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# Connecticut's Freshwater Wetlands

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## INTRODUCTION

Saltwater and freshwater wetlands cover five per cent of Connecticut's total land area. These wetlands consist of salt marshes, tidal flats, freshwater aquatic beds, emergent wetlands, scrub-shrub wetlands, marshes, and forested swamps, bogs and flood plains. Historically, many of these wetland environments have been considered as waste places, more suitable as agricultural land or for commercial or residential purposes. In Connecticut, nationally and internationally, this negative image of wetlands has given way to the recognition (particularly over the past quarter century) that wetlands are extremely important for a region's economic vitality, maintenance of human health and well-being, natural resource assets, wise land stewardship, and aesthetic interests. In this unit I focus on the freshwater wetlands of Connecticut, including aspects of wetland biodiversity, geology, soils, hydrology, and biogeochemistry. I give here only a cursory review of textbook wetland ecology subject matter, preferring to devote the greater part of the narrative to descriptions of six representative freshwater wetland habitats I have studied extensively in Connecticut. With this approach I hope to show how scientific study can be carried out by the teacher and brought into the classroom for similar involvement of students. The unit is intended for use in high school biology courses, and I believe that a good portion of the material presented here can be modified for elementary or middle school science instruction.

## DEFINITION OF WETLANDS

Globally, six per cent of present land surface is wetland, but the historical extent of wetlands was considerably greater worldwide and in the United States. America has a 400 year history of routinely filling in, dredging, draining, and converting wetlands to other uses—particularly agriculture. By the 1970s greater than fifty per cent of pre colonial wetlands had been destroyed, with the most pervasive damage being done between 1850 and 1950. Our growing awareness of environmental interests, scientific knowledge and legislative responsibilities over the past 25 years has led to the recognition of numerous wetland values. Federal, state and local regulatory protection has resulted.

Connecticut has an estimated 173,000 acres (70,000 hectares) of saltwater and freshwater wetlands. The state has an additional 86,500 acres (35,000 hectares) of deep water habitats (freshwater lakes and ponds). These are not trivial numbers for a small state such as ours. Anyone who has taken a flight in a small plane over Connecticut can attest to the widespread distribution of wetlands in our coastal and inland regions. (One acre, from the Imperial System of measurement, equals 43,560 sq. ft. One hectare, standard unit of land measurement in the metric system, is equal to an area 100 m by 100 m, or 10,000 sq.m.)

Wetlands are ecotones or transitional zones between uplands and deep water habitats. They are thus difficult to define by precise boundaries. The three mechanisms by which wetlands are delineated are by their hydrology (frequency of flooding), by the presence of obligate (requiring flooded conditions) and facultative (tolerating flooded conditions) wetland vegetation, and by the presence of hydric soils. Some wetlands remain flooded throughout the year, while others contain standing water for brief periods of time during the growing season. Seasonally flooded wetlands have a frequency and duration of flooding which lead to the development of hydrophilic vegetation. Wetlands have among the highest of net primary productivities of all ecosystems on earth. As suggested above, wetland ecology involves multidisciplinary study and consideration of a range of management issues.

The U.S. Fish and Wildlife Service defines wetlands as “lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year” (Cowardin 1979). Wetlands can be large or small, ranging in size from a vernal pool a few yards across to an ecosystem the size of the Florida Everglades or Georgia’s Okefenokee Swamp.

## WETLAND HYDROLOGY

Water can enter or leave a wetland through precipitation, surface water flow, ground water flow, flooding of rivers and streams, and tidal action. The main way by which nutrients enter or leave wetlands is through these inputs and outputs of water. Wetland plants and animals are highly adapted to their environments, and any alterations of the natural hydrology of these environments result in substantial changes in primary productivity of the ecosystem as well as the richness and diversity of wetland biota. Hydrologists use a variety of measuring methods in seeking to determine the hydroperiod of a wetland—the yearly pattern of water level in that wetland. Different wetlands have different hydroperiods (see below), the hydroperiod being determined by the capacity for storage of water, the geology, soils and topography of the landscape, and the surface and ground water conditions. Highly productive wetlands are those which have a pulsing hydroperiod, with alternating wet and dry periods and consequent alternating aerobic and anaerobic soil conditions. Loss of water from a wetland also occurs through evapotranspiration, the combination of evaporation of water from soil and plant surfaces and transpiration through vascular plant tissues such as leaves. Understanding the hydroperiod of a wetland can do much toward understanding the structure and functioning of the wetland.

## WETLAND BIOGEOCHEMISTRY.

The spatial and temporal transport and transformation of chemicals, including phosphorus, nitrogen, sulfur, carbon, and metallic ions (calcium, magnesium, potassium, sodium), in a wetland and their chemical pathways through the biotic and abiotic components of the wetland are referred to as wetland biogeochemistry. Cycling may occur within a wetland or between wetland and surrounding upland. The wetland soil is a principal conduit for these chemical pathways. Wetland soils are defined as those soils which are sufficiently saturated or flooded during the growing season that they develop anaerobic conditions and will support only hydrophytic vegetation. Wetland soils are mineral soils (consisting of less than 20-35% dry organic matter) or organic soils (where organic matter exceeds these percentages). Mineral soils develop a distinct profile (soil horizons) due to alternating wet and dry periods and aerobic and anaerobic soil conditions (causing the oxidation or reduction of soil metallic ions). Organic soils (called peat soils and made up of large and small fibrous matter) are less dense and have far greater water holding capacity. The peat forms from dead leaves, woody plant parts, herbaceous plants and mosses such as *Sphagnum* . Oxidized soils are brown to red in color. Reduced soils are blue-gray to black in color. Nitrogen is a key element in wetland and upland soils, and microorganisms play an important role in the retention or loss of nitrogen in the soil. Bedrock geology of a wetland site may have much to do with the types of organisms living in that wetland. Climate is equally important to a site's biota (Broker 1994). Wetlands produce, store or transform chemicals. Many wetlands show a seasonal pattern of nutrient uptake and release. Wetland net primary productivity through photosynthesis may be high or low. Human impacts on wetland biogeochemistry, (tree removal, stream channelization, delivery of waste water or agricultural runoff to a wetland, can be considerable.

## BIOTIC ADAPTATIONS TO A WETLAND EXISTENCE

Organisms living in an aquatic environment face specific stresses which, through evolutionary time, have given rise to ingenious structural and physiological adaptations. These stresses include life in an anaerobic (anoxic) environment, high salinity, concentration of toxic compounds, and extreme fluctuations in water level. For many plants and microorganisms the most severe stress is shortage or absence of oxygen in the soil. Without oxygen, plant and animal respiration occurs only through anaerobic metabolic pathways, slower and less efficient than aerobic pathways. Many bacteria, essential decomposers in wetland food webs, are obligatory or facultative anaerobes. They use metabolic pathways based on sulfur compounds—not oxygen—as the electron acceptors. Many plants have stems, leaves and roots which contain air spaces permitting transfer of oxygen from above water structures to submerged plant parts. The submerged basal leaves of Water Lobelia ( *Lobelia dortmanna* ), a common plant of coastal pond shores, are hollow. Emergent flower-bearing stems pump oxygen down to these hollow leaves and to growing roots. Floating leaves of water lilies do the same.

Wetland plants have far higher percentages of pore space in their tissues than do terrestrial plants. Trees of bottom land hardwood forests, cypress swamps, and coastal mangrove swamps have adventitious roots, emergent "knees" and prop roots which facilitate the transfer of atmospheric oxygen to submerged trunks and roots. Life history strategies in plants and animals often are adapted to life in aquatic environments. Pond shore plants growing in moist peaty sand above the water's edge, such as the carnivorous sundews (Drosera), lie dormant on pond shores in years of high water and germinate, grow quickly, flower and set seed when drought years expose expanses of shore.

Plants growing in salty coastal environments have the difficulty of surviving salt stress. Salt can be toxic to plant cells and tissue, or it can be disruptive to cellular osmotic balance. Salt marsh plants and plants of the coastal prairie in the Everglades are halophytic, or salt loving organisms. They have adaptations for removal of salt from tissues and salt separation from sensitive tissues. Vertebrate and invertebrate animals also have structural, physiological and behavioral modifications which allow them to thrive in wetland environments. Some of these are mentioned in the site descriptions below.

## WETLAND VALUES

Freshwater wetlands are now recognized as performing a number of valuable ecological and economic functions. They include (1) participation in the water cycle and the chemical cycling of carbon, nitrogen, and phosphorus; (2) functioning as a sink for natural and anthropogenic waste material; (3) filtering and purification of water; (4) reducing the impact of river, stream and coastal flooding; (5) acting as a protective barrier to coastlines, shorelines and deep water habitat; (6) recharging ground water aquifers; (7) providing habitat for a tremendous diversity of biota, including many threatened and endangered species.

## TEACHERS AND PROFESSIONAL DEVELOPMENT

I've constructed this unit to challenge myself and my colleagues in highly specific ways. Here's what I expect of myself and of those colleagues who put aspects of this unit to use in their classrooms: (1) get out in the field and look at nature; collect plant and animal specimens in responsible fashion, and bring them into the classroom. (Plants are always collected to leave the growing root and stem stock in place; animals always get returned to their precise locations of collection after brief use in the classroom); (2) read newspapers and magazines for current articles on science which relate to wetland ecology. Much of my teaching is current events-driven. There is an abundance of such articles today as we become more ecologically and environmentally aware, and as science policy is formulated and debated; (3) review Project 2061, National Research Council, National Science Teachers Association and other science education reform materials and get something out of the reading; (4) sign out slide sets for this unit from the Teachers Institute Resource Room; (5) use the Teacher Bibliography and the Student Reading list—I've pulled together a lot of the key references here; (6) develop familiarity with the use of field guides if not already experienced with them; (7) pick up a journal and draw material from it, whether it's *Scientific American and American Scientist* or *Science, Nature* and *Ecology* .

## SITE DESCRIPTIONS

The following sections describe six different wetland habitats which I have visited and studied extensively in preparing this unit. While it may be difficult for a class to go out in the field to these particular sites, the teacher easily can bring plant and animal components of these habitats into the classroom. The slide set that I have put together (see Classroom Materials) can serve to introduce the students to these wetlands.

## WEST ROCK RIDGE VERNAL POOL, HAMDEN, CONNECTICUT

(Topographic Maps: New Haven Quadrangle, New Haven County, Connecticut) Vernal pools are shallow wetlands which form in winter and early spring from snow melt and rainfall. Vernal pools may form in low-lying areas such as at the base of a slope or adjacent to a stream, or they may be perched on ridgetops in depressions. They typically persist until mid-summer in Connecticut, when the onset of consistently warm weather leads to their complete evaporation. Vernal pools (or spring pools) thus are ephemeral, or seasonal wetlands. Their food chain is based on the breakdown of detritus, the leaves, twigs and other organic matter which falls into the pool through the year.

West Rock Ridge in the towns of New Haven, Hamden, Woodbridge and Bethany has a number of vernal pools, most of them in the low-lying lands adjacent to the West River (west of the ridge) and beside Wintergreen Brook (east of the ridge). The vernal pool I have studied is one of a few located on top of the ridge; it is east of the paved overlook to Lake Dawson. The pool is approximately 50 meters long and 10 meters wide, and it is adjacent to the east slopes of the ridge. There is an old stone wall within a few feet of the north end of the pool, but I believe the depression to be naturally formed, perhaps from glacial scouring. Approaching the pool, the prevailing image one has is of being in a forest and simply finding a low, wet area of forest floor. The special biological characteristics of the pool only become apparent with closer examination over a period of weeks.

Because of the ephemeral nature of vernal pools, vertebrate and invertebrate organisms residing in them must complete key stages in their life cycles, particularly larval stages, during the brief time water is present. Several amphibian species are dependent on vernal pools for reproduction, including courtship, egg fertilization and deposition, larval development, and metamorphosis to the terrestrial stage. Amphibians I have found in the West Rock ridge top vernal pool are Spotted Salamander ( *Ambystoma maculatum* ), one of several *Ambestoma* salamander species found in the state, and Wood Frog ( *Rana sylvatica* ).

Wood Frog is a medium-sized frog with a brown body and a dark masked appearance around the eyes. This northern boreal frog reaches its southernmost distribution in the Appalachian Mountains south to Georgia. It is a widely distributed species throughout Connecticut in dense deciduous and coniferous forest. Wood Frog prefers to breed in vernal pools, where females deposit a communal egg mass in shallow water. It is also known to breed in wet meadows, swamps, bogs and fens, and roadside ditches. Spotted Salamanders live primarily in forested areas where there are nearby vernal pools or semi-permanent ponds. On March 18 of this year I visited the West Rock Ridge vernal pool on the night of March 21, and I observed hundreds of Spotted Salamanders engaged in reproductive behavior. This date matches the second earliest published record of Spotted Salamander breeding in Connecticut. The species overwinters in underground burrows or cavities, and individuals emerge in late winter and early spring when upper layers of soil thaw, air temperatures reach 50 degrees Fahrenheit, and then only after dark when there is a warm rain or heavy fog and humidity is high. Males migrate to ancestral vernal pools, followed shortly by females, and there begins an elaborate group courtship and breeding. Males locate and rub against females, then swim to the pool's bottom to deposit spermatophores on dead leaves. Females make contact with spermatophores and draw them into the cloacal opening for fertilization of eggs. Within 48 hours, females deposit egg masses of 50-200 eggs on submerged branches in the deeper sections of the pool. Spotted Salamander larvae eventually hatch out of the egg mass, grow in size, and metamorphose into air-breathing terrestrial tetrapods—all this before the vernal pool dries up completely. (Space constraints prevent me from giving a more detailed description of Spotted Salamander life history. I refer the reader to an upcoming issues of the West Rock Ridge Park Association Newsletter, which will carry an article I have written on this fascinating amphibian species.)

Other vertebrates using the vernal pool include Wild Turkey ( *Meleagris gallopavo* ), which digs in surrounding dry leaf litter and finds acorn mast for food, and White-tailed Deer ( *Odocoileus virginianus* ), which drinks from the water and beds down nearby. Birds which breed on the eastern slopes of West Rock Ridge in the vicinity of the vernal pool include Eastern Screech-Owl and Great Horned Owl, Downy, Hairy and Pileated Woodpecker, Great Crested Flycatcher, Eastern Phoebe and Eastern Wood-Pewee, Red-eyed Vireo and Yellow-throated Vireo, Black-throated Green Warbler, Ovenbird, Black-and-white Warbler, Worm-eating Warbler, Brown Thrasher, Wood Thrush, Hermit Thrush and Swainson's Thrush, and Scarlet Tanager.

Vernal pools contain a wide range of insects and other invertebrates. These organisms have the benefit of adaptation to life in a body of water which, because of its ephemeral nature, lacks fish populations—potentially their principal predators. I have not yet undertaken a systematic study of the invertebrates of the West Rock vernal pool, but this is described below as an activity for students. Invertebrates living in vernal pools include oligochaete worms, water fleas ( *Daphnia* ), copepod crustaceans, fairy shrimp (restricted to vernal pools), ostracods (seed shrimp), isopods ( *Asellus* ), water mites, mosquito larvae ( *Culex* ), dragonfly nymphs (Odonata), caddisfly larvae ( *Ptilostomis* ), diving beetles ( *Rhantus* ), water scavenger beetles ( *Hydrophilus* ), water bugs ( *Lethocerus* ), chironomid midges ( *Mochlonvx* ), water striders ( *Gerris* ), clam species, and snails ( *Physa* , *Gyraulus* ).

The forest surrounding the vernal pool is part of the larger oakhickory forest which dominates the ridgetop and upper slopes. Chestnut, Scarlet, Pin, Northern Red, and White Oaks, and Mockernut, Pignut, Bitternut, and Shagbark Hickories, Sugar Maple, Red Maple, and Yellow-Poplar trees are the principal deciduous trees. Eastern Hemlock and Eastern White Pine are also found in a grove near the vernal pool, and Eastern Red Cedar ( *Juniperus virginiana* ) grows from rocky outcrops on the east slopes. The most common shrubs are Sweet Pepperbush ( *Clethra alnifolia* ) and Pussy Willow ( *Salix discolor* ). Herbaceous plants of the region of the vernal pool include Yellow Corydalis ( *Corvdalis flavula* ), Wild Columbine ( *Aquilegia canadensis* ), Canada Mayflower ( *Maianthemum canadense* ), Early Saxifrage ( *Saxifraga virginiensis* ), and Wild Geranium ( *Geranium maculatum* ).

### DURHAM MEADOWS RED MAPLE-GREEN ASH-TUSSOCK SEDGE SWAMP, DURHAM, CONNECTICUT.

(Topographic Map: Durham Quadrangle, Middlesex County, Connecticut) Swamps are wetlands in which trees are the dominant vegetation. These are forested wetlands. In Connecticut and throughout southern New England, the most common type of wetland is a red maple swamp. Fully 80% of Connecticut's freshwater wetlands are *Acer rubrum* swamps. Red Maple, which derives its name from the plant's red flowers, fruits, petioles and fall foliage, grows to a height of 60-90 feet and a diameter at breast height (DBH) of 2 1/2 feet. While it grows in dry upland sites, it is most abundant and most closely a monoculture species (single species stands) in swamps or along stream banks. It is widely distributed throughout the eastern United States.

Durham Meadows is an outstanding example of a Connecticut red maple swamp. It is situated in the floodplain of the Coginchaug River between Routes 17 and 147 in Durham. Route 68 bisects the meadows in an east-west direction. My field work has focused on the southern half of Durham Meadows, between Routes 17 and 68. This region of Durham Meadows is easily accessible by those who don't mind getting shoes or pantlegs wet or muddy. The inner regions of this wetland are accessible only through considerable exertion, walking and wading through dense vegetation and over very uneven topography deep river channel, tussocks, grass mats, and windthrown trees.

There are at least three distinct plant communities in Durham Meadows. Just north of Route 17 an easy to reach red maple-tussock sedge swamp covers several acres. Penetrating further north into the meadows, one finds more dense growth of red maple and green ash on hummocks set back from the Coginchaug River. The immediate environment of the river is a wild rice grass riverine wetland. Scattered areas of cattail (Typha) are found on either side of the river. Further north, the forest closes in far more, with red maple and green ash dominating, and there is a dense growth of floating and emergent herbaceous plants.

Representative herbaceous and shrubby plants of the Durham Meadows wetland are sedges ( *Carex spp* .), Skunk Cabbage ( *Symplocarpus foetidus* ), Arrow Arum ( *Peltandra virginica* ), Cowslip ( *Caltha palustris* ), Yellow Iris ( *Tris pseudacorus* ), Larger Blue Flag ( *Iris versicolor* ), and Speckled Alder ( *Alnus rugosa* ).

Human activities have affected all three vegetation zones of Durham Meadows substantially, including tree-harvesting, channel dredging, laying of coaxial cable through the meadows, and agricultural runoff which infuses heavy doses of phosphorus fertilizer into the wetland. In fact, the three zones of Durham Meadows described here arose probably due to different periods of logging of the trees. The presence of beaver has affected this wetland considerably. Beaverdammed stretches of the Coginchaug cause extensive flooding to either side of the river. This is particularly noticeable after heavy spring and summer rains, when the red maple-tussock sedge environment pools with sheet flow of water. A large beaver lodge is visible from the fishermen's trail leading along the east side of the river. Muskrats also live in Durham Meadows, and their houses are scattered throughout the wetland. Meadow voles are present in the grass and sedge margins of this wetland, as are White-tailed Deer.

Durham Meadows is particularly interesting for its diverse populations of birds. Several rare, threatened and endangered breeding bird species live here, including American Bittern (state endangered) and Least Bittern (state threatened), Virginia Rail and Sora. These wetland species have declined in numbers over previous decades due in large part to loss of habitat—the draining of wetlands and their conversion to agricultural lands or residential and commercial tracts. Durham Meadows is, in fact, surrounded by farmiand, which has encroached on the historical boundaries of the wetland.

The 1984-85 Connecticut Breeding Bird Atlas confirmed breeding of both rails and Least Bittern at Durham Meadows. On May 21 of this year I several times heard the pumping sound of American Bittern deep in this wetland, convincing me that this species also breeds here. On May 5 I located the nest of Virginia Rail at Durham Meadows. It contained eight eggs the day of discovery, and one day later the nest held nine eggs. These eggs were incubated by both parents over the course of several weeks, when the nest was found to have been predated and the eggs destroyed—a common occurrence for these ground-nesting birds.

Other breeding birds of Durham Meadows include 6reen Heron, Wood Duck, Blue-winged Teal (Breeding Bird Atlas—one of only three confirmations of breeding in Connecticut), Red-shouldered Hawk (a wetland-nesting hawk), Eastern Screech-Owl, Belted Kingfisher, Willow Flycatcher, Least Flycatcher, Eastern Kingbird, Tree Swallow, Barn Swallow, Marsh Wren, Eastern Bluebird, Cedar Waxwing, Warbling Vireo, Red-eyed Vireo, Yellow Warbler, American Redstart, Common Yellowthroat, Swamp Sparrow, Bobolink, Red-winged Blackbird, Common Grackle, Brownheaded Cowbird, Orchard Oriole and Northern Oriole. Many of these birds are wetland species. Several, such as Eastern Bluebird, Bobolink, Brown-headed Cowbird, and Orchard Oriole, are grassland, meadow, or orchard species found here because of the surrounding agricultural lands. Migrant birds I have observed stopping over in Durham Meadows are Greater and Lesser Yellowlegs, Solitary Sandpiper, Spotted Sandpiper, Upland Sandpiper, and Common Snipe.

**CONNECTICUT RIVER SILVER MAPLE FLOODPLAIN FOREST, ROCKY HILL, CONNECTICUT.**

(Topographic Map: Hartford South Quadrangle & Glastonbury Quadrangle, Hartford County, Connecticut) While

Red Maple is the dominant tree species of Connecticut's swamplands, another member of the maple family, Silver Maple ( *Acer saccharinum* ), is the most abundant tree of floodplain forests. These forested wetlands, called bottomland hardwood forests in the southeastern United States, develop in low-lying areas along major rivers & streams—Connecticut, Thames, Quinnipiac, Naugatuck, and Housatonic. Silver Maples grow to 50-80 feet, fully mature individuals attaining a DBH of 3 feet. Trunks grow twenty or more feet without significant tapering, or lower to the ground they divide into several large forks. Silver Maples are fastgrowing trees, explaining their popularity as residential shade trees.

Fast growth enables silver maples to recolonize floodplain habitat which damaged by sudden, extensive and violent floods. Trunks and branches of Silver Maples are easily broken by strong floods or gale-force winds. Examining a floodplain forest along a major river, one finds many broken or split individual trees. An additional feature of Silver Maple, its ability to send out long, arching branches and for these branches to root in alluvial soils at points of contact or breakage, makes this tree ideally suited for floodplain environments.

Silver Maple shares floodplain habitat with Eastern Cottonwood ( *Populus deltoides* ), American Elm ( *Ulmus americana* ), and Black Willow ( *Salix nigra* ). Each of these species can exceed 100 feet and 4 feet DBH. They are all fast-growing and generally short-lived. Boxelder ( *Acer negundo* ), a shorter maple family member, also grows in floodplain forests. The Rocky Hill floodplain has abundant patches of Cinnamon Fern ( *Osmunda cinnamomea* ), Royal Fern ( *Q. regalis* ), Wood Nettle ( *Laportea canadensis* ), and Garlic Mustard ( *Alliaria officinalis* ). Poison Ivy (Rhus radicans), Virginia Creeper ( *Parthenocissus quinquefolia* ), and Riverbank Grape ( *Vitis riparia* ) are common vines.

The study site I use for Silver Maple floodplain forest is located along the Connecticut River in Rocky Hill, south of Exit 25 on Interstate 91. The floodplain is found between the 15 foot high banks of the Connecticut River and adjacent farmiands to the west. This region is characterized by "ridge and swale" topography, alternating regions of low deepwater or dried out channels and elevated sandbars populated on their margins by tall trees and having a mixture of trees and herbaceous plants on their highest portions. While you are in a forest, you're never far from the next open, river-cut swale. To stay dry, you enter a floodplain forest by walking the length of a ridge and cutting across the channel head to the next ridge, or you canoe in.

The silver maple floodplain forest wetland undergoes greater seasonal change than do any of the other wetlands described here. During major spring and summer floods the entire floodplain is submerged by 10 to 20 feet or more of river water. Only upper trunks and crowns of trees are visible. During non-flood stage, back channels (testimony to extensive river channel migration and to the previous locations of the main river channel) are present as dry depressions or deepwater bodies of still water. Mid-June and July visits to the floodplain give a completely different impression of this habitat. In these summer dry periods the channels are vegetated by obligate and facultative hydrophytic plants which grow to substantial heights.

The animal life of the silver maple forest is fascinating. Common Snapping Turtle ( *Chelydra serpentina* ) inhabits the quiet back channels, feeding on a range of fish species. On May 5, I observed a snapping turtle which certainly exceeded the state record of 17.5" carapace length, although I did not attempt to capture this turtle for measurement. (A noticeably smaller snapping turtle captured the same month at Konold's Pond in Woodbridge had a carapace measured at 16.5") Snapping Turtle is a major predator of the floodplain forest community. Tracks of river otter indicate this mammal's presence. It feeds on fish and aquatic invertebrates. Raccoons are present, also. Birds of floodplain forests include Great Blue Heron, Green Heron, woodpeckers, Eastern Bluebird, and many canopy species. Surrounding agricultural lands, while present at considerable expense to the floodplain forest, serve as breeding sites for Bobolink, a declining nesting species of wet meadows and fields. Spring-flooded fields are important for migrating shorebirds—plovers, yellowlegs, peeps.

The Connecticut River floodplain is affected profoundly by agricultural activity. In Rocky Hill and across the river in Glastonbury, vast floodplain acreage has been converted to agriculture—sod farms, corn, peas, and horse radish. The sod grown here typically is shipped to the state of Maine. North of Hartford these fertile fields are used for the growth of tobacco for making cigar wrappers, and in earlier times for the famous Wethersfield onions.

**MOHAWK STATE FOREST BLACK SPRUCE BOG, CORNWALL, CONNECTICUT.**

(Topographic Map: Cornwall Quadrangle, Litchfield County, Connecticut) Bogs are peat-accumulating wetlands without any significant inflow or outflow of water, which have acid-loving sphagnum mosses as the predominant ground cover. Bogs may be open wetland habitats ringed with trees and shrubs, or dominated throughout by trees. In northern temperate regions bogs usually are remnant glacial lakes and ponds which have filled in extensively with vegetational detritus over the 12,500-14,000 year period since glacial retreat. Connecticut's bogs are located fairly exclusively in the northwestern and northeastern parts of the state, although there is a Yale University-owned sphagnum bog in nearby Bethany, Connecticut. The representative black spruce bog I have studied is one at Mohawk State Forest south of Route 4. The entrance to this state forest is not more than a few hundred yards west of the Goshen-Cornwall town line. A short boardwalk enters the bog so that visitors can observe bog plants without trampling delicate bog surfaces. This bog is heavily forested with half a dozen species of coniferous and deciduous trees, has a dense shrub layer, and in late spring and summer has an extensive herbaceous layer consisting of sphagnum moss mats, flowering plants, and heavy patches of ferns. The black spruce bog is surrounded by drier upland on which grow a greater diversity of broad-leaved trees, Eastern Hemlock and Eastern White Pine. Bog topography is quite uneven, the numerous windthrow mounds produced during a long history of hurricane and tornado damage.

Characteristic tree species of the black spruce bog in Mohawk State Forest are the conifers Eastern Hemlock ( *Tsuga canadensis* ), Larch or Tamarack ( *Larix laricina* ), Black Spruce ( *Picea mariana* ), and Eastern White Pine ( *Pinus strobus* ), and the broad-leaved trees Red Maple and Yellow Birch ( *Betula lutea* ). In the east, Black Spruce grows from Labrador to New England, extending so far south as northern New Jersey. It grows to timberline in mountainous areas, and has one of the most northern distributions of any American tree species.

Herbaceous plants of the black spruce bog include some with rather remarkable adaptations for living in an extremely nitrogen-poor environment. These include the carnivorous Northern Pitcher Plant and the Round-leaved Sundew, two species which have evolved ingenious strategies for capturing and consuming small and large invertebrates. The Pitcher Plant ( *Sarracenia purpurea* ) is found from the southeastern United States north to Labrador and Minnesota. It grows from sphagnum mats in scattered locations within the Mohawk State Forest bog. The plant consists of a foot-wide cluster of basal, pitcher-shaped leaves possessing half-dollar sized openings at the top and tapering to pencil-thin bases. The "receiving end" of the pitcher consists of a colorful, aromatic surface covered with fine hairs, feeling like soft bristle to the finger, all pointing downward toward the pitcher base. The unsuspecting fly, ant, or dragonfly which lands on the mouth of the pitcher finds itself obliged to walk downward, in the direction of the hairs. Soon the hairs cease and the insect steps on a smooth, slippery leaf surface, falling into the pitcher bottom. It gets trapped in a pool of rain water and digestive juices from which it cannot extricate itself. Drowning, the insect is digested by the plant, providing a source of nitrogen from its body proteins. Cut open a pitcher plant leaf, and with a dissecting microscope you find a grizzly graveyard of dragonfly heads and wings, beetle carapaces, ant and fly body parts.

Pitcher plants have specially evolved flowers which are pollinated by bees, typically by bumblebees of the genus *Bombus* . The pitcher plant actually represents a minute ecosystem of organisms which are either predated by this carnivorous plant, eat the plant's tissues, or are obligate denizens of the pitcher. The range of organisms living within pitcher plant pitchers includes mosquitoes, flies, mites, amphipods, ants, and moths.

A recent study of *Sarracenia* pitcher plants has identified 16 species of arthropods which are obligate associates of this bog plant. Obligate species include the following: (1) a mosquito, *Wyeompia smithii* , which undergoes larval development in the pitcher's pool of water; here the larvae consume microscopic organisms and derived nutrients from suspended particulate matter; (2) a midge, *Metriocnemus knabi* , whose larvae eat other organisms trapped in the pitcher; this organism pupates above the water line of the pitcher; (3) 5 to 6 species of sarcophagid flies, including *Blaesoxipha fletcheri* , which has been found living only in pitcher plants; (4) two anoetid mites, including *Anoetus gibsoni* ; (5) moths of the genus *Exyra* , most notably *E. rolandiana* ; this moth lives out all stages of its life cycle in the pitcher, including mate location and copulation, egg-laying, larval development, pupation, and the adult stage. Before pupation, the soon to-be-metamorphosing larva chews a drainage hole in the pitcher plant wall just below where it will form a pupa, so that the pupa remains dry throughout its development—regardless of how much rainwater reaches the pitcher.

Several species of sundew of the genus *Drosera* are found in Connecticut's black spruce bogs, most commonly the round-leaved sundew, D. rotundifolia. This plant employs a different strategy for capturing small insects. Its tiny leaves are rayed by thin filaments, each with a sticky drop of liquid at the end. Insects are attracted to the plant, land on a leaf, and are held fast, as a person's finger might stick to epoxy glue. Special digestive enzymes digest the prey after the leaf closes around the captured organisms. Getting on your hands and knees with a hand lens and examining the sundew up close will reveal the stuck insects or their remains—again a field of carnage.

**CALCAREOS RED MAPLE-BLACK ASH-AMERICAN ELM SWAMP, SOUTH CANAAN, CONNECTICUT.**

(Topographic maps: Ashley Falls Quadrangle Massachusetts-Connecticut & South Canaan Quadrangle Litchfield County) Robbins Swamp is located in the cold climate of extreme northwestern Connecticut at an elevation of 650 feet. It occupies a valley east of the old Penn Central Railroad line (from which one can gain access) and west of the 1650-1950 foot Canaan Mountains. As with most Connecticut swamps, it contains abundant Red Maple, but other dominant trees are Black Ash ( *Fraxinus nigra* ), a northern species commonly found only in the northwestern part of the state, American Elm ( *Ulmus americana* ), and Swamp Birch ( *Betula pumila* ). Black Ash grows in wet soils of swamps and bogs and along streams. It is most likely to be found in colder climates and where soil drainage is poor -exactly those conditions found in Robbins Swamp. In comparison, the Green Ash present in Durham Meadows is found widely distributed throughout Connecticut.

Robbins Swamp is located in the northern Limestone Valley of Connecticut, and there is a large limestone or "marble" quarry located immediately west of the swamp, visible from the study area described here. The swamp is bisected by Swamp Brook, a slow-moving body of water. Mineral input from the brook and the surrounding uplands give Robbins Swamp some of the peat-accumulating properties of a fen. Vegetation of Robbins Swamp includes a number of rare and threatened species of herbaceous plants which grow only in highly alkaline soils. Those plants which are characteristic of or restricted to neutral or alkaline soils include the orchids Yellow Lady's Slipper ( *Cepripedium calceolus* ), whose species name derives from the plant's growth in calcareous, or calcium carbonate soils developed over limestone bedrock, and Showy Lady's Slipper ( *C. reginae* , state endangered), and Fringed Gentian ( *Gentiana crinita* ), and Grass-of-Parnassus ( *Parnassia* *glauca* ). At least fifteen special concern, threatened or endangered sedge species are found in northwestern Connecticut's Limestone Valley. Rare woody plants of the Limestone Valley include Shrubby Cinquefoil ( *Potentilla fruticosa* ), Swamp Birch, and Tamarack ( *Larix laricina* ). Poison Sumac ( *Rhus vernix* ), a medium-sized shrub with celery-like compound leaves highly toxic to the skin, is a common shrub species to be avoided in Robbins Swamp.

The most notable vertebrate species of northwestern Connecticut calcareous wetlands such as Robbins Swamp is the state endangered Bog Turtle ( *Clemmys muhlenberqii* ), a species found in eastern New York, western Massachusetts and western Connecticut, New Jersey, Pennsylvania, Delaware and Maryland. Bog Turtle is thus near its northernmost range extension in Connecticut. Adult Bog Turtles have a carapace length of less than 100mm (4"), making this the smallest turtle species in New England. Bog Turtle has a moderately domed and weakly keeled carapace, pyramidal carapace scutes, and an orange or yellow patch on either side of the head. The oblong carapace is light brown, and the plastron is brownish black with yellow midline.

Bog Turtle presents a number of conservation challenges, as its highly specialized habitat requirements (open-canopy wet meadows and fens alongside narrow or slow-moving rivers where soil is kept saturated by the steady flow of sheet water) make it vulnerable to any habitat alteration. The preferred wet meadows and fens are sensitive to water quality degradation from fertilizer and septic runoff into feeder streams, introduced wetland plants such as Purple Loosestrife (Lvthrum salicaria), drainage or flooding from stream disruptions, and chemical and heavy metal pollution. High nutrient input into wet meadows and fens results in more rapid growth of red maple which closes the canopy and makes the habitat unsuitable for Bog Turtle. Bog Turtle is considered highly endangered in the state of Connecticut. The Nature Conservancy of Connecticut maintains ownership of Robbins Swamp, managing the site to protect its high number of rare plants.

**ATLANTIC WHITE CEDAR SWAMP, NEW LONDON COUHTY, CONNECTICUT.**

(Topographic Maps: Old Mystic Quadrangle, New London County, Connecticut & Ashaway Quadrangle, Rhode Island-Connecticut; Wellfleet Quadrangle, Barnstable County, Massachusetts) Atlantic White Cedar Swamps, in which the Atlantic White Cedar ( *Chamaecyparis theoides* ) is the dominant tree species, are restricted to the Atlantic seaboard from northern Florida to Cape Cod, Massachusetts and, rarely, to coastal New Hampshire and southern Maine. These swamps develop in highly acidic, peat soils in glacially carved depressions which intersect the water table. They are characterized by deep peaty deposits 20-50 feet in thickness which have developed since deglaciation. Connecticut's Atlantic White Cedar Swamps visited for this study were a swamp north of Route 80 and west of Chatfield Hollow State Park in North Madison (owned by the South Central Connecticut Regional Water Authority), an extensive cedar swamp immediately adjacent to the main parking lot at Foxwood Resort & Casino off Route 2 in Ledyard, Assekonk Swamp south of Route 2 in North Stonington, and Bell Cedar Swamp, north of Route 184 and also in North Stonington. The slide collection is based on photographic work in the Atlantic White Cedar Swamp at the Marconi site, Wellfleet, Massachusetts in Cape Cod National Seashore. The Cape Cod cedar swamp has a boardwalk running through the wetland and is an important interpretive site for Seashore educational and recreational activities. This site is similar to cedar swamps in Connecticut.

Atlantic White Cedar Swamps resemble forested bogs in appearance, with white cedar trees and red maple trees growing in dense stands from windthrow mounds. There is a well developed shrub layer, with Sweet Pepperbush ( *Clethra alnifolia* ), Highbush Blueberry ( *Vaccinium corymbosum* ), and Inkberry (Ilex glabra) predominating. Sphagnum moss ( *Sphagnum spp.* ) is the principal ground cover, forming lush green carpets throughout the swamp and resting on the deep layers of peat, the dead, partially decomposed remains of earlier sphagnum layers. When the water table is high, as in spring or after heavy summer rains, the swamp floor is covered with sodden mats of sphagnum and has areas of pooled water. In conditions of drought, one can walk through cedar swamps and stay relatively dry. The abundance of decaying vegetable matter turns the pools of water a tea brown color.

Since early colonial times Atlantic White Cedar swamps have been logged for their valuable wood. The wood is extremely rot-resistant and is best known for use as building shingles. The uniquely American Cape Cod saltbox house is usually covered with cedar shingles. The wood is light brown to red-brown in color, and it weathers to a pleasing gray. It is ideally suited to withstanding coastal New England hurricanes, norteasters, and a steady rain of salt spray. White Cedar Swamps are a critical forested wetland habitat which has declined severely in distribution over the past several centuries due to extensive clearcut logging and drainage for conversion to agricultural uses. Connecticut has a number of well-developed white cedar swamps, although in our state also, cedar wetlands have been filled in or converted to other uses. In New England, many of these swamps have been converted to cranberry bogs. Extant white cedar swamps in Connecticut are located in approximately 20 different towns, mostly in New London County.

The Atlantic White Cedar is a tree species with highly specialized growth requirements. White cedars are fairly slow-growing, longlived species which historically grew to large size but which are generally restricted to small- to medium-sized trees today. They are capable of colonizing fire-, hurricane- or logging-disturbed sites successfully, outcompeting such hardwood trees as Red Maple. They are, however, dependent on regular disturbances occurring approximately in a twenty year cycle in order to maintain their dominance in the swamp forest. Cedars are more resistant to fire than are red maples, and even if they are killed by fire they will seed in and initially outgrow red maple seedlings. They similarly fill in clearcut swamps faster than do maples. If Red Maple is given extended opportunity to grow, as in long-undisturbed sites, it will overtop the cedars, cause them to die, and cut off the regeneration of younger cedar trees. Lie down on a boardwalk in an Atlantic White Cedar swamp, look straight up, and you can see that Red Maple stretches and bends to fill all available gaps in the swamp canopy. Mature maples also overtop the cedar canopy.

The predominant forest management strategy of past decades has been fire suppression, a disruption of the natural cycle of cedar swamp disturbance resulting in cedar swamps which year by year approach a condition of replacement by Red Maple swamp. Cape Cod National Seashore, the Regional Water Authority, and private landholders such as the Mashantucket Pequots will face decisions on whether to disturb and preserve existing cedar swamps or see them disappear.

Vertebrate life is less apparent to the observer in cedar swamps than in other forested wetlands, in part because of the near monoculture nature of these stands—impeding biological diversity and in part because of the shortage of available food for wildlife. The one notable exception to this is the widespread presence of Highbush Blueberry in cedar swamps. Representative raptorial birds of the swamp include Red-shouldered Hawk ( *Buteo lineatus* ) a nester in swampy woodlands, Barred Owl ( *Strix varia* —not found on Cape Cod) which occupies abandoned Red-shouldered Hawk nests, and Northern Sawwhet Owl ( *Aegolius acadicus* ). Several woodpecker species are found in cedar swamps, as are such perching birds as Tufted Titmouse and Blackcapped Chickadee. In comparison, the surrounding upland forest always seems to teem with a broad diversity of mixed canopy species. Whitetailed Deer can negotiate cedar swamps, and gray and red squirrels and a variety of smaller rodents live here.

## CLASSROOM ACTIVITIES AND SAMPLE LESSON PLANS

*SLIDES OF CONNECTICUT'S FRESHWATER WETLANDS.*

I have made a series of trips to photograph each of the six wetland habitats described in this unit, selecting the most representative slides depicting the habitats and their bedrock geology, vegetation, wildlife and dynamic processes. Each section below has a brief description of the slides, followed by a set of questions concerning the pattern and process of wetland ecology at the site. These are intended to encourage the student to observe and describe, ask original questions, develop explanations, communicate ideas to others, and apply knowledge to new problems. I can make available more detailed descriptions of these slides than can be presented here.

***WEST ROCK RIDGE VERNAL POOL, HAMDEN, CONNECTICUT.***
(1,2) West Rock Ridge and Konold's Pond: the west-facing cliffs and talus slope. View is toward Sleeping Giant State Park. (3,4) West Rock Ridge ridgetop vernal pool, January 1995. The pool is unfrozen, snow dusts surrounding upland. Vernal pool in mid-February 1995. Ice and snow cover the pool, making it indistinguishable from surrounding upland. (5-8) Vernal pool in early March 1995. Snow has melted on upland, but pool is completely ice-covered. Pool in late April 1995, at near-maximum size and depth. (9) Leaves and sticks on bottom: substrate for Spotted Salamander spermatophores. (10) Mass of Wood Frog eggs in vernal pool, late April 1995. (11) Wood Frog tadpole in hand, late April 1995. (12) Spotted Salamander ( *Ambystoma maculatum* ) from West Rock Ridge ridgetop vernal pool. (13,14) Spotted Salamander egg masses in vernal pool, late April 1995. (15) Vernal pool in late July, now completely dried up and difficult to recognize as wetland habitat.

Questions: How can a wetland form on top of a high ridge? How does this wetland change from one season to the next? What's the source of energy for all the animals living in this pool? How is the life cycle of the Wood Frog or Spotted Salamander matched to this temporary wetland? How would you go about studying small pool organisms?

***DURHAM MEADOWS RED MAPLE-GREEN ASH-TUSSOCK SEDGE SWAMP, DURHAM, CONNECTICUT.***
(1,2) Durham Meadows and the Coginchaug River, January 1995. Leafless trees and brown tussock sedges. Durham Meadows and the Coginchaug River, Spring 1994. Broad-leaved trees now leafed out. (3) Southern portion of Durham Meadows. Red Maples, tussock sedges, and emergent vegetation. (4) Coginchaug River with dense growth of Wild Rice grass ( *Zizania aquatica* ) and red maples ( *Acer rubrum* ) and green ash ( *Fraxinus pennsylvanica* ). Photo taken further north into the wetland than previous photographs. (5) Common Cattail ( *Typha latifolia* .) marsh in gaps in the red maple-green ash stand. (6,7) Red maple-green ash swamp with floating and emergent aguatic vegetation. (8) Close-up of green ash. (9) Coginchaug River with emergent aquatic vegetation. (10) Cinnamon Fern ( *Osmunda cinnamomea* ) with brown sporebearing fronds. (11) Cowslip ( *Caltha palustris* ), a spring-flowering plant of streambanks and swamps. (12) Yellow Flag ( *Iris pseudacorus* ), an exotic escapee. (13) Slender Blue Flag ( *Iris prismatica* ), native to wet meadows and marshes of the northeast. Fronds of Sensitive Fern ( *Onoclea sensibilis* ) in the background. (14) Arrow Arum ( *Peltandra virginica* ), an abundant emergent plant of shallow streams. A member of the Arum Family ( *Araceae* ). (15) Violet ( *Viola sp.* ) growing on windthrow mound. (16) Whitetail Dragonfly male ( *Libellula lydia* ), common to shallow rivers and freshwater ponds. Males are fiercely territorial and guard mates aggressively. (17) Green Frog ( *Rana clamitans* ). They feed on beetles, flies and spiders. (18) Common Snapping Turtle ( *Chelydra serpentina* ), largest freshwater turtle in New England. This one was found on the banks of the

Coginchaug River. It had a snub-tail, bitten off during combat with another male or when it was much younger. Snapping turtles prefer lakes, rivers, backwaters with muddy or peaty bottoms. (19) Nest of Red-winged Blackbird ( *Agelaius phoeniceus* ) with two eggs and two freshly hatched nestlings. (20,21) Virginia Rail ( *Rallus limicola* ) parent (#20) in immediate vicinity of nest (#21). The five year Connecticut Breeding Bird Atlas lists only 12 atlas blocks in the state with confirmed breeding of Virginia Rail. (22) Beaver ( *Castor canadensis* ) dam in Coginchaug River. This mammal has considerable influence on the Durham Meadows wetland system. (23) Muskrat ( *Ondatra zibethicus* ) house deep in Durham Meadows. (24) Plowed agricultural land bordering Durham Meadows.

Questions: How is this wetland different (similar to) a vernal pool? Identify a floating plant, an emergent plant, a shrub and a tree from this wetland, and describe how it is adapted to the wetland environment. How do the flowering plants get pollinated here? What predators live here? What is their food? What effect does the beaver have on this wetland? How does nearby farmiand affect marsh life?

***CONNECTICUT RIVER SILVER MAPLE FLOODPLAIN FOREST, ROCKY HILL, CONNECTICUT.***
(1,2) The Connecticut River at Rocky Hill, with surrounding floodplain forest. Banks of the Connecticut River. (3-7) Back channels of the Connecticut River. Note trees arching into the back channels from each side. (8) Dead Man’s Fingers fungus growing in broken limb of Silver Maple. (9) Royal Fern ( *Osmunda regalis* ), a tall fern of wooded swamps and moist woodlands. (10) Wood Nettle ( *Laportea canadensis* ), an herbaceous plant of bottomiand hardwood forests and floodplains. (11) Garlic Mustard ( *Alliaria officinalis* ), a spring-to-early summer flowering plant of open woods. (12) Poison Ivy ( *Rhus radicans* ) vine of considerable diameter and age. (13) Boxelder (Aser negundo), common understory tree of floodplain forests and streambanks. A short-lived, fast-growing tree easily damaged in storms or floods. (14) Flood damage to Silver Maples along Connecticut River back channel. (15) Dry back channel immediately adjacent to the Connecticut River. (16,17) Common Snapping Turtle from back channel (slide #15).

Questions: To what extent does change affect this site? What is the topography (surface features) of the site? Is there any evidence of serious floods? Is there evidence of channel migration? Describe the soil found here. How well can this site store water which overflows the river channel during floods? Do the trees grow in zones between river and surrounding farmiand? What advantage do vines have this habitat? Are there any young trees growing up here? What are the main predatory animals living here? How has human activity altered the floodplain? What is the range of human activity at this site?

***MOHAWK STATE FOREST BLACK SPRUCE BOG, CORNWALL, CONNECTICUT.***
(1) Connecticut’s hilly Western Highlands, from Mohawk Mountain. (2) Boardwalk entering Black Spruce Bog, Mohawk State Forest. (3) University of New Haven graduate students studying bog ecology. (4,5) Eastern Hemlock ( *Tsuga canadensis* ) trees. Dense ground cover of Cinnamon Fern ( *Osmunda cinnamomea* ). (6,7) Sphagnum moss ( *Sphagnum sp* .) ground cover in black spruce bog. Close-up of sphagnum moss. (8,9) Windthrow hemlocks and Black Spruce (Picea mariana), blown down by the tornado of July 10, 1989. Windthrow mound, which creates uneven topography of a black spruce bog. (10,11) Canada Mayflower ( *Maianthemum canadense* ), a common, low-growing white-flowering plant of bog margins. Starflower ( *Trientalis borealis* ), an abundant spring-flowering plant. (12,13) Carnivorous plants of the black spruce bog. Round-leaved Sundew ( *Drosera rotundifolia* ), whose leaves contain a sunburst of hairs with sticky drops at the tips. Pitcher Plant ( *Sarracenia purpurea* ), a plant with pitcher-shaped leaves which attract and capture small to large insect prey. (14-16) Close-up of Black Spruce tree, the species for which these northern wetlands are named. Eastern White Pine ( *Pinus Strobus* ). Tamarack, Eastern Larch ( *Larix laricina* ), a deciduous conifer of the bog. (17) Red Maple ( *Acer rubrum* ), the deciduous tree species which threatens the

long-term growth of Black Spruce. (18) Limestone outcrop adjacent to the bog, an indication of the proximity of the northern Limestone Valley of northwestern Connecticut.

Questions: How is the climate of northwestern Connecticut different from New Haven's climate? What types of weather will have greatest impact on this wetland? How have bog plants adapted to living in an environment where the soil is very poor in minerals and nutrients? What are the difficulties faced by the trees growing in this bog? In what ways is this wetland different from the Conn. River floodplain?

***CALCAREOUS RED MAPLE-BLACK ASH-AMERICAN ELM SWAMP, SOUTH CANAAN. CONNECTICUT.***
(1,2) Calcareous swamp of Northwestern Connecticut. These red maple, black ash ( *Fraxinus nigra* ) and American elm trees grow above a limestone bedrock in a highly alkaline soil. (3) Red Maple ( *Acer rubrum* ) saplings showing regeneration of the forest overstory, and herbaceous wetland plants. (4,5) Close-up of American Elm ( *Ulmus americana* ). Stand of Red Maple trees prior to their leafing out. (6) Ground cover of ferns and grasses. (7-9) Tussock sedges and pooled water of the calcareous swamp. Skunk Cabbage ( *Symplocarpus foetidus* ) and tussock sedges ( *Carex sp.* ) of the swamp. Violet (Yiola sp.) in flower. (10) Spreading Globeflower ( *Trollius laxus* ), a rare and local spring-flowering plant of swamps and moist soils. (11) Yellow Lady's Slipper ( *Cypripedium calceolus* ), a late-spring flowering orchid of alkaline swamps (12) Quarry building where limestone chips are prepared for commercial use. Mineral extraction is an important Conn. industry.

Questions: Why are many acid-loving plants unable to grow in this wetland? How does the bedrock found below these wetland plants affect the types of plants growing here? What does it mean to be an "endangered species"? What sorts of animals live in Robbins Swamp? Why are sites such as this often drained for human purposes? How would you protect a site such as this from development?

***ATLANTIC WHITE CEDAR SWAMP, NEW LONDON COUNTY, CONNECTICUT.***
(Photographs are from the Atlantic White Cedar Swamp in South Wellfleet, Massachusetts, accessible by an interpretive trail and boardwalk of the Cape Cod National Seashore.) (1,2) Entrance to the Atlantic White Cedar Swamp. Atlantic White Cedar ( *Chamaecyparis thyoides* ) trees on either side of the boardwalk in the heart of the cedar swamp. (3) Sphagnum Moss ( *Sphagnum sp* .), the predominant ground cover of the cedar swamp. (4) Inkberry ( *Ilex alabra* ), a swamp-loving shrub of the Holly Family. (5) Highbush Blueberry ( *Vaccinium corymbosum* ), a common cedar swamp shrub which produces tasty berries for wildlife and humans. (6-9) Atlantic White Cedar trees. Medium-aged dense tree growth. Older cedar trees of the swamp. Close-up of Atlantic White Cedar bark. This tree is resistant to fire, and it is the source of weather-resistant and rot-resistant cedar shingles. One of the few young, regenerating Atlantic White Cedar trees in this cedar swamp. (10,11) The Atlantic White Cedar canopy. Tall Red Maple trees ( *Acer rubrum* ) grow up into gaps in the canopy.

Questions: Where do white cedar swamps tend to form? What are the most common plants here? In what ways are animals adapted for life in the swamp? Why do these wetlands depend on disturbance?

**Lesson Plan #2**

***IDENTIFYING WETLAND PLANTS.***
Numerous field guides are available for use in identifying herbaceous and woody wetland plants (see bibliographies below). The teacher can locate a nearby wetland and collect cuttings from approximately 20 different plants for identifications. Field guides make use of a dichotomous key for identifications, use flower color to refer the reader to the correct guide pages, or use a key based on flower type, plant type and leaf

type. I have students collect the following information on identified plants: common name, scientific name (genus and species), plant family, preferred habitat, flowering time, page references (from one or more guides), and any notes which are important for understanding how the plant grows in a wetland environment. Ten to fifteen plants are set out in clearly marked stations, and each pair of students has a specified period of time—often five minutes—to make an identification. At the end of this time period, they are instructed to move on to the next station and try to make identification of the plant there. This enables each pair to see and study a number of plants in a class period. The laboratory activity is completed with a run-through of all plants for their identifications by students.

**Lesson Plan #3**

***INVENTORYING INVERTEBRATE LIFE IN A VERNAL POOL.***
Collect a small sample of dead leaves and detritus from the bottom of a vernal pool, and spread the collected material out in a plastic or metal tray. Have students gently probe through the leaf matter to locate any associated invertebrate life. Leaf samples can be made over a period of months, from January through May. The crustaceans (including fairy shrimp), isopods, water mites, mosquitoes, dragonfly nymphs, caddisfly larvae, beetles and bugs, midges, clams and snails can be identified, at least to family level, using one of several guides to aquatic arthropods that are available. Students can attempt to keep invertebrates alive in the classroom, using small fish tanks or other glass containers.

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Pfingsten, Ralph A., and Floyd L. Downs, eds. 1989. Salamanders of Ohio. Columbus, Ohio: College of Biological Sciences, The Ohio State University, 315pp. Best overview on salamander biology I have found, covering eastern species. Recent publication, pulling together recent research and the large body of historical, pre-1950s literature.

Rodgers, John. 1980. The geological history of Connecticut. *DiscoverY* , 15(1): 3-25. Written by Yale's great geologist/map maker for the Yale Peabody Museum's popular publication. Article dates back 15 years, is still the best single overview article on the geology of Connecticut.

Rodman, James E. 1975. Plants in the Peabody. *Discovery* , 10(2): 59-65. Fine introductory article on the Yale Herbarium and its local, American and international collections, by an outstanding former Yale botanist.

Rozsa, Ronald, and Joseph J. Dowhan. 1977. A summary and map of the biotic communities of West Rock Ridge. Connecticut Geological and Natural History Survey, Natural Resources Center, Department of Environmental Protection, 34pp. A DEP publication on West Rock's biotic communities. Excellent on plants, limited on animals.

Rymal, Debbie E., and George W. Folkerts. 1982 (October). Insects associated with pitcher plants (Sarracenia: Sarraceniaceae), and their relationship to pitcher plant conservation: a review. *Journal of the Alabama Academy of Science* , 53(4): 131-151. Dug out on a recent trip to Alabama. Basis for *Sarracenia* write-up in Black Spruce Bog section.

Thorne, Robert F. 1993. Phytogeography. Chapter 6 (pages 132-153 in Flora of North America Editorial Committee. 1993. *Flora of North America North of Mexico* , Volume 1 Introduction. New York: Oxford University Press, 372pp. A fine overview chapter on the geographic distribution of North American flora. In Volume I of the landmark work.

Tiner, Ralph W., Jr. 1984. Wetlands of the United States: current status and recent trends. U.S. Department of the Interior, Fish and Wildlife Service, National Wetlands Inventory, 59pp. Another Tiner publication, this one chronicling the first years of the National Wetlands Inventory. Defines wetlands, describes types of wetlands (see palustrine wetlands section), considers wetlands values. A concluding statement, "Wetland regulations at the Federal and state levels are vital to preserving America's wetlands and saving the public values they provide", conveys just how frightening the present Congressional effort to undo federal wetland regulations really is.

———, and Peter L.M. Veneman. 1987. Hydric soils of New England. University of Massachusetts Cooperative Extension, Bulletin C-183, Amherst, MA, 27pp. Key reference on major types of wetland soils. Delineation of wetland boundaries, table of soil taxonomy, glossary, color photos. Peat and muck never looked so good.

Wentz, W. Alan. Wetlands values and management. c1984. Washington, D.C.: U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency, 27pp. Lists wetlands values and management implications.

Wilson, E.O. 1988. Biodiversity. Washington, D.C.: National Academy Press, 521pp. Many useful chapters on biodiversity. One by Harvard biologist Ed Wilson on current state of biological diversity, one by John Cairns on biodiversity and restoration ecology. A publication of the National Academy of Sciences. Volume II is due out this fall.

## STUDENT READING LIST

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Audubon. 1990 (July). The last wetlands (special issue). Audubon, 92(4): 1-132. Nice pictures, lengthy text. It’s good, though.

Blaustein, Andrew R., and David B. Wake. 1995 (April). The puzzle of declining amphibian populations. *Scientific American* , 272(4): 52-57. Discusses probable causes of worldwide declines in frog, toad and salamander numbers, including habitat loss and global ozone depletion.

Connecticut Department of Environmental Protection. 1992. DEP Wetland Video Series. Hartford: DEP Wetlands Program. I. Wetlands Protection in Connecticut; II. Identifying Connecticut’s Wetlands & Watercourses: Soils and Vegetation; III. Wetlands of New England: Functions and Values. Well made tapes on Connecticut’s wetlands. Good film footage, good narration, good explanation of wetland ecological principles.

Duellman, William E. 1992 (July). Reproductive strategies of frogs. *Scientific American* , 267(1): 80-87. Frogs do it in amazing ways.

Graves, William, ed. 1993. Water: the power, promise, and turmoil of North America’s fresh water. National Geographic, 184(5A): 1-120. Raises a number of controversial issues on water use.

Kusler, Jon A., William J. Mitsch, and Joseph S. Larson. 1994 (January). Wetlands. *Scientific American* , 270(1): 64B-70. Pretty easily read. Says some interesting things.

Massachusetts Audubon Society. 1995. Pond watchers guide to ponds and vernal pools of eastern North America. Lincoln, Massachusetts: Massachusetts Audubon Society (laminated field card) New MAS release. Lots of information. Outstanding illustrations by Barry Van Dusen.

Mitchell, John G. 1992. Our disappearing wetlands. *National Geographic* , 182(4): 2-45. We lose 300,000 acres of wetland every year. Useful foldout cartographic work, beautiful Robert Kincaid-style photographs.

Tiner, Ralph W., Jr. 1987. A field guide to coastal wetland plants of the northeastern United States. Amherst, Massachusetts: University of Massachusetts Press, 286pp. Good for identifying wetland plants.

## CLASSROOM MATERIALS

1. Slide Set, “Connecticut’s Freshwater Wetlands.” A collection of nearly 100 slides showing the plants, animals, geology, topography, and biological structure of six representative wetlands in the state (see above text). The 10-25 slides for each wetland can be used in a single day. No more than two different wetlands should be considered during a day. The slides are intended to generate thinking, reasoning, discussion and debate—and to assist the student in “seeing the forest for the trees”. 2. Freshly collected plant material consisting of woody and herbaceous plants from the wetlands described in this unit. Collected by the teacher (and perhaps students) during the teaching of this unit, the cuttings can be used for identification purposes and discarded, or prepared as herbarium specimens. (See my 1994 unit, “Climate and Ecology”, for further hints on this activity. 3. Vernal pool detritus samples, collected by the teacher in non-destructive fashion from a local vernal pool. These small samples of leaf litter and pond water are to be examined with dissecting microscope and hand lens for the invertebrate larvae and adults found in vernal pool habitat. 4. Current events folder. A collection of newspaper, magazine and journal articles gathered from the New York Times, New Haven Register, science journals and other publications in recent months. They deal with the present debate in legislative circles about wetlands and wetland policy and management.