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# Fire in the Forests of Mount Rainier National Park

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ABSTRACT

Infrequent, catastrophic fires have been important forces in the forests of Mount Rainier National Park. The effectiveness of topographic features as fire breaks, the relative fire resistance of forest habitat types (Franklin et al. 1979), and the natural frequency of large fires in different habitat types are examined. Ridges, valley bottoms, and lower slopes are effective fire breaks. High as well as cool, wet, and low elevations and wet habitat types are relatively fire resistant. The same habitat types seem to experience lower frequencies of large fires. This information should be useful in fire management planning in a variety of ways.



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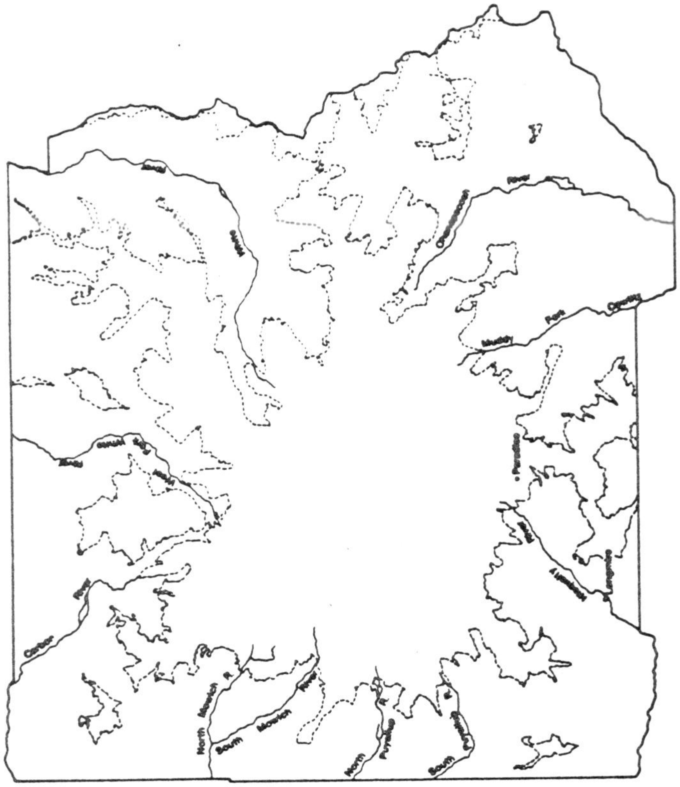

Figure 1.--Outline map of Mount Rainier National Park, Washington. Dashed line is approximate upper tree line.

To a great extent, the rich mosaics of forests in the Pacific Northwest reflect past fires. Fires initiate succession and trigger redistribution of plant and animal species. Fires respond to climatic factors, local environment, and fuel loads. Variable stages of forest recovery after fires produce mosaics of stand ages, species diversity and abundance, and forest structure. Patterns of tree ages in Mount Rainier National Park's (MRNP) relatively untouched forests reveal the presence of past large fires. Understanding the way fires have altered these forests is vital to understanding their succession, architecture, and species composition and distribution. In this paper, the roles of topography and forest habitat types as fire breaks and the effects of forest habitat type on large fire frequency are examined.

The purpose of this study was to answer several specific questions about the natural or pre-modern man role of large fires in MRNP's forest ecosystems:

1. How effective are topographic features as fire breaks?

2. How effective are different forest habitat types as fire breaks?

3. Are there differences in the frequency of large fires in different habitat types?

4. How can habitat types and topographic features help fire management planning?

Though Mount Rainier imposes strong orographic effects on weather patterns in the Park, its climate is typical of the western slope of the Cascades. Summers are warm and dry. Winters are usually wet and cool. July temperatures at Longmire and Paradise (837- and 1 682-m elevation) (fig. 1) average 16.2° and 12.1°C, respectively. January temperatures average -1.1° and -2.9°C. Most of the average annual precipitation, 205 cm at Longmire and 269 cm at Paradise, falls in the winter, accumulating as deep snowpack at higher elevations. Winter storms generally track from southwest to northeast; and because Mount Rainier causes a lee-side rainshadow, the river drainages in the Park's southern and western sectors receive more precipitation than those in the north and east (fig. 1).

Franklin et al.[1] described the Park's forest communities and habitats based on 497 sample plots and extensive field reconnaissance. The final classification defined 17 habitat and community types ranging from low elevation, wet forests through mesic to dry and high elevation forests. Plant communities and habitat types were mapped on a 1:50,000 scale whole-park USGS topographic map. The classification and map were upgraded after each of four field seasons.

The pattern of pre-modern-man fire in MRNP is representative of much of the central and northern west slope forests of the Washington and Oregon Cascades. Though stand ages range from less than 50 years to over 1,000 years, the majority of forests are over 350 years old (Hemstrom 1979). Large fires are infrequent and holocaustic. This pattern seems widespread as far south as the McKenzie River in Oregon (Franklin et al. 1979). There is some indication that large fires coincided with prolonged regional drought (Hemstrom 1979). Modern man may have increased the frequency of large fires during the late 1800's and decreased it since 1900 (Hemstrom 1979).

TOPOGRAPHIC FEATURES AS FIRE BREAKS

This study relied on maps of fire boundaries, tree ages from early seral trees, and forest habitat and community types which were produced by earlier studies in the Park (Hemstrom 1979) (see footnote 1). To examine the role of topography on fire behavior, I measured and classified the lengths of fire boundaries of recent, clearly defined burns into seven topographic classes: (1) major and secondary ridges, (2) upper slopes (within 120-m elevation of a major ridge), (3) mid slopes, (4) lower slopes (within 120-m elevation of a major valley bottom), (5) draws and valley bottoms, (6) snow avalanche tracks, and (7) other.

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[1] Franklin, J. F., W. H. Moir, M. A. Hemstrom, and S. G. Lewis. Forest ecosystems of Mount Rainier National Park. (Manuscript in preparation.)

Table 1--Percent of total fire boundary in major topographic units from six recent, large fires at Mount Rainier National Park

| Topographic feature | Percent of total fire boundary[1] |
|---|---|
| Major ridges unforested | 14 |
| Major ridges forested | 10 |
| Side ridges | 12 |
| Upper slopes | 8 |
| Mid slopes | 10 |
| Lower slopes | 12 |
| Valley slopes | 15 |
| Along fall line[2] | 9 |
| Other[3] | 4 |

[1]Total fire boundary: 288 km.

[2]Fire boundaries running along the fall line of an otherwise featureless slope.

[3]Includes benches at various slope positions and snow avalanche tracks.

Since fire boundaries form when a fire dies, their position on topographic surfaces may reflect the effectiveness of topographic features as fire breaks. Under ideal fire conditions, a large fire burns over forested topography until it encounters major fuel breaks. Under adverse weather conditions, a large fire may stop without encountering a break or upon encountering a minor break such as a low, forested ridge. If fires spread and stop without regard to topography as long as sufficient fuel is present, fire boundaries should materialize at random with respect to all but unforested topography. The extent to which fire boundaries are concentrated on certain topographic features indicates departures of fires from random movement and, therefore, the effectiveness of those features as fire breaks.

Despite the fact that weather and chance play important parts in determining where fires stop, certain topographic features seem to act as effective fire breaks (table 1). In fact, the two most important topographic fire breaks, ridges and valley bottoms, together account for over half the total length of fire boundary. Smooth slopes account for about 30 percent of the total length. Proportion of fire boundary increases downslope; a reasonable result considering convective heat movement. Ridges and valleys both are effective fire breaks because they require vertical shifts of fire movement, often downhill or onto wetter or cooler sites. Only a small portion of fire boundary was on open, featureless slopes, oriented along the fall line; a condition indicating fires that stopped without regard to topography.

Abrupt fuel changes over short distances would seem to make avalanche tracks effective fire breaks, but only a small portion of fire boundary was along avalanche tracks. In many cases, fires seem to have burned straight across large avalanche areas. Avalanche tracks often increase in size or are rejuvenated after a fire burns anchoring vegetation (Winterbottom 1974, Hemstrom 1979). An avalanche track which should have been an effective fire break might not have been as large or even have existed at the time a fire burned through the area.

HABITAT TYPES AS FIRE BREAKS

To study the role of forest habitat types as fire breaks, I first superimposed a map of six clearly defined, recent burns on a whole-park forest habitat type map. Unfortunately, classifying fire boundary by habitat type to indicate their fire resistance presents several potential sources of error. Some habitat types are usually restricted to certain topographic features, compounding the effects of habitat type and topography. Stand age boundaries within a habitat type may also represent changes in fuel loads. In addition, habitat types represent vegetation potentials and not necessarily the vegetation actually present. They are, therefore, more accurate predictors of environment than existing fuel loads. Many of MRNP's forests, however, are over 350 years old and are, at least in terms of fuels, similar to climax stands.

Another source of error is that the proportion of the landscape occupied by particular habitat types may influence the amount of fire boundary in each habitat type, irrespective of fire resistance. To correct for this bias to some extent, I divided the percent of the total fire line in each habitat type by the percent of the total area burned which was the same habitat type. The habitat types were ranked according to this calculation of relative fire resistance. If a habitat ranked high, the length of fire line relative to burned area of that habitat was low. In other words, most of the fires which burned into that habitat also burned through it without stopping. The habitat type would therefore be relatively less fire resistant than others which rank low. Some bias may be introduced by using a ratio of a linear quantity to squared (area) quantity which might change the ratio purely on the basis of the study area size. The ranks of habitat types according to relative fire resistance should not be affected.

Another way to look at natural burning rates by habitat types is to reconstruct episodes of fire back in time and calculate burn rates by habitat; hectares burned per year per hectare of habitat type for fires larger than 100 ha. In previous reconstrucion of fires at MRNP (Hemstrom 1979), I used a somewhat arbitrary set of rules to define old burn boundaries. For this study, I modified the rules to better incorporate topographic fire barriers. I then reconstructed fires to the first significant topographic fire break in all directions. In general, the new reconstructions are more conservative than the earlier ones.

Table 2--Percent fire boundary divided by percent burned area by habitat type for six recent, large fires at Mount Rainier National Park

| Habitat type[1] | F/B[2] | Rank |
|---|---|---|
| Tsuga heterophylla/Achlys triphylla | 0.45 | 1 |
| Abies lasiocarpa/Valeriana sitchensis | 0.49 | 2 |
| Abies amabilis and Tsuga heterophylla/ Gaultheria shallon | 0.68 | 3 |
| Abies amabilis/Xerophyllum tenax | 0.70 | 4 |
| Abies amabilis/Berberis nervosa | 0.84 | 5 |
| Abies amabilis/Rubus lasiococcus/ Rubus lasiococcus phase | 1.00 | 6 |
| Abies amabilis/Oplopanax horridum | 1.04 | 7 |
| Abies amabilis/Tiarella unifoliata | 1.32 | 8 |
| Chamaecyparis nootkatensis/Vaccinium ovalifolium | 1.81 | 9 |
| Abies amabilis/Erythronium montanum phase | 2.00 | 10 |
| Tsuga heterophylla/Polystichum munitum | 2.04 | 11 |
| Abies amabilis/Menziesia ferruginea | 2.35 | 12 |
| Abies amabilis/Rhododendron albiflorum | 3.17 | 13 |

[1]Some habitat types are minor and not included. (See footnote 1 in text.)

[2]F/B is the percent of measured fire boundary in a habitat type divided by the percent of the total burned area in the same habitat type. Total fire boundary measured: 237 km. Total burned area: 14 368 ha.

Comparing the ratio of percent burn line to percent burned area and reconstructed large fire frequency allows a relatively independent evaluation of the role of fire resistance and frequency by habitat type. The first method does not rely on reconstructions but is limited to recent, well defined fires. The second method reaches much farther back in time but requires accurate reconstructions. Both approaches depend on accurate habitat type maps and tree age data.

Some habitat types appear to be significant fire breaks (table 2). The Abies amabilis/Rhododendron albiflorum (Abam/Rhal) and Abies amabilis/Menziesia ferruginea (Abam/Mefe) habitat types appear to be very fire resistant. Since both of these types tend to occur on north facing, high elevation, wet slopes, much of their fire resistance may be due to topographic position. Sites where these types occur also experience heavy snowpacks, and fuels would be wet much of the time.

At the other extreme, the Tsuga heterophylla/Achlys triphylla (Tshe/Actr), Abies lasiocarpa/Valeriana sitchensis (Abla/Vasi), Tsuga heterophylla and Abies amabilis/Gaultheria shallon (Tshe/Gash and Abam/Gash), Abies amabilis/Xerophyllum tenax (Abam/Xete) and Abies amabilis/Berberis nervosa (Abam/Bene) habitat types all seem to burn readily in large fires. The Abam/Xete and Abla/Vasi habitat types tend to occur on high elevation, exposed sites which are subject to summer lightning. They are also dominant habitat types in the White River drainage, the driest in the Park. The Tshe/Gash, Abam/Gash and Abam/Bene habitat types are typical of dry sites where fuels might be flammable early in the season. The low fire resistance of the Tshe/Actr habitat type may be an artifact of its small extent relative to the other habitat types.

## FIRE FREQUENCY FROM RECONSTRUCTED FIRE HISTORY

Analysis of topographic features as fire breaks provide a basis for defining rules for reconstructing fire patterns in MRNP to 750 years ago. Calculations of burn rate for large fires and natural fire rotation for the Nisqually, Ohanapecosh, and White River drainages reveal a pattern of large fire frequencies which change between habitat types within a drainage and within habitat types between drainages (table 3). The overall pattern of large fire frequency in different habitat types strongly resembles the pattern of fire resistance by habitat types.

Over the three drainages, the Abla/Vasi, Abam/Bene, Tshe/Actr, Abam/Gash, Tshe/Gash, and Abam/Xete types experience large fires most often. The Abies amabilis/Erythronium montanum (Abam/Ermo), Abies amabilis and Tsuga heterophylla/Oplopanax horridum (Abam/Opho and Tshe/Opho), and Abam/Rhal habitat types burn least often. Except for Abam/Rhal, these were not the most fire resistant (table 2). This difference may stem from my use of the whole Park in fire resistance analysis but only three drainages in fire frequency analysis. The overall order of habitat types by fire resistance and decreasing fire frequency is remarkably similar, however.

There are some interesting, and in some cases unexplained, differences in fire frequency by habitat type between drainages. The Abam/Mefe habitat type ranks first in fire frequency in the Nisqually drainage and sixth in both the Ohanapecosh and White River drainages. The Abam/Xete habitat type ranks second in the Nisqually, third in the Ohanapecosh and tenth in the White River drainage. These examples may indicate gaps in our understanding of successional status of some of the Park's habitat types or may reflect bias from the relatively few fires sampled.

In general, the fire frequency of the same habitat type increases from the Nisqually to the Ohanapecosh to the White River drainage. The average fire frequency increases and natural fire rotation decreases from 0.0023 ha $ha^{-1}$ $year^{-1}$ (438 years) to 0.0031 ha $ha^{-1}$ $year^{-1}$ (324 years) from the Nisqually to the White River drainage. The average fire frequency and natural fire rotation for the three drainages is 377 years, lower than the whole Park natural fire rotation of 465 years (Hemstrom 1979).

## APPLICATIONS TO FIRE MANAGEMENT PROBLEMS

This analysis provides fire managers with information useful in: (1) pointing out the most effective places to put fire lines during fire fighting operations, (2) locating areas where natural fire frequency and natural fire breaks might make let-burn management feasible, and (3) indicating areas where fires, either prescribed or natural, are frequent and necessary parts of the landscape.

Table 3--Fire frequency[1] (FF) and natural fire rotation[2] (NFR) by habitat type for the Nisqually, Ohanapecosh, and White River drainages, Mount Rainier National Park

| Habitat type[3] | Nisqually drainage | | | Ohanapecosh drainage | | | White drainage | | | Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NFR | FF | Rank | NFR | FF | Rank | NFR | FF | Rank | NFR | FF | Rank |
| Abies lasiocarpa/Valeriana sitchensis | NA | NA | NA | 191 | .0052 | 1 | 282 | .0035 | 3 | 275 | .0035 | 1 |
| Abies amabilis/Berberis nervosa | 400 | .0025 | 4 | 303 | .0033 | 3 | 258 | .0039 | 2 | 295 | .0034 | 2 |
| Tsuga heterophylla/Achlys triphylla | NA | NA | NA | 360 | .0028 | 5 | 208 | .0048 | 1 | 308 | .0033 | 3 |
| Abies amabilis and Tsuga heterophylla/ Gaultheria shallon | 325 | .0031 | 2 | 305 | .0032 | 4 | 305 | .0033 | 3 | 313 | .0032 | 4 |
| Abies amabilis/Xerophyllum tenax | 348 | .0029 | 3 | 273 | .0036 | 2 | 490 | .0020 | 9 | 323 | .0031 | 5 |
| Abies amabilis/Menziesia ferruginea | 269 | .0037 | 1 | 396 | .0025 | 6 | 335 | .0030 | 5 | 343 | .0029 | 6 |
| Abies amabilis/Rubus lasiococcus/ Rubus lasiococcus phase | 667 | .0015 | 10 | 400 | .0025 | 7 | 318 | .0031 | 4 | 367 | .0027 | 7 |
| Abies amabilis/Tiarella unifoliata | 466 | .0021 | 6 | 405 | .0025 | 8 | 421 | .0024 | 8 | 426 | .0023 | 8 |
| Tsuga heterophylla/Polystichum munitum | 435 | .0023 | 5 | NA | NA | NA | NA | NA | NA | 435 | .0023 | 9 |
| Abies amabilis/Vaccinium alaskaense and Chamaecyparis nootkatensis/Vaccinium ovalifolium | 523 | .0019 | 8 | 494 | .0020 | 9 | 365 | .0027 | 6 | 474 | .0021 | 10 |
| Abies amabilis/Rhododendron albiflorum | 663 | .0015 | 9 | 551 | .0018 | 11 | 395 | .0025 | 7 | 478 | .0021 | 11 |
| Abies amabilis/Oplopanax horridum | 503 | .0020 | 7 | 700 | .0014 | 12 | NA | NA | NA | 535 | .0019 | 12 |
| Abies amabilis/Erythronium montanum | 729 | .0014 | 11 | 510 | .0020 | 10 | 592 | .0017 | 10 | 616 | .0016 | 13 |

[1]Burned hectares per hectare of habitat type per year for fires over 100 ha.

[2]The time required to burn an area equal to the total area of each habitat type given its burn rate (Heinselman 1973).

[3]The areal extent of some habitat types was insignificant. These are omitted. (See footnote 1 of text.)

The most effective places to construct fire lines are located where natural topographic or vegetative fire breaks would complement artificially decreased fuel loads. It might be important not only to construct a fire line on a ridge top, as is common practice, but to place the line next to a naturally fire resistant Abam/Rhal stand. While it might be essentially useless to put a fire line through a dense Abla/Vase, Abam/Xete, Abam or Tshe/Gash or Abam/Bene stand, a similar fire line next to Abam/Rhal, Abam/Ermo, Abam/Mefe, Abam/Vaal or Abam/Opho habitat types could prove effective. There is no assurance, however, that fires will stop on ridges or in an Abam/Rhal stand if conditions for fires are favorable.

Another application is in planning fire management. In some areas, natural flammability and vegetative and topographic fire breaks provide conditions which might make possible let-burn fire management. A slope covered with Abam/Bene habitat type and bounded on three sides by ridges and fire resistant habitat types might be left to burn if weather conditions were suitable. But fires in dense Abla/Vasi stands on gentle slopes abutting valuable timber land outside the Park could easily escape. A whole Park map could be divided into units for let-burn management based on habitat type, vegetative and topographic fire barriers, and consideration of adjacent ownership.

Finally, fire frequency information by habitat type indicates where fires are most important as natural processes and where they are most likely to occur in the future. The former could provide a scale for evaluating the urgency of applying prescribed burns or let-burn management. The latter could be important to fire lookouts, to fire bosses in action, and for planning future developments such as trails or facilities.

## CONCLUSIONS

1. Certain topographic features serve as effective fire breaks, especially ridges and valley bottoms.

2. Certain habitat types are more fire resistant than others. This may reflect their characteristic topographic location and environment.

3. Certain habitat types experience natural, large fires more frequently than others.

4. Both fire resistance and fire frequency vary between habitat types within river drainages and within habitat types between drainages. The driest river drainages have the highest natural frequency of large fires.

5. Natural vegetative and topographic fire breaks and differential fire frequencies between habitat types have important applications in fire management.

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