetated area to turbidity tends to be discontinuous. To construct this figure we assume the extreme case of total disappearence of vegetation from the lake when the turbidity exceeds a threshold value at which the critical light level for vegetation growth at this depth is reached. Consequently, the 'with vegetation' line applies below the critical turbidity and the 'without vegetation' line above this level. Hence, the dashed parts of the two equilibrium lines do not represent stable states. The emerging picture shows that at low nutrient levels only the vegetated clear equilibrium exists and at high nutrient levels only the turbid vegetationless one. However, over a range of intermediate nutrient concentrations two alternative stable states are possible. Here, the critical turbidity represents the breakpoint of the system separating the attraction areas of these alternative states. Arrows indicate the direction of change in turbidity when the system is out of equilibrium.



- Sediment stabilization

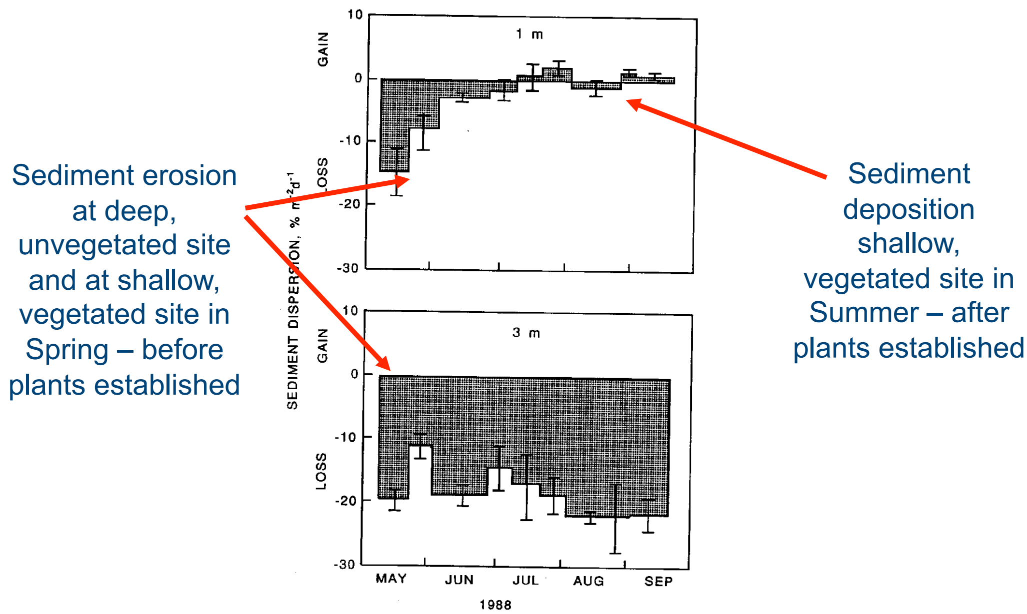


Fig. 4. Means (n = 3) and standard errors for dispersion of sediment from pans placed at a 1-m, vegetated site and at a 3-m, nonvegetated site.

Internal Factor in Lake Ecosystem Succession
Sediment accetion

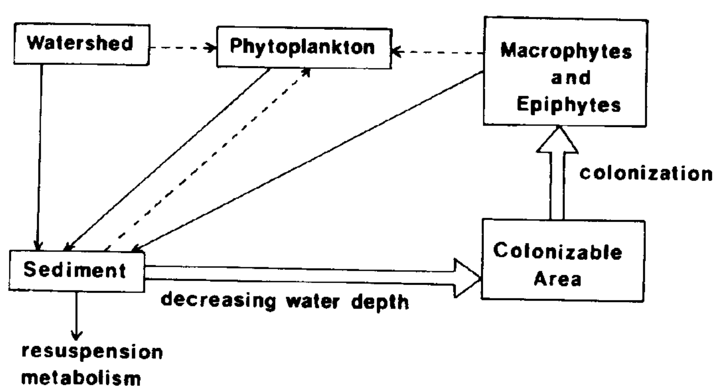
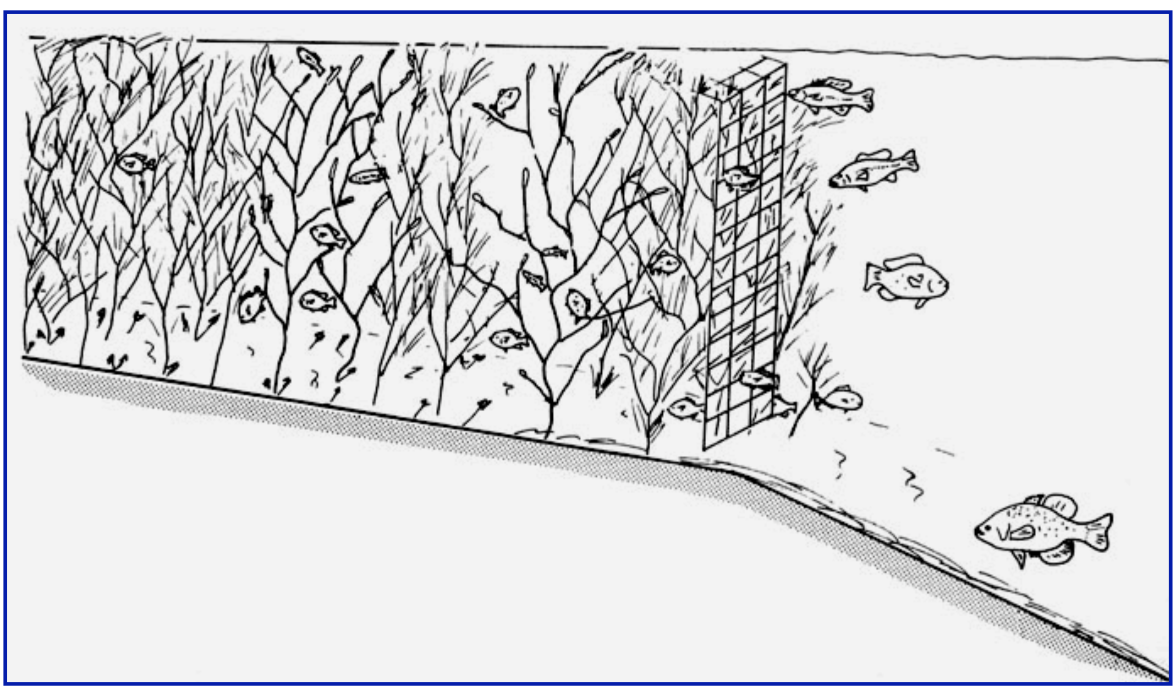
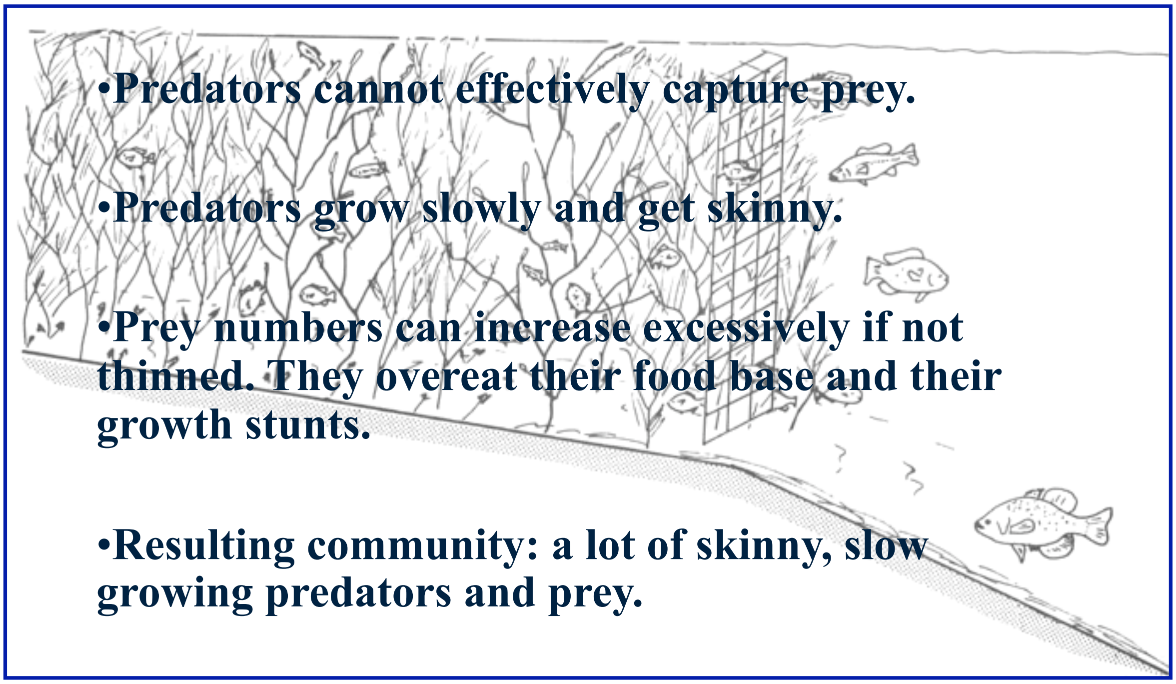


FIG. 3.—Major interactions that influence the formation of colonizable sediment area in Lake Wingra. Open arrows depict the formation of new colonizable sediment area as sediment mass builds above the 2.5 m depth contour, and increased production of macrophytes and epiphytes as the new area is colonized. Solid arrows represent fluxes of dry matter, including nutrients. Dashed arrows indicate fluxes of nutrients.

Dense macrophyte beds alter the "structure" of fish habitat





- •Predators cannot effectively capture prey.
- •Predators grow slowly and get skinny.
- •Prey numbers can increase excessively if not thinned. They overeat their food base and their growth stunts.
- •Resulting community: a lot of skinny, slow growing predators and prey.

Macrophytes also influence zooplankton abundance

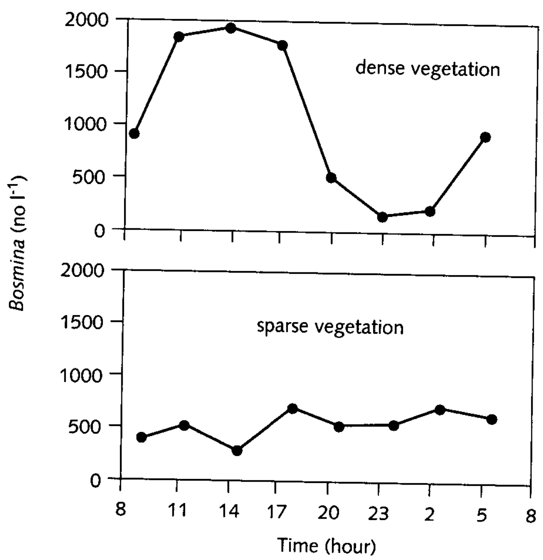


Fig. 5.8 Diurnal change in the density of *Bosmina* in a dense (PVI = 70%) and a sparse (PVI = 23%) vegetation stand in the Danish Lake Stigsholm. Only the dense stand is apparently used as a daytime refuge. From Jeppesen *et al.* (1996).

Effect of canopy formation on dissolved oxygen concentration

Brassenia schreberi
(floating-leaf)

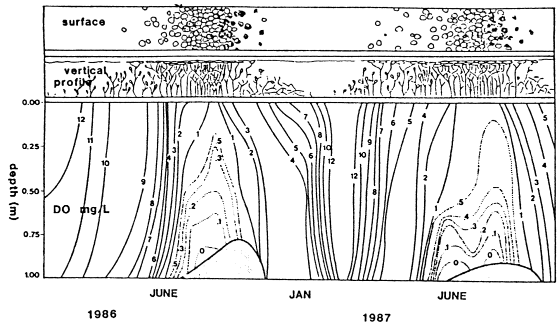
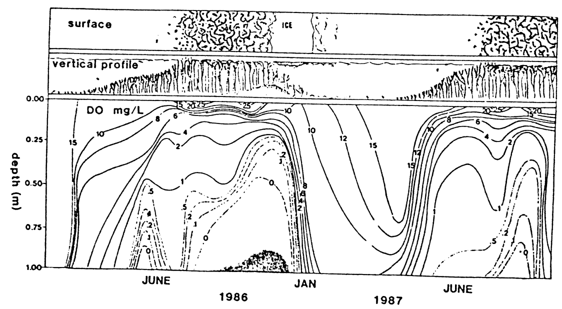


Fig. 3. Dissolved oxygen (mg l⁻¹) isopleths in a dense stand of *B. schreberi* in Keevies Lake from December 1986 to December 1987. The stippled area represents the bottom of the lake during summer low water.



Ceratophyllum demersum
(submersed, unrooted)

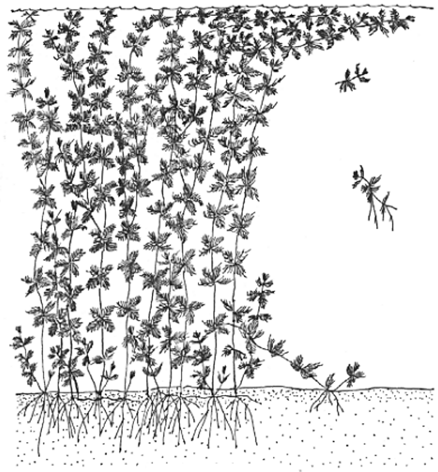
Fig. 7. Dissolved oxygen (mg l⁻¹) isopleths in a dense mixed stand of *C. demersum* and *M. exalbescens* in Bull Lake from March 1986 to December 1987. The stippled area represents the bottom of the lake during summer low water.

Characteristics of Aquatic Weeds

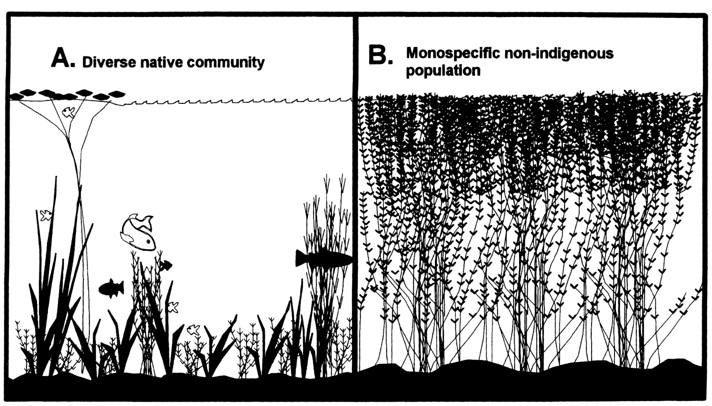
- **Vegetative reproduction**
  - **Often prolific propagule formation (e.g., hydrilla, curly leaf)**
- **Canopy formation (growth form)**
- **Low-light tolerant Unique biochemistry**
  - **Bicarbonate use**
  - **Carbon concentrating mechanisms**
    - **Photorespiration resistant**
    - **C4-like biochemistry**

Vegetative reproduction

- Often prolific propagule formation (e.g., hydrilla, curly leaf)



Canopy formation



Management of Aquatic Weeds

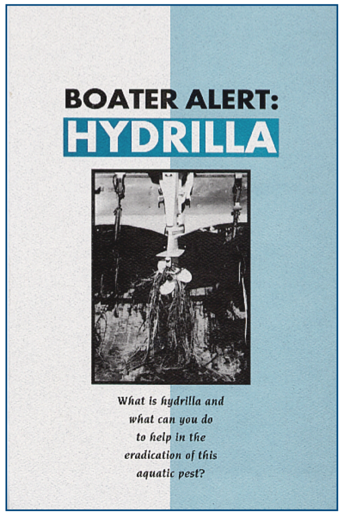
Prevention

- Identify pathways
- Develop interventions
  - Outreach/Education
    - Identify audiences
    - Develop message
    - Implement
    - Evaluate
  - Best Management Practices
  - Legal
    - Prohibitions
      - Importation
      - Transportion/sale
- Early detection and rapid response

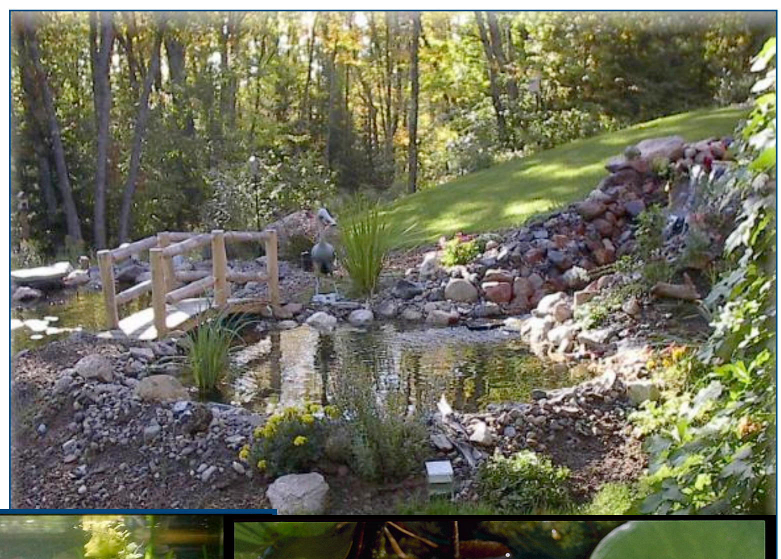
Hitchhiker Pathway

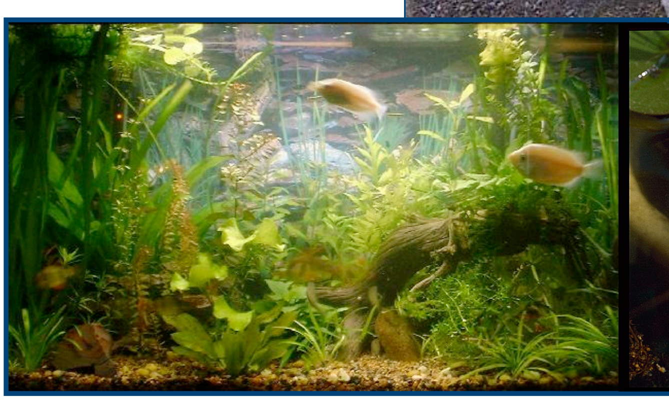
Hitchhiker Prevention

- Outreach and Education
  - Signs boat ramps
  - Brochures



Water Gardening /Aquarium/ Intentional Pathway

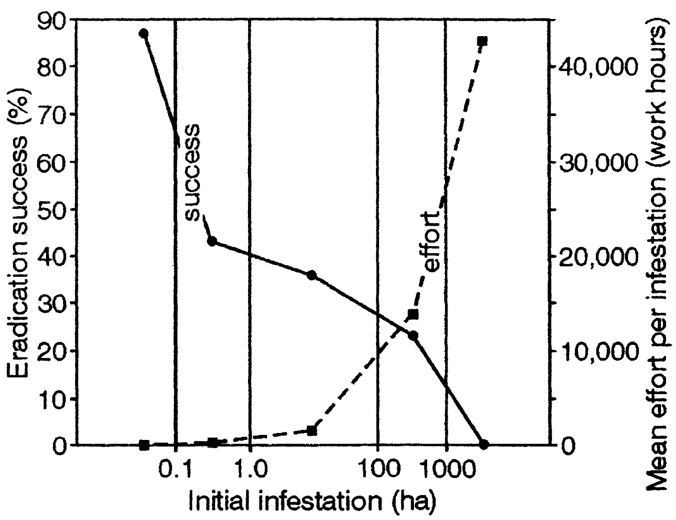




Water Current and Bird Pathway

Uncontrollable?

Early Detection and Rapid Response



Pitcairn and Rejmanek, 2002

Management of Aquatic Weeds

Management of Aquatic Weeds

Environmental manipulation

Drawdown – McNary GC, Blue Lake

Shading

Management of Aquatic Weeds

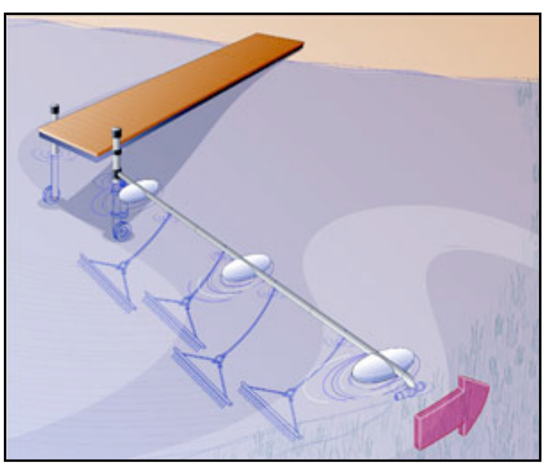
Environmental manipulation

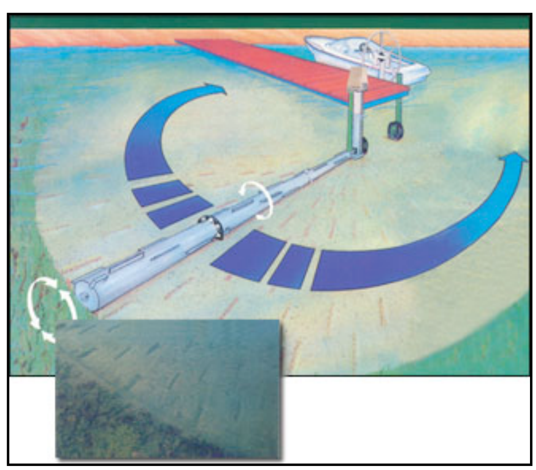
Bottom barrier

Management of Aquatic Weeds

Environmental manipulation

Weed rollers and rakes



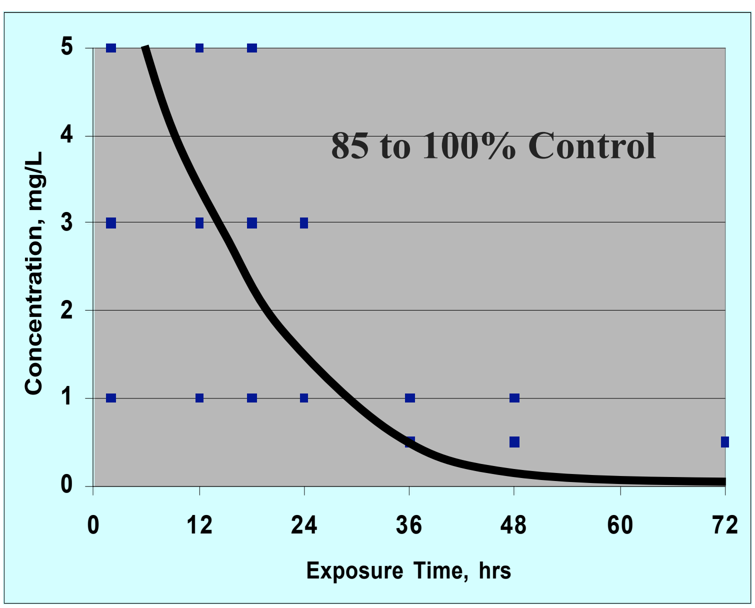


Chemical Control
Prerequisites for Efficacy

- Adequate Concentration
- Adequate Contact Time
- Proper Placement (Proximity for uptake)
- Appropriate Water Quality
  - ✓Turbidity interferes with diquat
- Optimal Season and Phenological Stage
- Appropriate chemical for weed species
  - ✓2,4-d for dicots

Advances in Chemical Control

Low rate, long contact time treatments permits selectivity



Endothall Concentration/Exposure Time Relationship for Milfoil

Chemical control

Partial – lake treatments

Problems with chemical control

Evolution of tolerance to some herbicides

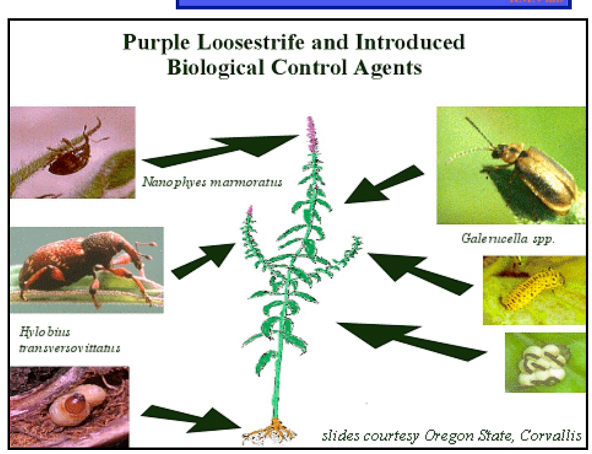
Permits and Perceptions

Management of Aquatic Weeds

Biological

Grass carp

Classical agents (insects, fungi, etc.)



Grass carp

Devil's Lake, OR

Pros and Cons of Grass Carp

PROS

- Relatively inexpensive
- Long-term control, but need to be restocked
- Biological alternative to chemical control.

CONS

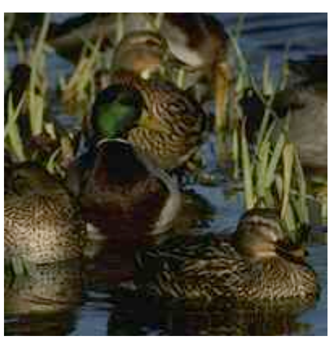
- May take several years to achieve plant control - in many cases control **may not** occur or **all** submersed plants may be eliminated.
- Preferred plants may also be those most important for habitat and for waterfowl food.
- A submersed aquatic plants may be eliminated. Removing excess fish is difficult and expensive.
- If not enough fish are stocked, less-favored plants, such as Eurasian milfoil, may take over the lake.
- Stocking grass carp may lead to algae blooms and turbidity.
- All inlets and outlets to the lake or pond must be screened to prevent grass carp from escaping into streams, rivers, or other lakes.
- Have definite taste preferences. Plants like Eurasian milfoil and coontail are not preferred. American waterweed and thin leaved pondweeds are preferred. Waterlilies are rarely consumed.
- Water temperature can influence efficacy in canals

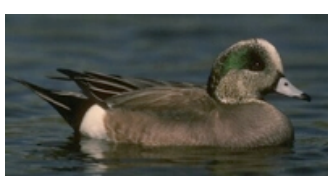
SUMMARY: Should be viewed as an ALL or NOTHING strategy

Grass Carp rules in Oregon

- permit from ODFW
- water body on private land,
- less than 10 acres,
- screen inlets and outlets to contain the carp,
- not in the 100-year flood plain during winter,
- grass carp must be triploid,
- greater than 12 inches,
- implanted with PIT tags to identify the owner,
- and stocked at rates lower than 22 per acre,
- OFWC can grant exceptions to the water body size limit and floodplain requirement on case by case basis

Change in waterfowl populations following grass carp stocking in Devils Lake Oregon





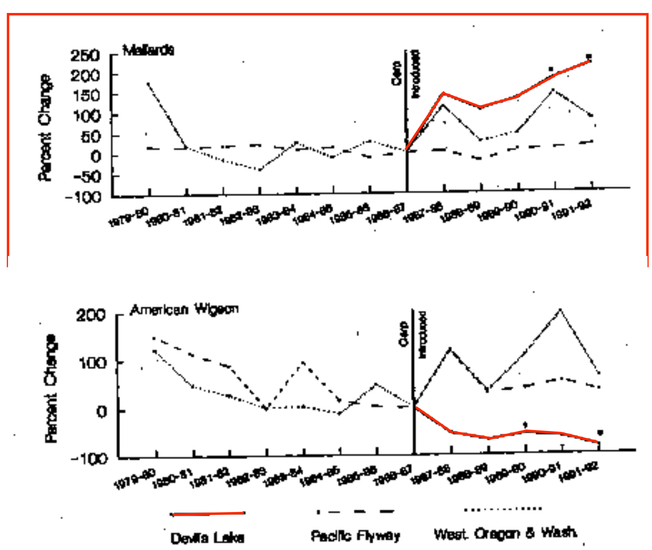


Figure 2. Percent change in abundance of wintering mallards, gadwalls, and American wigeon in the Pacific Flyway, western Oregon and Washington, and at Devil's Lake, Oregon between 1986-87 and 1991-92. Asterisk (*) denotes years for which abundance was different than 1986-87 (ANOVA; α = 0.05 for tests of contrasts).