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SEA LEVEL RISE INDUCED CONVERSION OF COASTAL FOREST INTO SALT MARSH: AN ECOLOGICAL SYSTEMS APPROACH FOR
Notes for a Lesson Plan

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LEARNING OBJECTIVE: Students should be able to construct a graphical "systems" model to explain the principal physical and ecological factors involved in the replacement of coastal forest by salt marsh.

APPROACH: With basic information about the dominant species, their interactions, and the biophysical drivers of ecosystem change, each student draws an ecological systems diagram.

--Upon arrival at the coastal field site where they will spend 2-3 hours, students collect small samples of 5-10 species they previously studied in class. With samples in hand, the group reassembles to share their observations about each species. At this point, details about the site visited (e.g., history) should be reviewed.

--In a preparatory session before the field trip, students search for pictures and natural history information about the species listed below. If they work in groups of 4-5 and divide up the list, they should be able to assemble pictures (e.g., from Google Images) of all species in a Powerpoint presentation in 1 hour. If sufficient time is allocated for this preparatory work (perhaps 2 hours), then each student could select a species about which to tell the entire group something about its natural history in a 1 minute presentation with 1-2 Powerpoint slides.

SOME BACKGROUND (which should be reviewed to assure understanding; there are plenty of websites with further explanation, videos, and etc.)

1. Plants, like animals, drown if deprived of oxygen. This response is related to their mitochondria, the organelles where respiration occurs, closely resemble the mitochondria in animals because they share the history of having evolved from single-celled bacteria that took up residence inside larger cells some 2 billion years ago.
2. There is much less oxygen in water than in air, and it diffuses 10,000 times slower in water. To obtain oxygen from water, some organisms increase the flow of water over their gills but all increase the surface area over which oxygen can be absorbed (e.g., much divided lobes on fish gills, pneumatophores on black mangrove roots, alveoli and very narrow blood vessels in your lungs).
3. All organisms require salt (NaCl) in small quantities but are killed by high concentrations in their cells. Salt kills plants by blocking their capacity to absorb water and actually drawing water from cells (osmotic effects) as well as by poisoning metabolic processes when it does get inside cells.
4. Salinities in all water bodies vary over time and space, but open ocean salinities average about 35 parts per thousand (ppt) whereas in the Gulf of Mexico near where large rivers discharge fresh water, salinities are often much lower (e.g., 15-20 ppt) because fresh water has a salinity of <0.5 ppt.
5. When water evaporates the salt is left behind. If it doesn't rain, areas inundated with even low salinity water can be converted into salt pans in which very few species can survive.
6. Hurricane return periods (i.e., the number of years between landfalls of hurricanes) in Florida's coastal counties range from 3 years in Dade County (Miami and vicinity) to 33 years in Taylor County in the Big Bend region along the Gulf Coast.
7. Storm surges associated with hurricanes and tropical storms can be 2-5 m high.
8. Along the Gulf Coast, approximate elevations above sea level (a.s.l.) of forests with different tree status:
   Healthy canopy and plentiful regeneration of oaks, pines, cedars, and palms: **>1 m a.s.l.**
   Only palms and cedars left in the canopy and still regenerating: **0.8 m a.s.l**.
   Palms and cedars alive but obviously suffering in the canopy but not regenerating: **0.6 m a.s.l.**
   All trees recently dead: 0**.4 m a.s.l.**
9. Mean rate of sea level rise globally = 3.2 cm/decade (1.26 inches per decade).

Trees of Coastal and Mangrove Forests

Avicennia germinans, black mangrove (Avicennianceae). Mangrove trees that north of Tampa can grow to be 5 m tall in 20 years, but are killed by hard frosts Roots take up salt water but glands on the leaves secrete salt (often evident as shiny crystals); pencil-like pneumatophores that help aerate the roots; tolerates soil water salinities of up to 50 ppt; crypto-viviparous seeds are spherical, about 3 cm diameter, float, and start to be produced when trees are only 3 years old.

Juniperus virginiana, red cedar (Cupressaceae). One of our most salt-tolerant trees (up to 5-8 ppt) , wood used for pencils and cabinets, trees either male or female (i.e., dioecious), seeds bird dispersed. Bark thin and even large trees can be killed by hot ground fires.

Quercus geminata, sand live oak (Fagaceae). Long-lived tree in coastal hammocks, tolerates salt spray but not soil water salinities of >3 ppt), spreads vegetatively to form oak domes with 5-50 trunks in clumps 5-10 m diameter, acorns eaten by jays, crows, squirrels, and other animals. Thick barked and fire resistant.

Rhizophora mangle, red mangrove (Rhizophoraceae). Mangrove trees that can grow to 5 m tall in 20 years but are killed by hard frosts; salt excluder (at the root-soil interface); prop rooted; viviparous seedlings up to 15-20 cm long start to be produced when the trees are only 3-4 years old.

Sabal palmetto, cabbage palm (Arecaceae). Perhaps our most salt tolerant tree species (up to 10 ppt). Individuals with 5 m tall trunks may be >150 years old, if their 35 year "establishment growth period during which they have no above-ground stem is taken into account. Harvested for edible palm "cabbage" and historically for brush fibers; cut trees do not resprout. Extremely fire resistant. Seeds dispersed by birds, raccoons, and etc., and preyed on by rodents and a species-specific bruchid beetle. Starts reproducing in the wild when 50-70 years old.

Schinus terebinthifolius, Brazilian pepper (Anacardiaceae). An exotic invasive tree/shrub/liana that produces large numbers of bright red fleshy fruits that are dispersed by a diversity of birds and mammals. Somewhat salt tolerant (5-10 ppt) and extremely competitive; within 5 years can grow to overtop the oaks, pines, and cedars with which it co-occurs.

Shrubs and Subshrubs (all are rainwater dependent and killed by salinities of >8 ppt)

Baccharis spp., saltbush (Asteraceae). Saltmarsh edge shrub, grows to be 1-2 m tall, small winged seeds.

Borrichia frutescens, sea oxeye daisy (Asteraceae). Slender-stemmed shrubs to 1 m tall with yellow flowers, spreads vegetatively with rhizomes, seeds small and winged.

Iva frutescens, marsh elder (Asteraceae). Common shrub on salt marsh margins, greenish flowers, spreads vegetatively with rhizomes, grows to be 1-2 m tall.

Lycium carolinianum, Christmas berry (Solanaceae). Shrub to 1.5 m tall with succulent leaves, lavender flowers, red fruits that look like little tomatoes, bird dispersed seeds (lots of horticultural potential).

Perennial/Annual Forbs and Grasses

Batis maritima, saltwort (Bataceae). A clonal perennial 2—30 cm tall that spreads vegetatively when the tips of long branches lean over and take root (seems to leap across the landscape in plant time).

Cladium jamaicense, sawgrass (Cyperaceae). A fresh-water sedge, head-high, leaves with toothed edges, spreads vegetatively to form dense and extensive clones 2-3 m tall.

Distichlis spicata, seashore saltgrass (Poaceae). Low statured (10-15 cm) clonal grass with leaves in two ranks.

Juncus roemerianus, black needle rush (Juncaceae). Clonal, C-3 species that dominates many salt marshes in Florida—slightly less salt tolerant than saltmarsh cordgrass. Burns spectacularly after which it produces viable seeds (otherwise seeding is rare). Susceptible to uprooting in high winds.

Limonium carolinianum, sea lavender (Plumbaginaceae). Rosette of large leaves and lovely baby blue flowers.

Salicornia perennis, perennial glasswort (Chenopodiaceae). Succulent with red betalain pigments. Edible stems. Tolerant of very high salinities.

Sesuvium portulacastrum, sea purslane (Aizoaceae). Succulent saltmarsh plant with red stems; forms mats.

Spartina alterniflora, saltmarsh cordgrass (Poaceae). Dominant in patches in saltmarsh, perennial, clonal C-4 grass throughout North America.

Spartina patens, saltmarsh hay (Poaceae). High marsh species, smaller than *S. alterniflora*. Highly invasive where not native.
Suaeda linearis, sea blite (Chenopodiaceae). Saltmarsh species with narrow, fleshy leaves.

SOME COMMON ANIMAL SPECIES IN SALTMARSHES AND MANGROVES

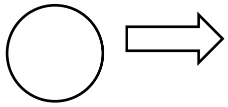
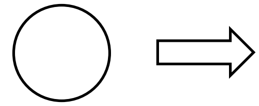
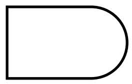
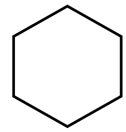
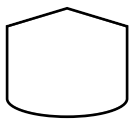
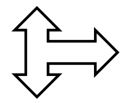
Alligator mississippiensis, American alligator. A mostly freshwater species that can spend some time in estuaries by seeking out lenses of fresh water that float on the more dense salt water.
Callinectes sapidus, blue crab. Eats snails, fish; caught in submerged traps baited with chunks of fish.
Caryobruchus gleditsiae, palm seed beetle that lays eggs either on the fruits or dispersed seeds.
Crassostrea virginica, oyster. Filter feeding subtidal mollusk; needs clean water 10-30 ppt (but thrives at 15-18 ppt) .
Littorina irrorata, marsh periwinkle snail. Scrapes surfaces of saltmarsh cordgrass and black needle rush, defecates on the damaged tissue, and returns to eat the fungus that grows on the damaged and fertilized tissues. Can decimate saltmarshes if populations not kept in check by predators.
Malaclemys terrapin, diamondback terrapin. Omnivore, eats shrimp, fish, crabs, and periwinkle snails. Drowns if caught in crab traps. Formerly a major food source for coastal human populations.
Oryzomys palustris, rice rat. Semi-aquatic, mostly nocturnal, builds nests of grass and rush leaves, omnivorous but eats palm fruits and seeds as well as the succulent portions of *Spartina* and *Salicornia* stems; also eats fiddler crabs, bird eggs, and insects.
Procyon lotor, raccoon. Eats all sorts of crabs, fish, diamondback terrapins, palm fruits (but the seeds pass through its digestive system unharmed).
Sesarma spp., marsh crabs. Herbivorous, feeds on black mangrove seedlings.
Uca spp., fiddler crabs. Males have one large claw and one small. Eat algae and microbes that live in the surface sediments, which they roll around in their mouthparts. Aerate the sediments by burrowing.

SALT TOLERANCES (RANGES)

0 ppt		**10 ppt**		**20 ppt**		**30 ppt**		**40 ppt**
Elm	**Schinus**		**Iva**			**Juncus**	**Spartina**	
Ash		**Palm**					**Batis**	
	Oak	**Juniper**	**Lycium**		**Limonium**		**Salicornia**	
	Pine						**Sesuvium**	
	Cladium				**Distichlis**			

GRAPHICAL MODEL SYMBOL CONVENTIONS/SUGGESTIONS

Identify these components of an ecological system:

Component	Symbol	Component	Symbol
Inputs:		Outputs:	
Producers:		Consumers:	
Storages:		Interactions:	
Energy Flows: