1. Home

“We’re thinking of cutting down our trees.” Caleb’s voice suggests a tinge of guilt, as if he’s looking for me to talk him out of it. Comfortable playing the role of the Lorax, I take the bait.

Caleb and Maya have good reasons. The trees might fall on their house—if an ice storm, tornado, or a crushing wind microburst drops down. Part of the house is rotting out from below, and fixing the rot requires digging a drainage ditch where one of the trees stands. The yard is too shady—they want to grow apples and their orchard would need more sun. The bumpy roots protruding above ground level make it hard to mow. They don’t really like pine trees anyway. They’d leave the oaks because oaks at least make acorns. But what good are pines?

I go to work defending the trees. They can regulate temperature—keeping your house cool in summer, warm in winter—by blocking sun and wind. You don’t want your child getting sunburned in your own yard, do you? Cool shade is ideal for a summer playground. Growing trees suck carbon out of the air—that’s where all the weight of their wood comes from—offsetting the greenhouse gas emissions that your family produces. Because the grass grows more slowly, you don’t need to mow as often under trees. The wildlife depends on these trees. White Pine is an awesome native species—the Haudenosaunee named it the Tree of Peace.

Think of the flocks of winter resident birds looking for a good evergreen shelter from the cold.

Their orchard argument is hardest to rebut. Caleb grew up in an orchard. Isn't local food key to a sustainable future? Since they moved in, Caleb has been working to get a productive garden going. But it's a struggle. The clay-filled soil is so wet that he resorted to bringing in a dump truck of topsoil and heaping it up so that vegetables would grow above ground level out of the water. Doesn't he deserve his dream orchard landscape?

WILD YARD

To be fair, I should note that Maya and Caleb are very eco-conscious, with every desire to do right by the world. Besides, I'm in no position to act high and mighty here—my own yard bakes in direct sunlight. When Sydne and I moved into our house ten years ago, the front lawn was mainly a large, green wasteland of grass. Just like our neighbor's, it had been mowed regularly to keep a nice trim profile. Being dominated by a single non-native grass species, the lawn invited few interesting animals to play. Then we moved in. Instead of buying a lawnmower, we bought a "wheeled trimmer," which looks basically the same but works on meadows and raspberry thickets. Today most of our yard hasn't been cut in ten years and trees are coming back (fig. 1.2). Some parts we still trim regularly as lawn—but even there, just as my dad once did for me when he mowed, we dodge wildflower patches for our kids to study.

We put a sign out front that says "Wildlife Habitat," and it's no lie. We have two species of foxes, coyotes, bears, turkeys, hatching monarchs, and endangered snakes. Birds feast on the pollinators and other bugs that overwinter in unraked leaves and abandoned raspberry canes. On summer evenings our yard is aglow with sparkling fireflies in all corners, whereas our neighbor's yard

Figure 1.2. The border between our yard and our neighbor's.

is just dark. Our yard is brimming with songs of myriad species of crickets and grasshoppers, in contrast to the monotonic hush next door. Our kids grow their minds by exploring a maze cut through the goldenrod. The neighbor's kids drive go-carts in never ending circles through their lawn—OK, I'll admit that does look like fun. And I can feel the glare from their second-story window looking down at these irresponsible neighbors who can't take care of their mess of a yard. But, I protest, we're not lazy. We're consciously putting our yard to work. It's sequestering carbon, supporting life, and enriching ours.

It was Susannah Lerman who inspired me to put the sign in front of our yard. Every day on her commute, she would drive past our house. She and I studied in the same graduate research lab—that of urban ecologist Paige Warren. Much of the time, though, one of us would be out in the field far from the lab. I was busy chasing rare salamanders across the landscape. Susannah studied urban birds in Phoenix and ways to better connect city people with the species around them. Our labmate, Rachel Danford, spent her time surveying Boston residents to see what it would take to convince people to leave more dead branches on their trees for woodpeckers to nest in.

One day Susannah remarked to me that she loved driving past our unkempt lawn but wondered how the neighbors felt. Particularly “Lawnmower Man.” He seemed to mow his lawn nearly every day, and I swear I once saw him mow it twice in one day—though perhaps that was more about riding the machine around than actually cutting grass. Or perhaps, seething in his seat, fingers clenched around his grips, he mowed for cathartic relief from the out-of-control nightmare unfolding on the other side of his property line. As Susannah had found in her own academic work, people often see wild yards as a blight—a betrayal of the neighborhood. But if you frame your yard appropriately, such as with a sign out front explaining your purpose, people often see it in a whole new light.

PHOENIX

With our graduate school days in my thoughts, I went to visit Susannah this year to hear again about her research, still stuck in my mind from many years ago. I opened the doors of the government complex where she now works and wound my way through the dim cubicles. Unsure of where her office lay, I crept uneasily around corners, feeling a bit like Ralph, the motorcycle-riding mouse who had been forced to run a maze in that week’s bedtime reading to my son Juno. Rather than peanut butter, my reward at the end would be Susannah’s insights into how homeowners unknowingly shape the bird universe.

Last I saw Susannah, she was running a project that involved mowing lawns in Springfield. She mowed different lawns at either one-week, two-week, or three-week intervals and then counted the numbers of flowers and bees in each lawn. Her results showed more flowers with a three-week rotation but more bees with a two-week rotation, although those two-week bees were dominated by just a few species. Some people worried about whether letting their lawn go would bring in more ticks. In that urban setting Susannah found no ticks in any yards. In our yard, unfortunately, ticks are a real concern that weighs on us daily.

I found Susannah's office at the end of a corridor, with Susannah hard at work inside. Next to her computer, a black frame on the desk held a *New Yorker* cover illustrating a man sitting on a city park bench. Above the man, a bird in a tree sang the sweet songs of spring. The man sat listening to his iPod, oblivious. Next to this image, a smaller frame on Susannah's desk was angled such that only she could see the picture, but I assumed it was a photograph of her son, Matan. As a three-month-old, Matan had accompanied Susannah for the intense fieldwork I had come to ask her about—work that began with a 2,500-mile journey to the Sonoran desert. In fact, a burning question on my mind was how Susannah had managed to pull off that work with an infant in her arms, alone.

A few days later I found myself in that same desert 2,500 miles away with my own children. We had flown to Phoenix, Arizona, to retrace Susannah's steps from years prior. For our single day there, we faced an ambitious schedule, squeezed between a 10:00 AM rental car pickup and a 3:00 PM drive to the Tucson airport. In those five hours, we needed to track down the four types of yards that drove Susannah's findings. As we talked in her office a few days prior, Susannah had pulled up Google Street View on her computer and walked me virtually through different Phoenix landscapes, pointing me to neighborhoods we should visit. Of course, in our five hours we also had to factor in time to eat at Susannah's recommended lunch spot, Señor Taco, and time to visit Susannah's recommended kid destination, the Musical Instrument Museum. Oh, and we needed to stop at REI to buy a new sun hat for Juno.

Before we even pulled out of the airport hotel parking lot, we started to see the important pattern Susannah had documented: house sparrows and starlings in the hotel's big trees. The hotel, like the typical mesic yard we were headed for later in the day, was landscaped in a manner totally inconsistent with the Sonoran desert. Mesic environments are defined by moderate amounts of water, unlike a desert. In a mesic yard you find expanses of grass under the shade of broad-leaved trees bordered by lush shrubs and flowers. Mesic homeowners seem to have a nostalgia for the eastern forest ecoregion; they use their garden hoses to transform the desert. The green and shady mesic yards we visited could just as easily have been in Baltimore. Xeric yards, by contrast, conform more to the desert. "Xeric" means "dry," and such yards are typified by desert and drought-tolerant plants (fig. 1.3). Beyond the obvious waste of water, Susannah found that the effects of mesic yards rippled throughout the ecological community.

I picture Susannah patrolling from house to house, holding Matan in one arm, a clipboard in another arm, and writing with a pencil held in the hand of her third arm as she recorded the extent to which native desert shrubs and cacti had been replaced by non-native plants in mesic yards. Then, waiting for the moments when Matan was quiet, Susannah would listen for the birds and record the species and abundances of all she heard and saw. Sometimes, when Matan was asleep in his car seat, Susannah would conduct surveys through her open window, watching the experimental feeding trays she'd set up to understand the underlying rules controlling which birds choose which yards. As she delicately conducted her scientific tests of ecological theory, she had to always hope that the infant wouldn't wake up screaming and send the birds scattering.

Not wanting to wake the baby is why Susannah didn't honk to prevent the all-too-preventable collision that marked, as Susannah sarcastically put it, the "high point" of her fieldwork. Surveying the birds from inside her parked car, Susannah watched in slow motion as a man slowly, very slowly, backed his car out of his driveway, across the street, and directly into her car. He then drove off without stopping. That day, like every other day that Susannah was alone in the desert caring for her infant while establishing her scientific career, she cried.

Susannah's commitment to her work paid off. Her data confirmed the stories people on the streets told. In the mesic neighborhoods people complained to Susannah about the noisy, messy flocks of pigeons, starlings, and house sparrows (fig. 1.4). Hearing that she was an ornithologist, they asked Susannah how to get rid of these birds. The mesic neighborhoods were full of nonnative species, and the residents detested their birds. But in the xeric neighborhoods people delighted at the roadrunners, cactus wrens, and Gambel's quail. These xeric neighborhoods were full of desert-adapted native species, and the residents loved their birds (fig. 1.5). Native plants support native wildlife. Cactus wrens and gila woodpeckers, for instance, are adapted to nest in cholla cacti and saguaro cacti. If you lose the special plants, you lose the special bugs, mammals, and birds. And people care.

But there are many layers to this story. Even when Phoenix homeowners plant desert species, they don't necessarily use less water. As my family and I drove through one of the xeric neighborhoods, a roadrunner darted down the sidewalk and underneath a spherically pruned green desert shrub. The desert birds were here, but this sure didn't look like a wild desert. The homeowners had carefully laid down uniform gravel instead of grass, placed cacti around meticulously pruned desert trees—although the cacti and tree species may have been borrowed from deserts on other continents—and maintained exhaustive control of the environment. In such yards homeowners often add water all year round to keep the vegetation green, negating the water-saving advantages of xeric yards. But desert plants are designed to go dormant for long stretches of the year; they don't need hoses and sprinklers.

Figure 1.3. Phoenix yard types: (a) wild xeric, (b) landscaped xeric, (c) barren, and (d) mesic.

In the wealthy Scottsdale neighborhood, I ducked through a fence of a gated community as a flock of Gambel's quail bobbed their heads under untamed, browning desert hackberry in someone's yard. This yard demonstrated the wilder approach to lawn care, where nature does all the work. Plants are allowed to go

brown like the surrounding desert in the dry season, and it's these yards that both support native species and save water.

I needed to capture a picture of the whole lot in context, so I headed back out to the sidewalk. There, I stood up on my tiptoes and held my camera over the massive wall that kept intruders out.

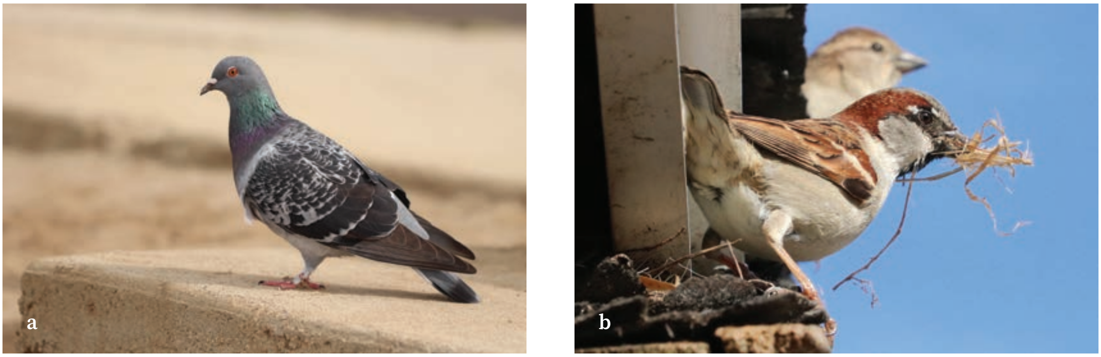


Figure 1.4. (a) Pigeon, and (b) house sparrow, exotic species in North America.

But my over-loved camera lens malfunctioned. I removed the lens from the body, smacked it against my leg, and shook it until the loose piece inside rattled to a new position—a trick that usually makes it work temporarily. The maneuver failing, I went back to the car and asked three-year-old Juno if I could borrow his camera.

All I wanted to do was take the picture and get out of there without finding myself in trouble, again. As a disheveled dude peering over an affluent fortress wall taking pictures of someone's estate, I didn't want to attract any more attention than necessary. I recalled Susannah's story of cops being called on her doing this fieldwork. Of course, the baby strapped to her front softened her image—a strategy I employ as well when I can.

As a field ecologist, I've had my own share of run-ins. There was the time Charley Eiseman and I were scheduled to present an evening slideshow on bug tracks at a church in the dead of winter. We showed up a couple hours early, as we always do, taking pictures of the miniature poops, cocoons, webs, and eggs on the outside wall of the church to incorporate into our slideshow. As the two of us crept slowly around the perimeter of the building staring at tiny bugs in the dimming light, an elderly woman working inside called 911. But just after she called, we left for a short pizza break, oblivious to our escalating peril. An hour later we were back tak-

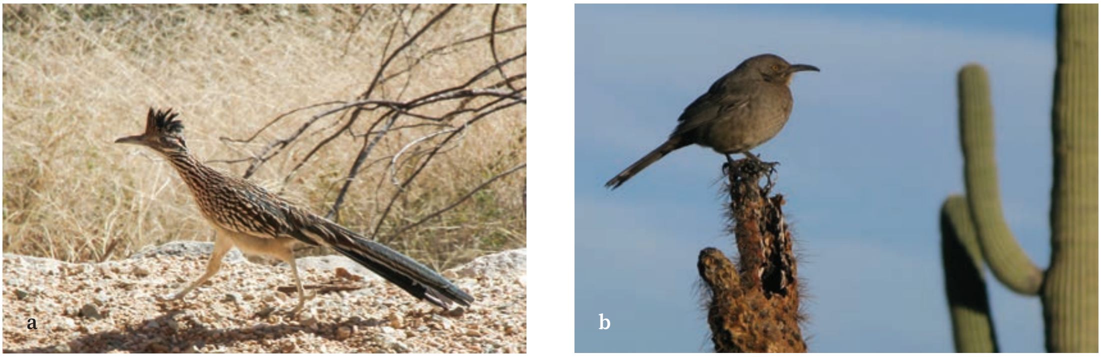


Figure 1.5. (a) Roadrunner, and (b) curve-billed thrasher, native species of the southwestern United States.

ing pictures of bug tracks on the church wall when a pair of policemen, having received a second 911 call from a terrified woman hiding under a church desk, came skidding up in their car and jumped out to apprehend us while their wheels were still rolling.

Or there was that time Sydne and I parked our rental pickup along a remote edge of forest above the river separating the United States and Canada. As we were hunkering at the water's edge sampling federally endangered plants, the border patrol came creeping up on us through the woods. We started yelling at them not to step on the plants, but they didn't seem to understand.

Oh, and what about that time in rural Vermont when Charley and I, parked at the end of a one-house road at 5:00 AM to begin the hike in to our assigned survey plot, were chased off by a stern woman from the house wielding a large silver revolver. Or that time I was strangled in the hills of Mendocino, California, by the two wiry hands of a long-haired man defending his property while the German shepherd I was hiking with wagged her tail next to me. I could go on.

But here's my broader point: as an ecologist, you can't forget about society.

It took us more than the allotted five hours to wrap up our Phoenix scavenger hunt, but we did succeed in witnessing the four yard types: wild xeric, landscaped xeric, barren, and mesic. We then raced down to Tucson to pick up my mom from the airport so that she could help watch the kids the following day while I headed off to the Mexican border.

The next day, with the long metal border fence snaking over low hills into the distance, Chelsea Mahnk held a metal antenna high in the air and listened through static on her transceiver for imperceptible beeps. Occasionally, border patrol SUVs drove by dragging giant tires along the dusty road to create a clean surface for finding footprints of migrating humans. But Chelsea and I were after a different migrating species.

Simply creating the right habitat for wildlife in your yard isn't always enough. The animals also need to be able to get there. For winged creatures maybe it's not so hard to fly over asphalt wastelands and plop down in a little glowing paradise. But down at the border fence, we were tracking turtles. Arizona mud turtles. These turtles migrate seasonally between desert ponds and uplands where they hole up in kangaroo rat burrows. The thing is, some of their upland habitat is over in Mexico. The fence in that spot is still open enough that the turtles can slip through—although we can't. The turtles were carrying radio transmitters, and we were straining to triangulate a position on them in Mexico from where we stood north of the border in the Buenos Aires National Wildlife Refuge. Later we planned to look down with Google Earth and try to understand their habitat needs. What, we wondered, will happen to the turtle populations if this fence becomes a less porous wall?

CONNECTING NATURE AND PEOPLE

As night set in, Chelsea and I headed back to Tucson, where I rejoined my family for a vacation in the desert. One of the rituals during this vacation was to get up at sunrise and head over to the bird ramada—a covered viewing platform surrounded by bird feeders. The feeders attracted many special desert birds, like quail, cactus wren, and curve-billed thrashers, and some other birds more familiar to me, like house finches.

Bird feeders. As a citizen, bird feeders are a great way to support wild animals and connect with nature. As a scientist, however, I see bird feeders as a great experiment. What species are we really supporting? Do the increased numbers of commercial sunflower seed-eating species, like house finches, crowd out other species, like phainopeplas, that specialize in wild bugs and desert fruits? Bird feeders have certainly helped expand the range of house finches from their native West to a continent-wide takeover. And what are we doing to the species as we feed them? Even as house finches rely on eastern bird feeders, researchers have shown that bird feeders facilitate the spread of a deadly eye disease, conjunctivitis, among the finches. Like a snot-covered daycare room, feeders sometimes give all the visiting finches pink-eye.

More than just altering which species live where, with bird feeders we are altering the very species themselves. Researchers in Phoenix found that the house finches within the city were evolving larger, stronger beaks to crack through thick sunflower seeds, compared to the house finches still fending for themselves in the wild desert. With a changing bill size, the urban finches are now evolving different songs. At the same time other urban forces are causing city finches to grow less colorful feathers than their country cousins.

And then there are the social science questions about bird feeders. That is, what parts of our society participate in the feeding of birds? Who gets to enjoy which birds? In Phoenix the social justice component of ecology is impossible to ignore. The richest neighborhoods have the best native birds. Along the mesic-to-xeric gradient, there are some advantages to yards with moisture-loving eastern trees—most notably that they keep your house a bit cooler in the hot desert. However, the poorer Phoenix neighborhoods don't even have that.

As my family and I drove through the poorest neighborhoods, we saw vast expanses of bare dirt, pavement, and gravel. No plants, no interesting desert birds, no cooling non-native trees, but lots of pigeon poop. The poorest peoples living in the most degraded environments. Beyond the desert, this is a pattern that holds true across many contexts.

BOSTON

In mid-May I pay a visit to my aunt and uncle in Boston. Loretta is an atmospheric chemist and Michael is a retired doctor but perpetual activist who has lived in this one tiny apartment for decades. He is a model citizen for the environment—and at times a bit fanatical about it. As I was growing up, I remember Michael pulling trash out of garbage cans to reuse, taking public transportation at all costs, riding his bike whenever he could, and minimizing his footprint by packing himself in among all the little bricks in the city.

Here's the paradox that Michael and Loretta's lifestyle presents for me. If you love nature, the best thing you can do for the environment is to live in a city. But, living in a city, we lose our connection to nature. We don't get to reap all its benefits, and I worry that we lose our ability to care for it appropriately. I've lived for brief periods of time in urban settings. At first it's sort of fun. But then I go crazy.

When I arrive at the Boston apartment, Lorretta is away in her office, presumably working out the fates of chemicals floating around in the sky. Michael is home, and he takes me out for a walk around the neighborhood. Knowing of my need for nature, he leads me to a small park where a few dozen of Boston's trees stand above a cleared understory. Red oaks, beeches, and some sort of pine with deeply furrowed bark. They seem to be in the hundred-year-old range but have an odd form. Most start out single-trunked like normal forest-grown trees. Then, about ten feet up, they split into multiple trunks. We scratch our heads trying to reconstruct the history of the land.

From across the park I notice a telltale discolored stripe running up the side of the pine tree. I point it out to Michael and bring him over to show how it's made of hundreds of little nicks, each half the width of a pencil. Each of these, in turn, consists of a pair of two grooves. The nicks are positioned at all sorts of angles and come in many shades of brown—from a rich mahogany to a weathered gray.

In all the years that Charley and I have taught animal tracking, we must have brought hundreds of students to trees just like this. As they stare at the marks on the ash tree next to one of our favorite spots—where coyotes once barfed up a pile of voles—we ask the students probing questions about what they notice, hoping someone will figure it out. Nobody ever knows what this is, even though they've all walked by such trees dozens of times, even though it's a blaringly obvious sign, and even though they're all very familiar with the animal that created it.

Of course, Charley and I didn't know this sign either until tracker John McCarter pointed it out to us. It's the territorial marking sign of gray squirrels. Generations of squirrels over many decades have come to this pine, sniffed, taken a quick bite with their incisors, then rubbed their cheeks into the bark to squeeze out pheromones from their scent glands. What does it all mean? Nobody knows. John told us that when he first discovered this, he broke off a piece of bark and brought it home. The squirrels in his yard went crazy over the scents on that bark. I've tried without success to recreate that experiment.

Michael leads me over to a depression that he says fills with water sometimes. The ground is a bit soft and covered with lesser celandine, an invasive spring ephemeral that takes over wetland margins. But there's not enough water standing now to support much life. Before all the roads around us diverted the rain into gutters, would spotted salamanders have bred here in a healthy vernal pool? Probably. Today there are no spotted salamanders left anywhere within dozens of miles of us.

Michael wants to show me the nearby greenway, so we start hiking north. We climb up and down a series of steep hills and wonder what these are. Michael suggests that they are drumlins—glacial formations created beneath a moving ice sheet. I'm tired, worried about my knees, and find it hard to keep up with Michael, who has over thirty years on me. I blame it on lack of sleep and the physical demands of having two little kids.

We get to the greenway—a paved bike path edged with two narrow strips of green on either side. Michael says that this is what passes for nature in the city. "Invasive-dominated degraded ecosystem," I say. We walk for a while, then come to an area where the ground alongside the pavement is muddy and the pedestrians are shaded by silver maples, red maples, elms, and a cottonwood. Floodplain trees. I close my eyes and see this spot as it once was: a forested wetland full of chattering wood frogs near a river. I open my eyes and see joggers, baby strollers, dogs on leashes, and asphalt painted down the middle with a solid yellow line.

HOME AGAIN

Back where we started, Caleb and Maya are still contemplating dusting off the chainsaws (see fig. 1.1). Despite my tree-hugging impulses, as a conservationist I can't be against cutting trees. After all, I rely on a woodstove to heat my house. Wood is a local, renewable resource. When harvested sustainably, burning wood can be a much more carbon-neutral way to heat your home than burning fossil fuel. The carbon I put into the air through my woodstove is recaptured by new trees growing out on the landscape. Modern conservation sees humans as a critical, interconnected part of protected landscapes. The goal is not to preserve nature untouched but to build a strong relationship between people and nature, making both healthier. And it all starts at home. In the United States more than 80 percent of people live in cities and suburbs, so it's in yards and urban green spaces that we must start. Home is where each individual can have the greatest control over our planet.

With this in mind, I know now what I want to say.

Dear Maya and Caleb,

Here's what it comes down to for me: if you're going to cut down your trees, you should at least get to know them first. More than just learning all the good things trees do for us, I want you to know these particular trees in the context of the whole system. How did these individual trees get here? Why these species, and where do they fit in a broader ecological narrative? How do wild animals use them?

And while you're at it, I want you to know more than the trees. How are the trees controlled by and influencing the rest of the parts of your yard? Why is your soil so wet? Where did the soil even come from? Where does the water that's rotting your house come from? Where is the water going?

And I want you to know more than just your yard. How do the features of your yard relate to your neighbors', to the community, and to the whole region?

And I want you to know your yard in time. How was your yard shaped by events in the past fifty years? Hundred years? Thousand years? Million years? Billion years? Where is your yard going? What will it look like in fifty, one hundred, one thousand years? I want you to see your yard as a bridge across space and time.

The pines, the oaks, the mud, the water, the land. It's not random but all part of a long, unfolding story that you have a role in. Dig up the details.

Then, only then, will I trust you as the shepherd of your yard. In managing your yard you control a whole universe, and I want *you to know that potential. Like giving thanks before killing and eating a deer. Like saying a blessing over your bread. Like actually stopping to absorb the artwork on the wall of the museum you've paid so much to enter. Know thy land.*

Love,
Noah

Knowing your own land. That's what this book is about. It's not really about facts, names, or specific places. It's about how to think about a landscape, what questions to ask, and how to connect the dots. And it's about your place in the landscape. This chapter isn't even about Caleb's yard, it's about your yard. Whether you own a house, rent an apartment, carry a tent, or sleep in a shelter, your land has stories to tell. Yard, sidewalk, park, mountain, or ocean, can you read the stories?

THIS BOOK

The best job I ever had was teaching a college course, *Field Naturalist*. Each Friday we would drive the van to a different site in the Connecticut River Valley where the students would be confronted with a mystery to solve. At each of these sites, we discovered the underlying stories of ancient volcanoes, glacial lakes, farming, logging, and other forces. Meanwhile the students' semester-long project was to tell the story of their own home site on campus, returning from our class field trips with new layers of questions each week.

This book is that course. Each chapter is a trip to one of the class field sites. The mystery of each site is depicted in the chapters' opening images, complete with the clues the students used to solve the puzzle. The home project site is yours to choose.

See what you can make of the opening images, imperfect as they are, before you read the chapters. What pieces do you see? Can you find any visual patterns, shapes, or gradients that might tell a story? Can you identify any species? What processes might be at play in forming the patterns? How might you value this landscape? I'll drop hints throughout the writing—see if you can pick them up to solve the puzzles or at least make some guesses. Then use the prompts at the end of each chapter to reflect on your own home site.

For the rest of this book, we'll be primarily exploring wild landscapes. But, just as in Boston and Phoenix, even if your world is paved over and penned in, you can learn to read the urban landscape with much the same approach.

If you're new to nature, don't worry about the particulars of species names and unfamiliar concepts. Just look for the visual patterns and try to imagine what the site might feel like. If you're a seasoned naturalist, go ahead and break out the field guides and try to nail down the species and habitat preferences—for a leg up, start with the plants in the table at the beginning of this book, which contains all the species you'll encounter in the opening images. If you're like me and only have time for audiobooks, well, just enjoy the stories, although the images are also posted on this book's website along with many more that couldn't fit in the printed book. If you're an educator, check out the appendices on the website and don't overlook the references—I've tried to document every idea from human-chasing moths to butt-itching roses.

Everything in this book is real. I promise not to cheat—although I do love fair tricks. These are the actual field sites from my course, the images were all taken on location, and everything is told just as it happened. These aren't stylized versions of nature; these are the thing itself, with many different layers overlapping and interacting. Likewise, the interpretations I give are my best shot at it and could be wrong. What I'm after here is not the answer but the process of critically engaging a landscape with all the perils that brings.

Wandering into my special places in nature, I find a sort of timelessness. This slips into our language when Charley and I talk about such places. We typically use the present tense in our conversations about whatever we, our students, or the other creatures did in a place, no matter how long ago we witnessed it. The memories always linger in the present. Among other things, it is a mirror to the structure of nature—if something happened once at a place, it's likely to happen again and again there. You'll notice that I've woven a small bit of our linguistic convention into the structure of this book in order to bring the field sites to the foreground and to help you experience their timelessness.

In college the most important thing I did was to join an informal band of students and locals dedicated to primitive skills such as animal tracking, wilderness survival, and generally knowing nature in a deep and intimate way. The Woodsy Club. At the start of any meeting or walk outside, we would express some creative form of the "Thanksgiving Address," an idea shared with us from Haudenosaunee traditions. Beyond anything magical, I see it as a little meditation—a way to slow down before starting something important to ensure it's done carefully and with focus. It's the same basic idea behind reciting a blessing before your meal, at least in my understanding of Jewish mysticism. But in my Sunday school, they never taught me the Hebrew blessing to say before wandering in the woods. The Thanksgiving Address filled that void for me.

In the Woodsy Club we didn't always stick to a specific script, but the thanksgiving would often follow the basic pattern of moving from bottom to top through the layers. We would start by giving thanks to the dirt and rocks, then acknowledge the plants and trees, then the little animals and big animals, the people, the birds, the weather, the sun, moon, and stars, the great mysteries, unknown forces, and a blanket thanks for anything else we forgot. For the basic skills that we practiced in the Woodsy Club, it felt essential. For whatever reason, I don't think I've ever successfully made fire-by-friction on occasions when I didn't take the time to center myself with a little thanksgiving first. And I've found this really prac-

tical as an ecologist—it reminds me to think about all the layers of interaction. Just before the path leads you into the woods, take a moment to pause, step back, and look at the whole picture (fig. 1.6).

Figure 1.6. *Field Naturalist* students on the last day of class.

MAJOR LESSONS FOR INTERPRETING A LANDSCAPE

- Think about how you manage your own yard and the ripple effects it has through the whole ecosystem.
- Even where nature seems paved over or mowed down, look for clues—like wetland trees still hanging on—that might tell a deeper story.








N
NE
E
SE
S
SW
W
NW
Silva






(overleaf)

Figure 2.1. A puzzle.

2. Land

LOSING THE TRAIL

It's an early August morning. The sun hasn't yet risen, but the birds have begun their dawn chorus. A few miles south of Caleb and Maya's house, I'm hiking up a forested trail carrying Juno on my back, already feeling the heat of the day. As the trail turns up a steep slope and the sweat starts to seep from my forehead, we abandon the path to take a less steep route off-trail along the landscape contours.

Following the trail is the easiest way to be lost. Sure, that trail might take us to a preordained destination faster, but we'll have no idea where we are when we get there. While we're on the trail, we lose track of what's around us and where we are in space—we are lost. We put our trust in the trail, ceding responsibility. We give up our awareness, our senses, our minds. Our interface with the landscape boils down to just two numbers: the total length of the trail and the distance we've traveled. Staring at the path a few feet in front of us, we are not fully engaged with the surrounding world.

Step off that path and suddenly we have to look up. Look at the shape of the land and decide how steeply we want to climb. Look at the trees in the distance and pick a target to walk toward. Keep looking behind so that we will recognize the forest when we encounter it from the other direction on our return trip. Study the shrub layer for gaps to duck through, following the occasional animal trails worn through the denser areas. Use the network of deer paths when traversing steep slopes to gain level footing. Keep an eye out for poison ivy, rose thorns, and ticks waving their arms in hopes of catching a ride. Study the patterns of light for clearings. Monitor the changing habitats near and far: white tops of sycamores in the distance signaling a creek; chestnut oaks nearby telling us we've reached the drier hilltops; the banjo-like plunk of a lone green frog calling from the wetland ahead that we hope to steer around. Keep an eye on the rising sun and remember where south is as we walk. This whole time, we maintain a map of the landscape in our heads, filling in the details as we go. That is how we get to know the world and our place in it.

OPPOSING SLOPES

This morning we hug the edge of a small valley, skirting a wet seep a few feet below. We gradually ascend as the valley narrows until it can narrow no more—we are standing in the bottom of a small "V." I raise my camera to my eye and capture the center photograph for the chapter-opening image (fig. 2.1). I think I'll call this spot Bark Hollow.

There's a mystery here. Looking on my camera LCD, I can see that I've captured it. It would be easy enough to miss, even in this photo. If you're not paying attention to the landscape, if you're not tuned in to vegetation, if you're not looking for patterns, if you don't stop. But once you know to look, it's impossible not to see the pattern in the image. It's not a product of the lighting; the pattern is real. The vegetation on the right is entirely different from the vegetation on the left. Here, in my *Field Naturalist* course, this left-right pattern was the central puzzle. We went home only when the students' mounting observations finally produced a narrative that coherently described the pattern.

The first thing I always ask my students to do when we get outside is to orient themselves. Playing in my head is that R.E.M. song "Stand," which asks us to face north, consider direction, question why we haven't before, and then look to the sun for help. But when I ask my students to check the sun for directions, they laugh as if this is just another of my sly jokes—because this must be an exceptionally difficult feat, right? Our lives are directed by walls, clocks, and GPS navigation. The sun has become meaningless. But doesn't the sun still rule our lives, even if we never look to it? Why wasn't it until college that I first understood the simple path of the sun through the sky? And it wasn't even college proper—it was that strange, unofficial student group, the Woodsy Club, that taught me to see the sun.

Where is the sun at noon? Most folks know that the sun rises in the east, generally, and sets in the west, generally. Where does it go for the rest of the day? If we are north of the Tropic of Cancer, which cuts through the center of Mexico, then the sun will be due south and our shadow will point north at noon—at least if it's true solar noon, defined by when the sun is highest in the sky and not by geopolitical time zones. Up at these northern latitudes, the sun spends the entire day in the southern part of the sky. And if you face the sun, it always moves from left to right. But not when you're in the Southern Hemisphere.

For our honeymoon Sydne and I took a trip around the world—funded by $10,000 we won with a spur-of-the-moment scratch ticket. We headed first through South America. Down there the landscape, species, and societies were all a bit different from those at home but not really that different. Squinting our eyes a bit, we could convince ourselves that we were still just in some far-off town in the United States. That is, until we looked up.

The real immutable difference is in the sky. At night it's not just that the constellations are arranged differently in the Southern Hemisphere, but the objects are of an entirely different quality. For the first time we saw the other half of the universe, and it was beautiful. Big, blurry galaxies hovered over us like clouds that wouldn't go away. Why don't we have anything that cool in the northern half of the universe? We were staring directly at the bright center of the Milky Way, partly obscured by dark nebulae hanging in front of it. A few familiar constellations, like Orion, still danced upside down across the northern part of the sky. But as we hiked along alpine ridges in the Andes, the dippers were nowhere to be found. And the South Star was missing. Whereas everything in the northern sky spins around Polaris (the North Star), down south, that center point was blank (although in a few thousand years, Earth's wobble will have reversed these fortunes). Most fundamentally, there was no denying that the stars turned the wrong way and the sun was moving backward. It was deeply disorienting and, on some level, horrifying.

ASPECT

In the Northern Hemisphere, if you're standing outside facing the sun at noon, you'll be facing south. Close your eyes and feel the heat on your face.

The sun's rays are, of course, what feeds plants. Each plant twists and stretches and fights its neighbors to get its little piece of the sun's light. But, as we know, too much sun isn't always good. The sun's heat causes water to evaporate, which can quickly turn a happy, lush plant into a crisp. Evaporation, it turns out, is one of the greatest threats to plants. You may be familiar with special adaptations that cacti and other succulent desert plants have, such as thick, waxy, bristly leaves to store water and reduce wind-driven evaporation. But even in lush forests, nonsucculent plants have tricks to hold on to water vapor, like folding their leaves and closing their pores at night when they need to breathe in less CO_2. Water retention is the reason evergreens of the north have round, waxy needles. It's a reason that many alpine plants are formed in miniature, round pincushions. It's a primary reason that deciduous trees shed their leaves in winter. Increased evaporation is why we expect many of the world's forests to grow more slowly as the globe warms. In short, water availability is a huge driver of ecological patterns.

Within any broad climate the local microclimate depends on many factors, such as the amount of sun, wind, and water that a site is exposed to. Up on the hill behind our house, there is a five-foot-wide and thirty-foot-deep rock crevice where the sun seldom shines. In that crevice the snow lasts months longer than the snow everywhere else around, and a whole set of mosses and ferns grow there that don't grow on the landscape nearby. To a lesser extent every hill, rock, hole, field, forest, building, and road influences the microclimate of the plants growing on or next to it.

While many species occur over broad geographic ranges, they often can only be found in specific habitats within that region. Suites of species adapted to similar habitats usually occur together. We talk about such "natural communities" and the key indicator species for any given habitat. Open any field guide and, in addition to telling you how to identify species, it will usually tell you the particular habitat type that the species belong in. Using two such guides, I looked up the site preferences for each of the species depicted in our chapter-opening image and put the results into figure 2.2. See for yourself.

One fundamental microclimate difference is between slopes that face north and slopes that face south. Just as the sun warms your cheeks as you face it, the sun warms and dries the soil of a south-facing slope. North-facing slopes, like the back of your neck,

Figure 2.2. The images of species depicted in figure 2.1 are replaced here with descriptions of the species' habitat preferences.

stay cooler and therefore the soil stays moister. Thus, you can usually find plants that love dry soils on south-facing slopes and plants that love moist soils on north-facing slopes.

With this understanding of the differences between north and south slopes, take some time to stare at figure 2.2 until you understand the pattern in your body—words alone will fail. As expected, on the right side there is a suite of species that love warm, dry sites. On the opposite slope there is a suite of species that love moist sites. And look at the compass arrows. The red arrow points north, just as the dry slope on the right faces north away from the sun. The slope with the moist-loving—

Hold on.

But wait, did I say the north-facing slope is the hot, dry site?

And the south-facing slope is the moist site? I mean, that's completely opposite of what we'd expect, right?

Something's wrong here. I guess we'd better dig deeper.

When I confront a vexing problem in science or life, the thing that works best for me is to stop trying so hard to solve it. Instead of powering through with logic, I do better when I let my mind and body wander freely for a bit. This allows me to leap over to the framework where I really need to be. So that's what we're going to do now—wander. Trust me, it will all come back around to the puzzle at hand.

ARTIFACTS

While poking around Bark Hollow taking photos, I feel a wave of nostalgia as I look down to see a half-buried mechanical pencil, most likely dropped by one of my students years ago on a class trip. Picking up the pencil, I examine the dirt-caked sides and feel a fondness for this treasure. As I savor the memory of that class, my mind flips to a summer I spent scanning for ecology treasures with a metal detector.

Thirty years ago, out in California, Peggy Fiedler was crawling around the open hills of California counting individual leaves of the small, endangered Tiburon mariposa lily. This species grows only on the small Tiburon Peninsula, adapted to the harsh conditions of the local serpentine soil—starved of nutrients and loaded with heavy metals due to the underlying metamorphic rocks from which the soil is derived. In an effort to understand how this lily grew, Peggy used hundreds of toothpicks to diligently mark and number every plant in one-meter squares (about three feet by three feet). She returned for three years (the typical length of a graduate field study) to measure the growth of each individual plant and used these data to build a demographic model—a model that tracks how plants of a certain size or age grow and reproduce each year. Such models can theoretically be used to project a species' fate into the future. Around the same time, 3,000 miles away, Sue Gawler was doing the same thing for the endangered Furbish's lousewort, which only grows along a single dynamic river on the border of Maine and Canada.

Decades later Sydne and I set out to see how well the demographic models would mirror population dynamics over time. So we trekked to the hills of California and the banks of the St. John River and searched with metal detectors—at times in white full-body hazmat suits to protect against the encroaching poison oak—until we found, still stuck in the mud as Sue and Peggy had planted them, hundreds of tiny thirty-year-old toothpicks and tent stakes, along with a few other treasures, like a spent Civil War–era bullet deformed from impact. It's amazing how long things stay in place that have no cause to move—and how long our legacy can last in nature. What Sydne and I learned from the study wasn't so surprising. Models built on a mere three years' worth of data didn't say too much about a population in the long run, nor were they intended to—we really need decades-long studies to understand patterns in ecology.

SURVIVAL

Beyond mechanical pencils, what other sorts of legacies have people left in this forest? In the middle of the right half of the chapter-opening image, notice the big multiple-trunk tree. This particular tree is a red oak, but if we look around off the frame, we'll find many more such multiple-trunk trees of other species about the same size. What does this tell us? Normally, as an oak grows from an acorn into a tree, there is a single leading stem that grows up into a tall, straight trunk. But if you cut down that tree, of-

Figure 2.3. Multiple-trunk oaks suggest a historic logging event.

ten little sprouts will regrow from the rim of the stump—a growth form known as coppice. Some of these stems may then grow up into full trunks again, this time with multiple big stems coming from a single base (fig. 2.3). A forest of multiple-trunk hardwood trees, particularly when multiple species are involved, often indicates a legacy of past logging. But it's not always logging that kills the aboveground half of a tree.

Consider the American chestnut on the right side of the chapter-opening image. It's a cluster of leaves at the base of a small dead shoot. Across the East, chestnuts primarily exist as stump sprouts. Massive chestnut trees used to dominate our forests—it's commonly suggested that prior to the 1900s, one in every four trees east of the Mississippi was a chestnut, and in Kentucky and Tennessee, it's said that one in every two trees was a chestnut. The nuts were a primary food source for bears, deer, fishers, turkeys, squirrels, mice, and humans. But then in the early 1900s, a fungus brought over on ornamental Japanese chestnuts jumped to American chestnuts and rapidly decimated the trees. By 1940 most American chestnuts were struck. The blight only kills the aboveground part of the plant, and trees that are killed while still young are able to sprout new shoots from their roots.

I've read that in places, particularly in the Southern Appalachians, you can still find grand "ghost" chestnut forests, where huge stumps and logs of giant trees that have been dead a hundred years still dominate the landscape. I've long wanted to see one of these forests, and I'd really like to have a picture of one in this book. So this year I asked around and picked up some leads about places near the Great Smoky Mountains.

In April we headed to the Smokies. It was 4:00 AM when I snuck out of the Gatlinburg hotel room to check out my first lead, trying not to wake Sydne and the kids. Walking without a flashlight in the cold, moonlit stillness, I passed silhouettes of trees, some dead, on my way to the top of Ramsey Cascades. I noted the locations of the dead trees but figured I'd inspect them on the way down, once the sun was up. Halfway to the top of the falls, I entered the zone of old growth, full of ancient, twisted, towering trees that had never been cut. At sunrise I reached the cascades, 4.5 miles up the trail, then turned to head down.

Leaping from dead tree to dead tree, I peered into the wood end grain. As wood grows, minute patterns of lines and dots form in characteristic ways for each species. This log had prominent "rays" that radiated outward from the tree center—it must have been an oak. This stump still had bark on it—it must not have died very long ago. The concentric growth rings of this log didn't have the little dark pores that indicate water-transporting vessels—it must have been a softwood, probably hemlock. This one did seem a lot like a chestnut—a big, solid, hollow stump, rotting from the inside out like hardwoods do. But the pores in its wood were all uniformly small—it was probably a black cherry like the other big black cherries living around it. Nothing seemed to be chestnut.

Instead of finding the remnants of a century-old blight, mostly what I saw was another unfolding blight—the death of the hemlocks. They're being killed by a little fuzzy aphid-like insect called woolly adelgid, introduced from Japan. In places on my hike, the entire canopy was just standing dead snags, like a fleet of ship masts towering over a sea of flourishing rhododendron. The rhododendron was thrilled by the new bonanza of sunlight (fig. 2.4).

As I neared the bottom of the Ramsay Cascades trail, I found a few old logs and cut stumps that seemed to have the features of chestnut but were less than impressive. So I returned to the hotel in time for checkout.

Sydne, Juno, Alder, and I then headed back into the park to follow up on another chestnut lead. We parked the car and stepped out onto a ridge-top trail. Within a few feet we started seeing many dead snags, bleached and dried in the sun. These clearly seemed to be chestnuts; they reminded me of the dead chestnuts I've seen in New England. But they also weren't much bigger than the chestnuts I've seen in New England, and I felt a bit defeated. Juno was happy we found the chestnuts before flying back to the Northeast. But I still wanted to see something more dramatic.

Two weeks later the kids and I were back in Nashville for my high school reunion. The plan this time was for us to drive out to the border of Tennessee and North Carolina, where we would camp for the night. From there we could hike in to a very specific location in an old-growth forest where researchers had mapped out dead chestnuts in the 1990s. Their notes described it as a beautiful small ravine littered with dozens of chestnut logs, just uphill from a dense hemlock stand.

The forecast called for rain, but only in the form of showers. Whereas rain in the forecast means something persistent and often heavy, showers are usually fleeting and light. It was only like a 30 percent chance of showers at noon. If we got there at noon and then checked the forecast again, we should be able to wait for a break in the showers to hike in to the chestnuts.

Figure 2.4. Rhododendron flourishing under dying hemlocks in the Smokies.

At 6:00 AM I filled a couple jugs of water in the sink, stowed the gear in the car, and then loaded the sleeping children for the five-hour drive. We were headed to the area where the Olympic Park Bomber, Eric Rudolph, hid out from the police for years eating salamanders and acorns.

An hour into the drive, I realized that I forgot the sleeping bags. Thinking about my days in college when I used to sleep in a debris hut made entirely out of leaves and sticks, I told Juno we could just make a nest with our clothes and a couple of spare blankets inside the tent. Just the night before, in fact, we'd come across an old photo of me showing off one of my debris huts to my bemused grandparents. "Yes, Daddy, we will be birds!"

I then realized that I also forgot my rain jacket. Well, at least the children had rain jackets. Oh, and I forgot matches. That, we really needed to stop for.

In wilderness survival there's a list of priorities. Shelter, water, fire, food, in that order—at least as preached by the naturalist and cult hero Tom Brown. Shelter first, because you can die of hypothermia in a warm rain. Water second, because you'd die in four days without water. Fire third, because it keeps you warm and you can use it to sterilize water and cook food. Food last, because you can survive two weeks without food. If you're dropped naked in the woods, your most important tool for survival, as Tom Brown preaches, is a knife, which you'll need to carve your fire-by-friction set. It doesn't need to be a knife of modern steel; you just need a rock that breaks with sharp edges to fashion a stone tool.

We stopped at a Love's truck stop, got three lighters for 99¢, and drove on to the mountains. About an hour from the site, we found ourselves on an exceedingly winding road. Halfway through, a photographer under a blue event tent took a picture of us. I stopped to ask him what was going on. The road, apparently, is infamous. We can now go online to buy a photograph of ourselves driving there. This, the Tail of the Dragon, is one of the curviest roads in the world, and folks come from all over to ride their motorcycles on it. That explained the strange biker clubs with dragon images and sculptures that we passed. And the signs exclaiming "318 curves in 11 miles!" And Juno's favorite, the "Tree of Shame," with parts of wrecked motorcycles hung all over it.

As we pulled into the trailhead parking lot, the dashboard thermometer said 54°F outside, and it was definitely raining. I went to check the weather forecast and realized I had no cell reception. I'd had a smartphone for less than six months, after defiantly holding on to my 2005 flip phone for twelve years, and I was already dumbly dependent. When would there be a gap in the showers? How should we decide when to start hiking? I guessed we should just go for the hike and hope the showers would pass soon. Freed from the cell phone, we could now live in the present.

I packed our bag, got the kids' rain gear on them, and donned my dad's old jacket not meant for rain. I found a couple umbrellas stashed under the seat—I'd never before hiked in the woods with an umbrella, but this seemed essential that day. With Alder loaded onto the carrier on my back, we set out on the trail. Immediately, we were rewarded with a big, bright orange spring salamander, who seemed to be eating a slug in the middle of the trail. A few minutes later we found another bright orange salamander, this one a black-chinned red salamander. It seemed odd to stumble across such large salamanders in the middle of the day, but I guess it was a sign that this forest is really healthy and the streams are really clean. It was also a sign that it was really raining.

With Alder chanting "more 'manders!" these finds provided motivation for our rainy hike up the steep trail. A mile and a half up the trail, we got to the point where we could either break off to the chestnut site or wander another three-quarters of a mile loop trail among giant 450-year-old tulip poplars. I really wanted the kids to see the old trees, and maybe if we wandered, it would give time for the showers to pass. The trees were huge, the forest understory was open and park-like, the ground was littered with wildflowers, and the wet leaves glowed bright green in the foggy rain.

We touched the bark of the giants, the kids posed for photographs, then we paused for a snack huddled under the two umbrellas I held. We got wetter and wetter. It didn't feel like scattered showers. It felt more like heavy rain. We had better just get to the chestnuts and get back to the campsite by our car.

I glanced at my map, and we cut off the trail. The chestnuts shouldn't have been far from that point. But immediately, we encountered a tangle of thick rhododendrons. Rhododendrons are an awesome plant, fond of the acidic soils around here. But they can make an impenetrable wall.

I folded the umbrellas, directed Juno through a low hole underneath some branches, then climbed up to the top of a huge mossy log. With Alder on my back, I balanced my way across the first impasse to meet Juno. Fighting through shrubs, saplings, and last year's thorny raspberry stalks, we inched forward across a very steep slope. After ten minutes I looked at the site notes and realized we had started in the wrong direction, so we turned up the hill to correct. To prevent from slipping downhill, I pointed out a sapling a few feet upslope and told Juno to hang on to that while I pushed him up. We inched toward the chestnuts.

At last I saw up ahead where we needed to go. But it was too late. There was one big fallen beech just up from us. All we needed to do was to scramble over that log, then we'd be at the spot in the old field notes littered with chestnuts. But the thing is, I no longer cared about chestnuts. At some level I knew that this whole journey had a singular mission, which we were on the cusp of accomplishing. But I'd been hiking through the rain for hours with a one-year-old and a four-year-old, we were off-trail, two miles from the empty trailhead parking lot, with no cell reception, no other person within miles, cold and wet to the bone, exhausted from scrambling on slopes, and my shins were bruised from banging into branches. My body was moving toward survival mode. Shelter. Water. Fire. Food. Old rotten logs just weren't on the list.

Where we stood, Juno spotted some big logs covered in a thick carpet of moss. Noting the young saplings taking hold in the moss, he excitedly exclaimed "nurse logs!" and implored me to take a picture. Could these logs be chestnuts? Maybe, I guess. Whatever. I saw nearby some American ginseng, suggesting that it was a calcium-rich forest, relatively unplundered by people. Without moving my body I despondently aimed my camera at the logs and snapped some pictures, but my lens was foggy.

Even if we found chestnuts, I doubted my wet lens could get a clear image. I could picture in my head what the chestnut logs would look like; did we really need to go see them? I felt like we'd gotten close enough to at least get a sense of the forest. And one thing's for sure: this was no longer the same beautiful, forested ravine that the researchers had visited in the 1990s.

Our off-trail trek was difficult in large part because the understory was much thicker than it was twenty years ago. Why? Because all the hemlocks are dead from adelgid. The beech, too, was likely felled by the recently introduced beech bark disease. Whereas the nearby tulip poplars haven't yet been struck by an invasive pathogen (knock on wood), this little ravine had seen its canopy of chestnuts, hemlocks, and beech all destroyed in the last hundred years. It was a stand in transition full of young growth.

The kids were still in great spirits but also ready to go. Going over that beech log just felt like one step more than reasonable. This, I guess, was my limit. I asked Juno if he'd like to go back to the trail or keep going. When he said he was ready to go back, I decided not to push him any further. More than anything, I wanted the kids to enjoy this adventure. Someday we'd have to return on a warm, sunny day. "No!" Juno protested. He only wanted to come back in the rain—to see the salamanders again.

So we headed back down to our tent in a valley, with the kids pretending to be motorcycles on the Tail of the Dragon. Behind our tent stood an open hardwood forest of tall tulip poplars, maples, and blooming dogwoods. In front of our tent, the opposite slope was blanketed densely with hemlocks and rhododendron. I wondered, was this pattern driven by the same forces driving the parallel vegetation pattern at Bark Hollow?

Back in the Northeast, I relayed my unsuccessful attempts at finding chestnuts to my colleagues. They weren't surprised. It seems that part of the problem is that the historic role of chestnuts in our forests may have been overstated. Ed Faison and David Foster did a recent analysis of old "witness trees." These are big trees that were historically left uncut to mark property boundaries. These trees can give us some sense for the original forest, prior to large-scale deforestation. Rather than 25 percent to 50 percent of the original forest, the witness tree data suggest that chestnuts were only 5 percent to 10 percent of the overall forest, if that. Although in local forests chestnuts were much more dominant.

Then an email from ecologist Tom Wessels sent us to the shoulder of a mountain in the very corner of Massachusetts. Here, as he described, was a thirty-acre stand with chestnuts still surviving up to a foot in diameter, getting big enough to cross-fertilize and produce viable nuts before succumbing to the blight. Here a thick wall of mountain laurel covered the slope—filling much the same niche as the rhododendron in the Smokies. Above the mountain laurel, it wasn't the grand forests of towering chestnuts of the past. But when Alder, Juno, Sydne, and I made our way up the mountain, we found chestnuts everywhere, including many seedlings along with many larger individuals much older than any I'd ever seen (fig. 2.5).

Somehow the trees in this stand were managing to just barely hang on to the thread of evolution. As long as they can keep re-

Figure 2.5. American chestnut: (a) a snag in the Smokies, and (b) a living individual, old and twisted from battling the blight and barely surviving to reproduce, in a stand with many similar trees in Massachusetts.

producing sexually, and if there is enough genetic variability left in the stand, generation after generation of natural selection will mix up their genes until nature arrives at a solution to the blight. It's places like this, Ed Faison says, that are his hope for chestnut's future. With chestnut seedlings seemingly sprouting all over, this corner of a mountain is nature's little laboratory. Scientists elsewhere are scrambling to produce hybrid American-Asian chestnuts, GMO chestnuts infused with a gene from wheat and virally weakened strains of the blight. But, ultimately, nature on its own may be more effective at chestnut restoration across the landscape. It will just take a long time—hundreds of years.

FOLLOWING CONTOURS

Back in Bark Hollow, could human activities such as logging have caused the left-right pattern? Or, similarly, could the pattern have been caused by a disturbance such as fire or wind that knocked down half of our site? Put another way, is one forest a lot older than the other? If so, we might see differences in the sizes of trees or the relative proportion of big versus little or understory versus canopy trees. A younger, or even a much older, forest might also be dominated by fewer tree species, rather than having a mix of many species.

Examining the chapter-opening image, the size of the trees and the relative proportion of big and little trees seems about the same on both sides. And neither side seems dominated by a particular species—rather, the two sides show a good mix of deciduous species, even if there aren't the same species on both sides.

But I do see evidence of humans currently using Bark Hollow. Though we got here off-trail, we seem to have arrived back at a trail of sorts—right down the center of the image. It's wide enough that people, likely even people on motorized vehicles, occasionally saunter through. And people probably aren't the only ones using this trail. Animals, like people, are always looking to conserve energy—you might say we're all naturally lazy. A cleared trail through the underbrush or snow is easier for animals just as it is easier for us. One question that's always good to ask about a trail is, why is it located here?

From where we're standing, if we look either to the east or the west, it's downhill in both directions—water would be draining away from us either way. If we look to the north or the south, it's uphill in both directions. We are standing at a tiny "saddle." Two natural travel paths intersect at saddles—the high point for valley-goers and the low point for ridge-walkers. Animals walking along wetlands in the valleys to the east or west get funneled into this saddle point—it's the easiest way to get from one drainage to the next. If you're interested in walking along the ridgetops, you similarly get funneled down into saddles. Wherever trails intersect is a place that animals—particularly predators—hang out to smell who's been by and scent-mark to leave their message. Thus, a saddle seems like the kind of place I would look for signs or put a wildlife camera if I wanted to see who's around.

Visualizing how animals will use the landscape is a fun game. If you're a beginning player, try river otters. Otters spend most of their time in ponds, lakes, and rivers. But they also move over land back and forth between water bodies, usually selecting the quickest route. If you look at a map, you can often pinpoint exactly where the otters should cross from one pond to the next. Then go out and look, and you may find a well-worn otter highway, sometimes marked at the ends by scat and otter scent piles and sometimes with a groove worn into the earth itself from the heavy use, even if the trail is a half-mile long.

So the trail is here in our site because it was funneled into this saddle. But, as Juno might ask again, *why*? Why is there a saddle here? Answering this requires delving into some geology.

PLATE TECTONICS

North America keeps bumping into things. Over the past billion years, it's happened several times. Each time, the leading edges of North America and the offending landmass buckle and crunch like cars in a demolition derby. And then, like a feuding couple, the continents eventually separate again—each carrying fresh scars. Rhode Island, for instance, used to be part of the drifting microcontinent called Avalonia before it glommed on to North America 450 million years ago—just as plants and insects were beginning to leave trilobite-infested waters for land.

Every time North America is squeezed from the side, like a water balloon in your closing fist, the top of the land rises up higher into the air. In this way, collision after collision, the Appalachian Mountains were formed. When amphibians were the dominant land predators and ginkgoes were just getting started, about 250 million years ago, the Appalachians were the size of our modern Alps.

Deep under these towering mountains, not far from our field site, a pocket of molten rock was slowly cooling. In this cooling magma, solid mineral crystals began to form—most notably quartz and feldspar, along with a few friends like mica and amphibole. The slower the cooling process, the more time the mineral crystals would have to form, and thus the bigger the crystals would grow. As dinosaurs began ruling the land above, the crystalized minerals cooled into a mass of solid rock. This rock, made of coarse grains and dominated by quartz and feldspar, would later be called granite by the naked apes.

But just as our little pocket of granite rock under the mountain was forming, with pterodactyls gliding overhead, the rocks on top of the mountain slowly weathered down. Big rocks broke into little rocks from the mechanical forces of wind, rain, ice, fluctuating temperatures, and stomping dinosaurs. Not only did rocks break, but the mineral composition began to change too. Although minerals like feldspar are stable deep underground, when they get to the earth's surface, feldspar doesn't last long. Such minerals chemically disintegrate and transform into more stable minerals like quartz and clay, along with dissolved ions carried away by water. Given enough time at the surface, most rocks will eventually turn into fine-grained quartz and clay. But not all rocks are given the time they need—sometimes they're reburied and rejoined with other rocks. Loose gravel, incompletely weathered and piled deeper and deeper at the foot of a mountain, might get transformed into sedimentary conglomerate given the right conditions.

While plesiosaurs chased Triassic fish 200 million years ago, the new Atlantic Ocean was about to form. Africa and North America were preparing to split. As the two continents set off on their separate ways, the land along the border stretched, thinned, and began to break up. In our little corner of the continent, a spreading fault line became a sinking rift valley as the mountainous walls of the valley moved away from each other. Repeated earthquakes tilted the valley floor as it slipped downward.

Molten lava erupted through the thin skin of the earth in the center of our little spreading valley, pooling in a huge, fiery lava lake. In the lava, characteristic minerals like olivine and pyroxene were forming. But it cooled and solidified relatively quickly, without enough time to form large mineral crystals—or even crystals big enough to see—into a rock known as basalt. Whether you find it in Iceland, Yellowstone, or on the ocean floor, basalt is a rock to know, as it reveals a volcanic past. While not as glass-like as obsidian, when broken, basalt still reveals relatively sharp edges due to the lack of large mineral crystals inside. Because of this, in a pinch, basalt can make a good primitive blade. And unlike many other rocks, when chemically weathered, basalt will readily release cations like calcium, sodium, and magnesium.

Volcanoes and earthquakes all promised to turn this little valley into a grand ocean separating two great continents. But promises aren't always fulfilled.

Up and down the east coast, from South Carolina to Nova Scotia, many such rift valleys were all dreaming of becoming the new Great Ocean. The winning contestant was a rift valley one hundred miles east of our little inland valley. While our valley tried to send Boston and Rhode Island off with Africa, it was not to be. The Atlantic Ocean started spreading, as it continues today, with the new ocean floor spewing out from the underwater volcanic mountain range of the mid-ocean ridge. As our mountains still crumbled into the valley, bursts of volcanic activity slowly subsided and stopped here.

According to some reconstructions, when *Triceratops* and *Tyrannosaurus* arrived, sixty-eight million years ago, they saw nothing of the great mountains and volcanoes that once marked our valley—not even the valley itself. Whereas eighty million years prior, *Stegosaurus* and *Archaeopteryx* had frolicked in the mountainous scenery, time had ground down the mountains and dumped them as fill into the valleys. Now there may have been just a gentle plain sloping down toward the new ocean.

But then as mammals began to dominate and only little birds remained of the great dinosaur lineage, the edge of our continent began to lift upward. Driven by tectonic forces below, the landscape was raised hundreds of feet into the air. Water in streams now fell further on its way down to the ocean, cutting with more force through the underlying bedrock. As dog-sized primitive horses galloped along the riverbanks, rushing waters pounded down through rock history. The water revealed layers of basalt from volcanic eruptions stacked between intervening sedimentary layers—the crumbs of the old mountains. And because our valley had been tilted millions of years ago during the rifting phase, these layers were angled sideways, with their edges now protruding from the ground. Basalt, it turned out, was harder for the rivers to cut through than the sedimentary layers. As sedimentary layers were washed away, basalt mountain ranges—the edges of the old lava lake that had hardened and tilted—rose up higher and higher from the valley floor.

It was a slice of that lava lake that I carried Juno up this early August morning to get here at Bark Hollow.

HEPATICA

Wrapped in my childhood blanket, Juno falls back asleep in the middle of our site. I take a breath and wander over for one last look at the hepatica. For such a small plant, hepatica seems to have quite a power over me. Why?

Is it that leaf shape? Bold, defiant, unapologetic. It didn't choose the standard three-leaflet form—like poison ivy, jack-in-the-pulpit, tick trefoil, bladdernut, or any number of plants where each leaf has three distinct blades on the stem. Nor do its three conjoined lobes accept the standard forward-thrusting, turkey-foot-like form that sassafras, great ragweed, and mulberry chose. It feels sinister, the way hepatica's symmetry slips through the forms my mind wants it to fit.

Is it the name? From the Latin *hepaticus* because it resembles a liver. Does some part of me think I see my own entrails in the leaf litter? My fear of death seems at hand with this plant. With cautious approach, I don't stare too long, just in case, as my primal reasoning goes, I might acquire some disease through association.

Is it the medicinal properties? I've never tried hepatica. I hear it's neither good tasting nor good for me.

Despite the dark associations in my mind, hepatica actually carries a strong message of hope. In late August these thick, fleshy leaves are a reminder of the early spring wildflower show. While most of the wimpy leaves of the spring ephemerals have long since withered, hepatica leaves will persist all winter. Hepatica's dainty lavender flower is one of the earliest blooms of color in spring. Closing my eyes, the rest of spring floods into view with carpets of toothworts, spring beauties, trout lilies, and squirrel corn amid the joyous birdsong and thawing air of an awakening forest.

More than just a time capsule to spring, hepatica makes a statement about the land itself. Where you find hepatica, you also often find a lot of other special plants—like wild ginger, ginseng, Dutchman's breeches, and rue anemone. Plants that in many regions are often rare or under threat. Plants that remind me of the rich central Tennessee woods where I grew up, on top of limestone.

These rich woods teem with life, and that's what I sense when I see hepatica.

Little hepatica. A small exclamation mark tucked into the leaf litter, the lone remains of a rich spring statement. To reconstruct its meaning you must have seen such punctuation in context. If not, your eyes scan past, your feet glide over, and you don't hear hepatica shouting.

CAPTURING THE ROCKS

When we return home in the afternoon, I examine the pictures I've taken. I flip in frustration through the mediocre images on my computer monitor, and it is clear that I failed to capture all the pieces. Most significantly, I need better shots of the rocks.

A whole year passes before I set out again to finish photographing Bark Hollow. I awake in the morning, eager to leave the house. The first stop will be to drop Juno off at preschool, and this time it will be Alder who will come with me up the mountain. I admit that some of my eagerness to get out the door is because I have filled my car rides this week by listening to an audiobook, *The Magpie Murders*. I'm hooked. Can I assemble the clues before the narrator reveals the solution? What better guide to writing my own nature detective book than a murder mystery?

As we leave the house, I pause at the large pile of heavy rocks outside the front door. In fact, these rocks have their own murderous record—they once nearly killed me and a colleague.

I bend down to hold a few of the rocks now, remembering the journeys they have taken. There is the flat, reddish chunk of mudstone, two feet across. If you search this layer enough in the field, you'll find abundant traces of insect tracks and occasional dinosaur footprints from 200 million years ago. There is the seventeenpound chunk of granite. The zebra-striped gneiss. The colorful, coarse conglomerate.

And then there is the finer-grained sedimentary rock. This rock comes from a rock unit that is primarily an arkose sandstone—made of sand-sized particles whose high amount of feldspar shows they haven't been fully weathered. However, toward the eastern edge of the rock unit, the particle sizes grade into something larger. This chunk of rock sitting before me has pebble-sized particles and so would be classified as a conglomerate within the arkose layer. This layer was made when the ancient mountain crumbled into the valley.

It is the arkose layer that I'm heading to photograph this morning. Instead of climbing the mountain with child in tow, why not just take a picture of this rock here in my yard? My lower back would certainly prefer that. After all, hadn't I collected the rock from the very same spot at Bark Hollow? Alas, I am a purist. What if Atticus Pünd, the sharp-eyed detective from the *The Magpie Murders*, ever reads my book? He will surely note the shadow of the yew bush that doesn't belong.

And there in my yard is the smooth black basalt—from the ancient lava that flowed into the rift valley. For my book I wanted to get a picture of this basalt turned into an arrowhead. So I recently grabbed a big chunk from this rock pile and went with Juno to see Neill Bovaird—an old friend from the Woodsy Club.

Standing in Neill's yard, I asked him if he could make an arrowhead or spearhead from this basalt. He said he could, but that's not really what basalt was traditionally used for. Arrowheads, Neill informed me, would have been made with local quartzite perhaps, or, more likely, flint traded from upstate New York. But the basalt layer at Bark Hollow? That's where everyone would go when they wanted to make an axe or an adze.

In a few deft strikes, Neill broke the rock into five fragments, with piercing thuds, and they fell to the grass. He was left holding one small piece, which he tapped on. "Hear that?" This piece of the rock made a higher-pitched sound, indicating that it didn't have any cracks in it. Those other pieces all had cracks. This one he could make something usable out of.

We left the shards outside and walked into Neill's house. His workroom upstairs was full of natural crafts—arrows, bows, bowls, baskets, skins, skulls, fire-making sets. Juno stood in awe of it all. Neill showed off a couple recent projects he was proud of: beautifully ornate, two-toned woven dogbane baskets and soft and tough fish skin he'd leathered. And then there were all the stone tools. Neill picked out a few basalt pieces in different processing stages. One was a Native American artifact a friend of his found. Another was a finished axe-head. For the best photograph of the axe-head he would make from the rock we'd brought him, he suggested that he mount it on a handle. Come back in a week or so, he said.

A few weeks later, I found Neill at the nine-year celebration and fundraiser for the camp he founded, Wolf Tree Programs. In a forest of slender trees stretching up to the canopy, a "wolf tree" is one whose massive trunk and horizontal lower branches tell that it grew here long before all the others, alone in a field. It was a cold rainy day at the celebration, but the community turned out, and it was a lively event.

On a table in the center of the celebration, I found an impressive display of crafts from Neill's workroom. Between a box turtle shell, a plaster track cast, a pair of deer antlers, and a finished arrow was a freshly carved piece of wood. The elbow at one end told that the wood came from a branch joint on a tree. At this bent end, bound with sinew, was the axe-head Neill shaped from the basalt of Bark Hollow (fig. 2.6).

Still staring at the pile of rocks in my yard as Alder and I prepare to revisit Bark Hollow, I think of why I gathered all these rocks—basalt, mudstone, conglomerate, granite, schist, gneiss. On the first day of my *Field Naturalist* course, students arrived to

Figure 2.6. Adze made from the basalt of Bark Hollow.

find these very rocks scattered across the tabletop. Hand-selected from each of the sites we would visit throughout the semester, the rocks told the students of the grand adventure ahead of us. The students' job that first day was to arrange the rocks into groups. I gave them no information about the rocks' origins or names, and most students had no background in geology. Yet the rocks slowly made their various ways across the table toward each other, finding appropriate geologic groups. The sedimentary rocks with the aggregate bits of particles. The igneous rocks with their randomized crystalline structure. The metamorphic rocks with the crystals formed into wavy lines. At the end of the exercise that day, without revealing any answers, I merely packed up the rocks and put them up on a shelf in my office to sit on display until needed again. The students then came to discover the same rock types later in the field, like finally meeting the parents of an old friend.

It was putting the rocks on the shelf that caused the trouble.

High above my desk, the shelf, it turned out, wasn't fully fastened to the wall. Many weeks passed before I came into my office for a routine meeting one morning. Not long before I arrived, people in the hall had heard an enormous crash erupt from my office. The shelf, along with the great weight of the valley's rocks, had leapt across the room. Wood had splintered from the table, the floor was dented all over, and many of the rocks had split. I shoved the rocks to the sides, and a few minutes later had my meeting. I'll never forget the uncomfortable look of my colleague, sitting amid a sea of rubble and the smell of fresh rock dust, knowing that we had both almost been smashed to bits. Afterward I added some extra supports and put the rocks back on the shelf, though knowing visitors always remained nervous.

NUTRIENTS

Finally back at Bark Hollow, I watch from up on the slope as Alder, several yards downslope, practices standing by leaning against a large, bumpy rock. Alder was named after the small wetland tree, a tree known for its important role in natural communities. Through a symbiotic relationship with nitrogen-fixing bacteria on its roots, alders fertilize the soil. These enriched soils set the stage for subsequent species to flourish. Here in this field site my son is the only alder growing. But there is something else giving nutrients to the soil.

Alder's patience with me wandering around the site fades, and I bound back down to scoop him up before too many tears are shed. I note the rock he's been leaning against. It's the same rock type on the bottom of our chapter-opening image to the right of the compass. It's irregular and seems to contain a mishmash of smaller rocks of various sizes and colors. These interior rocks are themselves variously weathered—with rounded edges, not sharp crystalline edges. Thus, we have a sedimentary rock—made from loose pieces that were compressed into a solid mass.

This sedimentary rock is quite unlike the spectacular red Navajo Sandstone pictured on Utah license plates. The smooth Navajo Sandstone is made mostly of quartz sand that was blown into a well-sorted pile of uniformly small, round grains. Weathering and sorting happen when wind and water are given sufficient time and distance to work.

No, our sedimentary pile seems to be very poorly weathered and poorly sorted. Instead of purely quartz, we still find a lot of feldspar along with other minerals present. Instead of uniform particle size, we see many different sizes. This pile was evidently formed not too far from the large mountain it came from, buried soon after it was deposited. The feldspar tells us of the granite in the mountain that once was. This is the conglomerate from the arkose layer.

I want to test the soil here, and Alder helps me dig into the ground. I forgot to bring a pH kit today, so we need to take some samples home to test later. We scrape our knuckles in the gravelly soil, looking for places with few rocks to get a good handful of fine dirt to test (fig. 2.7). What should we carry it back in? Searching my backpack for something to hold the sample, I find a weeks-old half-eaten egg-and-cheese croissant that Juno had asked me to save for later. The croissant is wrapped in foil. I tear off some foil and we pile in some soil.

I close my eyes and think about the giant mountains that once stood here. Today our closest real mountains are New Hampshire's White Mountains. I think of Olivia Bartlett, who is earning her PhD by scrambling up and down those mountains studying the soils.

I recently showed Olivia a picture of our little Bark Hollow, and she keyed right in on the basswood. On her mountains basswood is a strong indicator of the soil chemistry—where she finds

Figure 2.7. The rocky soil in Bark Hollow made of weathered basalt.

basswood, the soil has a lot of calcium and magnesium. Eager to understand soil science, I began interrogating Olivia about the term “rich.”

“Rich,” when applied to soils, refers to the availability of essential plant nutrients, like nitrogen, phosphorus, potassium, calcium, and magnesium. Calcium holds together plants’ cell walls.

Magnesium serves as the central atom in chlorophyll. Nitrogen and phosphorus are central components of DNA. Potassium controls leaf stomatal openings. All of these nutrients serve many other functions, and many other nutrients are needed for plant life.

My question to Olivia was why there seems to be an association between richness and moisture. It's not that all rich places are moist, nor are all moist places rich. But often plants that do well in one do well in the other. All else being equal, my sense is that if you add moisture to a dry habitat, it will support more species that love rich soils.

What I wanted Olivia to say was something simple like, "Yup, in moist soils, the extra water helps break down the parent rock material faster through chemical weathering, thereby pulling more nutrients out of the rocks and into accessible forms in the soils." But that's not what she said. Soils are complex, and it's not simple to predict soil characteristics. Soils are formed by the breakdown of rocks and sediments below the surface and the decomposition of vegetation above. These processes are in turn influenced by geologic forces, climate, topography, the work of burrowing animals, the amount of time that has passed since the last disturbance, and the movement of wind, water, and ice.

In Olivia's work, for instance, she sees that soils develop very differently depending on whether the groundwater at a spot flows horizontally or vertically. And consider plowing. Natural soils typically have distinct layers of colored bands as you dig down (called "soil horizons") with different properties. At the top there's typically a dark A horizon full of rich humus—decomposed organic matter. But in fields that people plow, the topmost layer gets all mixed up with the mineral layers below, and this can have a profound effect on soil nutrients, even centuries later.

To further complicate things, as soils become too acidic or too basic, the nutrients become less available to plants. Too many hydrogen or hydroxyl ions floating around cause the nutrients to bind up into compounds that the plants can't use.

Back home with a cheap pH kit from the garden store, I discover that the soil on the left slope in our chapter-opening image measures around 5.5, whereas the soil on the right slope measures around 4.5. In our region of New England, soils tend to be acidic. A pH of 4.5 is pretty typical.

When we have the occasional ancient lava flow driving soils into a more neutral range, it's special. That means we're going to find a lot of plant species growing here that won't be common across the rest of the landscape. If we travel to a limestone-rich region like middle Tennessee, we might see the reverse pattern. There we might expect to find the rarest plants on the landscape in occasional acidic soil islands amid a sea of richness.

Reflecting back on my question about the connection between richness and moisture, Olivia asked whether we might just be finding richer soils lower down on slopes because groundwater is transporting the nutrients through the soil from high points to lower points. Or is it just that the rich soils I'm thinking of are in the floodplains of waterways that deposit extra nutrients in the soils during floods? I guess the answer is, it's complicated and nobody yet has a full understanding of how soils work.

But we do know a little. We do know that basalt—the dark, angular, fine-grained rock on the left side of Bark Hollow—releases a lot of magnesium and calcium and raises the pH of soil as it weathers. That's not the case for the rocks within that arkose layer, which we see on the right side of the image.

And so we have the source of our pattern. The path in front of us delineates the edge where two bedrock layers meet. Hepatica and the other plants on the left are growing in rich soils formed from weathering basalt. The plants on the right are growing in the relatively poor, arkose-derived soils. Like Tiburon mariposa lily growing in the serpentine outcrops of Marin and like rhododendron's affinity for acidic slopes in the Smokies, the key is in the soil chemistry. It's not the moisture preferences in figure 2.2 that are important, it's the plants' preferences for soil richness. Bark Hollow is the crack between two layers of geologic past, slowly breaking down. Our plants are telling us the story of when Africa left our continent 200 million years ago.

FINDING THE SPOT

It was Karen Searcy who sent me to the south side of this mountain. I had looked at United States Geological Survey (USGS) bedrock geology maps and found arkose-basalt junctions on the north side of the mountain. But, Karen told me, the plants only reflect the pattern well on the south side. Karen should know; she spent years studying this pattern. My friend Meggie Winchell, one of Karen's students, describes sitting for hours staring at aerial photographs on a computer and circling patches of mountain laurel. Then Karen and her team fanned out to points all over the landscape, probing the soils and identifying the plants around Meggie's circles. The pattern we saw at Bark Hollow repeated over and over across the landscape.

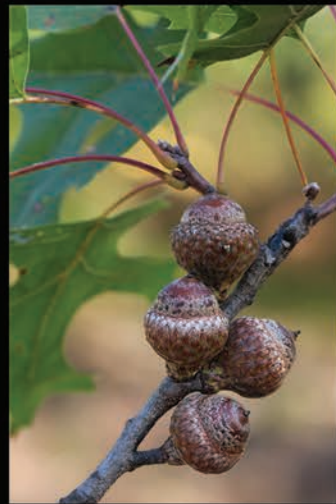
But it's rare to see such dramatic bedrock-driven patterns in the Northeast. Over the broad scale, yes, you tend to see more rich-loving plants in places like the Berkshires that have a lot of marble. But these patterns are often masked, especially at the small scale. If you travel down south, you'll see plenty of bedrock directly influencing the soil. But in the North the soils often don't reflect the bedrock below. For that, glaciers are to blame.

A mere 20,000 years ago, Bark Hollow was pinned under a mile-thick sheet of ice. As the climate warmed and the ice melted away, it dropped all the sand, gravel, rocks, and boulders it was carrying. Today most of the Northeast is covered by a five-foot-thick random jumble of various sizes and types of rocks. In addition to this "glacial till," the glaciers left behind other traces too. For instance, as the glacier retreated, the rift valley around Bark Hollow filled up with an enormous glacial lake, still evident from other surface deposits left behind.

Across the landscape the depth of glacial till is not uniform, and it's controlled by complex processes I don't understand: the patterns of glacial flow, ice melting, and subsequent erosion. Bark Hollow sits on the steep south side of a small mountain range, and this whole side of the range is largely free of glacial debris. Perhaps it's the steep slope that caused the sediments to wash downslope as the ice melted. Whatever the reason, the bedrock is exposed here, thankfully.

MAJOR LESSONS FOR INTERPRETING A LANDSCAPE

- Consider the geologic history of your site. How is the bedrock shaping the soil chemistry, and how are the plants reflecting this?
- Learn to orient yourself on a map and think about the topographic setting of your site.
- How have introduced pathogens changed your landscape?



(overleaf)

Figure 3.1. What a mess.

3. Water

Twenty miles from Bark Hollow, we drive northward along a straight country road through the woods. The land to the left is nearly flat, with a very slight tilt down toward a little facility in the forest. That's where state employees raise fish to stock regional streams and ponds. Looking to the right is a long and steep slope up—we are driving parallel to the base of this slope. We turn right, climbing upward. The road transitions from pavement to dirt, and suddenly we've reached the top. The land is level again, though the road is pocked with car-sized puddles that we weave in and around, splashing up and down. The kids in the back seat giggle at the bumps and splashes. We park the car and hop out onto the sandy road. After getting our gear together, we head off into the brush. We fight through thick branches and leaves for about a hundred feet before we arrive at our destination: Maggie's Forest (figs. 3.1 and 3.2).

As Juno gorges on blueberries and Alder naps in the carrier, I begin to snap photos. I'm immediately frustrated. This isn't how we left the woods four years ago. The pattern in the trees and plants that the *Field Naturalist* students set out to describe was blaringly obvious—though the cause of the pattern was not obvious. Now it's hard to find, and even harder to photograph. Though the tree pattern is subtle, there is some good news here. The changed forest

Figure 3.2. Aerial photograph from 2005 with the black triangle indicating the location of this chapter's site. (MassGIS, Sanborn LLC)

now makes another feature of the landscape strikingly clear: the shape of the land itself.

Did you see these patterns in the chapter-opening image?

Like at Bark Hollow, the trees on the left are entirely different from the trees on the right: pines versus oaks. Unlike Bark Hollow, the land is flat. Really flat. Look at that horizon line. Why is it so flat? And what's driving the tree pattern? And why does the bottom half of the chapter image just look like a mixed-up jumble of vegetation?

Did I mention how flat it is here? If you were tasked with shaping this landscape, how could you make something so flat? I mean, if I set you out in the woods and gave you only the tools of nature, could you come up with something perfectly flat? I'll give you some milkweed to make primitive string, and here's some white cedar and mullein that you can rub together to make fire. Maybe you could smash up some quartzite for cutting tools, which, together with the fire, you could use to carve out a little wooden bowl. Drop some pine needles into the bowl along with some water and some burning hot rocks from the fire to boil your tea. If you're really ambitious, maybe you could dig out a whole log and float a little canoe to the far side of the lake where the tasty cattail stalks grow. You'll need to gather sticks and leaves to make a little debris hut for sleeping. Where in your day of hard work with these rugged implements can you find something flat?

PINE NEEDLE TEA

As we think this through, let's have a seat by the fire, munch some cattails, and sip our pine needle tea. I love pine needle tea. OK, I'll concede that it's got a bit of a turpentine flavor to it. But in a good way, I say. Besides, it packs a ton of vitamin C. You've never tried it before? Well, I've made it with all sorts of pine species while I'm out on various adventures. It's always a reliable go-to soothing drink. Oh, that's a good question, what species is this one? Let's see. Looking closely at the needles, it seems they are grouped in bundles of three. That is, there are three thick needles coming out of one base. That means it's not white pine—that species has bundles of five thinner needles, which give the whole tree a fluffy aura about it. It's the five united needles that gave white pine the nickname "Tree of Peace," representing the original five nations of Haudenosaunee that long ago came together under a peace treaty. And let's have a look at that pinecone—see the little pointy tips sticking up at the end of each scale?

Pitch pine. *Pinus rigida*. If you're looking for indicator species, here's a good one. Pitch pine grows on poor soils that are sandy or gravelly, and it is well adapted to disturbances such as fire. Unlike most other pines, if the aboveground portion is killed, the tree will resprout from its roots. It's so good at sprouting new shoots

Figure 3.3. A pitch pine exhibiting epicormic sprouting.

Figure 3.4. Winged seeds of pitch pine on a fire-scarred piece of bark.

after trauma that, unlike other trees, where the bark is damaged, new pine needles will readily grow from the side of the trunk—called epicormic sprouting. This makes for some occasional funny-looking trees with a fur-like covering of pine needles along the trunk (fig. 3.3). The thickness of the bark also helps shield the living cells inside the trunk from the heat of the fire outside. Some pitch pines—mainly those that grow in areas with a long fire history—produce cones that stay tightly closed on the trees for a long time, held shut by resins. These serotinous cones open when they are exposed to heat. A fire, clearing the ground of competing vegetation, warms the cones. The cone scales spread out like fingers on an opening fist, allowing many little winged pine seeds to float away, sprinkled by the wind across the earth freshly prepared for a new generation of pitch pines (fig. 3.4).

Pitch pines are a common sight throughout northeastern coastal areas like Cape Cod, Long Island, and much of New Jersey. In these so-called pine barrens, along with pitch pine you'll see a lot of the same species we find here at Maggie's Forest. You'll see dry-loving scarlet oak—that's the canopy species on the right of our chapter-opening image. You'll see dwarf chestnut oak—which lives in the understory here. You'll see bear oak—the thicket-forming shrubs we fought through on our walk in. All of those and more are easy to find in coastal regions. But the nearest beach is one hundred miles away from here, and you'd be hard-pressed to find many of these species in the intervening landscape. What does this little inland site have in common with the coast? How did this pitch pine forest come to grow here?

Well, perhaps "forest" isn't the best word for what we're looking at. I suppose this looks more like a savanna. The trees are spaced far apart, and you can see lots of sky between the crowns. Forest canopies are typically closed, shading most of the ground. Where tree growth is restricted by lack of water, frequent fires, or heavy browsing, the tree canopies don't meet, and you get a savanna. Lots of sunlight reaches the ground in savannas, and beneath the trees you get a dense layer of grasses and other herbaceous plants (fig. 3.5). Think Serengeti, where the giraffes browse on tall acacia trees and zebras graze the grass.

But unlike the Serengeti, the understory here isn't grassy. No, it's shrubby. It's dominated by woody vegetation. In fact, the plants in the understory are primarily tree species—in the foreground of the chapter-opening image there are lots of oaks. This is a system in flux. With so much light available coming down from above, these oaks wouldn't be content just hanging out at toddler height. They are racing as fast as they can up to the canopy. Their small size can only be explained by the fact that they just started climbing in the last few years. Poke around under the shrub layer and you will find many stumps of recently felled trees. There used to be

Figure 3.5. Globally rare oak savanna ecosystem at Indiana Dunes National Lakeshore.

a dense tree canopy above, holding the understory oaks back. But then: *chop*, and the oaks were released from the shadows and began climbing up to the light. And some of these growing stems are shoots resprouting from the remaining bases of the old cut trees.

I remember those trees; we were standing in a closed-canopy forest when I taught my class here four years ago. We brought with us an increment borer—the tool foresters use to extract pencil-thick cores from trees for examining the rings—and the students proceeded to core the biggest canopy trees on both the oak and pine sides of the forest. Both were about a hundred years old. But the quick work of chainsaws brought an end to that hundred-year-old forest. Before I rile myself up with anger at how they destroyed my trees and my forest, I should remind myself that this land is owned and managed by the state wildlife agency. This logging operation was designed to improve habitat for rare species and as a component in the state's broader conservation objectives. If you're fresh out of the black-and-white world of environmental activism defined by the Lorax, the fight over clear-cutting of Pacific Northwest old-growth forests, and emotionally charged online petitions, this idea might take a minute to get used to: cutting down trees to help the environment.

FOREST SUCCESSION

What happens when you cut down trees? To start, we see logging as a "disturbance." Cutting down trees disturbs the forest. The trees have been standing for decades or centuries, creating a cool, shady, moist, tranquil shelter for the plants and animals that live beneath them. When machines come in, hack up the trees, and haul them away, everything changes. Sunlight beats down. Winds cut through. Some plants and animals are trampled during the operation; others can't survive the new hotter and drier environment.

But logging is just one type of disturbance. Fires. Floods. Wind bursts. Tornados. Hurricanes. Ice storms. Beavers. Insects. Even just trees tipping over from old age. Disturbance is natural. Sure, intact forests are important habitat that many species depend on. However, forests are but one type of habitat. Post-disturbance landscapes offer other types of habitat that different species depend on.

To really understand forest disturbance, we need to first get our heads around the language of successional stages. Imagine a forest dominated by mature oaks and pines. At the edge of our imagined forest, there is a freshly plowed farm field covered with dirt ready for planting. But instead of planting her crops this year, the farmer at last decides to move out West, abandoning her field. You see, she doesn't have enough firewood to keep her family warm for even one more winter (this is the story of many New England farmers in the mid-1800s). She's cut the last of the trees in the woodlot she owns. Perhaps decades from now there will be a new forest on her land sufficient to support a homestead. She wonders, will it be an oak forest or a pine forest?

After she heads West, first some "pioneer" plants move into her field. Small, fast-growing species whose seeds spread easily by wind. Grasses, dandelions, goldenrods, milkweeds. For several years these short-lived plants dominate the field. Cottontail rabbits hop from tasty morsel to tasty morsel. Meadow voles tunnel through the grasses. Toward dusk a red fox, seeing vole on the menu, trots out to the middle of the field, cocks her head, and listens. For a few minutes all is still. Then a soft flutter of tiny feet come racing through the grass beneath her. The fox pounces and, after a little tussle digging through the grass and dirt, is rewarded. She gulps the meal, leaves a little spot of blood, places a proud mark of her own urine, then trots off. As night falls, coyotes come to join the hunt for small mammals, and deer cautiously graze. Things might have gone on like this, day after day, forever. But the trees in the neighboring forest start sending in their seed missionaries, promising to convert the field.

Between the pines and oaks, whose seeds will arrive first? A large oak tree, making an admirable pile of acorns, sets off on a hopeful start to this race. She beckons a squirrel to come and carry one of the heavy payloads. The squirrel, inspecting several, chooses the tastiest-smelling nut. She grasps it in her jaws and hops daintily through the forest away from the tree. The tree beams as she watches the squirrel dutifully burying the acorn. A blue jay arrives as well, flying another acorn even further away before finding a clever hiding spot. The oak has her eye on that sunny field, waiting for some of her seeds to be carried there. Grinning mischievously while crossing the fingers on one of her branches, the oak now prays that the squirrel and blue jay forget where they placed the acorns, so her children become saplings instead of supper. Day after day, the oak watches the laborious work of the animals.

A pine glances over at the oak, rolls her eyes, and slaps her forehead. “Poor fool.” In one fell swoop, the pine scatters thousands of winged seeds into the wind and across the field. And that’s that. The pines have it. After a few years the farmer’s field is awash with pine seedlings.

Basking in the sun, the pines grow furiously. Up and up they climb. The grasses and dandelions are soon completely shaded out. It’s too dark for anything to grow beneath the pines. In the winter, snowshoe hares and grouse cut between the dense woody stems, munching on needles and hoping not to run into a bobcat. After decades of crowding each other, fewer and fewer pines remain. But the ones that do are big. Really big. Now they’re full trees, eighty feet tall and ten to twenty feet apart.

We’re standing in a forest. A few feet away a small mound of orange pine needles holds the scent of the healthy bobcat that made it. Some light filters down to the forest floor through the canopy needles, but it’s still pretty dark. Certainly too dark for offspring of the sun-loving pine trees to survive. Pine saplings crave light and cannot survive beneath a canopy of their own species. But wait, what’s this? This little set of dark green leaves, broadly lobed and tinged with red, gripping a tiny stick in the ground? There seems to be a little oak seedling emerging from a small hole. In fact, I see many of them. Who put these oaks here? They appear to be surviving just fine in the shade. Not growing furiously, but hanging on. Slowly, year after year, the little squirrel-planted oaks stake out their place in the forest understory and wait. And wait.

At last the hasty pines reach the end of their lifespan and begin to topple. The patient oaks are ready. They've waited a long time for this moment, and taking their cue, they spring toward the open sun.

The farmer never made it back to her land to see the forest that replaced her field. But many generations later one of her descendants, tired of digging irrigation ditches in Colorado, at last decides to go back East and search out the family roots. There, near the remnants of a stone cellar, the ditchdigger finds a magnificent oak forest on the old family farm. Sturdy oaks, patient and steady, won the race. Or did they?

Wandering beneath the oak canopy, the ditchdigger notices very few oaks in the understory. That the understory is different from the canopy tells the ditchdigger that the forest is still in flux. It's such a simple pattern to look for, and one we rarely do. I grew up in a Tennessee forest where giant tulip poplars stood watch over an understory deplete of tulip poplars. There beech and sugar maple promised to succeed into the next generation of canopy trees—the forest was in transition. What I saw growing up as an immutable old forest was itself merely growing up as well. Now I see tulip poplar forests in the South the same way I see white pine forests in the North—echoes of the old farm onto which these wind-dispersed, early successional species began the forest (fig. 3.6).

In the forest the ditchdigger inherited, he sees mostly beech saplings. With nuts flown in via blue jay, these beeches are even more patient and shade-tolerant than the oaks. More than patient, the beeches bring some secret weapons. Beech saplings can grow in the dark understory, adults cast a very deep shade on the competition, and they can reproduce clonally from their roots. When at last the oaks die and the beeches take over, this ultimate of long-lived hardwoods (at least in our region) may even employ chemical warfare. That is, they lace the soil with toxic compounds that kill other trees, so that only beech saplings survive beneath the beech

Figure 3.6. Early successional forests: (a) young white pine forest, (b) white pine forest with hardwood understory, (c) red pine forest with hardwood understory, and (d) tulip poplar forest with beech understory.

forest—a tactic called allelopathy. Only then, with the climax beech community, will the forest have reached a stable equilibrium.

At least that's how the story goes. This is a simplified version of forest succession, admittedly an imperfect fit for Maggie's Forest. For one thing, the eastern coyote we imagined prowling the meadow of a prior century hadn't even been invented yet, although that's a story for another site. More to the point, beech prefers moister soils than these, and which late-successional species—beech, hemlock, sugar maple, or someone else—dominate the climax community all depends on the local site conditions. But this narrative also sup-

poses that “stable equilibrium” is even a meaningful concept. Few ecologists really believe that any more.

PRIMARY SUCCESSION

The forest succession in the farmer’s field was really *secondary* succession—it wasn’t the first time plants had grown there. The ecosystem was given a jump-start from all that plowed soil, rich with organic material. *Primary* succession is when the system

Figure 3.7. Primary succession at Indiana Dunes: (a) young dunes with beach grass in foreground and lone cottonwood in background; (b) middle-aged dunes with junipers, fragrant sumac, and other shrubs in foreground and young trees in background; and (c) old dunes with a mature oak-maple forest.

starts from scratch, like bare rock left behind by a retreating glacier, newly formed sand dunes, or Charley's favorite abandoned parking lot—where tiny colonizers have been building soil on top of asphalt for the past few decades.

On the last night of a forty-day, 15,000-mile road trip, Charley and I rolled into the Indiana Dunes National Lakeshore after midnight. This was one of the first places that primary succession was formally charted out by ecologists. Charley fell asleep in the passenger seat, and I wandered out to sleep on the beach. In the morning I awoke to the crashing sounds of Lake Michigan, a cold gray wind, and the sight of a nuclear cooling tower looming disproportionately large over the lake. Charley soon came racing down the beach, agitated. He had recently awoken, noticed me missing from the driver's seat, and saw the furious waves in front of the car. He assumed I had drowned in the lake. After assuring him I was still alive, we wandered inland over the dunes, retracing the steps that ecologist Henry Cowles had taken a century prior when he made this place famous.

With my sleeping bag near the shore, I had slept on pure sand. Shifting, dry, and lacking organic matter, this is not a friendly place for plants. Walking away from the water, Charley and I began to encounter low beachgrass scattered across the dunes (fig. 3.7a). This pioneer species is the first to tame the hostile sands. Because the lake levels have dropped historically, the farther we walked from the receding shoreline, the older the dunes. As we walked, the species shifted. A bit further from the shore, juniper and a few other shrubs came to dominate (fig. 3.7b). As the dunes aged, larger pines replaced the junipers. Finally, forests of oaks and maples arrived, along with the whole rich suite of familiar plants that live in typical eastern forests (fig. 3.7c).

Each stage in the Indiana Dunes seems to depend on the prior stage. The pioneer species stabilize the loose sand of the dunes, injecting the first layers of organic matter. The developing soil now holds just enough nitrogen and moisture to allow junipers to grow, which then shade out the pioneer species. At first there's still not enough soil to support the bigger trees. But after the junipers have worked for years developing the soil further, the pines begin to enter and prepare conditions for the final wave of oaks and maples, which by now have waited hundreds of years for this moment.

Isn't it lovely how plants at each time step set the conditions to help out the next wave of plants? The pieces of nature are so well ordered and cooperative. The system grows like a well-designed “super organism” as it develops toward its predestined climax. At least that’s what the esteemed ecologist Frederick Clements would have said. But he’s been dead a long time.

There was another ecologist, Henry Gleason, who famously challenged Clements’s view of nature. Are all of the tree species really working together as one well-designed system? Or is that just our rosy view of the world? Maybe, deep down, each species is just selfishly doing its own thing competing for space. We might like to think that each species in the Indiana Dunes is an intricate part of a coherently evolved natural community; take away the oaks or the pines and the whole thing would deteriorate.

But consider the evidence that Margaret Davis brought, digging down into pond muck to find prehistoric pollen grains from thousands of years ago. With these microscopic fossils, she created maps of where trees lived in the past, reconstructing the march of species over time (fig. 3.8). Back when glaciers covered most of North America 20,000 years ago, neither oak, maple, beech, pine, nor hemlock would have been found on the shores of Lake Michigan. No, there was just a mile-high ice sheet there. The pines and hemlock, according to Davis’s pollen maps, were confined to a small region on the mid-Atlantic coast. At the time, the oaks, maples, and beeches were all down in the south—with oak extending farther east than maple and beech. Their ranges barely overlapped in space, so how could these species all depend on each other? Only later, after the ice sheets receded and each species migrated in its own peculiar path northward, did they end up in the same place. The maps have been updated since Davis worked on them, but the basic idea remains the same: over glacial time frames, species move around independent of each other, and which species grow together is constantly in flux. When you start taking such long views of the world, the idea of perfectly balanced, stable natural communities begins to crumble.

This debate—about whether the trees are working together for

Figure 3.8. Generalization of tree species migrations over the past 20,000 years. Following Davis 1981.

the good of the whole or acting as self-interested individuals—really cuts to the core of your philosophical outlook on life. Instead of a sugar-coated lullaby, for the last four years, my standard bedtime song for the kids is Neil Young's "After the Goldrush," often followed by "Don't Let It Bring You Down," "Ohio," or "Needle and the Damage Done." Strumming his ukulele, Juno belts out these songs with more understanding of their dystopian lyrics than you'd expect from a four-year-old. A few weeks ago I saw that Neil Young was on a solo tour, but the only tickets left for the nearby show were being hawked for over $1,000. However, there were still some reasonably priced seats out in Detroit, 700 miles west. From there it's only 250 miles more to the Indiana Dunes, which I was dying to get back to. So we all got in the car with our ukuleles and headed west.

The day before the concert, I arrived back at the Indiana Dunes for another look, this time with the sort of distrustful lens that might come from listening to too many Neil Young songs. Maybe it's not that the pines and oaks are waiting for the beachgrass and other pioneers to set the stage for them, but maybe it's more a matter of random probability. Pine seeds are eaten readily by mice and, to arrive at the beachfront, must travel a fair distance from the adult trees. Given this, it's a rare event that pine seeds end up in a position to sprout. The seeds of beachgrass, on the other hand, are abundant on the young dunes, disperse easily, and aren't as prized by mice. So by sheer chance more beachgrass seeds end up sprouting in the unsettled sands. Plus beachgrass spreads clonally, so it can often skip the whole seed stage altogether. Also, pines grow much more slowly and only sprout in wet years. So even if they sprouted side by side, the slow and steady pines don't end up growing very big until after many years in which beachgrass has been partying in the sand.

Rather than beachgrass helping pines in an orderly procession, it's just each species for herself in a random process. It turns out that the nutrients in the soil have basically no effect on the survival of species in the successional stages of dunes. Rather, soil development is just a by-product of the process. In a big experiment mixing up seeds and saplings of many species all across the developing dunes, that's exactly the conclusion that modern ecologist John Lichter came to.

CONSERVING SUCCESSION

Whether succession is random or guided by destiny, those species at the early stages of succession can't survive under the shade of the late-successional trees. If you want early successional species in your forest, you need to either pray for some natural disturbance to knock the trees down or cut them down yourself. And so a lot of species management in eastern forests involves cutting trees down and keeping them down. Consider the bobolink, a bird that is the focus of many conservation efforts in the East. This bird needs large fields, and so to keep it around here, we must keep mowing the fields to prevent trees from growing.

But why is a bird so dependent on lawnmowers? Out in the Midwest, natural forces—like a drier climate combined with large herbivores and occasional fires—can keep the landscape as prairie without the intervention of mowers. So bobolinks are much more common in the Midwest. It's just that in the East they need help to survive. Which raises the question: Do bobolinks even belong in the East? Why waste time and money supporting a bird that doesn't even seem to belong here?

In the mid-1800s, grassland birds like bobolinks were much more abundant in the Northeast than they are today because most of the landscape was covered with farmland. Perhaps they were historically limited to the western prairies, but when humans created artificial prairies in the East by cutting down all the trees, the prairie-dependent species moved into this new habitat. Then farmers abandoned their fields and forests regrew. Eastern populations of grassland birds have been declining ever since. With this view, bobolinks are just relics of an artificial prairie that maybe never belonged here in the first place. If we just removed humans from the equation and let nature take its course, recovering forests would probably wipe out the bobolink habitat. So maybe nature is telling us to forget about the bobolinks here. Although, arguably, there's nowhere that the bobolinks are safe, since prairies in the Midwest are facing increasing threats for other reasons.

Rather than trying to restore the artificial landscape of the 1800s, shouldn't conservation aim for something more pristine? Like, maybe we should be aiming for the landscape prior to 1492, prior to the massive destruction and change brought by Europeans? But then again, Native Americans had a heavy impact on many parts of the North American landscape as well. They farmed. They set fires to clear undergrowth for hunting and to encourage blueberries. Indeed, they may have maintained bobolink habitat in parts of the East as well. So if we're looking for a "natural" reference point free of human meddling, maybe 1491 isn't great.

OK, so what if we roll the clock all the way back to before Native Americans arrived? After all, when humans first invaded North America about 13,000 years ago, it marked a major turning point in the local nature. We helped drive to extinction North American mammoths, lions, cheetahs, camels, horses, and other large mammals. Does our moral obligation to cleaning up after our own species require us to look back that far? Some conservationists think so and propose "re-wilding" North America by introducing African and Eurasian elephants, lions, cheetahs, camels, and horses to our continent to restore natural processes and as a way to preserve these globally endangered lineages. Seriously.

What happens if we take that long-term perspective with bobolinks? Roll the clock back to 20,000 years ago. The glaciers were just receding, leaving in their wake a large swath of savannahs and grassland extending from the Great Plains all the way to New England. As millennia rolled on, the forests regrew and eventually dominated the local landscape for most of the past 8,000 years. But pockets of grassland likely persisted. At first mastodons, caribou, and peccaries trampled out open spaces. After these creatures left our local landscape, the still-abundant beavers created and abandoned ponds that formed meadows. Windstorms battered vegetation that on poor soils didn't regrow quickly. And people planted crops and set fires. From Georgia to Maine, many areas that are now within the eastern forest were, at times in the past several thousand years, covered in grass. Bobolink habitat.

Wherever we look in the past, it seems there were grasslands in the East. Yet, left to her own devices, nature seems intent on a future with very few grasslands here. Perhaps the distinction between the "natural" world and the human-modified world isn't helpful. For a variety of reasons—glaciers, climate, humans—bobolinks *are* in the East and have been for some time. The question is, do we value having them here? It's the edge of their range, so maybe we should just focus on protecting the birds in the core of the range. But sometimes the most important part of a species' range is at the edge. That's where evolution is pushing and pulling the most, and individuals at the edge might determine the future plight of the species. And these bobolinks in the East may be an important component for saving the whole species, which, like most grassland birds in the United States, has been dramatically declining for the past half century.

For whatever reasons, the people here like bobolinks and have decided to manage for them. To do so requires an active approach, with chainsaws, mowers, tractors, and matches. Of course, it's not all just for bobolinks—we're creating habitat for many similar early successional species while harvesting the agricultural and aesthetic resources that people draw from managed land.

The same logic explains the intensive management at Maggie's Forest. In the surrounding wildlife management area, we see a patchwork of pitch pine forests, scarlet oak forests, scrub oak thickets, and grasslands. We find barrens buckmoths, William's tiger moths, New Jersey tea inchworms, and wild lupine—all species that are rare in this region but common elsewhere. We find barrens metarranthis and spreading tick trefoil—species that are globally rare. Indeed the entire barrens community is globally rare. Today they seem to all depend on human intervention. The fire-adapted species are here because humans have been burning this pine barrens for at least 2,000 years. Without continued burning and cutting, white pine would replace pitch pine and closed-canopy forests would replace the thickets and fields. And in that transition the rare species dependent on this unique community would be lost.

That's not to say that fires are always a good thing in every ecosystem, nor are all wildfires the same. Some fires—surface fires—just creep along casually through the leaf litter and low shrubs. The ground-level heat might kill the trees, but often these surface fires do little more to trees than simply paint the bases black. But fires can also dramatically alter a landscape, especially in places not used to fire. Sometimes, for instance when people burn the trees on top of a mountain, they can cause all of the soils to wash away—soils that may have taken thousands of years to develop—creating a barren mountaintop and resetting primary succession.

Down in West Virginia there's a rare little salamander, called the Cheat Mountain salamander, which lives in the thick, moist layers of litter in high elevation red spruce forests. In the late 1800s and early 1900s, West Virginia's red spruce was extensively logged, leaving the forest floor exposed to the harsh sunlight. The layers of spruce needles, mosses, and lichens all dried out and became the fuel for massive fires. Deep, subsurface fires burned for months at a time, down to the bedrock. In 1914, for instance, a fire in one canyon started in May and burned until it was put out by November snows. Huge boulders that were once hidden underground rose to the surface as the soils burned up and washed away.

These fires and the loss of soils were terrible news for the Cheat Mountain salamanders. Luckily, throughout the fires, there were a few scattered boulders that held on to moist pockets of soil beneath them. It was in these spots that the salamanders clung to life during the blazing fires of the last century. And so today most of the surviving Cheat Mountain salamanders live right around the boulders that saved their ancestors.

Of course, species conservation is only part of the equation. Here at Maggie's Forest, fire control—and the associated risk to lives and property—is the highest management priority. Low, controlled ground fires are OK, but not raging crown fires leaping from tree to tree and then possibly to nearby buildings. Pitch pines, full of flammable oils, are highly susceptible to such fires, especially when the trees are packed tightly together. So how do you prevent such spreading crown fires? Thin the trees out so much that the canopy isn't closed and the trunks are widely spaced—cre-

ate a savanna. Then light many low fires to keep the forests from closing in.

This natural system is maintained through cutting and burning. And it has been for a long time. Just take a look at the oaks in the chapter-opening image: multiple-trunk trees. There's one at the center of the image and one way in the background. And there are many more off the frame (see fig. 2.3), evidently from logging in the recent past. In fact, in 1939 less than 1 percent of this pine barrens contained closed-canopy forest. A hundred years ago this was a place for growing corn, cutting timber, and extracting tar and turpentine from the pitch pines. Now the goal is to preserve a dynamic pine barrens ecosystem (fig. 3.9).

Figure 3.9. Fresh scars of intensive management adjacent to our field site.

FOUNDATIONS

But why *here*? How did the pine barrens get here? Because this place is special. At Bark Hollow the underlying bedrock was different from the bedrock in much of our area, and this created a natural community that was correspondingly unlike its surrounding communities. Maggie's Forest also sticks out like a sore thumb. If we were on the coast or in New Jersey, it'd be one thing. But a pine barrens here, far inland, surrounded by forests of maples, oaks, and white pines for hundreds of miles?

When we arrive here, one of the first things I ask the students to do is to collect some big rocks and bring them back to the group so that we can figure out the underlying geology. They dutifully search and search, dig and dig, and inevitably come back with the biggest rocks they can find: about the size of a blueberry.

"You can't do any better than that? Go out and find me a nice big rock that we can actually work with!"

A while later they come back, heads hung in shame with a rock the size of a walnut.

I ask, "What's the deal?"

At last they declare that "there just aren't any rocks here!"

And that's the truth. More or less. Dig as you will, you mostly just hit the same fine-grained sand and gravel, with some occasional bigger stones mixed in. And it's easy to dig here. That's why we bring along the soil corers, those metal tools in the bottom of the chapter-opening image. Jab them into the ground, pull them out, and voilà, a study of the soil. Try that back at Bark Hollow, and all you'd get is the clanking sound of metal hitting rock and a little dent in the tip of the empty instrument. But here the soil core captures a beautiful image of natural soil layers. The top few inches, rich in organic material, are darkly stained with decaying needles and beetle poop. A few inches down, the soil is bright and clean.

And the sand just keeps going. In fact, I think you'd have to dig sixty feet or so before you hit something different.

So this whole place is a giant sand pile. Well, maybe not quite a pile. I mean, when I think of a pile, I think of something shaped like a cone, like a mountain of sand. But this place is perfectly flat. Flat, flat, flat. Still, why aren't there any bigger rocks here?

In geologic terms the sediments here have been well sorted. We don't see different-sized particles all jumbled up together. Rather, we see that particles of the same size have all been sorted into appropriate piles. This tells us that the particles have been carried, by either wind or water, some distance from their original source.

Consider a small river carrying a bunch of variously sized rocks. Find a bend in the river, stand on the inside bank, and look across the river to the muddy cliff on the outer bank of the curve. Take your shoes off and wade across. As you first step in, notice that the water is moving slowly. But as you wade deeper and deeper, you have to fight harder and harder against the current to stand up. By the time you reach the steep wall of the outer bank, you are leaning considerably against the river's force.

Water sorts particles because the flow of water is not uniform. The fastest parts of the river can move boulders, but water in the slowest parts can barely lift a sand grain. So sand grains only settle to the bottom in the slow parts of the river, like the inner bank. The river would never let a sand grain rest in that fast current by the outer bank.

Even smaller than the sand grain are tiny particles of clay. It takes barely a swirl of motion to keep clay suspended in water. And it's not all about size.

Remember from Bark Hollow the end fate of rocks exposed to weathering on the Earth's surface? The two primary products of weathering are fine-grained quartz and clay. Although some people use "clay" to refer to any type of very small particles in soil, I use “clay” in the sense I learned in geology class—as reference to a particular chemical composition. When defined from this chemical perspective, quartz and clay are silicate minerals. They are primarily composed of silicate tetrahedrons—that is, a little pyramid with four oxygen atoms at the corners and one silicon atom in the center. In quartz all these little pyramids are stacked up in a three-dimensional network. As big quartz rocks weather, they break down in three dimensions, maintaining a more or less rounded shape. However, in clay the silicate pyramids are tied together in flat two-dimensional sheets. When clay minerals break down (and there are different types of clay minerals), they split apart in layers. Like separating a ream of paper into individual sheets, each tiny piece of clay has a large surface area relative to its volume.

In the water column a clay particle hangs, responding to every push and shove from the water just like a sheet of paper. Compared to clay, quartz sand grains, round and solid, drop like bowling balls through the water. And the relationship between water and soil particles cuts both ways. Just as a column of water can’t hold on to bowling balls for very long, a pile of bowling balls doesn’t do a good job of holding water particles. Pour water on a big pile of sand, and it will fairly quickly drain through to the bottom, leaving the top sand relatively dry. But a deposit of compacted clay, with its interwoven reams of paper tightly adhered to each other, is loath to let a drop of water pass through.

In our river a sand grain and a clay particle are carried along together in the swift current. Suddenly, the river meets a lake. The water slows down. The current can no longer lift the little bowling ball, so it falls out of the water column along with all the other sand. But there’s still enough current to carry the sheet of paper, which won’t settle down except in the stillest of waters where all the last little swirls have exhausted themselves. The clay drifts far out into the middle of the lake. There, finally, the clay particle gently saunters down to the bottom.

THE LAKE

So did you find a source of flatness in nature? In your cup of pine needle tea, perhaps? Or out in the canoe? Water. I can't think of anything flatter than the surface of water. That's what we're looking at.

We are sitting on a delta. This is where a flowing river suddenly meets standing water and dumps its sediment (fig. 3.10). The land around New Orleans grows ever further into the Gulf of Mexico because the Mississippi River brings fresh sediments year after year. Before inching forward, the river piles the sediments as high as she can—right up to sea level. Or, in our case, lake level. The land is flat because it's the surface of a lake.

A glacial lake. The lake that 15,000 years ago lapped up against Bark Hollow's basalt mountain. Full of meltwaters from the retreating glacier. Dammed up by a giant pile of debris that the glacier dropped into the rift valley farther south. Two hundred miles long and, in places, over 300 feet deep.

It only lasted a few thousand years, but that was enough for substantial deltas to form from Massachusetts to northern Vermont, like the one we're sitting on. About the same time, the first people were arriving here. I'm not sure there's any hard evidence that people saw the lake, but Native American oral histories still feature an ancient giant lake that once filled the valley. Can such information really be transmitted over 500 generations of the game of telephone? I like to think so. Somehow it gives me comfort to believe that people once set eyes on this lake, admiring its expanse and swimming with the mammoths.

The lake is long gone now. All we can do is read about it in the

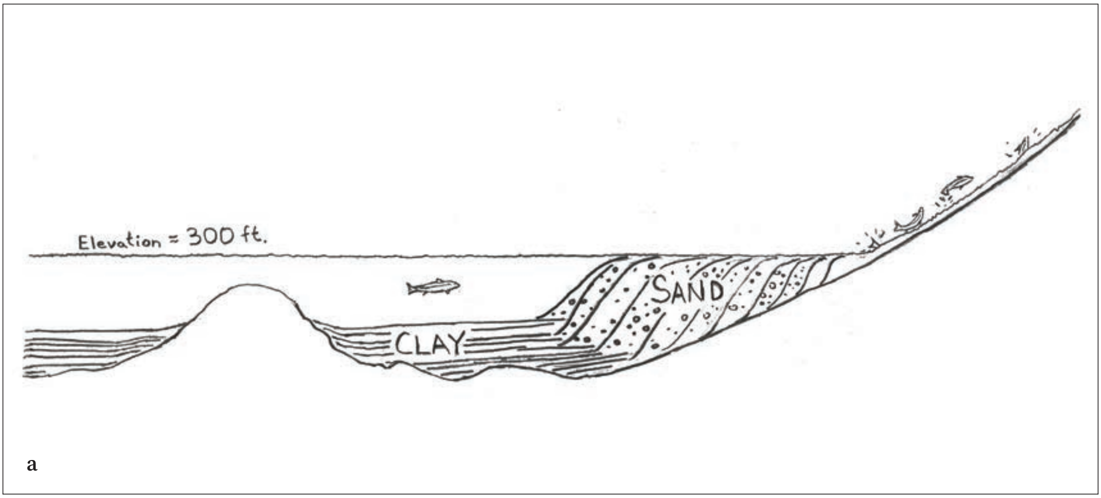


Figure 3.10. (a) When a river enters a lake, sand and gravel are deposited in a flat-topped delta near the shore, while clay drifts out and settles farther out. The delta height of 300 feet represents modern elevation at our field site. However, the actual elevation 10,000 years ago would have been closer to sea level; ever since the weight of the glaciers melted away, the land has been rebounding upward. (b) Another delta near Maggie's Forest has been turned into a gravel quarry.

pages of the land. The dry-loving pine barrens describe soils that are deep and sandy—an open drain for water. The horizon spells out the lake surface. The slope we climbed to get here—the underwater face of the delta—documents the lake depth. The fish hatchery on the road at the base tells us of the abundant springs from all the water that slips down through the sand, only to hit the clay layer below and be shunted sideways.

To be clear, not all flat, sandy pine barrens are ancient deltas. Travel across New Jersey and you will see other features that tend to be flat, sandy, and pitch-piney. As the glaciers retreated from the coast, they often left behind broad, flat landscapes of sand and gravel smoothed by myriad braided streams carrying meltwater—


b

called the glacial outwash plain. It's the context here at Maggie's Forest—a discrete pine barrens on a flat terrace with a steep slope down to "regular" woods in the valley below—that point the finger to a lake delta.

OAKS AND PINES

Our tea is down to the last drips, but we still haven't quite answered the original question: Why are the trees different on the left and right? If we were to poke around on the ground beneath the trees, the low understory species follow the same pattern.

Fire? Wind? Disease? Looking at the aerial photo in figure 3.2, none of these natural forces would seem likely candidates for driving the oak versus pine pattern. In this winter image the pines, still holding their needles, are visible as dark green. The bare oaks are light brown. The borders between these dark and light patches are straight. Rather than the ragged, irregular shapes that nature would opt for, I see rectangles.

Right angles and straight lines. This must be the work of humans. Not the recent intervention, but the remnants of land use from one hundred years ago. Back when Maggie's Forest was a farm. The giveaway is in the soil cores on the bottom of the chapter-opening image. You see, only one core shows a distinct A horizon. That narrow black band at the top. In the other core the top eight or so inches of soil have been mixed into a uniform blur. The farmer's signature, written with a plow. One side was plowed for farming. The other side? Maintained as a woodlot for logging timber—so say the multiple-trunk oaks.

One hundred years ago both patches might have looked similar—wide open and devoid of forest. An empty field, freshly plowed. A sea of stumps, the last of the trees cut down. The farmer flees. Then what? In the field, winged pine seeds outcompete the clumsy acorns to win the first heat of the race to forest succession. But in the old woodlot the oaks have the advantage. The logging operation only removed half of every tree. Underground, huge root structures, full of stored sugar, ready to capture every particle of passing water, sit poised for spring. The tiny pine seeds don't stand a chance against such massive reserves. In the cut woodlot the oaks leap to the canopy, sending multiple shoots from every stump, shading out the pines in the blink of an eye. And here we are today, a hundred years into the first wave of forest succession. One hundred years on, the trees are still just a shadow, outlining the farmer's saw and plow. What legacy will today's cutting leave?

MAJOR LESSONS FOR INTERPRETING A LANDSCAPE

- Consider the shape of the land. What surficial geologic processes are responsible for having moved, sorted, and shaped the sediment?
- What are the successional dynamics in your region, and what successional stages are represented in your site? Look for evidence of slow species turnover.


a
197 ft
a
b


b

(overleaf)
Figure 4.1. Know your place in the broader landscape. (Inset map: USGS)

4. Context

Mid-July, ten miles southwest of Maggie's Forest. I have only a couple hours and a lot of walking to do—this site has two parts. I ditch the car on the side of the highway, throw my backpack on, and cut into the woods. Dressed in a T-shirt, I think to myself, "Is there some reason I need long sleeves? No, it's a warm day." As I set off alone, I'm propelled by the memory of my students' bubbly anticipation, still hanging in the air from years ago. I warned them that this would be a long day and they needed to prepare for wet and muddy feet. They took the warning as a promise of adventure.

I start along an old logging road and find a collapsed bridge over a straight-walled creek. Crossing the creek, I forget about the trail and wind my way westward. It's fairly flat here, just scattered hummocks, bumps, and holes. Weaving alternately through patches of spicebush and mountain laurel, in about twenty easy minutes I make it to the first spot (fig. 4.1). Towering tupelos, pin oaks, and swamp white oaks provide shade for royal ferns, highbush blueberries, sedges, and mosses.

I set my gear down and start searching for the best picture angle. Swarms of mosquitos keep me moving quickly, hands flapping, as I crane my neck to read the canopy trees above and peer left and right through my lens. The topography is so uniform that, in my funny little dance, I lose my orientation. A bit panicked, I spin around and find a sense of relief when I recognize the solid trunk of one of the towering oaks.

In front of the oak is a little flat spot devoid of vegetation in which I see the students still digging a hole trying to solve the site's puzzles. They pass first through darkly stained bits of leaves and muck and then into layer after layer of grayish silt and clay. Four years on, they're still digging down through the clay. Other students are out collecting leaves, testing soils, lifting logs. At last they all finish their observations and come together in a circle between the oak and a tupelo.

Josh stands quietly, tucked discretely under the oak's arm, with his head a bit tilted as he listens to the other students. Calling out species names and pointing to the maps, the students spiral around ideas about the history that formed this site. Exhausted and a bit defeated, the students' eyes narrow as the ends of their theories don't meet. Josh gently steps forward and, gesturing with his hands, pulls together the whole story. Light returns to everyone's eyes.

It all makes sense as I plod through these apparitions back to the old oak, expecting my bag, tripod, GPS, and compass to be piled at the base. But there's nothing there. This isn't the same tree at all. My gear has drifted even further away. I need to slow down and pay more attention.

I stand motionless. I breathe. I center myself, relaxing back into my spine. I look in all directions, using my peripheral vision as much as my forward tunnel vision. When I start to move again, my body moves slowly and with intention. One foot goes up, tracks forward, and eases down—the whole while I am balanced on the planted foot. If needed, I could freeze at any point in the stride. In this way I find my gear again. I breathe relief. I snap some photos. Then, falling back into a faster rhythm, I trudge on to the next stop.

As the land starts to tilt upward, a little wood frog hops in front of me. I spring down to catch a picture. How many times have I gone crashing through woods in early spring destined for a lit-

Figure 4.2. Vernal pool specialists: (a) mating wood frogs surrounded by egg masses, and (b) fairy shrimp.

tle cold pond, plunged my hand into the icy water, and picked up a wood frog's translucent jelly-like egg mass? At the 560 ponds I visited for my dissertation, I counted nearly 10,000 wood frog egg masses. Still, every single one brings me a thrill.

Wood frogs are vernal pool specialists (fig. 4.2). In early spring, on the first rainy night, they leave their winter hideout in the forest and hop down to the pond, where the ice is just beginning to thaw. Males call out a cacophony, like a sea of laughing ducks, while a plump reddish female swims about looking for a mate. She lays her eggs as a grape-sized sphere with hundreds of little dark beads. Within a few hours the egg mass expands to the size of a grapefruit. Within a few weeks the larvae hatch out and begin eating algae. Within a few months the larvae transform into froglets and hop away just as the pond is about to dry out. It's important that the pond dry out—that kills off the fish, large dragonfly nymphs, and other long-lived predators that might otherwise lurk in the water and eat the defenseless tadpoles.

After I'm satisfied by the frog in my lens, I glance toward my elbows sinking into the wet mud and notice delicate toothed leaves kissing my arms. Poison ivy. If only I'd worn long sleeves. Luckily, there is a little puddle nearby—possibly the remnants of the vernal pool that my little friend hatched out of. I go through my poison ivy ritual: spread silky mud onto the affected area, scrub with dirt, rinse with water, repeat. Some folks swear by jewelweed, some swear by specialty soaps, but I think immediate application of the closest grit and water works wonders on poison ivy, washing away those itch-causing oils. Hopeful, I continue the gentle climb to the next spot.

Soon I'm there. The trees are entirely different: an upper canopy of mostly northern red oaks with an understory dominated by beech and a few small sugar maples and hemlocks. I recognize a heavy gray rock with rounded edges, the size of a toaster oven, under which my students had found a redback salamander. No salamander today. Instead, a flurry of tiny reddish ants scramble to cart their white larvae to a deeper spot safe from rock-lifting hominids. Meanwhile the air has warmed a bit, and the mosquitos are even more active. I unfold my tripod, stretch out its legs, and set its feet in the leaf litter so that it stands shoulder to shoulder with me. I wander over to a beech tree to have a look at the scars on its bark. Walking back toward my tripod, I rub my eyes trying to figure out why everything seems blurry. A little fuzzy dark cloud is hovering around the tripod. A swarm of mosquitos, dripping off the tripod head in opaque masses. Hundreds and hundreds of them. I've never seen anything like it. I really wish I'd worn long sleeves.

I take pictures as fast as I can and head for safety. About a hundred feet west, a long pile of boulders—an old stone wall—marks the boundary between the forest and an open field where courting bobolinks abound in the spring. The mosquitos don't dare follow me into the field, where the air is too dry for them today.

On our topographic map, the field shows up as white, whereas the forest is light green. As a military outgrowth, such maps historically used green to indicate "vegetation with military significance, such as woods, orchards, and vineyards," according to army field manuals. The modern makers of these topo maps probably aren't thinking in these terms, but this does make you wonder. How, why,