CONTENTS

Many forest trees like these *Populus* species and evergreens in the background are full-sun plants that provide shade. Similarly, plants growing in open grasslands, prairies, and many riparian areas do well in full sun, while also providing shade for the soil and ground-level vegetation.

lead to leaf wilt, scorched leaves, or localized burns, and can even kill the unadapted plants. Even large branches of trees breaking can leave parts of the tree accustomed to shade at risk of being burned and susceptible to infections, a common issue with fruit trees.

In landscape designs, many plans include drastically spaced-out plants with exposed soils or mulch between plants. Sometimes this is to provide enough room for mature plants to fill in, while at other times it is intentional to create a "crisp" appearance. Such designs often lead to stressed and dying plants in the midsummer or autumn heat and require more frequent watering. Adding shade cloths can decrease stress and heat while plants establish and adapt to an area, but a more natural approach is to fill those areas with other plants, including annuals, biennials, smaller

Black-eyed Susans (genus *Rudbeckia*) grow alongside grasses and other full-sun plants in an area with more than six hours of sun each day during the growing season.

Planter bed with unnaturally isolated plants and mulch. The mulch protects the soil a bit and prevents water loss, but dense planting of annuals to cover the soils provides better, more natural microhabitats for the plants to establish in.

perennials, trailing plants, and bunchgrasses. This more natural design also benefits wildlife and improves the overall habitat.

—Shade

Quite often, people think about lighting in the environment as sun or shade, which conveys the idea that there are only two types of lighting. However, shade is simply an umbrella term that covers many different levels of light in an area. The four most common categories used in horticulture are: part shade, dappled light, full shade, and deep shade. *Part shade* describes areas that receive four to six hours of direct sunlight. In nature, part shade is found near cliff faces and under isolated, tall trees with dense canopies. Due to the potential for direct sun, part shade can be further clarified by specifying the amounts of morning sun and afternoon sun due to the climatic differences sunlight has on an area at these times. *Dappled light* is when small patches of sunlight reach the ground. This is typical under some species of trees, under latticework, and in forested areas with spaced-out trees or loose canopies. Dappled light can also occur in areas under tall herbaceous plant communities in drier areas where exposed soils are present between bunchgrasses and low-growing shrubs. *Full shade* describes areas that do not receive much, if any direct sunlight, but are still bright enough for many shade-tolerant species to thrive. Naturally full shade occurs in open forests with dense canopies, under trees with large canopies, and on the north faces of rock shelves, canyons, and gullies. *Deep shade* describes areas that are too dark for most shade-tolerant plants to thrive. In wild landscapes,

A cave opening in the Spring Mountains, in Nevada. Light levels in the foreground are deep shade, but the area receives enough refracted light for some mosses and herbaceous plants to grow. Trees in the background receive full sun along their canopies and provide dappled shade to lower vegetation.

Palm trees growing in part sun under open pine canopies in Florida. Healthy management of these forests provides wide openings that allow sunlight to reach the forest understory.

deep shade occurs under dense shrubs, thick forests, below rock overhangs, and in cave entrances.

On a large landscape scale, shade types are important in descriptions of some habitats and areas like closed-canopy forests and the north faces of mountains. However, shade is typically discussed on a small scale specific to an area covered by a single plant, since plants depend on light to photosynthesize. Although all of the lighting types exist in urban and rural areas, the number of areas with deep shade has drastically increased because many buildings create it on their north side.

—Water

In every ecoregion in North America that has plants, water availability and abundance are major contributors to habitat, animal presence, and plant-community structure. Water availability includes frequency of rain, annual and seasonal precipitation, humidity, groundwater depth, surface water, and soil moisture.

Precipitation

One of the key differences between the Level I ecoregions of North America is the amount of precipitation each receives annually and seasonally. Differences in seasonal precipitation influence plant community structures and microhabitats, which are key to many animal life cycles. For example, in the Marine West Coast Forests ecoregion, chilly winter rains and snow raise groundwater levels, creating ephemeral springtime wetlands that are breeding grounds for cold-tolerant, cold-blooded insects and amphibians. Compare this to the North American Deserts and the Great Plains ecoregions, where summer rains create warmer ephemeral pools during hotter weather, when many cold-blooded animals are more active.

Large storm cloud near sunset that released over an inch of rain in less than three hours. Most soils cannot absorb water at this rate, which leads to localized scouring and flooding.

In the high desert and sky islands of New Mexico, rainstorms are often isolated and provide precipitation for localized areas. These storms are more common than rain events occurring across most of the landscape.

To be clear, there are numerous compounding factors that influence the amount of precipitation, seasonal differences, and water retention in an ecoregion. However, for the purposes of this section, precipitation will be discussed on a local scale. Seasonal precipitation patterns drive the life cycles of many organisms, including plants, fungi, and animals. Some ecoregions receive the majority of their precipitation in certain parts of the year. In the deserts, this is often called the "monsoon season," when the Mediterranean California climate experiences rain in the winter and spring. For ecoregions with wet and dry seasons, the ecosystems are adapted to annual droughts. To contrast with this, some ecoregions experience precipitation events throughout the year, like in the Upper Midwest and the Northeast. Ecosystems that receive rain and snow throughout the year have more water available to plants and animals that are less adapted for long, dry periods. Even though areas are still receiving precipitation, climate change is affecting precipitation patterns. Rainstorms are becoming less frequent in many areas, creating longer periods of drought followed by stronger inundations. This is harmful to habitats because organisms are stressed and killed in these extended weeks of drought, and then too much water follows. More intense rain events lead to longer flooding periods, different intensities of floods, and erosion, as well as increased stress and mortality pressures on organisms.

Understanding the historical rain patterns of an area is important because this knowledge does several things: it helps tell us when to water plants; it is a guide for when to provide ample clean water; and it allows us to notice the problems climate change is causing. As droughts become more frequent, providing plants with supplemental water can help an entire habitat survive. Similarly, garden designs should include proper drainage for times when precipitation is excessive.

Aquatic Habitats

When water in natural landscapes is discussed, many people immediately think of picturesque rushing rivers, gorgeous waterfalls, large, still ponds, and lakes. Even in major city installations, waterfalls, fountains, and ponds are the chosen aquatic feature type. However, water resources in the wild exist in a vast array, including the picturesque resources mentioned above, but also as muddy puddles, rocky-bottomed rain catchments, and heavily vegetated emergent wetlands that might be seasonally available or filled with water year-round.

Slot canyons, formed when seasonal rains carve out the walls and floor, are common in parts of the arid Southwest.

Picturesque aquatic habitat with wetland vegetation growing along the streambed.

Ecologists, biologists, and land managers have devised a variety of ways to describe water resources and the habitats they create. For the purposes of this book, standing water resources will be described with less technical terms. Most people can understand "muddy puddle," "meandering creek," and "vegetated pond," while technical terms like *palustrine* and *unconsolidated bottom* generally need further clarification. Just as for terrestrial environments, there are many ways aquatic habitats can be categorized. Aquatic habitats are affected by lighting, with shaded areas heating up less quickly than areas in full sun and the two supporting different vegetation and biotic communities. Similarly, the depth of water, its movement, the substrate, soils, and other elements all affect which species can live in these bodies of water. The depth of water bodies can affect temperature, provide refuge from terrestrial predators, and correlate to the persistence of the aquatic habitat in the landscape. Movement of water affects oxygen levels; fast-moving streams have more oxygen than slow-moving streams of the same temperature.

Depending on the habitat and ecoregion, standing-water habitats, like pools and emergent wetlands, can be common year-round or only during the rainy season. For all regions, these water resources are used by a variety of species. Most species rely on the habitat for drinking, some rely on it for hunting, and others need these habitats to complete their life cycles. In most cases, larger aquatic habitats (those that can persist for weeks to months after rains) are key resources for the life cycles of some native arthropods (including insects), fish, and amphibians. Animal life cycles that are dependent on aquatic habitats can be separated by the presence or absence of fish. Because most fish are predators, fishless habitats are vital for the larvae of amphibians, many dragonflies, and a variety of other insects. For example, mosquitofish (genus *Gambusia*) and their relatives are especially damaging to amphibian populations because they eat larval amphibians and their eggs, or simply peck at their tails, limbs, and gills, leading to death. Unfortunately, people have released mosquitofish in many wild aquatic areas to help control mosquitoes, with little success. (See the chapter 3 section "Mosquitoes" for other control options.)

Due to the wide range of natural aquatic habitats, for the purposes of this book, discussions will focus on habitats that can easily be reconstructed in small gardens. These habitats include puddles, fountains, seasonal ponds, vegetated wetlands, and even small, seasonal streams.

Roadside ditch culvert with abundant mosquitofish (genus *Gambusia*) and crayfish (superfamilies Astacoidea and Parastacoidea) in their native range. Both types of animals are widely invasive in other areas of the continent and world.

An American Toad (*Anaxyrus americanus*) sits in a small, rocky depression, soaking up water from sprinklers, in Westchester County, New York. Intentionally providing areas that collect water for short periods of time greatly benefits garden wildlife.

Puddles and small water catchments are found in all ecoregions after rains. They usually persist for a few hours to a few days after storms, quickly draining or drying up. Some form in soil depressions, others on rocks and even on plants and fallen leaves. These small, fresh bodies of water can provide drinking water for animals, as well as areas for bathing and soaking. Wet soils in and around puddles are used by a few bird species, a variety of wasps, and some bees to build their nests. In developed areas, many of the soils where puddles form are filled with pollutants from roads, including salts, which makes the water less suitable for drinking and the soils less suitable for nesting. Irrigated areas, however, provide these resources more regularly than natural cycles and can improve water access for animals and provide nesting resources for longer periods. In arid regions, urban development has helped swallows become more abundant due to the increase in mud and puddle availability, while bridges and building faces have provided new nesting spaces.

Longer-lived temporary bodies of water provide many of the same functions as puddles, but also persist long enough for some animals to carry out a stage of their life cycle or complete it. In drier regions, these areas are often called *playas* or *dry lakes*, while people in wetter regions often refer to them as *ephemeral pools* or *vernal pools*. Temporary bodies of water rarely support fish and can be vegetated or barren. While water is present, these areas support the complete life cycles of aquatic invertebrates like fairy shrimp, water fleas (genus *Daphnia*), and seed shrimps (class Ostracoda), as well as life stages of various amphibians and insects. As the watery habitats dry up, chemical changes in the water signal to wildlife to either emerge or complete their reproduction.

Longer larval periods help some salamanders, frogs, and toads grow larger and make them better suited for starting terrestrial life. Conversely, some species, like

Swallow (family Hirundinidae) nests along an overpass. Local mud resources and the sheer face of the infrastructure create prime nesting locations, and insect abundance provides great foraging.

Bladder Snails (*Physella acuta*) in a roadside trough, in Texas. They are regularly found in perennial and almost-perennial water bodies.

Couch's Spadefoot Toad (*Scaphiopus couchii*), have been found to do better when ponds dry up in a few months and have lower survival when ponds persist for longer. For some species, this is potentially due to differences in diet and prey. For amphibian breeding habitats re-created in gardens, it is critical to make sure the habitats suit the local species. Prior to installing any type of habitat project, research the target animals and their life cycles so that habitat characteristics, like the duration of water presence, mimic natural processes and vegetation.

Vegetation often grows in and around seasonally submerged habitats that can tolerate both dry and wet conditions. However, in arid regions, many playas (salt pans) do not support vegetation due to salt buildup in the soils and/or soils deprived of oxygen because of the sun-heated water. In wetter ecoregions, vernal pools can form in almost every type of habitat, including shaded forest floors, dense shrublands, and sun-exposed meadows. Each habitat can support different wildlife and plants within the vernal pools. In forested habitats, animals that live in the pools typically feed on leaf litter or plants already growing around the area. Algae is not a common food resource in these shaded habitats because most algae species need more light to flourish. The lack of sunlight also helps the water stay cool. Predatory organisms also live in the shaded pools, preying on other inhabitants. Shrublands and meadows typically have more light exposure, so more types of algae can grow. Waters in these sun-exposed pools can have drastic daily changes in temperature, which affects oxygen availability and metabolic processes. Animals and plants living in these pools have evolved different ways to handle these changes, with some species having seasonal restrictions for activity within the habitat, while others can breathe air when

An abandoned golf course in Texas supports deep wetlands with emergent wetlands along the shore. Tree cover on the south side provides habitat for rushes and broadleaf plants, while full-sun areas are dominated by cattails (genus *Typha*) and reeds.

necessary. Diets of animals in these pools may include floating algae, plant materials, and/or other animals living in the water. In gardens, re-creating these habitats should focus on the target wildlife, which typically benefit from partial sun exposure and water columns that are 2 to 3 feet (0.6–0.9 m) deep.

Perennial Ponds

Small, permanent water bodies are more common in ecoregions with year-round rain, but can also be found in drier environments. Perennial ponds are generally home to various aquatic snails, amphibian larvae (especially species with longer development periods like the American Bullfrog (*Lithobates catesbeianus*), certain dragonfly larvae, and a variety of other invertebrates. Organisms that use longer-lived seasonal pools often utilize perennial wetlands as well. Many ecoregions also have native aquatic vegetation, including complex green algae, horsetails (genus *Equisetum*), and flowering plants. Some examples are muskgrass (genus *Chara*), scouring rush (genus *Equisetum*), American Lotus (*Nelumbo lutea*), and American White Waterlily (*Nymphaea odorata*), all of which do well in deeper ponds. Emergent and bordering vegetation that prefers shallow waters, like rushes (genus *Juncus*), cattails (genus *Typha*), and Aquatic Milkweed (*Asclepias perennis*), generally do not do well with long periods of dry conditions but survive short seasons. Wetland plants also help shade the water, create microhabitats within the water body, and provide food for various animals.

Around human developments, small perennial wetlands are often filled in unless protected by law. This is because most people incorrectly equate standing water with stagnant mosquito breeding grounds. In reality, mosquitoes do best in degraded

Muskgrass (genus *Chara*) is a green alga that looks like a plant. These algae are common in freshwater, perennial, slow-moving bodies of water, including cattle troughs.

wetlands, but their larvae are mostly consumed in healthy wetland ecosystems. Water bodies that remain in developed areas are often polluted by runoff from roads and chemically treated lawns, as well as windblown trash. Pollution also occurs in agricultural areas from both agrichemicals and animal waste. The majority of invertebrates and amphibians that rely on these habitats are sensitive to pollution, nutrient levels, and overall water quality. In fact, scientists have created the Stream Health Assessment tool to evaluate the health of streams based on the presence or absence of specific aquatic species; state-specific tools are usually available through extension offices and state agencies. Stream Health Assessments rely on identifying aquatic insects and amphibians to calculate scores that correlate to the health of the water body. Many of the insect and amphibian larvae found in healthy streams can also be found in healthy perennial ponds.

Re-creating perennial pools in the garden is fairly simple with a little patience. There are premade shapes available, and fabric pond liners that hold water in free-form pits. Placing the pond in an area that receives enough light for the target habitat


A skimmer dragonfly (family Libellulidae) adult with prey. Dragonflies are important generalist predators that need water bodies to carry out their life cycle.

is key; for example, six hours of daily sunshine is necessary for irises (genus *Iris*), cattails (genus *Typha*), and waterlilies (family Nymphaeaceae). Two to four hours of sunlight a day helps keep water temperatures down and reduces algae growth. Once a pond liner is installed, adding stones, soils, sand, and a pump to aerate the water will start the habitat. Animals may arrive very quickly, with dragonflies and damselflies (order Odonata) usually the first insects to show up. After the water cycles for a few days, plants can be added. For more details on pond habitat designs, see the chapter 2 section "Water Resources in the Garden."

— Soils

Often overlooked when considering natural landscapes is the diversity of soils that exist in an area, because many habitats have covered soils and soils can be characterized in different ways. Depending on the purpose of the classification, soils can be grouped by temperature range, water retention, texture, pH, and nutrient availability. Most of these classifications, however, are not independent of one another. For example, ecoregions are often thought about in terms of the amount of precipitation they receive; however, soils are a major contributor to the water availability for plants. Water availability is influenced by precipitation, but in the end, it is determined by soil structure, permeability, texture, depth, organic content, pH, and nutrient levels. Vegetation and soil biota also depend on soil texture and water availability, which are key factors driving nutrient cycles and local soil temperatures via sun exposure. Soil

A deep cut from erosion exposes layers in soils and root depth. Very few habitats have deep, nutrient-rich soils (top dark soil layer above), and many have bedrock that plants must contend with, which is not present here.

pH affects nutrient availability for plants and animals and the nutrient cycle. In other words, there are specific variables in soils, but those variables are not necessarily independent. Even with the nebulous entanglement of soil characters, each aspect can still be understood as it applies to habitat.

Temperatures of soils are affected by texture, moisture, slope, depth, and exposure to the sun. Thermal extremes of soils are critical to the survival of many soil-dependent organisms. For example, bees, lizards, and turtles select nesting sites based on soil texture, aspect, and moisture content, which vary by species. Species that overwinter underground will not survive if temperatures get too low or stay too warm. Some plants even require soil temperatures to drop below specific levels before they will grow again (aka chill hours). In the summer, soil temperatures are important for burrows, nest sites, and other shelters, and poor placement can lead to the complete failure of nests, affect the sex of young (as in some turtles), and create areas where it is too hot for animals to shelter and plants to grow.

Viewing the landscape on a broad scale, soil temperatures can be assumed based on the slope and cardinal direction (aspect) the soils face. On steep mountains and rolling hills in the Northern Hemisphere, north-facing soils have the lowest temperatures in the winter and the summer due to the lack of direct sun throughout the day. Northern faces also tend to have the most water availability compared to the other aspects. East-facing soils have slightly warmer ranges for the area as they are mostly warmed by the early-morning sun. South- and west-facing slopes have

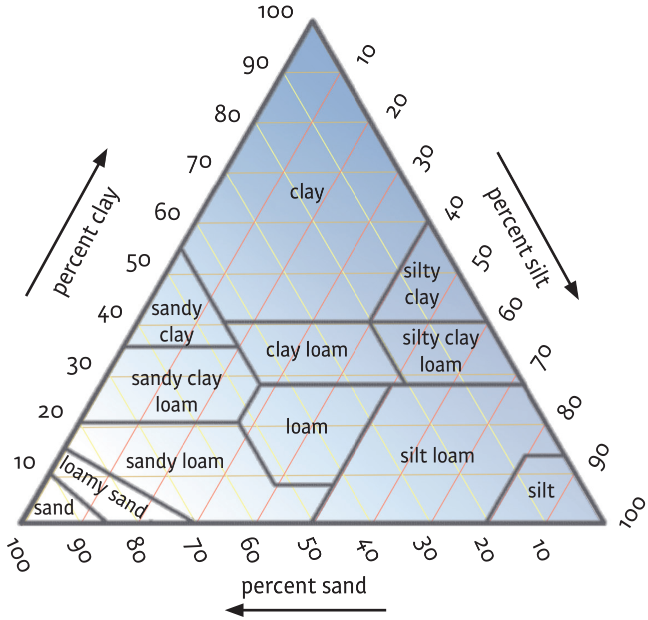
A turtle excavating its nest in soft, organic-rich soil. Turtles will search far from their regular watery habitat to find the right microhabitat for their eggs.

the highest ranges as they are the most exposed during the hottest parts of the day. Water availability is also assumed to be lower on the south and west aspects, as it will evaporate more readily with the increased heat.

On a small scale, slope and aspect are still important, but soil temperatures are also affected by exposure. Soils shaded by tall trees, dense shrubs, downed logs, rocks, erosional features, or other structures can have cooler microclimates compared to soils exposed to the sun. Habitats are also affected by flowing water (both rain and streams), as well as wind; both sort soil material and affect soil types. Biotic factors also diversify local soils. Burrowing animals excavate and deposit nutrient-poor soils, while toppled trees lift nutrient-rich soils into vertical shelves while also exposing nutrient-poor soils underneath. Plants and fungi can affect the pH and nutrients available, while insects and animal tunnels can aerate soils. Both animals and plants are able to utilize some of these soils while avoiding others for their life cycles.

The texture of soil affects topography and water availability, and it is important for many animals that burrow and shelter in soils because texture affects the soil's stability and thermal insulation. Soil texture is most often classified using a three-axis key, known as a ternary diagram. The three axes are the percentage of sand, silt, and clay that make up soil. Those components are laid out on axes that make up the outside of the diagram. Not mentioned in this diagram is the incorporation of larger stones, such as gravel, organic material, pH, or compaction, which can affect soil nutrients and water-holding potential. By laying out the percentages of sand, silt, and clay, we

Ternary diagram that maps soil components used to classify soil texture. Percentages of sand, silt, and clay are measured by shaking a soil sample in a straight-walled container and marking lines where materials settle at one minute, one hour, and one day.



can classify soils in a meaningful way that permits concise discussions. Having clear descriptions of soil textures allows us to convey information and to quantify soils in a way that is useful for identifying plant and animal preferences. These preferences are important in conservation because they assist with rebuilding soils to support target organisms. Ternary-diagram-based classifications can also be further described with other characteristics, including nutrients, pH, compaction, organic material, and moisture content. How to measure sand, silt, and clay content is explained in the chapter 2 section "Creating Soil Profiles for Plants and Animals."

Another aspect to consider for soil diversity is the layering of soils. Depending on the ecoregion and habitat, soils can have a variety of layers near the surface or just one. In communities with rich vegetation, there tends to be an organic layer sitting on top of nutrient-rich topsoils. However, areas like alluvial fans (gravel and sand deposits from rushing water), sand dunes, and exposed bedrock can have pockets of organic material and topsoil, but there is not a consistent layer. For habitats that have thick topsoils, a subsoil that tends to be lighter in color forms. Subsoils have lower humus content, are comparatively more rigid and compact than the topsoil, and have less organic content. Conversely, subsoils are mineral-rich, because water-dissolved minerals and salts are able to concentrate in this layer. In wet habitats, these soils can become oxygen-deficient or anoxic (oxygenless), which is one of the stressors wetland plants must contend with.

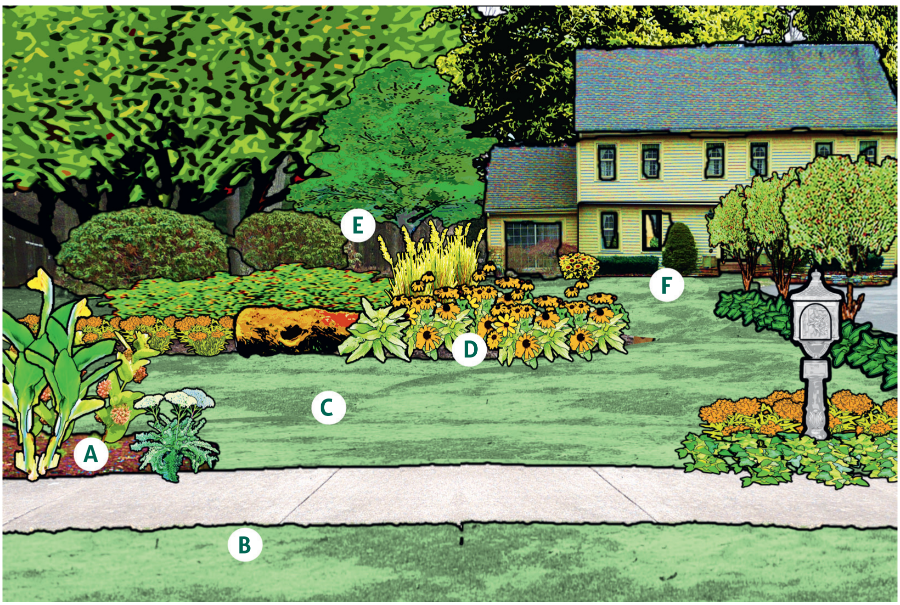
Uprooted trees often expose soil layers and create topographic changes that are not considered in the ternary diagram. Soil nutrients, slope, and aspect affect the microhabitats that will form. Re-creating these microhabitats is difficult in gardens and restoration projects. However, exposed vertical soils can be provided in well-designed rock walls. See chapter 2: Burrows, Caves, Crevices, and Rocky Shelters.

A fallow urban lot colonized by prairie dogs (genus *Cynomys*) in Westminster, Colorado. Previous soil compaction and construction work on this site makes it unsuitable for many native plants.

Within each ecoregion, there will be bountiful combinations of soil texture, depth, layers, temperatures, and water availability. Each combination permits or excludes some plant species while also being selected or avoided by wildlife—overall, driving local habitats and microhabitats. These different combinations can become hard to calculate as we consider larger habitats. In conservation, however, this complexity is often overlooked. For some restoration projects, environmental engineers try to replicate some of the soil diversity, especially with wetland and riparian habitats, because soil-erosion prevention and plant habitats require specific soil properties. However, many upland projects fail to incorporate soil diversity. Most often, areas are smoothed over and seed mixes are spread with the assumption that soil diversity will form on its own. Although some of the diversity will return in these projects, most of the soil diversity that existed in the natural environment will take decades to form again, and that is only if the restoration is allowed to undergo natural habitat successions.

In urban and suburban areas, soils are generally modified with nutrient-poor, dense earthen materials that are better for building stability. This is even more prevalent in newer housing developments. Agricultural practices and urban development homogenize soils, disturb topsoils, grade steep slopes, fill in caverns, and remove most local soil diversity. Subsequently, some species of wildlife that have specific soil needs are pushed out. Some examples include halophile plants that grow in salt-rich depressions, sand-dune-dwelling bees that nest in the sand, and cliff-nesting animals,

Soils around houses will likely vary based on disturbances and vegetation. Testing these different soils can help determine where soil amendments may help nesting animals. Similarly, adding specific soils to these spaces provides nesting options for wildlife. In the diagram are some great locations to test and consider amending. (A) Exposed garden-bed soils. (B) Soils near cement work because sand is often used as a base. (C) Mowed vegetation areas. (D) Shaded soils in garden beds. (E) Soils under large shrubs and trees. (F) Soils near foundations and around HVAC units.



like swallows and bees. Although rebuilding soil diversity in its entirety is nearly impossible, it is fairly easy to re-create topographic and texture diversity. For example, incorporating deep, sandy areas around rockscapes and paths, between plants, as well as around houses and fence lines diversifies soils with no major change to the appearance of the landscape. Further strategies and projects for soil diversification are presented in the chapter 2 section "Creating Soil Profiles for Plants and Animals."

—Temperature

There are a few different ways to think about temperature and the environment. Each approach has merit and describes parts of the local environment, but none fully capture the thermal ranges within an area. Average winter lows, for example, drive the USDA gardening zones, but frost-free periods describe the growing season. Both the USDA gardening zones and growing season length are used to guide crop selection. Considering temperatures on a more localized scale, north slopes are known to be cooler than south slopes, and deep-shaded areas are cooler than adjacent areas exposed to full sun (discussed more thoroughly in the chapter 1 section "Shade"). Similarly, developed areas are known to create heat islands caused by solar heat being stored in building materials and the lack of cooling from vegetation.

Cold and heat extremes in habitats are major factors affecting the ranges of species. However, many microclimates do not have thermal extremes that directly correlate to the local air temperature. For example, deep caves tend to have low variability in their temperatures compared to the surface temps at the entrance. Frost lines (how far down the soil will freeze) depend on a few variables, including the cold air, solar

Cinquefoil (genus *Potentilla*) flowers growing in cold temperatures that are below the extreme for the flowers of most plants. Incorporating early-blooming plants in garden designs helps the pollinators that emerge first in spring.

Winter landscape of a wooded area where many animals overwinter. Within this landscape, leaf piles, burrows, and tree trunks all provide warmer microclimates than the exposed surfaces. Similar resources can be added to garden designs; see chapter 2.

exposure, moisture, and how long the weather stays cold. Similarly, microhabitats reach different high temperatures based on material and solar exposure. Soils and rocks, for example, can regularly be 20°F (11°C) warmer than the air when in full sun.

Although the air-temperature extremes of an area affect wildlife success, the length of time areas stay near those temperatures also has a large impact. This is because areas where wildlife overwinter typically have limited insulation, except for caves. Large logs, soils, even leaf litter will stay above nightly lows if day temperatures and sunlight allow them to warm up. However, if daily highs stay close to nightly lows, then those microhabitats approach the coldest temperatures. A similar pattern exists in the summer and in the heat extremes of microclimates.

In gardens and landscapes, the placement of sheltering resources requires careful attention. Ensuring that the appropriate amount of insulation, solar exposure, and moisture are present will prevent microhabitats from reaching unsurvivable temperatures. Similarly, plants growing in areas of their cold tolerance do better in areas with more solar exposure during the winter than shaded areas. More details on shelter placement are discussed in the following section.

Burrows, Caves, and Crevices

Animals need places to hunker down and escape the elements. Many species take shelter in a wide range of structures in their natural habitat, from downed limbs to picturesque caves. Caves, ledges, and sinkholes are most commonly found in areas with limestone, basalt, and various sedimentary bedrocks. These structures provide necessary protection for a variety of animals, including insects, mammals, reptiles,

A natural rock outcropping with crevices and caves for wildlife to shelter in. Spaces like these are generally removed from urban and suburban environments, but should be considered for installation in gardens to provide suitable shelter.

slugs, and snails. In urban areas, caves are often filled or blocked off, ledges are demolished or covered, and downed limbs and trees are removed. This leaves washouts under cement foundations, basements, and sewers as places for animals to find shelter. Garden designs can include attractive rock shelters, hollow logs, and hidden burrows to provide similar shelter for animals to use.

— Burrows

Some of the most important features wildlife species need are refuges from the heat and cold. This is especially true for animals in hot, dry regions and any other exposed, full-sun habitats during the summer. Similarly, a wide variety of animals overwinter underground to avoid freezing and seek out areas below the frost line of soils. Many natural refuges are built by species such as Coyotes, foxes, jackrabbits, prairie dogs, tortoises, and other large burrowing organisms, most of which are generally extirpated from urban areas. The majority of large, burrowing species have been vilified as pests and extensively slaughtered, some to the brink of extinction. Excavation of burrows and tunnels by these animals also creates loose soil mounds that can be used by animals, like sphinx moths and beetles, that lay eggs, nest, or hibernate in softer soils.

Understandably, large holes appearing unexpectedly in urban environments can be dangerous for people and pets. So instead of trying to keep any large burrowing animals in your garden, we can re-create the needed structures to help our local wildlife. Installing deep, well-insulated burrows helps make better habitat for box turtles, toads, salamanders, crickets, lizards, and countless others. In gardens, burrows can be created with sturdy walls and open floors. Designs are explained in the chapter 2 section “Burrows, Caves, Crevices, and Rocky Shelters.”

Burrowing animals like Black-tailed Prairie Dogs (*Cynomys ludovicianus*) are ecosystem engineers. Their behaviors create necessary resources for many other wildlife. Prairie-dog burrows host hundreds of sheltering species, including Burrowing Owls (*Athene cunicularia*).

A suburban garden with large rocks and an unintentional burrow that became home to toads and lizards after the rodent was removed. Burrow-like structures can be added to garden designs to support wildlife. See chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters."

— Rocky Ledges, Stones, and Boulders

An incredible array of microhabitats occur in and around geologic formations. These formations include large rock outcroppings, glacial erratics, cobblestones, and exposed bedrock. Although there are many types of stones whose chemistry affects soils, thermal insulation, and even their ability to retain water, many rock types create similar microclimates. This is in part due to local abiotic factors, such as precipitation, winter weather, sun exposure, and wind, which also affect the microhabitats present

A large rock outcropping on Catalina Island, in California. Deep crevices and hollow caves within are important for lizards and endemic island foxes. Smaller-scale shelters can easily be added to landscape designs. For ideas, see chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters."

in each ecoregion. As rock formations crumbled, cracked, and eroded, organisms continued to evolve to utilize these habitats. Many species of plants, invertebrates, lizards, salamanders, and bats use rock crevices for shelter, while a variety of birds use rock ledges for nest sites. Similarly, an assortment of plants, including some ferns, succulents, and vines, have evolved for living in the specific microhabitats of rock formations.

Rocks are a natural impervious surface, transporting water into nearby soils, crevices, and basins. In the case of exposed bedrock, the rocks prevent the water from seeping into the earth and often create pools, seeps, and springs. Crevices and cracks collect organic matter, sand, and dust, which creates pockets of soils that support plants, function as nesting sites for animals, and facilitate further breakdown of the rocks. Stones that have soils below or around their sides provide a secure structure that some burrowing animals will rely on for structural integrity. Large boulders with soils below them often have mammal burrows beneath, including those of chipmunks, ground squirrels, and rabbits. Some animal species will also tunnel along stone faces extending vertically underground. Ground-nesting insects also utilize these rock/soil interfaces, with smaller stones, depending on the width and depth of their nests and soil composition.

Large omnivores, like raccoons and bears, regularly turn over stones and other objects while hunting. These disturbances create space between the moved items and the soil, sometimes covering plant material as well. Soil invertebrates, like worms, millipedes, and crickets, seek out newly covered vegetation to feed on while also sheltering under newly disturbed objects. Over time, as soils are moved by animals and

A small pocket in basalt provides a pool of water in Idaho. Birds and arthropods hydrate in these open areas.

A large rock outcropping rises above alpine vegetation. The rocks provide shade, soil accumulation, and water runoff for vegetation to establish in.

roots, and as changes in water saturation and temperature expand and shrink soils, the space under the objects can disappear. This phenomenon, often called "settling," creates new microhabitats used by some soil organisms. Without the presence of larger animals to turn over stones and logs, however, the microshelters and feeding areas many animals prefer to use can become very scarce in the landscape. In gardens, objects can be intentionally propped up off the ground to leave crawl spaces or disturbed every few months and placed back in position. For more information, see the "Exploratory Habitat Garden" text box in chapter 2.

Caves, ledges, crumbling rock outcroppings, and sinkholes in urban and suburban areas tend to be covered, filled, or removed. In turn, most of the microhabitats and the species dependent on those areas are extirpated. Some of the animals accustomed to living in and around rocks have adapted to areas around human development. For example, some of the animals that seek shelter in burrows and caverns use washouts under cement foundations, basements, crawl spaces, and even sewers for shelter. Cave-dwelling bats often use city sewers and bridges. Similarly, swallows, bats, and mud-nest-making insects have adapted to use buildings, overpasses, and bridges. On the other hand, most plants and animals that depend on rock-formation microhabitats have not adapted to human development. For many species, there simply are no areas that mimic the key resources they require or soils with the correct pH.

An unidentified vole species (family Cricetidae) peeks out from its home around the rocks, where its matrix of burrows also exists. These features are regularly destroyed and filled in around human developments.

A Cliff Swallow (*Petrochelidon pyrrhonota*) nest tucked into urban infrastructure. These areas are also regularly used by mud daubers (family Sphecidae or Crabronidae) and potter wasps (subfamily Vespidae).

However, with careful planning and attention to detail, many of these microhabitats that were removed from developed areas can be re-created for the more adaptable species. Attractive rockscapes with aboveground and belowground shelters can be designed as focal points or backdrops that support salamanders, lizards, plants, and other wildlife. Vernal pools and seasonal ponds are easy to design and work into garden designs. Planter beds with rock crevice gardens, rock gardens, decorative large rocks, and stone borders can also mimic natural microhabitats for wildlife. For further explanation of designs and resources, see the chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters."

A toad warms up on a cool day outside the shelter it has found in rocks along a garden bed. Intentionally providing crevices and access to specific soils will greatly improve habitat designs and wildlife health.

CAVES

Caves are important for many animals, including species of bats, birds, fish, and amphibians. In some of Earth's larger, older caves, endemic species live solely in the subterranean ecosystem, while many caves function as sheltering spaces for more mobile organisms. Although talk of caves can elicit thoughts of grandiose underground openings like Carlsbad Caverns, in New Mexico, Mammoth Cave, in Kentucky, or Devil's Den, in Florida, ecologically the term *cave* includes small openings as well as the larger gallery caverns.

Caves are defined ecologically as natural voids or openings with a ceiling, floor, and walls that are often further clarified by a minimum size large enough for a person to enter. A more nature-centric definition for a cave includes narrow, deep cracks in rock

Large rock formations, known as cave bacon, in Shasta Caverns, California. These structures are formed by deposits of dripping water in subterranean caves.

A small cave along a limestone outcropping on Mount Charleston, in Nevada. Structures like these often provide wildlife with areas for sheltering, nesting, and denning.

A Cascade Caverns Salamander (*Eurycea latitans*), which is endemic to the cave system it is found in near San Antonio, Texas.

outcrops, areas under large fallen rocks, long erosional pockets common in sandstones, and iconic large caverns (like Mammoth Cave and Carlsbad Caverns), and only rules out spaces the wildlife species could not fit into. Animals that use caves and that have also adapted to areas with human development often shelter in crawl spaces, attics, chimneys, culverts, and sewers. For folks who want to support species that use caves, hollow areas can be created for quite a few species. Artificial caves can attract animals away from dwellings that might be less suitable for wildlife to shelter in.

Key characteristics of a well-designed cave include good insulation, appropriate size for wildlife, appropriate placement for use, and rough, textured ceilings and walls for animals to climb; a cave suitable to live in does not flood (unless it always has water, such as a cave next to a pond). Insulation can be from deep soils, mulch, or thick stones outside the structure to keep the cave cooler than the outside temperatures in summer and warmer than winter lows. Note that these created spaces are similar to burrows. The size of the cave will depend on the species it is meant to support, which will also depend on the overall yard size. Raccoons and foxes, for example, should have caves that are 4 to 5 feet (1.2–1.6 m) deep in colder regions like zones 2–6, but openings and tunnels can be 14 to 20 inches (0.35–0.45 m) in diameter. Smaller animals, like salamanders, will use much shallower caves with openings that are less than 3 inches (7.5 cm) in diameter and need damp conditions. Placement is also important, as some animals will walk or crawl

continued overleaf

CAVES *continued*

into ground-level caves, but swallows and swifts will use caves with openings 8 feet (2.3 m) or higher off the ground.

Suitable materials for walls and ceilings include bricks, natural stones, animal kennel tops with a roughened interior, and durable plastic structures with deep scratches for climbing. Using cement or new cement blocks will work for reptiles and

A Tricolored Bat (*Perimyotis subflavus*) hibernating in a cave. During the summer months, these bats will seek shelter in dead leaf clumps of trees, tree hollows, and barns.

Organic Materials

— Leaf Litter

Many species of trees and shrubs drop their leaves seasonally. Plants that drop their leaves seasonally are known as deciduous. Some species drop their leaves during the dry season and droughts, while most species lose their leaves during winter. Deciduous plants provide crucial habitats and feed local nutrient cycles. In forested areas, the leaves typically make an even covering of the forest floor. Rain and snow help secure this leaf layer and prevent leaves from blowing around. In open woodlands, forest mammals, but the pH can harm amphibians and invertebrates. Care should be taken to ensure spaces that include access to soils and organic materials if salamanders, toads, or other invertebrates are the target residents. In regions with harsh winters, areas of the cave should be higher than the entrance. This helps warm air stay in the cave and prevents water from soaking the shelter. See the chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters" for design ideas.

A common cement cavity protecting plumbing and gas valves, which also functions as a pit trap for many animals, including snakes.

edges, and savannahs, dropped leaves are carried by the wind into areas under bushes and branches, creating localized, secured piles of leaves. Rainstorms that wash leaves and other materials into local heaps can create similar piles. Although some animals, like gall wasps and leaf miners, are left to chance for their survival and where leaves fall, most animals seek out secured leaves in suitable microhabitats.

Leaf piles create immediate protection from weather and provide insulated spaces with more consistent humidity and less variation in daily temperature swings. As leaves decay, bacteria, fungi, and decomposing organisms consume the organic materials. Their metabolic processes that break down the leaves involve chemical reactions

Fallen leaves along a deciduous forest floor are part of the nutrient cycle the mycelium of this mushroom facilitates.

Leaf fall by a boulder that is deeper than nearby areas. These microhabitats provide shelter for many terrestrial and non-fossorial animals (those not adapted to digging) and overwintering sites.

that produce heat, which creates warmer microhabitats compared to the surrounding areas. Pupating butterflies and moths, overwintering insects, various amphibians, nesting mammals, and many soil invertebrates rely on these warmer microclimates for protection from extreme cold temperatures to survive the winter.

In urban areas, hard surfaces allow leaves to be blown around and washed into less wildlife-friendly piles that are also viewed negatively by most residents. These materials can clog important drains, create traffic hazards, and make surfaces slippery. Due to these hazards, many cities and landowners bag up leaves and remove them

(continued...)

INDEX

Page numbers in **bold** refer to figures and tables.