Fire, Ecosystems and People: A Preliminary Assessment of Fire as a Global Conservation Issue

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Ed. note: In 2002, The Nature Conservancy (TNC), WWF (World Wide Fund for Nature) and IUCN–The World Conservation Union formed the Global Fire Partnership and pledged to work together and with partners to address the causes and ecological and social consequences of altered fire regimes across the world. Most of the data used to develop this report were derived from a May 2004 experts' workshop convened by the partnership. Experts from six continents gathered in Sigrisvil, Switzerland, and conducted a rapid assessment of fire conditions across the earth's most biologically significant ecoregions. The data were compiled, analyzed, and summarized by TNC's Global Fire Initiative, which is responsible for this report and any errors herein. TNC published the initial document in October 2004.

Ecosystems and people: living in a world of fire

FIRES ARE AS OLD AS THE EARTH ITSELF. For millions of years, fire has been, and continues to be, a major evolutionary force shaping the nature of life on earth.

Even in a rapidly modernizing world, fires are very common, whether naturally ignited by lightning or set intentionally or accidentally by people. Every day, somewhere on earth, thousands of hectares of forests, woodlands, savannas, grasslands, shrublands, tundra, deserts, wetlands and agricultural fields are burning, on every continent except Antarctica.

At present, scientists' best estimates suggest that, around the world, an area half the size of China burns in an average year.

Fire has many faces. For people and for ecosystems, fires can be harmful, beneficial, or benign, depending on where and how they burn. For thousands of years, human communities have benefited from fire and the burning of vegetation and other biomass to cook, heat, hunt, grow crops, manage vegetation, and produce energy. At the same time, fires can threaten human health and livelihoods.

From an ecological perspective, naturally ignited fires and fires started by people that reinforce natural fire cycles (Figure 1) are beneficial and life-sustaining in ecosystems that have evolved with fire. But fire can also be harmful, especially in ecosystems composed mainly of plants and animals lacking adaptations to withstand or take advantage of fire. Ecologically, human fire use is largely benign when restricted to agricultural fields.

Yet, ecologists believe that fires are behaving differently now than at any other time in history. Humans have become the primary source of ignitions, outstripping lightning and other natural sources. Human-induced global warming and changing patterns of rainfall and drought are likely already influencing the way

Figure 1. In fire-dependent ecosystems, prescribed fires, such as this one in the northeastern U.S., can be used to mimic natural fire and thereby achieve ecological objectives. © Jim Powers, Nantucket Inquirer and Mirror.

fires behave in many parts of the world. Coupled with other impacts like landscape fragmentation and the introduction of nonnative plants that thrive on fire, ecosystems that have seldom experienced fire are burning. At the same time, in fire-dependent ecosystems that have been exposed to flames for hundreds of thousands of years, scientists believe there are fewer hectares burning now than in the past because people are directly and indirectly excluding fire.

A growing number of ecologists and conservationists believe that "altered fire regimes"—meaning too much, too little, or the wrong kind of fire—are a major threat to biodiversity conservation. They believe that if not given full due and integrated with other efforts, fires (or the lack of fires) have the potential to undo decades of progress in conservation and sustainable development. Fires and the impacts of altered fire regimes are often overlooked by conservationists for several reasons: alteration of fire regimes is almost always linked to other issues, like agriculture or forestry; alteration can be a slow and mostly hidden process, occurring incrementally and quietly over decades; and large fire outbreaks, which are episodic and largely uncontrollable, capture most of the attention and funding, which subside as the fires wane, and are largely focused on impacts on people.

A preliminary assessment of fire as a global conservation issue

Is fire a major conservation issue? A growing body of anecdotal and scientific evidence suggests that it is, but the science remains uneven. The global extent of the conservation threat is still largely undocumented. The United Nations and other bodies have made various attempts to assess the impact of fires on people and the capacity of nations to manage fire outbreaks, but none of these assessments to date have addressed biodiversity conservation and fire's changing role in the earth's ecosystems. This report is a first attempt to address the relationship between biodiversity and fires. Developed by TNC working in partnership with the WWF, IUCN, and scientists from around the world, this report provides a preliminary, coarse-scale assessment of the extent to which fire is beneficial or harmful, principally from an ecological perspective. It looks at critical ecoregions to estimate the degree to which ecologically uncharacteristic fire regimes may pose a threat to the conservation and sustainability of major habitat types, and it identifies the major sources and underlying causes of fire-related degradation. Finally, it identifies—at this point, broadly—roles for conservationists, local communities, governments and scientists.

Assessing fire: overview of methods

This initial assessment was conducted using a classification of the earth's 13 major

terrestrial habitat types (Olson and Dinerstein 1998). Geographically, the assessment was performed on a subset of the WWF Global 200 ecoregions (Olson and Dinerstein 1998) plus additional ecoregions identified by TNC, that taken together, comprise some of the richest, most representative, rarest, and most distinctive examples of the earth's major habitats. Future versions of this assessment will include additional ecoregions.

Developing socially and ecologically acceptable and sustainable solutions to conservation problems depends on a sound understanding of ecosystem dynamics and human actions, including the role of fire. Understanding fire regimes is essential to determining whether and how human actions are beneficial, benign, or harmful from an ecological perspective. Ecosystems can be described in terms of typical fire regimes that operate within known or expected ranges of variation in key fire regime attributes or characteristics. Attributes include frequency (including the absence of fire), severity, intensity, spatial scale, seasonality, and predominant ignition source. Ecosystems and major habitat types can generally be classified as belonging to one of three broad fire regime types: fire-dependent/influenced (Figure 2), fire-sensitive, or fire-independent.

Figure 2. Fire is an essential process in fire-dependent/influenced ecosystems. Wildflowers and grasses thrive in a burned, fire-dependent lodgepole pine forest in Yellowstone National Park. National Park Service photo / Jim Peaco.

Fire regime alteration can be defined as the extent to which current patterns of fire have departed from the natural, historical, or ecologically acceptable ranges of variation in key fire regime attributes (e.g., fire frequency, severity) associated with and characteristic of different ecosystems. "Ecologically acceptable" fire regimes may be influenced by people, while still acting to maintain the associated plant and animal populations and ecological processes characteristic of a particular ecosystem (or major habitat type, in this assessment). Thus, altering key attributes of a fire regime is assumed to create current or long-term conditions that threaten the persistence of native plant and animal populations associated with that fire regime. From this perspective, altering one or more fire regime attributes stresses or degrades an ecosystem by significantly changing composition, structure, or function, which in turn can establish a trajectory toward a fundamentally different ecosystem type and fire regime. Evidence from a variety of ecosystems suggests that once a new trajectory is established, halting or reversing change can be very difficult or impossible.

For each ecoregion and major habitat type, experts were asked to determine alteration by describing current fire regimes and the departure from an ecologically acceptable range of variation in key attributes. (Later iter-

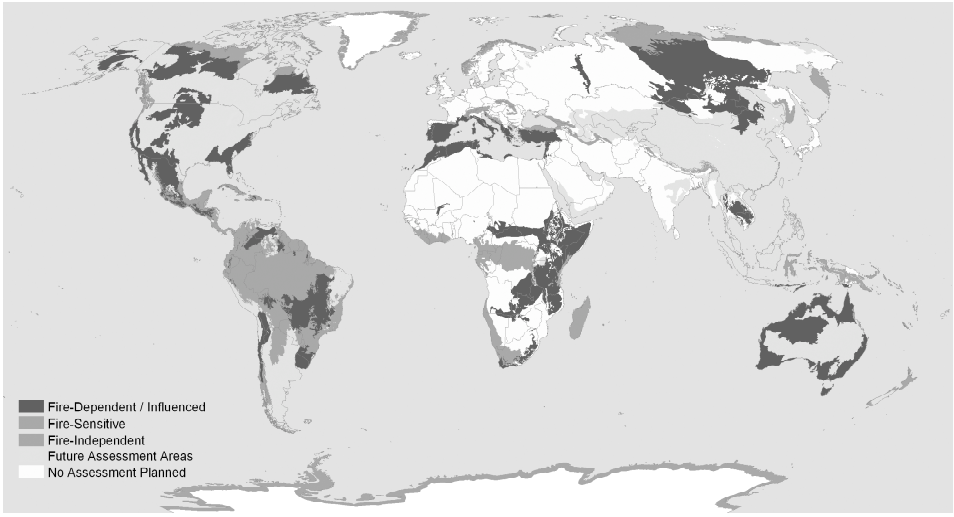
ations of this report will document the key attributes used in classifications and rankings, including a summary of related results.) Current status and trend were inferred by assessing how far key fire regime attributes have departed from what is considered to be ecologically acceptable and sustainable, and is the basis for identifying underlying causes and the human sources of altered fire regimes. This assessment will be updated as new and better information and data become available.

Fire regimes: the role of fire in ecosystems

Based on ecoregions assessed in this report, experts classified 46% of the global area of major habitat types as fire-dependent/influenced; 36% as fire-sensitive; and 18% as fire-independent (Figure 3).

In fire-dependent/influenced ecosystems, fires—either wildfires or fires set by people that mimic wildfires—are as fundamental to sustaining native plants and animals as are sunshine and rain. Many of the world's ecosystems, from the taiga forests of Siberia to the savannas of Brazil's Cerrado and the eucalyptus forests of Australia, have evolved with fires that occur within the bounds prescribed by annual and seasonal climates, vegetation types, lightning, fuel accumulation, topography, and a variety of other factors. Where ecosystems have evolved with fire, fires maintain a characteristic ecosystem structure and composition. Not all fire-dependent/influenced ecosystems burn the same way. For example, many forest, grassland, woodland, savanna, and wetland ecosystems are characterized by frequent, low-intensity surface fires that act to maintain an open structure with numerous grasses and forbs. On the other hand, some fire-dependent/influenced shrubland and forest types experience infrequent, intense, "stand-replacing" fires. What characterizes all of these ecosystems, though, is the resilience and recovery of their plants and animals following exposure to fires occurring within the range of variation characteristic of that ecosystem's fire regime type. In fact,

Figure 3. Priority ecoregions and dominant fire regions. Of important conservation ecoregions, experts estimated that 46% are predominantly composed of fire-dependent/influenced fire regimes, 36% are fire-sensitive, and 18% are fire-independent. Ecoregions almost always include multiple fire regime types, but were assigned to only one dominant type. © The Nature Conservancy: I. Levshina, Conservation Systems Office.



excluding fire often results in wholesale and ecologically and socially undesirable ecosystem changes. In some parts of the southwestern U.S., for example, fire exclusion has converted native grasslands important for both wildlife foraging and livestock grazing to closed canopy pine forests with few grasses, fueling very intense and damaging wildfires.

In fire-sensitive ecosystems, frequent, large, and intense fires were, until recently, rare events. In these ecosystems, most plants and animals lack adaptations that allow them to respond positively to, or rapidly rebound after, fire. These areas are typically cool or wet and consist of vegetation and an ecosystem structure that inhibits the start or spread of fire. Human-induced fires in a fire-sensitive ecosystem can influence long-term ecosystem structure and relative abundance of species, and/or limit an ecosystem's size. Examples of fire-sensitive ecosystems include the tropical moist broadleaf forests of the Amazon Basin (Figure 4), Southeast Asia, and the Congo Basin. These ecosystems are vulnerable to even mild fires that can trigger a cycle of more frequent and larger fires, leading to ecosystem conversion and creating conditions that favor fire-prone vegetation, including non-natives.

Figure 4. Many of the earth's tropical moist broadleaf forests, including those in the Amazon Basin, are vulnerable to fires. Initial low-intensity fires are followed by cycles of more fires of increasing severity. © Gustavo Gilabert/CORBIS SABA.

In fire-independent ecosystems, fire is largely absent because of a lack of vegetation or ignition sources, such as in Africa's Namibian Desert or tundra ecosystems on the coast of Antarctica.

Altered fire regimes: a preliminary estimate of status and trends

Experts concluded that some 84% of the area of ecoregions identified as being critical to biodiversity conservation and assessed in this report are at risk from altered fire regimes. In only 16% of these critical ecoregions (by area) was fire thought to be occurring within ecologically acceptable bounds (Figures 5–7).

Overall, fire-sensitive ecosystems—that is, ecosystems such as tropical moist broadleaf forests consisting primarily of plants and animals lacking adaptations to significant fire—were the most threatened, with more than 93% of the area judged as having altered fire regimes. Fire-dependent/influenced ecosystems—that is, ecosystems such as African savannas or boreal forests—while in relatively better condition, were still very much in trouble, with more than 77% of the area classified as having altered fire regimes.

Finally, although climate change was identified as a highly ranked threat in fire-dependent/influenced habitat types, the experts we consulted recommended that it be pursued separately, because of its complexity and scope. Thus, the impacts of climate change may be underestimated in this assessment and its ranking may change in future iterations of this report.

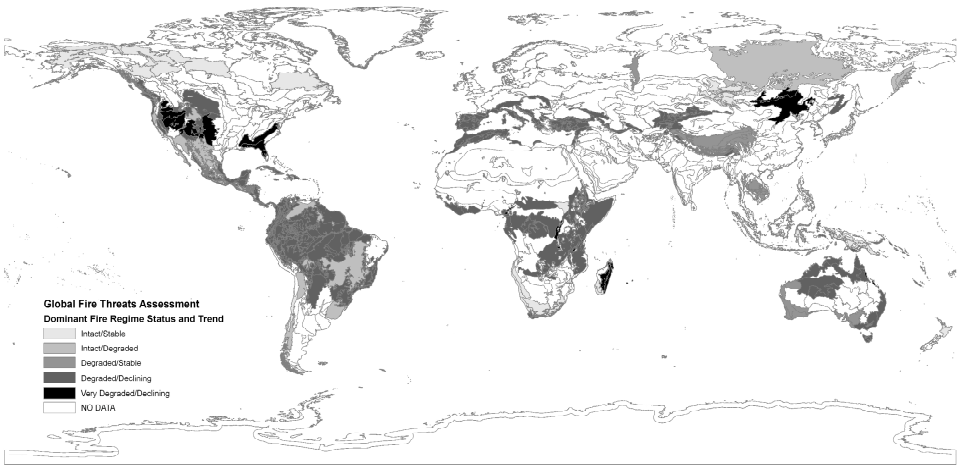


Figure 5. Current status and trends of fire regimes for major habitat types. They were derived by expert comparison of current fire regime attributes (e.g., fire frequency, severity) to ecologically acceptable regimes for that habitat type. © The Nature Conservancy: I. Levshina, Conservation Systems Office.

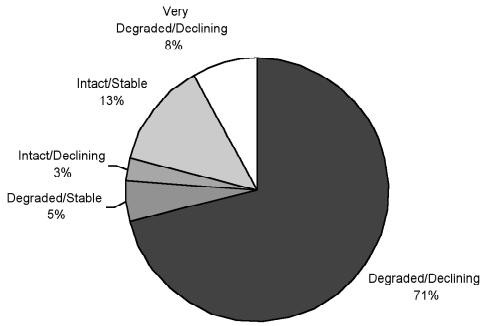


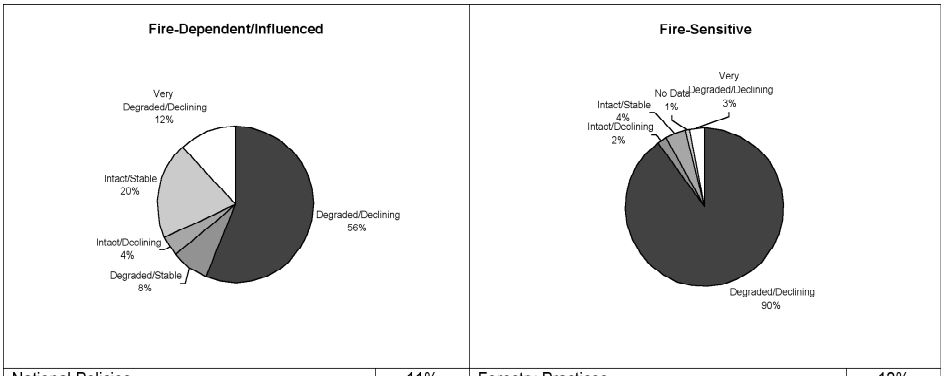
Figure 6. Fire regime status and trend for all terrestrial habitat types combined. A preliminary estimate of the overall status and trend of fire regimes indicates that an estimated 84% of major habitat types and ecoregions is degraded.

Sources of fire regime alteration

When fire ecologists review conservation and development plans, or the aftermath of catastrophic fire events, they are often puzzled as to why conservationists, local communities, and governments failed to integrate ecosystem fire dynamics in plans, or missed the warning signs of pending disasters. One answer, confirmed by this assessment, is that in many ecosystems fire regime alteration is a slow and incremental process, sometimes occurring over decades, and is often linked to multiple sources of degradation related to the many ways that people exploit ecosystems. Until some critical threshold is passed, change may not be noticed. Capturing the attention of the public and decision-makers often requires a triggering event, like a prolonged drought and uncharacteristically severe fires, even though by then it may be too late to avert catastrophic social and ecological consequences.

Understanding the linkages among alterations and sources of alteration is an essential step in identifying appropriate solutions. The sources of alteration identified by experts in this assessment were as different as grazing practices, climate change, and arson related to civil unrest.

In many fire-dependent/influenced ecosystems, experts identified declines in fire fre-



National Policies	11%	Forestry Practices	12%
Climate Change	11%	Rural Growth	11%
Grazing	9%	National Policies	11%
Rural Growth	9%	Fire Management Capacity (lack of)	10%
Arson	9%	Traditional Fire Use	10%
Fire Management Capacity (lack of)	8%	Illegal Forestry	9%
Crop Production	6%	Ecosystem Conversion	8%
Cultural Attitudes	6%	Arson	8%
Ecosystem Conversion	5%	Crop Production	8%
Invasive Species	4%	Climate Change	3%
Traditional Fire Use Cessation	3%	Other	11%
Mining, Oil, Gas Development	3%		
Fire Suppression	3%		
Urban Growth	3%		
Other	7%		

Figure 7. Status and trend of terrestrial habitat fire regimes and the major sources of alteration were estimated by experts. They considered the historical influence of people, including ecologically benign or beneficial uses of fire. Status was determined by the proportion of a given fire regime's key attributes (e.g., fire frequency, severity) that had departed from what experts judged to be ecologically acceptable.

quency and resulting fuel accumulation as the alterations that are causing uncharacteristically large, severe, and destructive wildfires, such as those now occurring in the western U.S. and southern Australia. In these two cases, the principal source of alteration is well-meaning national fire suppression policies aimed at protecting people, and which, in the U.S., is coupled with forest management and grazing practices.

Alternatively, in fire-dependent/influenced ecosystems fires also can be too frequent, such as those now occurring in Siberian taiga forests. Fire ignitions have increased as a result of rural population growth triggered by the decline of the Russian economy; the ecological result has been forest loss and declines in fire-dependent keystone species, such as larch, and the rapid liberation of millions of metric tons of stored carbon.

In fire-sensitive ecosystems, large, spectacular, and destructive outbreaks of fire tend to occur sporadically, such as those in Central America and Mexico's moist broadleaf forests in 1998 and 2000. These fires were triggered by large-scale logging, road-building, and increased human settlement in and near protected areas over time, coupled with a prolonged and severe El Niño-induced drought, which, in turn, was thought to have been exacerbated by global warming.

This assessment also indicates that the way that fire is directly used and managed by people—culturally and institutionally—is also a major influence, on par with other sources of alteration. For example, in fire-sensitive

ecosystems, traditional fire use and escaped fires, combined with the lack of fire management capacity, was judged by experts to be just as significant a contributor to ecosystem degradation as the indirect fire impacts of legal and illegal forestry, which tend to capture much more attention.

A call to action: broad overview

Experts convened by TNC, WWF, and IUCN identified altered fire regimes as a major conservation issue, affecting an estimated 84% of the area of ecoregions recognized by conservationists, scientists, and many countries as being critical to global biodiversity conservation. This assessment reinforces the urgency of accounting for fire regimes when assessing threats and developing socially acceptable and ecologically appropriate conservation strategies. Durable solutions are not as simple as suppressing unwanted fires or allowing beneficial fires. Managing an ecologically and socially acceptable role for fire will require investing in science, finding common goals, creating innovative approaches, and building institutional resolve. Collaboration across government, private, academic and community sectors will be critical. As a starting point, we recommend the following.

For communities. This preliminary assessment of underlying causes identifies a critical role for local communities and people. Rural population growth and local land uses, such as grazing, agricultural practices, and traditional fire use, can be both major sources of alteration as well as of ecologically appropriate maintenance of both fire-dependent/influenced and fire-sensitive ecosystems. In all nations, effective and integrated community-based approaches need to empower local people and institutions by engaging them in documenting and understanding the fire-related dynamics of local ecosystems; establishing socially and ecologically acceptable goals for ecosystems; integrating cultural and economic issues; addressing underlying causes, not symptoms; reinforcing, modifying, or finding alternatives to traditional fire uses; and building the capacity to plan for and manage fires effectively.

For government. Government policy emerged as an important source of fire regime alteration, ranking first and second in fire-dependent/influenced and fire-sensitive ecosystems, respectively. Government policies are an indirect driver of many sources of fire alteration, including rural and urban growth, rural abandonment, legal and illegal logging, and ecosystem conversion. And agreements between governments, for example those dealing with climate change, are critical. Governments can ensure that laws and policies result in equitable sharing of costs and benefits related to fires, recognize community-use rights, and remove incentives that encourage industry and local people to start harmful fires or suppress ecologically beneficial fires. In many nations, government economic and social policies are key drivers of rural development and resource use, and in an increasing number of countries, government agencies are major players in fire management. Governments, industry, and other landowners will need to invest in fire management, educate resource managers, and assist in developing local capacity for effectively managing both unwanted and desired fires.

For scientists. Scientists have a critical role to play. Building the case for action at global, country, and local levels requires credible assessments of fire regime types and underlying causes of fire-related problems. As is evidenced by this report, many data gaps still exist. Often even basic information on the ecological role of fire, fire impacts, and the relationships among biodiversity, fire, and

Fire Facts

- In Ghana, 29% of the gazetted forest estate, or about 320,000 ha, has been deforested, principally due to repeated forest fires since 1983. A further 55% has been partially degraded. It is estimated that an amount equivalent to 2% of Ghana's potential gross domestic product (US$100 million) is lost annually to fires, significantly reducing funds that could have supported schooling, health services, and poverty reduction.
- The 1997–1998 fires in Southeast Asia burned more than 9.7 million ha, resulted in US$10 billion in economic losses, severely damaged many fire-sensitive tropical forests in protected areas, elevated Indonesia to the upper tier of global greenhouse gas producers, and affected the health of more than 100 million people.
- Large fires in the U.S. in 2000 resulted in property losses of more than US$9 billion and suppression costs of $3 billion. Scientists estimate that 51 million ha of U.S. federal lands containing fire-dependent ecosystems are undergoing major shifts in composition, structure, and function because of nearly a century of fire suppression, especially in the interior West. Unless actively restored through prescribed fire and increased natural fires, augmented by judicious forest thinning, many natural communities and species identified as targets for biodiversity conservation will be imperiled. In 2001, U.S. federal agencies treated less than 1% of the total acreage necessary to reverse these changes.

A Call to Action

Communities
- Adopt integrated ecological fire management
- Document fire-related ecosystem dynamics
- Evaluate traditional fire use
- Establish ecosystem goals
- Identify and address underlying causes of altered fire regimes
- Integrate cultural and economic issues
- Build fire management capacity

Governments
- Ensure equitable distribution of fire costs/benefits
- Recognize community-use rights
- Remove perverse incentives related to fire ignition and suppression
- Invest in fire science, management and education
- Build local and national fire management capacity

Scientists
- Conduct research to broaden understanding of fire regimes and biodiversity
- Elucidate causes of altered fire regimes
- Conduct monitoring at local, regional and global levels
- Investigate complex relationships among fire, climate change, land use, and invasive alien species
- Assess and predict ecological implications of proposed strategies

Figure 8. Fire-loving alien plants can drastically change the fire regimes of both fire-dependent and fire-sensitive ecosystems. Here, non-native cheatgrass *(Bromus tectorum)* is invading sagebrush steppe in the western U.S. © John Randall, TNC.

land uses is lacking. Investment in basic research and rapid assessments is essential. At present, no credible estimates of regional burned area are available, nor is it easy to infer from remotely sensed data whether individual fires are beneficial, harmful, or benign from either an ecological or social perspective. Understanding the complex interrelationships among fire, climate change, land use, and invasive alien species (Figure 8) will be critical in order to understand long-term trends and develop adaptive conservation and development strategies. Lastly, practitioners need tools that help them envision long-term and landscape-level alternative scenarios and outcomes.

To download this document, graphics and subsequent versions, go to http://nature.org/initiatives/fire/science. For more information on TNC's Global Fire Initiative, see http://nature.org/fire.

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