CHAPTER EIGHT

The Effects of Natural and Man-Made Disturbances

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Not so many years ago, scientists and many others categorized major natural disturbances as catastrophic events disruptive of otherwise stable states (Clark 1991). Hurricanes, tsunamis, floods, and especially wildfires were thought to produce deviations from otherwise stable ecological systems—interruptions in the progression of species changes and ecosystems toward a climax, or a steady state (Cowles 1899, Clements 1937, Platt and Connell 2003). These views have changed. Natural disturbances are now recognized as integral and necessary components of ecosystems worldwide. Resources managers who once considered disturbances as deviations from orderly succession now view them as a natural part of ecosystems. Restoration and management actions are planned so as to include natural disturbances.

Now natural disturbances are considered non-catastrophic by many ecologists. Some individuals of most, if not all, species survive such events (Platt and Connell 2003). For natural communities, a self-sustaining "equilibrium" or "climax" state does not exist, even over a relatively large spatial scale. Moreover, the concept of "climax" states has yet to be demonstrated in the natural world (Sousa 1984). Instead, species are recognized as continually responding to changes in environments and to natural disturbances (Platt and Connell 2003). For example, we now know that fires favor species that survive fires in some life cycle stages and that are adapted for post-fire environments (Platt 1999). Different species thus may be favored under different fire regimes (e.g., Keeley and Zedler 1978, Glitzenstein et al. 1995). Moreover, some species may engineer disturbance, such as fires, through modification of characteristics and effects of fires, and thus these species influence species composition of ecosystems (Platt 1999). This more current thinking emphasizes the non-equilibrium nature of ecological systems—as a result of ongoing, recurrent, environmental changes, among which are disturbances. These changes are as much a part of biological life on military installations as they are anywhere else.

Disturbance Regimes

Ecological disturbances, current thinking holds, are relatively discrete events that affect landscapes in disruptive ways. Each disturbance type and even successive disturbances of the same type are unlikely to affect natural landscapes in precisely similar ways. Thus, it is difficult to predict the exact effects of the next disturbance in any natural landscape. Nonetheless, if similar or different types of disturbances recur with some periodicity, then a *disturbance regime* is produced that may generate predictable consequences. These disturbance regimes often are characterized by the type of disturbance, frequency/return interval, and seasonal timing. Examples include be the intensity of windstorms, duration of floods, and the frequency and season of fires. The characteristics of disturbances often vary within landscapes and also may interact with landscape components, as well as prior disturbances, to influence the size of the area affected. Also, local effects may influence the intensity, patchiness, and frequency of gaps or voids on the biota and the environment.

Disturbances often are numerous and occur at many different spatial scales. Here, we contrast disturbances at the largest and smallest scales. Disturbances at smaller scales tend not to affect landscapes or even entire ecosystems. These dis-

Hurricane Felix was a major disturbance—a category 5 hurricane that came ashore over northeastern Nicaragua on 4 September 2007, with sustained winds of 160 miles per hour. Hurricanes and typhoons provide often devastating illustrations of natural disturbance. (Photo: NASA image by Jeff Schmaltz, Goddard Space Flight Center)

turbances may be important, however, as a result of their combined effects over space and time. Burrowing animals can alter soil structure, for example, and over time change the substrate in ecosystems, as well as directly affect the plant communities in which they occur. Likewise, lightning strikes affect individual trees, but as a consequence influence whole guilds of cavity-nesting birds or wood-consuming insects and their associated predators and parasites. In forested land, a fallen tree can open a gap in the canopy that might produce a sunlit microclimate on the ground below—and this could favor the growth of understory species.

At the other end of the disturbance scale are large-scale disturbances such as fires, hurricanes, and volcanic eruptions. Large-scale disturbances are those that affect entire landscapes and their component ecological systems (Pickett and White 1985). Some examples include disturbances created by fire, wind, ice, and flooding. Invasive species can generate large-scale disturbances. For example, grasses that easily tolerate fire, may change an ecosystem's fire frequency (Brown and Lomolino, 1998) or intensity (Platt and Gottschalk 1991). Invasives also can wreak profound disturbance on the incalculable value of biodiversity on soil, as can pollution, changes in land use, and climate change (Wall et al. in Soulé and Orians 2001).

Any of these large or small-scale disturbances are as likely to happen on a military base as elsewhere. Numerous types of disturbances occur on military lands. Those induced there by humans are primarily related to land management—forestry, grazing, use of prescribed fire—and military maneuvers.

Variability

Natural disturbances vary in duration, scale, intensity, spatial pattern, and return interval in any landscape. Thus, similar or different disturbances occurring at different times and different places produce different effects on ecosystems at a landscape scale. An understanding of this is valuable for the military natural resources manager. For example, fires can be patchy and of differing intensities. Not all individuals of a species are affected equivalently by a single fire. Burning at different times of a year may affect species differently. Depending on the time between burns, some species may be able to complete their life cycles or reproduce before the next event. Survivors may be present in some, but not all, areas affected by a disturbance, and the environment may be changed in different ways in different parts of the area affected by a large-scale disturbance. Thus, diversity and heterogeneity at the landscape level are often enhanced by natural large-scale disturbances (Watt 1947, Bratton 1976, Connell 1978, Beatty 1984, Collins and Pickett 1982, Pickett and White 1985, Foster et al. 1998, Platt and Connell 2003).

Temporal heterogeneity of disturbances may be predictable or unpredictable (Platt and Connell 2003). If it is predictable, it can thus favor certain types of species. For example, large lightning-initiated fires in the southeastern U.S. tend to occur at certain times of the year and even under certain global weather patterns (Beckage et al. 2003, Slocum et al. 2007). This may favor the growth and survival of some plant species. For example, wiregrass, (*Aristida beyrichiana*) is recognized to flower primarily after growing season fires (Outcalt 1994, Mulligan et al. 2002, Peet 1993, Kesler et al. 2003). In some cases species may be uncommon because they thrive under certain disturbance regimes that occur rarely, but such species have mechanisms to survive the intervals between successive disturbances (e.g., Sheridan et al. 1997, Schuyler 1999, Norden and Kirkman 2004).

Ecological disturbances can also be categorized in other ways. Exogenous disturbances are external to the communities, ecosystems, or landscapes influenced by those disturbances. Most large-scale disturbances fall into this category. Endogenous or biotic disturbances are internal to the ecological system affected. Most smaller-scale disturbances fall into this category. Both exogenous and endogenous natural disturbances can be repetitive (recurrent fires or even volcanic eruptions; beaver dams on streams) or de novo (new volcanic eruptions; an invasion of a new species that re-engineers the ecosystem). Human disturbances can be considered as either exogenous (global climate change) or endogenous (clearcutting forests), but typically are de novo in nature. On military installations, disturbances caused by the military mission are examples of exogenous events. In summary, the role of disturbances (large- and small-scale, exogenous and endogenous; repetitive and de novo) is pervasive and of primary importance in natural landscapes.

Facing page: The eruption of Mount St. Helens in 1980 was an example of a major and intense natural disturbance. (Photo: U.S. Geological Survey)

Not in Isolation

The effects of natural disturbances cannot be considered in isolation. Disturbances may interact with one another, such that effects of an initial disturbance alter characteristics and effects of subsequent disturbances (Paine et al. 1998 Robertson and Platt 2001, Platt et al. 2002, Suding et al. 2004, Schroder et al. 2005). As a result, species may invade following sequences of disturbances, especially when de novo disturbances are involved (Kercher and Zedler 2004, Zedler and Kercher 2004).

Natural landscapes can be greatly affected by human-caused alterations of natural disturbance regimes and by de novo anthropogenic disturbances. Altering disturbance regimes changes the environments to which species may have become adapted. Habitat fragmentation as a result of human activity is a major cause of indirect alteration of disturbance regimes, especially those of large-scale disturbances. Fires that otherwise might have swept across large regions of the southeastern U.S., for instance, are contained in much smaller areas by a fragmented landscape (Gilliam and Platt 2006). The result may be less frequent, but more intense fires that are now less dependent on global climate patterns and more dependent on fuel accumulation (Slocum et al. 2007). Similarly, floodplain communities once linked to natural flooding cycles are in altered hydrologic regimes (Sparks 1998, Sparks et al. 1990).

Human disturbances of ecological communities may reduce standing biomass and simplify community structure and composition (Menges and Quintana-Ascencio 2003)—or, on other occasions, they may actually increase biomass by interrupting normal burning cycles. Most significantly, human disturbance regimes typically deviate from historic ecological disturbance regimes and oftentimes result in radical shifts in the ecosystem, such as the introduction of exotic species (Menges and Quintana-Ascencio 2003).

Military Disturbances and Associated Ecosystem Consequences

Ground disturbances at bombing ranges, such as here at the Warren Grove Air National Guard Range, New Jersey, are typical of impacts caused by military training operations. (Photo: Douglas Ripley)

Military lands are important ecological reserves because they often encompass large tracts of land that are protected from intensive agriculture and urban development (Boice 1997, Ripley and Leslie 1997a, 1997b, Lillie and Ripley 1998). Furthermore, some of the finest examples of fire-maintained ecosystems within the southeastern United States are found on military bases in and adjacent to artillery ranges where frequent fires are assured and unexploded ordnance provides protection from development (Peet and Allard 1993). But how do military training activities compare to the natural disturbance regimes? And how might military disturbances interact with land management activities on military bases?

Disturbances from military missions may enhance or exacerbate their effects on ecosystem components. In general, military training in terrestrial environments can be broadly categorized into two major types of disturbances—ground maneuvering (tracked and wheeled vehicles) and air-to-ground impacts. Military installations subject to usage by the U.S. Army are often subject to additional impacts from training exercises. Typically, maneuvers on Army installations involve large vehicles that can cover large areas in a single training exercise. The available land base for training has a strong influence on the intensity and frequency of usage (Demarais et al. 1999) and thus on the disturbance effects.

Large-vehicle maneuvers are a widespread use of land and consistently are shown to have negative effects across a variety of terrestrial ecosystems. These repeated human-induced disturbances have no natural analog. The negative effects of ground maneuvering training have been studied in California (Lathrop 1982, Prose 1985), Colorado (Milchunas et al. 1999), Georgia (Dilustro et al. 2002), Kansas (Quist et al. 2003), Washington (Severinghaus and Goran 1981), Wisconsin (Smith et al. 2002), Texas (Severinghaus et al. 1981), Manitoba (Wilson 1988), and western Europe (Vertegaal 1989). Although studies have been conducted across a variety of ecosystems (e.g. deserts, prairies, pine-oak forests, etc.) several generalizations have emerged. In particular, it is the cumulative effect of repeated military disturbances that ultimately results in reduced abundance of perennial species, overall losses of native species, increased numbers of introduced species, and an increase in the amount of bare and compacted soil.

While most studies have focused on effects of large vehicles, the observed results probably also include the effects of other vehicular disturbances as well (i.e. off-road vehicles) that oftentimes occur in conjunction with tracked vehicle maneuvering activities. Road-like features, including active and remnant trails and vehicle tracks, are the most prevalent disturbance features at installations with high-usage maneuvering areas (Dilustro et al. 2002, Quist et al. 2003). These disturbance features act to increase fragmentation of the landscape, which can in turn affect ecosystem-level processes (i.e. spread of fire, flooding, drainage, etc.).

In native grasslands where maneuvering has been examined, at least one study, (in Central Plains grasslands at Fort Riley Military Reservation in northeast Kansas), has shown increased bare soil, reduced total plant cover, and compositional shifts in plant communities (Quist et al. 2003). Reduced cover of the perennial, matrix-forming grasses and native species, and increased cover of annual and introduced species were also associated with high-usage maneuvering training activity. Quist et al. (2003) also reported high-usage maneuvering associated with increased sediment and reduced abundance of benthic insectivores, herbivore-detritivores, and silt-intolerant aquatic species. Watersheds with high military maneuver usage also were characterized by an abundance of trophic generalists and disturbance-tolerant species. Overall, the Quist study suggests that high-usage maneuvering areas had significant ecological effects on the properties of both terrestrial and aquatic ecosystems, with respect to recovery from past disturbances and ecological resilience to future disturbances. In an effort to prevent significant degradation of training areas and to provide a coordinated assessment and monitoring of these impacts, the U.S. Army has implemented an Integrated Training Area Management (ITAM) program.[1] This program emphasizes monitoring of military impacts (erosion, siltation, soil compaction, loss of native plant cover, hydrologic alterations, etc.) on training lands.

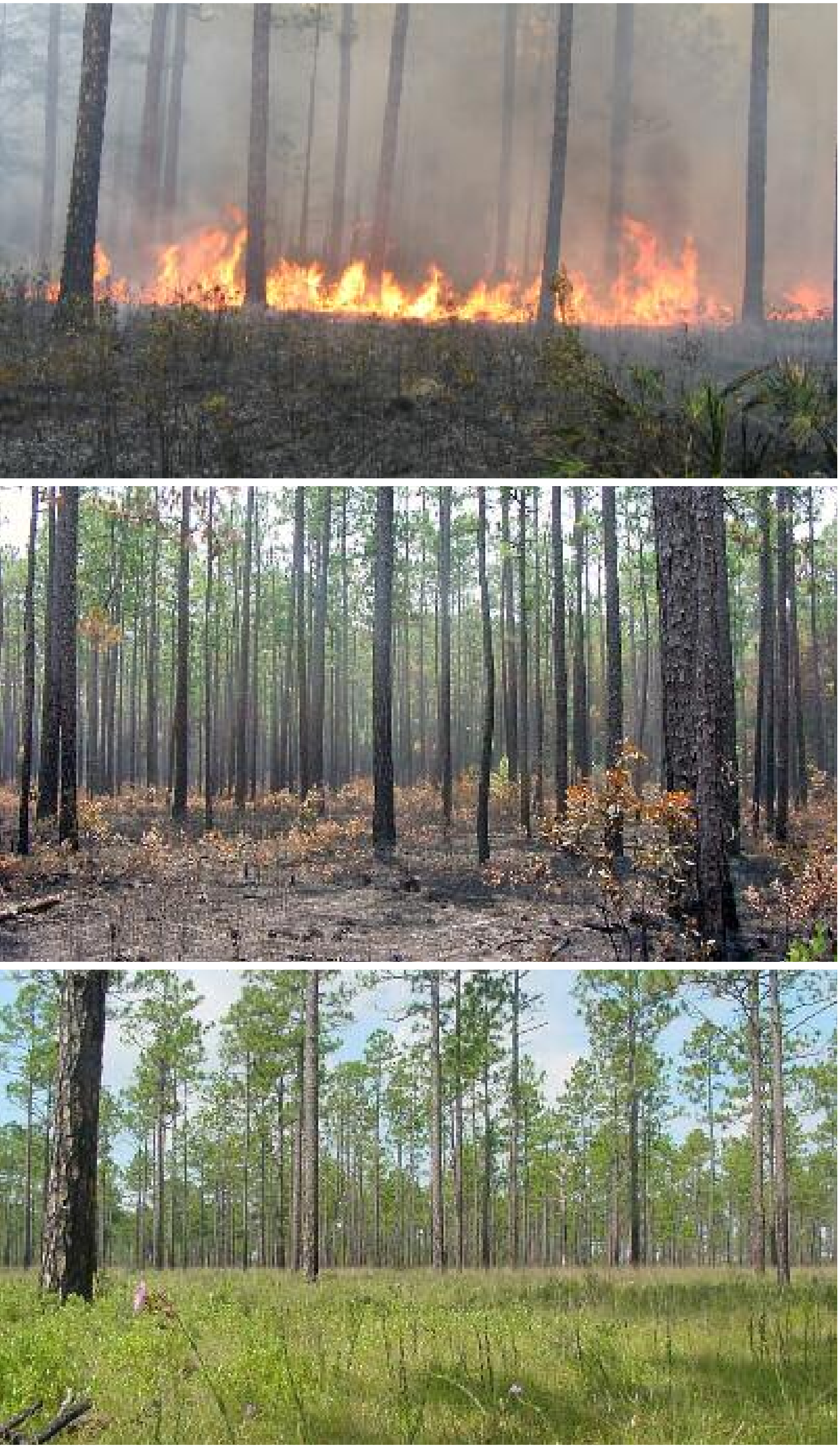
The careful cleanup of inert ordnance at the Barry M. Goldwater Range, Arizona, is an important part of the range restoration programs by the U.S. Air Force and U. S. Marine Corps. (Photo: Douglas Ripley)

Seven students from the Young Women's Leadership School in New York City's Harlem assist in various aspects of the Mill Creek stream restoration project at Eglin Air Force Base, Florida. This program is part of an on-going effort to restore streams on the Eglin Reservation that are home to the endangered Okaloosa Darter. (Photo: Jerron Barnett, U.S. Air Force)

In contrast to ground maneuvering activities, air-to-ground missions are capable of mimicking natural disturbance regimes in some ecosystems. This is particularly true when active bombing and gunnery ranges exist within fire-evolved ecosystems like prairies, savannas, and some wetland types. Aerial bombing and gunnery ranges used by fighter and bomber aircraft, and artillery and mortar gunnery from ground-based weapon systems can provide the ignition sources in fire-evolved ecosystems. Some of air-to-ground ranges that date back to pre-World War II contain remnant fire-maintained plant communities no longer found in the surrounding fire suppressed landscape.

An impact area on Avon Park Air Force Range in central Florida known to receive over a thousand high explosive rounds and several thousand non-explosive rounds strikes annually (Delany et al. 1999) has created a long history of frequent mission-caused wildfires that in turn have provided some of the variation inherent under a natural fire regime. Ordnance-ignited wildfires on this impact area are frequent (>1/yr), may occur year-round, and have occurred since the 1940s. As a result, the vegetation within the impact area has never been fire suppressed. Despite bomb craters created by high-explosive munitions, portions of the impact area with native vegetation support endangered birds, numerous rare plant populations, and some of the highest natural-quality examples of fire-maintained plant communities found in central Florida (Orzell 1997). Similar native species-rich plant communities, often containing enclaves of rare plants, have been recorded elsewhere in or near active air-to-ground impact areas in the southeastern United States (Peet and Allard 1993, Sorrie et al. 1997).

The influence of anthropogenic disturbance, in particular that associated with land management activities (forestry, grazing, etc.) and the military mission on ecosystem-level processes, is also pertinent when discussing disturbance effects. The interactive effects of ecological disturbance regimes and human disturbances (resulting from land management and military activities) also need to be considered, but few studies have examined these interactions. A study conducted by Dilustro et al. (2002) at Fort Benning, Georgia, in the Fall Line Sandhills ecoregion found significant interactions with other activities. In particular, forestry management practices with heavy mechanized training sites were found to favor pine dominance, and open-site, successional or fire tolerant ground cover plant species (Dilustro et al. 2002).[2]



Restoration of long-leaf pine forests and red-cockaded habitat at Fort Stewart, Georgia. These scenes show various stages of the prescribed burning process and the final result of a mature long-leaf pine forest providing excellent habitat for the endangered red-cockaded woodpecker. (Photo: U.S. Army)

Management Implications

Management should be guided by ecological principles and approximate as near as possible ecologically appropriate disturbance regimes, while never neglecting the overarching need to support the military mission. In many cases, restoration of natural disturbance regimes has a positive long-term effect (Van Lear et al. 2005). Special care must be taken, of course, if there are threatened and endangered species involved. Restoration of ecological communities that have long been modified by anthropogenic activities or invasion of exotic species may not necessarily have the intended result or immediately positive consequences. For example, Varner et al. (2000) found that re-introduction of fire to a longleaf pine forest after many years of fire exclusion and organic matter buildup led to an unforeseen high mortality of large longleaf pines. In areas long degraded by fire suppression, repeated burns may be necessary (Heuberger and Putz 2003). Another challenge for land managers is simulating natural disturbances on small parcels of land in a highly fragmented and human-dominated landscape—although one advantage of military installations may be that fragmentation and development are less of a problem than on surrounding, non-military lands. Incorporating disturbance regimes that approximate historic natural disturbances into management schemes should help to improve and maintain structure and function of the disturbance-dependent communities. Doing so, however, may be controversial and demands a great deal of planning and forethought.

NOTES

1. For more on ITAM, see http://www.sustainability.army.mil/function/training_itam.cfm.

2. For more on the Fall Line Sandhills ecoregion and the Department of Defense's interest in it, see http://www.serdp.org/research/CS/CS-1302.pdf.

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A serious disturbance. Strip mines (often called "surface mines" by their practitioners) are among the most visible of human-caused environmental disturbances. This one, in southern Maryland, formerly was devoted to pasture and row crops. (Photo: Fred Powledge)

Restoration work at the Warren Grove Air National Guard Range, New Jersey, where Drexel University has conducted numerous experiments to determine the most effective treatment to restore degraded vegetation on the range. (Photo: Douglas Ripley)

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