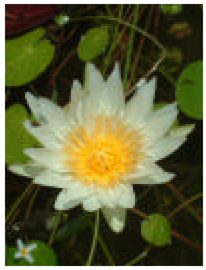
WETLAND & AQUATIC PLANTS

Structure & Functions

"…for there are some plants which cannot live except in wet; and again these are distinguished from one another by their fondness for different kind of wetness; so that some grow in marshes, others in lakes, others in rivers, others even in the sea. … Some are water plants to the extent of being submerged, while some project a little from the water; of some again the roots and small parts of stems are under water, but the rest of the body is altogether above it."

THEOPHRASTUS (370-C.285 B.C.)
Enquiry into Plants



Aquatic **MACROPHYTES** - all macroscopic forms of aquatic vegetation

x **MICROPHYTES**

1. CHLOROPHYTES
   Macroalgae (*Chara*)
2. BRYOPHYTES
   Mosses - *Fontinalis, Sphagnum*; liverworts – *Riccia*
3. TRACHEOPHYTES (vascular plants)
   a) Ferns (*Azolla, Salvinia, Marsilea, Isoetes)* "water ferns"
   b) Gymnosperms (rare)
   c) Angiosperms (flowering plants) Monocots x Dicots

Terrestrial origin of angiosperms **(Cretaceous Period, ~ 150 million y ago)**

Adaptation to the transition to aquatic environment:

Morphological adaptations (structural reduction, elongation of leaves, internal lacunae)

Physiological adaptations (HCO3 as a supplementary CO2 source, CAM)

Mode of reproduction

Predominantly asexual - clonal (successful - *Elodea canadensis* Europe; *Myriophyllum aquaticum* - North America)

Examples: shoot fragmentation (*Lemna*); creeping stems (*Ludwigia*); rhizomes (many)

Sexual - almost all aquatics retained the pollination mechanism from their terrestrial ancestors.

Myriophyllum spicatum

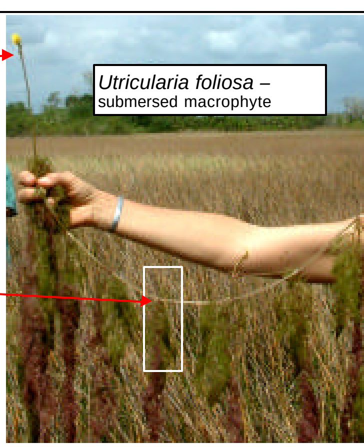
Thin, dissected leaves
– large surface x volume ratio

Reduced flowers

Flowers above water

Structural reduction

Shoot fragmentation



Distributional patterns

Highest species richness in cold temperate regions

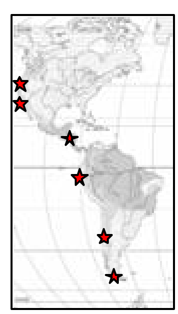
Genera with cosmopolitan distribution:

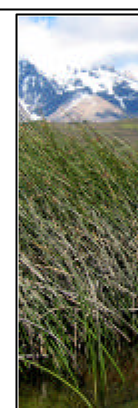
Phragmites,

Typha,

Scirpus,

Lemna





Scirpus californicus - Totora

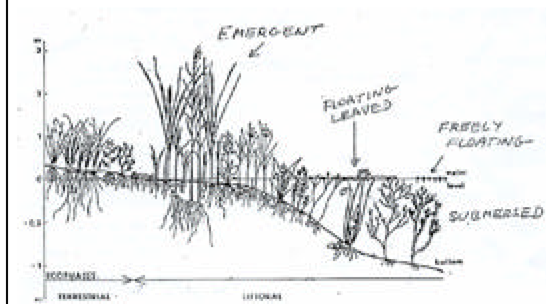
CLASSIFICATION:

Different attempts to classify wetland plants important when dealing with processes on landscape/regional scale

Functional groups -- growth form

MACROPHYTES

- A) Aquatic macrophytes attached to the substratum
  - Emergent
  - Floating leaved
  - Submersed
- B) Freely floating macrophytes



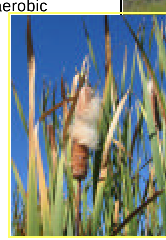
EMERGENT MACROPHYTES

(*Typha*, *Scirpus*, *Phragmites*)

- occur in the upper littoral zone on aerial or submerged soils to a depth of about 1-1.5 meter

-their root and rhizome system often adapted to permanently anaerobic sediments

- aerial reproductive organs



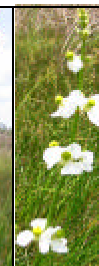
Scirpus acutus

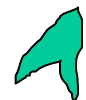
Scirpus californicus

Phragmites australis

Eleocharis cellulosa (rush)

Habenaria sp.



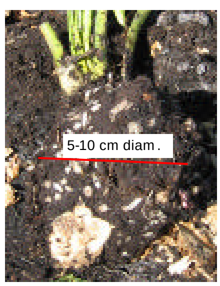


Arrowhead

Sagittaria latifolia

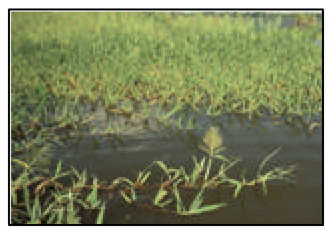
RHIZOMES

Carex rostrata



Nuphar polysepalum

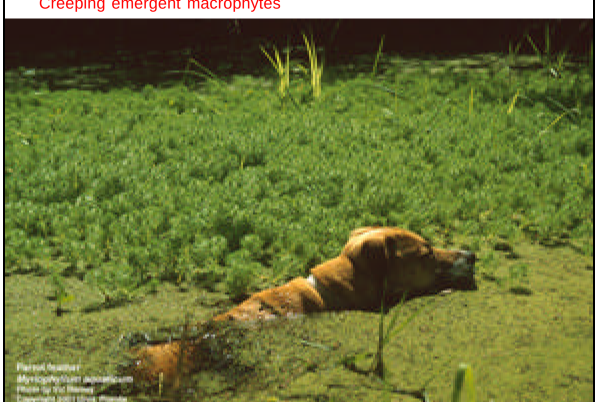
Creeping emergent macrophytes



Paspalum sp.

Ludwigia peploides

Creeping emergent macrophytes



Creeping emergent macrophytes

FLOATING LEAVED MACROPHYTES

(*Nuphar*, *Nymphaea*, *Victoria*)

-occur in the middle littoral zone at water depth from about 0.5 to 3 m

-heterophylly *Nuphar* – herbivory of floating leaves

-their leaves well adapted to mechanical stress from wind and water movements

-reproductive organs floating or aerial

Nymphaea ampla

Nymphoides humboltianum

Brasenia schreberi

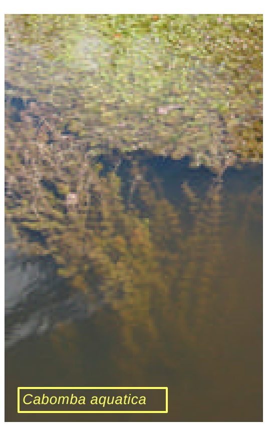
SUBMERSED MACROPHYTES

(*Isoetes*, *Chara*, *Elodea*, *Myriophyllum*, *Utricularia*)

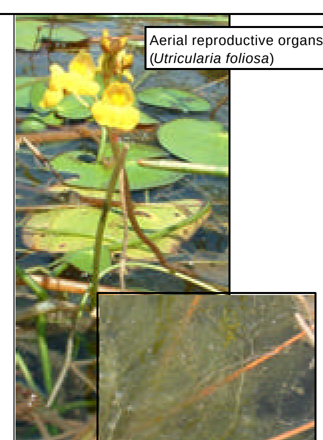
- occur mainly in the lower littoral zone, angiosperms in depths only to about 10m, pteridiophytes, mosses and charophytes at all depths within the photic zone

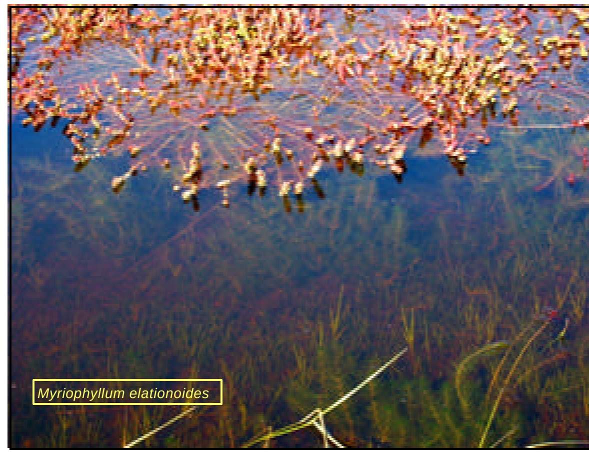
- leaves often elongated, ribbonlike or dissected

- reproductive organs aerial, floating or (rarely) submersed



Finely dissected leaves (*Cabomba aquatica*)





FREELY FLOATING MACROPHYTES

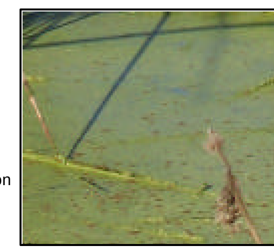
(*Eichhornia*, *Lemna*, *Salvinia*)

- mainly aerial and/or floating leaves

- reproductive organs aerial or floating

- vegetative propagation a common mode of expansion

- nutrient absorption completely from the water

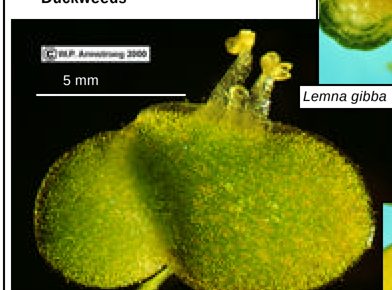


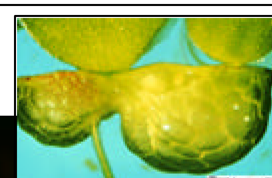
FREELY FLOATING

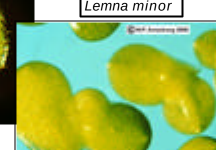
Aquatic ferns:

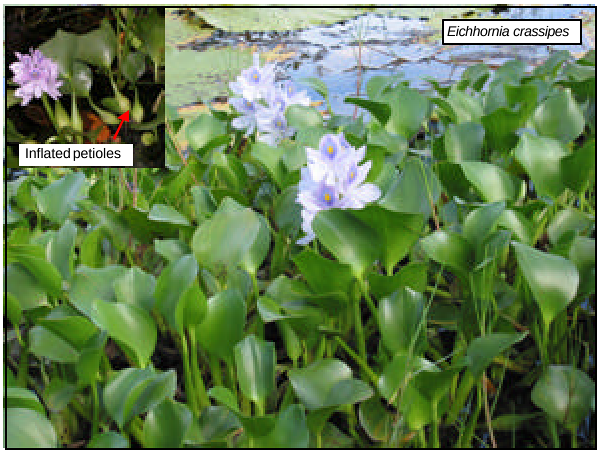
FREELY FLOATING

Duckweeds









PRIMARY PRODUCTION

Why is it important?

a) For energy and nutrient budgets (base of food chain)

b) Restored/created wetlands - comparison with reference wetland

c) Wastwater treatment facilities - how much nutrients; how much organic material

d) Production of particular plant parts - seeds for waterfowl

Net Primary Production, NPP, is the net biomass produced by plants per unit of area per unit of time

NPP = GPP - respiratory losses

Units:

g dry mass/m^2/time (sometimes AFDW = ash free dry weight)

C/m^2/time (g dry weight = about 0.5 g C)

NPP ~ maximum biomass (W max) for plants with one generation time (temperate zones)

(tropics NPP ~ 2 to 3 x W max)

Examples of NPP values:

Marshes:	Tall emergents:	average	1,500-2,000 g/m^2/y
		extreme: papyrus	9,000-15,000 g/m^2/y
	Other emergents:		500-1,000 g/m^2/y
	Submersed:	average	100-500 g/m^2/y
		extreme: pondweed	900 g/m^2/y
Phytoplankton		oligotrophic lakes	< 50 g/m^2/y
		meso-eutrophic	700-1500 g/m^2/y
Bogs and fens:		*Sphagnum* moss	10-500 g/m^2/y
		sedges	500-1000 g/m^2/y
		shrubs	300-1000 g/m^2/y

Factors affecting NPP in wetlands

1) Temperature (tropical x temperate regions; high T - respiration!)
2) Solar radiation (often limiting for submersed macrophytes; low compensation point for light)
3) Hydrologic regime - response to water depth
4) Soil regime - anaerobic conditions
5) Salinity - NaCl; H_2S
6) Biotic - grazers, parasites
7) Genome structure of local populations or ecotypes

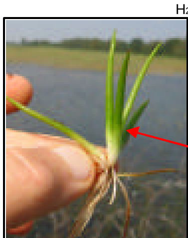
8) CO_2 limitation - for submersed; for a long time it was assumed that submersed have regular C3 photosynthesis using CO_2

(a) Steeman-Nielsen 1946 HCO_3 - about 50% capable of using bicarbonates (pH>7) (*Myriophyllum*)

$$H_2O + CO_2 \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

$$\downarrow$$

$$H_2CO_3 + CaCO_3 \longleftrightarrow Ca(HCO_3)_2 \longleftrightarrow Ca^{2+} + 2HCO_3^-$$



(b) Uptake of CO_2 from the sediments usually in oligotrophic lakes low in carbon,

typical trait - high Root/Shoot ratio

(*Litorella,* Plantaginaceae)

(c) CAM metabolism - capacity for fixation of CO_2 during the night; accumulation as malate in the cell vacuole; decarboxylation into CO_2 during the day (Keeley 1980's)

CO_2 concentration in water up to 30x lower during the day than at night

Isoetes andicola, quillwort (Isoetaceae; Lycophyta)

AVOIDANCE x TOLERANCE

3 different pathway for C fixation in photosynthesis:

C3 - single reaction to attach CO_2 to the organic molecule

- enzyme ribulosobiphosphate carboxylase (Rubisco)
- product 3-C org. acid
- about 50% of C fixed in photosynthesis lost in photorespiration

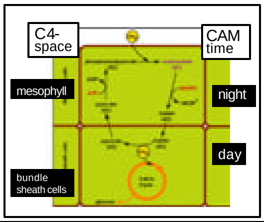
C4 - two stages: 1. CO_2 is incorporated into C4 product in mesophyll cells

- enzyme phosphoenolpyruvate carboxylase
- product 4-C (malate, asparate) moves to leaf interior (bundle sheeth cells) CO_2 is released and RuBP carboxylase fixes it into C3 product
- higher efficiency of photosynthesis (Rubisco protected from the inhibitory effect of oxygen)

Cyperus papyrus*, *Panicum*, *Spartina

CAM - two stages as in C4 but temporarily separated

Isoetes, *Crassula*



NUTRITIONAL QUALITY

Differences in absolute numbers of internal concentrations but similarities in the relationships among nutrient concentrations (C, N, P) across aquatic plant groups

-ECOLOGICAL STOICHIOMETRY (Sterner & Elser, 2002)

C differences reflect relative amounts and importance of structural C relative to C associated with metabolic compounds

(ATOMIC RATIO)	C :	N :	P	
	106	16	1	Redfield ratio
	435	20	1	Angiosperms
	800	49	1	Macroalgae
(MASS RATIO)	40	7	1	Redfield ratio

Alfred Redfield (1890-1983), oceanographer, C:N:P ratio of marine particulate matter ~ to the nutrient ratio in water

Nutrient translocations (resorption)

Typical for erect emergent macrophytes (*Typha*, *Scirpus*) and some floating leaved (*Nuphar*),

submersed macrophytes do not have well developed system of strong rhizomes for nutrient translocation

EXAMPLE:

P resorption efficiency, %

	no limitation	P-limited		maximum
Graminoids	45.9	76.4	***	89.3
Typha	64.3	73.2	**	83.4
Broadleaved	39.6	63.0	**	81.2

DECOMPOSITION

Fate of primary production - grazing
- microbial decomposition

litter, detritus,

In wetlands **detrital food chain often more important than direct grazing**

Definition: Decomposition is a process in which the organic matter is catabolized into its constitutive inorganic forms

Decomposition (destruction of organic matter)

(a) mechanical disintegration of plant material into a stage where the cell structure is no longer recognizable, sometimes called "litter breakdown" by shredders (invertebrates)

(b) the metabolism of organic compounds into inorganic forms degraders (fungi, bacteria)

sometimes leaching before (a) and (b)

Wetland systems - autochthonous and allochthonous (30%) sources of detritus
- some material carried away (mangroves)

Methods to estimate decomposition:

(a) mash-bag (litter bag) technique - measures the weight losses

- source of material (naturally senescing; oven vs. air drying)
- mesh size

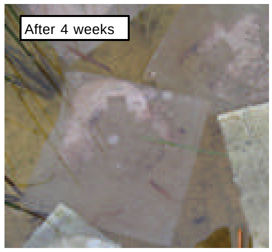
(b) "leaf packs"

(c) tagged senescent leaves

(d) cellulose test for estimating the microbial community efficiencies in different environments:

cellulose strips

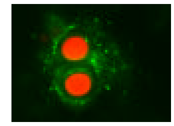
cellulose paper



Analysis of microbial assemblages:

Bacteria - plate counts

- epifluorescence - staining bacteria w. fluorochromes



- fluorescence in situ hybridization probes

Fungi - ergosterol analysis - sterol present in fungal membranes

Factors affecting decomposition:

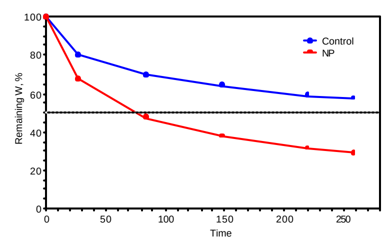
Temperature

Moisture

Oxygen - Redox conditions

Quality of decomposing material (C:N ratio; C:P ratio; lignin:N ratio)

Fast decomposing material in the tropics - Amazon floodplain



Negative exponential model usually applied to studies of litter decomposition

$X_t = X_0 * e^{-kt}$ X_o - original litter weight

X_t - litter weight at time t

k - decay constant

Half time decomposition:

$X_t = X_0 * e^{-kt}$ $\ln (X_t/X_o) = -kt$

for ½ time: $\ln (X_t/X_o) = \ln 0.5 = -0.693$ $t_{1/2} = -0.693/-k$

k – control: -0.00213 => $t_{1/2}$ = 325 days

K – NP: -0.00743 => $t_{1/2}$ = 93 days