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Climate and Ecology

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by Stephen P. Broker

Introduction.

Ecology is the study of the relationships of organisms among themselves and with their environments. Ecological theory and experimental work in laboratory and field make extensive use of a number of disciplines in the biological and physical sciences, including evolutionary biology, anatomy, physiology, molecular biology and biochemistry, behavior, geology, and meteorology. The traditional hierarchical nature of ecology includes studies of individuals of the same species living in the same place at the same time (population ecology), multiple populations which live together and interact (community ecology), and the complex interactions in broad geographic regions of living organisms and the abiotic world, including examination of energy flow and nutrient cycling (ecosystem ecology).

This curriculum unit takes an ecosystem approach to ecology, and it is developed in the context of the climatic factors which shape and have shaped the living and non-living worlds. I discuss the relation between ecology and climate by looking at two well-known and extensively studied regions of North America, the temperate rain forests of the Pacific Northwest—specifically, the Olympic Peninsula of Washington State—and the Florida Everglades. With the Olympic Mountains in the extreme northwestern corner of the contiguous United States and the Everglades in the extreme southeastern corner, these ecosystems are so far away from each other as they can be. Yet, they share a number of ecological characteristics, and their climates, somewhat surprisingly, have much in common.

The Olympic Peninsula is approximately 1 1/2 times the size of the state of Connecticut. Within this small area it has marine and estuarine communities, temperate old-growth rain forest, riparian habitat, montane forest, Arctic-alpine communities, and rugged, glacier-covered mountains. In South Florida, the combined Kissimmii River-Lake Okeechobee-Florida Everglades hydrologic system is equally diverse in its plant associations and habitat types. Everglades National Park, which occupies the southern tip of the Florida Peninsula, has marine and estuarine communities, coastal mangroves, coastal prairie, sawgrass marsh, tree islands (including bayheads, willowheads, bald cypress domes, and hardwood hammocks), and pinelands, and in nearby Big Cypress National Preserve there is also deepwater Bald Cypress swamp. Olympic temperate rain forest and Florida Everglades thus are characterized by tremendous spatial heterogeneity in their plant associations.

The diversity of the two North American regions considered here is due in large part to issues of climate. In looking at Olympic Rain Forest and Florida Everglades, I refer to their representative plants and animals and to some of the adaptations which enable these organisms to exist in their respective climates.

The unit is intended for high school students in introductory or advanced biology courses. The unit also is intended to be adaptable to biology courses offered at earlier grade levels. Teachers may use the unit to illustrate a number of themes in ecology, including the broad diversity of climatic regimes within North America (only two being considered here), the diversity of organisms living on our continent, the broad range of adaptive strategies these organisms have for survival and reproductive success, the complex interactions between the biotic (living) and abiotic (non-living) worlds, and the short-term and long-term changes which are regular features of most ecosystems.

The majority of my students have extremely limited travel experience. They know little about their own immediate natural surroundings, including the urban ecology of New Haven and the surrounding forests and coastal and inland wetlands of Connecticut. They know less still about ecological systems of other parts of the country. The concept of being in a forest, a marsh, or on a mountain top often is remote and typically is shaped by images presented by television or film. This unit is intended to acquaint my students with two remarkable ecosystems in the United States and to maximize an appreciation for the different biological regions of our country. While we cannot travel to the Olympic Peninsula or the Florida Everglades, we can learn about these special places through use of slides (available as Teachers Institute Classroom Materials), current newspaper articles, and reference articles and books, many of which are readily available.

I consider a number of philosophical issues to be important in the teaching of this unit. Science education should be interesting and exciting. It should be a cumulative endeavor, starting with reference to previous experiences and using an inquiry method of instruction to promote new experiences. Activities in laboratory and field should be a strong basis for learning. Discrete facts and information should be integrated into a larger picture of patterns and trends. (We want to see the forest as well as the trees.)

In addition, current topics in research should be considered as part of the study. Consideration should also be given to human attitudes and values relating to the subject matter, and to issues of environmental concern, on local, regional, national, and international levels. Finally, the study of science should suggest direct bearing on a student’s life. It should provide motivation for additional study based on a real connectedness to oneself and one’s future life activities. “What’s in it for me?” needs to be an inherent part of the reason for studying a given topic.

Because of shortage of space, this unit does not present information on the complex management issues of the Pacific Northwest old-growth forest and the Everglades or the severe ecological impact that human activity has had in each ecosystem. Teachers seeking information on these subjects will have no trouble finding it, as management of old-growth forest and restoration of the Florida Everglades have become the two highest priorities for integrating issues of ecology and economics in the country today.

The nature of Teachers Institute curricular units—indeed, of all curricular materials—is that they are works in progress, intended for future development, modification and refinement. This unit is no exception. In preparing it, I have devoted much of my writing to a consideration of Olympic climate and ecology, much less to Everglades climate and ecology, even though research time was fairly evenly balanced between the two topics. Some aspects of the unit are well developed, and others require more work, but I have attempted to provide background information and suggest teaching strategies which are representative of my thinking. Future work on this unit will shorten some sections, lengthen others, and strengthen all.

Olympic National Park, Olympic Peninsula, Washington.

The Olympic Peninsula contains the finest examples of Pacific Northwest old-growth forest in North America. On its western mountain slopes and in west-facing valleys, it supports a rare temperate rain forest dominated by coniferous trees which grow to enormous size and age. Fifteen species of trees grow to heights in excess of 200 feet (the tallest approaching 400 feet high). Several species regularly reach ages of 500 to 800 years, and the oldest live to 1200 years. The Peninsula is a 6500 square mile area of land located between 47 and 48 degrees North Latitude and 123 to 124.5 degrees Longitude in the extreme northwestern part of the contiguous United States. (Connecticut is at 41-42 degrees north latitude and is comprised of 4872 square miles of land.) The Peninsula is surrounded on three sides by saltwater: the Pacific Ocean to the west, Juan de Fuca Strait to the north, and Puget Sound to the east.

There is a tremendous diversity of environments on the Olympic Peninsula, due to proximity to the ocean, prevailing winds, and topographic differences. At its center are the Olympic Mountains, dominated by Mount Olympus, which rises to 7965 feet. Other high peaks in the Olympic Range are Mount Deception (7788 feet), West Peak (7365 feet), Mount Anderson (7321 feet), Mount Mathias (7168 feet), Mount Fricaba (7100 feet), Mt. Tom (7048 feet), and Mt. Carrie (6995 feet). Most tall peaks of the range are between 5400 and nearly 8000 feet high. These mountains are significant in rising within 50 miles of the Pacific Coast, an important factor in the development of the climate of the region. The mountains are steep and rugged, and they are dissected by rivers which radiate in all directions.

The Olympic Range was formed geologically when plate tectonic activity brought sea floor shale and sandstone sediments and lava seamounts up and over the continental plate. Subsequent faulting and glaciation led to the formation of today’s sharp peaks and deep valleys. The Strait of Juan de Fuca and Puget Sound were formed by glacial advances and retreats, thereby isolating the Olympic Peninsula from the rest of the continent.

The Olympics remained glaciated or were occupied by treeless tundra until approximately 18,000 years ago. The retreat of the most recent glacial ice covering much of the northern United States occurred by about 12,000 years ago, and for at least the last 6000 years the climatic conditions of the Olympic Peninsula have been ideal for supporting a dense, coniferous, temperate rain forest.

Five major valleys occur on the Olympic Peninsula today. From north to south, they are the Soleduck Valley (which is partly in Olympic National Forest), Bogachiel River Valley, the Hoh River Valley, the Queets River Valley (these three flowing from Olympic National Park), and the Quinault River Valley (in Olympic National Park and Quinault Indian Reservation). Five large lowland, glacially formed lakes occur on the Peninsula: Ozette, Crescent, Cushman, Wynoochee, and Quinault Lakes. Many small lakes are found in the high country. No roads are found running directly through the Peninsula, due to the extremely steep, mountainous terrain of the Olympic Range. State Highway 101 is the only road which loops around the lower mountain slopes to allow travel around the peninsula.

Land ownership on the Olympic Peninsula is by federal and state agencies and private companies and individuals. Olympic National Park (managed by the U.S. Department of the Interior, National Park Service) consists of 921,000 acres, including 876,000 acres of wilderness and 600 miles of trails. Olympic National Forest (managed by the U.S. Department of Agriculture, Forest Service) consists of 632,000 acres, including 250,000 acres owned by a private timber company. The State of Washington Department of Natural Resources controls 364,000 acres and manages it primarily for timber production. Another 236,000 acres of land make up three Indian Reservations, where timber harvesting is the main commercial management strategy. Timber companies own an additional 915,000 acres and have harvested old-growth and second growth forest on these lands.

The two greatest influences on Olympic climate are the Pacific Ocean and the Olympic Mountain Range. The "Westside" of the Peninsula— west-facing mountain slopes and valleys—is the wettest part of the contiguous 48 states, averaging 70-100" of precipitation a year in most areas and reaching 130-145" in the wettest areas. The Quinault Valley in Olympic National Forest, for example, receives 133" annually. In the extreme case, the windward side of Mount Olympus and headwaters of the Quinault and Wynoochee Rivers have received 220" in a single year. These conditions are ideal for development of coniferous rain forest.

The "Eastside" of the Peninsula, however, particularly the lands northeast of the Olympic Range, is an arid rain shadow where one finds coniferous forests tolerant of dry conditions. The town of Port Angeles, where Olympic National Park Headquarters is located, receives 22" of precipitation a year. East of the Peninsula, Seattle, Washington receives 33-42" precipitation a year, slightly less than that of New Haven, Connecticut. Pacific Northwest cities farther inland—Spokane, Washington and Pendleton, Oregon—receive 17" and 12", respectively.

There is a tremendous range in annual precipitation for Olympic Peninsula and regions to the east, and it is due to the Olympic Range intercepting moisture-laden air masses coming off the Pacific Ocean and producing extremely abundant rain to the west and arid conditions to the east. As prevailing westerlies from the Pacific Ocean pass across the Peninsula, the air is forced to rise when it reaches the mountains. For each 1000 feet the air is pushed up, it cools 5.5 degrees Fahrenheit. Less dense air at higher elevations is under less atmospheric pressure. As the air cools, it no longer can hold its water vapor, and moisture drops as clouds or fog. Water vapor which condenses extensively leads to precipitation—rain at lower elevations and snow at higher elevations. On the east side of the mountains, clouds disappear or scattered, light showers are produced.

The effects of the Pacific maritime climate, wind directions, and interaction of winds with peninsula topography change through the year. Winds blow in from the west southwest in winter and from the southwest in spring and fall. There is an extremely mild temperature regime year-round, including mild, wet winters with temperatures usually remaining above freezing, and dry summers averaging 75 degrees Fahrenheit and rarely exceeding 80 degrees. The period June through September has very little precipitation. Olympic temperature maximums during July are lower than maximums of northern Maine or Minnesota. Relative humidity is at 90% in early morning and decreases to 50-60% in the afternoon. Periodic summer winds from the northeast, called chinook winds, bring warm, dry conditions and are closely associated with the largest fires of the Peninsula.

A climatic belt running around the world at 40 to 60 degrees north latitude passes across the Pacific Northwest. During spring and summer the jet stream brings warm, subtropical air masses to this region, and in fall and winter cold polar air masses arrive. Moist polar winds reach the Pacific Northwest in December, the wettest month of the year. Winter air masses move counterclockwise in direction, and they produce cloudy, showery, or unstable weather. There is an unpredictability to both seasonal weather systems, resulting in year-to-year variation in weather conditions.

The major air masses reaching the Olympics during the year are the Pacific High of late spring and early summer, and the Aleutian Low of fall and early winter. The Pacific High is a fair weather system which moves eastward from Hawaii to North America. This high pressure system prevents most rain storms from reaching the Peninsula in spring and summer. The Aleutian Low brings winter storms down from the Gulf of Alaska. These high and low pressure systems produce an alteration between dry summers and wet winters on the Olympic Peninsula. Summer months, especially July and August, are a time of drought, when less than 10” of total precipitation reaches the Peninsula. Further south, in southwestern Oregon and northwestern California, the dry season persists for six months. Winter months are characterized by heavy precipitation, which peaks during the month of December.

In winter, freezing temperatures are reached fewer nights along coastal Washington than occur in northern Louisiana, which at 31-33 degrees north latitude is located 15 degrees to the south. This illustrates the considerable moderating influence of Pacific Northwest climate. Temperatures in lowland forests remain just above freezing most of the time. It becomes cooler further up mountain slopes, where precipitation falls as snow. With increased elevation, even more severe climatic conditions prevail. Trees are fewer, shorter, more misshapen. One hundred year old trees may be 3 feet tall. At timberline, no trees grow. Wildflowers predominate in this Arctic-alpine zone. The frost season of winter is quite short. However, there are cloudy skies many days of the year and lots of drizzle. Hurricanes and tornadoes do not occur, but winter storms may be severe.

During late summer and early fall, fog is a common feature of western mountain slopes and valleys facing perpendicular to the coast. Fogbanks develop at night along the Pacific Coast as air passing over ocean water is cooled. When the fog reaches the coast and passes over land and up mountain slopes, it warms and the fog dissipates by mid-day. Fog is believed to increase annual precipitation in the Westside by so much as 40” a year. During winter periods of high pressure, moist marine air blankets Olympic Westside valleys with low clouds and drizzle, while higher elevation peaks and slopes—those above 3000 feet—remain clear. Thus, there is a unique summer-winter split in precipitation.

The unusual feature of Olympic Peninsula climate, then, is that it is a temperate climate with dry summers and wet winters, summer droughts occurring annually and winter precipitation being very heavy. Most temperate parts of North America have precipitation distributed fairly evenly through the year. Most climates with distinct wet and dry seasons, on the other hand, are tropical, and they do not have recognizable summers and winters. The Olympic Rain Forest has a temperate climate with several of the most important seasonal and rainfall features usually associated with the tropics.

North America’s temperate rain forests are found only along a narrow band of the Pacific Coast and a short distance inland, from southeastern Alaska through British Columbia, Washington, Oregon, and to northwestern California. Outside North America, temperate rain forests are found only in southern Chile, western Scotland, portions of Norway, the northern Honshu coast of Japan, and New Zealand.

Four distinctly different habitats are found in Olympic National Park and Olympic National Forest. They are the marine and estuarine coastal areas, the temperate rain forest, the alpine meadows and unvegetated glacial peaks, and rain shadow forests and fields. The marine environment supports a tremendously rich and diverse biota, ranging from whales and dolphins to seabirds, marine invertebrates, and sea weeds and microscopic plankton. The temperate rain forest, equally diverse in its biota, is the subject of much of the discussion which ensues. It is located on lower Olympic slopes and in west-facing valleys of the Westside. Alpine meadows take over where trees no longer grow, at upper elevations of the Olympics. Rain shadow forests cover the northeastern slopes of the Olympics.

Considering only the forested regions of the Olympic Peninsula, six major vegetation zones are recognized, their distributions determined by climatic conditions including summer and winter temperatures, annual precipitation, presence of fog, and by elevation, and their names largely determined by the predominant coniferous species growing there. They are the Sitka Spruce, Western Hemlock, Silver Fir, Mountain Hemlock, Subalpine, and Douglas-fir zones. The Sitka Spruce Zone is found on the Westside, where maritime influences are greatest. It extends to just 600 feet elevation and requires in excess of 100” annual precipitation and extensive summer fog. Sitka Spruce is the dominant tree.

The Western Hemlock Zone is found above the Sitka Spruce Zone on the Westside and over an extensive area of lower slopes on the Peninsula’s north, east, and south sides. It extends to 2000 feet elevation in wetter areas of the Peninsula and to 4000 feet in drier areas. Conditions thus range from very wet to moderately dry. Fire is a common feature of this zone. In most portions of the zone Douglas-fir is the dominant tree species. The Silver Fir Zone is found on mid- and upper mountain slopes above the Western Hemlock Zone, wherever moist to moderately dry sites are found. Western Hemlock and Silver Fir are the most abundant trees.

The Mountain Hemlock Zone is on higher elevations of the Olympics, extending up to subalpine regions. Silver Fir and Mountain Hemlock are the abundant tree species, and Alaska Yellow cedar is a subdominant in some areas. This zone is distinguished from the previous one by greater elevations and deeper snowpack in winter—up to 10 feet deep. The Subalpine Fir Zone is limited to the northeastern part of the Peninsula at elevations of 4500 to 6000 feet. Snow accumulation in winter is less extensive than in the Mountain Hemlock Zone. Krummholz trees are found here (stunted trees with branches growing only on the downwind side of the trunk), growing in scattered clumps. A very restricted Douglas-fir Zone is found in the northeast where conditions are the driest. Douglas-fir dominates here. Douglas fir, while occurring in several zones mentioned above, is a far more dominant tree in old-growth forests of inland Washington and Oregon. The southernmost region of temperate rain forests, that of northern California, has Coast Redwood as the dominant tree species; these are the tallest trees in the world.

Plant and Animal Adaptations to the Temperate Rain Forest.

At least 15 species of Westside conifers grow to heights of 200 feet. Their huge size permits maximum exposure to sunlight during the year, especially when light levels are reduced in winter. There is also maximum exposure to moisture. The tallest species is Douglas-fir, the most valuable tree in terms of world timber commerce. It reaches 330 feet and 16 feet in diameter. It occurs in many kinds of ecosystems. Unlike most giant conifers, which begin life in shaded conditions, Douglas-fir is dependent on fire and it grows best in sunlit openings. It grows rapidly on good sites. The wood is used for framing lumber and plywood.

Western Red cedars are found in moister parts of the Pacific Northwest. They are typically scattered among other conifers. Sometimes they form pure stands in low spots where roots of other conifers would drown. This is a shade-tolerant species. It grows to 200 feet and 20 feet in diameter. It is fairly slow-growing. The wood is easily split, is decay-resistant, and is used for making shingles.

Western Hemlock is a moisture-loving species. It is probably the most abundant conifer from coastal Oregon to southeastern Alaska. It grows to 215 feet high, with a maximum diameter of 10 feet. It grows faster than Western Red cedar. Western Hemlock seedlings often blanket nurse logs. They are very shade tolerant. They can form extensive pure stands. The tree species is cut extensively for lumber and paper pulp.

Sitka Spruce towers over red cedars and hemlocks in foggy coastal forests, too wet to favor Douglas-fir. The tree reaches 300 feet in height and 17 feet in diameter. It is fast-growing and can reproduce in forest shade. Many gain an initial foothold in the forest on nurse logs. Sitka Spruce is a strong, light wood.

Additional species of old-growth conifers include Sugar Pine (maximum 250 feet high and 18 feet diameter), Ponderosa Pine (232 feet high, 8 feet diameter), Western White Pine (239 feet high, 7 feet diameter), Noble Fir (260 feet high, 9 feet diameter), Pacific Silver Fir (245 feet high, 8 feet diameter), Grand Fir (250 feet high, 5 feet diameter), White Fir (230 feet high, 6 feet diameter), Incense Cedar (225 feet high, 12 feet diameter), and Port Orford Cedar (240 feet high, 11 feet diameter). The uniqueness of the Olympic Rain Forest is illustrated by the number of world record sized trees found here. The world's largest Yellow Cedar, Western Hemlock, and Subalpine Fir trees are found in the Olympic Range.

Non-conifer trees include Bigleaf Maple, Red Alder, Vine Maple, and Black Cottonwood. Shrubs include Devil's Club and huckleberry. Herbaceous plants include ferns, mosses, club mosses, and lichens. An interesting adaptation to the low light levels and levels of precipitation reaching the forest floor is that a number of plant species—more than 100 in all—found in the Olympic rain forest are adapted to life up in the trees with no root connection to the forest soil. These epiphytes, plants which do not come into contact with the ground but are not parasitic, include liverworts, mosses, club mosses (*Selaginella*), lichens, and ferns (licorice fern and sword fern). They collect their water by soaking it up in soft plant tissues. Big-leaf Maple is the deciduous tree most likely to be covered with mats of epiphytes.

The unique climate and ecology of the Olympic Peninsula have produced a number of animals which are particularly well adapted to their surroundings. Several of them are endemic species or subspecies, found only in the Olympics. Two endemic species of fishes are Beardsley Trout (a type of rainbow trout) and Crescenti Trout (a cutthroat trout). The endemic species and subspecies of amphibians are the Olympic Salamander and Cope's Giant Salamander. Olympic Salamander inhabits mountain streams and creeks.

There are no endemic bird species, as these animals have the ability to disperse to other regions -of the Pacific Northwest, North America, and wider geographic areas. However, several species are recognized as indicator species of mature, old-growth forest. The Spotted Owl is an endangered species which has highly specialized habitat requirements—dense, mature stands of trees and a minimum of 3000 acres of contiguous forested land with mature, multi-layered and multi-aged canopy, large snags, deformed branches for perches, and internal defects for nest cavities. The Marbled Murrelet is an alcid (puffin relative) which spends most of its life as a pelagic (oceanic) species but which nests fairly exclusively in old-growth forests. It constructs its nest 180 or more feet up in old-growth trees which are 300 to 600 years old. This extremely specialized nesting bird is the last species of North American bird to have its nest discovered (1974). The Pileated Woodpecker, a species also found in Connecticut, is not a rare species in the Olympics, but it does require mature habitats and thus is an indicator species of the ecological balance and health of the forest.

Olympic mammals include the Roosevelt Elk and Columbia Blacktailed Deer. These animals have seasonal migrations to open or forested areas, based on availability of browse and winter forest cover. Their movements are closely tied to the climate cycle. Several endemic species or subspecies of mammals are found in the Olympics, including the Olympic Marmot, Olympic Chipmunk, Yellow Pine Chipmunk, Olympic Snow Mole, and Short-tailed Weasel. They have specific habitat requirements, such as alpine and subalpine habitats of the marmot.

The Florida Everglades.

The Everglades of the southern portion of the Florida Peninsula is a spatially and temporally heterogeneous region of plant communities which derive their diversity from climatic factors and periodic severe weather events. Florida is an extremely flat land underlain by limestone deposits, characterized by shallow soils, affected by a 12,000 year history of steady sea level rise. The Everglades ecosystem—the most intact portion of which is found in Everglades National Park—is based on sheet flow of an extremely shallow, wide, slow moving body of water. Water flows through the Everglades from Lake Okeechobee and the Kissimmii River System to the north. It empties out in Florida Bay, which is itself a highly important ecosystem. The water moves at a rate of a few feet a day in a river which is up 65 miles wide and no more than 6 to 12" deep. The extremely slow sheet flow is due to a tilted substrate which dips no more than one foot for every ten miles to the south.

Limestone bedrock underlies the Everglades, limestone having been deposited in earlier geologic times when South Florida was below sea level. The present plant associations of the Everglades—mangroves, coastal prairies, tree islands, and sawgrass marshes are approximately 5000 years old, according to geologic and pollen studies. Florida's climate has both temperate and subtropical features. The Everglades are on the southern edge of the North American temperate region where broad-leaved temperate species of plants are found, as well as the subtropical zone of the Caribbean and the West Indies. The plants and animals of the Everglades combine continental and West Indian origins.

South Florida has a summer wet season and a mid fall to late spring dry season. Greatest levels of precipitation are in the period June through September, with winter dry season or drought occurring during November through May. Coastal flooding occurs with summer and fall hurricanes. In times of drought, fires play an important role in Everglades ecology in sawgrass marshes, pinelands, and hardwood hammocks.

The annual hydro-period of the Everglades is critical to the distributions, feeding behaviors, and reproductive success of a number of species of vertebrates, including the American Alligator, American Crocodile, Snail Kite (a beautiful hawk with highly specialized diet), Wood Stork, numerous other colonial wading birds, River Otter, White-tailed Deer, and Florida Panther. Rainfall patterns appear to be associated with 5 to 8 year global climate cycles, including the El Nino-South Oscillation (ENSO) events originating in the Pacific Basin—which I will not describe here.

Average temperatures in the Everglades are warm year-round, including summer and winter daily maximums and minimums. Because occasional freezes occur in winter, minimum temperatures have the greatest effect on the geographic distribution of Everglades plants and animals. Most water enters the Everglades system through thunderstorms (either here or further north). Most water leaves the system through evapotranspiration, which is greatest in the late spring and summer growing season. Precipitation results from warm maritime air coming in from the Caribbean and cold continental air from further north.

The hurricane season is from June through October. Every year since the mid 1800s has had at least one hurricane strike the Florida peninsula; often there are several hurricanes in a season. Some of them have severe effects on Everglades ecology, particularly the (coastal) forested areas of the mangroves, pinelands and hardwood hammocks (see slides for descriptions of these plant communities). The most common severe weather events in the Everglades, then, are floods, droughts, freezes, hurricanes or tropical cyclones, and fire. I develop further connections between Everglades ecology and climate in the Sample Lesson Plans section of the unit and through available classroom materials.

Classroom activities and sample lesson plans.

Slide Set #1 Olympic Peninsula, Washington **.**

This slide set is intended for showing during one class period. For each slide, a question is posed to the students. The question should generate student discussion about issues of climate and ecology, and about those characteristics of plants and animals which make them well adapted to their surroundings. A worksheet based on information presented below is to be completed by students as they view and discuss the slides.

Slide 1. Glacier-covered peaks of Mount Olympus, Olympic Peninsula, Washington. Mount Olympus is 7965 feet above sea level, four times higher than any Connecticut mountain. What conditions of climate would you expect here?

Slide 2. Pacific coast of the Olympic Peninsula; driftwood logs piled on beach. Why are there so many logs on this beach, and from where did they come? (old-growth logs, washed here.)

Slide 3. Olympic National Park stream bed with fallen logs. Fallen logs are abundant (and important) on the Olympic forest floor and in rivers. What value do these logs have for the animals that live in the river?

Slide 4. Old-growth forest of the Pacific Northwest. What does an old-growth forest have that makes it “old-growth”?

Slide 5. The Hoh River, blue with transported glacial polish. The waters of this river are cloudy and blue-colored. What causes the water to appear this way? (suspended particles of glacial mill.)

Slide 6. Hoh River Valley—glacially carved valley. Notice the deep, U-shaped valley. How could such a valley have formed?

Slide 7. Arctic-alpine meadows of the Olympic Mountains; alpine wildflowers. What conditions are needed by wildflowers in order for them to grow? What adaptations must these alpine plants have to succeed high in the Olympic Mountains? (Ultraviolet light tolerance, extreme cold and wind tolerance, snowpack tolerance, short growing and flowering season.)

Slide 8. Olympic timberline—krummholz trees. What is unusual about the appearance of these trees? Why are the branches growing only on one side of the trunks? (protection from extreme winds.)

Slide 9. Interpretive sign—What Are Temperate Rain Forests? Make a list of the climatic factors that are required for the development of a temperate rain forest.

Slide 10. Fog bank rolling in from the Pacific Ocean. Fog can increase the level of precipitation in a temperate rain forest by 40” a year. How do plants (trees) get water from fog?

Slide 11. World’s largest Sitka Spruce (*Picea sitchensis*)—detail of trunk with person in front for scale; Lake Quinault area, Olympic National Forest. What competitive advantage must this tree species have over other species in the rain forest? (It grows best in fog and moist air, outgrowing in height all other trees.)

Slide 12. World’s large Sitka Spruce—full tree with person at base for scale. Describe the overall appearance of this tree.

Slide 13. Western Red cedars (*Thuia plicata*), with person to show scale. This unusual shaped tree is three trees fused together, producing a growth that is wider 30 feet up in the air than it is at ground level. Western Redder is the co-dominant tree species of the rain forest. How tolerant do you think it is of shade?

Slide 14. Old-growth forest. Describe the forest floor. Why do you think there are few plants of any size growing on the ground?

Slide 15. Several hundred year old trees germinated on nurse log. Notice that these trees are all large, and they all grow in a row. Explain how this might have come about.

Slide 16. Nurse log with conifer saplings. Estimate how many young trees are growing out of this log. One hundred years from now, how many do you think there will be still alive? Five hundred years?

Slide 17. Big-leaf Maple (*Acer macrophyllum*) in Hall of Mosses, Hoh Rain Forest. This maple is usually covered by epiphytes, plants that grow up in the air and have no roots reaching the ground. What problems do epiphytes face in making a living?

Slide 18. Club mosses (*Selaginella oregana*) hanging from Big-leaf Maple. How might this plant obtain water in the rain forest?

Slide 19. Club mosses and other old-growth forest epiphytes. In addition to club moss, what other plants grow up in these trees?

Slide 20. Detail of club mosses. Describe the club moss.

Slide 21. Ancient hollow snag. Many animals live in the old-growth forest. What types of animals might be found to live here?

Slide 22. Forest floor, with 200 foot fallen log. This tree might take 300-500 years to decay completely. What does that tell you about the nutrients of the forest?

Slide 23. Ancient hollow stump. Estimate the age of this stump.

Slide 24. Hoh River gravel beds. What observations can you make about this scene? (water-transported gravel, periodic flooding, unstable environment for growth of trees)

Slide 25. Red Alder (*Alnus rubra*) and Black Cottonwood (Populus trichocarpa) flood plain forest. How are these trees adapted to life near the river? (high tolerance of periodic and regular flooding, ability to grow in oxygen-poor soil)

Slide 26. Bracket fungi on large snag. What is a decomposer?

Slide 27. Old-growth lichen, *Lobaria oreoana* . Lichens consist of an alga and a fungus living together in a symbiotic relationship (perhaps not purely symbiotic). How might they help each other to survive up in trees?

Slide 28. Devil’s Club, *Oplopanax horridum* . Why do you think the species name of this plant is “horridum”?

Slide 29. Ground cover plant, sorrel (*Oxalis sp* .) One of the few abundant forest floor plants. What allows it to grow here?

Slide 30. An endemic Olympic mammal, the Olympic Marmot (*Marmota*). Why might the Olympic Marmot be different from marmots living in other parts of Washington State and the Northwest? (geographic isolation and evolution; consider isolation of the Olympic Peninsula from the rest of the state, especially in light of glaciation—different environmental conditions over time.)

Slide 31. Columbian Black-tailed deer (*Odocoileus hemionus columbianus*). What close relative lives in the east?

Slide 32. Roosevelt Elk (*Cervus elaphus roosevelti*). Unlike most elk of other parts of the west, Roosevelt elk are sociable animals. What advantages are there to sociability in deer family members?

Slide 33. Olympic Peninsula forest clearcut. How do people make a living in the Olympic Peninsula? What effect does the industry of the peninsula have on the old-growth forest?

Slide 34. Olympic Peninsula lumber mill operation. How do we use trees after they are cut down?

Slide 35. Fifty year harvesting rotation of former old-growth forest. Can old-growth forest develop here in the future? (Not with the current management plan for this tract of land.)

Slide 36. Old-growth forest of the Pacific Northwest. Old-growth forests are being managed for multiple use—by different people for different purposes. Of what value is this forest? How do we balance competing interests in old-growth forest?

Slide Set #2 Florida Everglades.

This slide set is intended for use in one class period. It is best spaced several days before or after the use of slides from the Olympic Rain Forest. Inquiry questions and worksheet questions are suggested below.

Slide 1. Map—Everglades National Park, Florida. When you hear the word "Florida, " what does it mean to you? What do you know about the State of Florida?

Slide 2. Everglades National Park, Royal Palms entrance. The rock shown here is the bedrock underlying all of South Florida. What type of rock is it, and how did it form? (Limestone deposited on former sea floor.)

Slide 3. Shallow limestone bedrock. Describe one or more ways in which this land could have previously been sea floor. (Discussion should lead to consideration of changes in sea level through time.)

Slide 4. Ancient coral reef inland at Everglades National Park. This "fossil" reef is several feet higher than surrounding land. How does the vegetation here differ from plants nearby?

Slide 5. The Anhinga Trail, Everglades. The Anhinga Trail is a popular spot for viewing Everglades wildlife. What conditions are available here for different types of animals?

Slide 6. Taylor Slough Boardwalk. Two "sloughs", or slow-moving, shallow rivers, are found in the Everglades, Shark River Slough and Taylor Slough. How are these sloughs different from rivers you are used to seeing? (Average depth is 6-12", greatest width of river is many miles, speed of flow is measured in feet per day.)

Slide 7. Taylor Slough water depth gauge. Measuring the depth of water in the Everglades is a regular activity. What does this suggest about the climate in South Florida?

Slide 8. Everglades dam, canal, and levee system. All water flow through the Everglades is controlled by man. Why has our activity of the past has led to such control of water flow?

Slide 9. “River of Grass”—the sawgrass marsh community. What would be the effect of hurricanes, flooding, drought, and fire on this community?

Slide 10. Periphyton beds in sawgrass marsh. Explain how this mixture of more than 200 species of algae can serve as the base of the food chain.

Slide 11. Hardwood hammock community. Tree islands inhabited by mahogany, gumbo-limbo, live oak, mastic, and other broad-leaved trees are called hardwood hammocks. Suggest a way in which a hammock might develop in an otherwise flat, marshy environment. (from a lodged piece of peat, wind throw, or other bump in the landscape.)

Slide 12. Largest Mahogany tree in United States. This tree, though hurricane damaged, is the largest mahogany in the U. S. Most Florida mahogany trees have been cut down. Why? (For their extremely valuable, beautiful wood—furniture making.)

Slide 13. The Gumbo Limbo Trail. Describe the bark of the Gumbo Limbo tree. This is a tropical species, found commonly in the West Indies/Caribbean area.

Slide 14. Pinelands forest. How might these Florida Slash Pine trees be resistant to fire? Their continued existence in the Everglades is dependent on periodic fires.

Slide 15. Pinelands pitted limestone bedrock. Walking across the pinelands is very difficult and hazardous, as the limestone bedrock is pitted everywhere with small to large holes. How do holes get eaten in limestone rock? What does this tell you about the effect of acid materials on limestone?

Slide 16. Everglades willowhead. Large holes developing in limestone bedrock are called solution holes. Where they fill up with water during the wet season, willowheads develop. Willow trees get sufficient water to grow here. When the dry season comes, surrounding land becomes dry but willowheads continue to hold pools of water. What animals might be attracted to willowheads in the dry season?

Slide 17. Cypress Dome. Depressions in limestone bedrock collect water and allow the growth of water-loving Bald Cypress trees. The resulting dome-shaped structures are called cypress domes or cypress heads. Why are the trees taller in the center of the head? (The water is deeper here, and peat deposits are thicker.)

Slide 18. Dwarf Cypress forest. These Bald Cypress trees are stunted forms of the cypress that grows in domes or heads. Why do they not gain greater height where they are growing here? (They are stunted by a shortage of water.)

Slide 19. Big Cypress National Preserve—Bald Cypress trees. Northwest of the Everglades is Big Cypress. Here, the trees grow the tallest. What can you predict about water level in Big Cypress? (It is deeper than Everglades water.)

Slide 20. Bald Cypress knees. Trees which grow in standing water face a hazard—soggy, oxygen-poor soil. How might these cypress “knees” assist the trees in getting oxygen for root and stem growth? (Absorption of oxygen from the air.)

Slide 21. Coastal Prairie. Inland from Florida Bay (south of the Everglades) but along the coast is a plant community called the coastal prairie. Consider the effects of hurricanes and severe storms on this community. With what special climatic and ecological conditions do the plants which grow here have to cope?

Slide 22. Coastal Prairie plant community—glasswort (saltwort). Periodic hurricanes deposit peat (partly decayed plant matter) and marl (a muddy mixture of limestone and clay) on coastal prairies. They also force saltwater inland. What effect does this have on plants able to grow in the coastal prairie? (Must be salt-loving.)

Slide 23.. Epiphytic bromeliad. Many Everglades are adapted to life up in the air. How does this plant gain access to water and soil?

Slide 24. Red mangrove community. Mangroves have developed prop roots to enable them to live successfully in coastal and inland saltwater regions. Explain why it is that prop roots are an important ecological adaptation.

Slide 25. Hurricane Andrew damage to pinelands. Two climatic and weather occurrences are common to the pinelands: regular hurricanes, and regular fires. How do hurricanes control the appearance of the pineland forests?

Slide 26. Uprooted Florida Slash Pine—Hurricane Andrew damage. What can you say about the pineland soils? (Extremely shallow)

Slide 27. Hurricane Andrew damage to the Gumbo-Limbo Trail. What has happened to these pine trees?

Slide 28. Hurricane damage to coastal prairie. Ecologists refer to the spatial (area) and temporal (time) diversity of the Florida Everglades. With the possibility of flood, drought, hurricane damage, or fire affecting the different regions of the Everglades at different times, great variability results in the plant and animal communities which are present.

Slide 29. Fire in the pinelands. How can fire promote growth of pine trees and prevent other species from coming into this region?

Slide 30. Liguus fasciatus tree snails. 52 color forms have been identified here. The snails live on tree islands among the deciduous trees growing there. How does this illustrate evolution?

Slide 31. Zebra Butterfly. A tremendous diversity of invertebrates is found in the Florida Everglades, including this neotropical butterfly species. Butterflies usually spend part or all of their life cycles in close association with specific host plants.

Slide 32. American Alligator. In periods of drought, willowheads and bayheads remain filled with water because they are enlarged by the activities of alligators. How do you think an alligator might be able to form “alligator holes” in the Everglades?

Slide 33. Florida Garfish. This consumer eats certain foods, and it serves as food for other animals. What does the garfish eat, and what eats the garfish?

Slide 34. Mrazek Pond birders and birds. Develop a list of reasons why thousands of people visit the Everglades each year.

Slide 35. Anhinga drying wings. Why must the Anhinga, a bird which uses its long bill to spear fish for food, periodically dry its wings from a tree perch?

Slide 36. Common Ibis. What adaptations does this bird have for obtaining food?

Slide 37. Tricolored Heron. How is the bill of the Tricolored Heron different from the bill of the ibis?

Slide 38. Wood Stork. Wood Stork populations are dependent on annual drying out of Everglades habitats, so that food sources can become more concentrated in pools of water. Explain how you think Wood Storks collect their food.

Slide 39. Statue of the Florida Panther—Royal Palm Visitor Center. In which Everglades communities would you expect to find the endangered Florida Panther, and why?

Slide 40. Sunset at Flamingo, the southern tip of the Everglades.

Keeping a Weather Log.

Students collect weather reports from the *New Haven Register* or the *New York Times* to establish a weather log. T is can be done as a class effort or with multiple teams of four students. Maintain tables for maximum high and maximum low temperatures, precipitation, wind direction, and high and low pressure systems for Connecticut or elsewhere. Plot data on graph paper for temperature and precipitation. These data are compared with climate data for Connecticut available from the National Weather Service. Discussion of weather data should bring out the fact that weather conditions are highly variable from one year to the next. Average conditions are determined by keeping records over many years. Consider also the biological adaptations of Connecticut's plants and animals to our northern temperate climate, including deciduous trees shedding leaves, annual, biennial, and perennial growth habits, and animal hibernation and migration.

Preparing Herbarium Sheets.

Students develop an awareness and knowledge of local plants by collecting samples of woody and herbaceous plants from nearby forested areas, such as East Rock Park. Woody plants should include representative deciduous trees (oaks, hickories, maples, beech, chestnut, birches, etc.) and coniferous trees (pines, hemlock, spruce, larch, red cedar), as well as herbaceous plants (annuals, biennials, perennials). One or more field guides to trees and shrubs and wildflowers are needed for field and laboratory work.

In collecting specimens, choose tree branches which have average-sized leaves which will fit on standard-sized herbarium paper. Keep specimens fresh by placing them in a vasculum or similar sturdy container. Place in a press between newspaper and blotting paper, using cardboard dividers. Dry for several days before mounting on herbarium paper with Elmer's glue. Label sheets as to species (common and Latin names), locality, habitat type, date of collection, name of collector, and additional notes of interest. Store specimens in a box or cabinet where they are protected from damage.

Lighthouse Point Park Fall Hawk Watch.

Lighthouse Point Park is one of most important hawk migration spots in the Northeast. Each September through November more than 30,000 raptors are counted migrating over New Haven's Lighthouse Point as they fly south to wintering grounds. Migrant raptors include vultures, Osprey, eagles, harriers, Sharp-shinned Hawk, Cooper's Hawk, Broadwings, Red-tails, kestrels, merlins, and Peregrine Falcon. Hawk watch activity begins at around 5:30 A.M. and continues through Noontime. Hawk numbers are recorded during half hour intervals.

Take students to Lighthouse Park for two or three morning hours of observation. Prior to the trip, review handout materials relating to diurnal raptor identification and migration patterns. Review field marks for birds flying overhead, such as dihedral wing shape and dark and light patterns on vulture wings, dihedral wings and white upper tail coverts for harrier, bull-headed appearance and rounded tail tip of "Coops", smaller head and square tail tip of Sharpies. At Lighthouse, record species and numbers of birds seen every 30 minute interval. Check results against records made by the Lighthouse Hawk Watch experts. Record wind direction and speed, condition of sky, and overall flight patterns of birds as they pass over the Morris Creek marshes and Lighthouse Park. Special attention should be given to use of binoculars, several pairs of which would be very useful for the group.

Binoculars should not be used to search the skies for birds. Rather, make a sighting with the naked eye, and then try to locate the bird with binoculars. If the bird is not found within the first 4-5 seconds of looking with binoculars, take the binoculars down and relocate the bird with the naked eye. Then, try again with the binoculars. Useful landmarks such as trees on the horizon or clouds in the sky can help tremendously in locating the hawks, which are usually seen as small specks in the sky by experienced hawk watch observers. Locate the large tree or cloud with the naked eye, put binoculars up to the eyes and find the reference point, then move the appropriate direction and distance to where the bird is believed to be. Such field skills as power of observation, recognition of field marks, and recognition of bird behavior can be sharpened on the trip.

As monthly data are obtained from the hawk watch group, large and small flight days should be matched against weather systems of Connecticut from weather reports collected from the newspaper. Weather conditions suitable for flight southward should be noted. Hawks fly south when weather systems permit. Strong winds from the southwest prevent all but the strongest fliers, Osprey and Peregrine Falcon, from passing overhead at Lighthouse Park.

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STUDENT READING LIST

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CLASSROOM MATERIALS

1. Slide Set *1. Everglades National Park, Florida. A set of 36 color slides taken by the author in the Florida Everglades and Big Cypress National Preserve in February 1993. Slides are intended for use in the classroom in a structured setting using an inquiry approach to learning. Each slide is shown to students with a question posed to them. Discussion is initiated to draw on students' interpretation of ecological/climatic concepts illustrated. After suitable discussion, additional information is provided to students as needed. A worksheet is completed by each student during the slide presentation. It is submitted at the end of class.

2. Slide Set *2. Olympic National Park, Olympic Peninsula, Washington State. A set of 40 slides taken by the author in Olympic National Park and Olympic National Forest in August 1993.

3. Freshly collected plant material consisting of woody and herbaceous plants from the oak-hickory forests of Southern Connecticut. Collected by the teacher and students during the teaching of this unit, the herbarium specimens are representative of forest plants found in our region.

4. Herbarium paper for preparing herbarium specimen sheets, and a plant press.

6. National Park Service maps for Everglades and Olympic Parks.

(Maps and figures available in print form)