# Discovering Delaware Water Gap

A Field Book for Young Naturalists

As you soar over Kittatiny Mountain, far beneath you on the rocky summit a tiny figure jumps and shouts, "Hey, everybody, there's a bald eagle!"

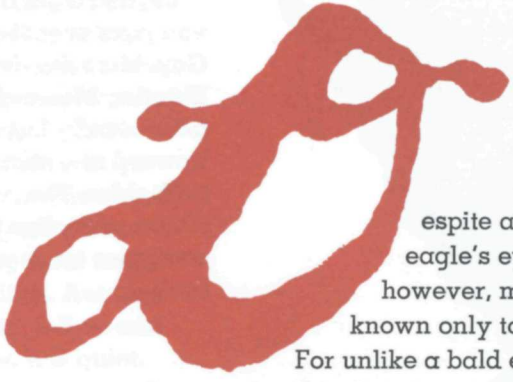
Immediately, sixty binoculars turn upward to catch a glimpse of you—America's rarely seen national bird—as you float easily on the rising air currents with your 2-meter wingspan. The hawkwatch observers can see your white head and tail, your curved yellow beak, and your dark chocolate body. Enjoying your wild freedom, you glide by them unconcerned.

Kittatiny Mountain, a prominent ridge of the Appalachian range, is your migration route southward each autumn. Other birds of prey, especially broad-winged hawks and red-tailed hawks, also follow this route, riding the strong updraft air currents and scarcely ever needing to flap their wings.

Below you, in eastern Pennsylvania and western New Jersey, lies Delaware Water Gap National Recreation Area, a 28,000-hectare swath of long ridges and valleys stretching north and south along the scenic Delaware River. The river flows between fields and woodlands, passing rural towns and beaches and picnic facilities. Autumn foliage paints brilliant red and yellow and orange across the land below. It is quiet.

With your keen eyes you can make out hundreds of humans below you, swimming, canoeing, boating, hiking, fishing, hunting, painting, bicycling, and exploring the natural communities of plants and animals.

Beyond sight of the hawkwatch observers, you pass over the famous Delaware Water Gap. Here the river cuts a huge slice through Kittatiny Mountain. High cliffs break forth from heavily forested hillsides and, jutting upward at a sharp angle, flank the river on both sides. The river itself is a blue-green ribbon as it slips through the water gap and continues on its way southeastward to the sea.



espite all that an eagle's eyes can see, however, much more is known only to the humans. For unlike a bald eagle they can go back in their imaginations into geologic time, when warm seas, awesome mountain ranges, and icy glaciers arrived and departed from this land. Only they can learn about the Lenape Indians who hunted bear and moose here 10,000 years ago. Only they can investigate the grass, ferns, trees, and waters, and discover the birds, mammals, and fish that an eagle would miss.

**What is the Delaware Water Gap?**
What happened in this place long ago to create this landscape of rivers, hills, and valleys? Clues to the answer lie everywhere around us. By carefully

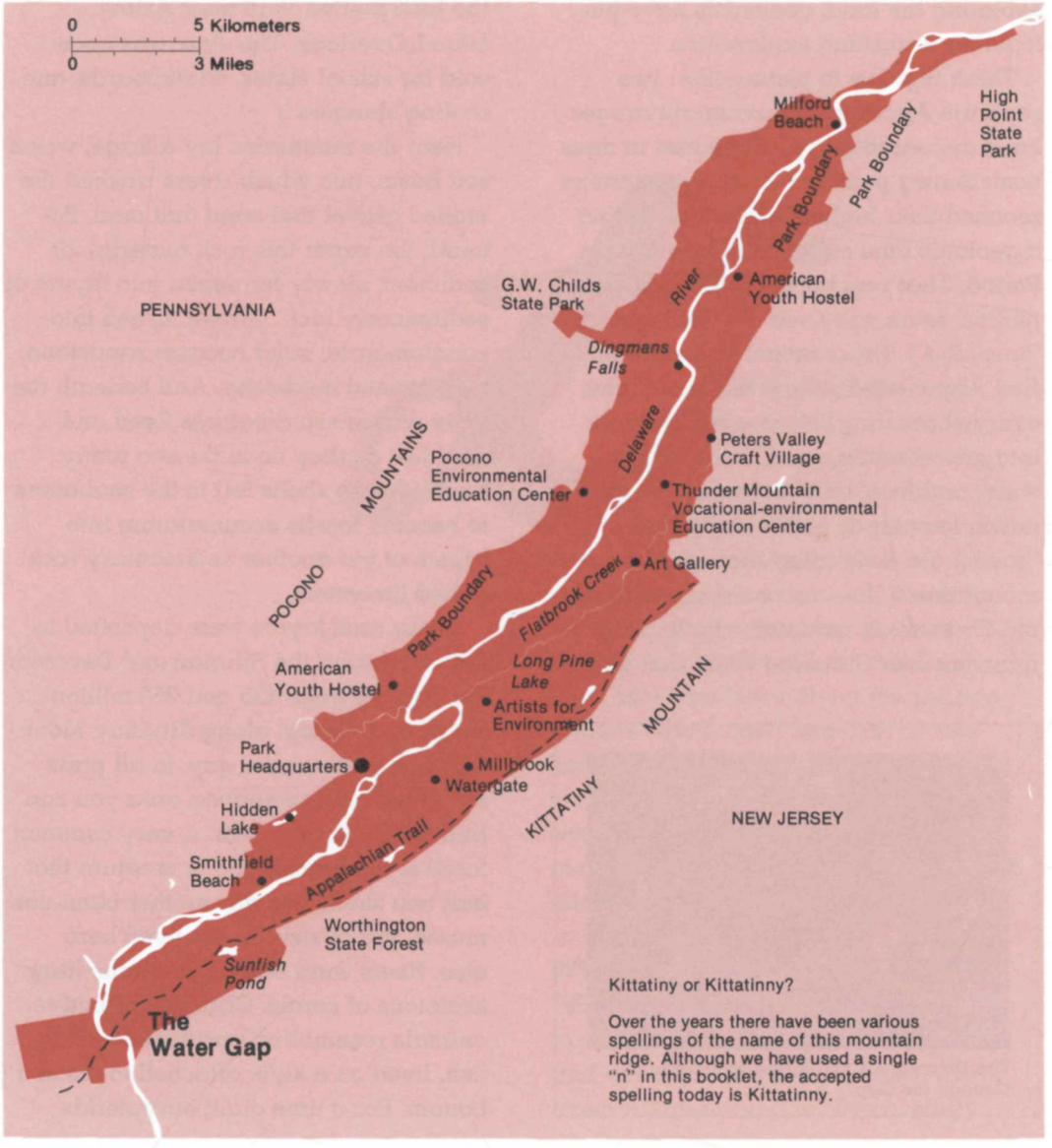
exploring the land, geologists have put together a startling explanation.

Think big! Try to picture this: two separate Appalachian mountain ranges have appeared and disappeared in ages past. Snowy peaks of the first mountains reached their highest elevations during a geologic time called the Ordovician Period. That was between 500 and 425 million years ago (see the Geologic Time Line). These mountains were the first Appalachians, and like mountains everywhere they began eroding away into gravel and sand and mud. Rain, wind, and frost slowly wore the peaks down, leaving us today only their "roots," the deep interior of the old mountains. (You can see rocks of these old Ordovician mountains in the slate quarries near Slateford Farm and along the Interpretive Trail near Arrow Island Overlook. The slate was once sold for school slates, chalkboards, and roofing shingles.)

The Delaware River makes an S-curve through the Gap.

Near the mountains lay a large, warm sea basin, into which rivers washed the eroded gravel and sand and mud. Beneath the water this rock material, or sediment, slowly hardened into layers of sedimentary rock. Gravel turned into conglomerate; sand became sandstone; mud formed mudstone. And beneath the salty waves sea creatures lived and died just as they do in the sea today. Their lifeless shells fell to the seabottom to become fossils accumulating into layers of yet another sedimentary rock, called limestone.

These rock layers were deposited in the sea during the Silurian and Devonian Periods, between 425 and 350 million years ago. Except along Kittatiny Mountain and in the water gap, in all parts of the national recreation area you can find fossils in the rocks. A very common fossil is the brachiopod, a creature that had two shells but was neither clam nor mussel nor oyster. Snails lived here also. Reefs were built up from the limy skeletons of corals. Crinoids, primitive animals resembling upside-down starfish, lived on a stalk attached to the sea bottom. For a time giant eurypterids




Kittatiny or Kittatinny?

Over the years there have been various spellings of the name of this mountain ridge. Although we have used a single "n" in this booklet, the accepted spelling today is Kittatinny.

**Exploration:**

(Use Your Senses) This booklet is a guide to exploring the environment of Delaware Water Gap National Recreation Area. Use it together with your senses and your imagination to discover the many exciting and beautiful features of this place. Your senses especially can link you to nature.

Look down into the Water Gap from high above on Mt. Tammany. Listen for ten whole minutes to the sound of a rushing waterfall. Watch a wild animal closely: how does it move, where is it going, how does it protect itself?

With your eyes closed, get a friend to lead you to a large tree. Touch its bark; can you identify it? By touch alone you can easily distinguish a shagbark hickory from a white oak or an American beech from a white pine. Walk barefooted on soft moss and pine needles. Resting on a damp stone or log, feel the cool stream water as it rushes through your fingers. Listen to birdsongs and learn to identify the singers, like an Indian, just by their sounds. Taste a pine needle. Taste the leaf of sorrel and add a bit to your salad.

Your nose can link you to nature. Scrape the bark of a spicebush twig with your fingernail, or crush a sassafras leaf; then sniff. Try smelling the blossoms of many different wildflowers and shrubs. Do the most colorful flowers have the most distinctive scents? What gives the pungent smell to a handful of forest soil? Does this tell you about its origin?

("sea scorpions") patrolled the waters, keeping company with nautiloids, which were like octopuses in straight or coiled shells. Trilobites scurried over the sea bottom, and primitive armored fishes darted among the corals and crinoid stalks.

After the seas had collected vast layers of rocks and fossils, the second Appalachian mountain range began to form from them. Slowly the rock layers rose up out of the sea to become the folded Appalachian Mountains. By the Permian Period, about 230 million years ago, these new Appalachian Mountains were reaching their greatest heights,

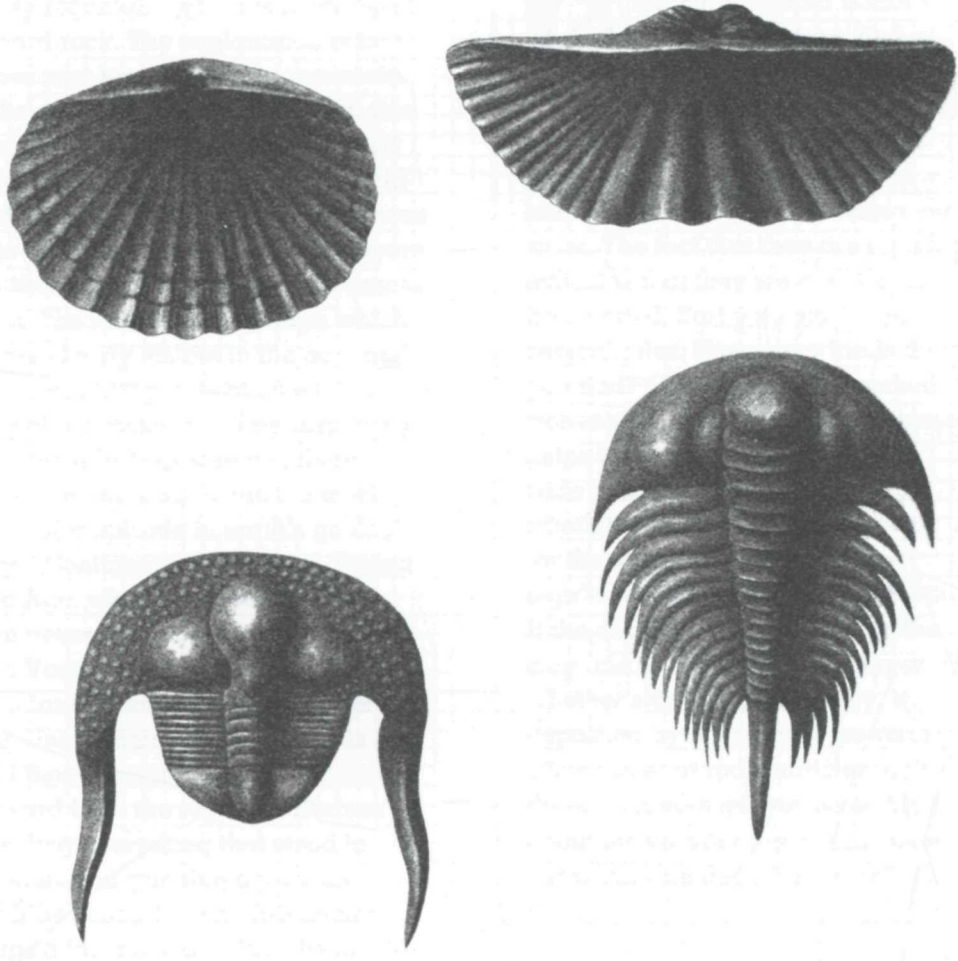
Fossils in the rocks of Delaware Water Gap are clues to the life of 400,000,000 years ago.

probably well over 3,000 meters high and comparable to today's Alps and Rocky Mountains. The layers of Silurian and Devonian rocks within them were being folded, bent, twisted, and crumpled. The seawater was pushed back, and on the fresh new land dinosaurs began foraging among the ferns, cycads (primitive, seed-bearing, nonflowering plants with large fernlike leaves), and conifers. All this required millions of years; folded mountains do not just explode from the earth.

Today we find no dinosaur fossils here. Why is this so? And what happened to those 3,000-meter peaks? You guessed it! Like the first Appalachian Mountain range, these new Appalachians have largely been worn away, including all traces of the dinosaurs that lived here. Today we see only ridges and valleys in the place of high mountains. The process of erosion has not stopped; every muddy stream that you see continues to carry away bits of the land.

**Exploration:**
(Look For Fossils) Ride or walk through the Delaware Water Gap, keeping a sharp lookout for bent or folded rock layers. From Point of Gap Overlook you can see the Silurian rocks (Shawangunk formation) that were lifted up during mountain building. Have you ever tried to bend a rock? If not, try it—can you imagine how much energy the earth must have if it actually bends rocks? Look for fossils everywhere you explore. But do not collect them, unless you have a permit! Try to identify what you find. Can you explain how fossils were preserved here? Where would you expect similar fossils to be forming in the world today?

Typical brachiopod fossils (top) and trilobite fossils.



# Notes

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You may wonder, when you visit the water gap, how the Delaware River managed to find or cut its way through Kittatiny Mountain, which is made up of very hard rock. The explanation is that the river was here before the mountain. Like the other mountains you see in this region, Kittatiny Mountain was formed by folding of the earth's crust. This folding occurred so slowly that the river was able to cut down through the rock layers faster than the folds were created across its path. The rock layers through which it cut are clearly visible in the gap, and there are several points at which the folding of the rocks is vividly displayed.

After the gap had been cut, there occurred an amazing event, the most recent major episode in earth's geologic history—Continental Glaciation. During the Ice Age, which spanned the last million years or so, the climate turned colder. Vast, thick ice sheets, or glaciers, accumulated from compacted winter snows. Under their own tremendous weight these sheets of ice spread slowly southward from the region of Hudson's Bay, killing everything that stood in their paths and grinding across the rocky hills beneath them. Advancing perhaps a few meters a day, the ice filled the valleys and overrode the heights. The scene was much like what you would see today on Greenland and the Antarctic subcontinent.

**Exploration:**
(Examine Glacial Rocks)
Away from the river, find a road bank or hillside full of rounded pebbles or stones; the region near Peters Valley, N.J., is good. These are glacial rocks, in hills deposited by the retreating ice sheet. The fact that they are rounded indicates that they were water-transported. Sort your stones into several piles. How many kinds do you find? (Breaking the smoothed stones open with a geologic hammer helps to determine the types.) A wide assortment of stones is characteristic of these glacial deposits, for the moving ice brought "foreign" rock materials from the north. If the deposit is layered, notice the clay and sand layers. Each layer, whether stones, sand, or clay, was deposited by a stream of icewater. Do the sizes of rock particles in the different layers tell you something about the varying force of the moving water that deposited them?

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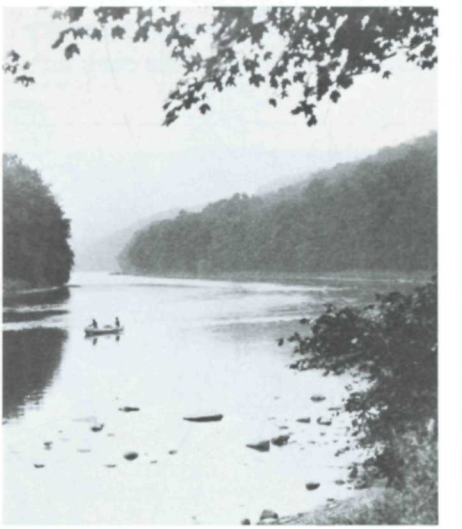
Evidence of the passing of the ice sheet is seen in grooved and polished bedrock.

Then the climate slowly warmed again. The ice sheets began to melt. Trees and animals returned as the soil emerged into sunlight. Indians came and made this their homeland. About 11,000 years ago the ice had entirely melted away. Left behind were many signs of its visit: scratched and polished rock surfaces (you can see these commonly on Kittatiny Mountain trails); hills of stones and sand (called drumlins and kame terraces); and millions of pasture stones (called glacial erratics), which you can see where farmers have used them to build stone walls.

Today, the Delaware River is a broad path of quiet water. Islands such as Shawnee, Poxono, and Minisink dot the river. They are made of material that the river is too weak to wash downstream except during floods. And from the surrounding slopes, dozens of streams rush down to meet the river. These tributary streams are fast, turbulent, and full of spectacular waterfalls. This pattern of fast and slow streams in the national recreation area is typical of the Appalachian Mountains.

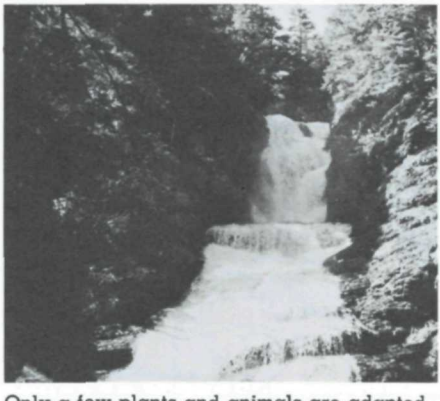


The life community of the quiet river is much different from that in the turbulent tributary streams.

## What are the Life Communities Here?

If you explore the streams on this land, you will discover important life communities in and near them. A life community is a group of plants and animals living together in a particular environment such as a stream, a pond, a woodland, or a rock cliff. These living things all depend upon each other and upon their environment for survival. Man often has a major impact upon these communities.

Flowing Waters. Let's look at the life community in a fast stream. Rushing through a deep, shady, cool ravine, the water is tossed and foamed by rocky rapids and waterfalls. This cool, turbulent streamwater has a high oxygen content. This is the kind of environment that oxygen-loving brook trout need for their survival. They prefer water that is about 4° to 10° C. Many insect larvae, such as the nymphs of certain mayflies, which also need cool, well-oxygenated water, are important food for the trout. Growing on the stones in the stream is a scumlike coating of green algae that the aquatic larvae eat. As you probably know, algae are green plants containing chlorophyll. Since green plants can manufacture their own food by the process of photosynthesis, they need not consume other living things for food.

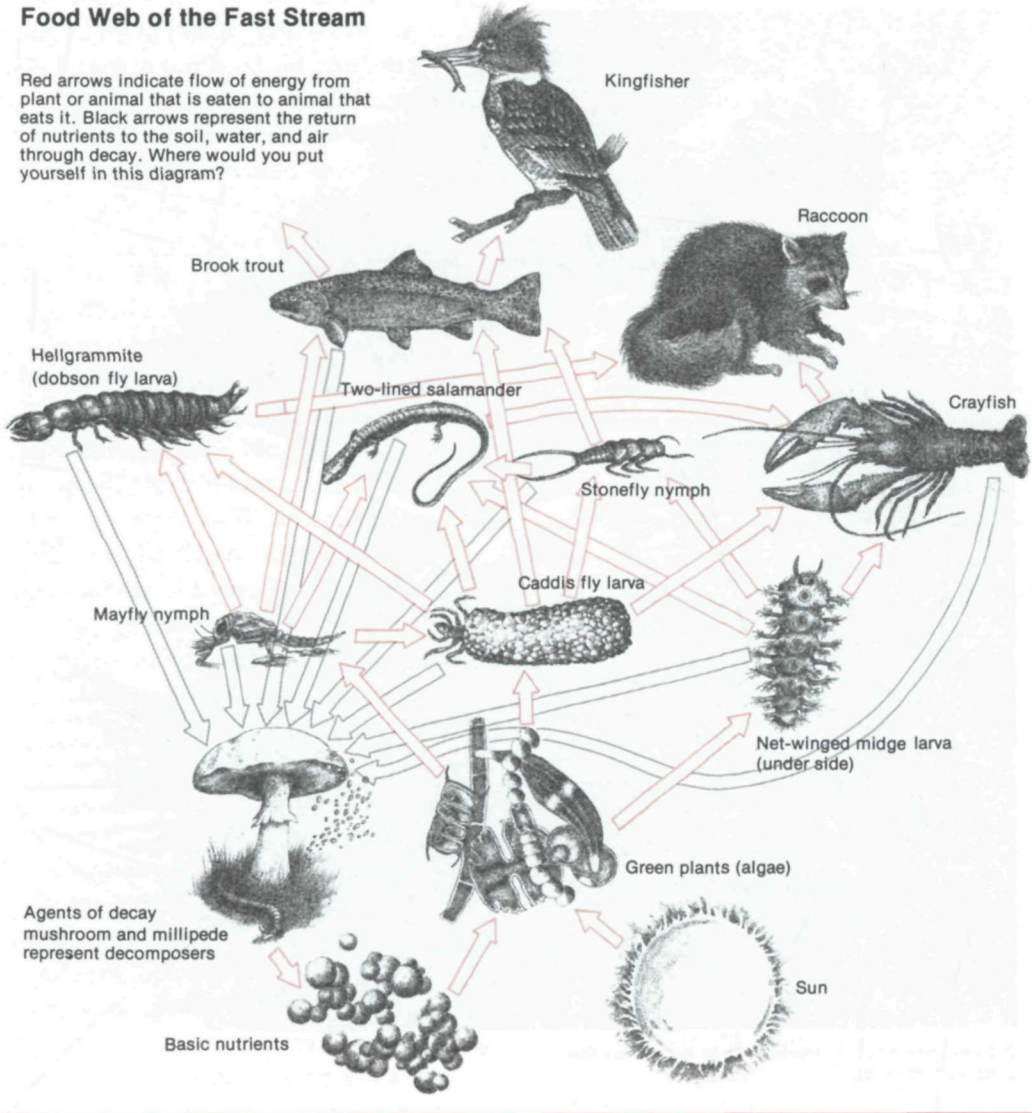


Only a few plants and animals are adapted to the severe physical environment of cascades and waterfalls.

We can link these members of the fast stream community into a chain to show how all animals ultimately depend on plants for food. In the food chain illustrated, the first link, the green algae, are *producers* (food makers); the mayflies are herbivores (plant eaters); and the trout are predators (animals that actively catch other animals for food). Since people sometimes catch trout and then eat them, we can add man to this food chain. Man is an omnivore (an animal that regularly eats both plants and animals). Of course, many other animals and plants also live here, so we should expect to find other food chains in this natural community.

## Food Web of the Fast Stream

Red arrows indicate flow of energy from plant or animal that is eaten to animal that eats it. Black arrows represent the return of nutrients to the soil, water, and air through decay. Where would you put yourself in this diagram?



A fine-mesh net is a useful aid in exploring the pond community.

Plant-and-animal communities can be harmed by the way people use them. What do you think would happen if all the big, shady trees were cut from the slopes along a fast-water ravine? Without shade, the sun would shine down full-force on the ground and water. What effects would this have on the fish and mayflies? In heavy rains, without the protection of trees, more soil would erode and be carried into the streams. The resulting suspended silt could choke the gills of many aquatic animals and suffocate fish eggs. Many fish that do not usually live in fast water swim up from the Delaware River and lay their eggs here. Do these facts suggest how the numbers of fishes in the slower river waters might be affected by the serious siltation that has occurred in recent years in many of the tributary streams?

Now let's look at the more slowly flowing river. Here the water environment is warmer and richer. It has less oxygen than the fast streams, but it is an unusually clean river with fewer pollutants than most streams its size. Because it is slower, the animals do not need special adaptations to avoid being washed away. It is richer in food partly because small organisms keep washing down from the tributary streams and from the river banks. This food is consumed by predators such as the smallmouth bass. In contrast to the brook trout, the bass seeks water that is 15° to 20° C.

**Exploration:**
(Investigate Life Under A Stone) At the edge of a fast stream find a medium-sized stone beneath the water and quickly flip it over. Examine the insect life clinging to its underside. Some of these animals will run away quickly. What would happen to food chains if pollution killed these small creatures? Look for their special adaptations for fast water: some are strong swimmers; some are flat; some have hooks or suction cups. Remember: these animals are always in danger of being washed away into the current below where hungry creatures are ready to snap them up for food. When you are finished, be sure to return the stone to the water. Why?

Still Waters. The standing water of lakes and ponds is calm beneath the surface, warm, and sometimes poorly oxy-

genated. Some ponds are shallow; others are deep. Some are millponds formed more than a hundred years ago by damming of streams. Others are formed by the gouging action of the great ice sheets thousands of years ago. Sunfish Pond, Catfish Pond, Long Pine Pond, and Hidden Lake were all formed this way. Water levels of the latter two are maintained with the help of concrete dams.

**Exploration:**

(Compare Ponds with Streams) At about midday, preferably not on a rainy day, use an ordinary thermometer to compare the water temperatures of a fast stream and a pond. How do these temperatures compare with the air temperature? Using a pond net or a kitchen strainer attached to a long handle, catch animals from the water and muck of a pond. Compare the creatures you find with those you found in the fast stream. Do these creatures have different adaptations? If you were a hungry heron, would you look for food in a pond or a fast stream? Why?

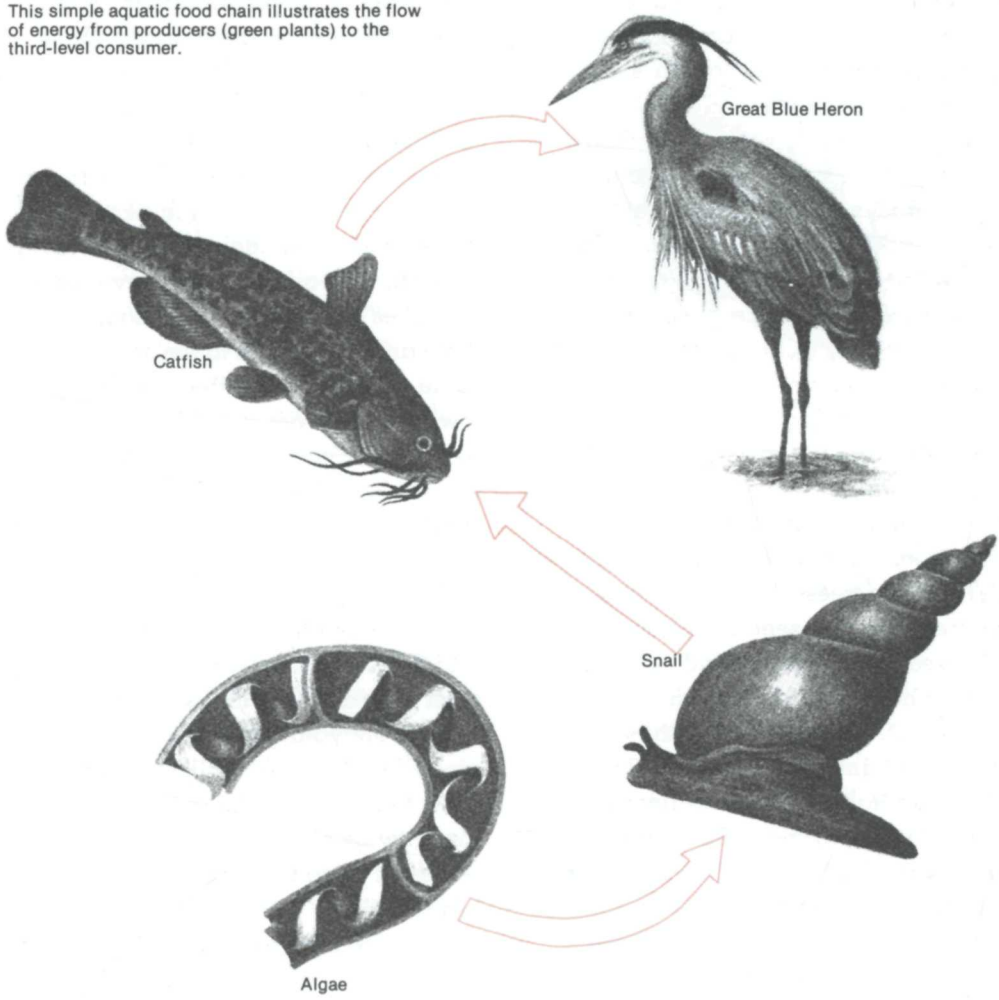
The brown bullhead is a catfish common in local ponds and lakes. Feelers, called barbels, around its mouth function in locating food among the algae and in the bottom mud—an adaptation especially helpful at night and in murky waters.

Here the heron, standing well over a meter tall and with a spearlike beak, is a predator on catfish. When ponds and lakes have too few predators, the catfish may become too numerous, requiring more food than the pond community can provide. Instead of a thinning out of the catfish through starvation of a few, however, all of the catfish population remains undernourished and becomes stunted. Stubby little catfish only 10 to 15 centimeters long can be found in some ponds; a normal adult in a well balanced pond community would be a 30 to 40 centimeter fish. As you can see, to insure full growth, these ponds should have more predators to keep the catfish population in balance with its food supply. Can you explain why predators are in short supply here?

Forest Communities. The most widespread life communities in this area are the woodlands. The less extensive summit woodlands on mountains higher than 400 meters are much different from those on the slopes below. Let's look first at

## A Pond Food Chain

This simple aquatic food chain illustrates the flow of energy from producers (green plants) to the third-level consumer.



the low-elevation forest communities of the slopes.

Imagine that you are wandering along one of the many country roads in the national recreation area. You pass by a variety of woods, fields, and brushy places. The first thing you notice about the woods is that some are open and partly shaded, whereas others have denser foliage. Stand at the road's edge and view the woods. Soon you see that the differences among these woods are not only in the kinds, or species, of plantlife they contain, but also in their vertical structure. From the crowns of the trees down to the soil, the plants grow in layers.

We can think of the forest layers as like the floors of an apartment building. Each floor has trees of different ages. Some trees are tiny seedlings, some are shrub-sized, some are tall and mature, and some have died and fallen to the ground to rot. Wherever a tree has fallen, a skylight has been opened, giving extra light to the lower floors of the woodland apartment. Extra light means extra plant growth in each layer. Extra growth means more food for the special animal tenants who live there.

For example, a forest made mostly of oaks and hickories may have five separate layers:

The uppermost layer, called the overstory or canopy, is the top floor and penthouse of the woodland apartment. In an oak-hickory forest this includes the crowns of all the taller trees—both deciduous trees, which shed their leaves in autumn, and evergreen trees, which retain their leaves all year. This layer gets the most sunlight, and like a roof, it casts a deep shade over all the layers beneath. The overarching leaves and branches also reduce the amount of rain that can fall through to the soil. At the same time, however, they shelter the lower layers from strong winds. The overstory layer is home to many kinds of warblers, the barred and great horned owl, flying squirrel, and the gipsy moth caterpillar (which is also found in the next two layers).

Next beneath the overstory layer we find the understory layer. Small species such as gray birch and sassafras, as well as the young of oaks, hickories, pines, hemlocks, and other canopy trees, grow here. Deer come to browse the lower twigs of the understory, and the red-eyed vireo builds its nest among the branches.

Closer to the ground is the shrub layer; here are woody-stemmed plants from about hip-high to twice the height of a man. These shrubs catch the limited

sunlight that filters through the canopy and understory. Among the plants of this layer are blueberries, witch-hazel, and spicebush. The apartment tenants of this floor include catbirds, wood thrushes, lace bugs, and the caterpillar of the spicebush swallowtail butterfly. A part-time visitor is the white-footed mouse, perhaps the most abundant of the forest mammals. The little fellow scampers nimbly up the stems to gather berries, seeds, and insects for food. The white-foot may visit all five layers of the woodland during a night of activity. Winter snows make it possible for such ground-floor animals as the cottontail to feed in this layer.

Nearest the ground is the shaded first floor of the apartment building, the herb layer. Here, the least amount of light is available for plant growth, but there is less evaporation of moisture. You will find many shade-tolerant plants—nettles, jewel weed, ferns, grasses, and mosses. Violets, wild ginger, and other wildflowers, sprouting and having a spurt of growth in spring before the foliage above has developed and cut off the sunlight, add color to the forest floor. Tiny seedlings of the tall trees also sprout here. Many animals live or forage in this layer, including snails, insects of various kinds, toads, box turtles, sparrows, cottontails, and gray foxes. Wild turkeys feed on acorns and beechnuts, and on dogwood fruits when they can reach them.

**The porcupine is a forest animal; its principal food, especially in winter, is the tender inner bark of trees.**

Finally, we can go underground into the soil layer. If you could explore it like a tunneling mole, you would find that, like a basement, it is dark, damp, and full of plumbing. Sand, silt, clay, rotting leaves, matted roots, and small tunnels provide just the right conditions for many woodland animals. These include millipedes, earthworms, beetles, and shrews (the smallest of mammals). This is the place where you'll find one of the most important components of the forest

## Profile of the Oak-Hickory Forest

The forest has a structure much like that of an apartment house, with a basement, ground floor, and upper stories. Each level has its own resident plants and animals, though many of the former grow through more than one story and many of the latter move up and down through the layers. The gray squirrel, for instance, feeds at all levels from the ground to the upper branches—but does not go underground like the chipmunk. Many of the woody plants of the understory are young individuals of canopy trees.

Canopy (overstory)

1. White oak
2. Bitternut hickory
3. Great horned owl
4. Flying squirrel

Understory

5. Gray birch
6. Young oak
7. Dogwood
8. Young hickory
9. Red-eyed vireo

Shrub Layer

10. Ovenbird (nests and feeds on forest floor)
11. Spicebush swallowtail butterfly
12. Arrowwood
13. Whitetail deer
14. Virginia creeper
15. Spicebush

Herb Layer

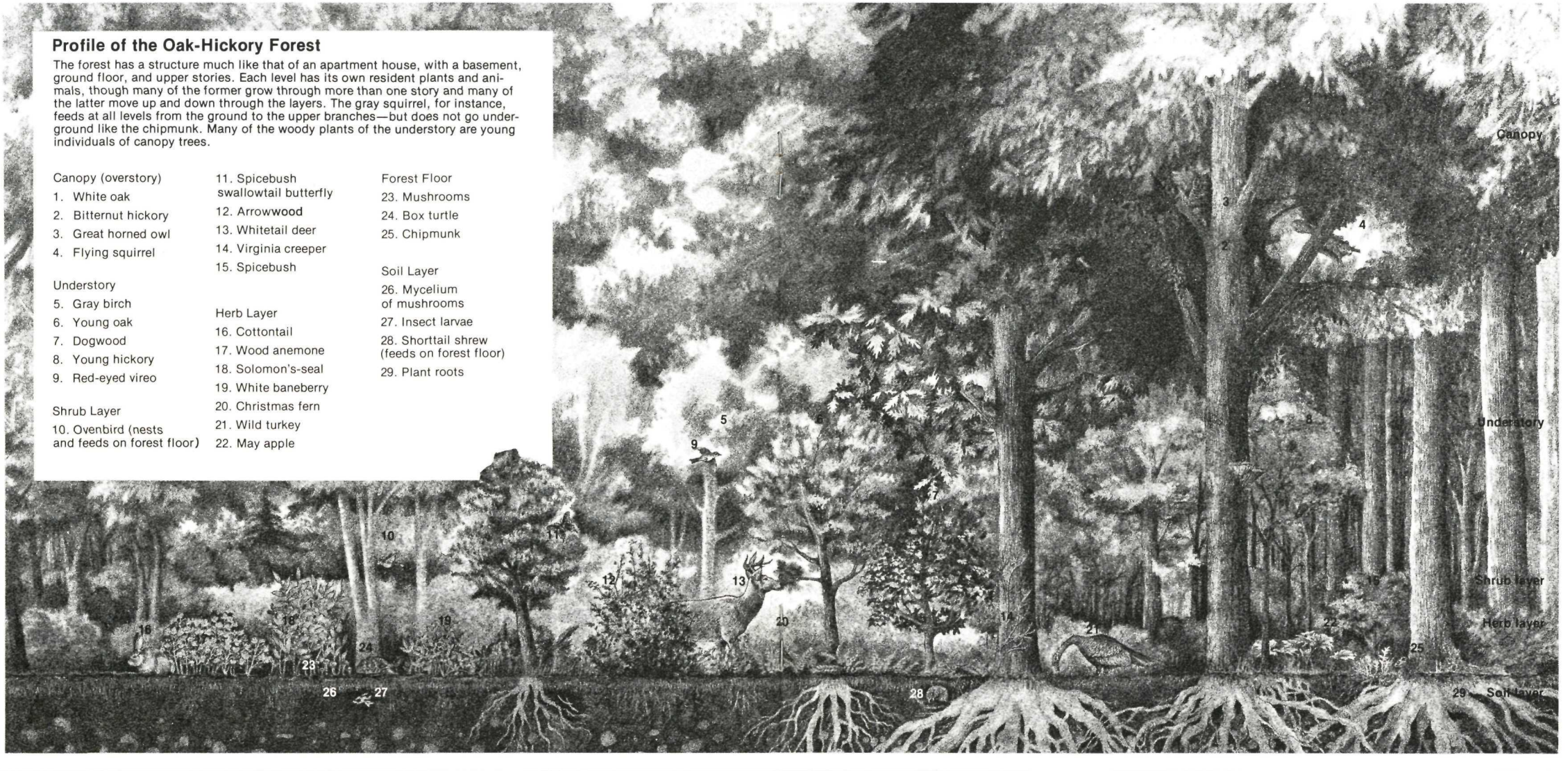
16. Cottontail
17. Wood anemone
18. Solomon's-seal
19. White baneberry
20. Christmas fern
21. Wild turkey
22. May apple

Forest Floor

23. Mushrooms
24. Box turtle
25. Chipmunk

Soil Layer

26. Mycelium of mushrooms
27. Insect larvae
28. Shorttail shrew (feeds on forest floor)
29. Plant roots



# Notes

community—the fungi. The mushrooms and toadstools you see above ground are only the fruiting parts of these plants; the vegetative body is an extensive underground network of threadlike structures. Along with the invisible bacteria, these and other fungi, including molds, decompose the dead bodies of animals and plants. By breaking down the dead material, they release vital minerals that were used in the growth of the living plants and animals. If there were no decomposers, minerals could not be restored to the soil for recycling in the forest community, and severe shortages would occur.

To complete the woodland apartment building, we must have stairs and elevators. For this purpose the tree trunks, branches, and vines do nicely. Red squirrels use the trunks to move between the canopy and the lower layers. Nuthatches, woodpeckers, and brown creepers get much of their insect food from the tree trunks. Other birds forage throughout for beetles, bugs, caterpillars, and spiders.

In your explorations you will find a woodland with only three layers: a soil layer, an herb layer, and an overstory. In some forests, black birch and red maple are the dominant trees. It is so shady under this canopy that shrubs and understory trees cannot grow. Why is this woodland shadier than the oak-hickory forest? The answer has to do with the type and age of trees in the overstory. All about the same height and more than 50 years old, they form a dense canopy. For many years they have blocked the summer sunlight that shrubs and understory must have to grow.

But if you think this woodland is shady, examine a stand of red pines. In places through the region are coniferous plantations set out by the Civilian Conservation Corps about 40 years ago. The red pine overstory casts such a dense shade all year long that the herb layer is almost non-existent. A thick carpet of pine needles also hinders plant growth. With such limited plant food, few animals can live in these pine plantations.

As you wander farther down the road, still other kinds of woods will appear. You will also find many brushy places sprouting young redcedars and pines. How can we explain this variety among the slope woodlands? Before we can answer this question, we have to know a little about the local history and a little about the process called natural succession. First, let's take some time to see who used to live here and how they treated the forest.

The Native Americans. The first people to live here were Indians, the Lenape (whom we now sometimes refer to as the Delaware Indians). Evidence shows that the earliest Lenape came here 10,000 to 12,000 years ago, just as the glacial ice was melting away. The land was probably a cold tundra or a spruce forest. The Lenape, who hunted big game with spears, followed herds of mastodons, musk oxen, and caribou. They had no farms, no towns, no cities, no roads, no airports, no hospitals, and no pollution. They lived as part of the natural community, adapting to nature's rhythms rather than trying to control them.

As the centuries passed, however, the climate slowly warmed. By about 7,000 years ago, pine forests had replaced the tundra and spruce. The mastodons and musk oxen had disappeared, to be replaced by moose, elk, wolves, and cougars. The Lenape not only hunted game, but also netted fish and harvested mussels from the Delaware River.

By about 2,000 years ago, the Lenape were hunting primarily deer and wild turkeys, as well as gathering nuts, roots, and berries. They learned to make clay pottery and to fashion tools from many kinds of local rocks. By 1,000 years ago, they were keeping gardens of corn, beans, squash, and pumpkins, and were using the bow and arrow in hunting. They lived in tiny villages near the river, using bark-sided longhouses for shelter. They were peaceful and did not fight with other groups of Indians.

Although the Lenape learned that by burning the forest they could encourage

**Exploration:**

(Pretend You're An Indian) Write an essay, plan a dramatic presentation, or hold a campfire discussion while imagining yourself in the moccasins of a Lenape. If this were 1,000 years ago and your home were here in a bark-sided longhouse, how would you feel about nature? Would you be afraid of it? Would the forest seem strange to you or familiar to you? Would you feel love for it? Try to tell about your feelings toward nature in the way you think a Lenape would have spoken. Complete your story by comparing how you, as an American in our own times, feel about nature. Do your personal feelings influence the way you treat nature?

sprouting of new growth, thus providing more food for turkeys and deer, their impact on the environment was on the whole nondestructive. They did not use plastic, glass, rubber, steel, or aluminum. They had never heard of beer, guns, or television. They knew the river and the forest, the fish and the deer, and the changing seasons. The river was not an obstacle but a road. The forest was a source of food and fiber, not a barrier to cultivation.

There were probably never more than a thousand Lenape here at any time. They felt that they were part of the land, like their brothers the bear, the bald eagle, and the beaver. They felt that their best guide to success was to please the spirit of nature rather than to tame the wilderness.

The Newcomers. In the 1600s European settlers began moving into the river valleys, and the peaceful Lenape began to disappear. Dutch and English immigrants brought with them liquor, guns, and terrible diseases that the Indians had not known before. The Europeans pushed the Lenape aside, cut down the forests, and trapped out the beaver and otter for their valuable pelts. The Lenape began fighting with both the Europeans and other Indians. By 1800 the Lenape were gone from the valley.

The new settlers felt they must tame the wilderness. They widened an old Indian trail to build the 160-kilometer Old Mine Road. They cleared thousands of hectares of forest for their farms, and they dammed many streams to make millponds. During a great period of logging in the 1800s, they stripped the land of its trees, causing soil erosion and siltation of streams. Only the steep, deep ravines were spared the ax and saw.

**Exploration:**
(Compare Lifestyles) Visit Slateford Farm and Millbrook Village to see how you might have lived here in the 1800s. As you enjoy these places, make a list of the natural materials used by farmers and villagers in those days and suggest where they might have been obtained. Write them under main headings such as food and water, shelter, clothing, protection, trade, transportation, and recreation. Do you find that the people used plastic, rubber, glass, steel, or aluminum? For interesting comparisons, make a similar list for your own home and lifestyle.

In the years since settlement, farming has slowly declined. Much of the farmland has been abandoned. Now, increasingly, this area is being used for recreation. Congress authorized the Tocks Island Dam and Reservoir Project in 1962 and the Delaware Water Gap National Recreation Area in 1965. As you see, primary use of the land over the centuries has changed from hunting (by Indians) to farming and logging (by European settlers) to recreation in a natural setting.

Natural Succession. Now let's go back to our country road and the slope woodlands. How have the woods been changed by human activity through the years? What happened to the vast pine forests that once covered the land? Where did today's woods come from? Since the Indians' impact was low, it must be that a new pattern of plant communities was brought about when the farmers and loggers cleared the pines from this land. New and different forests must have grown upon the land after they used it and eventually abandoned it. The changes by which cleared land returns to woodland are an example of the process ecologists call natural succession.

The basic idea of succession is simple: one kind of community is followed (succeeded) by another kind, and that kind by yet another kind, forming a succession of stages over many years. The key to the process is the way in which each community in turn creates conditions that favor the succeeding community. Succession is happening all around us; let's look at an example.

Suppose you are a farmer. You grow corn on your field for a few years. Then you stop farming and let the field sit without using it. After the corn stalks have dried and fallen, your field lies open to the sun and wind and rain. Only the soil layer and few small "weeds" are apparently present. Hidden from the eye, however, are many seeds of weeds that had been kept under control when the land was being cultivated. Now the conditions in the field are favorable for some of these weeds. The seeds sprout and soon the field becomes thick with grasses, mustards, goldenrods, asters, blackberry vines, bergamot, and other plants that can thrive under the existing balance of moisture and exposure. Within a year or two your cornfield has established a thick herb layer. We may call this an "old field." There is now more shade for seedlings and less drying of the surface soil by wind and sunlight.

Within three or four more years, low

Natural succession is the process by which one community replaces another until a relatively stable, permanent community is established. Upper left: recently abandoned field has grown to weeds; upper right: a few years later, shrubs are taking over; lower left: in time, a shrub-tree community develops; lower right, finally, a mature forest occupies the area.

shrubs and small trees appear: dogwood, sumac, gray birch, redcedar, blueberry, and small oaks and pines. These first trees are called pioneer trees. At first their seedlings took advantage of the herb layer for protection from wind and sun. But now they must compete with the herbs for water, minerals, and sunlight. The evergreen trees have an advantage, however: when spring returns each year, their leaves are out and ready for growth. They get a head start on the herbs.

After 10 or 15 years, the taller trees begin to dominate the old field. These include white pine, oak, hickory, red maple, and others. Their roots successfully compete for water and minerals from the soil, while their steadily enlarging crowns begin to shade out the herb layer beneath them. As the pines and oaks grow taller and fuller, they become

# Notes

overstory trees, shading the gray birch and redcedar, which become understory trees. As understory, these species cannot keep up, and they begin to die out. Seedlings of the pines, however, also need sunlight to sprout; but as the young forest matures, its shade prevents new pines from sprouting. The deciduous overstory trees now have the advantage over the pines, for their own seedlings are able to sprout in the shade. Finally, after many years of growth, a mixed stand of mature deciduous trees flourishes where long ago was a cornfield. If this is the stage of succession best suited to the prevailing climate, moisture, and soil, and is not by normal processes replaced by another plant community, we call it a *climax forest*. It will remain indefinitely unless fire, clearing by man, or other disruptive forces set it back to start the succession process again.

Over much of the national recreation area, the climax forest is a mixture of deciduous trees. Ecologists believe, however, that the forests known to the Lenape were composed mostly of white pine. We don't know enough about forest ecology and the history of man in this area to know how the pines achieved this dominant status—nor, indeed, do we know what is the true climax vegetation in many of these habitats.

Ponds and lakes also pass through stages of natural succession. At first a pond is open water. Lily pads and other floating and emergent plants grow in the shallows around its edges. Each year they die back to their roots; soil washes in from the land around the pond. This material builds up in layers on the bottom of the pond. As the pond gradually fills in, the area of open water gets smaller. Eventually the pond becomes a marsh. With the invasion of trees the wetland becomes a swamp. In time, a moist woodland occupies the site of the former pond.

Using this knowledge of history and succession, perhaps we can now explain the woods along this old country road. A brushy place with redcedars standing like statues about the field is probably an old field on its way to becoming a forest. A three-layer, even-aged wood of gray birch and red maple is a later stage of succession. A five-layer oak-hickory forest may be the climax woodland where once there was a field or pasture or logged-over area.

The two-layer pine plantations were, of course, planted. To tell how long ago they were planted, count the separate levels, or whorls, of stubs and branches

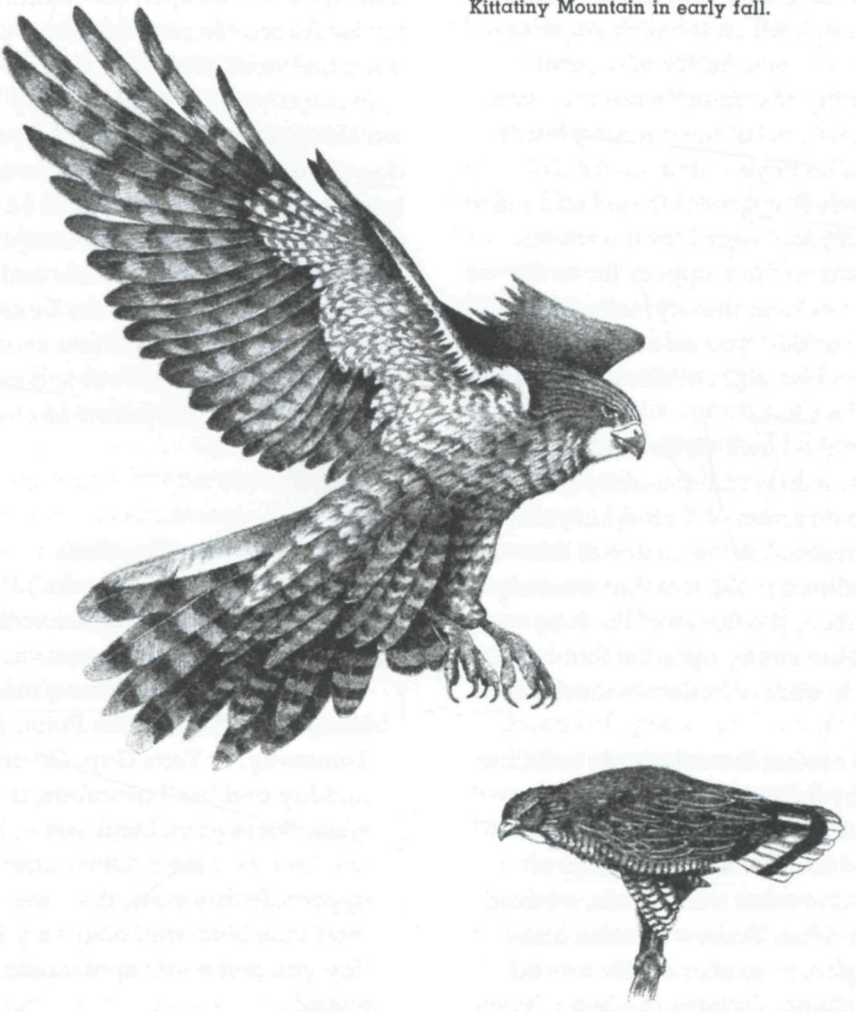
on a single pine tree from the ground to the top. Each level represents one year. Many of these pine plantations are about 40 years old.

With each stage of succession, the change in plants is matched by a change in the animals that live there. Animals that prefer the early old field include grasshoppers, meadowlarks, and woodchucks. Other animals—rabbits, deer, foxes, catbirds—prefer the later old-field stage with its shrubs. As the trees grow taller, the deer remain, and blue jays and squirrels appear. In the climax woodland, great horned owls, warblers, and woodpeckers come to find food and shelter.

**Exploration:** (Count The Insects) Explore an old field and its adjacent deciduous woods. Can you explain the plant layers in each area? On the ground, tie a string six meters long into a circle two meters in diameter. Kneeling within this circle, count the animals, especially insects, in each layer of the old field. Look for burrows, tracks, and other signs of animals. Do the same for the layers you can reach in the nearby forest. Which area has the most insects? Why? Check for light, moisture, and temperature differences. Next, repeat this exploration in a pine plantation. Can you make a table showing differences in feeding habits of the birds in the two types of habitats?

High and Low Places. Now let's leave the slope woodlands and climb to the ridgetops. At elevations above about 400 meters we encounter a different kind of forest. Here the soil is thin and very rocky and the winter weather is severe. Chestnut oak is the most common tree. Along the Appalachian Trail, which here follows Kittatiny Mountain, the chestnut oaks are stunted, averaging only eight meters tall. They are accompanied by a few stunted red maples, red oaks, scrub oaks, and pitch pines. Beneath them is a dense shrub layer of sheep laurel, mountain laurel, and blueberry.

There are places such as the Water Gap where the ridges are broken by sheer cliffs. From these high points magnificent views stretch out before you. The slopes beneath the cliffs consist of great masses of fallen rocks called talus. Like some deserts, these cliffs and talus slopes are hot in sum-



**The broad-winged hawk breeds in the wooded hills of Delaware Water Gap. Large numbers of these hawks can be seen migrating along Kittatiny Mountain in early fall.**

mer, cold in winter; and in most places they are extremely dry and lacking in soil. Only the crusty little plants called lichens grow well on the rock surfaces.

If you stand on a rocky viewpoint atop Kittatiny Mountain in autumn, you may witness part of the amazing hawk migration. Each year thousands of hawks, including broadwinged and red-tailed, wing southward for the winter. You can watch them appear far to the north as specks in the sky; follow them as they float past you on outstretched wings; and lose sight of them along the ridge to the south.

Why do the hawks follow this ridge? Of course, it does run generally north-south, the direction of their spring and fall migrations. But the choice of this route is related to the fact that westerly winds striking the flanks of the long ridges create strong updrafts that enable the birds to glide effortlessly much of the time.

Hawks are not the only birds to follow this energy-saving route. Non-soaring birds, including thousands of Canada geese and hundreds of thousands of warblers and other small birds, migrate along the ridge. Turkey vultures also use the updrafts to soar easily toward warmer climes. Vultures are huge, black birds with small, featherless heads. Some of them remain year-around in the Water Gap area, serving as "garbage collectors" of the open areas and woodlands. As scavengers, they feed on the dead bodies of animals.

Perhaps you have spent a day hawk-watching on Mt. Tammany. As you hike down the mountain before sunset, you leave behind the stunted trees on the summit. The trail descends steeply through the slope woodlands and enters another kind of forest along Dunnfield Creek. You find yourself in a shady ravine. Here the air is cool and moist. Lofty hemlocks and yellow birches cast

**Exploration:**
(Watch For Hawks) If you visit the national recreation area in autumn, you can enjoy hawkwatching along the Appalachian Trail at Catfish Point, Mt. Tammany, or Totts Gap. Go out at midday and use binoculars, if possible. Some days hundreds of birds sail by every hour. Other days none appear. In any case, the view is worth the hike; and on a very lucky day you just might spot a bald eagle!

deep shadows over the stream. Dunnfield Creek plunges down in small waterfalls and hurries over ledges of reddish rock. This forest has an aspect of primitiveness and permanence. In such a place one can experience a special feeling of peace and solitude.

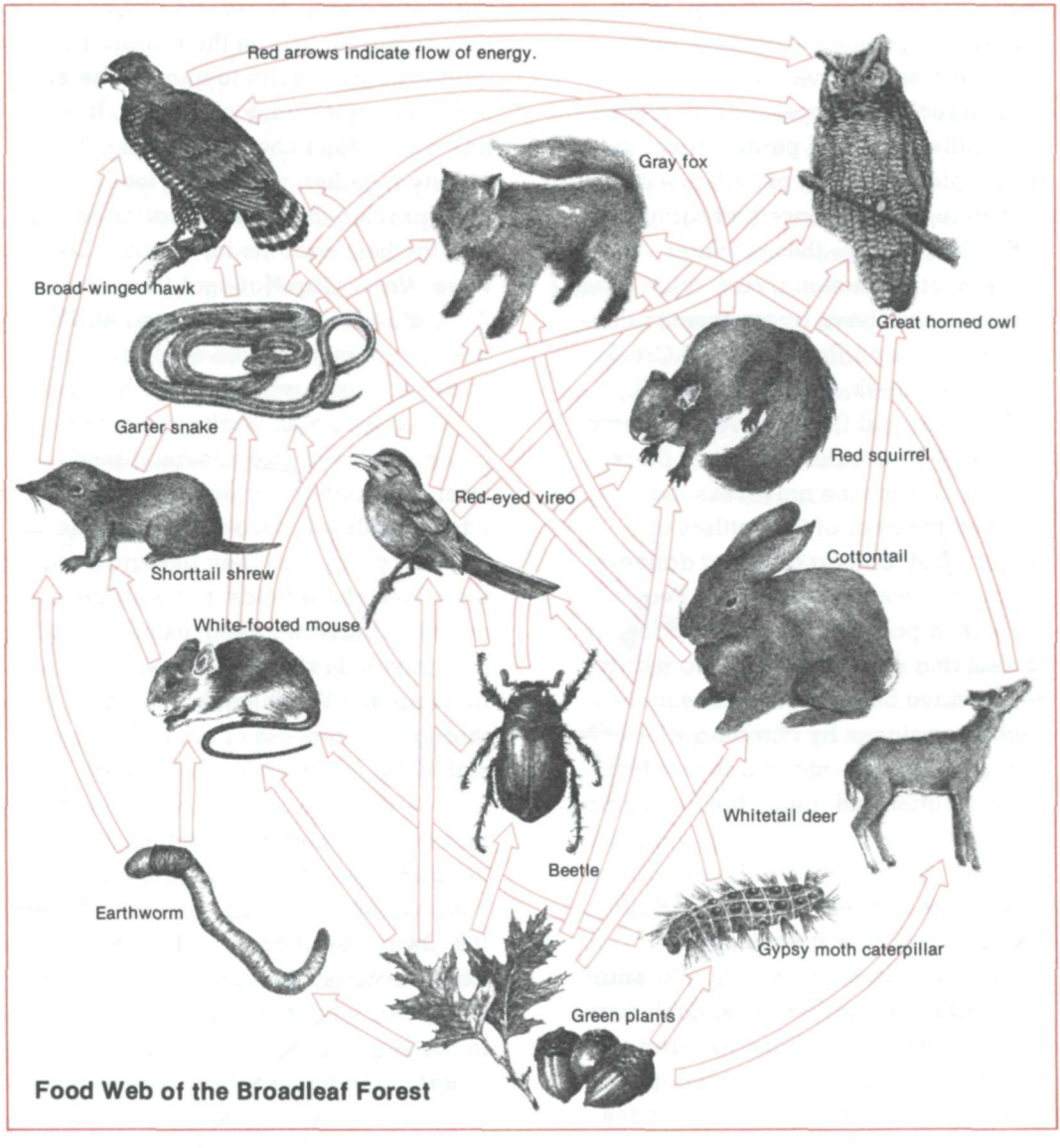
You can explore these ravines throughout the national recreation area. Many of them have large, spectacular waterfalls, as on Raymondskill Creek, Dingmans Creek, and the Bush Kill. ("Kill" is an old Dutch word for stream channel.) Hemlocks in some of these ravines may be the only trees that escaped the axes of the settlers and loggers. Yet today a different danger threatens these environments. People have been polluting them with cans, bottles, and other litter, and too many people have been causing erosion of their steep slopes by climbing wherever they wish. Do not add to this problem; leave no litter and follow the designated trails.

* * * *

We have now explored several life communities: fast streams, slow streams, ponds, slope woodlands, summit woodlands, and ravines. Each community is unique, with its own association of plants and animals occupying a special physical habitat that provides the water, food, shelter, and living space they required. Within their habitats, the animals may belong to many different, but interconnected, food chains. If we link all the food chains in a life community together, we have a food web.

To provide the best recreation for you and the best habitats for wildlife, Delaware Water Gap National Recreation Area must be carefully managed. The best conditions for both wildlife and recreation exist where varied habitats occur: open fields, sheltering woods, and a variety of streams and lakes. Deer and rabbits, for example, do best where fields join woods. More of the kinds of plant food they like grow along the edges of the fields. For wildlife management purposes, then, existing fields next to woods should be mowed to keep them open. (What would happen through the process of natural succession if the fields were not mowed?)

Dozens of species of mammals, birds, and other creatures make their homes here. In your exploration of the life communities, you will see some of them. It's always exciting to nightwatch for skunks, opossums, or raccoons as they forage for food; to see squirrels scamper in the sun and leap from bough to bough; to imagine soaring and skimming with the swallows over the lakes




**Food Web of the Broadleaf Forest**

and pastures; to be startled by a green frog leaping from your footsteps at the edge of a pond or by a garter snake crossing your trail.

Even more exciting and unusual creatures can sometimes be observed in these wild habitats. For example, have you ever seen a porcupine outside of a zoo? Sometimes one encounters a porcupine waddling along a trail. You may have to look closely to find one in the top of a tall tree where it is feeding on tender bark. This big, spiny rodent causes some damage to the trees it gnaws. It first appeared here about 1950 and has since been increasing. Its needle-sharp quills provide protection from most predators. The bobcat, however, is said sometimes to flip the porcupine over, exposing the tender belly to its sharp claws. Of course, you should never attempt to catch the formidably armed porcupine.

There are two poisonous snakes in the area: the fairly common copperhead and the rare and vanishing timber rattlesnake. Neither of these snakes will actually attack you. (Very few animals will.) But they will defend themselves; so, when you're exploring their habitat, don't put your hand or foot in a place you cannot see. There is always a small chance that you might unintentionally disturb one of these snakes, which may then bite in self defense.

Probably the most common mammal in these woodlands is the white-footed mouse. About 20 centimeters long, tail and all, this little rodent runs over the dry leaves in little bounding jumps, and frequently climbs shrubs and low trees in search of food. Its reddish-brown fur contrasts with its white underparts, and its black eyes bulge from its head like tiny marbles. Since it is quite common,

**Exploration:**
(Peer Under A Log) Sketch yourself into the food web at left. Is there ever a time—even at home, at the movies, or at school—when you are not part of a food web? Habitats of animals can be large or small. Find a small log or stone and look for animals under it. How are these creatures adapted for living in this special habitat? Compare this habitat to a tree trunk (look for differences in light, heat, moisture, and protection from weather and enemies). Roll the log or stone back in place as you leave. (Why?)

**Exploration:**
(Detect Browsing Evidence)
Search for signs of browsing by rabbits and deer along edges between fields and woods. Are the twigs freshly browsed or are they dried? Look at the larger redcedars. Do they lack branches near the ground? This is because deer browsed them in winter when other food was scarce. The deer do not favor redcedar twigs, but they will eat them to avoid starvation in cold weather. A high amount of redcedar browsing is therefore an indication that the deer population is too large for the available food supply. In the absence of wild predators such as wolves and mountain lions, what living thing do you think is today's main predator on the whitetail deer?

you have a good chance to see it—but only at night. It sleeps all day, leaving its nest at nightfall to gather seeds and insects. It is preyed upon by snakes, shrews, weasels, skunks, foxes, hawks, owls, and sometimes even fish. For this reason, the white-footed mouse is one of the most important links between green plants and predators in the forest food web. From the human point of view, the white-footed mouse is also important because it is one of the few animals that eat the damaging caterpillars of the gypsy moth. It is fun to follow its tiny footprints in the morning snow after a winter storm. Then we can see how busy it has been during the night.

Don't expect to see the black bear, for it is shy and avoids the roads. If you do spot one, it will probably run away. This bear weighs up to 135 kilograms; treat it with great respect. Stay out of its way and do nothing to anger or frighten it. Be especially cautious if you see cubs. And remember that you are an intruder in the bear's woodland home.

If you remain quiet and watchful, you'll quite likely spot a whitetail deer. Search for their tracks along streams and around ponds. Deer rest much of the day; at sunrise and after sunset they come to the edges of fields and meadows to eat. Sometimes they are a hazard to drivers (and vice versa) along roads at night.

**How Do I Relate?**

Planners predict that eventually up to

150,000 persons a day will visit the national recreation area. Each will have an impact on the land and water communities. We will walk the trails, drive the roads, boat on the river, explore the forest, have a picnic, and so on. Some of us will bring paper, glass, plastic, metals, and camera film—things that are not of nature—into this natural setting. Each of us can cause some pollution of the land, air, water, and natural beauty, and we can diminish the very solitude we seek. Most of our impact will be unintentional; few people purposefully break limbs, chop trees, vandalize visitor facilities, scatter litter, or break glass bottles. Can the recreation area withstand this growing pressure and survive intact?

The damage we do here is often the result of not thinking. Have you ever asked yourself if pulling up a green plant is a good thing to do? Our attitudes are important. What attitudes do you bring with you?

Do you feel that these scarce habitats and life communities should be treated with reverence and special care? Or do you assume that whatever you do at home or at school you are free to do here, too? (Will your parent or school custodian sweep up litter that you leave along the trail?)

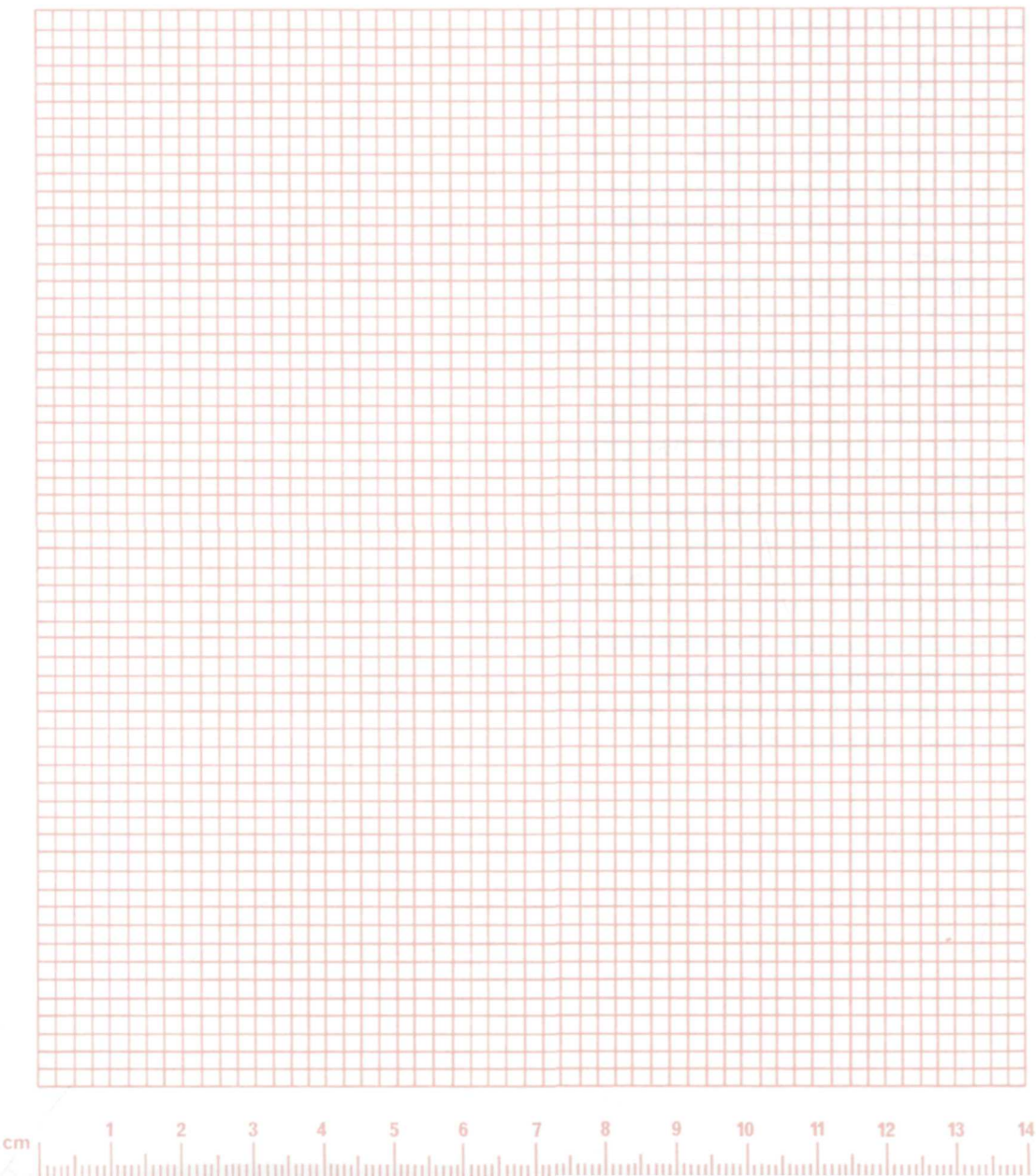
Or do you believe that "anything goes," that out here you are free to abuse, remove, or destroy, as long as no one catches you? Of course, this attitude would ruin what you came to enjoy.

Remember: freedom to play is not freedom to ruin. Out here, for your survival and for the survival of this environment, you need to think about what you do.

**Further Explorations:** (Choose A Compatible Activity) During your visit to Delaware Water Gap National Recreation Area, you can choose from among many kinds of recreational activity that will help you to relate to nature and that are compatible with the environment. Here are some examples: canoeing, swimming, hiking, picnicking, bicycling, visiting historic sites, attending naturalist programs, fishing, ski touring, and snowshoeing. Not to be ignored is the art of communing with or getting to know nature by just being quiet and letting it "soak" into your deepest self.

You may find that getting to know the recreation area takes more than a hurried visit. To catch the true spirit of the land, spend time here in different activities and in more than one season. The Lenape lived their entire lives here, so they knew the spirit well. You may want to get close to the land as they did. Take a whole summer's day and float down the river in a canoe. Or follow the trails of Kittatiny Mountain when autumn foliage sets the hillsides afire with color. Come back after a heavy snowfall and track the footprints of deer, fox, and mice across the old fields. Observe the brightly colored birds migrating north in spring, as rains fill the ravines with thundering waterfalls. Or sit quietly on the river shore by moonlight, listening for owls. Get to know the national recreation area on very personal terms. Then you will soon feel the spirit of the land flowing into you.

# Notes



## Suggested Readings

**Ecology,** by Taylor R. Alexander et al, and other books in the Golden Science Guide series, Golden Press.

**The Life of the Forest,** by Jack McCormick, and other books in the Our Living World of Nature series, McGraw-Hill.

**Pondlife,** by George K. Reid et al, and other books in the Golden Nature Guide series, Golden Press.

**A Field Guide to Animal Tracks,** by Olaus Murie, and other books in the Peterson Field Guide series, Houghton Mifflin.

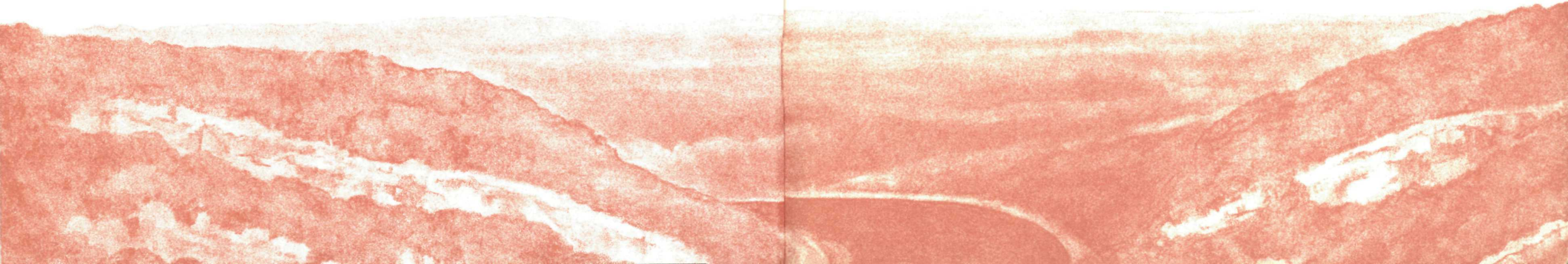
**The Balance of Nature,** by Lorus and Margery Milne, Knopf, 1960.

**Our Threatened Wildlife,** by Bill Perry, Coward-McCann, 1970.

**Materials prepared by Delaware Water Gap National Recreation Area.**

Your teacher or librarian can help you find these and other helpful books.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.



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