RUSSIAN FORESTS WITH AN INTACT FIRE REGIME PROVIDE FOREST STRUCTURE REFERENCE POINTS FOR ALTERED EASTERN WASHINGTON FORESTS

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ABSTRACT

In 1997, fire regime, fire history, and stand structure were defined for 14 mixed conifer stands on southerly aspects in both Eastern Washington (U.S.) and in forest reserves of Siberia, Russia. Russian and U.S. stands shared a common mixed fire regime, but not fire history (number of fires and length of current fire free period). Fire history of current Russian stands most closely matched that of U.S. forests of 1796. Russian stands (and U.S. stands of 1796) appeared to be sustainable and in a dynamic steady state. U.S. stands of 1997 and those approximately 100 years BP (1896) were neither sustainable nor in a dynamic steady state. Examining pre-Euro-settlement U.S. and current Russian fire history suggests that sustainability and dynamic steady state conditions rarely coincide and that neither condition is common. Constant re-adjustment to prior fire cycle aberrations is the norm and we might better use our resources to maintain the longer-term disturbance and recovery cycles rather than manage for short-term vegetation patch equilibrium. The array of stand structure present in the "pristine" Russian habitat may serve as a reference for CROP lands that share a common fire regime, but only for U.S. sites with a similar period of stand development. The mixed fire regime of Russia stands was a composite of two fire groups that varied in fire frequency and fire histories. The mean abundance of large (>16 in. dbh, dia.) trees, snags and logs was similar among the two fire groups, but small trees and snags were greater in the fire group with the current longer fire free period. Mean number of large live trees was 18 to 20 (95% CI 34.5 to 6.0), large snags 17 to 19.3 (95% CI 33.3 to 4.9) and large logs 5.0 to 5.3 segments (95% CI 12.2 to 0.0) per acre. The broad confidence intervals indicate "required" variability in stand conditions (no one-reference state) and flexibility in implementing Eastside Screens (USDA 1995) for ecosystem integrity.

INTRODUCTION

CROP lands are U.S. Forest Service administratively designated overstocked small diameter conifer forests in Eastern Washington that are representative of many such stands in the inland west (USDA 1997). The stated goals for the management of these lands includes the creation of desired resource conditions, forest products, and social-economic stimulus (USDA 1997). To meet these goals the forest resource must be conserved and defensible biological reference points provided that assist in defining sustainable forest systems. Turner et al. (1993) suggested ecosystem integrity is maintained and a dynamic steady state possible when the disturbance interval and recovery period are equal. In a dynamic steady state a portion reaching post-disturbance recovery balances the proportion of habitat disturbed. As fire is the dominant natural disturbance in CROP lands, the inherent fire regime and the array of stand conditions that result from fire effects would be a logical biological reference point.

Fire scar analysis has been used by Schellhaas et al. (2000, [a,b]) to define the inherent fire regime for many forest settings in CROP lands. Schellhaas et al. (2000, [a]) reported a mixed fire regime with a point-based mean fire frequency interval (MFFI) of 15.7 to 46.7 years for CROP land sites in the South Deep Watershed. Reduction in indigenous peoples burning in the mid-1800s, organized fire suppression beginning in the early 1900s, and the combination of livestock grazing, selective timber harvest, and roading have altered forest composition and tree densities (Covington et al. 1994). As a result we have no intact reference sites for eastern Washington (including CROP lands) that define the forest structure supported by the inherent fire regime. To develop forest structure reference points for altered eastside forests we need an homomorphous forest (similar appearance) where the fire regime is similar, intact and the current forest stand structure reflects fire as the dominate disturbance factor. The mixed Siberian pine (*Pinus sibirica*), Siberian larch (*Larix siberica*), Siberian scotch pine (*Pinus sylvestrus*) forests in the dedicated Science Reserves of the Lake Baikal Region have not been subjected to timber harvest, roading, livestock grazing nor fire suppression. These forests have the same physiognomy and general fire regime as eastern Washington's historic western larch (*Larix occidentalis*), ponderosa pine (*Pinus ponderosa*), and large Douglas-fir (*Pseudotsuga menziesii)* mixed forest (Schellhaas et al. 2000).

SCIENTIFIC APPROACH

In this study our first task is to determine fire metrics most appropriate to define disturbance/recovery periods, stand sustainability, and dynamic steady state conditions. Then we will use the selected fire metrics to test for similar fire regimes in Russian and U.S. forests. If a similar fire regime is evident then we will match Russian fire history with a period in U.S. fire history and evaluated for sustainable habitat, and dynamic steady state conditions for both U.S. and Russian Forests. If Russian stand and landscape structure is shown to be sustainable then we have a valid reference for eastside forest structure at a specific point in stand development. The Russian stands would provide a defensible biological reference for the relative abundance of live trees, snags and logs supported by the inherent fire regime common to both areas. The forest manager could incorporate this information in the description of an array of desired future forest conditions.

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Fire Metrics

Fire metrics listed were evaluated for use in this study. When the metric is computed for multiple stands the mean value (e.g. MFFI, MFFIe, ...) may be given or the median value will be indicated. All metrics are described in detail below the listing:

Fire Frequency Interval

FFI - - (time from most recent burn to earliest burn)/number of fires (Traditional)

FFIp - -(time from most recent burn to pith)/ number of fires)

FFIe - - (time from the cambium date to pith date)/number of fires)

Fire Free Periods

FFPp- -time from pith date to 1st fire

FFPc- - time from the last fire to the cambium

Fire Frequency Interval Out

FFI-out ratio = FFPc/FFI, indicates where the stand is in its fire cycle and collectively if the fire regime for the habitat is being maintained.

FFIe-out ratio = FFPc/FFIe, indicates if the stand is likely to have a stand altering fire and collectively if stand diversity is being maintained in the habitat.

Reoccurring Fire Period

RFP-- the period of time from the first to the last fire on the fire scar.

Fire frequency interval (FFI) defines the "disturbance/ recovery period" between successive non-stand replacement events during the reoccurring fire period (RFP). Where fire frequency interval FFI for a habitat has remained constant for decades (as in this study) FFI would appear to define **both** the disturbance and the recovery interval. As any value divided by itself equals 1, then the Turner et al. (1993) test for sustainability is reduced to testing if FFI is being maintained. Dividing FFPc by FFI (FFI-out) gives an indication how far the stand is into the next fire cycle and in the altered U.S. system how many fire frequency intervals have passed since the last fire.

The mean FFI-out value for the habitat indicates if the preceding fire regime is continuing (being maintained). Mean habitat FFI-out values that are greater than one indicate a prolonged fire free period (a precursor for a more severe fire event in the future), values less than one indicate too frequent of fires (reduced recovery period) and a value close to one indicates a balanced disturbance-recovery system that is sustainable.

Mean FFI-out presents a "Sustainability-Dynamic steady state paradox." For sustainability we want disturbance interval/recovery period to balance with a mean FFI-out ratio of 1.0. Conversely for dynamic steady state equilibrium of post-fire successional states we want a mean FFI-out value close to 0.5. For a dynamic steady state in vegetation patch dynamics approximately half the habitat should be in early stages of post fire recovery and the other 50% in the later stages of recovery prior to the next fire event. Our solution from this quandary is to assume that fires within the normal FFI do not alter stands significantly (as the fire regime would change) and do not maintain stand diversity within the habitat.

FFIe represents the overall fire frequency interval for the life of the stand and includes FFI and fire free periods FFPp and FFPc. The two fire free intervals increase the "computed" fire return interval beyond the "traditional" FFI and FFIe would describe a period where fuels buildup setting the stage for a more severe (stand altering) fire event. In this study we use FFIe as a surrogate for the fire frequency of stand altering fires; the mean time between initiations of different stand cohorts (which we will test later).

A median FFIe-out value close to 0.5 for habitat is suggested to indicate a dynamic steady state where half of the stands are less than 50% recovered and the other half are over 50% recovered from the last stand altering fire event. Lesser values indicate over-burning in the habitat with a reduced stand diversity weighted toward recently burned areas; larger values indicate too little burning with reduced stand diversity weighted to over-recovered forest stands. Also, the FFIe-out metric indicates if the current fire free interval (FFPc) is in excess of the fire frequency interval for stand altering fires. We recognize that as fire severity and fire extent increases this solution to the sustainability/ steady state paradox no longer applies, as non-equilibrium systems will predominate (Turner et al. 1993).

METHODS

This study was restricted to the mixed severity fire regime and stand structure of forests stands (U.S. and Russian) on southerly aspects in mixed conifer forests. The extensive fire record and stand structure data set of the Wenatchee Forestry Science Lab (Schellhaas et al. 2000 [a,b]; Everett et al. 2000 [b]) was queried for all sites in eastern Washington with a mixed severity fire regime that occurred on southerly aspects. A total of 14 sites (3 in the CROP lands) were located with stand specific fire records that could be used (Fig. 1a). Cooperating Russian scientists identified stands in forest reserves adjacent Lake Baikal as having a mixed fire regime and a total of 14 Russian stands on southerly aspects were chosen at random from Russian stand maps (Fig. 1b).

The same vegetation sampling protocols were used for U.S. and Russian plots. At each stand a circular (1/10 ha =.25 acre) plot was sampled for tree, snag and log abundance by size class (1-5 in., 5-9 in., 9-16 in., 16-25 in., and >25 in., dbh, dia.). A minimum of two trees of each diameter class were cored at breast height and the age of the trees determined. Decay class of snags and logs was recorded according to the methods of Cline (1980). We collected two fire scars from each Russian stand and compared that fire history to the fire history from two fire scars (randomly selected from many) collected from each of the U.S. stands. The collection of only two fire scars allowed us to sample more Russian stands in our limited field time frame, but reduced the accuracy of our fire history estimate. Comparison of the fire record as defined by two fire scars and the complete fire record for U.S. sites (multiple fire scars from each site) indicate this study over estimates FFI by approximately 3 years in sampled U.S. (and by inference Russian) stands.

Analysis

For this initial analysis of the data the abundance of live trees, snags and logs were grouped into size classes of forest structure: large (> 9 in. dia) and small (<9 in. dia). Comparisons of structural elements were made between Russian and U.S. stands for the two size classes. We estimated the time between initiation of cohorts in the Russian stands by a greater than a 20-year difference in tree ages (aged tree cores) and using Siberian larch establishment as a bioassay for stand openings.

Fire scars were examined for fire free period from pith to the first fire, the number of fires, duration of the RFP, and years since last fire. The dates of fires recorded by the two fire scar samples were combined to give an estimate of FFI for the site. We computed FFPp, FFPc, FFI, FFIe, FFI-out, FFIe-out values for 1997 U.S. and Russian stands. We computed these same values for historical U.S. stands at specific points in time: 1) at 20 year intervals from 1796 to 1916, 1920 (showing the impacts of effective fire suppression), and 1937 when FFPc diverged from its historical range. Also, we estimated these values for Russian stands in 1981 (1980, a regional fire year) and in 1961 (20 years previous).

Cluster analysis was used to find the closest match between Russian and U.S. stand fire histories. We used analysis of variance with Tukey's all mean comparison to test for significant differences in fire metrics and forest structure (JMP, 2000). The best Y variable Box-Cox Transform was used to correct skewness and kurtosis in all data sets prior to statistical testing.

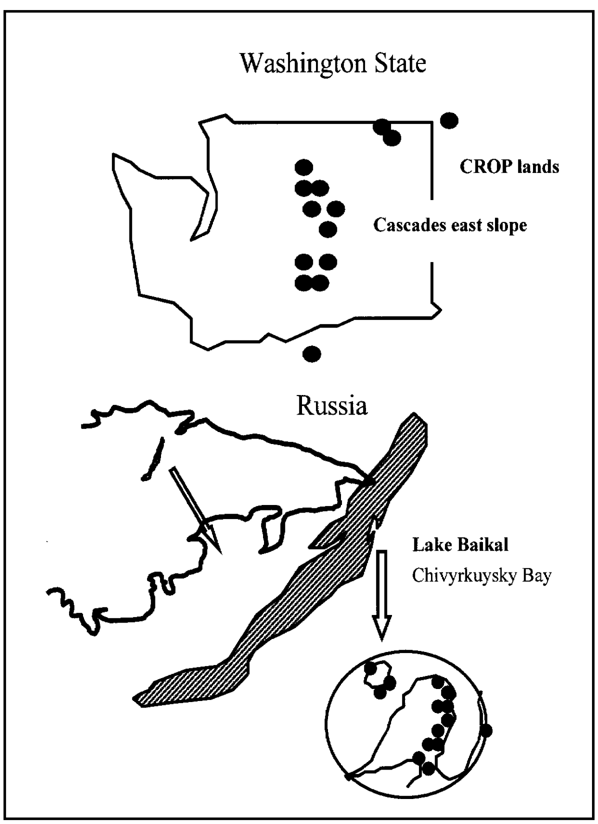


Figure 1.—Sample plots in Eastern Washington (a) and adjacent Lake Baikal in Siberia, Russia.

RESULTS AND DISCUSSION

Fire Metric Observations

The mean fire free interval (MFFI) has remained fairly consistent over the last two centuries (Fig. 2). Because FFI is defined during the period from first to last fire the metric has been constant since 1929 when the last fire was recorded in our "2 fire scar-limited" U.S. sample. The lengthy absence of fire could be an artifact of the limited number of fire scar samples, but longer fire free intervals of 75 to 105 years have been reported for the same forest type by Arno et al. (1997). Because FFI is based on the pre-fire suppression era, FFI-out remains the best estimate of divergence from the previously established fire return interval and follows lock step with FFPc.

FFIe is partially based upon and responsive to FFPc duration (FFI is not), but the response is buffered by the other two components in the metric (FFI and FFPp). Mean duration of FFIe was significantly greater than FFI (1997 U.S. mean FFIe 173% of mean FFI, Russian mean FFIe 200% of mean FFI) and this extended interval is estimated to provide the time required for sufficient biomass buildup to cause stand altering fires. In the unaltered Russian fire regime the median FFIe was 43 years (Table 1) approximating the fire free period from cohort initiation to the first recorded fire (FFPp, median 39 yr.), a "potential" stand altering fire event. If we allow a decade for trees to establish following disturbance the median 43-year FFIe would appear to link well with the median 54-year interval for the establishment of new cohorts on the Russian sites. We in no way state that the FFIe is the true frequency interval for stand altering fires, but that it does serve as a surrogate that may suit our needs until a better estimate is provided.

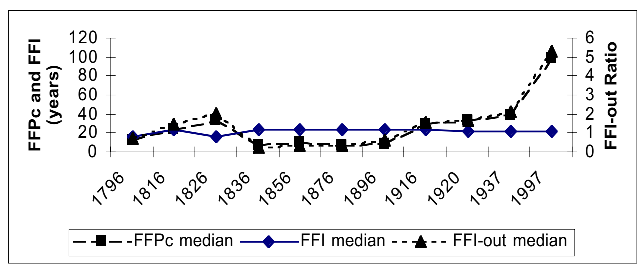


Figure 2. —FFI, FFI-out and FFPc for U.S. stands over time.

U.S. and Russian Fire Regime

Russian and U.S. stands have a similar fire regime based on MFFPp, MFFI, and MFFIp (Table 1). The difference in MFFI between Russian and U.S. stands was less than 2 years. The inclusion of the FFPp increased the fire frequency interval (MFFIp) to 30.9 and 26.3 years Russian and U.S. habitat, respectively. This represents the fire frequency during the unaltered portion of fire history for U.S. stands. The inclusion of FFPc increases the fire return interval for the current stand history (MFFIe) by another 11 to 12 years. Both U.S. and Russian stands shared a FFPp of similar duration (37-43 yrs, Table 1). Mean FFPp and FFPc are currently similar for Russian stands (37-39 yrs, Table 1). In U.S. forest stands duration of FFPc was less than the initial fire resistant period (FFPp) until 1937. In 1997 FFPc was in excess of two times the duration of FFPp. We could detect no significant differences ($p < 0.1$) between U.S. and Russian fire metrics listed in Table 1.

Table 1.—Mean FFPp, FFI, FFIp and FFIe for U.S. and Russian stands.

Fire metric	MFFPp		MFFI		MFFIp		MFFIe	
Stands	Russian	U.S.	Russian	U.S.	Russian	U.S.	Russian	U.S.
Years*	36.8	43.0	21.3	22.9	30.9	26.3	42.5	37.3

* No significant (p< 0.1) difference between any U.S. and Russian values.

U.S. and Russian Fire History

A prolonged fire free period (median 99 years, Table 2) where FFPc > FFI, is currently found in all sampled U.S. stands (Fig. 3a). Whereas, Russian habitat is comprised of stands where the FFPc is both > and < FFI (Fig. 3b). Russian stand structure is notably different between the two states (Fig. 4a, b). Based on the Russian reference we should expect a portion of U.S. stands to have a prolonged FFPc, but not all of the stands. Schellhaas et al. (2000 [a]) found the interval for fire return to vary from 5 to 83 years (MFFI, 29.5) at one CROP land site.

Russian stands have a shorter fire history than the U.S. stands (Table 2). The mean RFP was approximately 84 years compared to 207 years for U.S. stands. U.S. and Russian stands may have the same fire regime, but the U.S. stands have run through the disturbance/recovery cycle twice as often as their Russian homologues. We do not know the cumulative effects of repeated fire cycles on stand structure and therefore can not use Russian stands as a reference point to define U.S. forests of 1997.

Table 2.—Mean and median FFPc, RFP and FFIe-out for Russian and U.S. stands in 1997.

Fire metric	Russian 1997	U.S. 1997	Russian 1997	U.S. 1997
	mean	mean	median	median
FFPc	39 **	100	21**	99
RFP	83.6**	207.7	86**	187
FFIe-out	0.9**	2.83	0.5**	2.98

** Mean and median values for FFPc, RFP and FFIe-out are significantly (p < .05) different between Russian and U.S. forest stands.

The median FFIe-out value of 0.5 for Russian stands indicates the habitat is potentially in a dynamic steady state and a fire event would not alter the majority of habitat (Table 2). However, the mean FFIe-out value (0.9) is almost double the median indicating there are stands within the habitat with a lengthy FFPc and those stands may be subject to stand altering fire (Fig. 3b). Mean and median Russian FFIe-out values are significantly ($p< .05$) less than for the U.S. stands. The U.S. habitat is not in a dynamic steady state and all stands appear subject to stand altering fire events (FFIe-out median = 2.98).

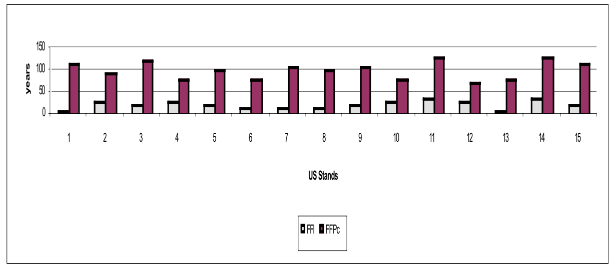


Figure 3a.—FFPc in excess of FFI in all sampled U.S. stands.

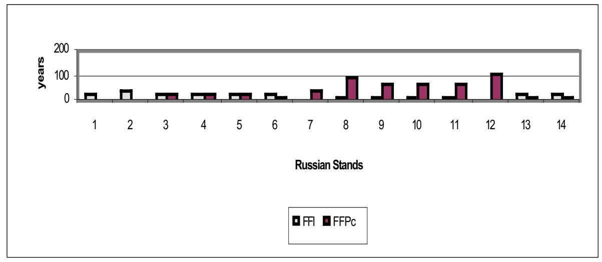


Figure 3b.—Russian stands with FFPc both greater and less than FFI.

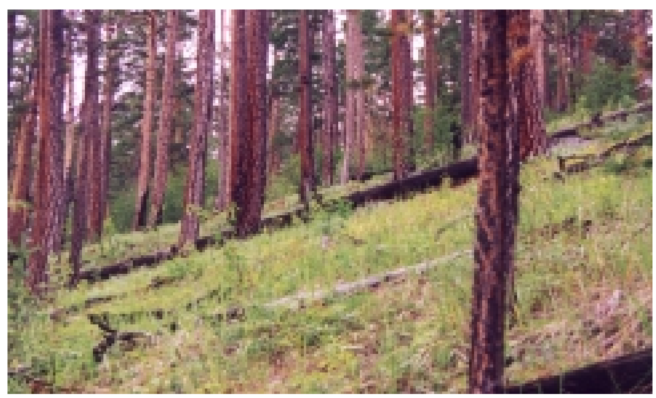


Figure 4a.—Russian stands where the current fire free period is within the fire free interval [FFI> FFPC].

Figure 4b.—Russian stands where the fire free period exceeds FFI [FFI<FFPc].

Matching Russian Fire History to Historical U.S. Era

The cluster analysis using median FFPc, RFP, FFI and FFIe metrics as matching criteria grouped 1997 Russian stands with U.S. stands of 1796 and 1826 (Fig. 5). All Russian dates (1961, 1981, and 1997) grouped together. The U.S. stands cluster into three main groups, 1796-1826, 1816-1896, and 1916-1997. These U.S. groups may be characterized as periods of reduced fire occurrence, periods with frequent fire and a fire suppression period, respectively.

By comparing landscape composition (proportion of stands < 0.5 and > 0.5 FFIe-out) between Russian and historic U.S. stands we find a potential match close to 1796. Russian stands in 1997 had 57% and 43% of stands < and > 0.5 FFIe-out, respectively. This same ratio occurs three times in the U.S. fire history around 1796, 1836, and 1896 (Fig. 6). We chose U.S. fire history at 1796 as the best match with current Russian fire history because it is a period of transition from more to less burning (as is 1997 Russian habitat), and because of agreement with cluster results above. However, the match is of little use in providing a reference forest structure supported by an intact fire regime unless the current Russian stand/habitat structure is both sustainable and exists in a dynamic steady state.

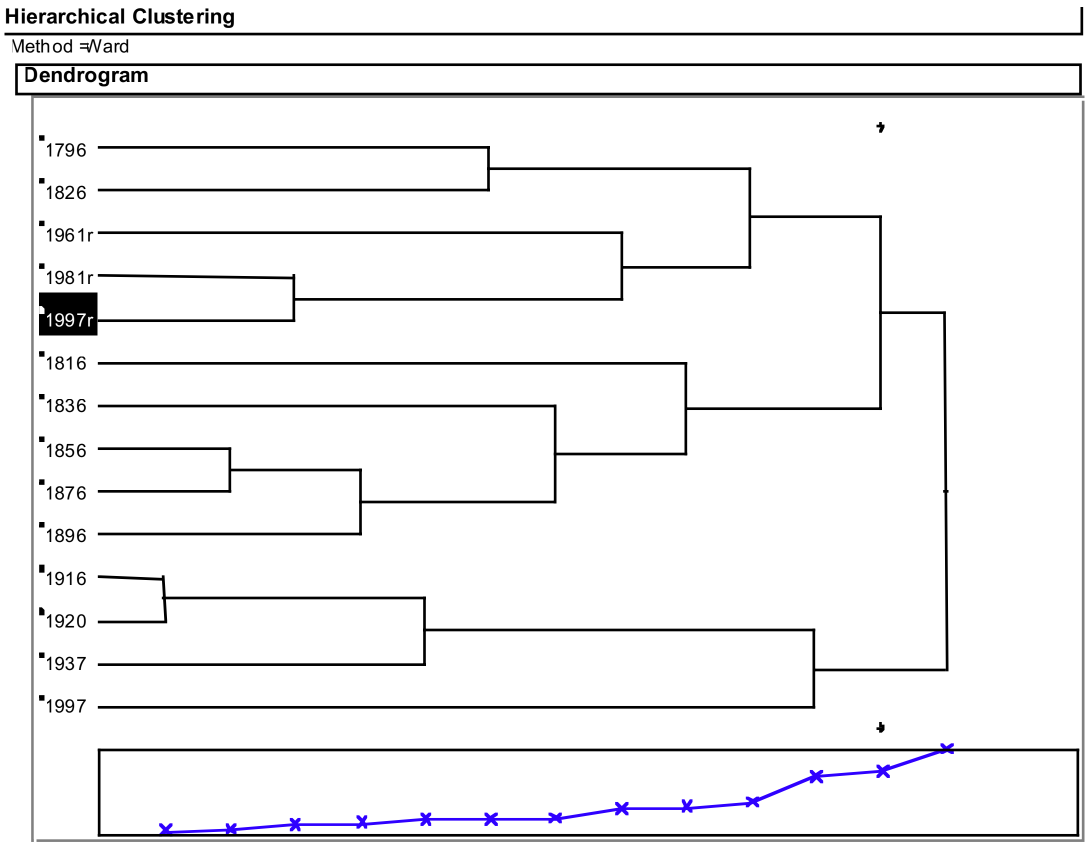
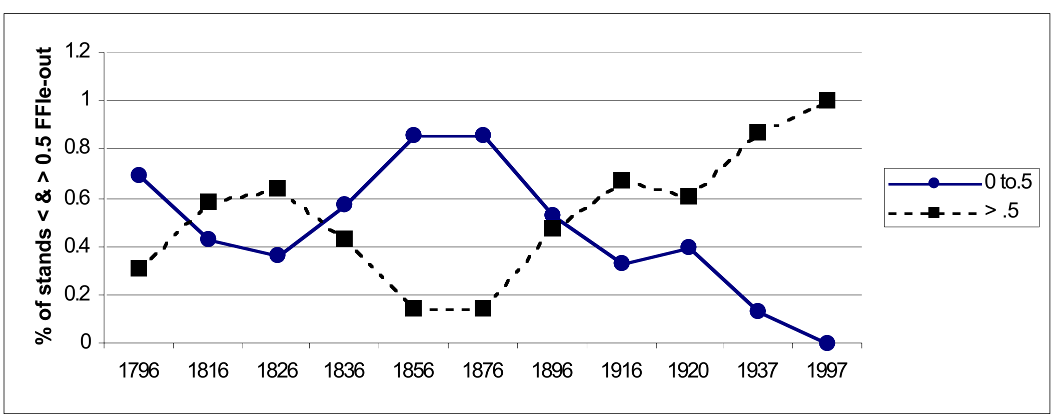


Figure 5.—Cluster dendogram of Russian (r) and historical U.S. fire histories using FFPc, RFP, FFI and FFIe fire metrics. (Lower curve shows relative difference among clusters at various grouping levels)

Figure 6.—Proportion of U.S. stands < and > 0.5 FFIe-out over time. 1997 Russian values were 57% < 0.5 and 43% > .05 FFIe-out.



Sustainability and Steady State Dynamics

1997 Russian stands had a median FFI-out ratio of 0.83 indicating reoccurring fire before complete recovery. However, disturbance and recovery intervals are approximately equal (FFI =1), FFI is being maintained and the habitat appears sustainable (Table 3). There is a fairly even division (57% to 43%) between stands where the FFI exceeds and is less than FFPc indicating high stand diversity in the habitat (Fig. 3b). The median FFIe-out value is 0.51 indicating a dynamic steady state (approximately 50% of the stands are in early post-fire recovery and 50% are in late post-fire recovery). The mean FFIe-out value of 0.9 indicates that on some Russian stands sufficient time has past since the last fire event (FFIe >1) for biomass to accumulate and more severe (stand altering) fires to occur (Table 2).

Table 3.—Mean FFI-out values and the proportion of stands where the fire frequency interval FFI is greater than fire free period FFPc (time since last fire within the FFI) for Russian and U.S. stands (current and historical).

	Russian 1997	U.S. 1997	U.S. 1896	U.S. 1796
Median FFI-out	0.83	5.4	0.58	0.74
% stands FFI>FFPc	57	0.0	86	62

The current Russian habitat appears to be both sustainable and in a steady state equilibrium. However, had we sampled Russian stands in 1961 we might of thought them borderline sustainable (median FFI-out = 1.4) and borderline dynamic steady state (median FFIe-out = 0.7) because of too infrequent fires (Fig. 7). 1980 appears to have been a regional fire year with numerous stands burned. Had we sampled in 1981 sustainability (median FFI-out = 0.2) and dynamic steady state (median FFIe-out = 0.1) would not have appeared probable because of too frequent of fire occurrence. Following 1961 and 1981 fire and forest structure interacted and ultimately achieved a more sustainable stand and landscape structure in 1997. This phasing in and out of sustainable forest structure conditions is anticipated to continue over time based on the longer U.S. fire history (Fig. 8).

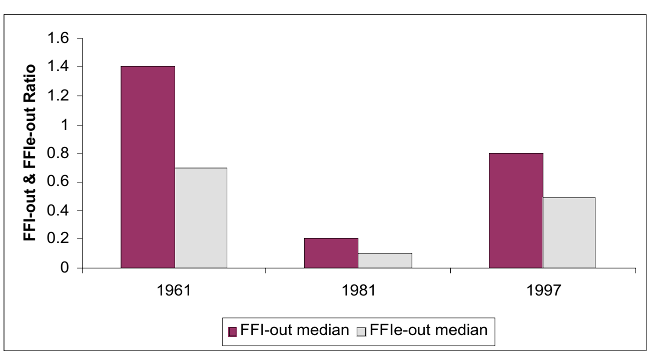


Figure 7.—Change in FFI-out and FFIe-out ratio for Russian stands over time.

Tracking median FFI-out and median FFIe-out values for historic U.S. stands shows that stands vary around the sustainability FFI-out value of 1 and dynamic steady state FFIe-out value of 0.5 (Fig. 8). Only in 1796 did values that approximate sustainability and a dynamic steady state occur simultaneously. However the grand mean for FFI-out and FFIe-out for the period from 1796 until we start to see effects of fire suppression in 1916 was 0.93 and 0.53, respectively. Fire history records suggests we may expect too much to ask current stands to always be sustainable, but rather we should strive to maintain the sustainability of the longer-term disturbance and landscape recovery cycle. The divergence from the historical record on or around 1937 is evident in Figure 6 and we do not know whether the longer-term disturbance/recovery cycle has been jeopardized.

1997 U.S. stands had a mean FFI-out of 5.4 indicating the stands were on an average at least five fire frequency intervals out from their last burn (Table 3). There are no stands where FFI > FFPc which indicates reduced habitat diversity weighted to prolonged post-fire recovery stages (Fig. 3a). The mean and median FFIe-out value of 2.8 indicates that the next fire could well be stand altering and that the habitat is not in a dynamic steady state. 1997 U.S. stands appear neither sustainable, nor in a dynamic steady state equilibrium.

The cyclic nature of FFI -out and FFIe out (Figs. 6 and 8) suggests we should not be surprised to find other time periods in U.S. history where the sampled forest habitat was neither sustainable nor in a dynamic steady state. In 1896 (approximately 100 yrs before the current sample date) we find an FFI-out ratio of 0.58 indicating disturbance is occurring prior to full recovery from the last disturbance event (FFI = 1) and sustainability is questionable. Approximately 86% of the stands had a FFI > FFPc, indicating reduced stand diversity weighted to early post-fire recovery. The median FFIe-out value of 0.42 indicates that fires were probably not stand altering, but were occurring too often for a dynamic steady state of all post-fire recovery states.

In 1796, our closest match to current Russian fire history, the median FFI-out value was .74. Sustainability appears borderline with too frequent burning, but this approximates the current Russian FFI-out value of 0.8. In ap-

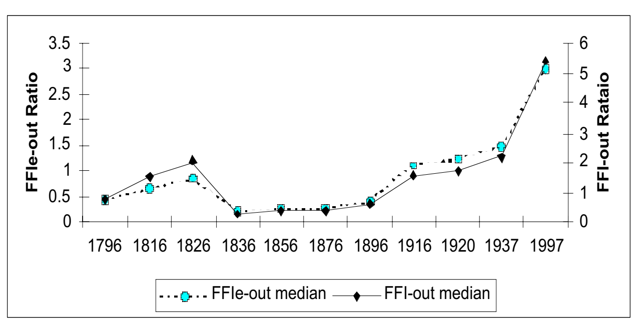


Figure 8.—Plot of median FFI-out and median FFIe-out for U.S. stands over time. Median FFI-out = 1.0 indicates sustainability and median FFIe-out = 0.5 indicates a dynamic steady state condition.

proximately 62% of the stands FFI > FFPc indicating moderate habitat diversity weighted toward earlier stages of post-fire recovery. Mean and median FFIe-out values of 0.51 and 0.44 suggest fires are not generally stand altering fires, and the habitat is approximating a dynamic steady state.

Current Russian stands and U.S. stands of 1796 appear to be both sustainable and in a dynamic steady state. The current structure of the Russian stands should provide some indication of the live tree, snag, and log densities supported by the same fire regime and fire history present in the U.S. in 1796. The reader is cautioned that we are providing a point reference for a dynamic forest system as indicated in Figures 6 and 8. Figure 6 indicates a reoccurring cycle of shifting habitat dominance between early and late post-fire successional states in U.S. forests. A vegetation patch steady-state condition rarely occurred during the entire fire history for the U.S. habitat. Thus if we define a sustainable forest structure, it most likely would be transitory in nature and contrary to the dynamics of the system to try and maintain the "sustainable" condition over time.

Mixed Fire Regime: A Composite of Fire Regimes and Stand Fire Histories

To use the Russian stands as a reference we must first place them within the context of their larger burn cycle as burn history impacts present stand structure. 1997 Russian stands are in an infrequent fire phase of their long-term cycle as indicated by increased FFI-out and FFIe-out ratios from 1981 (Fig. 7). Because the Russian stands are in a period of reduced fires we should anticipate the presence of increased amounts of small diameter stand structure within the habitat, but this will be stand specific based on whether the FFPc of the stand exceeds the FFI (Fig. 3b, 4 a,b).

Clustering Russian stands according to FFPp, FFPc, FFIe, FFIe, FFI-out, FFIe-out and RFP provided two distinct fire groups that differ in both fire regime and fire history (Table 4). Fire group a is characterized by a longer FFI, a shorter FFPc, and a longer RFP than Group B. The FFPc of Group B is greater than Group A by a factor of 4.

The mixed fire regime in the U.S. stands similarly produced two distinct fire regime/fire history groups in cluster analysis. Schellhaas et al. (2000 [a]) findings of stands having short mean FFI (11 years) and long mean FFI (39.4 years) within the mixed fire severity regime of the CROP South Deep Watershed would support this concept. In our U.S. sample fire Group A is again characterized by a longer FFI, a shorter FFPc, and a longer RFP than Group B (Table 4).

Table 4.—Fire metric differences between Russian fire groups and U.S. fire groups.

	Russian Fire		U.S. Fire	
	Group A	Group B	Group A	Group B
Fire metric	- years -		- years -	
FFI	26.6**	11.1	28.7**	15.2
FFPp	37	40	41	45
FFPc	17	72**	98	103
RFP	110**	38	243	177
TFH	164	150	380	325

** Comparisons within rows are significantly ($p < .05$) different
TFH, total fire history (FFPp + FFI + FFPc)

Comparison of Structure Between Russian Fire Groups

Variability within each Russian fire group precluded determining statistical significance ($p < .1$) among structural components, but the means did reflect expectations based on fire history (Table 5). Mean number of small (< 9 inches dbh) live trees and snags was greater in fire Group B than Group A as anticipated by the prolonged FFPc. Large (> 9 in. dbh) tree and snag abundance was more consistent between fire groups, but the opposite was true for large logs. We speculate the lengthy FFPc in Group B allowed the accumulation of large logs that would have been consumed by more recent fires in Group A. The use of two rather than one reference condition (based on fire groups) appears warranted because of the significant over and under estimates created using the grand mean.

Table 5.—Stand structural elements of Russian fire Groups A and B.

	Mean Group A	Mean Group B	Grand Mean	% over or under estimate using grand mean	
Structural element	———— number/acre————			% a	% b
Live tree 1 to 9 in. dbh.	51.4	120	85.7	+ 68	-29
Live tree > 9 in. dbh	75.4	88	81.7	+ 8	-7
Snag < 9 in. dbh.	9.7	42.7	26.2	+170	-39
Snag > 9 in. dbh.	17.1	19.3	18.2	+ 6	- 6
Log < 9 in. dia.	38.3	48.6	43.5	+14	-11
Log > 9 in. dia.	20.6	37.3	29	+ 41	-22

Comparing Stand Structure of Current Russian and U.S. Forest Stands

Any comparison of Russian and U.S. stand structure needs to match stands in Russian fire Groups A and B with similar groups in the U.S. (Table 6). The reader should look at comparisons of Russian-U.S. stand structure from the view point of what changes in U.S. forest structure would need to occur to reach a sustainable condition rather than defining the desired future condition as the Russian stands. The reader should take special notice of the structural differences between the two Russian fire groups (Tables 5 and 6) to appreciate the flexibility possible in stand structure within a mixed severity fire regime.

U.S. stands have significantly greater abundance of small diameter live trees and snags than the Russian reference stands. Also, small logs are more abundant in U.S. stands than Russian stands, but this is only statistically significant in fire Group A. A greater abundance of large trees and snags is found in the U.S. than Russian stands, as could be anticipated from the additional 120 years of stand development in U.S. forests (Table 4). Three times the number of large logs are found in U.S. fire Group A as in the Russian fire Group A, but numbers were similar in fire Group B.

The Eastside screens [Amendment 2] (USDA 1995) to maintain ecosystem integrity in forest projects recommends 4 snags (>20 in. dia.) and 8 green tree replacements per acre. The mean abundance of snags in both Russian fire groups is 4 times this recommendation (Table 7), but we don't know if large snag abundance declines as stands mature and this difference is a result of longer stand development in U.S. stands. Eastside screens also suggest 15-20 large (> 12 dia.) logs per acre and the Russian stands had 1/4 to 1/3 that amount. But, we speculate this is a result of decay and log breakage in the U.S. habitat (longer FFPc) as linear feet of log was comparable (eastside screen recommendation, 100-140 ft/acre and the Russian stands, 169 ft/acre).

Given the same fire regime and fire history, current Russian stands may be a suitable reference for the U.S. stands of 1796. However, the lower abundance of large diameter stand components in 1796 (assuming current Russian stand structure) may not be socially or economically acceptable.

Table. 7.—Abundance of large (> 16 in. dia.) live trees, snags and logs in Russian fire Groups A and B.

	Group A			Group B		
	mean	upper CI	lower CI	mean	upper CI	lower CI
live tree	16.6	23.5	9.7	20.1	34.5	6.0
snags	2.9	8.4	0.0	2.7	6.0	0.0
logs	5.7	14.2	0.0	5.3	11.7	0.0

U.S. stands have a greater amount of almost every stand structural component than the Russian stands, but they have the same inherent fire regime. We would logically question the sustainability of the small diameter live trees, and snags in U.S. stands because most would have established since the start of the fire free period (FFPc). Also, sustainability of larger structural components is in question because of the elevated fuels and potential for severe crown fires.

CONCLUSIONS

We suggest that a well-established fire frequency interval (FFI) define both the disturbance interval and recovery period for a fire event in these forests. A median/mean FFI-out value of 1.0 for stands within the habitat indicate that the FFI is being maintained, disturbance and recovery are in balance and the habitat is sustainable in the long-term. We used the fire metric FFIe-out as a temporary surrogate to estimate the time period between stand altering fires (a value supported by cohort ages) that would maintain habitat diversity. We suggest that a median/mean FFIe-out value of 0.5 is an indicator of a potential dynamic steady state of stand types within the habitat.

An analysis of Russian and U.S. fire metrics suggest the two sampled habitats have similar fire regimes, but differ in fire history because of the lengthy fire free period and longer reoccurring fire period in U.S. stands. The Russian fire history in 1997 matched the fire history of U.S. stands in 1796. The occurrence of a lengthy fire free period for a portion of sampled stands is anticipated (Schellhaas et al. 2000), but its presence on all U.S. stands indicates a significantly altered fire regime. The proportion of stands

Table 6.—Abundance of stand structural elements in Russian and U.S. fire Groups A and B.

	Russian Group A	U.S. Group A	Russian Group B	U.S. Group B
Structural element	———— number/acre————			
Live tree 1 to 9 in. dbh.	51	707***	120	605***
Live tree > 9 in. dbh	75	123**	88	117
Snag 1 to 9 in. dbh.	10	104*	43	130**
Snag > 9 in. dbh.	17	19	19	21
Log < 9 in. dia.	38	241	49	101
Log > 9 in. dia.	21	69	37	36

***, **, * Significant difference (p < .01, .05, .1) between Russian and U.S. stands.

where the current fire free period (FFPc) exceeds or is less than the fire free interval is approximately equal for the intact Russian fire regime. Relatively fire free and fire prone phases are cycling on individual Russian stands while an overall median FFI-out = .83 occurs for the habitat as a whole. In 1997 the intact Russian system had both habitat diversity (FFIe-out = 0.53) and overall stand sustainability; the U.S. forest habitat had neither of these attributes.

Sustainability and a dynamic steady state condition do not appear to be the norm at any given point in time for either Russian or U.S. forests habitats. Long-term cycles comprised of alternating periods of frequent fires and fire free periods create a system always in adjustment. Stands rarely appeared sustainable either because fire intervals were shorter than previous recovery periods (FFI-out <1) indicative of a degrading system (Turner et al. 1993) or because a lengthy fire free period (FFI-out >1) would allow biomass buildup and a subsequent stand altering fire. The result is a non-equilibrium forest habitat rarely comprised of equal proportions of early and late post-fire recovery stands.

The fire regime from 1796 to 1916 had an overall median FFI-out equal to 0.93 (approx. 1.0) and a median FFIe-out of 0.53 (approx. 0.5) that indicate habitat sustainability and landscape equilibrium over the long-term. Rather than focusing on sustainability and dynamic steady state for a set of current conditions, perhaps we should focus on maintaining the ebb and flow of disturbance and resulting landscape patch dynamics in the long-term.

The U.S. fire record suggests sampled stands were subjected to two periods of habitat homogenization where the long-term disturbance/recovery cycle was not maintained; the first a period of ubiquitous frequent burning in the 1800's (during Euro-settlement) and the second a period of blanket fire suppression in the 1900s. The impacts of altering the long-term disturbance cycle can be seen in the homogenization of eastside forest stand and landscape structure (Lehmkuhl et al. 1995). The unanswered question is what would the U.S. stands of 1796 (represented by current Russian stands) now look like if they had not gone through the homogenization process?

Russian stands can not serve as a reference for current U.S. stands because they differ in fire history and duration of stand development. Given that Russian habitat has the same fire history as U.S. stands of 1796 and that the Russian habitat appears to be both sustainable and in a dynamic steady state, then the current Russian stand structure may serve as a reference for U.S. 1796 stands. In 1796, eastside forest habitat was sustainable and in a dynamic steady state. As 1796 forest structure is only a single reference point in time for a dynamic forest system its best use is to provide an estimate of the abundance and types of stand structures supported by the inherent fire regime of the area. Then use that information to define desired future forest conditions that have reduced risk to catastrophic fire and that meet other public expectations (Everett et al. 1996; Everett and Baumgartner 1997). Current U.S. stands have a significantly greater number of small diameter live trees, snags, and logs than occurs in Russian stands with an intact fire regime. Current live tree, snags and log loadings in eastside forests may be outside that supported by inherent fire regime of the area.

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