The Pine Barrens:
up close & natural

A Guide for Teachers

Carleton Montgomery & Russell Juelg
The Pinelands Preservation Alliance

Photography by
Mitchell Smith Natural Art Films

Funded by a grant from
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ACKNOWLEDGEMENTS

This guide for teachers was made possible, first and foremost, by those who enabled the Pinelands Preservation Alliance (PPA) and Natural Art Films to create *The Pine Barrens: up close and natural* through their generous donations to the project: David O. Johnson provided the concept, inspiration, and initial funding to make the film. The J.M. Huber Corporation, Public Service Gas & Electric (PSE&G), Conectiv, and the members of PPA provided the rest of the funding we needed to complete the film. In addition to supporting the creation of the film, the J.M. Huber Corporation has funded and encouraged the creation of this Teachers' Guide with an additional grant. We are very grateful to all those, including our members, who provided the funds needed to make this project a reality.

We at PPA also wish to thank Mitchell Smith and Natural Art Films for the superb job they did in making *The Pine Barrens: up close and natural* - the very first true nature film about the New Jersey Pine Barrens. Mitch also has helped us to create this Teacher's Guide by providing stills from the film.

Finally, we wish to acknowledge the invaluable help of the educators who have contributed their insights and constructive criticisms as we developed the Teacher's Guide. Kevin Kopp, an environmental educator, has served as our consultant on this project and is continuing to work with PPA to develop lesson plans around the themes of the film. The following educators have volunteered their time and expertise to review and provide suggestions on the Teacher's Guide, and we very grateful for their help:

Melissa Chin, Animal Husbandry Department, Liberty Science Center

Solveig Jakobsen, Medford Memorial School

Bunny Jaskot, Scotch Plains-Fanwood High School

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Table of Contents

How To Use This Guide
Electronic Edition

This guide is designed to help teachers and other educators use the film, *The Pine Barrens: up close and natural*, by providing more detailed information on the ecology, history, land use patterns and conservation efforts for the New Jersey Pine Barrens. Ther guide consists of a copy of the narration transcript from the film and a more in-depth discussion of the Pine Barrens, as well as appendices listing additional print and web resources and scientific names for the species discussed in the guide.

There are two ways to get into the material:

(1) Start with the narration transcript to find the topics you are interested in, then click the link for each topic to jump to the relevant section of the in-depth section.

(2) Dive directly into the in-depth discussion, which is designed as a unified, stand-alone introduction to the Pine Barrens.

For more information, investigate the web and print resources listed in the appendix.

Please contact us with your thoughts, corrections, experiences and other feedback! We need your help to improve our work product and be the most valuable resource we can.

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click on the logo below to visit our web site at www.pinelandsalliance.org

The Pine Barrens: up close and natural
Narration Script

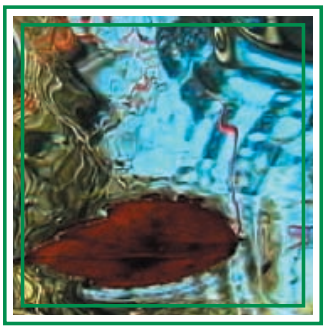
A Pinelands forest at night. The warmth of June has triggered a chorus. Voices of Pine Barrens Tree Frogs echo through the woods. While the voices seem plentiful here, they are, in fact, so rare they call in only a handful of places on earth.

One of these places is the Pine Barrens of New Jersey. This tiny Tree Frog has become an emblem of New Jersey's Pine Barrens. For this creature as for many other rare species, the Pine Barrens is its greatest surviving stronghold. The chorus of tree frogs has been heard here on summer nights for thousands of years. It is now the chorus of an endangered species

Small enough to perch on a leaf, males climb low lying limbs to call out. When a female accepts his invitation, courtship and mating is carried out in a nearby pond or bog. Here the eggs will hatch and a new generation of frogs will come forth.

For more, click here and here and here.

For links, click here.



The water that nurtures each generation of frogs defines the nature of this unique landscape. This water is largely hidden. Except where it breaks the surface to form streams and wetlands, the water is concealed within deep layers of sand and clay beneath the forest. Geologists call this the Kirkwood-Cohansey Aquifer system. The aquifer is estimated to hold an astounding 17 trillion gallons of fresh water. This is enough water to cover the entire state of New Jersey six feet deep. The abundance and quality of this water is the key to understanding the Pine Barrens and to its survival.

For more, click here.

For links, click here.

Surrounded by over 20 million people, the Pine Barrens is the largest undeveloped coastal area between Massachusetts and Virginia. Slightly larger in size than the state of Rhode Island, the New Jersey Pine Barrens occupies over 1 million acres in one of the most developed regions of the world.

For more, click here.

For links, click here.

Today, at nearly half its original size, the Pine Barrens occupies the southern coastal plain of New Jersey. The remarkable geology of this region has created a place that is unique on Earth. A place on which its human inhabitants are vitally dependent for water, clean air and open space.

Broom Crowberry offers a glimpse into the geology of this landscape. This unassuming plant grows throughout the sandy plains. It's a 'disjunct' species, meaning it grows here in the Pine Barrens and is not found again until the northern realms of Maine and Labrador.

For more, click here.

For links, click here.

Broom Crowberry most likely arrived as the last ice age was waning 12,000 years ago. The northern part of New Jersey was buried under the Wisconsin Ice Sheet. The ice sheet was part of a vast glacier extending from Canada down to the northeast.

Worldwide sea levels were much lower then. The coast of New Jersey lay 90 miles out at sea. The landscape resembled the arctic. It was the most recent ice age capping off eons of freezing and warming that repeatedly submerged New Jersey beneath the ocean. This cycle of flooding deposited layer upon layer of sand and clay hundreds of feet deep. Today the flat terrain gives few clues to this dramatic past.

For more, click here.

For links, click here.

The Pine Barrens is not really barren at all. The name came from early European settlers who had little success cultivating traditional row crops in the acidic, nutrient poor soils. But this landscape of sand and flowing water has created plant and animal communities elegantly adapted to this extraordinary environment.

Today, the upland reaches of the Pine Barrens are populated by nearly endless stands of Pitch Pines, Heaths and Oaks. This vast wilderness enticed European settlers to harvest timber for fire wood, charcoal and building materials. The entire Pine Barrens region has most likely been harvested many times. Native plants revived and flourished as industries moved west, leaving the Pine Barrens to recover.

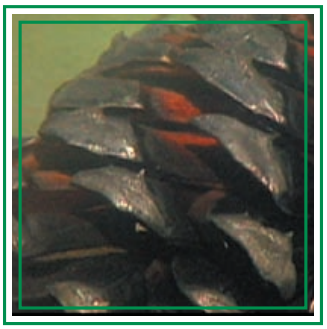
For more, cick here.

For links, click here.

The Pitch Pine thrives here because it has developed adaptations to survive in these nutrient poor soils. Its ability to dominate in such harsh conditions is further challenged by another defining element in Pine Barrens ecology … fire.

The Pine Barrens is one of the most fire prone places on Earth. Fire is a natural and necessary element of this landscape. It can rumble over and consume thousands of acres of forest. Many other trees succumb, their bark and roots burned beyond recovery. The Pitch Pine uses fire to its advantage. Without fire the pine forest would give way to other plants and trees.

During a blaze, thick bark protects the wood of the pine. The tree may appear burned and dead yet new buds will sprout from its charred trunk. The Pitch Pine's cones are often serotinous. Serotiny refers to their curious adaptation to fire. These cones are tightly sealed until exposed to extreme heat.



When fire sweeps through the forest, the cones open and release seeds that are spread throughout by the fires' own wind storm. Dispersal ensures genetic diversity. It also ensures that the pines reclaim areas occupied by other species less resistant to fire such as oak trees.

Fire sweeps the forest floor clean of dead pine needles and leaves. These layers of leaf litter build up over many years preventing the tiny pine seeds from taking root. Larger oak seeds have no trouble penetrating the thick leaf litter. Without fires to remove this barrier, the oaks would eventually dominate the forest.

For more, click here.

For links, click here.

Adaptations to fire have culminated to form a distinct and fantastic region of the Pine Barrens; the Pine Plains. Scarcely the height of a person, this stunted forest reflects the qualities of the Pine Barrens in miniature. The Pine species are the same but mysteriously have assumed a dramatically smaller stature. Although not entirely understood, the dwarf forest seems to have developed special adaptations to frequent fires. The cones of the dwarf forest Pitch Pines are nearly100% serotinous. More frequent fires in the past have most likely created this severe and unusual adaptation.

For more, click here.

For links, click here.

Fire moves quickly. Many animals flee underground or into wetlands. New plant growth is seen soon after. Pine seeds released by their cones provide food for mammals and birds. Though destructive, fire sets in motion a rebirth of the forest and life continues.

For more, click here.

For links, click here.

This Timber Rattlesnake survived the fire in an underground burrow. A shy and retiring creature, it hunts for small prey in these upland areas and throughout the Pines. Most of New Jersey's few, surviving populations of timber rattlesnakes inhabit the Pines. Their numbers have dwindled since Europeans arrived in the Pine Barrens. It is now an endangered species in New Jersey.

For more, click here.

For links, click here.

Many of the Pine Barrens' reptile species are in peril. Surrounded by intense urban sprawl, the Pine Barrens is a refuge for reptiles and amphibians as well as plants and other wildlife.

A rattler lies patiently and waits in ambush for small mammals. This lack of aggression makes the rattler unlikely to cross paths with humans and even less likely to strike. Only uninformed human behavior results in rare accidental snakebites.

An expert at digging burrows, this female Pine Snake hides her clutch of eggs in an underground den. She no longer has any contact with the father. After hatching, the young will be on their own. Superbly adapted to the Pines, she is at home in her sandy lair or hunting high in the trees. The Pine Snake is a swift and cunning predator. Lacking a venomous bite, she uses stealth and constriction to dispatch her prey of small mammals.

For more, click here.

For links, click here.

The Pine Snake finds the sandy soils ideal for a burrow. Plants however, find the lack of nutrients very challenging indeed. Water flows quickly through the sandy soil to the aquifer and its water table, which is extremely close to the surface. Few nutrients are left behind. The same soil characteristics that discouraged early farmers present an inhospitable environment to plants that are not native to the region. Such unique soil limits the plant community largely to specialists. Some specialists have devised extraordinary strategies to cope with the nutrient poor conditions.

For more, click here.

For links, click here.

Few plants excited colonial botanists more than the carnivorous plants of the eastern North American bogs. A mere three inches tall, this sundew is equipped with a deadly trap for small unsuspecting insects. Sticky fluid coats the tips of hair-like projections. Expecting an easy meal, insects land and become hopelessly ensnared. This one struggles only to become more imprisoned. The sundew, signaled by the vibration of the struggling insect, will fold its hand shaped leaf around the body of the insect. When fully enshrouded, digestive juices reduce the insect to nutrients that are then absorbed by the plant.

Another carnivorous species is the Pitcher plant. Its leaf forms a watertight chamber that collects rainwater. This adaptation allows the Pitcher plant to obtain the nutrients that it finds difficult to derive from the soils within the forest. Pitcher plants are a remarkable botanical trap armed with an array of attractions and snares for unsuspecting prey. Special scent glands attract insects with an enticing odor. The colorful lip of the pitcher invites the insects to investigate and risk a deadly fall. Down facing hairs and a slippery wall provide little purchase. Unable to escape they drown. Enzymes decay the corpse into nutrients that are absorbed by the plant.

For more, click here.

For links, click here.

Some organisms are immune to the digestive enzymes. These insect larva take advantage of this watery oasis to feed and develop. In turn, the Pitcher plant derives nutrients from their waste.

Like so many specialists of the Pine Barrens, Pitcher Plants are found along streams that flow seaward. The source of these streams is rainwater that percolates through the soil and recharges the aquifer. These tea color rivers of the Pine Barrens are famous for their beauty and their defiant ability to flow in the most severe droughts. All Pine Barren rivers are born within the forest and flow to the Atlantic Ocean or Delaware River. Often at the headwaters are swamps of Atlantic White Cedars.

For more, click here.

For links, click here.

Cedar trees are perfectly suited for life along rivers. Their wood is non-resinous and resists rotting in the damp swamps. Growing straight and close together, cedar wood was, and still is, a favorite among shipbuilders and as shingles for buildings.

It's likely that most cedar stands in the Pine Barrens have been harvested more than once.

"Cedar water" is a popular description of water flowing from these bogs. The reddish brown tint is caused by tannin from decaying plant material.

For more, click here.

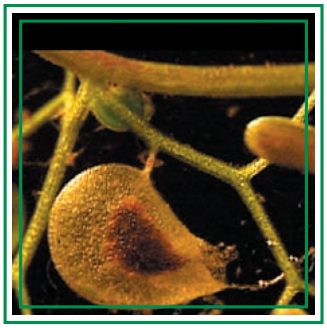
For links, click here.

Ponds and lakes in the Pines do not occur from natural geologic forces. The industrious lives of Pinelands residents have created many of these lakes. The Beaver too has reshaped the landscape here. Felling trees and damming up waterways supports the Beavers aquatic lifestyle. Here they browse on the aquatic plants near the surface.

For more, click here.

For links, click here.

Life beneath the surface of these rivers is just as special. Plants like the bladderworts thrive here. Another carnivorous plant, these specialists have evolved to survive in nitrogen poor waters and soils. The bladderwort attracts tiny aquatic life to miniscule sacks. As prey approaches, a hair trigger springs a trap door that opens and sucks its victim inside to be digested. The bladderwort sends a small flower above the waters surface to attract insects that will make cross-pollination possible.

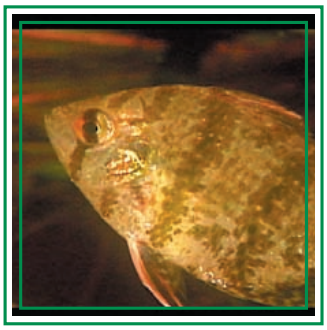


For more, click here.

For links, click here.

Only the hardiest of fish, like this Pickerel, can survive and reproduce in these acidic rivers. A handful of species are found here including the black-banded sunfish. It will likely spend its entire life in a small section of stream.

Like so many aquatic species, the black-banded sunfish is a specialist that has adapted to survive in the narrowest set of conditions. Very subtle changes in water quality may cause such a species to disappear and can raise concern about the health of the aquifer.



For more, click here.

For links, click here.

Occasionally river otters may be sighted prowling a river or lake, usually near the Atlantic coast. Otters have come to symbolize the vitality of life beneath the surface. They hunt fish and are more comfortable traveling through the water than on land. Their appearance in the Pine Barrens can indicate an abundant fish population.

For more, click here.

For links, click here.

Perhaps the most exotic plants of the Pine Barrens are its orchids. Ornate and showy, this diverse group of plants can be found in nearly every temperate environment of the world. At least 30 varieties of orchid grow wild in the Pine Barrens. Most are rare. Pink Lady Slippers have a single large blossom to attract insect pollinators … while delicate white-fringed orchids bear many small flowers on a single stalk. Orchids require a special set of conditions to grow and often must mature over many years before blossoming. Unfortunately several species of these gems of the Pine Barrens have almost disappeared, due to the loss or degradation of their habitats.

For more, click here.

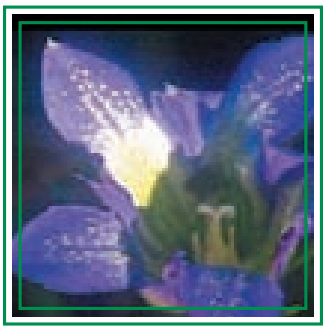
For links, click here.

Pitch pines and oaks dominate the forest canopy. Beneath this cover, another group of plants rules the forest floor. In the Pine Barrens, heaths are able to flourish in conditions that most plants find intolerable. The heaths include blueberries, huckleberries, and laurels.

For more, click here.

For links, click here.

Along with blueberries, the American Cranberry is a native that grew wild long before cultivation by farmers. Wild cranberries grow in the wet areas of the woods and along streams and ponds.



This ethereal flower is the Pinebarren Gentian. It is a quintessential plant of the pines. A rare southern species, it reaches the northern limit of its range in New Jersey. The nearest populations grow in Virginia and North Carolina where it has been nearly wiped out. For this beautiful wildflower, the Pine Barrens of New Jersey may become its last stronghold on earth.

For more, click here.

For links, click here.

As seasons change the cycles of life are unwavering. During winter the Pine Barrens provides refuge for many species. Some plants and animals lie dormant, waiting springs renewal. Rain and snow recharge the aquifer below. For people, its serenity offers welcome relief from the hectic pace of suburban and urban life.

Despite laws to protect it, the Pine Barrens is in jeopardy. Suburban sprawl around the perimeter is approaching build out. Pressure to develop more of the Pine Barrens for housing, industry and recreation is growing. For many areas, irreplaceable habitats are giving way to these pressures. Water quality is being changed to the detriment of plant and animal communities, as well as human inhabitants.

- **For more, click here.**
- **For links, click here.**

Much of the Pine Barrens has given way to development. How much more can be lost before this unique ecosystem collapses? Will unbridled demand on the aquifers turn the coastal plain to a desert? How long before this extraordinary island of nature is lost forever?

Despite these threats, the Pine Barrens can be saved. The answer lies in broad public support for preservation, for saving a special piece of the natural world as a haven for plants, wildlife, and people.

In the end, success will be told by the voices within the pines, and whether they will continue to call for generations to come.

- **For more, click here and here.**
- **For links, click here.**

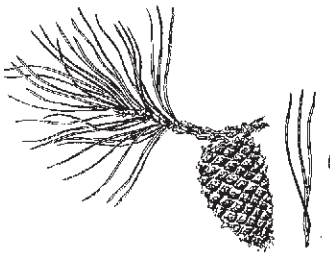
The Pine Barrens

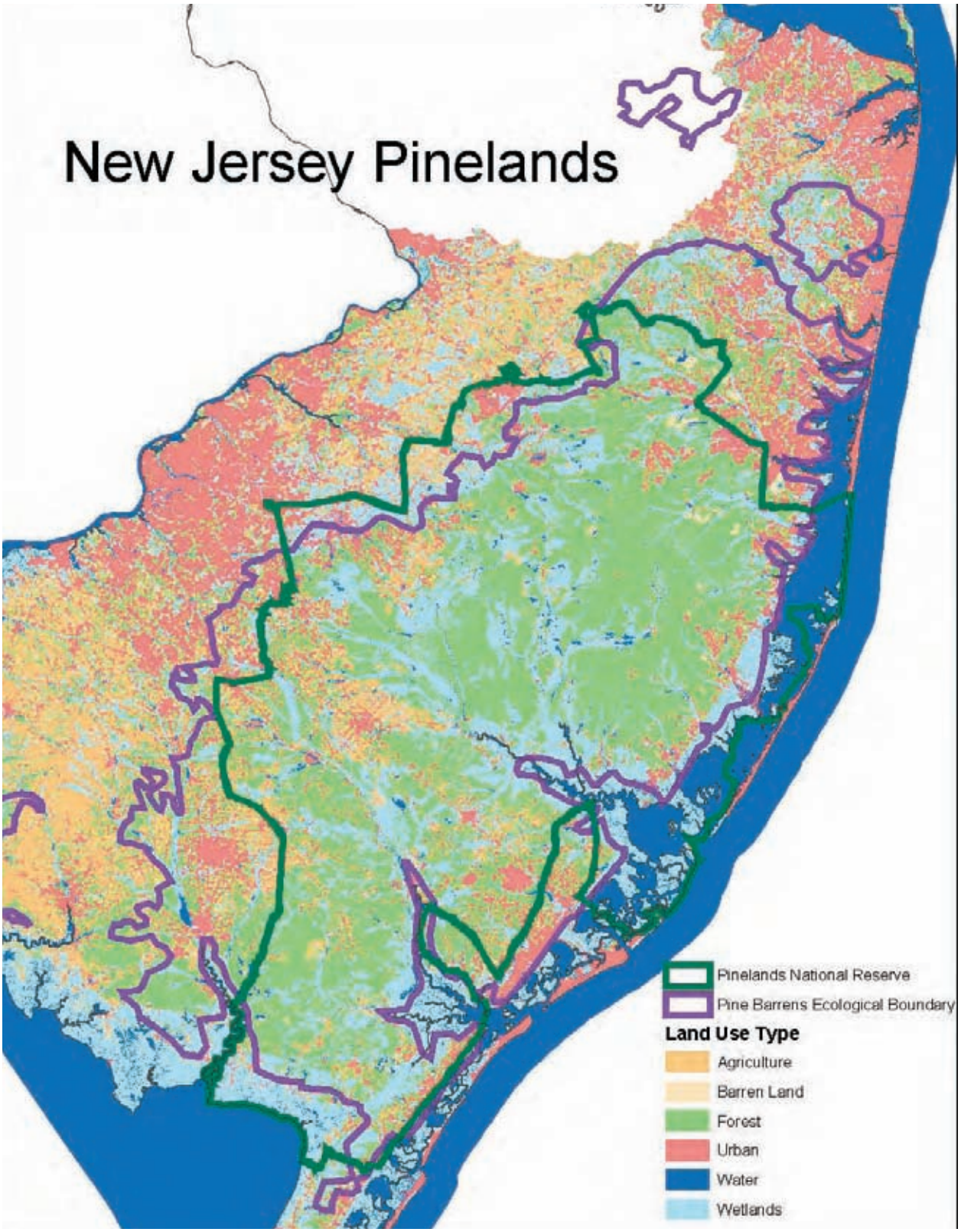
The Pine Barrens Treefrog has become an emblem of the New Jersey Pine Barrens. This tiny creature is an appropriate symbol for many reaasons. Among these reasons, the Pine Barrens Treefrog embodies two features that make New Jersey's Pine Barrens so important: that the Pine Barrens is a refuge, a kind of island of biodiveristy, for many species that have lost, or are quickly losing, their habitats elsewhere to human development; and that it is yet a fragile refuge that succeeds to fill this ecological mission only so long as we humans do not change the distinctive acidic, low-nutrient chemistry of its soils and waters. These themes inspire and shape this Guide as they inspired and shaped *The Pine Barrens: up close and natural.*

The wild communities of the New Jersey Pine Barrens have often been described as a mosaic. As the observant explorer moves across the land and over the water bodies, he or she will surely notice that the appearance of the landscape is constantly changing. This is most apparent on cross-country treks. At times, you are surrounded by thick, old gnarled Pitch Pines with bristly-looking trunk sprouts, with huckleberry bushes providing most of the understory. In other areas, the pines are scattered here and there, upstaged by stately oaks, and perhaps Bracken Fern dominates the forest floor. As the land slopes to damp and wet areas, you'll see an abrupt, dramatic change of scenery, as oaks and pines disappear to be replaced by tall, handsome Atlantic White Cedars. Suddenly, Highbush Blueberry bushes surrounded you, and sedges and rushes are springing from the lush, green sphagnum moss.

The same is true when you visit the water bodies of the Pine Barrens. A canoe trip on the Oswego River takes you winding along a narrow corridor with tall cedars on each side. On a similar trip in the upper reaches of the Mullica River, you'll paddle past numerous beaver lodges in a wide vegetated pond. Batsto Lake provides a stunning display of Spatterdock and White Waterlilies, while the numerous intermittent ponds scattered throughout the Pinelands host globally rare wildflowers and provide breeding sites for Pine Barrens Treefrogs.

Why, then, the name Pine Barrens? Most experts have attributed the name to early settlers who couldn't grow the crops they wanted. Others have pointed out that the Pine Barrens isn't rich in species diversity - that is, the total number of distinct species - compared to some of our other forests. This is undoubtedly true, yet within the Pinelands region, one may encounter well over a dozen different broad categories of natural communities, over 800 different vascular plant species, about thirty-four mammals, 144 birds, thirty reptiles, twenty-four amphibians, thirty-six fishes and about 10,000 insects. Add to this the abundant and diverse species of mosses, liverworts, lichens, fungi, and algae, and the inestimable number of arthropods other than insects, and one can only conclude that the Pine Barrens really isn't barren at all.




New Jersey Pinelands
Pinelands National Reserve
Pine Barrens Ecological Boundary
Land Use Type
Agriculture
Barren Land
Forest
Urban
Water
Wetlands

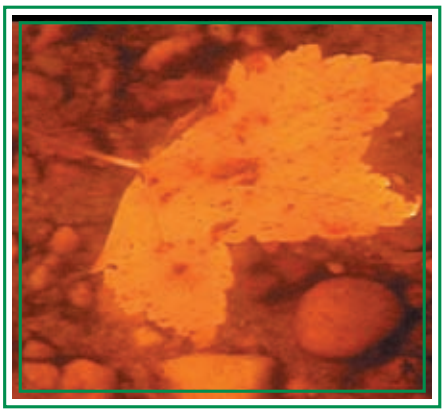
As elsewhere, the unique geologic history of the Pine Barrens has shaped its character today. The most basic outline of this history, according to contemporary understanding, is as follows. Prior to the Cretaceous Period (about 145 million years ago), what is now the Outer Atlantic Coastal Plain consisted of metamorphic rock formations. Through the next 140 million years of the Cretaceous and Tertiary Periods, the coastal plain was repeatedly submerged as worldwide sea levels rose and fell during global cycles of glaciation and melting. The seas deposited deep layers of sands, silt, and clays that dominate the formations beneath the Pine Barrens today. The Kirkwood and Cohansey formations, for which the Kirkwood-Cohansey aquifer system is named, are extensive formations laid down during this period. Altogether, these unconsolidated soils make a huge east-to-west wedge of mostly very permeable material that is deepest at today's Atlantic coast and grows progressively thinner until it disappears a little east of the Delaware River.

After the last retreat of the seas in the latter part of the Tertiary Period left a coastal plain whose shore extended far to the east of today's coast, the ice age of the Pleistocene Epoch brought glaciers as far south as today's New York harbor. While the Pine Barrens were not covered by glaciers, the climate was much colder and run-off from the glaciers deposited sands and gravels along streams and deltas that carried melting glacier water to sea. Intense wind erosion and deposition of soil is thought to have scoured large amounts of material from the region's surface and helped create the topography we see today. The ecosystem of that period is thought to have been a sub-arctic tundra, similar to what is now found in Labrador. It appears that today's disjunct populations of northern plants, like Broom-Crowberry, arrived here during the final phases of the ice age. The Wisconsin Ice Sheet, last of the glaciers to advance into New Jersey, finally retreated about 10-12,000 years ago.

The result of these processes is a region marked by a very flat terrain, very sandy soils, unique plant communities, and extensive wetlands, marshes and stream systems fed by the shallow aquifer system. Indeed, the highest point in the Pine Barrens is said to be Apple Pie Hill at 205 feet above sea level.

The New Jersey Pine Barrens ecosystem once covered about 1.4 million acres of land, as shown on page 2. While much of that ecosystem survives today, much has been lost to suburban and urban development.

New Jersey's Pine Barrens is not the only example of pine barrens in the world (there are about two dozen examples in the northeastern United States). But it is the largest and biologically most diverse pine barrens in the world. The New Jersey Pine Barrens is a globally important refuge for biological diversity, because its is home to communities of plants found nowhere else in the world, as well as to individual plant and animal species that are either unique to this region or will soon become so due to the destruction of their habitats in other places.



What Makes the Pine Barrens So Different?

Walk through the Pine Barrens and compare the landscape in your mind to images you have of other forests. The Pine Barrens is obviously different from what we might call a "typical" northeastern forest. Why is that?

The distinctive look of the Pine Barrens ultimately arises from its soils. Pine Barrens soil is largely sand. From this fact all else follows. The predominance of sand means Pine Barrens soils are highly porous to water, do not retain nutrients and organic matter very well, and are highly acidic.

The sands of South Jersey were deposited on the ocean floor as the sea level repeatedly rose and fell between 13 million and 25 million years ago, during a time that geologists call the Miocene period. In later epochs, the ocean retreated to its current level as more and more sea water was frozen into the polar ice caps. It also appears that the land itself rose during tectonic shifts in the earth's crust.

Sandy soils are made up of large mineral particles, much larger than those in soils we call silt and clay. The large gaps between sand particles mean this soil is very porous - water drains easily through it. As rainwater and melting snow drain rapidly through Pine Barrens soils, they carry with them the organic matter - the particles of decomposed pine needles, leaves and animal bodies - that have the nutrients plants need. Thus, even though the Pinelands may receive the same amount of rainfall as land along the Delaware River or in northern New Jersey, the water moves so rapidly through the sandy soil that little moisture and few nutrients are kept. The sandy soil acts more like a course sieve than a sponge. This makes Pine Barrens soils very low in nutrients compared to most other soil types.

The sandiness of Pine Barrens soils also makes them highly acidic. Here are some examples of the pH of typical Pine Barrens soils and stream water, compared with some common liquids:

Substance	Acidity	
Stomach juices	1.5	
Pine Barrens soils	3.6 to 5.0	More acidic
Oswego River water	3.99 to 4.52	
Pure water	7.0	Neutral
Milk of magnesia	10	
Household bleach	12.5	More basic
Oven cleaner	13.5	

Why are Pine Barrens soil and water so acidic? There are a couple of reasons. One is that even unpolluted rainwater is somewhat acidic, and polluted "acid rain" can be very acidic. Most soils have the ability to buffer, or neutralize, this acidity. The Pine Barrens' sandy soils do not have this ability, because they do not hold the minerals and organic matter that does this buffering in richer soils. Another reason is that Pine Barrens soils have relatively high proportions of aluminum, which tends to break down water molecules (H2O) into an H+ and an OH^{-} ion, keep hold of the OH^{-} ion and release the H+ ion into its surroundings.

Acidic soil and water are hard on most plants and animals. The reasons this is so are not yet clear to scientists. Nor is it clear how certain plants and animals have adapted to these conditions. Why can Pine Barrens Treefrogs prosper in an acidic environment, while Bull Frog eggs seem to wither and die in these conditions? Why are the heath family of shrubs so happy in acid soils, while most others simply cannot live or cannot compete in Pine Barrens conditions? These are fascinating questions that call out for answers.

Many species of plants cannot adjust to the low-nutrient, acidic conditions in the Pine Barrens. Only those species that are either specifically adapted to acid conditions, or those flexible enough to thrive across a broad range of acidity, can prosper in the Pine Barrens.

A number of distinctive Pine Barrens plants are found here as "disjunct" populations. This means the Pine Barrens populations are isolated from the other places these species are found, in some cases far to the north and in some cases far to the south of New Jersey. These plants arrived in the Pine Barrens during the advance and retreat of glaciers in prior epochs, and they have persisted here because of the special soil and water conditions of the Pine Barrens. Why do they thrive in the Pine Barrens and not, say, in North Jersey or Pennsylvania? There are at least three reasons this happens:

1. The plant requires acidic, low nutrient soils because it is specially adapted to these conditions. A prime example are the sphagnum mosses, which require acidic water and even release chemicals into their surroundings that help keep the conditions very acidic. There are about 30 different species of sphagnum mosses in the Pine Barrens.
2. The plant can grow in a variety of conditions, but it is out-competed in other places by plant species that prosper in non-Pine Barrens environments. An example is the rare white wildflower, Pine Barren Boneset.
3. The plant has lost its natural habitats outside the Pine Barrens due to human destruction or alteration of its habitats elsewhere. The Bog Asphodel, a very beautiful wildflower discussed below, is an example.

The Pine Barrens is a refuge for plants and animals that are losing habitat in other places. Increasingly, the Pinelands is a true Noah's Ark for biodiversity. This is so in at least three ways.

First, the Pinelands is a refuge for species whose habitats are being destroyed elsewhere in the state, the nation, and the world. Plants like the Bog Asphodel will soon be found nowhere but in the New Jersey Pine Barrens - a phenomenon we should expect will continue and worsen with time. Other species, such as the Swamp-pink wildflower and the Pine Bar-

rens Treefrog, may persist in a few other places but will still find their greatest stronghold in the Pine Barrens.

Second, the peculiar chemical conditions that make the Pine Barrens distinctive - the droughty, highly acidic and relatively nutrient-poor soil and water - create a natural barrier against invasive species that cannot tolerate this environment. As a result, the Pine Barrens is one of the few places in North America that has not suffered significant ecological disruption from non-native, invasive species. At least, that's true where the ecosystem that has not suffered chemical changes to soil and water from fertilizer runoff, liming of soils and other contaminants from suburban lawns and farm fields.

And finally, the unique geological history of the Pine Barrens has left here a unique plant community - or rather collection of communities - where northern and southern species survive together as they do nowhere else in the world.

The distinctive communities of plants and animals inhabiting intact Pine Barrens habitats tell us about the special geology and history of this ecosystem. They also provide a test or a standard for judging how well the Pine Barrens ecosystem is faring amidst human alteration of the landscape. For more than 10 years, scientists have been studying whether suburban, urban and agricultural development are altering the Pine Barrens ecosystem. They have found that the chemical features of stream water (such as pH and dissolved nutrients), the plants in and along the streams, and the fishes and frogs inhabiting the streams and wetlands are very accurate indicators of human impacts on the ecosystem.

The Kirkwood-Cohansey Aquifer System

To understand the ecology of the Pine Barrens, and how the Pine Barrens links to the coastal estuaries, one must start with the Kirkwood-Cohansey aquifer system. An aquifer is a body of water embedded in the earth. The Kirkwood-Cohansey aquifer system is the vast body of water embedded in the sands of New Jersey's coastal plain.

Picture in your mind pouring water into a bucket of sand, filling it until the water comes up to just below the surface of the sand. Then draw your finger through the sand to create a depression deep enough to expose the water. You now have a good idea of the Kirkwood-Cohansey aquifer system. It is a surficial aquifer, meaning it is exposed to the surface of the earth, rather than being confined underground in some deep layer of soils or rock. But where there are depressions in the surface, such as in streams and wetlands, the water is actually visible. In one respect, this static thought experiment is not accurate, for the water that makes up the Kirkwood-Cohansey aquifer system is always on the move. The whole body of underground water is generally flowing slowly to the east, towards the seacoast. A portion of the underground water is drawn into rivers and streams and flows gently downhill into the estuaries along the Atlantic seaboard or the Delaware River.

The simplified drawing in Figure 1 shows how the Kirkwood-Cohansey aquifer occupies the top of the enormous wedge of sand that makes up most of South Jersey, and how it is related to the other partially confined aquifers (especially the Atlantic City 800-foot Sands) and fully confined aquifers (such as the Potomac-Raritan-Magothy aquifer) that lie beneath the Kirkwood-Cohansey.

We call the Kirkwood-Cohansey an "aquifer system" because it is contained within two connected geologic formations, the Kirkwood and the Cohansey sands, and has many local variations caused by variations in the soils in which it is embedded. For example, in some places, the aquifer may be partially confined because of a local layer of impermeable clay beneath the surface. These variations can affect the influence the aquifer has on the biology of the surface, the flow of pollutants in the water through the ground, and the impacts that pumping the water for human use will have on nearby streams and wetlands.

The Kirkwood-Cohansey is the life blood of the Pine Barrens. Ninety percent of the water in the streams and wetlands of the Pine Barrens is supplied by the aquifer system, rather than direct runoff from rain or melting snow. If the water table - the highest surface of the aquifer - were to fall far enough, the streams and wetlands and all their inhabitants would become severely stressed for lack of water, and would eventually die.

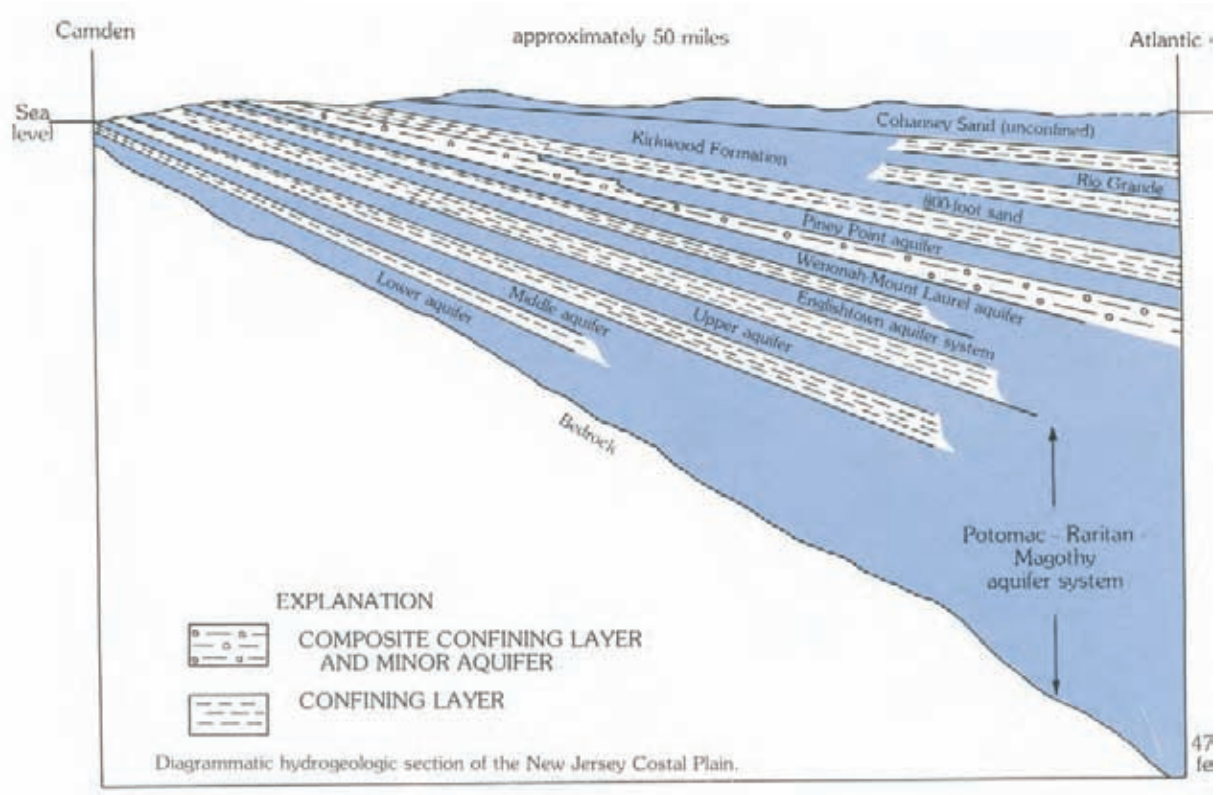
The Kirkwood-Cohansey aquifer is fed, or "recharged," by rainfall and melting snow. At the same time, the aquifer is losing water due to both natural and human causes. As water flows out of the ground into streams, it flows out of the system and into the coastal bays and estuaries. And when humans pump water out of the aquifer for home use and irrigation, most of that water

is also lost to the system. Much of it is ultimately flushed out to sea in sewer discharge. A great deal of the water used for irrigation is actually lost to evaporation.

In its natural state, the aquifer gains through recharge what it loses through discharge. The key question is whether the aquifer is still in equilibrium after we take into account the consumptive uses we human are making of the water.

Scientific studies have shown that pumping water out of the Kirkwood-Cohansey has in fact begun to lower the water table in some areas, such as in the Toms River basin. That means human consumption is reducing the amount of water in nearby rivers, streams and wetlands. Salt water from the ocean is beginning to enter the aquifers along the coast, a phenomenon called "salt water intrusion." As fresh water is drawn out of the aquifers, the boundary between fresh and salt water in the sands along the coast moves inland. At the bottom of the Cape May Peninsula, this boundary has moved far enough inland that public drinking water wells are now drawing up salty, undrinkable water. Scientists are now trying to understand what impacts these changes are having on the natural systems, plants and animals living on the surface.

The Kirkwood-Cohansey is critical to the natural landscape not only in the volume of water it provides for streams and wetlands. It is also critical for the quality of the water it supplies. Being exposed to the surface of the earth where we humans live and play, the Kirkwood-Cohansey is especially vulnerable to contamination by pollutants we put on the surface and allow to be washed into the aquifer. We will examine the special water quality characteristics of Pine Barrens waters, and how human activities are influencing water quality, below.



Aquifers underlying the Coastal Plains of Southern New Jersey (Source: United States Geological Survey)

Natural Communities of the Pine Barrens

We can think of the Pine Barrens as being made up, primarily, of three distinct kinds of communities: uplands, lowlands and aquatic communities. These broad categories are learning devices we invent; lots of the natural areas, especially transitional or "ecotone" areas, don't fit neatly into these three broad categories, but have characteristics of more than one.

Uplands are quite varied in the Pine Barrens, but most of them are forested. The **Pine/Oak Upland Forest** is the most common and the most characteristic natural community in the Pine Barrens. It is defined by its flora, but is also home to a diverse fauna. Many of the mammals, birds, reptiles, amphibians, and insects use the uplands for all or part of their life cycles. Many amphibians - for example, the Pine Barrens Treefrog - are really creatures of the forests, and the adults use the wetlands mainly for breeding. Here you'll notice that the majority of the canopy trees are Pitch Pines, the most characteristic tree of the Pine Barrens, with a smaller number of Shortleaf Pines, and, in some areas, a few Virginia Pines. The understory is made up of shrubs such as Scrub Oak, Mountain Laurel, Low Blueberry, Pine Barrens Heather, and Sweet-fern. Other shrubs, such as Sheep Laurel and Sand Myrtle, are more typical of damp areas often find their way to the uplands at times. And the ground cover consists of low-lying plants such as lichens, mosses, ferns, annual and perennial wildflowers, and sub-shrubs like Bearberry, Teaberry, Hudsonia and Trailing Arbutus.

Oak/Pine uplands are simply areas where the oaks predominate. Ecologists believe that oaks are likely to predominate in areas where wildfire has been suppressed over long periods. In some areas, the oaks may out-compete the pines so thoroughly as to become virtually exclusive.

Pine Plains

The **Dwarf Forests or Pine Plains** of the Pine Barrens of New Jersey are upland forests that have long intrigued biologists. A botanist who visited one of the sites in 1889 described it as, "a desert of sand so sterile that even the trees of Pinus rigida [Pitch Pine], which sparsely clothe it, can attain only to the height of three or four feet." Early in the 20th Century, Witmer Stone described them as "desolate stretches of white sand barrens … for the most part devoid of trees higher than one's knees." The Dwarf Forests are dominated by dwarfed Pitch Pines and Blackjack Oaks in the low canopy. Pine Barrens Heather is frequent in the understory. Ground cover includes lichens, mosses, and the sub-shrubs Bearberry and Teaberry.

All of the tree species in the Dwarf Forests are also found throughout the Pine Barrens, so why do they take on a dwarf form in the Plains? Though the mechanisms are not entirely under-

stood, most experts believe that a combination of factors are involved. The Pine Plains soils are particularly droughty and nutrient-poor, and, as plateaus elevated above their surroundings, the plains are subject to higher winds. Most importantly, for centuries these forests have been exposed to wildfires at least twice as frequently as other Pine Barrens forests. These extremely harsh conditions have created a forest with Pitch Pine trees that are stunted and have adopted certain genetic peculiarities. The pines of the Plains almost exclusively produce "serotinous" cones - cones that open only when subjected to the heat of wildfire - and have an extraordinary ability to send up new growth from their roots, even when the rest of the tree is completely burned. We will discuss the Pitch Pine's adaptations to fire in more detail below.

Lowlands include swamps, lowland forests, and wet meadows. A swamp may be defined as a forest that is periodically inundated. Lowland forests may never be inundated, but they have a high water table, so only plants that can tolerate having their roots in water thrive in lowlands. Wet meadows are covered mostly with herbaceous vegetation and very few or no shrubs and trees.

Atlantic White Cedar swamp

Atlantic White Cedar Swamps are the characteristic swamps of the Pine Barrens, though they are now much reduced in both size and number due to over-harvesting in the past. Old, well-established cedar swamps are magnificent. It tends to be cool and shady in an old cedar swamp. The straight-trunked cedars arise from hummocks usually covered with sphagnum mosses and various other plants, the diversity and vigor of which depend on the amount of sunlight reaching the floor. The plants growing on the hummocks typically include an occasional Swamp Maple or Pitch Pine. You'll also find Highbush Blueberry, Swamp Magnolia, Gray Birch, Swamp Azalea, Pitcher Plants, sundews, several species of orchids, various wildflowers, as well as grasses, sedges, and rushes. A great many of the Pinelands animals use cedar swamps for breeding, feeding, nesting, and resting. Some of our rarest flora and fauna have safe harbors in these communities.

One of the most famous plants of New Jersey, the tiny Curly-grass Fern, is found almost exclusively in Cedar Swamps, and always in association with Atlantic White Cedar trees. Curly-grass Fern was first recognized by botanists in 1805 at Quaker Bridge, in what is now Wharton State Forest. It can still be found in that vicinity and in many other places that provide its rather precise habitat requirements. It usually grows in early-successional spots where there is a fair amount of sunlight. Smaller populations can also be found in the Pine Barrens of Long Island, NY, and in Sussex County, DE, but it doesn't appear again until you get all the way up to Nova Scotia and Newfoundland. Botanists worldwide have made pilgrimages to the Pine Barrens to see Curly-grass Fern simply because it is so small and so rare.

Hardwood Swamps are wetland forests where the canopy is made up primarily of deciduous hardwoods - mostly Swamp Maple and Black Gum, and, in some areas, Sweet Gum. Today, hardwood swamps may be more common than cedar swamps, having developed because of over-harvesting of the cedars in the past. You may find some cedars here and there in a hardwood swamp, or cedars may be in small patches or groves. Shrubs include Highbush Blueberry, Dangleberry,

Sweet Pepperbush, and Leatherleaf, and there is some variety of herbaceous plants, grasses, sedges, and rushes. Hardwood swamps are also important wildlife habitat. Extensive hardwood swamps are good nesting habitat for both Barred Owls and Red-shouldered Hawks, for example, and they are populated by a great variety of mammals, birds, reptiles, and amphibians.

Pitch Pine Lowlands may be recognized by the abundant Pitch Pines intermingled with a great variety of moisture-loving plants, since the water table is quite close to the surface. These lowlands are hotspots for rare plants such as Yellow Fringeless Orchid, Pine Barren Gentian, Sand Yellow-eyed-grass, Rose-color Coreopsis, and Long's Woolgrass.

While Pine Barrens soils are dominated by sand, these soils are really a mosaic of sand interspersed with pockets of gravel, silt and clay. These pockets can shape and alter the landscape. Clay layers in the soil can create "clay lenses" or places where water cannot pass easily. These lenses sometimes create Pine Barrens "spongs." Spongs (pronounced like "spungs") are small isolated wetlands that hold water and provide a very distinctive habitat for plants, amphibians and other animals in the Pine Barrens.

Pine Barrens savanna

Some of the most beautiful lowland communities in the Pinelands are the **Wet Meadows or Savannas**. They vary greatly in size and species make-up, but are recognized by the lack of trees, and abundance of herbaceous plants, grasses, sedges, and rushes. This is another hotspot for rare plants, some of them of worldwide significance. They include globally rare species such as New Jersey Rush, Bog Asphodel, and several of the Beaked-rushes.

Experts say many of the savannas are shrinking due to natural succession, the process by which open areas gradually become colonized grasses, then shrubs, and finally by forest trees. It is likely that people who were digging out bog iron long ago created at least some of the savannas we see today. The process undoubtedly severely disrupted the land surface, leaving a wide, wet, sandy/mucky surface. No one knows how long it may have taken such areas to become colonized again by plants, but we may be seeing a late stage of the long, complex process of succession in these shrinking sites. In natural cycles, some savannas would be maintained and, occasionally, created by wildfires and storms. Today, humans suppress wildfires in the Pine Barrens to protect property and lives. The effect of wildfire suppression on savannas is one of several ways in which our efforts to prevent uncontrolled fires is shaping the natural landscape of the Pine Barrens.

Aquatic habitats of the Pine Barrens are particularly important to this curriculum, be-

Why are Pine Barrens streams "teacolored"?

This is one of the most frequently-asked questions among visitors to the Pine Barrens. The answer is that the tannins and other organic molecules are leached out of dead leaves and cedar and pine needles by the acidic waters. Iron molecules, which are abundant in the soils, attach to these compounds and color the water reddish brown. Some of the iron also precipitates out of the water and is deposited on stream bottoms, eventually forming thick mats of "bog iron."

Typical Pine Barrens stream

cause they provide the laboratory in which we can study the effects of human development, the "built environment" on the Pine Barrens ecosystem.

Looking at a map, you can see that most of the **Rivers and Streams** in the Pine Barrens flow east into the estuaries and bays along the Atlantic. One river, the Rancocas Creek, flows west to the Delaware River. These are all slow-moving streams and rivers, fed by rains and the Kirkwood-Cohansey aquifer. These rivers and streams, when undisturbed by human impacts, are highly acidic and very low in nutrients. These key water quality characteristics shape the biological cycles and communities within the rivers, streams and wetlands.

The streams and rivers of the Pine Barrens support unique plant communities and complex wildlife communities. About sixteen species of fish are considered indigenous to the Pinelands waters, and another forty-six species, including peripheral and introduced species, may be encountered.

Permanent natural Lakes are absent from the Pine Barrens. The only natural ponds or lakes in the Pine Barrens are those created by beaver, which dam up streams to create ponds and foster growth of the aquatic plants they like to eat. The larger lakes one sees today are all manmade. People have been damming up watercourses in the Pinelands since the earliest European settlers arrived. Impoundments that can be called lakes in a technical sense (with water deep enough to limit plant growth in some areas) are the result of activities designed to use water power: people built dams and waterwheels to drive machinery such as grist mills, sawmills, and the bellows associated with the forges and furnaces.

Ponds are technically any body of fresh water that is shallow enough to permit plant growth from the bottom throughout the entire area of the pond. Small impoundments made by people for various reasons qualify as ponds. Beavers make ponds throughout the area, when they have the opportunity.

A very important kind of pond are the **Intermittent Pools or "Pingoes,"** sometimes also called vernal ponds. These pools are only filled with water part of the year. They form in shallow depressions where the water table is very near the surface for most of the year. These ponds fill with water in the fall, winter and early spring, then dry up in the late spring and summer as the water table falls. Intermittent pools support many rare plants and animals. For example, they are favored by Pine Barrens Treefrogs and salamanders for breeding because they do not harbor fish that would prey on the amphibians' eggs.

Pine Barrens Plants

Broom Crowberry is a quintessential northern plant found as a disjunct population in the New Jersey Pine Barrens. Thought to have arrived here in front of the glaciers of the last ice age, Broom Crowberry is quite common in the Pine Plains, but is entirely absent, with few exceptions, outside the Pine Barrens until one reaches its "normal" habitats in Labrador. The exceptions are several other disjunct populations in the Shawangunk Mountains of New York and along the coasts of Massachusetts and Maine. Broom Crowberry's northern origins are displayed in the very early blooming period – around the middle of March – of the Pine Barrens population, and in its tough, woody stems and needle-like leaves. In its unusual origins, unassuming appearance and adaptations to difficult conditons, Broom Crowberry exemplifies the fascination which the plants of the Pine Barrens hold in store for us.

The Pine Barrens is home to many forest and wetland species of plants, many of which are considered threatened or endangered because of their rarity in the State, the nation or the world. First, some numbers. The Pine Barrens is home to 8 species of gymnosperms (plants like the pine trees that do not produce true flowers), 800 species of flowering plants (angiosperms), 25 species of ferns, 274 mosses, and at least 100 (but probably 300-400) species of fungi. Of these 180 species are currently deemed threatened or endangered.

King among the gymnosperms of the Pine Barrens is the **Pitch Pine**, the single most characteristic plant species of this ecosystem. The Pitch pine has evolved to prosper in the Pine Barrens' droughty, acidic and highly fire-prone conditions. Pitch Pine occupies about 283,300 hectares (700,000 acres) in New Jersey. Pitch Pines have thick, resinous bark, which helps to protect them from being killed by fire and insects. They also grow deep root systems, allowing them to reach down to the water table in many upland areas. Pitch Pine are a key food source for deer, which browse sprouts and seedlings; rabbits, mice and birds, which eat pine seeds; and many insects, which feed on various parts of the tree and needles.

Each Pitch Pine tree has both male "flowers" and female "flowers," although these organs are really cone-like structures, not true flowers in the scientific use of the term. This species relies on wind to blow the pollen from male "flowers" onto the ovulate cones of female "flowers" on the same or different trees in the area. The ovule produces the seeds and the pine cone, which protects the seeds while they develop.

Fire opens a serotinous Pitch Pine cone

On any given tree, some of these cones may open and release their seed upon maturity, but others are "serotinous" and will only open after being heated by a hot fire. As noted earlier, the dwarf pines of the Pine Plains are almost entirely

serotinous. Why would Pitch Pine evolve to have serotinous cones? What is the evolutionary advantage? The answer appears to be that Pitch Pine seeds can out-compete oak seeds only when wildfire has cleared the ground of dense beds of fallen leaves and needles. When there is a thick cover of needles and leaves, Pitch Pine seeds do not germinate as readily as the acorns of oak trees. Where oak seedlings germinate more readily, the saplings and trees into which they grow block sunlight and take up moisture and minerals, making it even more difficult for pine seedlings to grow. In contrast, where ground conditions favor pine seed germinate, pines beat oaks to the punch by grabbing the sunlight, moisture and minerals.

Pitch Pine sprouting new growth after fire

Pitch Pines have another extraordinary adaptation: they can easily grow new branches from their trunks and even from their roots. This unusual feat is possible because Pitch Pines develop dormant buds beneath the trees' thick bark. The thick bark protects the cambium layer and dormant buds from all but the hottest fires. The dormant buds begin to grow when stimulated by fire damage (or other similar harms.) Some of these buds lie at the base of the tree, where Pitch Pines typically produce a "basal crook" or bend that keeps the base of the trunk beneath the soil. Again, this is an adaptation that takes advantage of the fire-prone conditions in the Pine Barrens. After a wildfire, you will often see Pitch Pine trees that are completely blackened by the fire and appear to be dead, except for the bright green shoot coming out of the trunk of the tree. The shaggy look of so many pines in our region results from repeated cycles of fire and new growth from the trunk.

Within a season after a fire in the Pine Plains, one may see broad stretches of trees burned to black above ground, but growing new shoots from their roots – a process that frequently creates trees with multiple trunks. This ability to sprout from its trunk and roots is unique to just a few species of pines.

In the dry soils of Pine Barrens uplands, wildfires are common – or were before modern human cultures began suppressing wildfire. Pitch Pines have taken advantage of frequent fire by developing their own strategies for survival in the constant competition with oaks and other species for space, light, water and nutrition. It has even been suggested that one evolutionary purpose of the high resin content of Pitch Pine needles is to create a highly flammable bed of fuel that encourages hot wildfires. The ability to regrow from roots also suggests that some Pitch Pines in the Pine Plains may be very, very old, having regenerated themselves through hundreds, perhaps thousands of cycles of fire and regrowth.

Among the flowering plants, we will focus on the oaks, the heath family, three wildflowers that have their worldwide stronghold in the Pine Barrens, the orchids, and the carnivorous plants found here.

Oaks are the second-most dominant tree in Pine Barren. Several species of oak thrive in this environment. Like the pines, oaks in the Pine Plains remain short in height, more like shrubs than trees. Unlike pine needles, the leaves of oaks are broad and flat, enabling them to capture sunlight for photosynthesis more efficiently than can needles. Oaks reproduce by drop-

Highbush Blueberries

Forest Understory

American Cranberry

ping acorns, which contain the oaks' seeds. Acorns have evolved to be nutritious food for squirrels and other forest mammals, which store acorns for consumption but forget to dig up and eat a certain percentage of the acorns they have gathered. Acorns also germinate and sprout more easily in thick ground cover than do pine seeds.

On the other hand, oaks are more vulnerable to being damaged or killed by fire than are pines, and oaks have no ability to grow new branches from dormant buds after wildfires. Because of the different survival strategies of oaks and Pitch Pines, it is likely that oaks will eventually come to dominate if human beings continue to suppress wildfires and do not impose prescribed or controlled burns capable of mimicking the effects of wildfire on Pitch Pines.

The understory of Pine Barrens forests and stream-side vegetation are dominated by members of the **Heath family** of plants. Heaths of the Pine Barrens include Sheep and Mountain Laurels, Blueberries and Cranberries, Swamp Azalea, Bear Berry and Wintergreen. Heaths are adapted to acidic soils and prosper in the Pine Barrens understory, but exactly how they handle these conditions is not well understood at this point.

Three extraordinarily beautfiul wildflowers, **Pine Barrens Gentian**, **Bog Asphodel** and **Swamp Pink**, provide a lesson in the importance of New Jersey's Pine Barrens to preserving global biodiversity. These wetlands flowers have been virtually exterminated elsewhere, but are locally abundant in the Pine Barrens. Pine Barrens Gentian is protected as threatened or endangered by the Pinelands Comprehensive Management Plan; Swamp Pink is listed under the national Endangered Species Act as threatened; and, for now, Bog Asphodel is considered endangered in New Jersey and, based on its rarity, certainly merits a national designation. In fact, the Bog Asphodel is now thought to survive only in the New Jersey Pine Barrens. Even in the Pine Barrens, these plants have suffered from illegal collection, alteration of habitat, trampling by off-road vehicles and other careless recreational activities.

Swamp Pink

Pine Barren Gentian

These plants are adapted to specific wetlands conditions, so any serious alteration of their wetlands habitats, whether through construction of cranberry bogs or alteration of stream flows, threatens these flowers. Other impacts are natural. These include the natural succession of wet meadows as shrubs and trees colonize savanna areas, predation by deer, geese and insects, and even the flooding of their habitat because of beaver dams. It remains an open question whether there are enough of these extraordinary plants and enough intact habitat for their long-term survival.

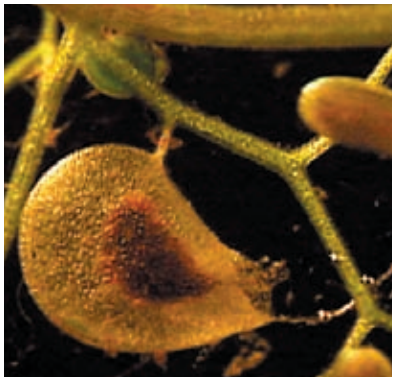
Similar concerns with habitat degradation and collecting arise with many of the **Orchids** found in the Pine Barrens. The Pine Barrens is home to a delightful array of wild orchids. About 30 species occur within the Pinelands National Reserve, of which about 15 species are characteristic of true Pine Barrens habitats. Several, such as Rose Pogonia and Grass-pink, are very abundant and easily found along Pine Barrens streams and in wet meadows and open swamps. The elegant Pink Lady's-slipper may be common in sandy woods. Other orchids range from the rare to the imperiled, the most critically imperiled being Spready Pogonia, Yellow Fringeless Orchid, and Lace-lip Ladies'-tresses.

Yellow Fringed Orchid

The carnivorous species of the Pine Barrens, **Pitcher Plant**, **Sundews** and **Bladderworts**, have evolved different ways to capture and consume insects and other tiny animals. Pitcher Plants develop large, water-tight basins from specialized leaves, which trap rainwater and contain digestive enzymes. Pitcher Plants exude enticing aromas that attract insects to investigate, and when the insects move or fall into the "pitcher," downward facing hairs stop them from escaping. In contrast, sundews trap insects on sticky leaf surfaces, which then release enzymes to digest the animals. Bladderworts have tiny sacs attached to their modified leaves, which into water or are embedded in boggy soil, depending on the species. Very small animals are sucked into the sacs when they approach the sacs' openings, where they are subsequently digested. Scientists believe these carnivorous abilities evolved to supplement the plants' diets in conditions where it is difficult for plants to obtain enough nutrients from the soil and water alone.

Pitcher Plant

Spatulated-leaved Sundew



Bladderwort

As in other ecosystems of the world, **Fungi** play a critical role in the Pine Barrens. Indeed, life as we know it on earth would not be possible without the fungi. Decomposition in acidic soils is primarily carried out by fungi, because bacteria prefer less acidic soils. The plant litter of Pine Barrens vegetation is slower to decompose than leaf litters of plants growing on richer soils. Our litters contain high levels of polyphenols and tannins, chemicals that can be toxic to most other organisms and therefore require special enzymes for their breakdown. Many basidiomycete (mushroom forming) fungi possess those enzymes.

Once leaf litter has been broken down to release the nutrients in a form available for plant growth, the uptake of nutrients by roots is aided by the presence of mycorrhizae (literally 'fungus-root'), a symbiotic relationship between fungi and roots. The fungal hyphae (threads or sometimes ropes of hyphae) run further from the root surface into soil than root hairs, thus the effective surface area of the root is increased for less maintenance cost than supporting root hairs. This fungal network can explore and exploit a larger volume of soil than the root alone, thus improving nutrient uptake efficiency. Additionally, some of these mycorrhizal fungi have the ability to produce the enzymes that are required for the breakdown of the complex organic molecules contained in leaf litter. Thus they act as decomposers as well as mycorrhizae. This means that they can tap directly into the leaf litter to obtain nutrients, rather than relying on the decomposers to provide material for them. Hence the term 'direct nutrient cycling' was coined to describe this process.

Fungi in the form of **Lichens** are common on bare sand in our region. An association between fungi and their symbiotic algae and cyanobacteria, lichens play an important role in nitrogen fixation. Their dead remains form the initial soil structure, which stabilizes the sand and allows other plants to colonize.

Pine Barrens Animals

Among animals, we find 34 species of mammals, 36 species of fish, 24 amphibians, 30 reptiles, 144 birds (either year-round or migratory residents), and more than 10,000 invertebrate species (mostly insects, worms and other arthropods). Of the animals, 36 species are currently deemed threatened or endangered.

Among the animals, the Pine Barrens lost its top predators, Black Bears, Cougars and Wolves, long ago to hunting and trapping. The Pine Barrens today is home to 34 species of **Mammals**. Large mammals are now restricted to white-tailed Deer, Coyotes, the rare Bobcat, Beavers and reclusive River Otters. White-tailed Deer are plant-eaters which have proliferated in the Pine Barrens (as elsewhere in the country) due to the fragmentation of forests, which creates more edible plants of the forest edge than does a continuous, mature forest. We also find Red and Gray Fox, Mink, Long-tailed Weasel, Southern Bog Lemming, 8 species of bats, as well as raccoon, muskrat, various squirrels, chipmunks, voles and mice.

American River Otter

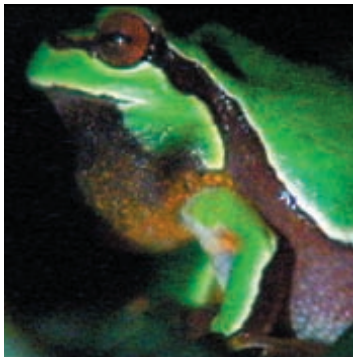
River Otters are elusive denizens of Pine Barrens streams and wetlands. Happy in fresh and brackish waters, they most often are reported in the lower stretches of rivers flowing into the Atlantic coast estuaries. But they are also sometimes seen in cranberry bogs and reservoirs in the heart of the Pine Barrens. Otters have not been studied in the Pine Barrens. They once thrived throughout Canada and most of the United States, and while they have been extirpated in most of their historic range by humans, they are being reintroduced successfully in many places. Feeding mainly on fish, Otters will also eat shellfish, frogs and small mammals and birds. They are reported to enjoy blueberries. Given their secretive habits, one is far more likely to see otter-signs, such as the slides they wear in stream banks, than to catch sight of an otter itself.

Northern Pine Snake

About 20 species of snakes inhabit the Pinelands, and several of these populations are quite remarkable. For example, **Timber Rattlesnakes** (pictured above) is the only venomous species in the Pinelands and exists here as a disjunct population. Having been extirpated from the immediate environs of the Pinelands, they have managed to survive in about seven reproducing populations scattered through the region. The closest neighboring populations are in far north Jersey. The **Northern Pine Snake** populations of the Pinelands are also cut off from their own kind. Northern Pine Snakes are not found again until you get all the way down to Virginia and West Virginia. Similarly, the Pinelands hosts the northernmost population of the Corn

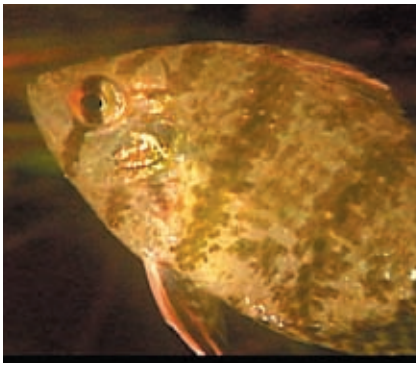
Snake. The most common snake of the Pinelands may be the Northern Water Snake. Surely the most bizarre snake of the area is the Eastern Hognose, also known as the Puff Adder, since it often spreads its neck, cobra-like, when alarmed.

Two **Toads** and twelve **Frogs** are known to inhabit the Pinelands. All of these amphibians are dependent on high-quality aquatic habitat for breeding, but some of them are otherwise more closely associated with uplands. The Pine Barrens is the global stronghold for the Pine Barrens Treefrog, which uses mostly intermittent ponds in characteristic Pine Barrens areas for breeding. Residential development and farming in the Pinelands often result in changes to the chemistry of breeding habitats of these animals, and an influx of non-native species that can displace them. Carpenter Frogs are another characteristic Pine Barrens species, the presence of which indicates a healthy aquatic wildlife community. Some of the other more visible and well-known frog species of the Pine Barrens are the Green Frog and the Southern Leopard Frog.



Pine Barrens Treefrog

While the diversity of **Bird** species in the Pine Barrens is unremarkable compared to richer areas, one may still encounter about 144 species, many of which breed in the Pinelands. The Pine Barrens is important to many migrating and wintering birds. The forests and swamps of the Pine Barrens provide nesting habitat for about 100 species, including wood warblers and other songbirds. The Pine Barrens is an important area for breeding, feeding, nesting, and resting for a great variety of waterfowl, such as ducks and geese, and magnificent raptors, such as the Bald Eagle, Red-shouldered Hawk, and Osprey. Many of our bird species that rely on the estuary systems benefit directly from the quality water flowing from the Pine Barrens streams and rivers into the coastal estuaries.



Backbanded Sunfish

Pine Barrens streams are good habitat for a very limited range of **Fish** species, because of the streams' acidity. Most fish cannot reproduce in the Pine Barrens' naturally acid waters, because the acidity interferes with the development of their eggs. The relatively low level of algae and aquatic vegetation may also exclude some species that require their habitat to provide a greater quantity or variety of food. Native fishes include New Jersey species that are only found in the Pine Barrens and those that thrive both in the Pine Barrens and in other, non-acidic waters. Species found in the Pine Barrens are Banded Sunfish, Blackbanded Sunfish, Pirate Perch, Mud Sunfish, Swamp Darter and Yellow Bullhead. Species found in the Pine Barrens and elsewhere in New Jersey are American Eel, Bluespotted Sunfish, Eastern Mudminnow, Redfin Pickerel, Chain Pickerel, Creek Chubsucker and Tadpole Madtom.

There are several species of fish that are not found in pristine Pine Barrens waters, but are sometimes found in streams that have been altered and degraded by pollution. These species include Tesselated Darter, Bluegill, Largemouth Bass, Pumpkinseed, Brown Bullhead, Golden Shiner and Yellow Perch. We will return to these species as indicators of human alteration of the ecosystem below.

Development and Exploitation of the Pine Barrens

Early History: At the time of European contact, the Lenape Indians inhabited the Pinelands region. As Europeans began to populate southern New Jersey, the Indians sold or abandoned their lands. Disease and sporadic fighting with whites reduced the native population. By 1758, the few remaining Indians in the state were placed on the Brotherton Reservation at Indian Mills (Shamong Township), located within the Pinelands. This 3,258-acre reservation was one of the first in North American. By the turn of the 19th century, most of the Indian families had left Brotherton and moved to New York or to Indian territory in the West.

The first Europeans to come to the Pinelands were woodcutters. From the early 1700's, these men exploited the vast forests. For lumber merchants, the Pinelands represented an untapped and apparently inexhaustible supply of materials for shipbuilding, pitch, tar, and turpentine. By 1749, the reduction of timber in some areas was so great that Benjamin Franklin "advocated conservation and intelligent forestry to combat the reckless and wanton slaughter of woods" (Pierce 1957 p. 5).

The maritime industry in the Pinelands was flourishing prior to the Revolutionary War. New Jersey's coastal plain provided most of the raw materials needed for shipbuilding, including timber such as cedar, oak, pine, maple, hickory, walnut and wild cherry. In addition, the Pinelands yielded tar used to caulk hulls, pine resins used to produce turpentine for hull preservation and iron products necessary to make ship hardware. By 1800, the shipyards of southern New Jersey supplied 10 percent of the vessels needed for commerce in the Philadelphia area.

Another important 18th century economic activity was the production of iron from the limonite ore found in stream beds and bogs throughout the Pinelands. From the mid-1700's to the mid-1850's, the Pine Barrens provided the ore, the charcoal used to produce the iron, and the water power used to operate the furnaces. "Company towns" developed around the furnaces and forges, with the local population serving as the labor force and wealthy residents of the Delaware Valley acting as the financiers.

Unlike the lumber industry, the bog iron industry required enormous outlays of money. Businessmen were willing to make substantial investments in the Pinelands in the hopes of reaping great profits. But some furnaces ran into financial difficulties even before they were completed. With the discovery of anthracite coal in Pennsylvania during the 1840's and the advent of the railroads in the 1850's, the New Jersey bog iron industry could no longer compete with the Pennsylvania ironworks.

European settlers built numerous sawmills, gristmills and other local businesses. As the bog iron industry collapsed, the buildings and water-power installations were converted to glass factories, paper mills, cotton mills, sawmills, and brick and tile factories. These industries, however, could not assure continuity of employment. Persistent forest fires plagued the mills and factories. Workers often migrated between towns in search of job opportunities.

After the Civil War, production of cranberries in the Pinelands began on a commercial scale. By 1928, approximately 13,000 acres of lowland were cleared for use as cranberry bogs. By the mid-1950's, however, only about 6,000. acres were being cultivated. Blueberry cultivation began on a commercial scale before 1916, and occupied 8,500 acres by 1963. Cranberry and blueberry growing represent domestication, improvement, and commercial use of plants native to the area. The industries are self-sustaining, in contrast to lumbering, which was self-destructive for lack of conservation practices.

Since the 18th century, the Pinelands has been a refuge for European immigrants. The earliest settlers favored coastal areas. They generally avoided inland areas, which were unsuitable for agriculture and which posed transportation problems because of swamps. After 1850, ethnic groups including Germans, Russians, Italians, and Jews began to move into the interior areas of the southern Pinelands (south of the Mullica River). They were drawn by the availability of land previously used for industrial ventures, the introduction of chemical fertilizers to make the soil more suitable for farming, and the presence of railroads which permitted easier access.

Recent History: Since World War Two, South Jersey has seen increasingly rapid development. Land in and adjacent to the boundary of the Pinelands National Reserve is being developed for suburban housing developments and commercial malls, vacation or resort housing, the casino industry and some light industry.

To get a flavor of the last decade's rate of growth in the counties that are within and around the Pinelands National Reserve, examine the population figures from the 1950, 1990 and 2000 censuses in Table 1.

The Map on page 2 shows the land use or land cover for South Jersey in 1995. Red marks land that has been developed as urban or suburban. The land use/land cover map shows that

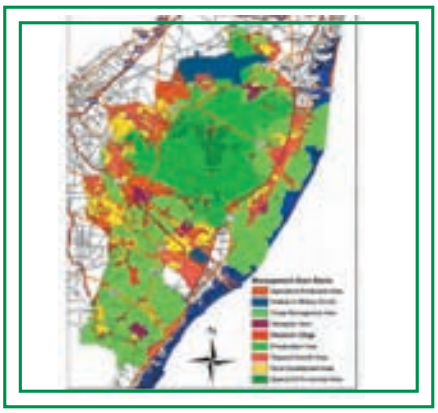
Table 1: Population Growth in New Jersey Counties, 1950 to 2000. (Source: United States Census Bureau)

County	1950 Population	1990 Population	2000 Population	% Growth 1950-2000
Atlantic	132,399	224,327	252,552	91%
Burlington	135,910	395,066	423,552	212%
Camden	300,743	502,824	508,932	69%
Cape May	37,131	95,089	102,326	176%
Cumberland	88,597	138,053	146,438	65%
Gloucester	91,727	230,082	254,673	178%
Ocean	56,622	433,203	510,916	802%
New Jersey	4,835,329	7,730,188	8,414,350	74%

the surviving Pine Barrens forests and wetlands are now surrounded by cities and suburbs, and the Pine Barrens is almost cut in half along the corridor between the city of Hammonton and Atlantic City. Table 2 shows some figures on population growth in the Atlantic and Ocean County growth areas. These growth rates greatly exceed the statewide average rate of just under 9%.

Table 2: Population Growth in Selected Pinelands Regional Growth Area Municipalities 1990 - 2000. (Source: United States Census Bureau)

Municipality	1990 Population	2000 Population	% Growth 1990-2000
Egg Harbor Township	24,557	30,717	20%
Galloway Township	23,306	31,197	29%
Lacey Township	22,141	25,346	15%
Jackson Township	33,233	42,816	29%



Pinelands Protection Act and Comprehensive Management Plan

The Pinelands National Reserve and the Pinelands Comprehensive Management Plan are laws aimed at protecting the natural resources and ecological systems of the Pine Barrens and, to some extent, the coastal estuaries. They aim to protect these ecosystems by controlling development. These laws are the primary, but not the only, tools that government has adopted to manage development and protect natural resources in the Pinelands and coastal area.

In the late 1970s, a consensus arose among New Jersey's political leaders that something had to be done to save the Pine Barrens ecosystem before it was lost to development and exploitation. For many years, citizens of the region had been working to save the Pine Barrens because they recognized its incredible ecological and recreational importance to the people of this very crowded part of the country. With strong leadership from then-Governor Brendan Byrne and New Jersey's representatives in the United States Congress, the Pinelands National Reserve came into being. The term "Pinelands" was coined for the land given special protections. The *Pinelands* National Reserve is both more and less inclusive than the Pine Barrens ecosystem:, since the Pinelands boundary includes coastal and transitional farming lands, and leaves out perhaps one-quarter of the Pine Barrens ecosystem.

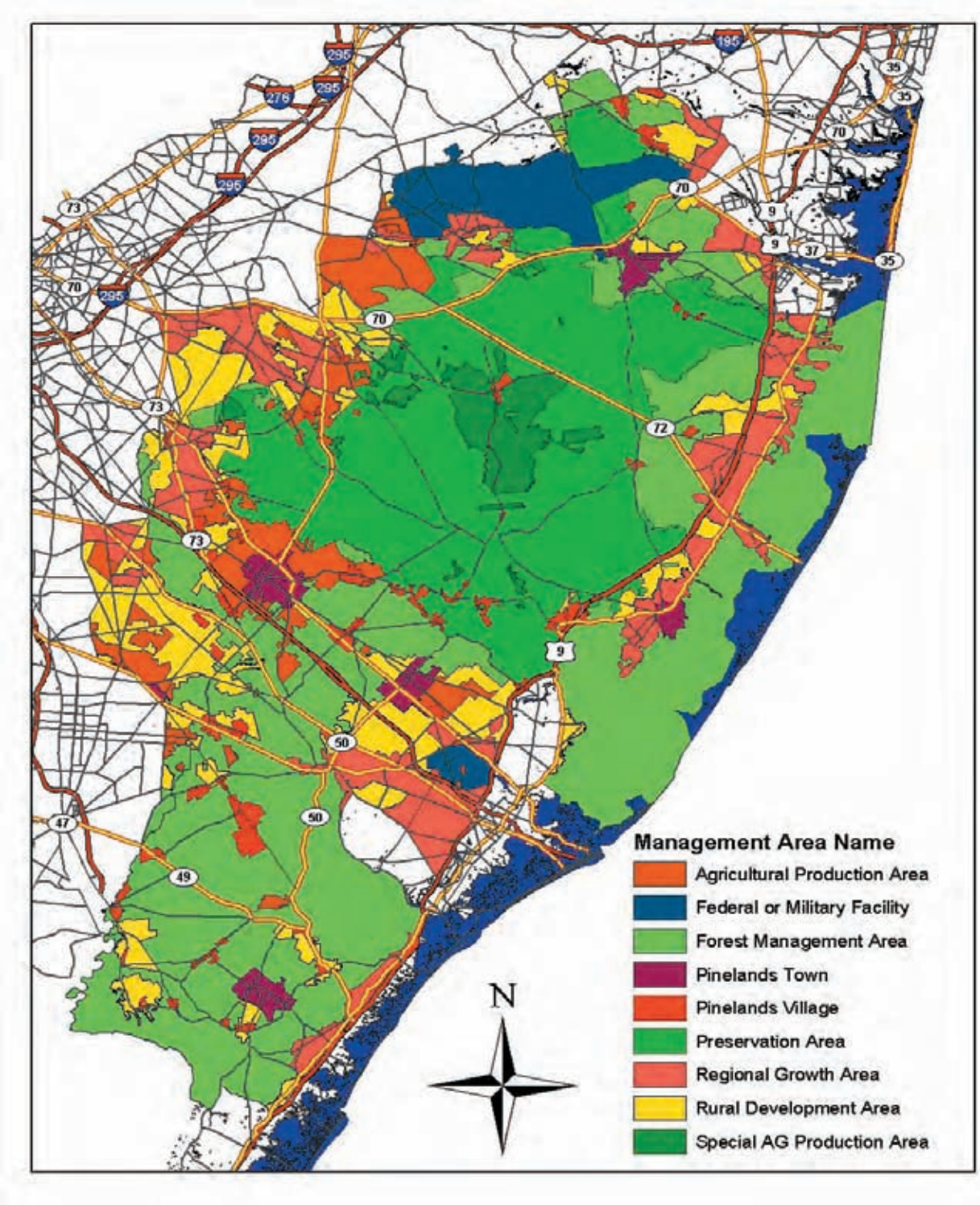
The Pinelands National Reserve was created by the United States Congress in the National Parks and Recreation Act of 1978. Unlike a National Park, where the government owns the land, the concept of a National Reserve was to mark out a large area and institute programs to control development in order to save the area's natural resources. The State of New Jersey took the lead in carrying out this goal when it enacted the Pinelands Protection Act in 1979.

With passage of the Pinelands Protection Act, New Jersey and the federal government became partners in saving the Pine Barrens ecosystem and rural landscape. The Act created a special government agency, the Pinelands Commission, to write and implement a land use management plan called the Pinelands Comprehensive Management Plan ("CMP").

The Pinelands CMP essentially dictates what kind of development or other alteration of the land is allowed to take place in each part of the Pinelands. The CMP says that development can take place in its Regional Growth Areas and Rural Development Areas, as well as in preexisting towns and cities, but little or no development can take place in the Preservation Area and Forest Areas. The CMP also has strong rules to protect the habitats of rare, threatened and endangered species of plants and animals from the adverse impacts of development.

The Pinelands is divided into 8 "Management Areas," which specify what kinds of development is allowed in each area. This chart shows the relative total areas or size of each Management Area. The green shaded areas are preservation-oriented. The red and orange are development oriented. The brown is for upland farming, and the blue is U.S. military, some of which is preserved and some intensively developed.

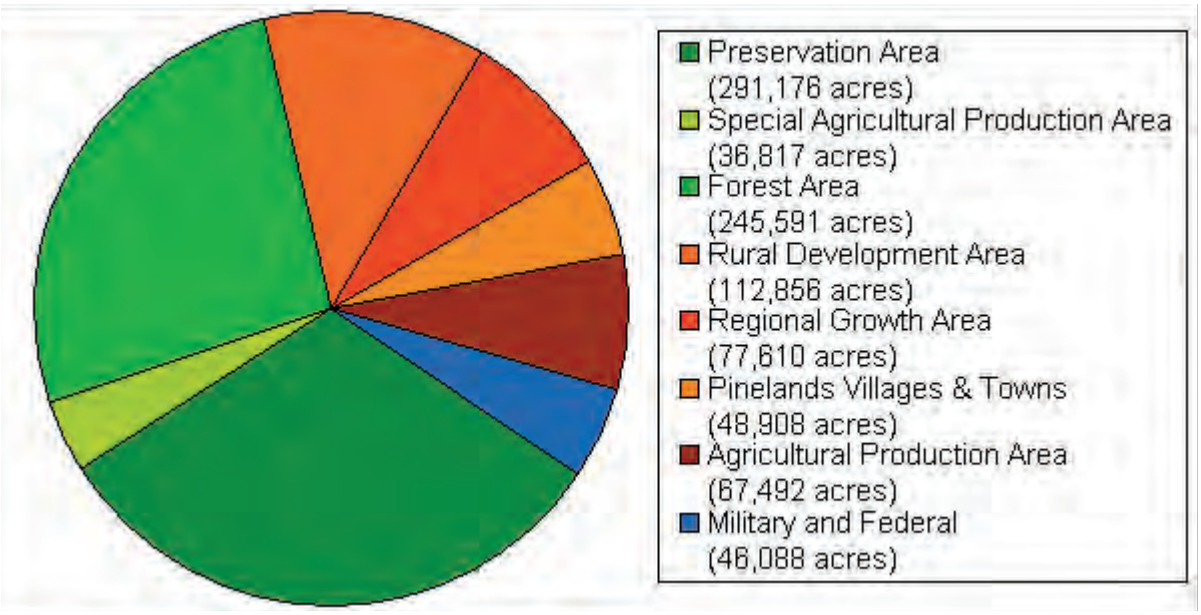
The Pinelands Comprehensive Management Plan (CMP) Land Capability Map, showing the Pinelands "Management Areas" that dictate permitted forms of development and land uses. (Source: New Jersey Pinelands Commission)



A little over half of the Pinelands Area - in fact 62% - is devoted to natural preservation. But a substantial portion - 26% - is dedicated to development. The balance, 12% is for farming and federal government uses.

The goal of the Pinelands Protection Act and CMP is to achieve "sustainable development" or "smart growth." There are many definitions of sustainable development and smart growth among the many people working in this field. Some believe truly sustainable development is not possible in our modern, market economy, because we simply use up too many natural resources (land, water, clear air, forests and so on) to live this way forever. Others believe that modern American cities, suburbs and rural areas can be built and managed in a way that uses, but does not destroy or deplete, the natural resources on which we depend. The Pinelands CMP is an experiment designed to achieve that ideal of thriving economies and healthy natural landscapes.

The portion of land in the Pinelands Area that lies in each Pinelands CMP Management Area. (Source: New Jersey Pinelands Commission)



How Is Development Affecting the Pine Barrens Ecosystem?

If distinctive Pine Barrens plant and animal communities are created and sustained by the harsh chemistry of the soil and water, what should we expect to happen when that chemistry changes? Over the last two decades, scientists have studied the Pine Barrens ecosystem and looked to see how human activities, particular development in and around the Pinelands, is affecting the ecosystem. There are several ways that development of cities, villages and suburbs might affect the ecosystem, such as:

- Contamination of rivers, streams, wetlands and aquifers with polluted runoff;
- Loss of rare plants and animals and the destruction of their habitats, by the building of roads across the Pine Barrens, clearing of vegetation, and building of houses and buildings on the land; and
- Fragmentation of forests, leading to the isolation of local plant and animal populations from one another.

Among these, scientific work has focused most on the contamination of water, both surface water (rivers, streams, ponds and wetlands) and ground water (underground aquifers.) Here we will discuss the work of scientists who work for the Pinelands Commission. The Pinelands Commission is the state government agency that oversees the Pinelands Comprehensive Management Plan and reviews nearly all developments in the Pinelands to be sure they comply with the Plan before they are built.

The Pinelands Commission science program has studied two of the major watersheds in the Pinelands: the Mullica River watershed and the Rancocas River Watershed. They have recently begun to survey the Barnegat Bay Watershed as well. Their basic goal is to see how well the Pinelands Comprehensive Management Plan is working to preserve healthy Pine Barrens plant and animal communities.

The scientists began this initiative in the Mullica River watershed. This watershed is mostly undeveloped (only about 15% of the entire watershed is developed or farmed), but there is intensive development of its western headwaters area. In a series of related studies, the scientists looked at Pine Barrens streams whose drainage areas were completely undeveloped - that is, pristine streams - as their reference points for undisturbed Pine Barrens ecology. The scientists recorded the chemical characteristics of the water for pH, "specific conductance" (a measure of ionized molecules, and therefore the dissolved compounds, in the water), and nutrients in the form of nitrogen compounds. The scientists also examined the plants growing in and around the streams, the fish species living in the water, and the frogs calling in the immediate vicinity. They compared their results with the work of earlier naturalists and other modern scientists who have detailed the plants and animals of the Pine Barrens. In this way, the scientists developed a picture of a Pine Barrens stream ecosystem unaffected by development or other disturbance of the land. This picture of an undisturbed stream became the reference point or baseline against

which they would compare other streams in the watershed.

The baseline picture of an undisturbed Pine Barrens stream habitat included average pH of 4.4 (very acidic) and specific conductance of 39 µS/cm (micro-Siemens per centimeter). The stream vegetation was made up of plants that botanists early this century identified as native to the Pine Barrens. The fish species they found were limited to the native varieties discussed earlier, such as Blackbanded Sunfish and Pirate Perch. Frogs were also restricted to the native species like the Pine Barrens Treefrog and Green Frog.

With their baseline picture of conditions in an undisturbed stream basin, the scientists went out to survey numerous additional stream locations for these same factors of pH, specific conductance, plants, fish and frogs. They picked sites having a wide spectrum in the amount urban/suburban development and farming in the basin. They surveyed each location several times over a period of years, in order to ensure their results were not unduly affected by transient weather conditions or other short-lived influences.

Water chemistry: The Pinelands Commission scientists found a strong correlation between pH, specific conductance and high levels of nitrogen (in the form of nitrate), on the one hand, and human land uses, on the other. Based on these results, the Pinelands Commission scientists concluded that "Water-quality conditions recorded for the 26 stream sites clearly related to watershed conditions. … The strikingly different characteristics of the reference-stream sites and the degraded-stream sties illustrate the effect of land-use patterns on Pinelands water quality."

Stream vegetation: The Pinelands Commission scientists studied the plant species growing at 72 stream sites. They found that streams with a higher percentage of development, pH and nitrate concentrations also had differences in the composition of the plant communities growing in and along these streams, when compared to acidic, low-nutrient reference streams. To analyze these differences, the scientists listed their study sites in order, ranking them by a combination of the percentage of developed or agricultural land in their drainage areas, pH, specific conductance and channel sediment.

The scientists found that non-Pine Barrens species came to dominate the local plant communities as the level of development, pH and specific conductance rises. The more human disturbance in the stream basin, the more non-native plants they found there.

Fish: In order to see whether fish communities varied with disturbance in the basins of Pine Barrens streams, the Pinelands Commission scientists examined the fish they caught at several undisturbed reference sites with the fish species they found across a broader range of disturbed and undisturbed streams. Disturbance was again measured in terms of pH and specific conductance of the water in the streams and development in the streams' drainage basins. Initial studies enabled the scientists to develop lists of native Pine Barrens, wide-ranging, and non-native fish species. They found that nonnative species only appear at sites with high pH, specific conductance and suburban/urban development of the drainage basin. The Pinelands Commission scientists concluded that the species composition of fish communities provide an excellent indication of water quality changes in Pine Barrens streams and lakes.

Frogs and toads (anurans): Finally, the Pinelands Commission scientists studied frog and toad populations at 242 sites in the Mullica River watershed. As with stream vegetation, they found that the species of frogs and toads living around a water body correlated with the pH,

specific conductance and nutrient levels in the water - and that all these factors correlated with the amount of development in each sub-watershed. Where Pine Barrens conditions of acidic water, low conductance and low nitrates existed, the native Pine Barrens species like Pine Barrens Treefrog thrived - and non-Pine Barrens species like Bullfrog were absent. But where the water chemistry had been altered to reduce the acidity and raise the levels of conductance and nitrates, the native species were either absent or less common and non-Pine Barrens species had found a foothold. An especially striking and important finding was that where Bullfrogs were able to enter an area and establish a reproducing population, Pine Barrens Treefrogs were not to be found. This finding suggests that Bullfrogs - an aggressive predator far larger than the tiny Treefrog - may prey on Treefrogs and their eggs, thus displacing the native species from habitats altered by human impacts.

It is important to emphasize that altered stream habitat does not just mean we find species of plants and animals that are not native to the Pine Barrens. It also means we do not find the native species, or do not find them in the abundance they naturally would enjoy. In some cases, individual species may be entirely displaced by invasive species that normally could not prosper in the Pine Barrens. The Pinelands Commission science program has extended this survey to the Rancocas River, Barnegat Bay and Great Egg Harbor watersheds.

What is causing these changes in water quality and natural communities in waters near developed or farmed areas? The principal agents are nutrients and liming compounds. Nutrients are all the food molecules that plants or animals need to live. For plants, the most prominent nutrients are nitrogen and phosphorous. Because the availability of nitrogen and phosphorous in forms that plants can use tends to be the major factor limiting plant growth, fertilizers containing these chemicals are applied to farm crops and residential lawns in developed areas. And because the naturally acidic soils of this area tend to inhibit the growth of nonnative food crops and lawn grass species, people put liming compounds on farm fields and turf to neutralize the acidic pH of the soil. In practice, these treatments are not very efficient - that is, much or most of the chemicals applied do not remain in the top soil and are not used by the plants growing there, but instead are washed through the sandy subsoils into the Kirkwood-Cohansey aquifer. Soon they are transported through the ground to streams and wetlands. Those streams and wetlands closest to where the chemicals are applied receive most of the chemical input, and are most dramatically affected by the ecological changes these chemicals bring about.

Another source of nitrogen can be found in the thousands of septic systems in people's homes. Septic systems generally do not treat the human waste we flush into them, but instead simply allow it to seep gradually into the soils. The effluent from our homes includes lots of nitrogen from our bodily wastes, as well as metals, household detergents and many other chemicals. Some of these contaminants are filtered and retained in the soil, but, especially in the sandy soils of this region, much is transported through the aquifer into streams, wetlands, wells and, ultimately, the coastal estuaries.

The full range of impacts that fertilizers, liming and septic effluent have on ground water quality is not yet well understood. But these impacts appear to be complex and extensive. For example, scientists with the United States Geological Survey have found that nitrogen, calcium and magnesium leaching from fertilizers and lime enter the water table and cause naturally occurring radium - a radioactive molecule - to break away from soil particles to which it is normally attached and move with the flow of the aquifer through the ground, ultimately entering

wells that pump water from the shallow aquifers. As another example, there is evidence that, in addition to the direct discharge of compounds like nitrogen, septic systems may interact with pollutants deposited from air pollution to release mercury into the aquifer. Such a process may explain why as much as 10% or more of wells in the Kirkwood-Cohansey aquifer are testing positive for dangerously high levels of mercury. The long-term environmental effects of contamination such as radium and mercury have yet to be studied.

What Do Changes in Water Quality Mean for the Pinelands?

More than 20 years ago, the United States and New Jersey adopted a very strong and innovative plan to save the Pine Barrens ecosystem. A central motivation for this program was the unique ecology of the region – the extraordinary collection of rare, threatened and endangered species, the huge Kirkwood-Cohansey aquifer system, and the particular biological communities found here and nowhere else on earth. The New Jersey Pine Barrens was an island of biodiversity that, if lost, could not be replaced. The impacts on water quality we have been examining, and the resulting alterations in the plant and animal species of affected streams and wetlands, raise fundamental questions about the future of the Pinelands.

Are the impacts of development and farming static and stable, or will they slowly spread over time throughout the ecosystem? The scientific work to date provides a snapshot in time of the correlation between land development patterns and ecological change. No study has yet been conducted on whether, how or at what speed the ecological changes may be spreading.

Can we devise ways to limit the impacts of human activities on the Pine Barrens ecosystem? There may be things we can do in the way we design houses, subdivisions, roads and ballparks, or in the way farmers grow crops on the land, that will slow or even reverse the flow of polluting chemicals into the soils and waters of the Pine Barrens.

What responsibility do we have, as individuals living in this region, to the landscape in which we live? As our understanding of our connection to the landscape, and of the ways we affect the natural systems around us, grows, we may find ways we can live more compatibly with our surroundings. This is the goal of those seeking to create "sustainable development" practices tailored to the ecology of this region.

In sum, are the Pine Barrens big enough for the treefrog and the builder, the farmer and our families? The Pinelands Protection Act, CAFRA and all our plans for housing and businesses in this region assume that it is possible to save the Pine Barrens ecosystem and all the organisms that make it special, while also building houses, roads and shopping malls for literally millions of human beings. But do we know that is possible over the long run? If we find that perhaps it is not possible to have it all, which of these valuable things - natural communities or successful towns and cities - will our society choose to keep and promote in the Pine Barrens?

Suggested Activities

The ideas listed here are just that: ideas. We know that bringing off these ideas successfully with students takes a lot more. If we can help, call us at PPA and we will try to assist in whatever way best suits your needs.

Field Trips

There are many sites in the Pine Barrens that are easily accessible by vans and buses for field trips. Other sites are accessible by four-wheel drive vehicles, but may present difficulties for vans or buses. If you plan a trip into public lands, such as a State Forest, it is a good idea to talk to the agency staff to give them a heads up and pick their brains on local conditions and activity ideas. For more information and ideas on sites to visit, or for help in organizing a field trip, please call or e-mail Russell Juelg at PPA, russell@pinelands alliance.org.

- Join one of PPA's Pinelands Adventures. The schedule and program descriptions are available on our web site at www.pinelandsalliance.org.

- Upland forest surveys and hiking, to investigate topics like tree species distribution, disturbance and its impacts on plant species, birds and life in the forest soil. Try any of the Pine Barrens' State Forests (links are listed in the Resources section.)

- Water quality surveys on Pine Barrens lakes, to investigate the health of aquatic ecosystems in terms of factors like pH, nutrients, native and nonnative fishes, and the presence of Pine Barrens and non-Pine Barrens plants.

- Document the various habitats and native and nonnative plant and bird species in your school grounds or neighborhood.

- Community development survey, to investigate how different communities have been designed and the impact of community design on environmental resources like water quality, forest habitats and wildlife corridors.

- Using digital cameras, document as many different habitat types as you can find in the Pine Barrens.

- Compare a Pine Barrens habitat you have studied with a non-Pine Barrens habitat nearby. Document and explain differences in water chemistry, fish and plant communities, bird life, and topography.

Classroom Activities

- Create a Pine Barrens aquarium. Native fish aquariums are very easy to set up and maintain, and you can easily catch native fishes. You will need a collecting permit to catch and keep native (non-game) fish like Banded Sunfish. For a permit, contact the DEP's Division of Fish & Wildlife at (609) 292-2965.

- Research the sources and flow of water which your school uses. Where does it come from? What do we do to the water before we use it? Where does it go when we're done? What conservation measures is your school using, or might use, to save water? And how might human consumption of water affect the ecosystem in your area?

- Research the sources and destinations of solid waster generated at your school. What kinds of solid waste are being generated, and do different types of waste raise different challenges for safe disposal? Where does your solid waste go, and why? How is it disposed of? What conservation measures is your school using, or might use, to reduce its solid waste.

- Introduce your students to Geographic Information Systems (GIS) – that is, making maps and analyzing natural resource information on your computer. A good place to start is the New Jersey Department of Environmental Protection (DEP) web site's iMap program at www.state.nj.us/dep/gis/newmapping.htm.

- Investigate population change in your town and region over time, and the impacts human population change has had on plants, animals and natural resources in your area. Population information is available at the U.S. Census Bureau's web site at www.census.gov.

- Web research. See the sites listed in the Resources section.

Get Involved in Conservation

There are many ways for students to get involved in protecting your environment and promoting smart use of our natural resources. Teachers might suggest:

- Meet your mayor, town council, and planning board members. Ask them how they see the future of your town unfolding, and what they think about protection of natural resources. Attend the regular council and planning board meetings.

- Write to the newspapers with your thoughts on growth and the environment. Local papers like to print the views of thoughtful young people on important issues.

- Write to the Governor, your state legislator and your local town officials with your thoughts and concerns. Every voice they hear has some influence on how our elected officials make the decisions that shape our futures.

- Volunteer with an environmental organization, like the groups sponsoring this program. These groups have lots of volunteer opportunities, and this is a good way to get into the world of environmental advocacy:
    - Assist with running outdoor programs
    - Help maintain nature preserves, trails and other facilities
    - Work on advocacy campaigns and public education programs
    - Help represent the group and its mission at fairs, festivals and other public events

- Get together with friends and other students at school to organize a club, do field trips, educate the rest of the school about the environmental challenges facing your area, and communicate with state and local leaders.

Suggested Reading

BEANS, B. & NILES, L. (eds.), 2003. Endangered and Threatened Wildlife of New Jersey. New Brunswick, NJ: Rutgers University Press.

BOYD, H., 1991. A Field Guide to the Pine Barrens of New Jersey. Medford, NJ: Plexus Publishing, Inc.

BOYD, H.P., 1997. A Pine Barrens Odyssey. Medford, NJ: Plexus Publishing, Inc.

BOYD, H.P., 2001. Wildflowers of the Pine Barrens of New Jersey. Medford, NJ: Plexus Publishing, Inc.

COLLINS, B.R. & ANDERSON, K.H., 1994. Plant Communities of New Jersey: A Study in Landscape Diversity. New Brunswick, NJ: Rutgers University Press.

COLLINS, B.R. & RUSSELL, E.W.B., (eds.), 1988. Protecting the New Jersey Pinelands: A New Direction in Land-Use Management. New Brunswick, NJ: Rutgers University Press.

FORMAN, R.T.T. (ed.), 1979. Pine Barrens: Ecosystem and Landscape. New York: Academic Press, Inc.

GELLER, M., 2002. A Key to the Woody Plants of the New Jersey Pine Barrens. New Brunswick, NJ: Rutgers University Press.

KENNISH, M. (ed.), Journal of Coastal Research, Fall 2001, Special Issue 32, p. 82.

KENNISH, M., 2001(f). The Scientific Characterization Barnegat Bay-Little Egg Harbor Estuary and Watershed. Barnegat Bay Estuary Program.

McPHEE, J., 1967. The Pine Barrens. New York, NY: Noonday.

PIERCE, A.D., 1957. Iron in the Pines. New Brunswick, N.J.: Rutgers University Press.

PINELANDS COMMISSION, 1980. The Pinelands Comprehensive Management Plan. New Lisbon, N.J.: Pinelands Commission.

ZAMPELLA, R., BUNNELL, J., LAIDIG, K. and DOW, C., 2001. The Mullica River Basin, A Report to the Pinelands Commission on the Status of the Landscape and Selected Aquatic and Wetland Resources. New Lisbon, NJ: New Jersey Pinelands Commission.

Selected Scientific Names

Mammals - Pine Barrens

Beaver *Castor candensis*

Bobcat *Felis rufus*

Coyote *Canis latrans*

Gray Fox *Urocyon cinereoargenteus*

Long-tailed Weasel *Mustela frenata*

Mink *Mustela vison*

Red Fox *Vulpes fulva*

River Otter *Lutra canadensis*

Southern Bog Lemming *Synaptomys cooperi*

White-tailed Deer *Odocoileus virginianus*

Birds - Pine Barrens

Bald eagle *Haliaeetus leucocephalus*

Barred Owl *Strix varia*

Great Horned Owl *Bubo virginianus*

Osprey *Pandion haliaetus*

Red-tailed Hawk *Buteo jamaicensis*

Red-Shouldered Hawk *Buteo lineatus*

Screech Owl *Otus asio*

Snakes - Pine Barrens

Corn Snake *Elaphe g. guttata*

Hognose Snake *Heterodon platyrhinos*

Northern Pine Snake *Pituophis m. melanoleucus*

Northern Water Snake *Nerodia s. sipedon*

Timber Rattlesnake *Crotalus h. horridus*

Turtles - Pine Barrens

Painted Turtle *Chrysemys p. picta*

Spotted Turtle *Clemmys guttata*

Box Turtle *Terrapene c. carolina*

Frogs - Pine Barrens Native

Pine Barrens Treefrog *Hyla andersonii*

Fowler's Toad *Bufo woodhousii fowleri*

Green Frog *Rana clamitans melanota*

Southern Leopard Frog *Rana spenocephala*

Northern Spring Peeper *Hyla c. crucifer*

Eastern Spadefoot *Scaphiopus h. holbrookii*

Frogs - Not Native, Disturbance Indicators

Bullfrog *Rana catesbeiana*

Finfish - Pine Barrens Native

American Eel *Anguilla rostrata*

Banded Sunfish *Enneacanthus obesus*

Blackbanded Sunfish *Enneacanthus chaetodon*

Bluespotted Sunfish *Enneacanthus gloriosus*

Chain Pickerel *Esox niger*

Creek Chubsucker *Erimyzon oblongus*

Eastern Mudminnow *Umbra pygmaea*

Mud Sunfish *Acantharchus pomotis*

Pirate Perch *Aphredoderus sayanus*

Redfin Pickerel *Esox americanus*

Swamp Darter *Etheostoma fusiforme*

Tadpole Madtom *Noturus gyrinus*

Yellow Bullhead *Ameiurus natalis*

Finfish - Pine Barrens Disturbance Indicators

Bluegill *Lepomis macrochirus*

Brown Bullhead *Ameiurus nebulosus*

Golden Shiner *Notemigonus crysoleucas*

Largemouth Bass *Micropterus salmoides*

Pumpkinseed *Lepomis gibbosus*

Tessellated Darter *Etheostoma olmstedi*

Yellow Perch *Perca flavescens*

Trees - Pine Barrens

Black Cherry *Prunus serotina*

Black Gum *Nyssa sylvatica*

Black Oak *Quercus velutina*

Blackjack Oak *Quercus marilandica*

Chestnut Oak *Quercus prinus*

Pin Oak *Quercus palustris*

Pitch Pine *Pinus rigida*

Post Oak *Quercus stellata*

Red Chokecherry *Aromia arbutifolia*

Scarlet Oak *Quercus coccinea*

Shortleaf Pine *Pinus echinata*

Southern Red Oak *Quercus falcata*

Swamp Maple *Acer rubrum*

Swamp Magnolia *Magnolia virginiana*

Sweet Gum *Liquidambar styraciflua*

Virginia Pine *Pinus virginiana*

White Oak *Quercus alba*

Willow Oak *Quercus phellos*

Shrubs - Pine Barrens

Bearberry *Arctostaphylos uva-ursi*

Dangleberry *Gaylusacia frondosa*

Dwarf Huckleberry *Gaylussacia dumosa*

Fetterbush *Eubotris racemosa*

Highbush Blueberry *Vaccinium corymbosum*

Hudsonia *Hudsonia ericoides*

Inkberry *lex glabra*

Leatherleaf *Chamaedaphne calyculata*

Lowbush Blueberry *Vaccinium pallidum*

Mountain Laurel *Kalmia latifolia*

Sand Myrtle *Leiophyllum buxifolium*

Sheep Laurel *Kalmia angustifolia*

Staggerbush *Lyonia mariana*

Swamp Azalea *Rhododendron viscosum*

Sweet Pepperbush *Clethra alnifolia*

Teaberry *Gaultheria procumbens*

Trailing Arbutus *Epigaea repens*

Winterberry *Ilex vertillata*

Herbaceous Plants - Pine Barrens

Arethusa Orchid *Arethusa bulbosa*

Bladderworts *Utricularia* spp.

Bog Asphodel *Narthecium americanum*

Bracken Fern *Pteridium aquilinum*

Broom Crowberry *Corema conradii*

Curly-grass Fern *Schizaea pusilla*

Grass Pink Orchid *Calopogon tuberosus*

New Jersey Rush *Juncus caesariensis*

Pine Barrens Boneset *Eupatorium resinosum*

Pine Barrens Gentian *Gentiana autumnalis*

Pitcher Plant *Sarracenia purpurea*

Rose Pogonia *Pogonia ophioglossoides*

Sundews *Drosera* spp.

Swamp Pink *Helonias bullata*

Plants - Non-Native, Disturbance Indicators

Swamp milkweed *Asclepias incarnata*

Purple-stemmed beggar ticks *Bidens connata*

Beggar ticks *Bidens frondosa*

False nettle *Boehmeria cylindrica*

Larger water starwort *Callitriche heterophylla*

Sallow sedge *Carex lurida*

Straw-colored cyperus *Cyperus strigosus*

Common wild yam *Dioscorea villosa*

American barnyard grass *Echinochloa muricata*

Pilewort *Erechtites hieracifolia*

Eastern joe-pye weed *Eupatorium dubium*

Stiff marsh bedstraw *Galium tinctorium*

Spotted touch-me-not *Impatiens capensis*

Short-stalked false pimpernel *Lindernia dubia*

Cardinal flower *Lobelia cardinalis*

Water purslane *Ludwigia palustris*

Eulalia *Microstegium vimineum*

Climbing hempweed *Mikania scandens*

Deertongue grass *Panicum clandestinum*

Halberd-leaved tearthumb *Polygonum arifolium*

Mild water pepper *Polygonum hydropiperoides*

Dotted smartweed *Polygonum punctatum*

Arrow-leaved tearthumb *Polygonum sagittatum*

Nuttall's pondweed *Potamogeton epihydrus*

Small pondweed *Potamogeton pusillus*

Common elder *Sambucus canadensis*

Mad-dog skullcap *Scutellaria lateriflora*

Marsh fern *Thelypteris palustris*

Broad-leaved cat-tail *Typha latifolia*

Links

There are many, many web sites with information and images relating to the themes and species discussed in *The Pine Barrens: up close and natural* and this Guide. Below are some links you may find useful.

Links for more information on topics in the film and Teacher's Guide

Pine Barrens – General Information

- Pinelands Preservation Alliance
- Burlington County Library
- The New Jersey Pinelands Commission

Animals

- Beaver
  - Info, links and pictures
- Blackbanded Sunfish
  - Article
  - Drawing
- Pickerel
  - Info
  - Info and pictures
- Pine Barrens Treefrog
  - Info and picture
  - Info and picture
  - Hear the Treefrog's call
- Pine Snake
  - Info
  - Pictures
  - News article

River Otter

River Otter Alliance

Info and picture

Timber Rattlesnake

Milwaukie Public Museum

New Jersey Division of Fish & Wildlife

Fire

New Jersey State Forest Fire Service

United States Forest Service

Pinelands Commission Article

Geology, Soils and Water

United States Geological Survey – Search NJ Topics

The Jersey Devil

Strange New Jersey

Kirkwood-Cohansey Aquifer System

Real Time Water Level Data

USGS Research Paper

Pine Plains

Article

Research Paper 1

Research Paper 2

Plants

Pine Barrens Plants

Georgian Court College

Michael Hogan Photographs

Mike Baker Photographs

Atlantic White Cedar

- Article
- Restoring White Cedar

Blueberries

- US Dept of Agriculture
- All About Blueberries

Broom Crowberry

- Mike Baker Photo Site

Carnivorous Plants

- NatureServe
- International Carnivorous Plant Society

Cranberries

- Rutgers Univ. Site

Pitch Pine

- Pennsylvania Dept of Natural Resources
- NJ Dept of Parks & Forestry
- US Forest Service

Many regional, state and federal agencies are involved with Pinelands preservation and regulation.

The New Jersey Pinelands Commission

Environmental Protection Agency

New Jersey DEP

U.S. Fish and Wildlife Service

United States Geological Survey

U S National Park Service

New Jersey License Plate

The Pinelands Preservation Alliance is joined by several other organizations in trying to save the Pine Barrens. These are our Partners in Preservation.

Pinelands Preservation Alliance

New Jersey Audubon Society

New Jersey Conservation Foundation

Sierra Club New Jersey Chapter

The Forked River Mountain Coalition

Woodford Cedar Run Wildlife Refuge

American Littoral Society

Save Barnaget Bay

Barnegat Bay Watershed and Estuary Foundation

The Nature Conservancy

The Handbook of Landowner's Options

There are many sources of information on Pinelands nature, culture and policy. The following lists some of these sources.

Michael Hogan - Pinelands Photos

Sugar Sand Ramblers

Burlington County Library

Georgian Court:Plants of the Pine Barrens

Outdoor Club of South Jersey

Pineypower

Rutgers University Pinelands Field Station

Southampton Township Environmental Commission

Weymouth Township Environmental Commission

Whitesbog Historic Village

Wild & Scenic Maurice River

There are many organizations working to protect and preserve our environment.

Delaware Riverkeeper Network

Alliance for a Living Ocean

Earth Share of New Jersey

Earth Day Earth Site

ANJEC

Delaware Bay Schooner Project

Garden State Environet

Native Plant Society

Sierra Activist

New Jersey Environmental Lobby

New Jersey Environmental Federation

New Jersey DEP antisprawl campaign

There are many organizations who study the natural world and help us as we expand our knowledge of Pinelands nature .

Torrey Botanical Society

Academy of Natural Sciences

Philadelphia Botanical Club