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Introduction: a crescendo of destruction

1.1 DISTURBANCE AND HUMAN INTERACTIONS

The pristine world of the past was filled with cataclysms. Volcanoes, earthquakes, floods and fires shaped today's landscapes and every living organism evolved in response to natural disturbance. What we call *Nature* survived in a finely tuned balancing act between the forces of destruction and recovery. Recovery of Nature after destruction was inevitable, but it occurred at variable rates and with a constantly evolving mix of plants and animals. Occasionally natural disturbances were so violent that many species became extinct. Today, the rules have changed; humans have profoundly altered the balance of destruction and recovery, by intensifying natural disturbances and creating many novel ones, without an equal emphasis on recovery. What are the consequences of this meddling by humans with the future of this planet?

Humans have always been at the mercy of large natural disturbances, though we try to forget this fact. The Minoans left little but legends (e.g. Atlantis) after the massive eruption of Santorini (Thera) in about 1623 BC. Agriculture in Japan suffered terrible blows from sixth century volcanic eruptions, as did the economies of both Iceland and Europe by the eruptions of Laki in 1783. Yet we continue to build on active volcanoes, steep slopes prone to erosion and floodplains subject to flooding. Recently, we have felt a growing, yet false, sense of protection from the natural forces of destruction because many of us now live in safe, artificially created environments. Ironically, this decoupling from reality, combined with our immense population growth, results in three dilemmas.

First, that there are many more humans now than ever before implies greater contact with and greater mortality from the same set of natural disturbances. Dense populations now inhabit clusters of cities

Fig. 1.1 The alien butterfly bush (*Buddleja davidii*) is shown in a New Zealand riverbed. A native of Asia, it has invaded floodplains in many parts of the world.

where volcanoes once spewed ash onto uninhabited lands. Second, our collective "ecological footprint" magnifies the effects of natural disturbances on humans. Tsunamis and hurricanes are more devastating where protective coral reefs and mangrove swamps have been destroyed. Landslides are more frequent where logging or road building destabilizes slopes. Deforestation also intensifies the severity of natural floods, while grazing semi-arid lands fuels the expansion of desert dunes. Finally, humans continue to modify the earth so much that an entirely new set of disturbances threatens. These new effects include pollution, biological invasions (Fig. 1.1), overgrazing (Plate 1) and rapid global climate change. Mining and energy production create toxic landscapes (Fig. 1.2). We have homogenized the world's fauna and flora and global warming is changing how species are distributed around the world. What was once "background noise" from human activities has become the principal signal, impossible to ignore.

This book describes how we can harness the natural processes of recovery to address some of these dilemmas caused by humans.

Fig. 1.2 Coal mine tailings in the Midlands of England (UK) produce extremely acid surfaces that challenge restoration. Many such industrial activities create barren, infertile and toxic environments.

Our challenge is to mitigate the immediate effects of disturbances, then to apply the best knowledge and technology to redress the damage.

There is a synergistic interplay between nature and human actions as humanity expands. The geographic and cultural landscapes of this planet have changed dramatically, altering the interactions among humans and disturbances. As the human population grows, it expands into increasingly fragile environments, intensifying impacts of natural disturbances (Fig. 1.3). With some validity, many natural philosophers speak of the ''end of nature'', implying that no place on earth now escapes significant human impacts. Against the background of pervasive human impacts, we believe that our efforts to hasten recovery of landscapes should intensify dramatically.

The barrage of recent natural disasters around the world highlights our vulnerability to the forces of Nature. The Indian Ocean tsunami of December 26, 2004 demonstrated that the 39 percent of us living near coastlines are certainly living in a risky habitat. Those not in coastal areas face other direct hazards (e.g. volcanoes, earthquakes, landslides, fires) and also such indirect impacts as reduced production and shipping of resources from the impacted coastal communities. Damage to one society affects us all in this new era of globalization.

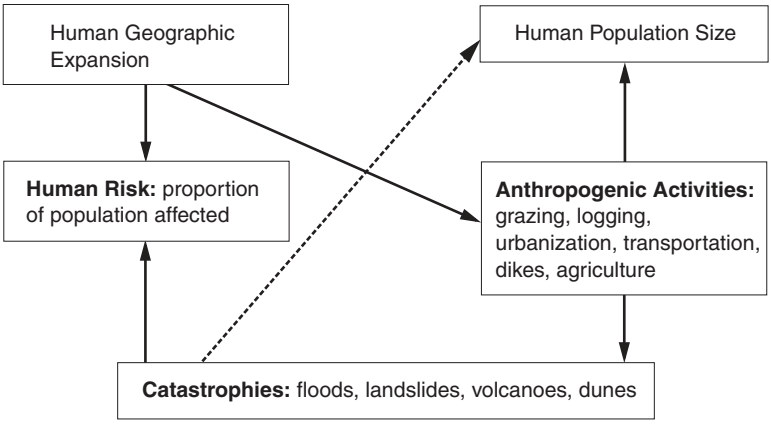

Fig. 1.3 How humans intensify the disastrous effects of natural catastrophes. Solid arrows indicate increasing effects; dashed arrow indicates a retarding effect.

Further, most of the world's active volcanoes are near oceans and can cause underwater landslides that can, and have, resulted in catastrophic tsunamis.

The first, and most tragic, loss from any natural disaster is human life (Table 1.1). More people die, unheralded, from natural disasters than from wars. A second loss is that of property, investments and livelihoods. Obvious direct costs spawned by disturbances such as the Bangladesh floods in 1970, or Hurricane Katrina in the USA in 2005, continue to increase, and the costs even to plan for mitigation of the impacts from these events are staggering. Jobs are lost, people are driven from their homes and lives are devastated. The third type of damage incurred is to the structure, efficiency and productivity of natural ecosystems. Although rarely considered, let alone quantified, these losses are also immense. For example, Hurricane Katrina destroyed over 250 km^2 of coastal wetlands, about the size of the Cayman Islands. Multiple natural disasters have a cumulative, destructive impact on natural resources that puts us all at risk. Human activities exacerbate natural disturbances and create novel ones on increasingly large scales. For example, fires and logging destroy several hundred thousand square kilometers of forest per year, an amount of carbon equal to two-thirds of the total carbon emitted by burning fossil fuels. In Europe, 8,000 km^2 of forest (an area the size of Cyprus) per year burns, and the size, number and intensity of wildfires is increasing. We face a true crescendo of destruction of our own making.

Table 1.1. *Major natural disturbances in human history. The devastation from volcanoes may be direct or indirect from climatic effects or tsunamis. Earthquakes directly destroy cities, but they may also generate powerful tsunamis, or create huge landslides. Dates are AD except where otherwise noted.*

Type	Date	Description	Consequences
Salinization	1500 BC	Irrigation practices in Indus valley cause crop failures; process is repeated over the millennia	Collapse of earliest civilizations
Volcanoes	1623 BC	Thera (Santorini) explodes; tephra falls	Akrotiri destroyed
	1815	Tambora (Indonesia), the largest eruption in history	10,000 killed; ash cloud cools planet leading to further 100,000 deaths from famine and disease
	1902	Mount Pelée (Martinique)	30,000 killed by pyroclastic flows
Earthquakes	526	Antioch (Turkey)	75,000 killed; weakens Christianity in east
	856	Corinth (Greece)	45,000 killed; city abandoned
	1556	Shanzi Province (China)	800,000 killed directly; huge toll from landslides
	1755	Lisbon (Portugal), followed by tsunamis that devastate coastal regions	100,000 killed; Portuguese influence plummets
	1923	Kanto Plains (Japan)	150,000 killed; modern Tokyo reconstructed
	2003	Bam (Iran)	23,000 killed in poorly built houses
	2005	Mountainous Pakistan	80,000 crushed in building collapses and landslides
Tsunamis	1623 BC	Collapse of Thera caldera causes 150 m tall tsunami	Huge toll; Minoan culture devastated
	1531	Earthquake triggered; Lisbon (Portugal)	70,000 killed (30,000 in earthquake)
	1883	Collapse of Krakatau cone (Indonesia)	37,000 killed; some climate effects
	2004	Indian Ocean 9.3 earthquake	300,000 killed; many communities destroyed

Table 1.1. (cont.)

Type	Date	Description	Consequences
Landslides	1966	Mine waste heap collapses at Aberfan (Wales)	144 people killed
	1998	Hurricane Mitch (Honduras)	18,000 people killed (from all impacts)
Floods	1931	Yellow River (China)	3.7 million people killed; weakened resistance to invasion by Japan
Fires	64	Two-thirds of Rome burned	Death toll limited; Christians blamed for destruction
	1666	London	Most of London burned; a true restoration followed
	1871	Chicago	300 killed, but this allowed rejuvenation of city
Hurricanes	1274	Sea of Japan	12,000 Mongols killed invading Japan
	1281	Sea of Japan	70,000 Mongols killed during second invasion
	1780	Lesser Antilles (Martinique, Barbados, St. Eustatius)	20,000 killed
	1900	Galveston, Texas	12,000 killed
	1970	Bangladesh	500,000 killed by storm surges
	1974	Honduras (Hurricane Fifi)	10,000 killed

Disturbances have altered the course of human history in many ways (Table 1.1). In this book, we will focus on how humans respond to and often intensify the effects of large-scale, natural disturbances such as volcanoes, earthquakes, floods and fires. We will also cover some purely anthropogenic disturbances, such as grazing and mining, that impact landscapes on a large scale. However, we will not discuss natural and human generated disturbances that do little damage to landscapes, even if their impact on humans is enormous (e.g. urban fires, epidemics and famine). We will say little about deliberate destruction, usually associated with warfare. Examples include the massacres that followed the capture of such cities as Milan (by Goths in AD 538),

Jerusalem (by Christians in 1099) and Nanking (by Japanese in 1937–8). The "normal" business of military activity, however, is included. For example, driving heavy vehicles across the landscape destroys vegetation which should be restored.

Disturbances are not all traumatic exclamation points. Many result when the natural ability of an ecosystem to withstand chronic adverse effects and yet remain productive is finally overwhelmed. Many systems will not be able to recover from certain disturbances even when the disturbance ceases. Deforestation and overgrazing are well-known causes of gradual yet severe disturbance. Both processes promote erosion and nutrient losses. Others, less widely appreciated, include accumulating pollutants, siltation of marshes, the gradual desiccation of lakes due to plunging water tables and the filling in of wetlands. We will explore these slowly unfolding disturbances in several places.

We will also describe a few devastating forces from the perspective of how ecosystems respond. In particular, lakes and coastal ecosystems are being subjected to natural disasters, such as hurricanes, and human behaviors that destroy marshes and lakes. As the sole species that is a global geological force, we must accept the duty of stewardship. It has been rare for a society to understand the consequences of chronic disturbances and rarer still for effective policies to be instituted to avert crises. Forces that a healthy society could withstand can destroy a weakened one. To guard against adverse impacts of changing climates and other insidious disturbances such as soil erosion and desertification, ecosystem damage should be avoided and repaired to retain productivity and resilience. Morality aside, it is in our own best interests that we mitigate the effects of both self-imposed and natural disturbances.

Ecology has emerged from the academies to become a discipline that is inextricably tied to the fate of humanity. Concepts such as sustainability and biodiversity are now widely discussed and ecological journals that deal with practical applications are common. Restoration has joined conservation as a scion of ecology. While ecologists know a lot about restoring land, much remains to be learned and translated into action. As is always true, the ability to act has to be combined with the will to act. The will of a society can only be derived from a political and economic calculation that demonstrates that action is more valuable than inaction. We believe that the political will for a broad and comprehensive approach to landscape rehabilitation does not yet exist. While the final reports of endless international conferences are filled with action plans to improve the land, those plans

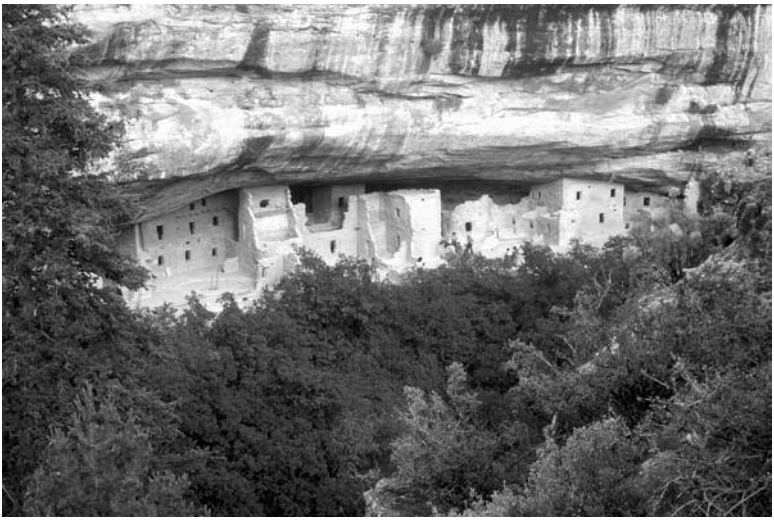

Fig. 1.4 Cliff dwellings of the Anasazi people at Mesa Verde (Colorado, USA). These dwellings, now protected in a US National Park and recognized as a World Heritage Site, housed this native population for the final 100 years of a rich Pueblo culture that thrived from AD 600–1300. Abrupt abandonment of the area was likely due to a combination of drought, crop failure, resource depletion and overpopulation.

are rarely implemented. We will demonstrate that restoration is a necessary, though far from sufficient, action to sustain societies, mitigate foreseeable disturbances and provide opportunities for greater human well-being. Today, we can make choices. Informed choices enhance the productivity of ecosystems and promote the stability of a society. As Jared Diamond convincingly demonstrates in "Collapse," the wrong choices have led many civilizations to fail. The Babylonians, Mayans and the Anasazi (Fig. 1.4) were three advanced groups that disappeared or became ghosts of their former glory due largely to disturbances after long-term environmental degradation. Many cultures rose and fell due to low-grade disturbances such as overgrazing or poor agricultural practices that caused salinization and erosion. Rarely were signs of gradual decline noted until some extreme event triggered the crash of the economic basis for the culture in question.

Security can ultimately be defined in ecological terms, and restoring ecosystems to productivity and health is fundamental to the security of any society. In these terms, human societies are less secure now than at any time since the expansion of agriculture. Various threats

exist, not only to particular countries or regions, but also to the globe and to all its inhabitants. The environment, and the magnificent biodiversity that it sustains, is gravely threatened. Direct pressures include conversion of habitats (e.g. forests to farms; farms to deserts), invasions of exotic species, over-harvesting of resources and pollution. Indirect pressures include habitat fragmentation and climate change. We will not survive long on this planet without addressing the urgent issues of ecological security and sustainability.

1.2 DISTURBANCE AND RECOVERY

Intense natural disturbances are normal events that can benefit ecosystems. Floods deposit nutrients that in turn support fertile alluvial valleys. Fires rejuvenate soils, help to control diseases and often stimulate new growth. Even volcanoes benefit the landscape by creating fertile land. Indonesia and Sicily, two densely populated regions in the world, were formed by volcanism and their soils retain their fertility even under intensive agriculture. Such disturbances as floods, fires and volcanoes thus initiate cycles of renewal without which the landscape would otherwise degenerate, as nutrients are lost. Very old soils such as are found in Australia and Africa are relatively infertile. The new surfaces that result from disturbance are often more fertile than the surfaces they cover or remove. Under natural conditions, biological colonization and physical weathering repair the devastation spawned by natural disturbances through the process of natural recovery or *ecological succession*.

The key to being able to meet the challenges posed by natural disturbances is an understanding of succession. Ecological succession describes how ecosystems repair themselves after disturbances. Ecologists are developing a deeper understanding of these processes and have learned many of the constraints on natural succession. We can use these lessons to accelerate and improve restoration efforts on devastated land and to improve the economic efficiency of these efforts (Fig. 1.5).

Natural recovery may resurrect an ecosystem if disturbance is within historical bounds. Primary succession is one of the most important ecological processes on the planet (Box 1.1). It results when the biota reclaim newly formed land, often against severe odds. Among the constraints to succession are combinations of infertility, lack of suitable germination sites, lack of soil, drought and the failure of colonists to reach the site. Secondary succession is the recovery from less

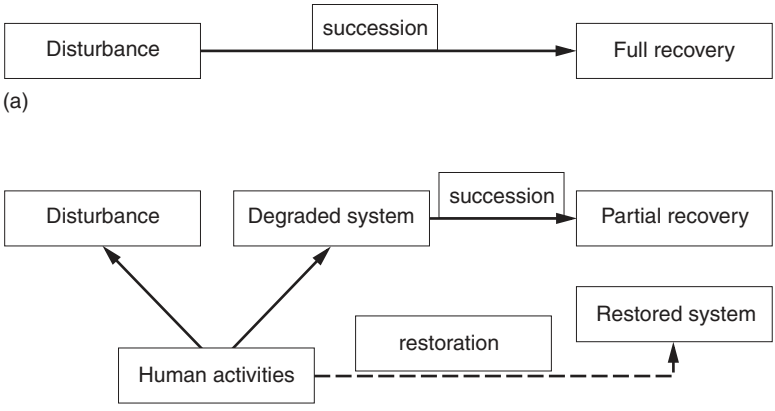

Fig. 1.5 Models of ecosystem dynamics. (a) Natural disturbance followed by ecological succession leads to full recovery. (b) Humans intensify disturbance, permitting only partial recovery, often to a degraded form. Intervention (dashed line) may promote greater recovery and closer approximation of the initial vegetation mosaic.

profound disturbances that allow at least some survivors to reestablish. It is more rapid and less constrained than is primary succession.

Where human impacts are limited, succession can produce intact, fully functional ecosystems, even if they are composed of arrays of species that differ from the pre-disturbance collection. In the contemporary context, where barriers to dispersal and migration abound and where even the air is sometimes toxic, natural recovery is problematic. Normally, renewal includes weathering, nutrient inputs, colonization and habitat improvements both by the colonizing species and others. Today, it is unlikely that unaided recovery can produce natural landscapes. Agriculture *arrests* succession at a young stage so that, when the land is abandoned, it may not recover. Forestry *deflects* succession to more economically productive but biologically impoverished habitats such as tree farms. When forestry ceases, many integral species may not be available in order for succession to proceed unaided.

Humans interact with the disturbance regime of any region by mimicking natural effects (e.g. pavement resembles lava) and altering the frequency (e.g. by fire prevention, flood control) or intensity (e.g. by adjusting grazing levels) of a disturbance. Humans also create unprecedented disturbances of many types (e.g. mine tailings, acid deposition). These alterations make it increasingly unlikely that natural succession can restore damaged landscapes without help.