HANDOUT No. 4 (For 10/18 & 10/20 2004):

WETLAND & AQUATIC PLANTS
Structure & Functions

Not in M&G;
Teaching Resources computer unit on plants

Aquatic Macrophytes - all macroscopic forms of aquatic vegetation

1. Macroalgae (Chara) CHLOROPHYTES
2. Mosses - Fontinalis, Sphagnum; liverworts - Riccia) BRYOPHYTES
3. Ferns (Azolla, Salvinia, Marsilea, Isoetes) "water ferns" TRACHEOPHYTES
   Gymnosperms (rare), Angiosperms - Monocots Dicots

Terrestrial origin of angiosperms

Adaptation to the transition to aquatic environment:
   Morphological adaptations (structural reduction, elongation of leaves, internal lacunae)
   Physiological adaptations (HCO$_3$ as a supplementary CO$_2$ 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.

Distributional patterns
   Highest species richness in cold temperate regions
   Genera with cosmopolitan distribution: Phragmites, Typha, Scirpus, Lemna

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
   1. Emergent macrophytes (Typha, Scirpus, Phragmites)
   - occur in the upper littoral zone on aerial or submerged soils to a depth of about one meter
   - their root and rhizome system often adapted to permanently anaerobic sediments
- aerial reproductive organs

2. Floating leaved macrophytes (Nuphar, Nymphaea)
   - 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

3. Submersed macrophytes (Isoetes, Chara, Elodea, Myriophyllum)
   - occur mainly in the lower littoral zone, angiosperms in depths only to about 10 m, pteridophytes, mosses and charophytes at all depths within the photic zone
   - leaves often elongated, ribbonlike or dissected
   - reproductive organs aerial, floating or submersed

B) Freely floating macrophytes (Eichornia, 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

Primary production

WHY DO WE WANT TO KNOW?
1) For energy and nutrient budgets
2) How much organic matter would a particular wetland produce

3) Production of particular plant parts - seeds for waterfowl
4) Wastewater treatment facilities - how much nutrients; how much organic material
5) Restored/created wetlands - comparison with reference wetland

\[
\text{NPP} = \text{GPP} - \text{respiratory losses}
\]

amount of product per unit area per unit time
\[
g \text{ dry mass/m}^2/\text{time} \quad \text{(sometimes AFDW = ash free dry weight)}
\]
\[
g \text{ C/m}^2/\text{time} \quad \text{(g dry weight = about 0.5 g C)}
\]

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: 100-500 extreme: pondweed 900

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

sedge ~ 500 – 1000 g/m\(^2\)/y

shrubs ~ 300-1000 g/m\(^2\)/y

Production = maximum biomass (W max)

for plants with more than one generation time more than W max

temperate: close to 1; tropical about 3

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) 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 ; predominates at pH>7(Elodea, Myrioph.)

   (b) CO\(_2\) from the sediments usually in oligotrophic lakes low in carbon, typical trait - high R/S ratio

plastids (photosynthetic pigments) located in cells surrounding gas spaces
Litorella (Plantaginaceae)
(c) CAM metabolism capacity for fixation of CO$_2$ during the night accumulation as malate in cell vacuole decarboxylation into CO$_2$ during the day
Isoetes (Keeley 1980's)

(3 different pathway for C fixation in photosynthesis:

**C3** - single reaction to attach CO$_2$ to the organic molecule enzyme ribulosebiphosphate carboxylase product3C org. acid about 50% of carbon fixed in photosynthesis lost in photorespiration

**C4** - two stages: 1. CO$_2$ is incorporated into C4 product in mesophyll cells, catalyzed by phosphoenolpyruvate carboxylase (malate); it then moves to the centre of the leave (bundle sheath cells) when it is broken down and CO2 is released and then RuBP carboxylase fixes it the second time into C3 product; enhances the efficiency of photosynthesis Rubisco inefficient in the presence of O$_2$, sequestering this enzyme in the interior of the leaf, C4 reduce this inhibitory effect

**C4 : Cyperus papyrus, Panicum, Spartina, Echinochloa**

**CAM** - two stages as in C4 but temporarily separated

3) Hydrologic regime - response to water depth
4) Soil regime (anaerobic conditions)
5) Salinity (NaCl; H$_2$S)
6) Biotic (grazers, parasites)
7) Genome structure of local populations or ecotypes

NUTRITIONAL QUALITY

Differences in absolute numbers of internal concentrations but similarities in the relationships among nutrient (C, N, P) concentrations across aquatic plant groups (ECOLOGICAL STOICHIOMETRY). C differences reflect relative amounts and importance of structural C relative to C associated with metabolic compounds

C : N : P (ATOMIC RATIO)
110 16 1 (Redfield ratio)
435 20 1 Angiosperms
800 49 1 Macroalgae

(SECONDARY COMPOUNDS)

Probably less than terrestrial, except for Nuphar, Nelumbo
“ to grow or to defend?”

Nutrient translocations
Typical for erect emergent macrophytes (Typha, Scirpus) and some floating leaved (Nuphar), creeping macrophytes do not have well developed system of strong rhizomes for nutrient translocation.

Utricularia - carnivory
- Carnivorous plants restrict to nutrient poor environment
- Drosera (sundew), Saracenia (pitcher plant) - bogs,
- Utricularia - nutrient poor marshes
- being carnivorous improves their nutrient input, esp. nitrogen - there is a cost to it - reduced photosynthetic capacity associated with the growth and maintenance of prey-capturing organs
- Utricularia, bladders attached by short petioles, can be removed, no roots

DECOMPOSITION

Fate of primary production
- grazing
- microbial decomposition
- litter, detritus,
  detrital food chain 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

Methods to estimate decomposition:
- mash-bag (litter bag) technique - measures the weight losses
  - source of material (naturally senescing; oven vs. air drying)
- mesh size
"leaf packs"
tagged senescent leaves
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
Oxygen
Quality of decomposing material (C:N ratio; lignin:N ratio)
Redox conditions

Fast decomposing material in tropics - Amazon floodplain

Negative exponential model usually applied to studies of litter decomposition
Decomposition (decay) coeffic

\[ X_t = X_0 \cdot e^{-kt} \]

\( X_0 \) - original litter weight
\( X_t \) - litter weight at time t
\( k \) - decay constant

Half time decomposition:

\[ \ln \left( \frac{X}{X_0} \right) = -kt \]
for ½ time: \( \ln \left( \frac{X}{X_0} \right) = \ln 0.5 = -0.693 \quad t_{1/2} = -0.693/k \)
REFERENCES:
Aquatic Botany 1993 (44). Special Issue on Evolution of Aquatic Angiosperms.