YELLOWSTONE

Up In Smoke?

Disturbance and Succession in the Greater Yellowstone Ecosystem

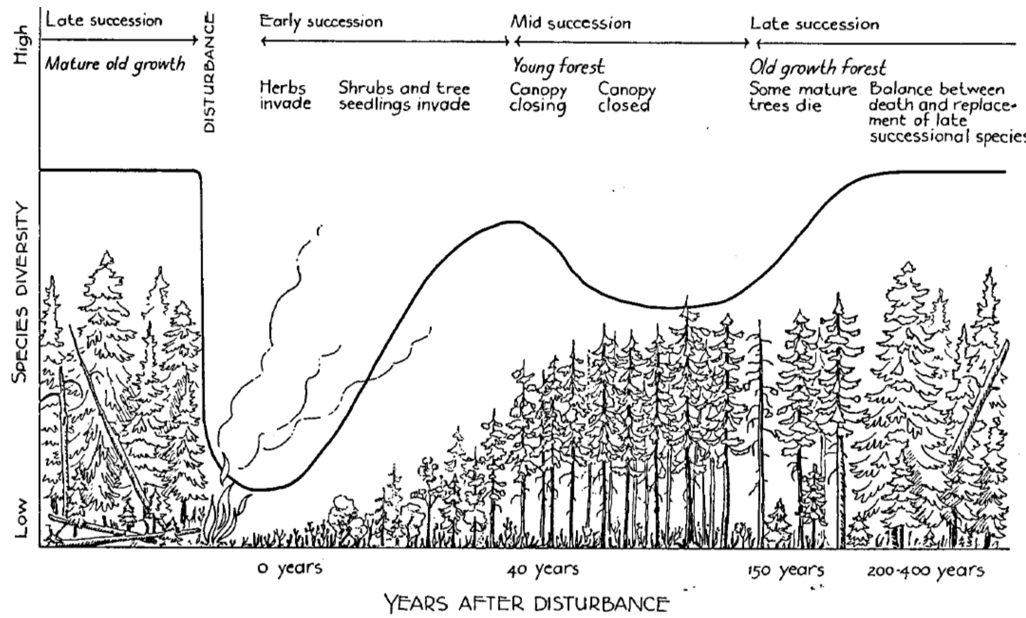
Ecosystems are not static. In fact, ecosystems are constantly changing as a result of natural processes. One of the most important instruments of change in nature is **disturbance**. Trees falling over, windstorms, landslides, avalanches, floods, fires, and disease epidemics are all examples of natural disturbances. Along with climate and soil, such disturbances play a major role in determining which plants and animals will be found living in any given place at any given time.

Fire is probably the most influential natural disturbance in the Greater Yellowstone Ecosystem. Like all disturbances, fire in the GYE triggers the cyclical process of **succession**. Succession is the replacement over time of one community by another. (Recall that a community is the assemblage of all plant and animal populations living in a certain place at a certain time.) In general, any disturbance causes some species to disappear from an area and makes room for other species to move in. The first species to move into a disturbed site are **early-successional** species. As these species grow and reproduce and die, they create conditions which allow other species to colonize the site—**mid-successional** and eventually **late-successional** species. Additional disturbances can interrupt this process at any point and shift it back to the beginning, early-successional stages.

How quickly a forest goes through the cycle from early to late succession after a fire, and the exact pattern of succession it follows, is different for every site. Many factors play a part in determining the future of each burned area, including the intensity of the fire, the size and shape of the burned area, its microclimate and soils, the community composition in surrounding areas, and random chance. But research has shown us that succession does follow some generally recognizable patterns. The cycle of species diversity in a typical subalpine forest in the GYE after a fire is depicted in **Figure 1** and described below.

Fire opens up the forest **canopy** (the highest layer of vegetation in a forest, made up of the crowns of the trees). Removal of the forest canopy allows much more sunlight to penetrate to the ground. Fire also releases the nutrients that had been bound up in dead leaves and wood and deposits them in a mineral-rich ash on the forest floor. The increased sunlight and nutrients in a burned area stimulates a lush growth of early-successional herbs and shrubs. These in turn attract elk, deer, and other animals which can take advantage of this rich food supply. Many early-successional species are considered to be generalists, or "weedy" species—species that are relatively common and widespread because they can tolerate a wide range of environmental conditions and often thrive in disturbed habitats.

Many species in the GYE have evolved ways to survive and even to benefit from fires. For example, lodgepole pines, which are by far the most common trees in the GYE, have two kinds of cones One kind matures and releases its seeds normally, but the other, called a **serotinous cone**, only releases its seeds when heated by fire. When a fire sweeps through a lodgepole forest, many trees may be killed, but hundreds of thousands of seeds will be freed from their cones and deposited in the rich soil to generate new trees. Other plants, such as aspens, have roots and other below-ground



parts that are insulated by the soil during a fire and that can resprout vigorously within the first year after the fire.

In time, the early-successional plants create a shadier, cooler environment in the burned area. Young trees—usually lodgepole pines in the GYE—and more shade-tolerant plants are able to take over the site. Other forest-dwelling plants and animals eventually move from surrounding unburned areas to recolonize the growing forest. After 200 years or more, mature, **old-growth forest** will completely cover the burned area. Lodgepole pine, subalpine fir, and Engelmann spruce trees of all ages and an understory of shrubs and herbs create abundant, diverse niches that support a wealth of late-successional animals. Dead wood accumulates in the forest as older trees weaken, die, and fall over. At some point, enough dead wood may accumulate to fuel, under the right circumstances (namely, severe drought), another major fire which will start the cycle of forest succession all over again.

Fire can behave very erratically, burning all vegetation to the ground in one area while leaving an adjacent area untouched. Fire may skip over some areas, or burn them less intensively, because of wind and weather conditions or because some areas simply don't have enough fuel to burn. As a result, fires usually create a patchwork, or mosaic, of clearings and partially burned or unburned stands of forest, as shown in **Figure 2**. Over time, fires burning different areas in different years create and maintain a **fluid** (constantly changing) **mosaic** of patches representing the complete range of community types and successional stages found in the region.

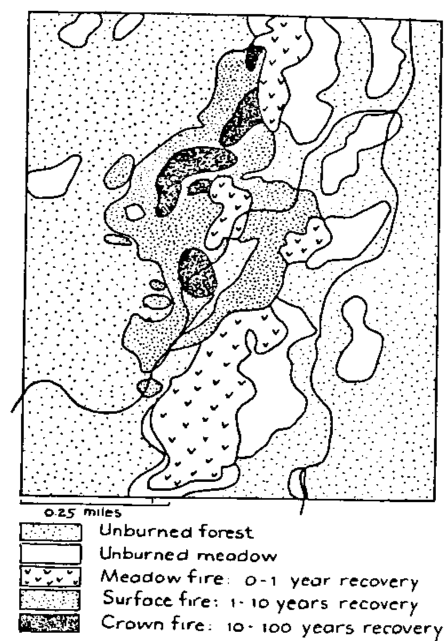


Figure 2. A typical mosaic of different burn intensities resulting from a 70-acre fire in the Lava Creek drainage in Yellowstone National Park, 1988.

(Adapted from D. Jeffery, Yellowstone: the great fires of 1988, National Geographic 175(2):255-273, 1989.)

In any single forest site, total species diversity is generally greater in the late-successional forests than in the early ones. For instance, an old-growth spruce-fir forest usually has more species living in it than does a stand of young lodgepole pine trees, as indicated in Figure 1. But late successional stages may not harbor all of the early-successional species found in recently disturbed areas, just as the recently disturbed areas will not support many species found in mature forests. Since the regional mosaic created by natural disturbances such as fire includes all different successional stages, it will support greater species diversity than does an area that has only one stage or community type.

Like natural disturbances, human disturbances, from development to logging to pollution, can also trigger succession in ecosystems. Logging is an important economic activity on National Forest lands and private lands in the GYE. The impacts of logging on forest ecosystems are superficially similar to the impacts of natural fires. Both disturbances, for example, result in cleared patches of land which are readily colonized by early-successional species. Some people suggest that logging be used throughout the GYE to prevent fires and to simulate fire's ecological effects. They argue that, in addition to supplying us with timber and timber products, logging can also provide us and the ecosystem with the benefits of fire (increased habitat diversity, increased food supplies for certain species) while avoiding fire's negative impacts (threats to human lives and property).

But there are many significant differences between natural and human disturbances and their impacts on ecosystems.

The plants and animals in the subalpine forests of the GYE have had thousands of years to evolve means of coping with fires. Lodgepole pines, for example, did not acquire serotinous cones overnight. But the GYE has been exposed to logging for only about one hundred years—a brief moment in the life of a forest.

Once a major fire burns an area in the GYE, it is probably naturally safeguarded against fire for another 200-400 years by a lack of accumulated fuel. In the absence of other disturbances, therefore, burned areas can mature fully into old-growth forest before being destroyed again by fire. People, in contrast, often use logging intentionally to prevent forests from reaching maturity, because timber production is usually greatest during the early and middle stages of forest succession. Some species may benefit from habitat disturbances caused by logging, but many of these species are already common (elk, deer, early-successional generalists or weeds) and not in need of protection or additional habitats. Old-growth forests, on the other hand, which support many rare or threatened late-successional species like the spotted owl of the Pacific Northwest, are disappearing rapidly throughout North America.

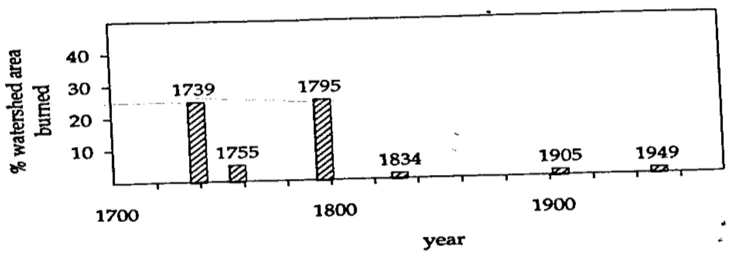


Figure 2.

Percent of watershed area burned in fires from 1738-1978 in the Little Firehole River watershed in Yellowstone National Park.

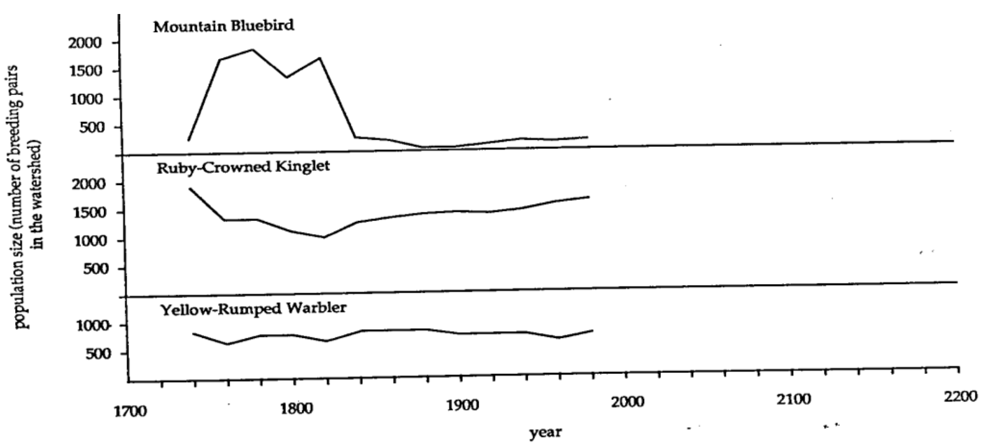


Figure 4.

Estimated population sizes of breeding birds in forests of the Little Firehole River watershed from 1738-1978.

Furthermore, logging always causes more disturbance than just the removal of trees. Roads must be built to bring in logging equipment and take out the harvested trees. Road building can increase soil erosion and landslides on steep slopes. Roads fragment habitats and can serve as barriers to the dispersal of some animals. And once the logging is finished, the roads usually remain, increasing people's access to previously remote areas for recreation, house-building, and other activities that can further disturb the natural ecosystem.

Various methods and tools are used for cutting and removing trees, which affect forests to varying degrees. Heavy machinery compacts and often erodes soils, making it more difficult for plants to recover the area. Large clearcuts (where all trees are removed) will regenerate more slowly than smaller areas that are selectively cut (some trees and undergrowth are left standing). Also, logging operations often remove standing dead trees that fires leave behind. These snags are host to myriad insects and other invertebrate species and are important perching, nesting, and feeding sites for numerous birds and small mammals.

Finally, fire tends to conserve and recycle nutrients in an ecosystem, whereas logging permanently depletes nutrients. As mentioned above, fire converts live and dead organic matter into a mineral-rich ash that fertilizes the soil and gets recycled into new plants that in turn support new animals. Logging, on the other hand, removes organic matter from the system, at rates much faster than new minerals and nutrients can be accumulated from the air, water, and bedrock in the ecosystem.

Biologists and foresters are experimenting with new methods of logging that minimize logging's impacts or more closely simulate natural disturbance regimes. This is a difficult and challenging task. There is still very much that we do not understand about how natural processes like disturbance function to keep ecosystems healthy and diverse. As the Yellowstone fires of 1988 showed us, these processes can be highly complicated, and can act in random and unpredictable ways that we may never fully succeed in controlling or imitating.

In the meantime, however, there is no doubt that we can learn a great deal about managing ecosystems to conserve biological diversity, simply by watching places like the GYE—places where, at least for the time being, nature still has the upper hand.

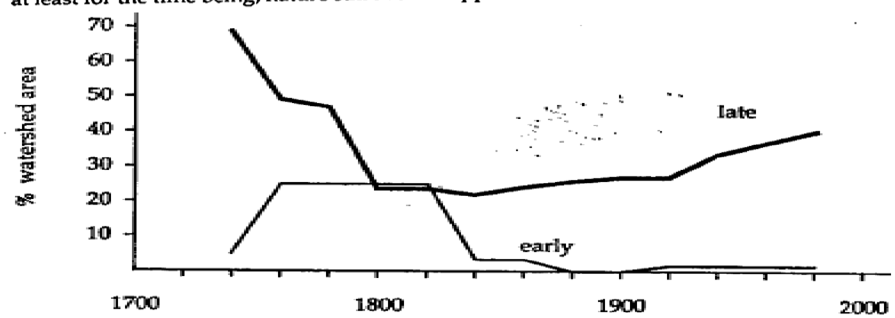


Figure 3.

Percent of watershed area covered by early and late stages of forest succession from 1738-1978 in the Little Firehole River watershed.

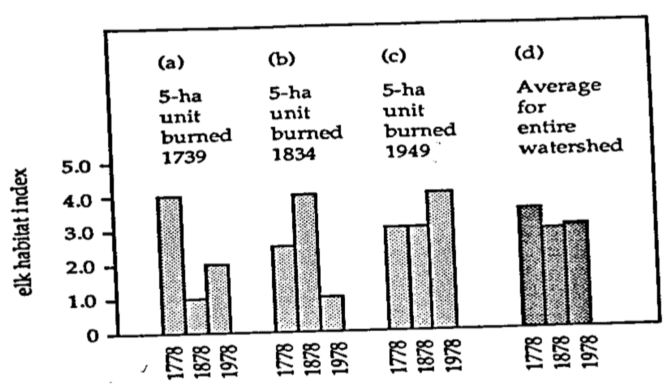


Figure 5.

Elk habitat index for three 5-hectare (ha) units within the Little Firehole watershed, and for the entire watershed (d) in 1778, 1878, and 1978.