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Forum

Fire and Parasites: An Under-Recognized Form of Anthropogenic Land Use Change and Mechanism of Disease Exposure

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Abstract: Anthropogenic land use changes have altered ecosystems and exacerbated the spread of infectious diseases. Recent reviews, however, have revealed that fire suppression in fire-prone natural areas has not been recognized as a form of anthropogenic land use change. Furthermore, fire suppression has been an under-recognized mechanism altering the risk and transmission of infectious disease pathogens and host–parasite dynamics. However, as settlement patterns changed, especially due to colonial expansion in North America, Africa, and Australia, fire suppression became a major form of land use change which has led to broad-scale ecosystem changes. Because parasites of humans and animals can vector viral, bacterial, prion, fungal, or protozoan pathogens, concomitant changes associated with anthropogenic-induced changes to fire frequencies and intensities are of concern. I provide reference to 24 studies that indicate that restoring fire in natural areas has the potential to reduce ectoparasites without wings such as ticks, chiggers, fleas, and lice; ectoparasites with wings such as mosquitos, horn flies, face flies, and stable flies; and endoparasites affecting livestock and wildlife. This suggests that fire ecology and parasitology be considered as a priority area for future research that has implications for both humans and animals.

Keywords: fire, global change, infectious disease, livestock, medical, parasites

Introduction

Anthropogenic land use changes have drastically altered ecosystems globally and exacerbated the spread of infectious diseases (Gottdenker et al. 2014). Identified forms of anthropogenically driven land use change associated with infectious disease exposure include deforestation, rangeland expansion, urbanization/suburbanization, infrastructure development, hydrological alteration, agricultural development, and natural resource extraction (Gottdenker et al. 2014). Although other studies have recognized changes of ignition patterns and sources as a global consequence of land use (Foley et al. 2005), it appears that fire suppression has been an under-recognized mechanism altering the risk and transmission of infectious disease pathogens and host–parasite dynamics. This is not too surprising, however, as the fields of fire ecology and infectious disease are not intrinsically related, at least on the surface.

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Ecological and Historical Role of Fire

Ecosystems across many continents are considered fire-dependent or fire-prone, or at least the pre-settlement plant community was regulated by regular occurring lightning and anthropogenic fire (Bond and Keeley 2005). The regular disturbance of fire, and subsequent benefit to both animals and humans, was recognized by indigenous cultures that served as an important source of ignition (Archibald et al. 2005; Anderson 2006; Murphy and Bowman 2007). However, as settlement patterns changed, especially due to colonial expansion in North America, Africa, and Australia, fire suppression became a major form of land use change (Pyne 1982; Murphy and Bowman 2007; Trollope 2011). Fire suppression, out of fear of destruction of life and property, has become the norm on many continents leading to an alteration of fire frequencies and intensities that cause broad-scale ecosystem changes (Pyne 1982). For example, fire suppression in North American grasslands has led to the encroachment of fire-sensitive conifers in both mesic and semi-arid ecosystems (Bragg and Hulbert 1976; Miller and Rose 1999). Even though fire return intervals vary broadly (from 3 years in tallgrass prairies to 230 years in Douglas-fir forests), fire is critical to the regulation of ecosystem patterns, ecological processes, and parasite dynamics (Agee 1993; Anderson 2006). Fire has a critical and complex role in the ecological interactions between fire, plant communities, and diseases; both plant diseases and wildlife diseases (Hardison 1976). Because parasites of humans and animals can vector viral, bacterial, prion, fungal, or protozoan pathogens, and are sensitive to changes in habitat from fire, the changes concomitant with anthropogenic-induced changes to fire frequencies and intensities are of concern.

Ectoparasites Without Wings

Perhaps the most studied parasite response to the fire disturbance has been of ticks. Ticks can vector many infectious diseases to both humans and animals including tick-borne encephalitis, Crimean-Congo hemorrhagic fever, Lyme borreliosis, tularemia, ehrlichiosis, rickettsiosis, and babesiosis (Goodman et al. 2005). North American studies demonstrated that fire altered the microhabitat of ticks and reduced larvae, nymphs, and adults (Scifres et al. 1988; Mather et al. 1993; Stafford et al. 1998; Cully 1999). Patchy fires also changed animal foraging decisions and tick burdens on both cows and calves (Polito et al. 2013). In Tanzania and South Africa, similar reductions of ticks with prescribed burning, primarily out of concern for tick-borne diseases, such as babesiosis, have been attributed to the alteration of micro-habitat (Trollope 2011). There has been some disagreement about the efficacy of fire between studies of the same species; conflict that arises when different studies compare different fire frequencies (i.e., annual or biennial burning in Davidson et al. 1994; greater than 2 years post fire in Allan 2009). Fire similarly reduced chiggers, fleas, lice, and mites (Metz and Farrier 1971; Seastedt 1984; Nyariki et al. 2005). All of these parasites are causes of irritation and dermatitis for both humans and animals. Fleas can also be vectors of viral, bacterial, and rickettsial diseases as well as protozoans and helminths. Lice transmit at least three pathogenic bacterium including *Borrelia recurrentis* (an agent of relapsing fever), *Bartonella quintana* (an agent of bacillary angiomatosis, endocarditis, and chronic lymphadenopathy), and *Rickettsia prowazekii* (an agent of epidemic typhus) (Raoult and Roux 1999). Fire is also important for altering host–pathogen dynamics and possible extirpation of amphibians from epidermal infections. Wildfires altered micro-climate required for the development of the aquatic fungi *Batrachochytrium dendrobatidis* and the infection of chytridiomycosis as boreal toads captured in burned areas were half as likely to be infected (Hossack et al. 2013b).

Ectoparasites with Wings

Parasites that are able to fly and more readily disperse also appear to respond to fire suppression as a mechanism of change. Globally, mosquitos are a major concern to both humans and animals. In the Great Plains of the US, suppression of fire and the concomitant increase of fire-sensitive conifers have been attributed to an increase in *Culex tarsalis*, a vector of West Nile virus and western equine encephalitis (O'Brien and Reiskind 2013). Egg survival of *Aedes aegypti* (yellow fever mosquito), a vector of yellow fever virus, dengue virus, chikungunya virus, and the global epizootic disease *Bacillus anthracis* (anthrax), has been reduced significantly with controlled burning in Kenya (Whittle et al. 1993; Turell and Knudson 1987). It has also been postulated that the reduction of *Aedes aegypti* with fire may be a way to mitigate Rift Valley fever, a viral zoonosis vectored by *Aedes aegypti*. Filth fly parasites of livestock, particularly in the order Diptera and the family Muscidae,

Table 1. Research on the Reduction Effects of Fire on Endo- and Ectoparasites that Vector Infectious Diseases in Humans and/or Animals

Parasite species	Effect of fire	Type[a]	Location and reference
Chiggers (*Trombicula* species)	Reduced	Exp	South Carolina, USA Metz and Farrier (1971)
Epidermal infections of amphibians (chytridiomycosis)	Reduced by 50%	Exp	Montana, USA Hossack et al. (2013b)
Face flies (*Musca autumnalis)*	Reduced 50% on cattle	Exp	Iowa, USA Scasta (2014)
Fleas (*Ctenocephalides* species)	Cultural use for reduction	Obs	East Africa Nyariki et al. (2005)
Gastrointestinal parasites (in sheep; unspecified)	Reduced free-living stages	Obs	Australia Barger (1978)
Gastrointestinal (*Haemonchus* species)	Cultural use for reduction	Obs	Kentucky, USA Hepworth and Hutchens (2011)
Horn flies (*Haematobia irritans*)	Reduced 41% on cattle	Exp	Iowa and Oklahoma, USA Scasta et al. (2012)
Internal nematode parasites of amphibians	Reduced if they have terrestrial free-living stages	Exp	Montana, USA Hossack et al. (2013a)
Lice (*Pediculus* species)	Cultural use for reduction	Obs	East Africa Nyariki et al. (2005)
Lungworm (*Protostrongylus* species)	Reduced	Exp	British Columbia, Canada Seip and Bunnell (1985)
Meningeal brain worm (*Parelaphostrongylus tenuis*)	Reduced gastropod host and infection in ungulates	Obs	Southeastern USA Weir (2009)
Mites (Oribatid; Mesostigmatid)	Reduced	Exp	Kansas, US Seastedt (1984)
Mosquito (*Aedes aegypti*)	Reduced egg survival 95%	Exp	Kenya, Africa Whittle et al. (1993)
Mosquito (*Culex tarsalis*)	Decreased with fire-sensitive conifer decreases	Exp	Oklahoma, USA O'Brien and Reiskind (2013)
Stable flies (*Stomoxys calcitrans*)	Below threshold with regular fire	Exp	Iowa and Oklahoma, USA Scasta (2014)
Tick (*Amblyomma americanum*)	Reduced larvae and adults	Exp	Kansas, USA Cully (1999)
Tick (*Amblyomma americanum*)	Reduced load on cattle	Exp	Oklahoma, USA Polito et al. (2013)
Tick (*Amblyomma americanum*)	Reduced with annual or biennial burning	Exp	Georgia, USA Davidson et al. (1994)
Tick (*Amblyomma americanum*)	Higher in >2 year since fire areas than unburned areas	Exp	Missouri, USA Allan (2009)
Tick (*Amblyomma americanum; Ixodes scapularis*)	Reduced by several orders of magnitude	Exp	Georgia and Florida, USA Gleim et al. (2014)
Tick (*Amblyomma maculatum*)	Reduced 75–90%	Exp	Texas, USA Scifres et al. (1988)
Tick (*Ixodes dammini*)	Reduced 49%	Exp	New York, USA Mather et al. (1993)

Table 1. continued

Parasite species	Effect of fire	Type[a]	Location and reference
Tick (*Ixodes scapularis*)	Reduced nymphs/larvae	Exp	Connecticut, USA Stafford et al. (1998)
Tick (unspecified)	Cultural use for reduction	Exp	South Africa and Tanzania, Africa; Trollope (2011)

[a]Type of study; *Exp* experimental, *Obs* observational

may also be reduced by restoring historical fire disturbance regimes. Horn flies (*Haematobia irritans*) and face flies (*Musca autumnalis*) on cattle were both reduced with patchy fires but drought may limit the effective application of fire (Scasta et al. 2012; Scasta 2014). Horn flies vector mastitis and skin helminths and face flies vector bovine keratoconjunctivitis (pinkeye) and nematode eye worms (Hall 1984; O'Hara and Kennedy 1991; McDougall et al. 2009). Stable flies (*Stomoxys calcitrans*), a filth fly known to mechanically transmit *Bacillus anthracis* (the causative agent of anthrax), were also well below economic thresholds with both patchy fires and complete pasture fires, although the direct effects of fire are less clear than for other filth fly species (Turell and Knudson 1987; Scasta 2014). Both horn flies and stable flies have been implicated as vectors of bovine leukosis (Buxton et al. 1985).

Endoparasites

Endoparasites of livestock and wildlife can also be susceptible to fire. In Australia, fire reduced the free-living stages of gastrointestinal parasites of sheep and controlled burning of pastures has been suggested to reduce gastrointestinal nematodes (specifically *Haemonchus*) and the susceptibility for sheep and goats (Barger 1978; Hepworth and Hutchens 2011). Native sheep (*Ovis dalli stonei*) in British Columbia, Canada that had access to recently burned areas had up to ten times lower lungworm (*Protostrongylus* spp.) loads than sheep without access to burned areas (Seip and Bunnell 1985). Fire in the southeastern US has also been applied to disrupt the microhabitat of the gastropod hosts of the meningeal brain worm (*Parelaphostrongylus tenuis*) which has been devastating to native ungulates such as elk and deer (Weir 2009). Internal nematode parasites of amphibians can also be reduced by fire if they have a free-living terrestrial stage, but fire is not effective if the parasite is transmitted aquatically (Hossack et al. 2013a). While the transmission of infectious diseases by endoparasites and effects of fire are less clear than ectoparasites, it is clear that they can transmit protozoan parasites mechanically, and the potential public health implication for reductions of endoparasites as causative agents of gastrointestinal diseases is an area that needs additional research.

Discussion and Conclusions

I have provided reference to 24 studies (Table 1) that have documented effects of fire and 23 (96%) demonstrate fire as an effective tool for managing vegetation, parasites, and disease. Most studies in the current review were experimental (79%) with the remainder reporting observations of cultural use (21%). However, a limitation to the studies presented here is the majority of studies only documented the reduction of the vector but did not quantify changes in pathogens. I suggest that future studies not only quantify vector changes but also quantify pathogenic dynamics (for example see, Mather et al. 1993; Allan et al. 2010; Mayo et al. 2012; Gleim et al. 2014). Based on the studies presented, it appears that the mechanistic reduction of parasites by restoring functional fire disturbances can be direct (mosquitoes in Kenya; Whittle et al. 1993), indirect (ticks in Oklahoma USA; Polito et al. 2013), or both (horn flies and face flies in Iowa and Oklahoma USA; Scasta et al. 2012, Scasta 2014; Scasta et al. 2014). Ultimately, the reduction of arthropod parasites with fire may be a way to reduce exposure of humans and animals to arboviruses. The restoration of fire disturbances in fire-dependent ecosystems may also help restore ecological integrity and biodiversity while also serving as a logistically feasible method of cultural parasite control across broad landscapes (Fuhlendorf and Engle 2004).

Because disease vectors are highly sensitive to environmental change, I suggest that the area of fire ecology and parasitology be considered as a priority area for future research. Furthermore, I suggest that cross-disciplinary collaboration between fire ecology, parasitology, animal production, and human health may have societal benefits that are far reaching. Lastly, the majority of the studies presented were focused on benefits to livestock and wildlife and further work is needed on human risk and exposure. This need is especially acute for cultures that interact very closely with livestock and wildlife such as nomadic pastoralists.

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