Fire Regimes and Approaches for Determining Fire History

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Fire has been an important evolutionary influence in forests, affecting species composition, structure, and functional aspects of forest biology. Restoration of wildland forests of the future will depend in part on restoring fire to an appropriate role in forest ecosystems. This may include the "range of natural variability" or other concepts associated with fire as a disturbance factor. Yet fire on the forested landscape has not been a constant in either space or time. Its frequency, intensity, seasonality, extent, and other characters—collectively know as a fire regime—varied considerably across western forest landscapes. A series of techniques can be used to understand this history, and accurate interpretation depends on using the best fire history technique for a given fire regime. The following synopsis of these techniques is based on a more detailed explanation provided in Agee (1993).

Fire Regimes

There is no magical way to define a fire regime, as there are myriad combinations of fire frequency, intensity, etc., that could be formed. Natural fire regimes are usually defined in a historical sense, typically restricted to the pre-1900's, but they clearly are natural in the sense of incorporating effects of indigenous cultures—we cannot, in most cases separate out the human component of historical fire regimes. A generalized system of classifying fire regimes, given the wide range possible, is to define fire severity categories of high, moderate, and low. Low severity fire regimes typically had frequent, low intensity fires. High severity fire regimes had infrequent but stand-replacing fires, and the moderate severity fire regimes (also called mixed severity) had complex combinations of high, low, and moderate severity fires.

The evidence left behind for reconstruction of fire regimes will vary by fire regime. In the low severity fire regimes, fire scars will often be created on residual trees, so that the year, and sometimes the season, of a fire can be determined. In moderate severity fire regimes, with longer fire return intervals, some scars are likely to heal over, and multiple age classes of fire-induced tree regeneration are likely to result. In high severity fire regimes, few survivors are left, and the most common evidence, besides presence of charcoal, are even-age stands (which themselves can have substantially varying age ranges). The implications for fire history are that the techniques for reconstructing fire history must vary by fire regime because of the nature of the evidence left behind.

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Fire Histories

Two primary types of fire history reconstructions are made: those for "point frequency" estimates, and those for "area frequency" estimates. Point frequency estimates attempt to reconstruct the fire history at a point, and are usually used in low severity fire regimes. Area frequencies, as the phrase implies, deal with fire at more of a landscape level, and are used in those fire regimes of higher severity. These differences are very important for interpreting past fire history and planning for fire restoration. Different techniques can derive widely varying fire return intervals.

Point Frequencies

The use of point frequencies depends on sampling fire scars. Slabs from stumps or live trees containing the annual ring-fire scar record are usually removed with chain saws. Samples can be removed using increment borers if there is just one scar, but generally this technique is used only when slab removal is not possible. Samples with many fire scars (sometimes up to 30 scars) can be found and provide the best record. Samples are taken to the laboratory, sanded, and the sections are carefully cross-dated. Cross-dating is extremely important, because the fire years recorded on nearby samples may sometimes be combined to provide a more complete record of fire near a given point. It is important that fire years be accurately identified.

It is rare that any tree will contain the entire record of fire over its lifetime; although a tree is the best "point" on the landscape, it is usually not the best sample unit to use to derive a "point estimate" of fire. Usually the combination of cross-dated records from two or more closely spaced trees are used. Each sample tree is itself a point sample, and as the number of trees whose records are combined grows, two things usually happen: the fire record becomes more complete, so that the fire return interval becomes shorter; and the point frequency tends to become an area frequency as the area over which records are combined expands. Over how large an area can fire scar records be combined? This is a judgment call, but for most stand-level applications several hectares is the maximum recommended.

Steve Arno's work in the Rocky Mountains clearly shows the influence of increasing area on fire return interval (Arno and Petersen 1983). And a practical example was provided by Joyce Bork (1985) in Oregon. Harold Weaver had sampled individual trees (points) in the 1950's and found an 11-16 year fire return interval. Bork, I was told, had found a 4 year fire return interval in the same vegetation type. Actually, she described her data carefully by area, and my informants had only reported the 300 acre (125 ha) fire return interval of 4 years. If expressed as point samples on individual trees, her data were more variable than Weaver's, but as he sampled only the best specimens, his "point" data are probably most equivalent to her "plot" average of 11 years. Thus, careful interpretation of fire history data is very important.

Area Frequencies

Fire history techniques based on aggregation of stand ages across the landscape (thus the term area frequency) are used in moderate and high severity fire regimes, as fire-scarred trees are either less commonly or not commonly found. Two primary techniques are used here: natural fire rotation, and the fire cycle.

The natural fire rotation technique is more applicable to Western United States forests. Natural fire rotation is a simply calculated statistic: it is the time period divided by the proportion of the study area burned in that time period (which can exceed 1). For example, if in a 100 year period 40,000 acres of a 50,000 acre area burn, the natural fire rotation is 125 years (100/[40,000/50,000]). The major problem with natural fire rotation is that all previous fire events must be reconstructed, and as time goes by, older events are obscured by younger ones. Usually, the record for the distant past includes only the major fire events.

Fire events are defined on the basis of age classes of seral tree species likely to have regenerated following a disturbance: for example, Douglas-fir (*Pseudotsuga menziesii*) in a moist, west Cascade landscape or the serotinous-coned lodgepole pine (*Pinus contorta*). Fire is assumed to be the primary disturbance on the landscape. For event reconstruction, a set of rules have to be defined, such as "two stands of the same, older age, separated by a stand of younger age, are assumed to have been part of a single event, the evidence of which was destroyed by the younger-aged event."

Most landscapes exhibit substantial variability in fire occurrence, so that a single natural fire rotation value (for example, 162 years) is not very meaningful. Once the reconstruction of fire events is complete, the record can be disaggregated by time (century by century), aspect (usually south aspects burn most frequently), and forest types in the study area, if these have also been geographically identified. Separate return intervals for low versus moderate and high severity fires can be calculated, too, as has been done by Morrison and Swanson (1990) in the central Oregon Cascades. Variability can also be described by Poisson distributions, evaluating the probability of 0, 1, 2, etc., fires in grid cells across study areas. This may be important in defining fire refugia (grid cells with few occurrences) or fire-dependent vegetation (grid cells with many occurrences) in a heterogeneous landscape.

Models

Mathematical models such as the Weibull have been used with success in the high severity fire regimes of the boreal forest and Canadian Rockies (Johnson and Van Wagner 1985), but at scales below about 125,000 acres (50,000 ha) this variety of model has not been used with success in western U.S. forests. A special case of the Weibull function, the negative exponential (where flammability of a forest stand remains constant with age), was first used to recalculate the natural fire rotation for the Boundary Waters Canoe Area, and found shorter fire return intervals. A nice aspect of these models is the use of current age class data so that reconstructions of past fire events is not needed. However, flammability by stand age has to be a monotonic function: increasing, decreasing, or remaining constant over stand age. Fire has to strike randomly across the landscape—rare in our forested western mountains. While the natural fire rotation technique has been criticized as a form of "storytelling," the use of models such as the Weibull can be just a more elaborate storytelling framework if not properly applied.

Applying Forest History Knowledge

If the use of fire for forest restoration expands on our western landscapes, among the most critical questions will be "where, how frequently, how intense, and when it should be applied." Fire history studies can provide answers in an historical context. These studies may not result in firm direction for the future, but can provide an accurate picture of how forest ecosystems interacted with fire in the past. A note of caution should be injected into the "natural range of variability" paradigm as a model for future management of disturbances like fire.

First, the range may be so broad as to be meaningless as a guide for management: almost any fire outcome might be acceptable in this situation.

Second, we are not dealing with the ecosystems of historical times. Even "natural" areas are surrounded by severely manipulated landscapes (at least in terms of fire exclusion). There are endangered species "fine filter" issues that were not significant in historical landscapes. Introduced plants are more common and often well adapted to disturbances. A "desired future condition" may require alteration of the natural range of historic fire variability, concentrating at one end of the spectrum or another. When attempts are made to define this spectrum, complexity emerges as a key characteristic. There are ranges of fire frequency, intensity, extent, seasonality, and synergism with other disturbances like insects, disease, and windthrow. Across the forest landscape, fire regimes vary, and fire histories vary; such data must be carefully collected and analyzed to provide a meaningful historical template. How that template is used in future management is a judgment call that involves far more than fire regimes and fire history.

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