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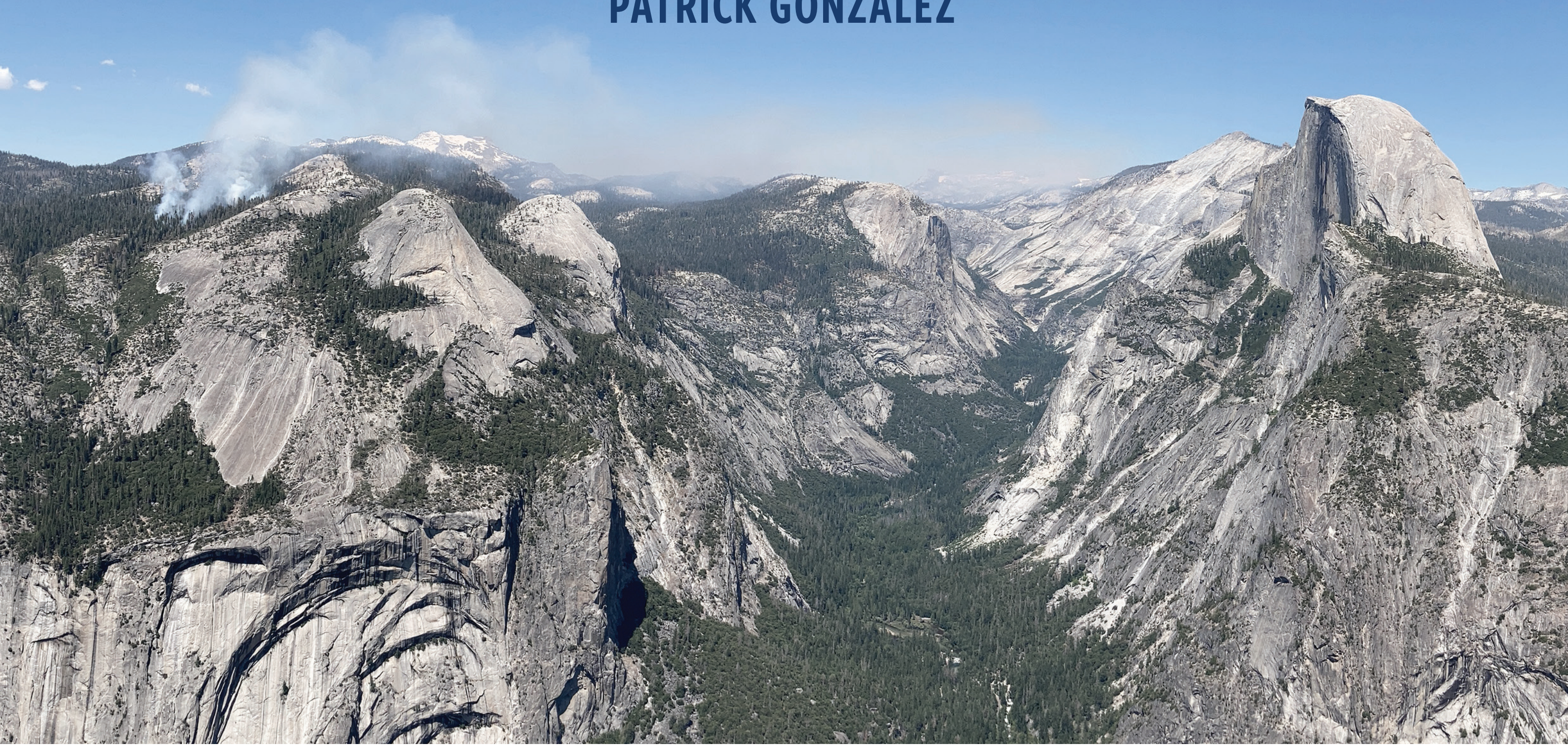
Wildfire, Climate Change, Forest Resilience, and Carbon Solutions

PATRICK GONZALEZ



On June 29, 2023, lightning naturally ignited a wildfire in Yosemite National Park. Two weeks later, I hiked the trail from the floor of Yosemite Valley up 1000 m in elevation to Glacier Point. Under a brilliant blue sky, the view at the top swept in an arc from Yosemite Falls to Half Dome to the distant crest of the Sierra Nevada. Smoke from that wildfire streamed up from the opposite edge of the valley and away to the north.

In many temperate forests in Yosemite and around the world, wildfire is natural and essential for long-term forest health (Dodge 1972; Bowman et al. 2020; Stephens et al. 2021). The US National Park Service determined that this particular fire in Yosemite, named the Pika Fire, did not threaten people or property but that it would help decrease future fire risk by reducing an unnatural buildup of coarse woody debris and small trees from former policies of suppressing all fires. So, park fire crews were managing this wildfire for its natural benefits, though containing it within an area bounded by existing trails and topography, following the national park fire management plan.

Many temperate forests require periodic natural wildfire because it kills pests, thins out small trees, releases seeds from pine cones closed by pitch, and serves other functions critical for ecological integrity (Dodge 1972; Bowman et al. 2020; Stephens et al. 2021). Starting in the early 1900s, however, national and state policies sought to suppress all wildfire, even natural fires, across the western US, generating unnatural accumulations of woody fuel (van Wagtendonk 2007; Taylor and Scholl 2012; North et al. 2022). Seasonally dry forests in

▲ The Pika Fire, Yosemite National Park, California, July 10, 2023, a lightning-ignited wildfire managed for its natural ecological functions. PATRICK GONZALEZ

Yosemite and the western US require a low severity–high frequency fire regime, with fires every 10 to 30 years (Stephens et al. 2007). Other temperate forests and shrublands and boreal forests experience a high severity–low frequency regime, with stand-replacement fires every 30 to 300 years (Van de Water and Safford 2011; Hennebelle et al. 2018). In boreal forest, oil and gas operations and activities on roads and in towns accidentally ignite many fires (Kuklina et al. 2023).

In tropical and temperate rainforests, sub-alpine forests, Arctic tundra, and deserts, fire is not natural. In the tropical rainforests of the Amazon, Congo, and Indonesia, people intentionally burn vast forest areas to expand beef cattle pastures, soybean fields, and palm oil plantations, with timber logging causing accidental fires (Curtis et al. 2018; Vancutsem et al. 2021). China, Europe, and the US import a large fraction of the products of tropical deforestation (Busch et al. 2022; Villoria et al. 2022; zu Ermgassen et al. 2022; Partzsch et al. 2023; World Bank 2023).

At the same time, human-caused climate change is intensifying the heat that drives wildfires. Scientific research has detected statistically significant changes in numerous fire factors and attributed these changes to human-caused climate change more than other causes. Human-caused climate change has lengthened the fire weather season up to two months in parts of the world from 1979 to 2013 (Jolly et al. 2015; Zhuang et al. 2021), doubled the average annual area burned by wildfire over natural levels across the western US from 1984 to 2015 (Abatzoglou and Williams 2016), tripled the average area burned by wildfire in summer across northern and central California from 1996 to 2021 (Turco et al. 2023), and increased burned area 7 to 11 times over natural levels in British Columbia, Canada, in the extreme fire season of 2017 (Kirchmeier-Young et al. 2019). In protected areas of Canada and the US, climate factors (temperature, precipitation, relative humidity, evapotranspiration) accounted for 60% of burned area from 1984 to 2014, outweighing local human factors (population density, roads, and built area) (Mansuy et al. 2019). In these cases, climate change raised combustion potential by increasing the aridity of air, soil, and vegetation.

Detection and attribution analyses have also found cases in which climate change and wildfire have

▼ The Las Conchas Fire, New Mexico, July 4, 2011, one of the wildfires that burned during the period in which human-caused climate change doubled wildfire area in the western US above natural levels (Abatzoglou and Williams 2016). KARI GREER, USDA FOREST SERVICE

▲ Burned Amazon rainforest, to expand agriculture or cattle pasture, just outside the Parque Nacional de Anavilhanas, Brazil. PATRICK GONZALEZ

degraded vegetation. In the western US, climate change reduced post-fire regeneration of ponderosa pine and Douglas-fir by half from 1979 to 2015 (Davis et al. 2019). In Table Mountain National Park, South Africa, the heat and aridity of climate change and legacy effects of invasive alien species reduced post-fire plant species richness 12% in globally unique fynbos vegetation from 1966 to 2010 (Slingsby et al. 2017).

In the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC 2022), colleagues and I found that western North America is currently the only region in the world where climate change exerts a greater influence on the area burned by wildfire than deforestation, ignitions from people, short-term cycles like El Niño, or other non-climate change factors (Parmesan et al. 2022). In addition, no analyses have yet examined the relative influence of climate change and non-climate change factors, such as human population and building growth, in explaining deaths and property damage in wildfires.

Globally, 3 to 4 million km^2 per year of land burned in fires from 1994 to 2015, equivalent to the land area of India, with tropical deforestation causing over 80% of the burning (Andela et al. 2017; Forkel et al. 2019; Tyukavina et al. 2022). In the western US, the combination of old fuel accumulation from outdated policies and climate change increased average annual burned area 1000% from 1984 to 2020 (Abatzoglou et al. 2021; Juang et al. 2022).

Globally, wildfire generated carbon emissions of 1.8 ± 0.3 billion tons per year from 2000 to 2019, mainly from tropical deforestation and burning of tropical peatlands (Zheng et al. 2021). In the Amazon rainforest, the combination of deforestation and climate change has driven fires and tree mortality that now emit more carbon to the atmosphere than vegetation growth naturally removes (Hubau et al. 2020; Gatti et al. 2021; Qin et al. 2021; Fawcett et al. 2023). In California, wildfires have caused ecosystems to emit more carbon than they remove, with two-thirds of ecosystem carbon emissions coming from the 6% of the land that burned (Gonzalez et al. 2015). Fire feeds back into climate change in a self-reinforcing cycle—climate change causes more fire, which emits carbon, which makes climate change worse, which causes more fire.

Globally, climate change of 4°C above pre-industrial temperatures could increase burned area 50% to 70%

(Knorr et al. 2016; Kloster and Lasslop 2017) and increase fire frequency across one-third to two-thirds of global land (Gonzalez et al. 2010; Moritz et al. 2012). In the lower 48 US states, climate change of 4.5°C could increase burned area 1400% (Barbero et al. 2015; Abatzoglou et al. 2021; Anderegg et al. 2022). Cutting carbon emissions would limit increases in temperature and fire (Anderegg et al. 2022).

Continued climate change also exacerbates fire risks in the two largest sinks of ecosystem carbon in the world: Arctic tundra and Amazon rainforest. Climate change of 4°C above pre-industrial temperatures could cause fires in and thaw extensive areas of Arctic permafrost, releasing the equivalent of up to 15 years of 2019 global carbon emissions (Turetsky et al. 2020; Miner et al. 2022). Fires due to continued climate change and deforestation could convert up to half of Amazon rainforest to non-forest, releasing the equivalent of one to three years of 2019 global carbon emissions (Salazar and Nobre 2010; Assis et al. 2022; Cano et al. 2022).

Natural resource managers can strengthen forest resilience and reduce risks of catastrophic wildfire under climate change through field measures specific to the three broad fire regimes: low severity–high frequency fire, high severity–low frequency fire, and no natural fire.

In ecosystems adapted to low severity–high frequency fire where natural fire has been suppressed, such as in seasonally dry forests of the western US, scientific research and field experience have shown that two practices can reduce risks of catastrophic fire under climate change: letting remote naturally ignited fires burn (managed wildland fire) and pre-emptively setting low-severity fires during safe weather conditions (prescribed burning) (Stephens et al. 2009; Parks et al. 2015; van Mantgem et al. 2016).

When a wildfire crosses into an area previously burned with one of these practices, the fire generally continues along the ground at low severity. Ground-level fires clear the understory, enabling the remaining trees to grow larger. In contrast, wildfires in unburned areas can become catastrophic, going up into the canopy crown and completely burning trees.

In areas close to towns and suburbs and in densely overgrown forest, mechanical thinning is necessary before prescribed burning, to avoid high-severity crown fire (North et al. 2021). Thinning complements prescribed burning but does not replicate the ecological functions and long-term risk reduction of fire (McIver et al. 2013).

After decades of unnatural fire suppression, the US National Park Service began to restore natural fire in Sequoia National Park in 1968 and Yosemite National Park in 1972 (van Wagtendonk 2007). Through the continuation and extension of this policy, the use of managed wildland fire and prescribed burning is restoring ecological integrity and reducing hazardous fuels in Grand Canyon National Park (Stoddard et al. 2020), Yosemite National Park (Stephens et al. 2021), and other public lands. The Pika Fire is one example of managed wildland fire.

Moving from after-the-fact firefighting to proactive use of natural fire could strengthen forest resilience and reduce catastrophic wildfires under climate change (Stephens et al. 2013; Stephens et al. 2020; Prichard et al. 2021). Furthermore, prescribed burning and managed wildland fire can increase long-term carbon storage as the growth of large trees takes up more carbon over time than the short-term carbon losses from the burns (Hurteau and North 2009; Harris et al. 2019; McCauley et al. 2019). This net removal of carbon from the atmosphere reduces the cause of climate change. Recently, colleagues and I completed an update for the US National Cohesive Wildland Fire Strategy that integrates climate change considerations into national wildfire policy for the first time (WFLC 2023).

In ecosystems adapted to high severity–low frequency fire where human ignitions cause unnaturally frequent fire, such as boreal forest in Canada or chaparral shrubland in California, preventing unnatural ignitions, removing invasive alien grasses, and mechanical thinning to restore mixed-structure vegetation mosaics can reduce risks of catastrophic fire under climate change (Keeley et al. 2005; Syphard et al. 2017a; Halofsky et al. 2018).

▲ Prescribed burn, Sequoia National Park, California. REBECCA PATERSON, US NATIONAL PARK SERVICE

Wildfires have tragically killed many people, so saving human life remains the first goal of US national fire policy (WFLC 2014). In the US, 25 million more people have moved into and 13 million more houses were built in fire-prone areas from 1990 to 2010 (Radeloff et al. 2018). Deaths and losses of homes are a function of the number of people who live in fire-prone areas. So, avoiding building new homes in fire-prone areas offers a common-sense precaution.

In ecosystems where fire is naturally absent or rare, including tropical and temperate rainforests, subalpine forests, tundra, and deserts, halting intentional burning and other human ignitions is the most effective action to reduce risks of catastrophic fire under climate change (Morton et al. 2008; Adeney et al. 2009; Syphard et al. 2017b; McCarty et al. 2021). In addition, removal of highly flammable invasive alien grasses is critical in some desert ecosystems or other disrupted areas, such as abandoned agricultural lands in Hawaii.

Halting the intentional burning and deforestation of tropical rainforests requires substantial policy and economic measures. One measure, protection of forests in national parks, Indigenous reserves, and other protected areas, offers an effective way to halt deforestation (Adeney et al. 2009; Ernst et al. 2013; Gonzalez et al. 2014; Goncalves-Souza et al. 2021; Shah et al. 2021). Halting tropical deforestation would protect globally important biodiversity and cut global carbon emissions 10% (Friedlingstein et al. 2022), reducing climate change.

In each issue of *Parks Stewardship Forum*, I offer a specific solution that each of us can implement to reduce climate change and help protect natural areas. From the January 2023 issue (Gonzalez 2023), you may recall that, if all the cars and light trucks in the US were a separate country, they would be the eighth-biggest carbon polluter in the world, generating more than all sources in Canada and France combined (Friedlingstein et al. 2022). So, you can take meaningful action on climate change by walking, biking, or taking public transit. I live a car-free life and recommend a further action that I take: ride public transit to visit national parks.

Public transit goes to many parks, including Yosemite National Park. When I travel to Yosemite from my home in Berkeley, California, I go completely by public transit. I walk to the Bay Area Rapid Transit

▲ YARTS public transit, Yosemite National Park, California. PATRICK GONZALEZ

(BART) station for a train to Richmond, California. Then I board an Amtrak train to Merced, California. A Yosemite Area Regional Transportation System (YARTS) bus meets the train at the station and runs to Yosemite Valley.

I've also taken the Metrolink train and Ventura County bus to Santa Monica Mountains National Recreation Area, California, the South Shore Train from Chicago to Indiana Dunes National Park, the Park Connection bus to Denali National Park, Alaska, the MyCiti bus to Table Mountain National Park, South Africa, and Indian Railways and a local bus to Kanha National Park, India. I've visited many urban national parks in the US by public transit, using the T in Boston, the subway in New York, BART in San Francisco, and Metro in Washington, DC. On arrival, many parks operate public transit for travel within the park.

You can take public transit to make your national park trip more sustainable. The train or bus journey becomes part of the national park adventure. Taking public transit to and within parks can help cut the carbon pollution that causes climate change, helping prevent catastrophic wildfires and other risks to people and nature.

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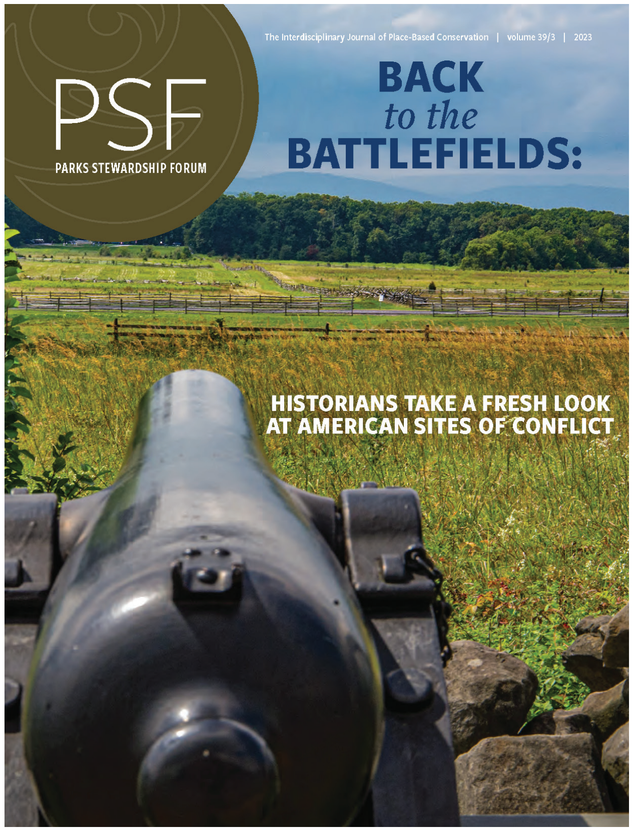

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