

Progression and Behavior of the Canoe Fire in Coast Redwood¹

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Abstract

Lightning caused fires occur in coast redwood forests, but large fires have been rare since the 1930s. Coast redwood (*Sequoia sempervirens*) is considered fire resistant. In 2003, the Canoe Fire, a lightning fire started in an old-growth redwood stand in Humboldt Redwoods State Park, burned 5,554 hectares (13,774 acres) before it was contained. Fuel characteristics and weather contributed to fire progression. Topography, access, fuel loading and management considerations affected fire suppression tactics and effectiveness. From the old-growth redwood stand, fire progressed into young-growth, producing significant changes in fire behavior and effects. Old-growth redwood stands should be managed to anticipate wildfire impacts.

Key words: fire, fire behavior, redwood

Introduction

On September 3, 2003, a major lightning event over northwestern California ignited numerous fires. The Canoe fire, starting in Humboldt Redwoods State Park, became the largest recorded fire in old-growth coast redwood (*Sequoia sempervirens*) since the beginning of the fire suppression era. The fire proved difficult to contain due to weather, poor access, fuel conditions, other fire activity, and park management considerations. The Canoe fire presents a case study of fire progression and behavior in mature and young-growth coast redwood.

Coast redwood is considered a fire resistant species, but not dependent on fire for regeneration. Since implementation of fire suppression policies in the 1930s, large fires in redwood have been rare (*fig. 1*). The last recorded large fires in coast redwood were Comptche in 1931 at 13,064 hectares (32,283 ac), Will Creek in 1945 at 11,672 hectares (28,841 ac), Strong Mountain in 1950 at 7,522 hectares (18,588 ac), and A-Line in 1936 at 5,583 hectares (13,797 ac) (California Department of Forestry and Fire Protection 2003). These fires occurred primarily in young-growth redwood. The Canoe fire in 2003 started in old-growth redwood and burned 5,554 hectares (13,774 acres), becoming the fifth largest fire on record in this vegetation type.

¹ This paper was presented at the Redwood Science Symposium: What does the future hold? March 15-17, 2004, Rohnert Park, California

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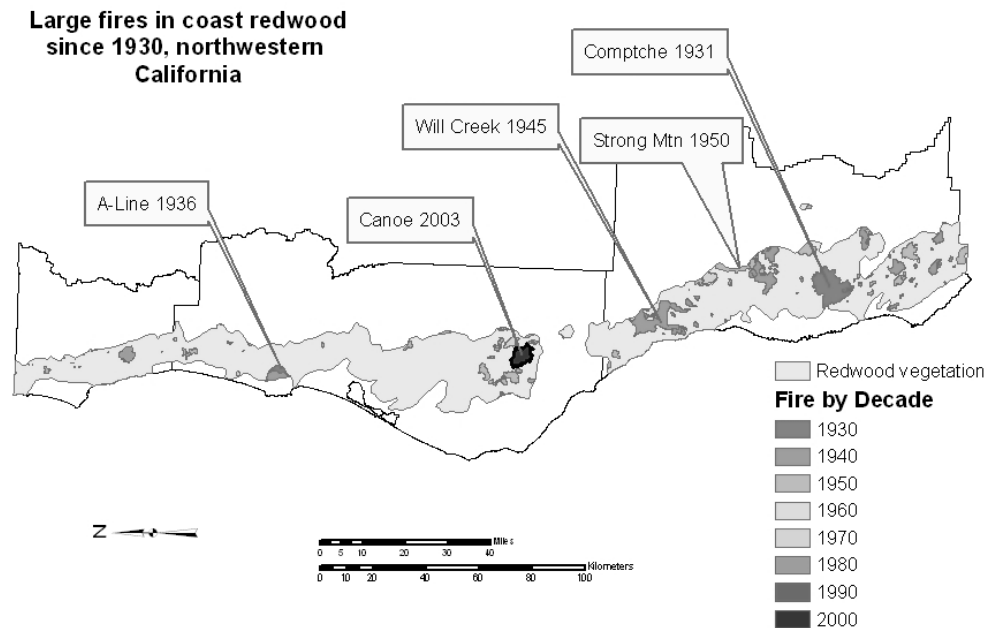


Figure 1—Large fire locations in coast redwood since 1930.

Before the era of fire suppression, coast redwood forests burned often. Mean fire return interval in the pre-settlement period for redwood in Humboldt Redwoods State Park was measured as 24.6 years, with an estimated fire cycle ranging from 26.2 to 51.6 years (Stuart 1987). Fires burning in old-growth redwood produced mortality in approximately two percent of trees over four-foot in diameter (Fritz 1932).

Research on fire behavior in coast redwood has been limited. Young-growth redwood is resistant to being killed in low intensity prescribed burning, but increased mortality was likely when large amounts of fuel were present and burned (Finney and Martin 1993). At Redwood National Park, Nives (1989) found fuel moisture, influenced by elevation and topographic position, a determining factor in fire spread rates, with fuel depth and load affecting the intensity and duration of the fires.

Methods

This is a qualitative evaluation of the fire progression and behavior, primarily based upon fire information found in the documentation of daily firefighting operations for the Canoe fire. The old-growth redwood areas burned were generally inaccessible and precluded using quantitative methods during active burning. Weather information was obtained by reviewing forecasts, data records from Remote Automated Weather Stations (RAWS) near the fire, and in discussion with meteorologists that analyzed weather conditions. Fuel information was gathered from limited sampling in the area and fuel moisture modeling in the Weather Information Management System (WIMS).

Results

Weather

The occurrence of lightning in northwestern California during fire season is infrequent, but not considered rare. The years 1987, 1990, 1994, 1999, 2002, and 2003 experienced major lightning fires in this area.

By late August 2003, northwestern California had warm and very dry conditions, provided by strong high pressure over the western states and a surface thermal trough along the coast. Dry, offshore winds reduced daily minimum relative humidity regularly into the lower to mid teens to set up a critical fire weather pattern for northern California. The Keetch-Byram Drought Index forecast for Eel River Camp was 763.

Early on September 3, a band of cumulonimbus rapidly formed and generated numerous lightning strikes in Lake and Mendocino counties. As the band tracked northwest through and exited western Humboldt, the county was peppered with lightning strikes. Sixty-four new fires were reported. Rainfall ranged from zero precipitation at Eel River Camp and Cooskie Mountain to 0.08 inches at the Alderpoint and Honeydew RAWS. After the Canoe fire started, a series of weak systems and strong highs affected the fire area. Morning inversions were common.

Vegetation, Terrain and Fuel Condition

The Canoe fire started approximately mid-slope in the Canoe Creek watershed of Humboldt Redwoods State Park (*fig. 2*). This is an area of old-growth redwood, west of the south fork of the Eel River. The area had been designated state wilderness in 2001.

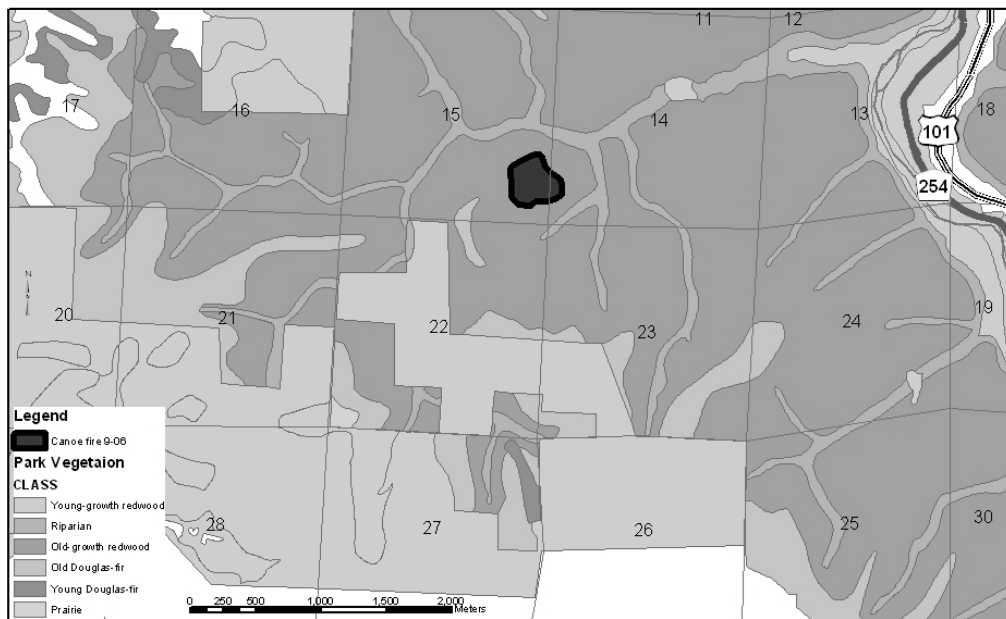


Figure 2—Canoe fire origin and area vegetation.

Humboldt Redwoods State Park was established in 1920, through land acquisition by the Save the Redwoods League. This area is primarily old-growth redwood, but some areas of pre-acquisition selection harvest are scattered in this

area. Other areas were in young-growth timber, with few residual old-growth present. The area had some ridge roads. Old skid trails were few, and had reverted to heavy vegetation. Other roads had become trails within the park. The area where the Canoe fire started had no ground access, except by off-trail travel.

Live fuel information forecast by the WIMS using the Eel River Camp RAWS predicted live fuel moisture at 70 percent for September 2. On August 13, live fuel moisture in the Miranda area reached 100.1 percent in manzanita, drier than the average of 108 percent for early August for the years 1995 to 2002. On October 9, live fuel moisture had dipped to 78.6 percent in manzanita, well below the seasonal average of 88.6 percent. Dead fuel moisture for the 10-hour size class dipped to one percent on September 2, and then rising rapidly after the thunderstorm passed. The daily 10-hour fuel moisture lows did not again reach below four percent until September 13. The large dead fuel moisture ranged from 11 to 14 percent during the fire. No quantitative analysis of fuel loading had been done in this area. The area had a heavy fuel load, and no past fires were documented for this area.

Sequence of Events

The morning of September 3, a lightning storm tracked in from the southeast of Humboldt County, moving northwest and out to the ocean near the mouth of the Klamath River. This started the Canoe fire, which was detected later that afternoon. For this area, the Humboldt–Del Norte Unit of the California Department of Forestry and Fire Protection (CDF) is responsible for wildland fire suppression.

Initially, fire behavior was estimated from aerial reconnaissance, fire expansion, and ground-based lookouts. Light smoke and flame lengths of 15 to 30 centimeters (six inches to one ft) were observed, with no torching of trees. The rate of spread remained slow, up to about six m per hour (20 ft/hr) for surface fire during the peak burning periods.

During the first few days, the weather was cool, relative humidity high, and winds were light. Fire progression was slow in the first two weeks (*fig. 3 and 4*). From its ignition on September 3 until fire crews made access on September 10, the only fire suppression activity came from water drops by helicopter. This effort was limited to a few hours per day.

Access to the Canoe fire was subject to several constraints. It had to be sufficient for supporting the firefighters with food, water, equipment, and emergency evacuation. The fire was located in a state wilderness area, which also limited options. While not subject to the strict constraints of federal wilderness, the State Park needed to agree on suppression strategy if mechanical equipment was used or large trees felled.

Fire crews unsuccessfully attempted creating two different hiking routes into the fire. These routes would take several hours to hike and were not sufficient for firefighter safety and support. On September 9, a bulldozer was walked in along a ridgeline for several miles to construct a helispot near the fire. Weather had become overcast with light rain, halting fire advance and moderating fire behavior. Crews began trail construction to the fire from the helispot. On September 10, seven days after it started, ground resources arrived at the Canoe fire, now at 21 hectares (51 ac).

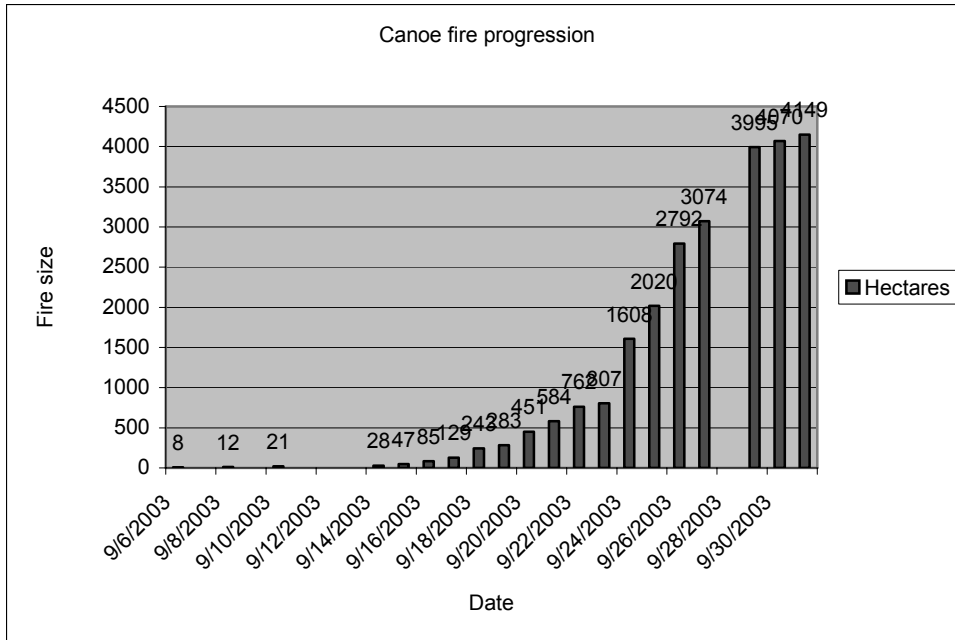


Figure 3—Canoe fire area growth.

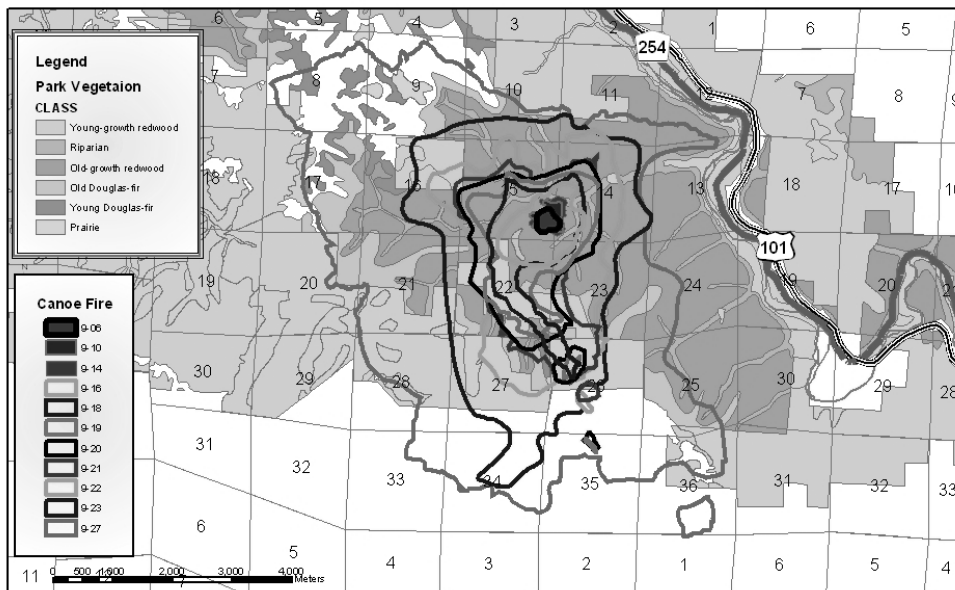


Figure 4—Canoe fire perimeters.

Red flag warnings were in effect for high winds and low humidity on September 11, 12, and 13. Fire growth remained slow, increasing to 28 hectares (69 ac) by September 14. Fire behavior was described as flame lengths of 15 to 30 centimeters (six inches to one ft) and a spread rate of 4.9 m per hour (16 ft/hr). However, active burning periods were occurring both in the afternoon and in the early morning hours. As inversions settled into the Eel River valley, a thermal belt of warm, dry air influenced the fire on the mid and upper slopes, increasing fire activity at night. This was a common occurrence until the fire was contained.

The old-growth area had many standing dead trees prone to falling as the fire burned. The fire moved slowly, but had a long residency time as it consumed deep fuel layers. Given the heights of these trees and the long burn out times, working near the active fireline posed a significant risk to firefighters.

On September 16, several spot fires crossed the west flank control line. Short range spotting was becoming the main factor in fire growth. Crews were unable to establish control lines around all the spot fires before nightfall. After dark, the snags posed too great a hazard to continue work. Control line construction directly on the fire edge was no longer an option on the Canoe fire.

Suppression strategy changed on September 17 to indirect control methods, using the Grasshopper Trail, Grasshopper and Greig Roads, and fire line construction on the southern boundary of the park. The fire progressed southward up Canoe Creek past the helispot, actively burning in young-growth redwood stands by September 18.

On September 19, the Canoe fire had burned 283 hectares (700 ac), growing by 34 hectares (85 ac) in five hours. Relative humidity dropped into the teens and gusty northeast winds were forecast for the fire area. As the fire remained on the lower slopes and in dense forest, wind effects were negligible. But on ridgelines, swirling winds caused spot fires well ahead of the main fire.

The fire growth came from a combination of slow expansion of the main fire, firefighters conducting burnouts along the southern constructed fire line, and spot fires crossing the southern control line. The State Park boundary/control line followed the ridge and swirling winds pumped embers onto private land, creating numerous spot fires. By September 20, acreage growth was more influenced by suppression activity than the fire itself.

The fire had now established in young-growth redwood areas (estimated age 70 years). Fire behavior in these areas was substantially different than observed in old-growth redwood. In both areas, fire would climb well up the tree boles. In old-growth, some of this burning material would fall and establish new fire just ahead of the flaming front. This form of short range spotting was common. In young-growth redwood, the crown of individual trees burning (torching) lofted embers farther distances and was source of short, medium, and long-range spot fires.

Discussion

Fuel characteristics and weather contributed to fire progression. The fire was weather caused, but the fire advance was fuel driven.

The Canoe fire displayed different fire behavior in old-growth redwood than observed in young-growth areas. Observed fire front advance in old-growth areas exhibited flame lengths of up to 0.3 m (one foot) and very slow rates of spread, up to 6 m per hour (20 ft/hr). Adjusting for slope and wind factors, these characteristics are considerably lower than predicted by the BEHAVE model for the most closely matched standard fuel model, Fuel Model 10 (Anderson 1982, Andrews 1986). Predicted flame lengths of 1.5 m (five ft) and maximum rates of spread of 152 m per hour (500 ft/hr) were common from the model. Heavy fuel loads produced long duration fire intensity within the burn. While torching of the tall, living trees was rare, standing dead trees were common and readily burned. These became aerial fuels, providing embers that advanced the fire through a short range spotting effect.

Upon entering young-growth redwood areas, Fuel Model 10 more closely predicted the actual fire behavior observed, but still over-predicted the rate of spread. In both young-growth and old-growth redwood stands, the wind effect on surface fire was minor. The canopy reduced the wind to approximately 0.1 times the forecasted 6.1-meter (20 ft) wind speed, reducing the advance of the fire front. Nor did surface wind from diurnal effects appear to be a factor in the spread rate.

Fire commonly would climb into the canopy in dead branches, moss, and lichens in both vegetation types, producing falling embers. Torching trees were more common in young-growth redwood. These effects produced substantial fire advance from ember ignited spot fires, some reported as far as one-mile ahead of the main fire. Spot fires were common and predictable downwind from ridges.

Topography and access were important factors in the Canoe fire. Only limited logging had occurred on the area's moderate to steep slopes before park designation. Using old skid routes and ridgelines, bulldozer access to the fire area was feasible, as was demonstrated by the eventual construction of a helispot. Further use of bulldozers for fire suppression was not implemented at that time, given management constraints.

Because the Canoe fire started in a state wilderness area, managers implemented a Minimum Impact Suppression Tactics (MIST) approach that affected fire suppression effectiveness. The balancing of resource impacts from operations against the impacts of wildfire was a delicate issue. Using the Eel River and the nearest road system for control was possible on the north, east, and west and would increase the 12-hectare (30 ac) fire to 5,000 plus hectares. But on the southern flank, no logical firebreak was present within the park. Keeping the fire on the State Park was a declared objective. Direct suppression was selected as the best of several poor options.

Low impact overland access was attempted via several routes. It took several days to determine that this was not feasible given firefighter safety issues. Escalating the impact, bulldozer access (blade up) was made to create a helispot. Fire crews were inserted, access made, and direct fire line construction started. Firefighter safety issues resulted in abandoning this plan, as spot fires started that could not be safely contained. Twelve days after the Canoe fire started, the road system and park boundary became the targeted control points. Critical fire weather conditions were now also affecting the fire area.

After constructing and improving the control lines on the north, west, and south fire flanks, firing operations were implemented to create a wide area of burned fuel before the main fire reached these control lines. Along the southern ridge control line, spot fires were large and numerous, requiring new control lines well onto private land. On the western flank, the fire crossed the control line near Grasshopper Lookout before firing operations could be completed. The eastern flank, between the Eel River and the main fire, was intentionally burned using helicopter dropped incendiaries on a 230 meter by 305 meter (75 ft by 100 ft) grid.

Within the old-growth stands, canopy loss from direct burning was rare. However, the long duration burning of surface fuels is likely to have killed the cambium layer of trees in all size classes. The two-percent mortality reported by Fritz in the early 1930s represented old-growth stands that likely had experienced occasional, low intensity fire. The Canoe fire area has been subject to years of fire exclusion. The larger dead fuels that contribute to long duration burn times would be

in greater abundance than in areas with frequent fire cycles. This produces a higher intensity and duration of burn that may likely produce greater mortality than found in the earlier study.

Younger stands adjacent to the old-growth areas burned with greater intensity, spread rates, and flame lengths. Both old-growth and young-growth fuel complexes were resistant to control, but improved access in young-growth stands increased suppression effectiveness.

The long duration burning produced smoke impacts that lasted for weeks. The North Coast Unified Air Quality Management District issued daily health advisories for southern Humboldt County. Measured peak levels of PM10 from smoke in Myers Flat often exceeded 800 $\mu\text{g}/\text{m}^3$. Some schools near the fire area closed and many residents left the area due to poor air quality (Torzynski, personal communication). While a relatively short-term impact, the smoke impacts from wildfire, or prescribed burning, must be a management consideration.

Conclusions

Fire behavior prediction models over-predicted flame lengths and spread rates for old-growth redwood stands. The duration and intensity of burning lasted many days beyond the initial passage of the fire front. Inability to access the Canoe fire with ground-based fire suppression resources while it was still small was the main factor allowing the fire to grow. Embers falling a short distance ahead of the fire front were the primary means of fire advance. Trees and snags fell at a high rate, presenting a greater risk to firefighters than from fire spread rates or flame lengths. While direct damage to old-growth tree crowns was rare, the high intensity of the surface fire, due to fuel accumulation during an extended fire-free period, is likely to produce higher mortality. Regional smoke impacts from wildfire in this old-growth stand were substantial. Parks must be managed to anticipate and mitigate impacts that fire will have on vegetation, habitat, watersheds, and neighboring property. Prescribed burning should be applied to decrease the fire-free interval, reducing fuel accumulation and potential damage to habitat. Fire management access must be improved by planning approved routes, helispot construction, and maintenance. Parks must incorporate fuels management adjacent to private land to reduce potential future wildfire risk and impacts.

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