The Benefits of Natural Disasters

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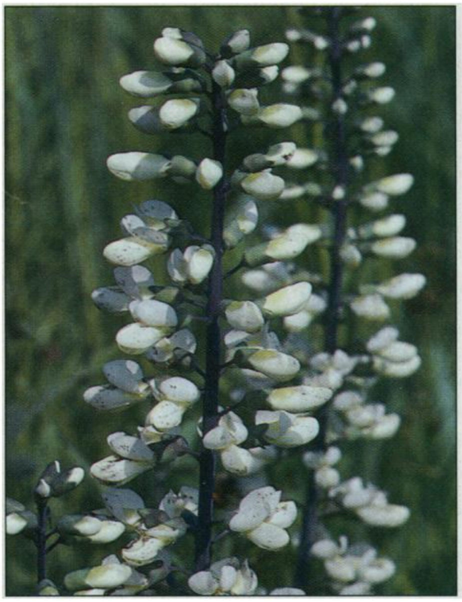
Humans have battled fires and floods for eons, but it is only in the past half century that we have started to gain the upper hand. Although the short-term benefits of human interference are clear, human-mediated modifications of the physical forces of nature can have unintended long-term costs. A simple example is provided by the huge losses caused by the floods of 1993 in the midwestern United States, which were exacerbated by dikes that eliminated a natural safety valve—the river flood plains. Two papers in this issue (*1*, *2*) now show that the disruption of landscape-level processes such as floods and fire has unexpected, cascading consequences on the abundances of many species.

The unintended consequences of suppressing natural disasters illustrate the complexity of natural ecosystems. Complexity, however, does not mean that ecosystems are mysterious or not amenable to accurate prediction. As ecology has matured as a discipline, its focus has shifted from descriptive natural history (often of a single species) to mechanistic and predictive approaches that increasingly analyze interactions among species, ecosystem processes, and feedback among these.

In an elegant example of this mature approach, Wootton *et al*. experimentally determined the effects of changes in the intensity and duration of floods on fish and aquatic invertebrates in California rivers. At first inspection, it might seem that periodic flooding would harm such predatory fish as steelhead trout by scouring their habitat free of the aquatic invertebrates upon which they feed. Not so, discovered Wootton *et al*. In an analysis of the food chains of these rivers, they found that scouring floods did harm aquatic invertebrates, but some species much more than others. The species most harmed by flooding was also the most resistant to feeding by predatory fish. The species that survived scouring floods best, and that dominated the streams afterward, were much better food for the steelhead. Thus, periodic scouring floods, which are prevented by dams (unless there are deliberate releases, as have occurred recently on the Colorado River) are essential for steelhead. This results from an interspecific life history tradeoff in the aquatic invertebrates: The species most resistant to fish predation, protected in spaces between rocks, are also the most susceptible to scouring floods because they are crushed by rolling rocks in turbulent water. A simple mathematical model of this multitrophic level system predicted the results well. A major take-home lesson from the study is that the ecology of a species can only be understood in the context of its ecosystem and the disturbances that its ecosystem experiences. A simple focus on the physiology and life history of steelhead would miss the big picture. By analogy, efforts to manage other species may be similarly misguided if they take too narrow a view. This suggests that the best way to preserve biodiversity is to preserve entire ecosystems and their landscape-level forces. The proof, though, is in the pudding, and the second paper, by Leach and Givnish, provides a savory final course.



Wild white indigo (*Baptisia lactea*). Like many nitrogen-fixing species of midwestern prairies, wild white indigo may have undergone a dramatic decline because its habitat is no longer visited by periodic fires (*2*). [Photograph by T. J. Givnish]

During the 1940s and 1950s, the great botanist John Curtis surveyed the plant species compositions of prairie remnants in Wisconsin, which has lost about 99.9% of its original prairie. Leach and Givnish built on this heritage by resampling 54 of Curtis's sites, originally chosen to control for differences in soil fertility. This important long-term study showed that about one-third of the plant species originally present at each of these "undisturbed" sites had been lost during the intervening 40 to 50 years, that is, had gone locally extinct. Moreover, even when data for all 54 plots were combined, more than 14% of the 266 plant species originally present in this group of sites had been lost. Some of these species had been replaced by woodland species that invaded the former prairie sites, but there was still a net loss of about 7% of the plant species diversity of each site.

The loss of species is consistent with the conventional wisdom of ecology—that habitat fragmentation leads to species extinctions—but the magnitude of the losses is surprising. Analyses of the traits of the lost species provided a bigger surprise. The species lost from the prairie remnants were a highly biased subset, composed of smaller, shorter plant species and nitrogen-fixing legumes. Such species, Leach and Givnish suggest, are fire dependent, and their biased loss may be caused by an unexpected component of habitat fragmentation—the loss of a major landscape-level force, periodic fire. The disruption of natural fire cycles resulting from agriculture, roads, and other human activities, as well as from overt fire suppression, it seems, was the major force behind the unexpectedly high rate of species loss in these prairie remnants.

The forces controlling the species composition, diversity, dynamics, and stabilities of Earth's ecosystems remain one of the major mysteries of modern science. The interactions among dozens to hundreds of species within a local ecosystem are complex enough and have been the focus of most research to date. However, these papers and others [for example, (*3*)] show that the interactions among species also depend on landscape- and ecosystem-level physical processes such as floods and fire, and that disruption of these can have just as great—or greater—an impact than classical habitat destruction. A seemingly pristine river that has been dammed, or a forest or prairie remnant that is inadvertently protected from fire, is not being preserved.

The study of global change is, in reality, the study of unintended consequences of societal activities. Whether the actions be the human-caused release of CO_2 and other greenhouse gasses, the introduction of exotic species, human domination of the nitrogen cycle, the destruction of natural ecosystems, or human-caused interruptions of landscape-level ecosystem forces such as fires and floods, it is becoming increasingly clear that the world will be a markedly different place if we continue to ignore the long-term consequences of our actions.

References

1. J. T. Wootton, M. S. Parker, M. E. Power, *Science* **273**, 1558 (1996).
2. M. K. Leach and T. J. Givnish, *ibid.*, p. 1555.
3. C. D'Antonio and P. Vitousek, *Annu. Rev. Ecol. Syst.* **23**, 67 (1992).

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