Pyrophiles and Pyrophytes: Unique Fire Adaptations in the Fungal, Plant, and Animal Kingdoms

Elliot Maxwell

Fire Ecology (FOWS 6240)

December 9, 2025

Much of public education surrounding fire has its roots in fire exclusion campaigns, such as the Smokey Bear PSA Campaign, founded by the United States government in 1944.[1] The Smokey Bear campaign came about when the United States Forest Service partnered with an advertisement agency following WWII era concerns that incendiary shells along the western coast could start severe wildfires.[2] Given that early fire suppression policies have their roots in nationalist sentiments, citizens felt compelled to protect US forest resources in an attempt to contribute to the war effort. The patriotic roots of fire exclusion policy combined with simple campaign messaging centering around the idea of preventing forest fires have led generations to believe that all forest fires must be stopped. As we have discussed over the course of this semester, the consequences of fire exclusion policy have had social and ecological consequences.[3]

Fortunately, this has been changing over the past 50 years. With the rise of fire ecology in the 1970s and 80s, we have begun to develop a better understanding of the roles that fire plays in many different ecosystems around the world. Indeed, disturbances are an inevitability in nature, and our perception of them as negative often comes from our limited anthropocentric perspective. In her 2015 book, *Fierce Climate, Sacred Ground*, Elizabeth Marino writes on the subject of disturbance in the context of society and ecology, comparing the perception of severe flooding in Nigeria to severe flooding in Shishmaref, a small predominantly Iñupiat island village in Northwestern Alaska: “Flooding itself is simply a condition of high water, and conditions of high water alone do not necessarily produce negative consequences.”[4] Fire, similarly, is just another type of disturbance. Kobziar et al describe the role of fire in their 2024

---

[1] Smokey Bear. "Smokey’s Story."
[2] Smokey Bear. "Smokey’s Story."
[3] CBD. Living with Fire: A Guide for Community-Based Forest Fire Management. Secretariat of the Convention on Biological Diversity.
[4] Marino, Elizabeth. Fierce Climate, Sacred Ground: An Ethnography of Climate Change in Shishmaref, Alaska. 21.

literature review as follows: "Fire sustains or alters ecosystems through direct and indirect ecological effects that result from the interactions between fire energy exchange and the abiotic and biotic components and functions of an ecosystem."[5] Simply put, fire is a force of nature; a keystone ecological process with behavior determined "by immutable laws of chemistry and physics."[6]

The chemical reaction of fire as experienced on Earth, is a process that is unique to this planet.[7] Much of Earth's plant life has evolved alongside fire, and many species have adapted to fire in unique ways. Fossil evidence shows that early vascular and non-vascular plants were predisposed to burning as early as the Devonian Period. Pyrophytes, or plants which have evolved to tolerate and even depend on fire, began to develop as early as the Permian Period.[8] Some traits of early pyrophytic trees, such as pyriscent serotiny, lower branch shedding, and flammability, live on in their modern-day descendants. For example, serotinous closed-cone pines in the *Pinus* genus, such as *Pinus contorta* and *Pinus clausa* depend on the heat of fire to melt the waxy coating from their cones, releasing their seeds into the post-fire seedbed.[9] Plant adaptations to fire, however, don't end there. Additional strategies for survival in fires include "protected buds, meristematic tissues, and xylem conduits," as well as, thick bark, epicormic resprouting, forming bud banks or lignotubers, and methods of storing carbohydrates for quick regrowth following fire.[10] Adaptations such as thick, corky bark are present in many of the *Pinus* species, while adaptations like protected buds and epicormic resprouting are present in many eucalypts and other savannah trees.[11] These adaptations serve to aid plants in recruitment after a

[5] Kobziar et al. "Principles of Fire Ecology." Fire Ecology 20, no. 1 (2024), 2.
[6] Vaillant, John. Fire Weather: A True Story from a Hotter World, 67.
[7] Vaillant, John. Fire Weather: A True Story from a Hotter World, 65
[8] Kobziar et al. "Principles of Fire Ecology." Fire Ecology 20, no. 1 (2024), 4.
[9] Kobziar et al. "Principles of Fire Ecology." Fire Ecology 20, no. 1 (2024), 7.
[10] Kobziar et al. "Principles of Fire Ecology." Fire Ecology 20, no. 1 (2024), 5-6.
[11] Kobziar et al. "Principles of Fire Ecology." Fire Ecology 20, no. 1 (2024), 6.

fire has burned through. Post-fire conditions, such as canopy availability, exposed mineral soils, and low competition create the perfect environment for new plants to grow uninterrupted. Interestingly, plants are not the only ones who are interested in these low-competition environments. Some species of insects and fungi, referred to as pyrophiles, have evolved to depend on fires for their survival.

Pyrophilous insects make up a small portion of the general insect population. Pyrophilous behavior has been observed in insects of the orders *Hemiptera, Lepidoptera, Diptera and Coleoptera*, including those of the genera *Microsania, Melanophila, Merimna, Sericoda, and Aradus*.[12] These insects rely on recently burned areas for their reproduction. As mentioned before, forest fires can be considered disastrous, given that they can generate a significant amount of dead biomass and consume and kill large numbers of trees. Fires, however, also play a significant role in increasing biodiversity by creating "between-patch heterogeneity" and allowing for increased age and species diversity in plant populations. As a result, insect and fungal diversity is also affected.[13]

Some insects that have developed relationships with fire do not depend on fire for their survival, and are separated into a different group, often referred to as "disturbance-favoured species."[14] Pyrophilous, or "fire-loving," insects have developed unique biological adaptations that allow them to interact with their environments in unique ways and depend on fire for their survival. The insects referred to in this paper will specifically be insects who rely on fire for their survival. This raises the question: how are these insects able to detect where fires have recently occurred if they rely on them for their survival?

[12] Hoang, Thi Phuong. "Adaptations of Pyrophilous Insects to Burnt Habitats: Odor Signals, Infrared Receptors and Behavior." Current Opinion in Insect Science 12 (2015), 5.
[13] Hoang, Thi Phuong. "Adaptations of Pyrophilous Insects to Burnt Habitats: Odor Signals, Infrared Receptors and Behavior." Current Opinion in Insect Science 12 (2015), 3.
[14] Bell, 2.

Some specific adaptations of pyrophilous insects include antennae that are specifically adapted to detect smoke, a diet that primarily consists of pyrophilous fungi, IR sensors that allow them to navigate during fires, have extended phenology/period of activity, and have reproductive synchronicity with fire.[15] Certain pyrophilous insects, including buprestid beetles (*Melanophila* and *Merimna*), flat bugs (*Aradus*), and cleroid beetles (*Acanthocnemus*), have evolved infrared sensors along the sides of their bodies, allowing them to sense the heat and IR radiation from fires.[16] In *Melanophila*, the IR sensors "are confined to a pair of metathoracic pits that consist of bundles of small dome-shaped cilia," which function by responding to warming with expansion and increased pressure and thus compression of the dendrite, signalling to the insect the level of present IR radiation.[17] IR sensors of *Aradus* function similarly, but have different locations along the body, namely on the prothorax and mesothorax. Those of *Acanthocnemus nigricans* function in a different manner which is not completely understood, but they are thought to have a thermosensory function that measures temperature changes following exposure to IR radiation.[18] Those of *Merimna* function similarly to those of *A. nigricans*, but are instead located on the second, third, and fourth abdominal sternite of the beetles.

Not all pyrophilous beetles are equipped with these IR sensors, however. These sensors have been noted only in 19 species of pyrophilous insects, and often their specific presentation varies depending on the insect.[19] Often, saproxylic beetles, or beetles that consume rotting wood, are attracted to recent burn sites, given the wide availability of burned and newly dead plant

---

[15] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 3.
[16] Hoang, Thi Phuong. "Adaptations of Pyrophilous Insects to Burnt Habitats: Odor Signals, Infrared Receptors and Behavior." Current Opinion in Insect Science 12 (2015), 6.
[17] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 7.
[18] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 7-8.
[19] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 7-8.

matter available.[20] Additionally, when plant matter is burned by fires, volatile organic compounds such as isoprenes, terpenes, and methane, also known as VOCs, are released. VOCs are also produced in non-fire settings by plants, animals, and fungi. For example, volatiles are produced during the process of thermal oxidation of wood, and as a byproduct of metabolic activities. Insects often rely on chemical compounds for communication in the context of "mating, oviposition, finding food resources, and intraspecific communication."[21] The process of pyrolysis breaks down the carbohydrate polymers that make up plant cells into chemicals such as hydroxyacetone, furanes, levoglucosan, guaiacal, and other compounds.[22]

Due to the olfactory nature of most insect communication, it is theorized that these volatiles are interpreted in similar ways as pheromones, apneumones, kairomones, and allomones.[23] It is thought that insects are able to utilize this chemical information to make decisions about where to land and establish their populations. Pyrophilous beetles are noted to have more highly developed thermoreceptors and chemoreceptors in their antennae than other insects, providing sensitivity to certain volatiles that indicate the presence of fire or wood smoke.[24] Furthermore, many of these insects have highly specialized chemoreceptors that allow them to detect levels of VOCs much lower than other insects are able to. Findings from some studies even suggest that their modified receptors allow them to discern the quality of the plant material being burned by analyzing the VOCs. *Melanophila acuminata*, *Merinma atrata*, flies in

[20] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 2
[21] Hoang, Thi Phuong. "Adaptations of Pyrophilous Insects to Burnt Habitats: Odor Signals, Infrared Receptors and Behavior." Current Opinion in Insect Science 12 (2015), 7.
[22] Hoang, Thi Phuong. "Adaptations of Pyrophilous Insects to Burnt Habitats: Odor Signals, Infrared Receptors and Behavior." Current Opinion in Insect Science 12 (2015), 8-12.
[23] Hoang, Thi Phuong. "Adaptations of Pyrophilous Insects to Burnt Habitats: Odor Signals, Infrared Receptors and Behavior." Current Opinion in Insect Science 12 (2015), 8.
[24] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 6.

Hormopeza and *Microsania*, and *Hypocerides nearcticus* have been observed to use olfactory chemoreceptors to detect smoke and the associated VOCs in order to locate fire.[25]

What, then, motivates these beetles to seek out recently burned sites? There are numerous theories as to why these beetles have evolved to depend on fire. Recently burned sites are an open playing field. With sterilized soils, open canopy, an abundance of available food sources, and extremely limited competition, they make the perfect location for these insects to reproduce. Sterilized substrates and wood make oviposition much safer, as there is a reduced presence, or even an absence, of egg-killing pathogens, such as fungi, bacteria, or potential predators.[26] Other theories suggest attraction to fire in order to evade predation by birds and other predators.

As mentioned before, insects are not the only ones attracted to recently burned areas. This area of low competition as described above, is the perfect playing field for rapidly colonizing species of bacteria, fungi, and plants. In fact, some pyrophilous fungi can be indicative of the presence of certain pyrophilous beetles. In an examination of the ascomycete fungus, *Daldinia loculata*, which grows preferentially on fire-killed tree, Lars-Ove Wikars explains that 19 species of fire dependent insects were found to be strongly correlated. [27] At least nine insect species are known to feed solely on *D. loculata*. This study shows a potential symbiotic relationship between these fungi and their fire-loving insect companions.

It can be difficult to determine which species of fungi are truly pyrophilous, and which are simply opportunistic colonizers taking advantage of limited competition. In fact, in regard to fungi, it is currently not possible to distinguish between species that rely on fire for their survival, whether in regard to heating, or to resource availability, and species that benefit from

[25] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 7.
[26] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 9.
[27] Wikars, Lars-Ove. "The Wood-Decaying Fungus Daldinia loculata (Xylariaceae) as an Indicator of Fire-Dependent Insects," 265-266.

the low competition environment provided by fires.[28] That being said, some fungi have evolved to only produce their reproductive structures after exposure to fire. Pyrophilous fungi have been noted within the Acomycota, Basidiomycota, and Mucoromycota, primarily occurring in the former, with specific genera of interest including *Anthracobia*, *Morchella*, *Neurospora*, and *Pyronema* within Ascomycota, and *Coprinopsis*, *Pholiota*, and *Psathyrella* in the Basidiomycota.[29] These fungi differ from others in that they exhibit specific pyrophilous traits, including a propensity to fruit only on burned or heated soil or fruiting that is enhanced by fire. Pyrophilous fungi are unique, in that they have longer spore longevity than most other fungal species. They have evolved to store their spore bank in the soil, where they lie dormant until they are heated by fire. Once the first significant rain occurs following a fire, these fungi produce their fruiting bodies in order to distribute more spores, replenishing their spore bank[30] From a conservation standpoint, these insects and fungi depend on forest fires for their survival. Clear-cut forests often do not burn hot enough to produce a signal for these pyrophiles to recognize.[31]

In conclusion, fire ecology is an extremely important new field with implications that likely were previously unknown. Studying fire and its relationships with plant, fungal, and animal life provides valuable, previously unknown, insights into the workings of different ecosystems. This newly improved understanding of ecology will play a large role moving forward in informing conservation, education, and policy decisions surrounding the use of fire and management of natural fire.

---

[28] Wikars, Lars-Ove. "The Wood-Decaying Fungus Daldinia loculata (Xylariaceae) as an Indicator of Fire-Dependent Insects," 263.

[29] Midgley, David J., Michael D. G. Jeffries, Michael D. Jones, Michael A. Castellano, and Jeffrey M. Trappe. "Where Are They Hiding? Testing the Body Snatchers Hypothesis in Pyrophilous Fungi." 1.

[30] Claridge, Andrew W., James M. Trappe, and Karen Hansen. "Do Fungi Have a Role as Soil Stabilizers and Remediators after Forest Fire?", 2.

[31] Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023), 8.

Bibliography

Bell, A. J. "Like Moths to a Flame: A Review of What We Know about Pyrophilic Insects." Forest Ecology and Management 528 (2023): 120629. https://doi.org/10.1016/j.foreco.2022.120629.

CBD. Living with Fire: A Guide for Community-Based Forest Fire Management. Secretariat of the Convention on Biological Diversity. Accessed December 8, 2025. https://www.cbd.int/doc/pa/tools/Living%20with%20Fire.pdf.

Claridge, Andrew W., James M. Trappe, and Karen Hansen. "Do Fungi Have a Role as Soil Stabilizers and Remediators after Forest Fire?" Fungal Biology Reviews 28, no. 1 (2014): 1–9. https://doi.org/10.1016/j.fbr.2013.12.001.

Hoang, Thi Phuong. "Adaptations of Pyrophilous Insects to Burnt Habitats: Odor Signals, Infrared Receptors and Behavior." Current Opinion in Insect Science 12 (2015): 14–22. https://doi.org/10.1016/j.cois.2015.09.006.

Kobziar, Leda N., J. Kevin Hiers, Claire M. Belcher, William J. Bond, Carolyn A. Enquist, E. L. Loudermilk, Jessica R. Miesel, Joseph J. O'Brien, Juli G. Pausas, Sharon Hood, Robert Keane, Penelope Morgan, Melissa R. A. Pingree, Karin Riley, Hugh Safford, Francisco Seijo, J. Morgan Varner, Tamara Wall, and Adam C. Watts. "Principles of Fire Ecology." Fire Ecology 20, no. 1 (2024): 39. https://doi.org/10.1186/s42408-024-00272-0.

Marino, Elizabeth. Fierce Climate, Sacred Ground: An Ethnography of Climate Change in Shishmaref, Alaska. Fairbanks, AK: University of Alaska Press, 2015.

Midgley, David J., Michael D. G. Jeffries, Michael D. Jones, Michael A. Castellano, and Jeffrey M. Trappe. "Where Are They Hiding? Testing the Body Snatchers Hypothesis in Pyrophilous Fungi." Fungal Biology Reviews 37 (2021): 1–11. https://doi.org/10.1016/j.fbr.2020.10.003.

Smokey Bear. "Smokey's Story." Accessed December 8, 2025. https://smokeybear.com/smokeys-story.

Vaillant, John. Fire Weather: A True Story from a Hotter World. New York: Alfred A. Knopf, 2023.

Wikars, Lars-Ove. "The Wood-Decaying Fungus Daldinia loculata (Xylariaceae) as an Indicator of Fire-Dependent Insects." Entomologisk Tidskrift 123, no. 3 (2002): 131–134.