Forest fire and biological diversity

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Fire serves an important function in maintaining the health of certain ecosystems, but as a result of changes in climate and in human use (and misuse) of fire, fires are now a threat to many forests and their biodiversity.

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Fire is a vital and natural part of the functioning of numerous forest ecosystems. Humans have used fire for thousands of years as a land management tool. Fire is one of the natural forces that has influenced plant communities over time and as a natural process it serves an important function in maintaining the health of certain ecosystems. However, in the latter part of the twentieth century, changes in the human-fire dynamic and an increase in El Niño frequency have led to a situation where fires are now a major threat to many forests and the biodiversity therein. Tropical rain forests and cloud forests, which typically do not burn on a large scale, were devastated by wildfires during the 1980s and 1990s (FAO, 2001).

Although the ecological impact of fires on forest ecosystems has been investigated across boreal, temperate and tropical biomes, comparatively little attention has been paid to the impact of fires on forest biodiversity, especially for the tropics. For example, of the 36 donor-assisted fire projects carried out or ongoing in Indonesia, a megadiversity country, between 1983 and 1998, only one specifically addressed the impact on biodiversity.

ECOSYSTEM EFFECTS OF FIRE

Forest fires have many implications for biological diversity. At the global scale, they are a significant source of emitted carbon, contributing to global warming which could lead to biodiversity changes. At the regional and local level, they lead to change in biomass stocks, alter the hydrological cycle with subsequent effects for marine systems such as coral reefs, and impact plant and animal species' functioning. Smoke from fires can significantly reduce photosynthetic activity (Davies and Unam, 1999) and can be detrimental to health of humans and animals.

One of the most important ecological effects of burning is the increased probability of further burning in subsequent years, as dead trees topple to the ground, opening up the forest to drying by sunlight, and building up the fuel load with an increase in fire-prone species, such as pyrophytic grasses. The consequence of repeated burns is detrimental because it is a key factor in the impoverishment of biodiversity in rain forest ecosystems. Fires can be followed by insect colonization and infestation which disturb the ecological balance.

The replacement of vast areas of forest with pyrophytic grasslands is one of the most negative ecological impacts of fires in tropical rain forests. These processes have already been observed in parts of Indonesia and Amazonia (Turvey, 1994; Cochrane *et al*., 1999; Nepstad, Moreira and Alencar, 1999). What was once a dense evergreen forest becomes an impoverished forest populated by a few fire-resistant tree species and a ground cover of weedy grasses (Cochrane *et al*., 1999). In North Queensland in Australia, it has been observed that where the aboriginal fire practices and fire regimes were controlled, rain forest vegetation started to replace the fire-prone tree-grass savannahs (Stocker, 1981).

IMPACTS OF HUMAN-INDUCED OR SEVERE NATURAL WILDFIRE ON PLANT DIVERSITY

Wildfire is unusual in most undisturbed, tall, closed-canopy, tropical rain forests because of the moist microclimate, moist fuels, low wind speeds and high rainfall. However, rain forests may become more susceptible to fire during severe droughts, as experienced during El Niño years. In these forests which are not adapted to fire, fire can kill virtually all seedlings, sprouts, lianas and young trees because they are not protected by thick bark. Damage to the seed bank, seedlings and saplings hinders recovery of the original species (Woods, 1989). The degree of recovery and need for rehabilitation interventions depends on the intensity of burning (Schindele, Thoma and Panzer, 1989).

Tropical forests are also subject to fires started by humans for agricultural clearing. Deforestation fires, which are more common in disturbed forests, can vary in intensity and burn standing trees, at the worst completely burning the forest leaving nothing but bare soil.

There is some concern that salvage logging (removal of dead timber from severely burned logged-over forest or burned primary forest), used as a management and financing tool after fires in Indonesia in 1997-1998, may adversely affect the course of vegetation succession (van Nieuwstadt, Sheil and Kartawinata, 2001).

Although fire is a frequent natural disturbance in boreal forests and they usually regenerate easily after fire, frequent high-intensity fires can offset this balance. As a result of extremely severe fires in the Russian Federation in 1998, more than 2 million hectares of forest have lost most of their major ecological functions for a period of 50 to 100 years (Shvidenko and Goldammer, 2001). Severe fires have had a significant negative impact on plant diversity. Southern species that are at the northern edge of their geographic range are particularly vulnerable. For example, in Primorsky Kray (Russian Federation), human-induced fires have contributed to drastic reductions in the populations of 60 species of vascular plants, ten fungi, eight lichens and six species of mosses during the past two or three decades (Shvidenko and Goldammer, 2001).

NATURAL FIRE REGIMES AND FIRE-ADAPTED PLANT SPECIES

In tropical forests where fires occur every dry season (savannah woodlands, monsoon forests and tropical pine forests), tree species exhibit adaptive traits such as thick bark, ability to heal fire scars, resprouting capability and seed adaptations. The ecological importance of these annual fires on forest formations is significant. Fire strongly promotes fire-tolerant species, which replace the species potentially growing in an undisturbed environment.

Fires are a natural and important disturbance in many temperate forests, and this is seen in plant adaptations such as thick bark, which enables a species to withstand or resist recurrent low intensity fires, while less well-adapted associates perish. Some tree species in North America, notably Jack pine (*Pinus banksiana*) and lodgepole pine (*Pinus contorta*), have serotinous (late-opening) cones. While closed, these cones hold a viable seed bank in the canopy that remains protected until fire affects the tree. After fire, the cone scales open, releasing the seed into a freshly prepared ash bed. Many plant species have the ability to resprout after being burned, either from the rootstock or the stem (Agee, 1993). Mountain ash (*Eucalyptus regnans*), a eucalypt of temperate Australia, also requires a site to burn completely and be exposed to full sun for the species to regenerate prolifically (IUCN/WWF, 2000). Forest flammability is high in the Mediterranean Basin and most plant communities are fire prone. *Quercus ilex* is resistant to mild fires, and woodlands recover without any major floral or structural change (Trabaud and Lepart 1980). If fire is

In moist tropical forests, the threat to biodiversity posed by clearing for agriculture is compounded by the use of fire if not kept under control – pictured, the Brazilian Amazon

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Fire has an important function in some forest ecosystems; some species thrive after fire – like these* Eucalyptus *sp. resprouting after a natural fire in Senegal

neither frequent nor intense, open cork oak (*Quercus suber*) forests can persist.

Fire, often with high intensity, is the major natural disturbance mechanism in boreal forests. Fire return times (the average interval of time between two fires in the same place in one ecosystem) in natural forests vary greatly, from as little as 40 years (in some Jack pine [*Pinus banksiana*] ecosystems in central Canada) to as long as 300 years depending on climate patterns (van Wagner, 1978). In Sweden, it has been estimated that about 1 percent of the forest land burned yearly before systematic suppression of fires started in the late nineteenth century (Zackrisson, 1977). Most boreal conifers and broad-leaved deciduous trees suffer high mortality even at low fire intensities owing to canopy architecture, low foliar moisture and thin bark (Johnson, 1992). Some North American pines (*Pinus banksiana, P. resinosa, P. monticola*) and European pines (*P. sylvestris*) have thicker bark and generally greater crown base and height, and old tall trees can often survive several fires. The disturbance regime of fire creates succession patterns which cause the mosaic of age classes and communities. Fire refuges exist in some parts of the forest on moist sites with local humidity, where fire may be absent for several hundred years. Fire refuges are vital to the forest ecosystem in the boreal region because many species can survive only in such areas, and then supply a seed source to recolonize the burned areas (Ohlson *et al.*, 1997).

In the natural forests of the northern and sparsely stocked taiga and forest tundra, particularly on permafrost sites, surface fires occurring at long-return intervals of 80 to 100 years represent a natural mechanism that prevents the transformation of forests to shrubland or grassland (Shvidenko and Goldammer, 2001).

EFFECTS OF FIRE ON FOREST FAUNA

In forests where fire is not a natural disturbance, it can have devastating impacts on forest vertebrates and invertebrates – not only killing them directly, but also leading to longer-term indirect effects such as stress and loss of habitat, territories, shelter and food. The loss of key organisms in forest ecosystems, such as invertebrates, pollinators and decomposers, can significantly slow the recovery rate of the forest (Boer, 1989).

Estimates from the 1998 fires in the Russian Federation suggest that mammals and fish were badly affected. Mortality of squirrels and weasels, estimated immediately after the fires, reached 70 to 80 percent; boar 15 to 25 percent; and rodents 90 percent (Shvidenko and Goldammer, 2001).

Loss of habitat, territories and shelter

The destruction of standing cavity trees as well as dead logs on the ground has negative effects on most small mammal species (e.g. tarsiers, bats and lemurs) and cavity-nesting birds (Kinnaird and O'Brien, 1998). Fires can cause the displacement of territorial birds and mammals, which may upset the local balance and ultimately result in the loss of wildlife, since displaced individuals have nowhere to go. The severe fires of 1998 in the Russian Federation led to increased water temperatures and high carbon dioxide levels in lakes and waterways, which adversely affected salmon spawning (Shvidenko and Goldammer, 2001). In areas where frequent burning occurs on a broad scale, preserving a range of microhabitats can make a substantial contribution to conserving biodiversity (Andrew, Rodgerson and York, 2000).

Loss of food

Loss of fruit-trees results in overall decline in bird and animal species that rely on fruits for food; this effect is particularly pronounced in tropical forests. A few months after the 1982-1983 fires in Kutai National Park, East Kalimantan, fruit-eating birds such as hornbills declined dramatically, and only insectivorous birds such as woodpeckers were common because of the abundance of wood-eating insects.

Burned forests become impoverished of small mammals, birds and reptiles, and carnivores tend to avoid burned over areas. The reduction in densities of small mammals such as rodents can adversely affect the food supply for small carnivores.

Fires also destroy leaf litter and its associated arthropod community, further reducing food availability for omnivores and carnivores (Kinnaird and O'Brien, 1998).

Fire-adapted fauna

Not all species suffer from fire. For instance, grass-layer beetle species in Australia's savannahs show remarkable resilience to fire, although fires affect abundance, species and family richness (Orgeas and Andersen, 2001).

In the fire-prone Mediterranean region, the current fire regime has probably contributed to maintaining the bird diversity at the landscape level in Portugal (Moreira *et al.*, 2001). In Israel, richness of fauna species in certain areas was the highest two to four years after a fire followed by a decrease over time (Kutiel, 1997).

Fire can have positive effects on wildlife populations in boreal forests, where fire is a major natural disturbance mechanism. In North America, although moose are occasionally trapped and killed by fire, fire generally enhances moose habitat by creating and maintaining seral communities, and is considered beneficial to moose populations (MacCracken and Viereck, 1990). The beneficial effects of fire on its habitat is estimated to last less than 50 years, with moose density peaking 20 to 25 years following fire (LeResche, Bishop and Coady, 1974).

Fire has contributed to the reduction in populations of grey wolf (*Canis lupus*) in Minnesota, United States, by limiting its prey – including beaver (*Castor canadiensis*), moose and deer, fire-dependent species that require the plant communities that persist following frequent fires (Kramp, Patton and Brady, 1983).

EFFECTS OF SUPPRESSION OF THE NATURAL FIRE REGIME

Temperate forests in the United States and Australia in which fire was deliberately suppressed are now experiencing devastating wildfires because of an unnatural accumulation of fuel. Deliberate human suppression of fire can also have direct negative impacts on species. In forests where fire is a natural part of the system, plant and animal species are adapted to a natural fire regime and benefit from the aftermath of a fire.

In North America, fire suppression in some areas has contributed to decline in the numbers of grizzly bear, *Ursus arctos horribilis* (Contreras and Evans, 1986). Fires promote and maintain many important berry-producing shrubs, which are an important food source for bears, as well as providing habitat for insects and in some cases carrion. The 1998 fires in Yellowstone National Park increased availability of some food items for grizzly bears, especially carcasses of elk (Blanchard and Knight, 1990).

In boreal forests, exclusion of fire induces the build-up of organic layers that prevents melting of the upper soil during spring and summer and rise of the permafrost layer, resulting in impoverishment of forests, decrease in productivity and conversion of forests to marshes. ◆

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Most plant communities in the Mediterranean Basin are fire prone; if fire is neither frequent nor intense, cork oak (**Quercus suber*****) (shown here in Morocco) can persist***

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