Ecosystems & Ecophysiology – Lecture 5

Wetlands

Objectives

1. Define a wetland and know the different types.

2. Understand the relationship between the height of the water table and development of anoxic conditions in wetland soils.

3. Describe the interactions of a river with its flood plain, and contrast the flood pulse and river continuum concepts.

4. Compare the major ecological features of, and export of material from, floodplain, marsh, swamp and sudd.

5. Understand the zonation of organisms within saltmarshes and mangals, and why this differs from that on rocky shores.

6. Describe the conditioning of detritus in saltmarshes and mangals, and the relative importance of use within the ecosystem versus export.

Wetlands

■ Wetlands of conservation interest, largely because they are common resources and so overexploited or damaged. RAMSAR convention (Ramsar, Iran 1971) on wetlands defines them very broadly:

“Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water < 6m deep at low tide”

This includes lakes, rivers, even coral reefs. For this course, define them as areas of permanent or temporary open water with emergent macrophytes

■ Exclude mires, not associated with open water (but may be formed as end of the hydrosere):

a) Fens (minerotrophic mires) in valleys, water from by groundwater or runoff, nutrient rich
b) Bogs (ombrotrophic mires) above water table, water from precipitation only, nutrient poor, formed by *Sphagnum* moss

Include floodplains, marshes, swamps (marshes with trees), sudd (floating marshes) saltmarshes and mangals (manrove swamps), all characterised by exchange of nutrients and OM with open water

Physical environment is dominated by the position of the water table, which determines the availability of oxygen in the soil. Permanently flooded soils usually anoxic due to decomposition and slow diffusion of oxygen

■ Anoxic soils also usually deficient in nitrate, as release from decomposition is slow, and it is used by denitrifying bacteria

Nitrification

Organic N	$\rightarrow$	NH_4^+	$\rightarrow$	NO_2^-	$\rightarrow$	NO_3^-
	1	ammonium	2	nitrite	3	nitrate

Reaction 1 (decomposition) by a variety of microorganisms, both aerobic & anaerobic. Reactions 2 by *Nitrosomonas* & 3 by *Nitrobacter*, both aerobic

Denitrification

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

Anaerobic denitrifying bacteria convert nitrate to gaseous nitrogen, lost

Nitrogen usually limiting in permanent wetlands due to denitrification. Temporary wetlands have nitrification when dry, releases nutrients when wet

Anaerobic wetland soils usually have toxins, such as H_2S and CH_4. Plants may avoid toxic conditions with a dormant period, or have shallow roots & air tissues to transport oxygen

■ Can be as productive as tropical rain forest, energy often used for vegetative reproduction. But nutritional quality poor, so little grazing, enters detritus pathway. Conditioned as in rivers & estuaries (HO 3)

Detritus from saltmarsh & mangroves. Increased protein content & lower carbohydrate (cellulose) as particle size decreases, gives lower C:N ratio & increases quality as food

Freshwater wetlands
Freshwater marshes not clearly divided from lake littoral, just greater extent. L. Chilwa (Malawi) has equal area of open water (700 km^2) & marshes

Low water flow among rushes (*Typha*) so detritus trapped within the marsh. Water less oxygenated than open water due to decomposition, sometimes anoxic. Inhabited by lungfish & catfish with accessory air breathing

Marshes & swamps also associated with rivers. These are usually wet, whereas floodplain is usually dry, but all involved in exchange with the river

■ River continuum concept stressed longitudinal links along the river. Flood-pulse concept stresses lateral links, between river and its floodplain, for large rivers with predictable flooding, e.g. Amazon, Nile

Exchange of organisms, OM and nutrients between river and flooded area, often greater than from upstream

Aquatic plants grow rapidly on immersed floodplain. Nutrients high compared to marshes & swamps as soils have dried & become aerobic, with nitrification. Then flow of nutrients & detritus to river as floodwaters subside

Rivers with floodplain more productive. Floodplains intermediate between lakes (accumulate material) & rivers (transport downstream). Seasonal accumulation then transported away

■ Blackwater rivers in southern USA have swamps in floodplains. Colour from high DOM. Inundated for several months each winter, > 95% of DOM in river is from subsiding floodwaters

Most (>70%) DOM is humic acids, nutritionally extremely poor, only used by bacteria (in biofilm). DOC 1-4 mg l^{-1} in streams, 2-10 mg l^{-1} in rivers, 10-30 mg l^{-1} in blackwater rivers

Autotrophic middle reaches don't develop in blackwater rivers, respiration of imported OM always > photosynthesis

■ Sudd. Mats of floating vegetation, especially papyrus in the upper Nile, Sudan. Rhizomes of sedge *Cyperus papyrus*, colonised by other species

Consequence of anoxic soils, shallow roots break free from substrate after storms, plants float because of air tissues.

Functionally similar to mats of floating fern *Salvinia* & water hyacinth *Eichhornia*, from Amazon but widely introduced in the tropics, can be dense enough to walk on

Differ from wetlands of rooted plants, which take up nutrients from the soil. Detritus from floating marsh falls below the mat, nutrients must enter water before they are available to the floating plants

Detritus below the mat also exported to open water. Rooted marshes trap detritus, which does not enter open water

Saltmarshes

- Temperate & subpolar distribution in estuaries & protected coasts – develop where sediment has accumulated, on mud or sand.
- Mangroves are the tropical equivalent of saltmarsh (HO 6)

- Saltmarshes are communities of low plants on soils inundated by tides. Plants are halophytes (salt-loving)

Soil has high salt content, but often sudden variations. From near zero in heavy rain to full sw when immersed, or hypersaline after evaporation

Many saltmarsh plants are facultative halophytes, will grow better if transplanted to the non-saline area above the marsh, but normally outcompeted there

Saltmarshes are usually species-poor, relatively few species can adapt to harsh environment. These are similar over a wide geographical area

Worldwide, dominant plants are *Spartina* grasses, *Juncus* rushes, and *Salicornia* & other succulent halophytes, of terrestrial origin

Most animals of marine origin, crabs *Uca*, winkles *Littorina*, plus insects from land as there is always some vegetation above water

- In the Eastern USA the grass *Spartina alterniflora* invades intertidal mudflats, spreads vegetatively by rhizomes. Tolerates immersion & anoxic soils as it has air tissue to get oxygen to the roots

Grass slows tides & increases deposition of sediment, which is stabilised by the roots. A young marsh is a monoculture of *S. alterniflora,* but zonation develops as the marsh grows

Productivity can be very high, > 3 kg C m^{-2} yr^{-1}, usually nitrogen-limited. Seaward edge of marsh often has mussels (*Geukensia*), nitrates in faeces increase *Spartina* productivity by 50%

Few herbivores, most (90%) of plants are consumed as detritus. Leaves of *Spartina* die in winter, POM and DOM exported to sea

Amount is controversial. Early evidence was that saltmarsh was a major contributor to estuary production. Now thought to be less, equivalent to 10% of phytoplankton in the estuary

Isotope composition of detritus offshore from saltmarshes shows most is derived from phytoplankton, not from the marsh

Current idea is that export of POM from saltmarsh is low, but export of nitrogen is considerable. This supports the phytoplankton, so indirectly leads to high detritus in the estuary

■ Zonation. Lower limit of each zone is set by tolerance of immersion in seawater, upper limit is set by competition. Physiological adaptation has costs, so tolerant species usually outcompeted if no stress (HO 6)

Zonation is thus similar to that on rocky shores (Lecture 6), but in reverse – there, upper limit set by tolerance, lower limit by biotic factors

Reversal is due to the different origins of organisms. Saltmarsh plants are of terrestrial origin, so physiological limit of immersion. Rocky shore organisms are of marine origin, so physiological limit of exposure to air

Zonation has upper zone of *Juncus*, middle zone of *Spartina patens*, low zone of *S. alterniflora*. Competition shown by removal & transplantation expts, superior competitors have denser root mats

■ Often vegetation-free areas (salt pans) in high marsh, surrounded by very salt-tolerant plants – *Salicornia* salt meadow. Soil salinity up to 100

Initiated by chance, storm debris kills vegetation, then bare soil becomes hypersaline after evaporation in sun, prevents seed germination. Eventually colonised by *Distichlis* grass, grows by runners

Mangroves

■ Line about 75% of tropical coasts. Probably outcompete saltmarsh in tropics by shading. Independent origin in 4 families, convergent evolution of appearance, physiology & reproduction

Only in shallow water & intertidal areas, greatest extent where the tidal range is large. Not in high energy locations, prefer mud, can use sandy soil and coral islands. Sea inundates roots & lower stems with each tide

Best developed where lower salinity, from high rainfall or in estuaries. Can grow in fw (facultative halophytes, as saltmarsh plants) but not found there, limited by competition

■ Shallow rooted, spread roots widely or with prop roots from trunk or branches for stability. Air tissues to obtain oxygen in anoxic mud (HO 7)

Unique communities, terrestrial organisms on trunks, marine life among roots. Similar to muddy shores, plus hard substrate of roots with Littorinids and oysters (HO 8)

■ Adapted for water dispersal, floating offspring. Viviparous, no resting seed stage, seed germinates while on parent plant & grows into seedling for up to 3 years. Elongates and becomes bottom-heavy

Dropped and spears mud or floats, horizontal in sw & upright in brackish water. Carried by currents until root end strikes the bottom

So can be dispersed by currents, but avoids stranding at the high tide mark, & grounds in suitable water depth, especially where brackish. Then puts out roots to anchor, established in 2 days

■ Extend as high as upper tidal influence, with zonation away from the sea. Key factor is the duration of immersion

Simple zonation in Florida, only 3 species: high level white mangroves, mid level black mangroves (*Avicennia*), low level red mangrove (*Rhizophora*). (HO 7). More complex in Asia, many more species

Mangal converts marine to terrestrial system, zones are a true succession as they modify the habitat. But new land is from trapped sea sediments, not accumulation of detritus (unlike peat in hydrosere)

Productivity like terrestrial forest, up to 3 kg litter m^{-2} yr^{-1}. Processed by *Uca* fiddler crabs, form up to 80% of macrofauna

Export detritus offshore? Controversial, like saltmarshes. Current evidence (from isotope analysis) is that most of the leaf litter from mangroves is consumed by mudflat fauna, not exported

Mangrove litter identified in the sea is mostly from fringing species. Litter from other species used within the mangal