Recognizing Fire History in Northern Redwood Forests

Clues from the past as a guide for the future

A Legacy of Burning

Have you ever leaned up against an old redwood and discovered soot on your hand? Ever stood inside their room-sized hollows called 'goosepens'? These features are evidence of a legacy of fire. While some have dubbed redwoods *(Sequoia sempervirens)* 'asbestos forests' due to their thick bark and moist habitat, the portrayal that they don't burn is not quite true. In fact, redwoods have some of the most flammable leaf litter of any western conifer. They also have the incredible ability to survive and thrive with fire. Coastal redwood's fog-laden home, thick bark, high canopy, and relentless ability to resprout all lend to their success, but they are not impervious to fire. Scars from a deep history of repeated low and moderate severity fires are evident in both individual trees and the greater old-growth forest, if you know where to look.

'So if redwoods inhabit such a wet and lightning-limited place, how did these fires start?' Indigenous peoples have inhabited the redwood range for time immemorial. Tribes used and continue to use fire to manage important food, medicinal, and ceremonial resources; as well as to reduce fuel loads, and maintain open forests. Cultural burning practices were so prolific and routine in redwood forests that tree-ring records show historic fire regimes were not tied to climatic, topographic, or latitudinal differences in moisture; but to distance from village sites, ceremonial sites, travel routes, gathering sites and other areas utilized by tribes. While occasional lightning strikes do start fires in redwood forests, and fires from settler activities make up much of the recent record, the old-growth forests we know today were shaped by indigenous burning. Old-growth forest features important to native peoples, settlers, wildlife, and possibly even climate stability, rely on the revitalization of these practices.

Figure 1: This basal hollow expanded dramatically during a low intensity prescribed fire, after many decades of fire exclusion and rot growth.

See the Forest or the Trees?

As fire moves through a forest, it has lasting effects both large and small. The form and features of individual trees, and the structure and composition of the forest can display these effects for centuries. Visual evidence provides clues into a forest's fire history, but without site-specific research, the dates, sizes, and severities of fires cannot be determined. We can, however, gain valuable insight into generalized fire regimes and their results. Supplied with a basic knowledge of the unique stand dynamics and fire effects in redwood forests, the keen observer will notice that fire was once a common occurrence here.

Fire in the Redwoods

Notches, Sprouts and Cavities

The story of a redwood forest is written in the bark of its oldest trees. The soot and ash remaining in fire scars, and their deeper cousins *'goosepens'*, are obvious indicators of past fires. While less obvious, charred bark, sprouts from the trunk and base, and complex crowns can also provide clues into how past fires burned.

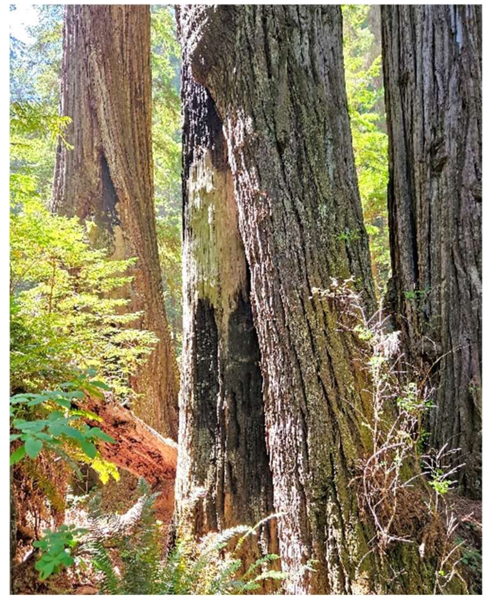
Fire Cavities

'Goosepen' or *'catface'* are colloquial terms for fire-excavated hollows in the trunks of old trees (Fig. 1). In old-growth redwoods, modeling and experimental burning suggests that large room-sized cavities form through frequent fires occurring throughout the lifespan of the tree; in a complex collaboration between scarring, healing and decay. This process starts when a tree is scarred by a fire while its bark and heartwood are relatively thin. As the tree heals over, fungi begin to rot the dead wood behind the callus tissue. If another fire occurs before the tree can close the wound, the rot will burn out to form a small cavity. Once the opening becomes concave, heat reflects between the cavity walls and accelerates the excavation process through successive fires. If radial growth can keep up through these cycles of healing, decay, and excavation, the tree can stand for centuries with dramatic structural defects.

Once a goosepen forms, frequent fire may become critical to the tree's survival. If the intervals between fires become too long, fungi can decay heartwood and sapwood to extents that can cause 'catastrophic excavation' during the next fire. Trees with cavities perforated on more than one side, or that have a pronounced lean, are highly susceptible to falling during the cavity excavation process.

If a redwood doesn't experience a fire until it has developed thick bark and a wide heartwood core, the cavity creation process takes a different trajectory. Northern coastal redwood stands with infrequent fire regimes have the highest fuel loading of any forest measured. Logs, branches, and leaves accumulate around the bases of trees, then burn for hours during fire events. Long-duration heat can kill cambium and even consume bark and sapwood. However, redwood's fire-retardant heartwood is not as easily consumed. This leaves a scar with a convex face, and so does not undergo the excavation process described earlier (Fig. 2).

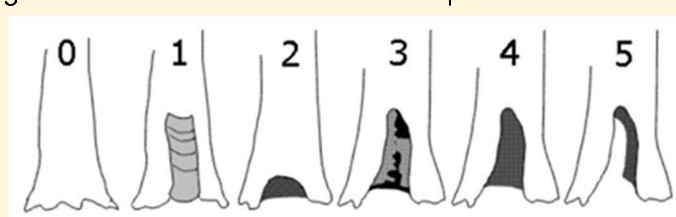
Figure 2: Two old-growth redwoods show convex fire scars. Paired with other indicators, these features suggest an infrequent fire regime.



Redwood Cavity Index

Norman et al. 2009

In an innovative report, researchers categorized redwood fire scars to create a fire regime **rapid assessment tool**. Cavity classes are averaged by plot then across a stand to develop a *'redwood cavity index'*. Informed by the unique cavity formation process, the index can be used to reconstruct the site-specific fire regime of both old growth and second growth redwood forests where stumps remain.



Class 1 cavities are the result of radiant heat from accumulated fuel loads. This kind of damage suggests hot and infrequent fires. Class 2 cavites are common and have the ability to heal over. Classes 2-5 represent the successional process of 'goosepen' formation, under a frequent fire regime. Class 5 trees have a high likelyhood of collapse, especially if leaning.

Epicormic Sprouting and Complexity

The name *'sempervirens'*, Latin for ever-living, describes redwood's almost endless ability to resprout. After a damaging fire, redwoods can look like a 'bottlebrush', covered in epicormic sprouts from protected buds (Fig. 3, left tree). These bushy growths will eventually develop into a new canopy. In old-growth trees, clumps of small branches on large portions of the lower trunk, with large, crooked branches above could indicate this process.

As fire climbs bark, it ignites litter and dead wood held in branches and tops, damaging them. The redwood's propensity to grow back from dormant bubs creates the incredible complexity found in old-growth canopies (Fig. 3, left tree).

Figure 3: Three redwoods show varying canopy responses to fire. The left tree is recovering branches through epicormic sprouting. The tree in center has died back to basal sprouts. The right tree retained most of its canopy branches. This damage is likely caused by heavy fuels accumulating between crowded trees under an infrequent fire regime.

Bark Notches

While a redwood's thick 'fire resistant' bark insulates the cambium from damage, it is far from fire retardant. The fluffy and fibrous structure of the outer bark is perfect for holding embers and then smoldering for long periods. Arranged in linear strips travelling the length of the trunk, ignited bark can carry fire like a slow fuse from the base to the branches. While ash on the bark's surface only lasts so long, the 'notches' resulting from this process can provide long lasting evidence of fires that were not severe enough to cause scarring (Fig. 5).

Figure 4: Three generations of sprouts emerge from a collapsed parent tree. The largest of these redwoods likely dates back to the last fire.

Fairy Rings

Not much will kill a redwood, but too much fire damage can cause old and decadent trunks to succumb. If the main stem is severely damaged, a redwood will shoot growth from its base, utilizing resources stored in its roots. The result is circular groupings of trees called *'fairy rings'* which are very common in logged forests. In old-growth forests, these arrangements can indicate past fires.

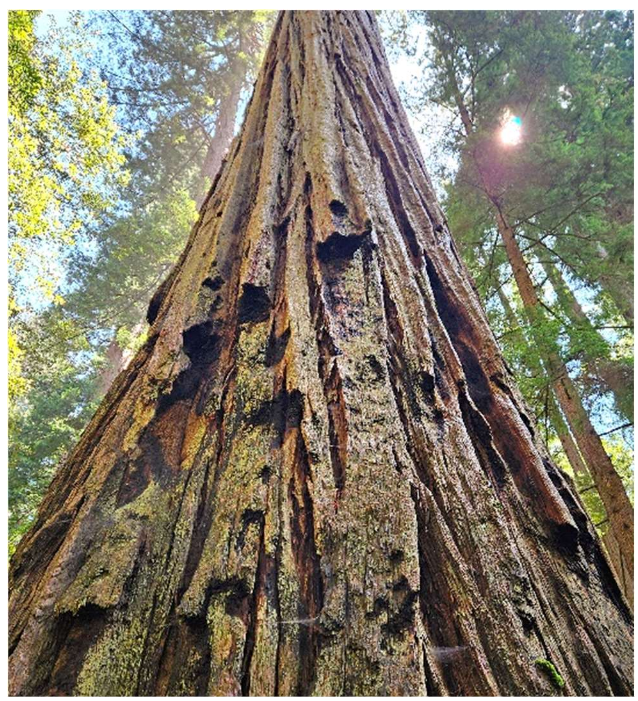


Figure 5: Bark notches show evidence of many past fires. Strips of fibrous outer bark can carry fire up into the canopy, even under low fire behavior conditions.

Fire in the Forest

Indications from Plant Adaptations

The composition of a forest is a function of the plant species present and past disturbances. The sizes, ages, arrangements, and distributions of plants with varying fire adaptations can provide clues into the stand's disturbance history. Plants' fire survival and recovery strategies can be grouped into 4 categories: resisters, resprouters, reseeders, and avoiders. Resisters often have thick bark and high crowns. Resprouters respond to damage by shooting growth from dormant buds maintained in stems, basal burls, or roots. Reseeders rely on a persistent seed bank or seeds from adjacent living trees to recolonize the fire area. Avoiders must rely on fire-limiting environments, litter beds with low-flammability, and mosaic fuel consumption to stay out of harm's way. Every species employs a unique combination of these strategies to persist through various fire regimes. The trees discussed below by no mean represent a full list of plant fire adaptations or fire indicators in redwood forests. However, they provide the clearest context for fire history in the northern redwood range.

Redwood

Redwoods are the ultimate fire survivor, having traits of all four fire response strategies. Its habitat is moist and ignition-limited. Thick bark and high canopies minimize damage to mature trees. When damaged, redwoods sprout from protected buds on their branches, trunk, burl, and roots. If all else fails, redwood seeds take advantage of ashy mineral soil to establish. With these strong traits, redwoods dominate the overstory of forests with histories of both infrequent and very frequent fire. While redwoods are incredibly persistent, fires of mixed frequency and severity can wear away at older and more complex individuals, slowing growth rates or hollowing trunks to the point of failure. This process creates canopy gaps that allow for a diversity of other tree species to establish.

Douglas-fir

While lacking the ability to resprout after fire, Douglas-fir's *(Psuedotsuga menzeisii)* thick bark, high canopy, and compact litter beds provide for its success as a long-lived co-dominant fire-resister in redwood forests. Scars on chunky Douglas-fir bark show evidence of surviving many fires. However, the lifecycle requirements of Douglas-fir also offer insight into the frequency and severity of past fires in the forests they inhabit. Without shade tolerance or the ability to basal sprout, Douglas-fir's only hope for regeneration is seeding in after a disturbance. Once germinated, a Douglas-fir seedling requires a minimum of a quarter acre gap in an old growth forest canopy to establish and survive. With these limitations in mind, one can note the size and arrangement of Douglas-fir trees to rewind a forest's history. A large area of co-dominant Douglas-fir could represent a long-ago stand replacing event. Small groupings of Douglas-fir trees may show where individual redwoods have succumbed to repeated fires and created canopy gaps (Fig. 6). While logging, landslides, windstorms, and other disturbances also initiate these forest dynamics, Douglas-fir stand dynamics can provide insights into a redwood forest's fire history.

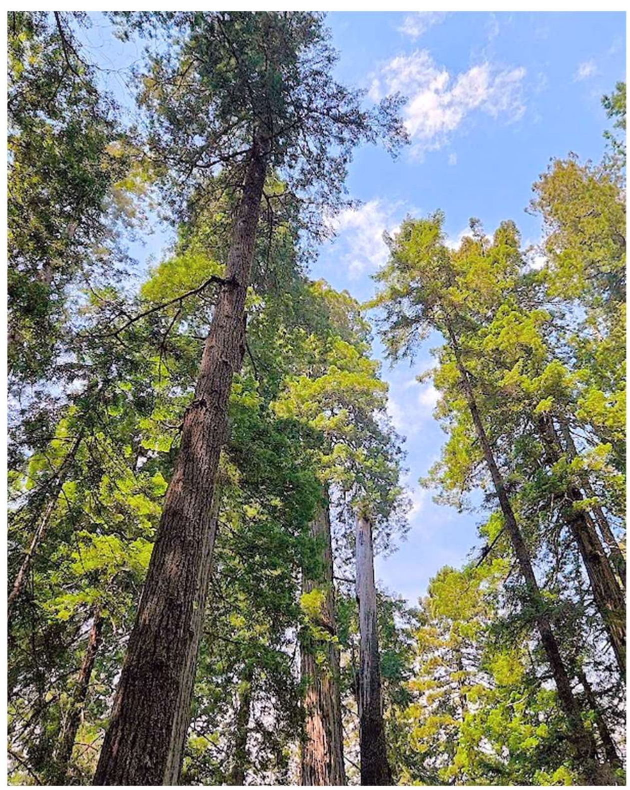


Figure 6: Mature Douglas-fir trees take advantage of a canopy gap created by the collapse of a fire-damaged old-growth redwood, visible in center frame.

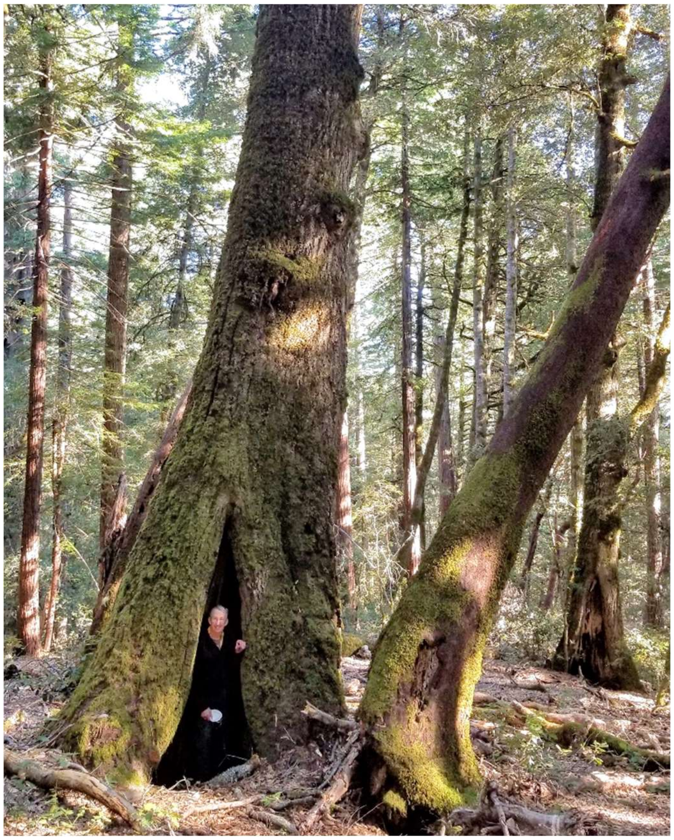


Figure 7: A stand of legacy tanoak trees, showing evidence of indigenous management, occupy the midstory of an old-growth redwood forest.

Tanoak

Tanoaks *(Notholithocarpus densiflorus)* are unique and sacred trees in redwood forests. Bearing the most nutrient-rich acorn of all California 'oaks', indigenous peoples manage tanoak stands with frequent, low-intensity fire to maintain abundant and pest-free harvests. Tanoak groves comprised of large diameter, deep-crowned and uncrowded trees produce the most acorns. Clear and open forest understories provide for easy acorn collecting. While fire is the tool of choice to keep these stands healthy, tanoak trees are easily killed in all but low severity fires. Thin bark provides little protection, so tanoaks respond to fire damage by resprouting from a basal burl, resulting in multi-stemmed sprout clumps after disturbance. To create and maintain the 'acorn groves' of large old trees, the intentional and frequent application of low-intensity fire is required. Large diameter tanoaks with sprawling canopies and often large basal cavities, standing alone or in the midstory of a redwood forest (Fig. 7), are indicators of these tended places.

> ***"Older, taller, co-dominant single stalk tanoaks with a high ground to crown ratio are usually indicative of a former low to moderate intensity fire regime such as from Native American burning and management."***
>
> *– Frank Lake, 2007*

Spruce, Hemlock, Grand Fir, and Yew

Sitka spruce *(Picea sitchensis),* western hemlock *(Tsuga heterophylla)*, grand fir *(Abies grandis)*, and Pacific yew *(Taxus brevifolia)* are a few common fire-avoiders found in the northern coastal redwoods. With thin bark and shallow roots, these trees are easily killed in even the lightest of fires. Under a frequent fire regime, these species only occupy sites that offer protection from fire. Once fire is excluded, fire-avoiders can establish in abundance. Coring and aging trees of these species often provides the date of the last major disturbance. Without an increment borer, the relative size and distribution of the oldest and youngest fire-avoiders can indicate the kind of fire, or lack-there-of, that a forest has experienced. Small diameter and sapling Sitka spruce and western hemlock carpeting the understory of an old-growth redwood forest can indicate a recent change in the disturbance regime (Fig. 8). Mature fire-avoiders on sites that do not provide refuge may indicate a long fire-free interval.

Figure 8: Sitka spruce and western hemlock establish in the understory of a once fire-frequent forest.

References

Berrill, J. P., K. L. O'Hara, and N. E. Kichas. 2020. "Bark Thickness in Coast Redwood (Sequoia sempervirens (D.Don) Endl.) Varies According to Tree- and Crown Size, Stand Structure, Latitude and Genotype." *Forests* 11(6): 637. https://doi.org/10.3390/f11060637

Brown, P.M., T.W. Swetnnam. 1994. "A cross-dated fire history of a coast redwood forest near Redwood National Park, California." *Canadian Journal of Forest Research* 24: 21-31. https://doi.org/10.1139/x94-004

Carroll, A.L., S.C. Sillett, & R. Van Pelt. 2018. "Tree-Ring Indicators of Fire in Two Old-Growth Coast Redwood Forests." *Fire Ecology* 14: 85–105. https://doi.org/10.4996/fireecology.140185105

Dale, V. H.; Hemstrom, M. A.; Franklin, J. F. 1984. "The effects of disturbance frequency on forest succession in the Pacific Northwest." In: *New forests for a changing world: Proceedings of the 1983 convention of The Society of American Foresters*; 1983 October 16-20; Portland, OR. Bethesda, MD: Society of American Foresters: 300-304. https://doi.org/10.1139/x86-010

Finney, M.A. 1996. "Development of fire scar cavities on old-growth coast redwood." In: *J.Leblanc (tech coordinator) Proceedings of the conference on coast redwood forest ecology and management* June 1996, 18-20, California Polytechnic University, Humboldt, Arcata, CA: 96-98. https://web.archive.org/web/20050310100631/http://www.cnr.berkeley.edu/~jleblanc/WWW/Redwood/rdwd-Developm.html

Fonda, R. W., L. L. Burley. 1998. "Burning characteristics of western conifer needles." *Northwest Science* 72(1): 1-9. https://www.cabidigitallibrary.org/doi/full/10.5555/19980614291

Graham B. D., 2009. "Structure of downed woody and vegetative detritus in old-growth Sequoia sempervirens forests." Master's thesis. California State Polytechnic University, Humboldt. http://localhost/files/v979v5390

Gray, A. N., T.A. Spies. 1996. "Gap Size, Within-gap position, canopy structure effects on conifer seedling establishment." *Journal of Ecology* 84: 635-645. https://research.fs.usda.gov/treesearch/54624

Halpern, A. 2016. "Prescribed fire and tanoak *(Notholithocarpus densiflorus)* associated cultural plant resources of the Karuk and Yurok Peoples of California." PhD diss., University of California, Berkeley. https://escholarship.org/uc/item/02r7x8r6

Lake, F. K. 2007. "Traditional Ecological Knowledge to Develop and Maintain Fire Regimes In Northwestern California, Klamath-Siskiyou Bioregion: Management and Restoration of Culturally Significant Habitats." PhD diss., Oregon State University. https://ir.library.oregonstate.edu/concern/parent/1z40kw515/file_sets/1g05ff07j

Lorimer, C. G., D. J. Porter, M. A. Madej, J. D. Stuart, S. D. Veirs, S. P. Norman, K. L. O'Hara, W. J. Libby. 2009. "Presettlement and modern disturbance regimes in coast redwood forests: implications for the conservation of old-growth stands." *Forest Ecology and Management* 258(7): 1038-1054. https://doi.org/10.1016/j.foreco.2009.07.008.

Norman, S. P. 2007. "A 500-year record of fire from a humid coast redwood forest." *Report to Save-the-Redwoods League*: 34. https://www.savetheredwoods.org/wp-content/uploads/pdf_norman.pdf

Norman, S.P., J.M. Varner, L. Arguello, S. Underwood, B. Graham, G. Jennings, Y. Valachovic, and C. Lee. 2009. "Fire and fuels management in coast redwood forests." JFSP Research Project Reports 158 https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1156&context=jfspresearch

Parminter, J. 1983. "Fire history and fire ecology in the Prince Rupert Forest region." In: *Trowbridge, R. L.; Macadam, A., eds. Prescribed fire--forest soils: Symposium proceedings;* 1982 March 2-3; Smithers, BC. *Land Management Report Number* 16. Victoria, BC: Province of British Columbia, Ministry of Forests: 1-35. https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/2196.pdf

Ramage, B. S., K. L. O'Hara, and B. T. Caldwell. 2010. "The role of fire in the competitive dynamics of coast redwood forests." *Ecosphere* 1(6): art20. https://doi.org/10.1890/ES1000134.1

Scanlon, Hugh. 2007. "Progression and behavior of the Canoe fire in coast redwood." *USDA Forest Service Gen. Tech. Rep.* PSW-GTR 194. https://research.fs.usda.gov/treesearch/28264

Sillett, S. C., R. D. Kramer, R. Van Pelt, A. L. Carroll, J. Campbell-Spickler, M. E. Antoine. 2021. "Comparative Development of the four tallest conifer species." *Forest Ecology and Management* 480: 118688. https://doi.org/10.1016/j.foreco.2020.118688.

Woodward, B.D., W.H. Romme, and P.H. Evangelista. 2020. "Early postfire response of a northern range margin coast redwood forest community." *Forest Ecology and Management* 462 :117966. https://doi.org/10.1016/j.foreco.2020.117966

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