Baker Study Area

The results of the fire return interval analyses for this study area are separated into three different categories: stream size comparisons, forest type comparisons, and slope aspect comparisons.

Stream Size Comparisons. Overall, riparian fire return intervals in the Baker study area are longer than upslope fire return intervals (Figure 12), although, depending on how the fire return intervals are categorized, the differences in fire return interval lengths may or may not be statistically significant or ecologically relevant. When fire return intervals from both large and small streams are combined, riparian fire return intervals are statistically longer than upslope fire return intervals (15 year and 11 year WMPIs, respectively, p = 0.001, two-tailed Mann-Whitney U-Test for unmatched samples). As with the Dugout study area, however, the difference between the WMPIs is small (4 years) and unlikely to represent a biological difference.

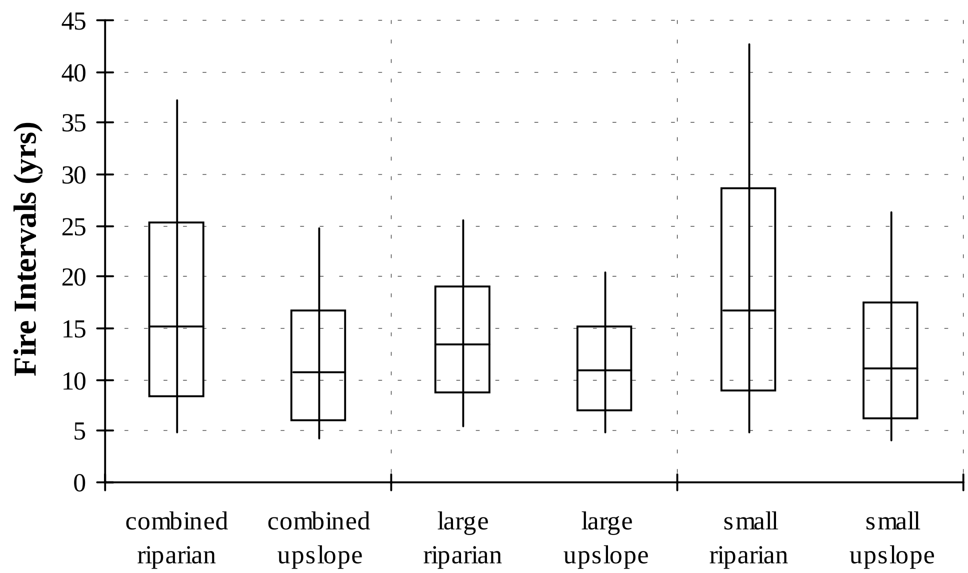

Figure 12. Fire return interval ranges for combined riparian and combined upslope plot categories, large stream riparian and upslope plot categories, and small stream riparian and upslope plot categories, Baker. Box plots represent, from top to bottom: 90th percentile and 75th percentile exceedance levels, WMPI, 25th percentile and 10th percentile exceedance levels (all percentiles calculated from the Weibull distribution).

There is no significant difference between large stream riparian fire return intervals and their corresponding upslope fire return intervals (13 year and 10 year WMPIs, respectively, $p = 0.10$, two-tailed Mann-Whitney U-Test for unmatched samples), yet there is a difference between small stream riparian fire return intervals and their corresponding upslope fire return intervals. Small stream riparian fire return intervals are statistically longer than upslope fire return intervals (17 year and 10 year WMPIs, respectively, $p = 0.0002$, two-tailed Mann-Whitney U-Test for unmatched samples) and the confidence interval is wider for small stream riparian fire return intervals compared to small stream upslope fire return intervals. Finally, the large stream riparian fire return intervals are slightly shorter but not significantly different from small stream riparian fire return intervals (13 year and 17 year WMPIs, respectively, $p = 0.15$, two-tailed Mann-Whitney U-Test for unmatched samples), yet the confidence interval for small riparian fire return intervals is considerably wider than the confidence interval for large riparian fire return intervals.

Forest Type Comparisons. Fire return interval lengths within riparian plots varied according to forest type. Riparian fire return intervals within dry forest types were significantly shorter than those within mesic forest types (12 year and 19 year WMPIs, respectively, p = 0.01, two-tailed Mann-Whitney U-Test for unmatched samples) and had a much narrower confidence interval (Figure 13).

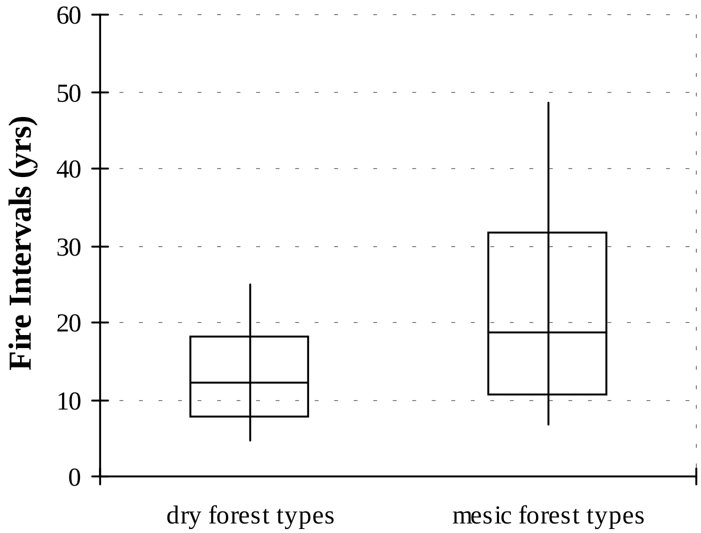

Figure 13. Fire return interval ranges for mesic forest type riparian fire return intervals compared to dry forest type riparian fire return intervals, Baker. Box plots represent, from top to bottom: 90th percentile and 75th percentile exceedance levels, WMPI, 25th percentile and 10th percentile exceedance levels (all percentiles calculated from the Weibull distribution).

Slope Aspect Comparisons. Fire return interval lengths also differed according to slope aspect. When all of the riparian plots in the Baker study area were analyzed, riparian fire return intervals from the north-facing halves of the plots were significantly longer than those from the south-facing halves of the plots (21 year and 16 year WMPIs, respectively, p = 0.02, two-tailed Mann-Whitney U-Test for unmatched samples) and had a somewhat wider confidence interval (Figure 14).

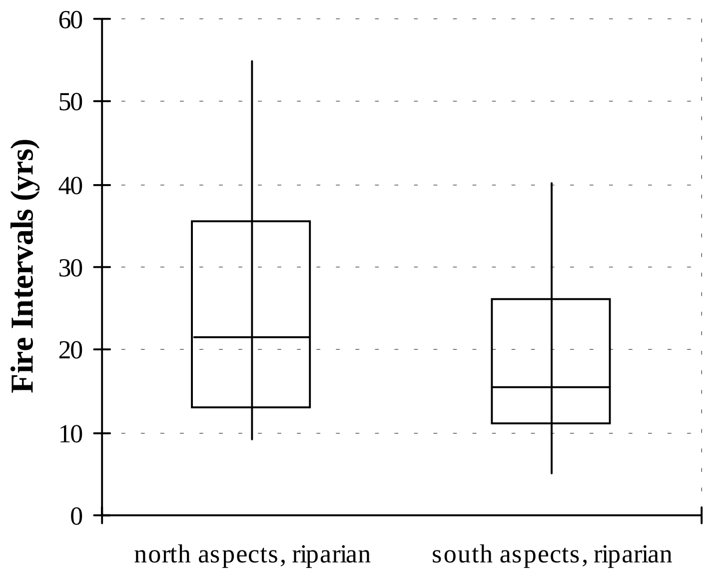

Figure 14. Fire return interval ranges for riparian fire return intervals from north aspects compared to south aspects, Baker. Box plots represent, from top to bottom: 90th percentile and 75th percentile exceedance levels, WMPI, 25th percentile and 10th percentile exceedance levels (all percentiles calculated from the Weibull distribution).

When both riparian and upslope plots within only the Marble Creek drainage were analyzed, only the riparian fire return intervals from the north-facing halves of the riparian plots stood out as being different than the other aspect categories (Figure 15). They were significantly longer than their upslope counterparts (26 year and 15 year WMPIs, respectively, p = 0.01, two-tailed Mann-Whitney U-Test for unmatched samples) and were also significantly longer than fire return intervals from the south-facing halves of the riparian plots (15 year WMPI, p = 0.01, two-tailed Mann-Whitney U-Test for unmatched samples). Additionally, the range of north-facing riparian fire return intervals is wider than ranges for other categories of fire return intervals. No significant difference was found between riparian fire return intervals from the south-facing halves of the riparian plots compared to their upslope counterparts (both had 15 year WMPIs, p = 0.53, two-tailed Mann-Whitney U-Test for unmatched samples), nor was there a significant difference between north- and south-facing upslope fire return intervals (again, both had 15 year WMPIs, p = 0.78, two-tailed Mann-Whitney U-Test for unmatched samples).

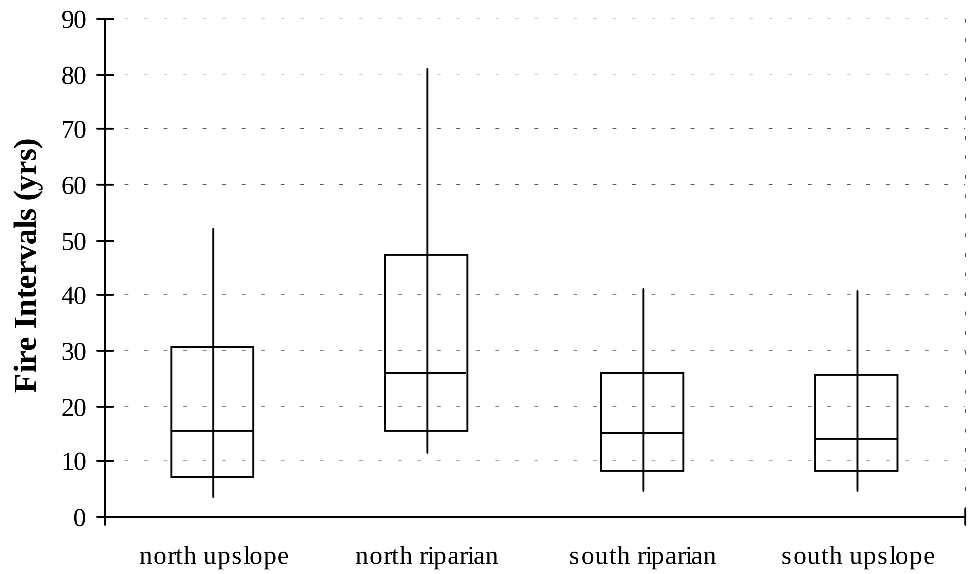

Figure 15. Fire return interval ranges for riparian and upslope fire return intervals from north- and south-facing aspects in the Marble Creek drainage, Baker. Box plots represent, from top to bottom: 90th percentile and 75th percentile exceedance levels, WMPI, 25th percentile and 10th percentile exceedance levels (all percentiles calculated from the Weibull distribution).

In contrast to the analysis of the larger portion of the Marble Creek drainage, when just the middle elevations of the watershed were analyzed, the south-facing upslope fire return intervals were shorter (12 year WMPI) than the other categories of fire return intervals (Figure 16). They were significantly shorter than the riparian fire return intervals from the south-facing halves of the riparian plots (19 year WMPIs, p = 0.03, two-tailed Mann-Whitney U-Test for unmatched samples) and were also significantly shorter than north-facing upslope fire return intervals (20 year WMPI, p = 0.02, two-tailed Mann-Whitney U-Test for unmatched samples). Additionally, the range of south-facing upslope fire return intervals is much narrower than the ranges from other categories of fire return intervals. There were not enough fire return intervals to calculate a WMPI for the riparian fire return intervals from the north-facing halves of the riparian plots. However, no significant difference was found between riparian fire return intervals from the north-facing halves of the riparian plots compared to their upslope counterparts (p = 0.12, one-tailed Mann-Whitney U-Test for unmatched samples), nor was there a significant difference between riparian fire return intervals from the north- and south-facing halves of the riparian plots (p = 0.08, one-tailed Mann-Whitney U-Test for unmatched samples).

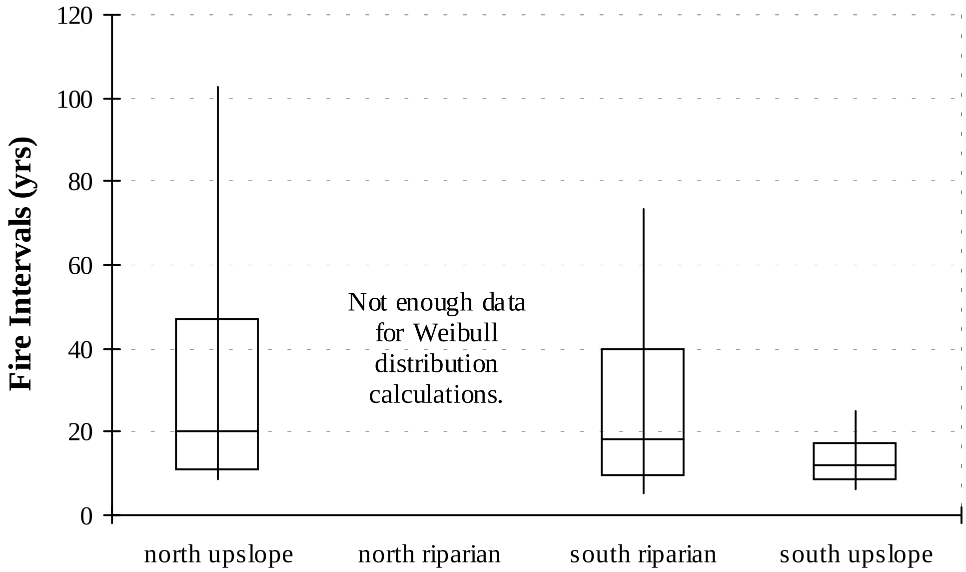

Figure 16. Fire return interval ranges for riparian and upslope fire return intervals from north- and south-facing aspects in the mid-elevational range of the Marble Creek drainage, Baker. Box plots represent, from top to bottom: 90th percentile and 75th percentile exceedance levels, WMPI, 25th percentile and 10th percentile exceedance levels (all percentiles calculated from the Weibull distribution). There were not enough fire return intervals in the north-facing riparian fire return interval category to determine a WMPI or confidence intervals.

Fire Maps. Fires in the Baker study area burned frequently in the riparian zones. Forty of the 52 fires that occurred between 1650 and 1900 (for which fire extents were determined by Heyerdahl 1997) showed evidence of fire in riparian plots. Fire evidence from riparian plots was recorded as occurring on one or both sides of the stream. This helped identify fires where the stream did or did not act as a fire barrier. It was also useful to help determine the influence of aspect on fire in riparian zones.

All of the fires within the largest fire extent class showed riparian plots recording fires somewhere within the fire's boundaries (Figure 17), and most of those fires showed evidence of the fire burning on both sides of the stream within at least one of the riparian plots. Fires burned on both sides of the stream within the same riparian plot for the three largest size classes, but not the smaller size classes. More fires burned into the south aspects of the riparian plots than fires that burned into the north aspects of the riparian plots, and this is true for all fire extent size classes. This may indicate that fires on south-facing slopes tended to back down into the riparian zone and then stop along the creek, whereas either fewer fires occurred on north-facing slopes, or they were less likely to back down into the riparian zone.

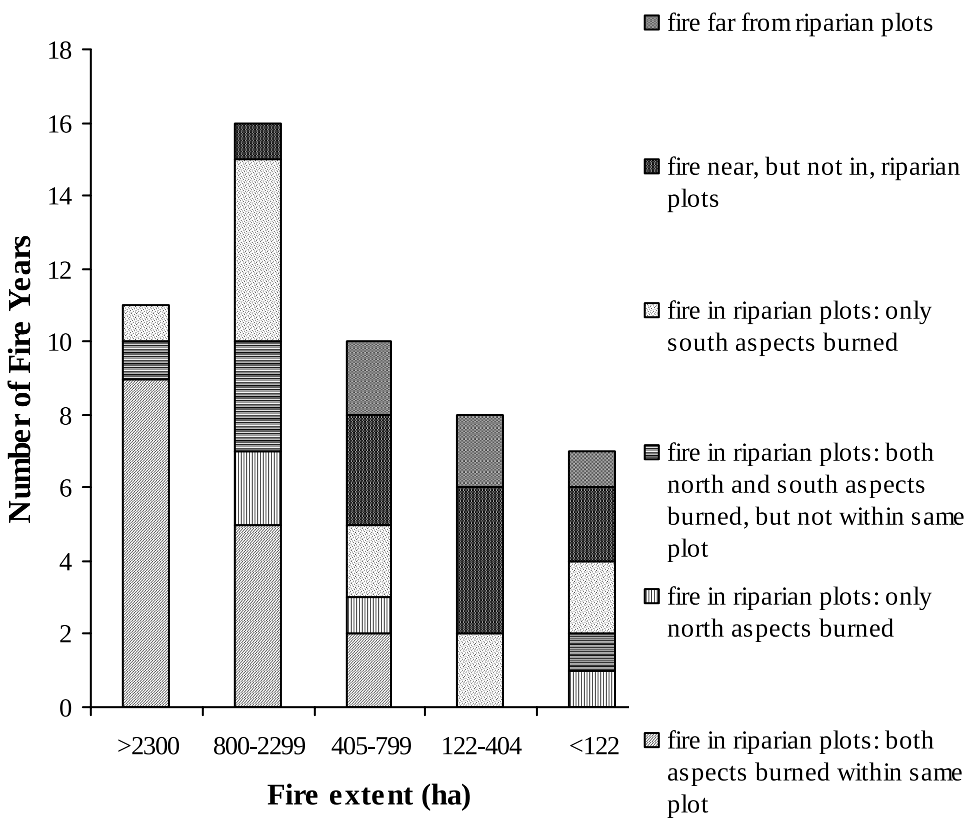

Figure 17. Number of fires that burned in Baker riparian plots, categorized by fire extent size classes and the aspect within the riparian plot.

Steamboat Study Area

The results of the fire return interval analyses for this study area are separated into two different categories: stream size comparisons and slope aspect comparisons.

Stream Size Comparisons. Fire return interval lengths in riparian forests are slightly longer but not statistically different from fire return interval lengths in upslope forests, and this is consistent for plots along both large and small streams. When fire return intervals from both large and small streams are combined, riparian fire return intervals are statistically similar to upslope fire return intervals (38 year and 29 year WMPIs, respectively, $p = 0.15$, two-tailed Mann-Whitney U-Test for unmatched samples) and they have similarly wide confidence intervals (Figure 18). There is no significant difference between large stream riparian fire return intervals and their corresponding upslope fire return intervals (35 year and 27 year WMPIs, respectively, $p = 0.13$, two-tailed Mann-Whitney U-Test for unmatched samples), or between small stream riparian fire return intervals and their corresponding upslope fire return intervals (39 year and 36 year WMPIs, respectively, $p = 0.80$, two-tailed Mann-Whitney U-Test for unmatched samples). Additionally, there is no difference between large stream riparian fire return intervals and small stream riparian fire return intervals (35 year and 39 year WMPIs, respectively, $p = 0.27$, two-tailed Mann-Whitney U-Test for unmatched samples). Confidence intervals for both small riparian fire return intervals and their corresponding upslope fire return intervals are similar in width, yet they appear to be wider than the confidence intervals for both large riparian fire return intervals and their corresponding upslope fire return intervals (which are also similar in width).

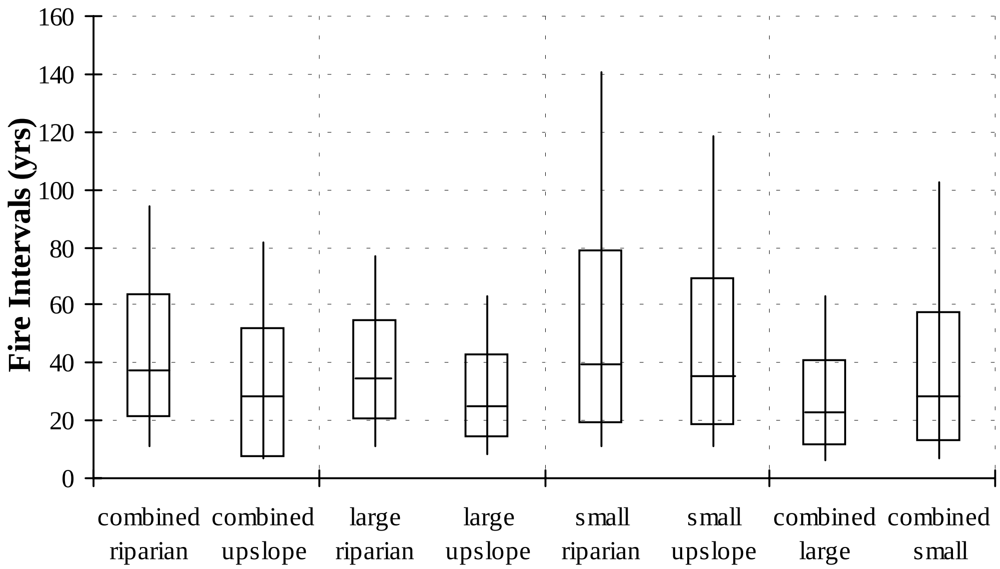

Figure 18. Fire return interval ranges for combined riparian and combined upslope plot categories, large stream riparian and upslope plot categories, small stream riparian and upslope plot categories, and combined large stream and combined small stream plot categories, Steamboat. Box plots represent, from top to bottom: 90th percentile and 75th percentile exceedance levels, WMPI, 25th percentile and 10th percentile exceedance levels (all percentiles calculated from the Weibull distribution).

When pairs of plots were combined into a single plot, and interval calculations were made from these combined pairs, no significant differences were found between large stream pair fire return intervals and small stream pair fire return intervals (23 year vs. 29 year WMPIs, respectively, p = 0.28, two-tailed Mann-Whitney U-Test for unmatched samples, Figure 18), yet the confidence interval for the combined small stream fire return intervals still appears to be wider than the confidence interval for the combined large stream fire return intervals. So the vicinity to a large stream or a small stream may play a role in how fire regimes vary within the Steamboat study area.

Slope Aspect Comparisons. Fire return interval lengths do not differ by aspect, either when fire return intervals from riparian and upslope plots are combined or compared separately. Although fire return intervals from west-facing plots were slightly longer than those from east facing plots, which were slightly longer than those from north-facing plots, there were no significant differences between the fire return intervals (45 year, 36 year and 27 year WMPIs, respectively, p = 0.34, Kruskal-Wallis one-way nonparametric analysis of variance, Figure 19).

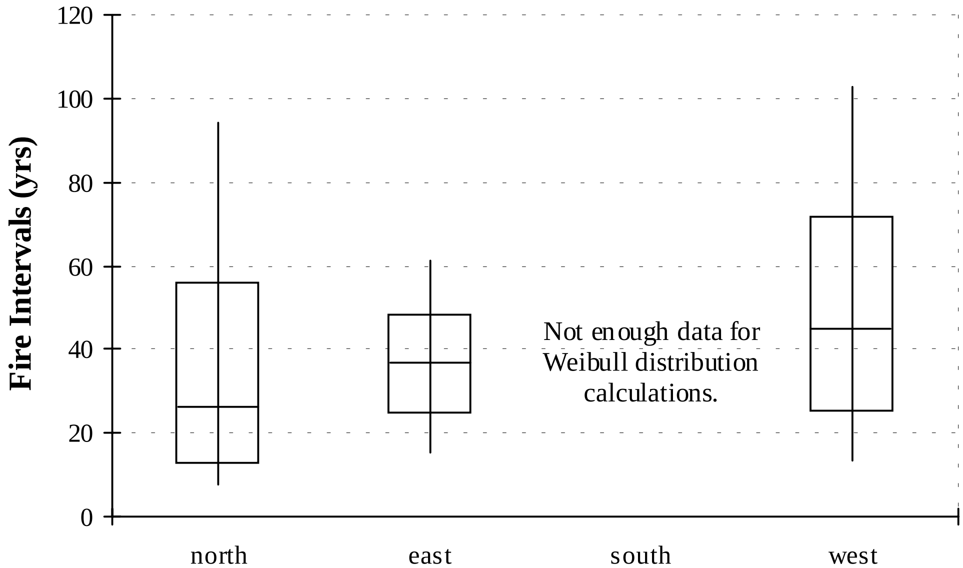

Figure 19. Fire return interval ranges for combined riparian and upslope fire return intervals from north, east, south and west aspects, Steamboat. Box plots represent, from top to bottom: 90th percentile and 75th percentile exceedance levels, WMPI, 25th percentile and 10th percentile exceedance levels (all percentiles calculated from the Weibull distribution). There were not enough fire return intervals in the south-facing fire return interval category to determine a WMPI or confidence intervals.

When the aspects were differentiated by riparian and upslope fire return intervals, no statistical differences were present (p = 0.46, Kruskal-Wallis one-way nonparametric analysis of variance, Figure 20) except when the west-facing riparian fire return intervals were compared to the west-facing upslope fire return intervals. West-facing riparian fire return intervals are longer than their upslope counterparts (56 year vs. 30 year WMPIs, respectively, p = 0.02, one-tailed Mann-Whitney U-Test for unmatched samples) and the confidence interval for west-facing riparian fire return intervals is considerably wider than the confidence interval for west-facing upslope fire return intervals. Sample sizes for these aspect categories are very small, however, and based on a non-statistical analysis, riparian fire return intervals appear to be somewhat longer than upslope fire return intervals for each of these three aspects, and the differences between the riparian and upslope fire return intervals may also be decreasing from west-facing plots to east-facing plots to north-facing plots.

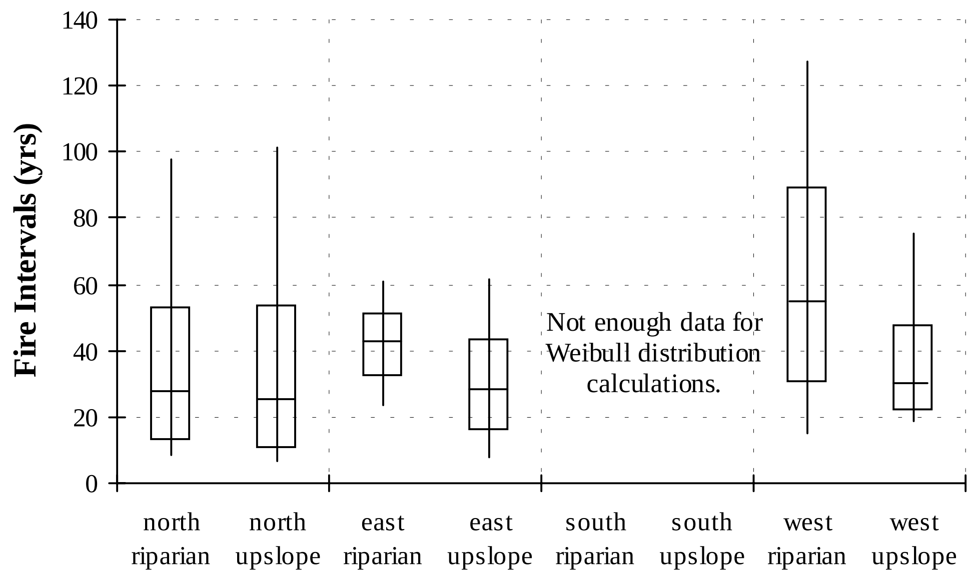

Figure 20. Fire return interval ranges for riparian and upslope fire return intervals from north, east, south and west aspects, Steamboat. Box plots represent, from top to bottom: 90th percentile and 75th percentile exceedance levels, WMPI, 25th percentile and 10th percentile exceedance levels (all percentiles calculated from the Weibull distribution). There were not enough fire return intervals in the south-facing riparian and upslope fire return interval categories to determine WMPIs or confidence intervals.

Fire Maps. Most fire years did not appear to be burning much of the study area, as they were recorded only in one pair of plots (32 out of 47 of the fires occurring between 1650 and 1900). But 11 fire years included two pairs of plots, and there were individual fire years where three, four, five and 11 pairs of plots burned during the year (Figure 21).

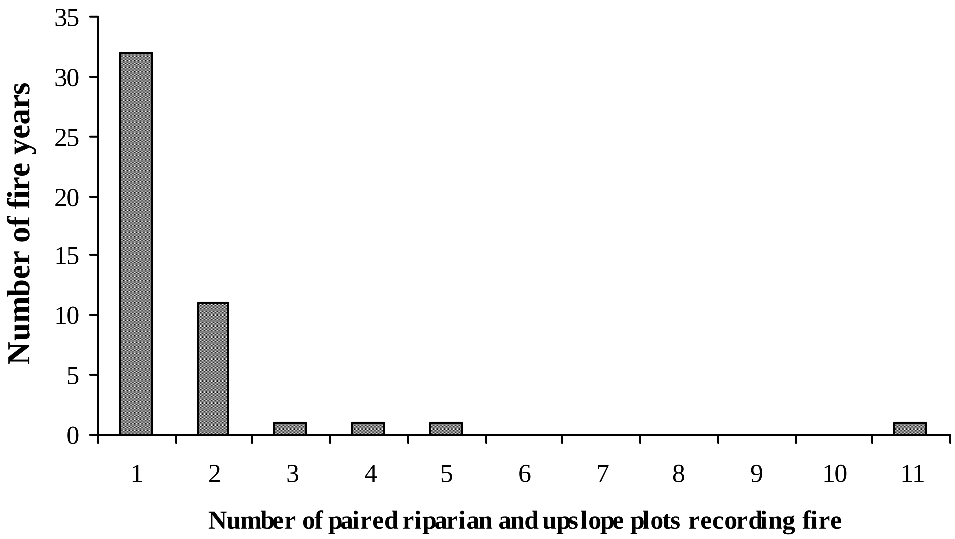

Figure 21. Number of fire years in the Steamboat study area between 1650 and 1900, in relation to the number of paired riparian and upslope plots recording each fire.

Figure 22 can be interpreted as an indication as to how widespread fires might have been within the study area. When the 15 fire years that included two or more pairs of plots are graphed in terms of distance between the farthest plots against the total number of pairs burned, there is a wide range of distances between pairs during fire years when just two pairs burned, but there may be an overall trend of increasing distance between pairs and number of pairs that burned. This would be expected for years where either an extensive, contiguous fire burned within the study area, or for years where conditions within the study area were suitable to multiple fires from multiple ignitions. Two fire years outside of the 1650-1900 time period also appear to have large fires. The 1568 fire may have ranged over 6.4 km, if evidence of possible post-fire tree establishment is included. And the 1615 fire year had 3 pairs of plots recording fire ranging over 2.9 km. This increases to 5 pairs over 5.0 km, if evidence of possible post-fire tree establishment is included.

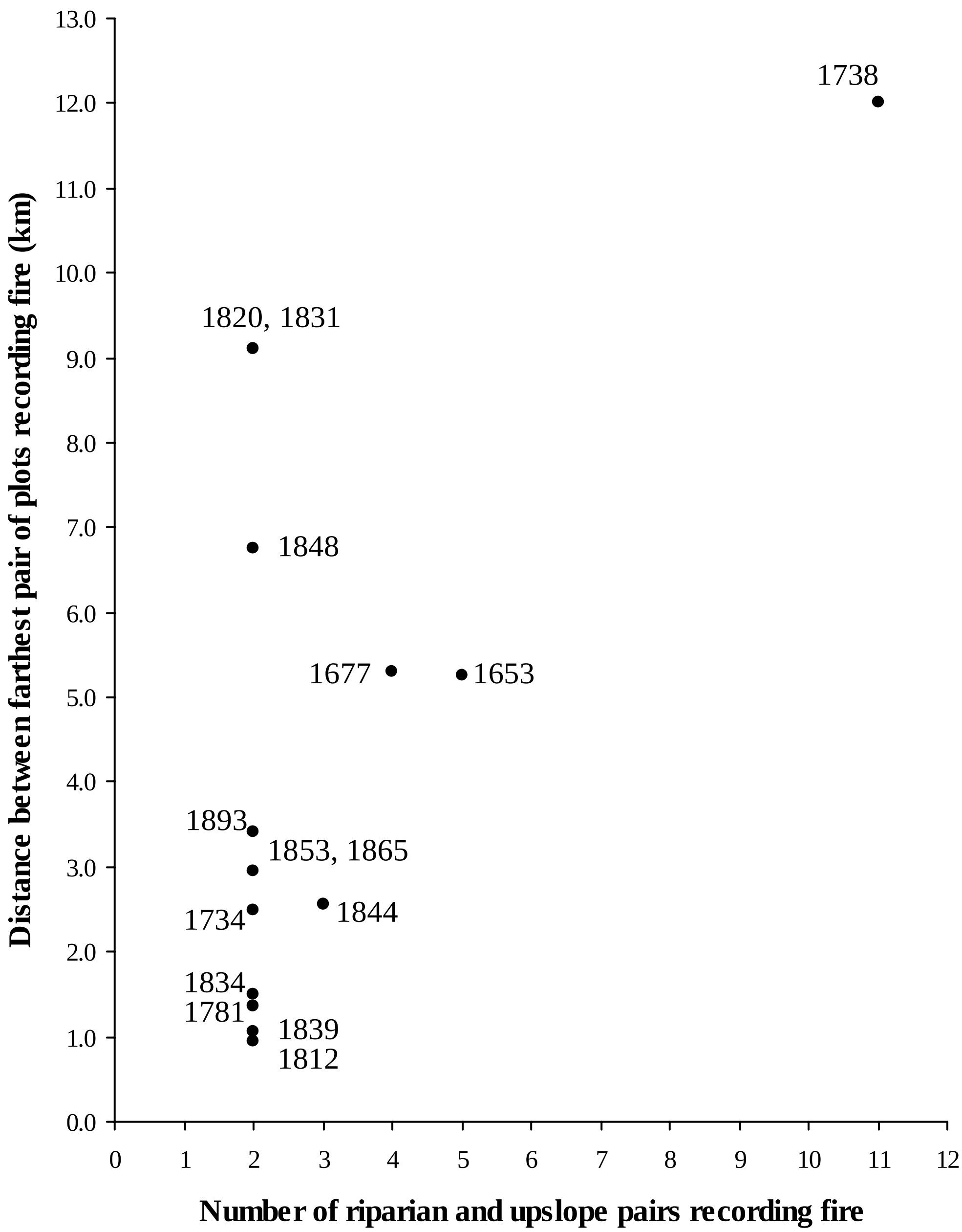

Figure 22. Fire years between 1650 and 1900 showing evidence of fire in two or more pairs of plots, and the distance between the two farthest plots recording each fire, Steamboat.

Another fire map analysis looked at whether there were fire scars in both riparian and upslope plots within a pair during a fire year. Throughout the 47 fire years, there were 77 incidences of fire scars occurring within at least one plot of a pair. Only 33 of the 77 incidences included fire scars in both plots, while 21 included fire scars in only the riparian plot, and 23 included fire scars in only the upslope plot (Figure 23).

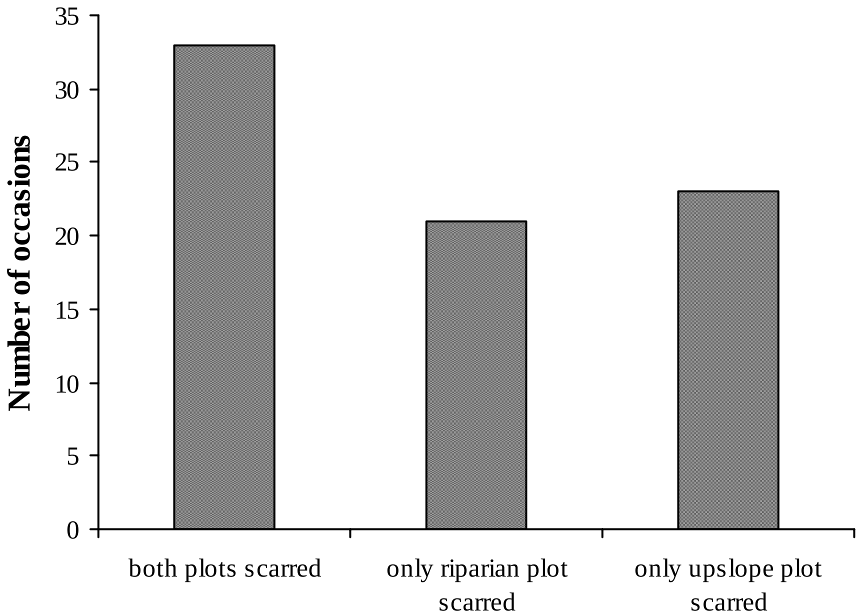

Figure 23. The number of occasions where fires scarred both riparian and upslope plots, compared to occasions where fires scarred only the riparian plot or only the upslope plot, Steamboat.

Examination of the earliest tree ring records or establishment dates for each site revealed no clear trends (Figure 24), although it is possible that riparian plots generally showed older tree ring records than upslope plots. Since this information was only incidental to the study and not part of the sampling scheme, only limited interpretations can be made. It is apparent, however, that records generally extend farther back than 1700, and aspect does not seem to influence the length of record within a plot.

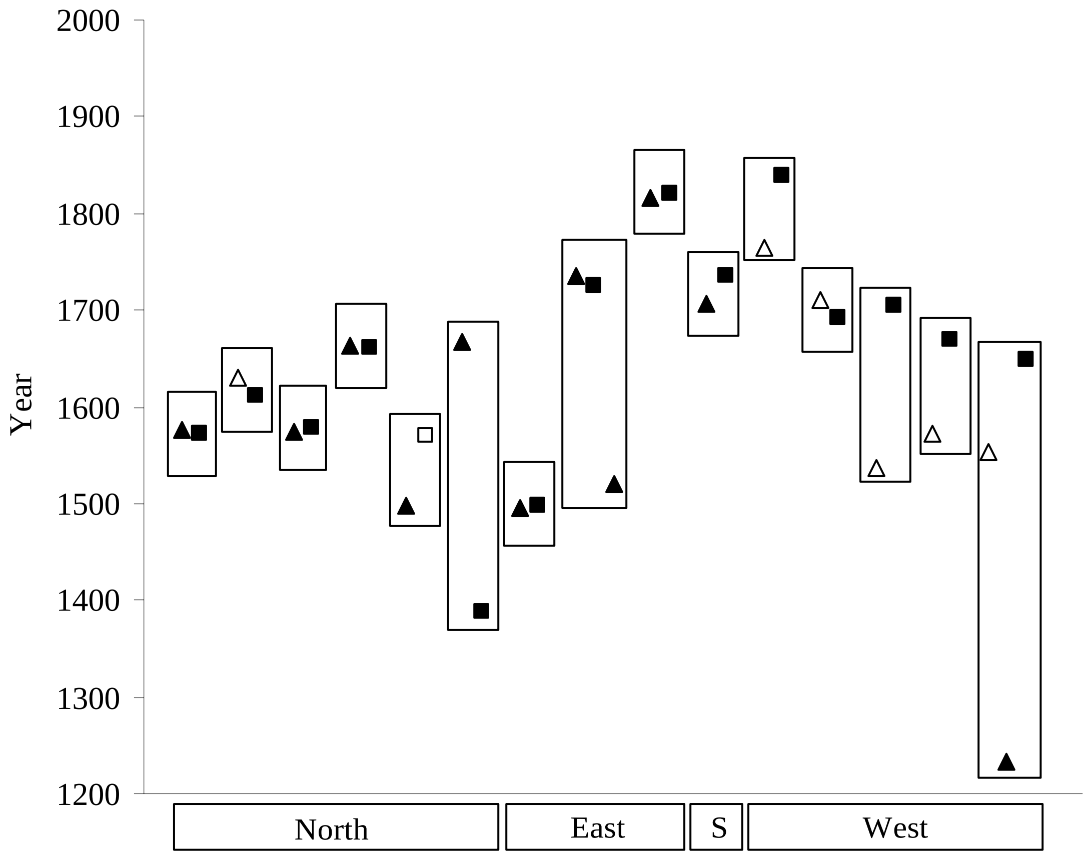

Figure 24. Earliest tree ring records or establishment dates recorded for each of the riparian and upslope plots, according to aspect. Boxes were placed around paired riparian and upslope plots. Triangles represent riparian plots and squares represent upslope plots. Blackened shapes indicate estimated tree establishment dates and hollow shapes indicate the earliest tree ring for that site (establishment dates could not be estimated).

DISCUSSION

Dugout Study Area. Although statistical differences were found between riparian and upslope fire return intervals for both the combined stream size and small stream size categories, the small WMPI differences (one to two years) suggests that the significant differences between fire return interval categories has little ecological significance. The statistically significant differences may be due to the fact that fire return intervals in riparian zones in both the combined stream size and small stream size categories have slightly wider confidence intervals for riparian fire return intervals compared to upslope fire return intervals. These significant differences may also be explained by the large sample size of fire return intervals (237 and 292 for combined stream size riparian and combined stream size upslope fire return intervals, respectively, and 127 and 197 for small stream size riparian and small stream size upslope fire return intervals, respectively), which may allow even small differences in fire return interval lengths to be statistically significant.

Regardless of whether there were significant differences between fire return intervals for the different riparian and upslope categories, fires occurred frequently in riparian forests, averaging every 13 or 14 years. These results definitely put riparian forests in the Dugout study area well within what is considered to be a low-severity, high frequency fire regime. And they show that fires are more common in the riparian forests than had previously been documented. Because there was so little overall variation in fire return interval lengths across the different categories, the only additional analysis that was made was the fire map analysis. Terrain in this study area is gentle and the forests rather homogeneous in terms of vegetation and structure. Because Heyerdahl (1997) found that fire recurrence in the Dugout study area did not vary according to topography, additional analyses with respect to topography or forest type were not done.

The fire map analysis revealed what would be expected: large fires included riparian plots more often than smaller fires. This is intuitive based on the fact that larger fires will cover an area that includes more riparian zones. What was interesting about the results, however, was that only the largest fire extent class (>2300 ha) showed evidence of burning in riparian plots within both sides of the North Fork Malheur river riparian zone. Other fire extent classes showed evidence of a fire burning within upslope plots on either side of the river, or within riparian plots within one side of the riparian zone and in upslope plots on the other side of the river, but did not indicate that the fire burned within both sides of the riparian zone. This suggests that the fires in the smaller extent classes may not have been as contiguous across the landscape and the river may have acted as a fire barrier.

Baker Study Area. As with the Dugout study area, fires were also frequent historically in the riparian forests of the Baker study area, averaging between 12 and 26 years, depending on how the fire return intervals were categorized. Generally, fire return intervals were slightly longer and have a wider variation in riparian forests than in upslope forests. Although statistically significant, there was little difference (4 years) between the average fire return intervals in riparian forests as a whole, relative to neighboring upslope forest. And when fire return intervals from large stream riparian forests are separated from those from small stream riparian forests, the only significant difference in fire return intervals is that small stream riparian fire return intervals are longer than their corresponding upslope fire return intervals. This result contradicts the original expectation that riparian forests along small streams would be more similar to upslope forests than riparian forests along large streams. It is important to note, however, that the larger streams occur only at the lower elevations of the watershed, where topography tends to be flatter and forests are generally categorized as drier forest types, and conversely smaller streams had a greater representation at the higher elevations. Therefore it was necessary to take other factors into account besides simply the proximity to large or small streams.

Heyerdahl (1997) determined that fire recurrence decreased as elevation increased. She did not, however, find a difference in fire recurrence according to aspect. But since forest types tend to differ in the Baker study area according to aspect (Figure 2), both forest type and aspect were analyzed in terms of riparian fire return intervals.

Based on data from just the riparian forests in this study, it was found that fire return interval lengths varied by both forest type and by aspect. Dry forest types not only experienced shorter fire return intervals, they also showed less variation in fire return interval length, compared to mesic forests. Although most of the riparian forests sampled in this study had mesic forest type plant associations, which would be expected for areas with higher moisture levels, four of the 16 plots had dry forest type plant associations, including one of the three plots along large sized streams. Additionally, dry forest type riparian average fire return intervals (12 year WMPI) were nearly identical to the upslope average fire return intervals used in this study (10 and 11 year WMPIs, calculated from Heyerdahl 1997), most of which occurred in dry forest type plant associations. This similarity helps explain why differentiating fire return intervals according to proximity to a stream is less indicative of fire regime variations than differentiating according to forest type.

Forest types are correlated with slope aspect (Holland and Steyn 1975), and this is especially evident for the Baker study area (Figure 2). When riparian forests were analyzed in terms of aspect, fire return intervals were longer in the north-facing portions of the riparian zone. This makes sense in terms of reduced insolation and subsequently higher moisture levels. Even though Heyerdahl (1997) did not find differences in fire recurrence according to aspect for the upslope forests in the Baker study area, the riparian forests logically occur in the most incised portions of the landscape and should therefore show the greatest differences in insolation relative to aspect.

When aspect analyses were narrowed to just the Marble Creek drainage, fire return intervals from the south-facing portions of the riparian forests and the north- and south-facing portions of the upslope forests were all similar, with only the north-facing riparian fire return intervals standing out as being longer and more variable. Fire return intervals from north-facing upslope forests still are not being differentiated from south-facing upslope forests at this scale. This is likely due to the fact that north-facing slopes in lower elevations of drainage are still dry forest (comparable to their cross drainage, south-facing counterparts) and therefore have short fire return intervals. However, the differentiation of fire return intervals between north-facing riparian forests and north-facing upslope forests suggests that fires entered the riparian forests less frequently than they burned upslope forests on just the north-facing aspects, whereas this did not appear to be the case for south-facing aspects. Unfortunately, this result cannot be corroborated at this time with a comparable forest type analysis for each portion of the riparian plots, because riparian plant associations were not differentiated according to north- or south-facing portions of the plot. The plant associations represent an average of both portions of the plot.

The final aspect analysis looked only at plots within the middle elevations of the Marble Creek watershed. This is the transitional point within the watershed where mesic forests dominate both aspects above this elevation and dry forests dominate both aspects below this elevation. It was at this scale where differences in fire return intervals for different upslope forest aspects began to be teased out of the data. The fact that south-facing upslope fire return intervals were significantly shorter than both south-facing riparian fire return intervals and north-facing upslope fire return intervals (neither of which were significantly different than north-facing riparian fire return intervals) indicates that this point in the watershed is where fires on south-facing upslopes were less likely to enter riparian forests. And this is likely due to the fact that at this elevation, mesic forest types occur in the riparian zones and on the north-facing aspects, while dry forest types still occur on the south-facing aspects. Above this elevation, the influence of aspect is likely overridden by elevational effects, and below this elevation, aspect is likely overridden by both elevation and the degree of topographical dissection.

As with the Dugout study area, the Baker study area fire map analysis showed that large fires included riparian plots more often than smaller fires. There was also evidence that fires commonly burned both sides of riparian plots in the three largest fire extent classes (encompassing 405 ha fires to >2300 ha fires). Unlike the Dugout study area where only the North Fork Malheur river was analyzed, all riparian plots in the Baker study area were analyzed in terms of whether a fire burned on both sides of the stream, therefore the results are not directly comparable between the study areas. Regardless, the Baker fire map analysis supports the conclusion that fires frequently entered riparian forests, and during the larger fire extent years, streams did not appear to act as fire barriers.

Steamboat Study Area. Fire return interval lengths in the Steamboat study area are representative of a moderate-severity fire regime, with average fire return intervals ranging between 23 and 56 years, depending on how the study plots are categorized. And the overall range of fire return intervals was between 3 and 167 years, showing a wide variation in length, which is consistent with moderate-severity fire regime forests (Agee 1993). Fire return intervals were found to be statistically similar for riparian and upslope forests, even when the riparian plots were categorized according to whether they occurred in riparian zones along small or large streams. The only indication of a possible difference is that the confidence intervals for small riparian and small upslope fire return intervals are wider than those for large riparian and large upslope fire return intervals. This suggests that fire regimes in the Steamboat study area may be less influenced by whether the plots are located in riparian or upslope forests than by whether they are located in the vicinity of large streams or small streams. However, when paired plots were combined into a single plot and categorized according to the combined plot's proximity to large or small streams, the average fire return interval from plots along small streams was not statistically different than the average fire return interval from plots along large streams. Nevertheless, the confidence interval for small stream fire return intervals was still wider than that for large stream fire return intervals. Perhaps with a larger sample size, the two categories may have been statistically different. Regardless, it is still apparent that fire return intervals in riparian forests and upslope forests are similar, and that some other variable may be what differentiates fire return intervals in this study area.

Perhaps the lack of differentiation between the riparian fire return interval and upslope fire return interval lengths is a result of a flawed riparian zone definition. The upslope plot locations may in reality not experience conditions different enough from the riparian plot locations to change the fire regime. Riparian plots tended to over represent the outer portion of the riparian zone. There were no samples taken immediately adjacent to large streams due to buffers left at the time of cutting, most of the samples were at least 30 m from large streams. Samples were taken closer to smaller streams, since buffers were typically smaller or non-existent along these streams. A more realistic definition of a riparian zone may be narrower than what was used for this study, or perhaps the zone extends into what was considered upslope for this study. Either way, it is clear that fires occurred at similar fire return intervals within the managerial definition of a riparian zone as they did outside of that zone. The riparian plot locations in this study are likely comparable to the lower regions of what other researchers have termed "lower slope positions" (Impara 1997, Weisberg 1998). Many of the upslope plots also may fall within that category, since they rarely extended farther upslope than the middle of the slope.

As expected, fire return intervals in the Steamboat study area are shorter than those determined by Means (1982), Teensma (1987), Morrison and Swanson (1990), Garza (1995), Impara (1997), Van Norman (1998), and Weisberg (1998) for western Oregon Cascades forests to the north and Oregon Coast Range forests to the west. These other studies found average fire return intervals ranging between 73 years and 246 years for forests within the western hemlock and Pacific silver fir zones. Furthermore, the average fire return intervals found in the Steamboat study area are longer than those found by Wills and Stuart (1994), Skinner (1997), and Taylor and Skinner (1998) in Douglas-fir forests of the Klamath Mountains of northern California, south of the study area. Fire return intervals in these forests were found to average between 8 and 42 years. And the average fire return intervals from this study were comparable to the range of fire frequencies found for the Siskiyou Mountains (16 to 64 years, Agee 1991).

When fire return intervals were separated according to aspect, no significant differences in fire return interval lengths were found between aspects. When riparian and upslope fire return intervals were compared within each aspect, the only significant difference was that west-facing riparian fire return intervals were longer and had a wider confidence interval than west-facing upslope fire return intervals. It is very likely that the results of aspect analyses suffer from a small sample size. Perhaps with a larger sample size more significant differences would have been found between the different aspects, since it appears there may be a trend of decreasing fire return interval lengths from west-facing plots to east-facing plots to north-facing plots (Figure 19). Additionally, riparian fire return intervals appear to be somewhat longer than upslope fire return intervals for each of these three aspects, and the difference between the riparian and upslope fire return intervals may be decreasing from west-facing plots to east-facing plots to north-facing plots. There are too few fire return intervals from south-facing plots to comment on where they fall within the trend.

In their Klamath Mountains study, Taylor and Skinner (1998) found that average fire return intervals on south- and west-facing slopes were shorter than on north- and east-facing slopes. If the trend of differences between aspects from the Steamboat study area is in fact a real one, it is then essentially opposite the trend found in the Klamath Mountains. Additionally, based on establishment dates of Douglas-firs, Taylor and Skinner (1998) found that the upper slopes and ridgetops throughout their study area, and intermediate south- and west-facing slopes, appeared to experience larger patches of higher severity fires relative to lower slopes and east- and north-facing slopes. Similarly, Weisberg (1998) found that north-facing slopes in the Blue River watershed experienced lower severity fires, and lower slope positions experienced lower severity fires. Impara (1997) found both severity and frequency were higher for the upper slope positions. And Van Norman (1998) found south-facing aspect fire return intervals were longer than those on north-facing aspects, which was interpreted by Agee (pers. comm. 2000) as higher severity fire on south aspects, resulting in fewer fire scars.

It is unclear how results from these other studies relate to those from the Steamboat study area. Perhaps, in general, fires in the Steamboat study area were patchier in terms of high-severity patches intermingling with low-severity patches, and the sampling scheme was effective at capturing the overall frequency of fires but not the spatial variability. Moister conditions on north- and east-facing slopes may have caused fire intensity to be lower within these areas. Maybe the drier conditions on south- and west-facing slopes were dry enough that fires were of higher intensity and, based on the complex stand structure in these forests, consequently higher severity (leaving fewer fire scarred trees).

As with results from the fire return interval analyses, results from the fire maps support the classification of the Steamboat forests as having a moderate-severity fire regime. Based on the number of occasions where a fire scarred only plot within a pair of riparian and upslope plots, either 1) most fires were small in terms of the size of the study area, or 2) fires were very patchy either in continuity across the landscape or in severity. The fact there is not a predominance of fire scars in riparian plots or upslope plots supports the previous finding that fires occur at similar intervals in riparian forests compared to upslope forests, although it is surprising that the similarity in fire return intervals is not necessarily due to both plots burning at the same time, but rather often burning at different times with a similar frequency. This again supports the suggestion that fires were patchy. It is also possible that fires were not always recorded on trees. Mature

Douglas-fir have extremely thick bark, therefore some individuals may not scar during a fire. Or perhaps some fires were not recorded on trees within the plots. If a fire is able to scorch or torch the crown of a tree, the tree usually dies and once it decays will subsequently be lost in terms of recording that fire.

Weisberg (1998) summarized fire history studies in the Washington and Oregon Cascades, and determined there is considerable evidence supporting two periods of widespread fire, one roughly between 1450 and 1650, and the other roughly between 1800 and the early 1900s. Two of the four potentially large fire years in the Steamboat study area (fires that burned at three or more pairs of plots), 1653 and 1844 fall within these periods. If the 1568 and 1615 fire years are also assumed to be large fire years, then four of the six largest fires in the study area occur within these time periods.

Finally, examination of the earliest tree ring records or establishment dates for each site suggested that, although riparian plots may tend to have older tree ring records than upslope plots, records were generally long (extending farther back than 1700), and aspect does not seem to influence the length of record within a plot. Although limited interpretation can be made from these results, it is clear that none of these sites experienced strictly high-severity fires since at least the early 1700s, and many sites had records extending back more than 400 years. This supports the conclusion that the higher severity and intensity portions of fires were generally either small or patchy, not continuous across large portions of the landscape.

Study Area Comparisons. Historical fires were common in the riparian zones of all three study areas. The study areas seem to represent a gradient of low- to moderate-severity fire regimes, ranging from Dugout, which is essentially entirely a low-severity fire regime forest, to Steamboat, which is representative of a moderate-severity fire regime. Baker shows a greater similarity to Dugout than to Steamboat, which is expected considering its proximity to Dugout. The lower portions of the Baker study area are categorized by a low-severity fire regime, but as elevation increases and the topography becomes more dissected, so does the severity of the fire regime, and perhaps the patchiness of individual fires.

When forests occur where climate and topography interact such that riparian forests reflect large vegetational differences relative to upslope forests, then fire return intervals differ, suggesting that forest composition plays a larger role than just whether or not a forest is located within a riparian zone.

Dry forests in the Dugout and Baker study areas experienced large, frequent fires that burned consistently across the landscape, including the riparian zones. Riparian forests within these dry forest types burned at essentially the same frequency as upslope forests. The dry forest types and subsequent low-severity fire regime are likely due to the gentle topography and dry climatic conditions present throughout the entire Dugout study area (only two riparian plots, out of all of the riparian and upslope plots, were mesic forest types) and the lower portions of the Baker study area. The similarity between riparian and upslope fire return intervals in the Dugout study area and in the drier, lower portions of the Baker study area is consistent with Heyerdahl's (1997) findings that fire recurrence in the Dugout study area did not vary according to topography (either aspect or elevation) and that fire recurrence in the Baker study area varied only according to elevation.

However, as elevation increases and terrain becomes more dissected in the Baker study area, longer and more variable fire return interval lengths begin to emerge. This is likely a result of forest composition changes related to both topography and elevational changes in temperature. Insolation differences are greater in terms of aspect in these steeper forests. Riparian valleys are deeper and therefore receive less insolation, and subsequently the forest composition on north-facing slopes and riparian zones is more mesic than on south-facing upslope forests. This study shows that more mesic conditions result in longer fire return intervals and perhaps patchier fires, suggesting a more moderate-severity fire regime.

Within both the Dugout and Baker study areas, the characteristics of the fires within the different fire extent classes may be representative of the overall fuel moisture conditions within the study area during the year of the fire. If it can be assumed that years with large fires had continuously dry fuels, then it appears that moisture levels during those years were not high enough to inhibit fire spread from the upslope forests to the riparian zones in either the Dugout study area or the lower portions of the Baker study area. Additionally, streams did not appear to act as fire barriers during these large extent fire years. Fire years where extents fell within smaller size classes may have had patchier fuel dryness conditions across the study area, and fuel moisture levels may have varied enough within and between riparian zones and upslope forests, resulting in smaller fires and greater variations in burning.

The Steamboat study area, on the other hand, is located within an extremely dissected landscape. It experiences a moister, more maritime climate than do the Blue Mountains. All of the riparian and upslope plots occur either within the dry end of the western hemlock forest series or the wet end of the Douglas-fire forest series. Fire return intervals are longer and appear to be more variable than in both the Dugout and Baker study areas, undoubtedly because the climate is moister. Like the Dugout study area, however, the topography in the Steamboat study area is consistent throughout the study area and forest composition is similar between riparian and upslope forests. Fire return intervals are also similar between riparian and upslope forests, and perhaps according to aspect, suggesting that topographical variation influences the fire regime in this area less than climate.

Overall, it appears that fire return intervals are influenced more by forest composition and overall climate than they are by whether they occur in riparian forests or upslope forests.

When the moisture gradient from the riparian zone to the upslope forest is large enough to allow a mesic riparian forest type to occur adjacent to a dry upslope forest type, then there will be a difference between fire return intervals in the riparian forest relative to the upslope forest. But when forest compositions are similar between riparian and upslope forests, the are likely to be the result of similar moisture levels within each of the forests, and they subsequently will experience similar fire return intervals.

MANAGEMENT IMPLICATIONS

Fire was a common occurrence in the riparian forests of all three study areas. Therefore, if the goal of forest management within these three areas is to restore forests to historical conditions, then reintroducing fire to riparian forests needs to be a part of that management. If the goal is to maintain these forests as they stand today, it is important to recognize the role that fire played in determining the structure and vegetational composition within these forests. Keeping fire out of the ecosystem will not only continue to alter the structure and vegetational composition of these riparian forests, but will also allow the buildup of fuels that could result in unprecedented fire intensities, and subsequently higher fire severities, than were present in the system historically. If the goal of forest management is to restore historical disturbance regimes to these forests, results from this study indicate riparian forests should be managed according to the historical fire regime of the forest type rather than distance from a stream. In both the Dugout and Baker study areas, drier forest conditions similar to adjacent upslope forests can occur well within the current managerial definition of a riparian zone, and this may be true for the Steamboat study area as well.

Understandably, reintroducing fire to riparian forests is not necessarily a feasible management option when there are concerns about threatened and endangered species (e.g., bull trout) within the streams or streamside forests. In a synthesis of literature about fire and aquatic ecosystems, Gresswell (1999) concluded that salmonid species have evolved strategies to survive disturbances occurring at the frequency of historical fires, but that local populations may have been ephemeral. At present, long term detrimental effects of high-severity fires are generally limited to areas where native populations have either declined or become isolated due to human influences. Therefore, although fire was common in riparian forests within these study areas, it may be necessary to totally protect some of these streamside forests. Historically, it is likely that riparian fires were a result of upslope fires backing down into the riparian zone. Subsequently, if upslope forests are treated for fuels reduction, either with prescribed fire or other silvicultural treatments, then perhaps a wildfire ignited within the upslope forests would be less likely to gain the intensity needed to burn within the wetter portion of the riparian zone. However, the possibility that entire riparian zones may have burned historically in the Dugout and Baker study areas during the larger fire years suggests that, if fuel conditions are dry enough, these forests may be susceptible to ignition even from a relatively low intensity fire. Williamson (1999) found that nearly 95% of the riparian forests sampled in the vicinity of the Dugout study area were currently at risk to crown fire ignition under 90th percentile weather conditions. Therefore, it may be necessary to reduce current fuel loads within riparian forests in order to protect them from crown fire ignition.

In terms of coarse woody debris recruitment within these riparian forests, and the subsequent addition of large woody debris to the streams, it is likely that inputs followed cycles comparable to the length of the historical fire return intervals. Within the drier forests of the Dugout and Baker study areas, coarse woody debris input into the system was likely to be rather small but continuous, with a rather short residence time. Fires occurred roughly every 12 to 14 years but seldom killed large trees. Therefore, when trees died and snags eventually fell down, it was likely due to synergistic effects between fire and other disturbance processes, such as insects or pathogens. Once logs were on the ground, they were likely consumed by the frequently occurring fires. Within the more mesic forest types of the Baker study area, as well as the moister forests in the Steamboat study area, fire intervals were longer and more variable in length, and appeared to include at least patches of higher severity fire. The higher severity patches within these fires would have resulted in higher amounts of tree mortality in these forests. So it is possible that coarse woody debris creation could have occurred patchily and in pulses (lagging a few years after fires, accounting for the time it takes for the snag to fall) roughly every 19 years in the mesic riparian forests of the Baker study area, and roughly every 38 years in the riparian forests of the Steamboat study area.

RECOMMENDATIONS FOR FURTHER RESEARCH

The paired plot approach to sampling riparian forests and upslope forests was a logical first step to studying the fire history of riparian zones, because it allowed sampling at multiple locations throughout each study area. However, based on the general lack of differentiation of fire return intervals between riparian zones and upslope forests as they are defined in this study, it would be interesting to hone in on a few locations within the Baker and Steamboat study areas and sample plots along a transect from the stream edge to the ridgetop. It would also be useful to do an age class analysis and thorough sampling of species composition along with the fire scar sampling in order to address historical fire severities. In study areas such as the Steamboat study area, where stumps are necessary to locate fire scars, it will be important to sample the fire scars before the stumps have decayed. I had difficulty cleanly removing scars from stumps in clearcuts greater than 15 years old. Since the Steamboat study is part of the Northwest Forest Plan's system of Late Successional Reserves, clearcutting ceased in 1994. Therefore, it is important to recognize that the window of opportunity for fire scar collection off of stumps is passing quickly, in this study area as well as similar areas within the western Cascades.

In the Baker study area there are growth suppression events apparent within increment cores from larch, focused roughly around 1914 and 1980, perhaps from a larch defoliator. Considering the current mortality levels and the resulting large amounts of fuel from the spruce budworm and Douglas-fir tussock moth outbreaks in the 1980s, it would be useful to design a study to look at the synergism between different types of disturbances and how they relate to topography and forest composition.

Additionally, it would be interesting to look at what sorts of historical anthropogenic influences could be associated with fires in the riparian plots within these three study areas. For example, could the interesting patterns of the 1793 and 1794 fires in the Dugout study area be correlated with known Native American cultural sites? Could the unexpectedly short fire return intervals found along large streams in all three study areas represent higher numbers of Native American ignitions along travel corridors? Understandably, this type of study would be extremely speculative. However, considering the known use of fire by Native Americans, and the fact that streamside forests would likely have been attractive locations when it came to proximity to water, both in terms of camp location as well as hunting grounds, it is possible that the historical presence of fire in riparian zones was not strictly a result of upslope, lightning-ignited fires backing down into the riparian forest.

Finally, it would be useful to study the physical, chemical and biological processes involved with reintroducing fire into riparian forests. It is often assumed that the short term detrimental impacts of intense silvicultural treatments such as prescribed fire or understory thinning on the survival of threatened fish and wildlife populations would surpass the positive impacts associated with the reduction of fuels. However, Gresswell (1999) notes that local extirpation of fishes is often patchy in the case of extensive high-severity fires, and that recolonization is rapid. If this is indeed the case, perhaps a series of carefully designed and implemented fuels reduction treatments within riparian forests could elucidate how effectively fire can be reintroduced to these forests.

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APPENDIX A. Plot and stream characteristics tables by study area.

Appendix A summarizes the plot and stream characteristics for each of the three study areas. Riparian plant associations in the Dugout and Baker study areas were determined from Crowe and Clausnitzer (1997) and upslope plant associations were determined from Johnson and Clausnitzer (1992). Both riparian and upslope plant associations were determined from Atzet et al. (1996) for the Steamboat study area. Stream descriptions were based on classifications in Montgomery and Buffington (1993).

Table 3. Dugout riparian plot and stream characteristics (bold, this study) and characteristics of the corresponding upslope sites (Heyerdahl 1997).

Plot ID	Plant Association	Forest Type	Elev. (m)	Aspect (degree)	Slope (degree)	Longitude (degree)	Latitude (degree)	stream order	stream description	bankfull avg. (m)	floodplain avg. (m)
NFM1	**Psme/Syal floodplain**	**dry**	**1390**	**258**	**33**	**-118.380**	**44.183**	**4**	**regime**	**12.0**	**37.9**
11.2	Psme/Caru	dry	1520	--	0	-118.374	44.189	--	--	--	--
NFM2 (12.1)	**Psme/Syal floodplain**	**dry**	**1400**	**280**	**23**	**-118.379**	**44.187**	**4**	**regime**	**(12.7)**	**(49.8)**
11.2	Psme/Caru	dry	1520	--	0	-118.374	44.189	--	--	--	--
NFM3	**Psme/Syal floodplain**	**dry**	**1410**	**274**	**34**	**-118.381**	**44.189**	**4**	**regime**	**(12.7)**	**(49.8)**
11.1	Psme/Caru	dry	1490	340	9	-118.378	44.191	--	--	--	--
NFM4	**Pipo/Syal floodplain**	**dry**	**1410**	**72**	**26**	**-118.383**	**44.196**	**4**	**regime**	**13.3**	**61.8**
6	Abgr/Caru	dry	1720	107	10	-118.402	44.206	--	--	--	--
NFM5	**Pipo/Syal floodplain**	**dry**	**1430**	**263**	**27**	**-118.382**	**44.204**	**4**	**regime**	**13.3**	**82.4**
6	Abgr/Caru	dry	1720	107	10	-118.402	44.206	--	--	--	--
NFM6	**Pipo/Caru**	**dry**	**1440**	**76**	**10**	**-118.383**	**44.215**	**4**	**regime**	**11.7**	**63.2**
5	Abgr/Caru	dry	1690	40	12	-118.401	44.220	--	--	--	--
NFM7	**Psme/Syal floodplain**	**dry**	**1460**	**240**	**38**	**-118.382**	**44.220**	**4**	**braided**	**10.2**	**55.0**
4.1	Psme/Caru	dry	1600	260	11	-118.377	44.223	--	--	--	--
NFM8	**Pipo/Syal floodplain**	**dry**	**1480**	**255**	**28**	**-118.384**	**44.233**	**4**	**regime**	**10.2**	**78.8**
2.1	Psme/Caru	dry	1590	280	10	-118.379	44.230	--	--	--	--
ELK1	**Abgr/Vasc**	**mesic**	**1590**	**63/250**	**2/38**	**-118.409**	**44.248**	**2**	**step-pool**	**4.9**	**5.4**
4	Abgr/Caru	dry	1720	69	5	-118.409	44.239	--	--	--	--
ELK2	**Pipo/Syal floodplain**	**dry**	**1490**	**349/171**	**5/5**	**-118.392**	**44.249**	**2**	**plane-bed**	**6.1**	**10.1**
19	Abgr/Cage	dry	1520	65	3	-118.400	44.251	--	--	--	--
STC1	**Abgr/Syal floodplain**	**dry**	**1470**	**328/143**	**30/38**	**-118.377**	**44.208**	**1**	**step-pool**	**1.5**	**2.8**
7.1	Psme/Caru	dry	1600	--	3	-118.377	44.210	--	--	--	--
STC2	**Psme/Syal floodplain**	**dry**	**1700**	**21/250**	**21/18**	**-118.334**	**44.211**	**1**	**step-pool**	**2.1**	**5.5**
6.6	Psme/Caru	dry	1760	170	5	-118.346	44.213	--	--	--	--
DUG1	**Psme/Syal floodplain**	**dry**	**1480**	**332/172**	**29/24**	**-118.377**	**44.199**	**1**	**step-pool**	**1.8**	**2.2**
9.2	Psme/Caru	dry	1610	324	9	-118.372	44.200	--	--	--	--
RSP1	**Pipo/Syal floodplain**	**dry**	**1520**	**302/138**	**23/22**	**-118.371**	**44.184**	**1**	**step-pool**	**0.8**	**2.6**
11.4	Psme/Cage	dry	1640	220	7	-118.361	44.191	--	--	--	--

Table 3 (continued). Dugout riparian plot and stream characteristics (bold, this study) and characteristics of the corresponding upslope sites (Heyerdahl 1997).

Plot ID	Plant Association	Forest Type	Elev. (m)	Aspect (degree)	Slope (degree)	Longitude (degree)	Latitude (degree)	stream order	stream description	bankfull avg. (m)	floodplain avg. (m)
LCC1	**Abgr/Syal floodplain**	**dry**	**1640**	**279/99**	**26/26**	**-118.414**	**44.185**	**2**	**step-pool**	**5.4**	**6.3**
9	Psme/Caru	dry	1620	--	0	-118.410	44.179	--	--	--	--
LCC2	**Pico(Abgr)/Vasc/Caru pct**	**mesic**	**1730**	**45/249**	**24/12**	**-118.422**	**44.214**	**2**	**plane-bed**	**2.7**	**6.1**
7	Abgr/Caru	dry	1810	190	8	-118.417	44.219	--	--	--	--
WTC1	**Psme/Syal floodplain**	**dry**	**1530**	**91/229**	**18/19**	**-118.396**	**44.166**	**1**	**step-pool**	**2.3**	**6.0**
10	Psme/Caru	dry	1560	65	8	-118.403	44.167	--	--	--	--
BRC1	**Pipo/Syal floodplain**	**dry**	**1610**	**86/260**	**22/17**	**-118.308**	**44.200**	**2**	**plane-bed**	**1.9**	**5.6**
14	Pipo/Caru	dry	1550	261	21	-118.307	44.198	--	--	--	--
BRC2	**Pipo/Syal floodplain**	**dry**	**1640**	**12/194**	**2/18**	**-118.322**	**44.211**	**1**	**pool-riffle**	**1.8**	**17.0**
13	Pipo/Caru	dry	1590	150	15	-118.330	44.207	--	--	--	--
BRC3	**Pipo/Syal floodplain**	**dry**	**1660**	**346/194**	**19/18**	**-118.323**	**44.219**	**1**	**pool-riffle**	**4.6**	**13.0**
12	Pipo/Cage	dry	1610	190	8	-118.335	44.219	--	--	--	--

Table 4. Baker riparian plot and stream characteristics (bold, this study), including characteristics split by aspect, and characteristics of the corresponding upslope sites (Heyerdahl 1997).

Plot ID	Plant Association	Forest Type	Elev. (m)	Aspect (degree)	Slope (degree)	Longitude (degree)	Latitude (degree)	stream order	stream description	bankfull avg. (m)	floodplain avg. (m)
MAR1	**Abgr/Acgl-floodplain**	**mesic**	**1620**	--	--	**-118.019**	**44.790**	**2**	**cascade**	**1.4**	**3.4**
MAR1N	--	--	--	**356**	**30**	--	--	--	--	--	--
MAR1SE	--	--	--	**135**	**42**	--	--	--	--	--	--
4.5	Psme/Caru	dry	1660	170	23	-118.018	44.793	--	--	--	--
5.5	Abgr/Libo2	mesic	1620	10	20	-118.015	44.789	--	--	--	--
MAR2	**Abgr/Acgl-floodplain**	**mesic**	**1310**	--	--	**-117.997**	**-44.800**	**3**	**step-pool**	**3.1**	**11.1**
MAR2N	--	--	--	**351**	**32**	--	--	--	--	--	--
MAR2SE	--	--	--	**133**	**25**	--	--	--	--	--	--
2.8	Psme/Caru	dry	1430	135	25	-117.997	44.802	--	--	--	--
3.9	Psme/Caru	dry	1480	5	17	-117.990	44.799	--	--	--	--
MAR3	**Abgr/Acgl-floodplain**	**mesic**	**1380**	--	--	**-118.001**	**44.796**	**3**	**cascade**	**2.6**	**5.1**
MAR3N	--	--	--	**2**	**33**	--	--	--	--	--	--
MAR3SE	--	--	--	**128**	**37**	--	--	--	--	--	--
4.7	Psme/Caru	dry	1520	180	20	-118.005	44.796	--	--	--	--
4.8	Abgr/Libo2	mesic	1470	13	30	-118.000	44.794	--	--	--	--
MAR4	**Abgr/Syal-floodplain PCT**	**dry**	**1270**	--	--	**-117.993**	**44.803**	**3**	**step-pool**	**2.5**	**10.2**
MAR4NE	--	--	--	**318**	**30**	--	--	--	--	--	--
MAR4SE	--	--	--	**123**	**30**	--	--	--	--	--	--
2.9	Psme/Caru	dry	1360	135	9	-117.994	44.803	--	--	--	--
2.10	Psme/Caru	dry	1320	85	19	-117.984	44.803	--	--	--	--
MAR5	**Abgr/Acgl-floodplain**	**mesic**	**1490**	--	--	**-118.010**	**44.793**	**2**	**cascade**	**1.5**	**5.6**
MAR5N	--	--	--	**354**	**32**	--	--	--	--	--	--
MAR5SE	--	--	--	**149**	**28**	--	--	--	--	--	--
4.6	Psme/Caru	dry	1560	170	20	-118.010	44.796	--	--	--	--
5.7	Abgr/Libo2	mesic	1540	330	16	-118.003	44.789	--	--	--	--

Table 4 (continued). Baker riparian plot and stream characteristics (bold, this study), including characteristics split by aspect, and characteristics of the corresponding upslope sites (Heyerdahl 1997).

Plot ID	Plant Association	Forest Type	Elev. (m)	Aspect (degree)	Slope (degree)	Longitude (degree)	Latitude (degree)	stream order	stream description	bankfull avg. (m)	floodplain avg. (m)
MAR6	**Abgr/Acgl-floodplain**	**mesic**	**1700**	--	--	**-118.016**	**44.784**	**2**	**cascade**	**2.3**	**5.8**
MAR6N	--	--	--	**350**	**32**	--	--	--	--	--	--
MAR6SE	--	--	--	**142**	**34**	--	--	--	--	--	--
5.6	Psme/Caru	dry	1670	125	18	-118.011	44.787	--	--	--	--
6.6	Abgr/Brvu	mesic	1650	290	20	-118.010	44.785	--	--	--	--
MIL1	**Abgr/Acgl-floodplain**	**mesic**	**1640**	--	--	**-118.030**	**44.806**	**1**	**step-pool**	**4.0**	**7.7**
MIL1NE	--	--	--	**42**	**37**	--	--	--	--	--	--
MIL1SE	--	--	--	**138**	**32**	--	--	--	--	--	--
3	Abgr/Caru	dry	1550	132	24	-118.026	44.810	--	--	--	--
MIL2	**Abgr/Clun**	**mesic**	**1610**	--	--	**-118.026**	**44.799**	**2**	**cascade**	**3.7**	**8.2**
MIL2NW	--	--	--	**335**	**30**	--	--	--	--	--	--
MIL2SE	--	--	--	**128**	**28**	--	--	--	--	--	--
3.4	Abgr/Vame	mesic	1620	350	25	-118.022	44.798	--	--	--	--
SAL1	**Abgr/Acgl-floodplain PCT**	**mesic**	**1600**	--	--	**-117.973**	**44.774**	**2**	**cascade**	**2.2**	**3.3**
SAL1NW	--	--	--	**302**	**30**	--	--	--	--	--	--
SAL1E	--	--	--	**82**	**36**	--	--	--	--	--	--
1	Abgr/Caru	dry	1660	59	24	-117.981	44.778	--	--	--	--
SAL2	**Abgr/Acgl-floodplain**	**mesic**	**1610**	--	--	**-117.995**	**44.773**	**1**	**cascade**	**1.0**	**2.0**
SAL2NW	--	--	--	**310**	**37**	--	--	--	--	--	--
SAL2E	--	--	--	**74**	**33**	--	--	--	--	--	--
SAL3	**Abgr/Acgl-floodplain**	**mesic**	**1610**	--	--	**-117.999**	**43.773**	**2**	**cascade**	**2.2**	**3.6**
SAL3N	--	--	--	**356**	**36**	--	--	--	--	--	--
SAL3SE	--	--	--	**139**	**34**	--	--	--	--	--	--
8.8	Abgr/Caru	dry	1610	45	24	-117.996	44.777	--	--	--	--

Table 4 (continued). Baker riparian plot and stream characteristics (bold, this study), including characteristics split by aspect, and characteristics of the corresponding upslope sites (Heyerdahl 1997).

Plot ID	Plant Association	Forest Type	Elev. (m)	Aspect (degree)	Slope (degree)	Longitude (degree)	Latitude (degree)	stream order	stream description	bankfull avg. (m)	floodplain avg. (m)
ECR1	**Abgr/Cage**	**dry**	**1470**	--	--	**-117.959**	**44.736**	**2**	**step-pool**	**3.7**	**14.6**
ECR1NE	--	--	--	**62**	**32**	--	--	--	--	--	--
ECR1SW	--	--	--	**236**	**32**	--	--	--	--	--	--
8	Psme/Cage	dry	1550	130	10	-117.959	44.742	--	--	--	--
ECR2	**Abgr/Libo2**	**mesic**	**1560**	--	--	**-117.971**	**44.745**	**2**	**step-pool**	**2.1**	**5.1**
ECR2E	--	--	--	**86**	**28**	--	--	--	--	--	--
ECR2SW	--	--	--	**242**	**29**	--	--	--	--	--	--
8	Psme/Cage	dry	1550	130	10	-117.959	44.742	--	--	--	--
ECR3	**Abgr/Cage**	**dry**	**1540**	--	--	**-117.961**	**44.742**	**1**	**cascade**	**0.9**	**2.5**
ECR3E	--	--	--	**110**	**34**	--	--	--	--	--	--
ECR3SW	--	--	--	**240**	**32**	--	--	--	--	--	--
8	Psme/Cage	dry	1550	130	10	-117.959	44.742	--	--	--	--
ECR4	**Abgr/Syal-floodplain PCT**	**dry**	**1380**	--	--	**-117.944**	**44.728**	**2**	**very altered**	--	
ECR4NE	--	--	--	**26**	**25**	--	--	--	--	--	--
ECR4S	--	--	--	**194**	**26**	--	--	--	--	--	--
9	Pipo/Cage	dry	1380	200	11	-117.945	44.731	--	--	--	--
WSH1	**Abgr/Acgl-floodplain**	**mesic**	**1390**	--	--	**-117.933**	**44.759**	**2**	**plane-bed**	**2.4**	**13.6**
WSH1N	--	--	--	**8**	**21**	--	--	--	--	--	--
WSH1S	--	--	--	**169**	**26**	--	--	--	--	--	--
7	Psme/Cage	dry	1500	221	10	-117.940	44.763	--	--	--	--
11	Psme/Cage	dry	1370	94	20	-117.757	44.757	--	--	--	--

Table 5. Steamboat riparian plot and stream characteristics (bold) and characteristics of their paired upslope sites.

Plot ID	Plant Association	Elev. (m)	Aspect (degree)	Slope (degree)	Longitude (degree)	Latitude (degree)	stream order	stream description	bankfull avg. (m)	floodplain avg. (m)
HHC1	**Tshe/Acci-Gash-SWO**	**700**	**298**	**40**	**-122.593**	**43.527**	**2**	**step-pool**	**3.3**	**6.1**
HHC1.5	**Tshe/Gash-Rhma3-SWO**	**670**	**278**	**42**	**-122.594**	**43.526**	**3**	**step-pool**	**8.1**	**10.6**
HHC2	Psme/Arne-SWO?	790	260	36	-122.592	43.526	--	--	--	--
HHC3	**Tshe/Acci-Rhma3**	**980**	**349**	**26**	**-122.563**	**43.540**	**1**	**colluvial**	**0.6**	**4.2**
HHC4	Tshe/Acci-Rhma3	1030	336	25	-122.563	43.540	--	--	--	--
HHC5	**Thpl/Bene2/Pomu**	**680**	**0**	**34**	**-122.578**	**43.517**	**1**	**step-pool**	**2.6**	**7.1**
HHC6	Tshe/Gash-Rhma3-SWO	730	334	42	-122.576	43.517	--	--	--	--
HHC7	**Tshe-Thpl/Rhma3**	**640**	**64**	**28**	**-122.599**	**43.518**	**3**	**step-pool**	**9.1**	**12.3**
HHC8	Tshe/Gash-Rhma3-SWO	700	64	38	-122.600	43.518	--	--	--	--
CCR1	**Psme/Acci-Bene2**	**740**	**53**	**41**	**-122.604**	**43.510**	**1**	**bedrock**	**2.0**	**3.2**
CCR2	Psme/Gash-Rhma3	800	78	42	-122.605	43.511	--	--	--	--
CCR7	**Tshe/Gash-Pomu-SWO**	**630**	**95**	**35**	**-122.601**	**43.508**	**3**	**step-pool**	**11.6**	**14.1**
CCR3	**Abam/Rogy/Actr**	**1490**	**118**	**40**	**-122.648**	**43.568**	**1**	**colluvial**	**1.0**	**2.6**
CCR4	Abam/Tshe/Vame/Actr	1540	125	30	-122.659	43.565	--	--	--	--
CCR5	**Tshe/Gash-Rhma3-SWO**	**610**	**240**	**25**	**-122.598**	**43.506**	**3**	**step-pool**	**10.7**	**14.1**
CCR6	Psme/Acci-Bene2	670	232	30	-122.597	43.506	--	--	--	--
LRC1	**Abam/Rogy/Actr**	**1470**	**224**	**39**	**-122.661**	**43.560**	**0**	**colluvial**	**0.5**	**1.8**
LRC2	Abam/Rogy/Actr	1550	230	24	-122.621	43.561	--	--	--	--
LRC3	**Tshe-Thpl/Rhma3**	**720**	**356**	**35**	**-122.636**	**43.501**	**1**	**step-pool**	**2.2**	**3.6**
LRC4	Tshe/Rhma3-Gash-SWO	780	354	22	-122.643	43.500	--	--	--	--
LRC5	**Tshe/Gash-Rhma3-SWO**	**720**	**272**	**35**	**-122.654**	**43.516**	**3**	**step-pool**	**8.8**	**10.7**
LRC6	Tshe-Cach6/Gash-Rhma3	800	286	40	-122.653	43.516	--	--	--	--
LRC7	**Psme/Acci-Bene2**	**610**	**194**	**35**	**-122.611**	**43.503**	**4**	**step-pool**	**12.1**	**18.2**
LRC8	Psme/Acci-Bene2	670	204	30	-122.611	43.504	--	--	--	--
LRC9	**Tshe-Thpl/Rhma3**	**670**	**40**	**8**	**-122.636**	**43.509**	**4**	**step-pool**	**11.6**	**11.8**
LRC10	Tshe-Cach6/Gash-Rhma3	740	24	45	-122.645	43.508	--	--	--	--

Table 5 (continued). Steamboat riparian plot and stream characteristics (bold) and characteristics of their paired upslope sites.

Plot ID	Plant Association	Elev. (m)	Aspect (degree)	Slope (degree)	Longitude (degree)	Latitude (degree)	stream order	stream description	bankfull avg. (m)	floodplain avg. (m)
STB1	**Tshe/Gash-Rhma3-SWO**	**760**	**343**	**37**	**-122.524**	**43.512**	**3**	**step-pool**	**6.2**	**7.8**
STB2	Psme/Gash-Rhma3	850	343	26	-122.523	43.511	--	--	--	--
STB3	**Tshe/Gash-Rhma3-SWO**	**790**	**278**	**35**	**-122.786**	**43.520**	**1**	**bedrock**	**0.8**	**1.7**
STB4	Psme/Acci-Bene2	890	278	32	-122.785	43.520	--	--	--	--
STB5	**Tshe/Gash-Rhma3-SWO**	**1180**	**339**	**38**	**-122.509**	**43.496**	**0**	**step-pool**	**1.2**	**2.3**
STB6	Psme/Acci-Bene2	1240	319	28	-122.507	43.496	--	--	--	--

APPENDIX B. Plot statistics tables by study area.

Appendix B summarizes fire return interval statistics for each of the plots in the three study areas. "Oldest tree ring record" represents either the pith date for a sample or the earliest ring recorded for a sample. The rest of the statististics were output from the FHX2 fire history software developed by Grissino-Mayer (1995), with the exception of plots where the degrees of freedom were less than three. In these cases, the mean was calculated by hand.

Table 6. Dugout plot statistics (1650-1900), riparian plots (bold, this study) paired with closest upslope site (Heyerdahl 1997). A "--" indicates there is not enough data to calculate the value.

Plot ID	Oldest tree ring record	Number of fires	Interval Min.	Interval Max.	Interval WMPI	Interval 80% CI	Interval Mean	Interval Median	Std. Dev.	Coeff. of Var.	Deg. Freedom
NFM1	**1433**	**13**	**7**	**31**	**16**	**8-27**	**17**	**15**	**8**	**0.47**	**12**
11.2	1547	17	5	31	13	5-23	13	12	7	0.55	16
NFM2 (12.1)	**1454**	**16**	**7**	**25**	**14**	**7-22**	**14**	**12**	**6**	**0.41**	**15**
11.2	1547	17	5	31	13	5-23	13	12	7	0.55	16
NFM3	**1665**	**12**	**5**	**30**	**15**	**7-25**	**15**	**14**	**8**	**0.49**	**11**
11.1	1625	17	5	25	12	5-21	13	11	7	0.53	16
NFM4	**1493**	**16**	**5**	**25**	**12**	**5-21**	**13**	**11**	**6**	**0.49**	**15**
6	1539	18	5	31	13	5-23	14	12	8	0.55	17
NFM5	**1613**	**15**	**5**	**23**	**13**	**7-19**	**13**	**13**	**5**	**0.37**	**14**
6	1539	18	5	31	13	5-23	14	12	8	0.55	17
NFM6	**1515**	**13**	**3**	**29**	**17**	**9-26**	**18**	**19**	**7**	**0.37**	**12**
5	1507	19	5	23	13	6-20	13	12	5	0.41	18
NFM7	**1447**	**14**	**4**	**54**	**12**	**3-30**	**14**	**11**	**13**	**0.90**	**13**
4.1	1640	15	4	39	15	6-28	16	13	9	0.58	14
NFM8	**1565**	**19**	**6**	**29**	**13**	**6-21**	**13**	**11**	**6**	**0.46**	**18**
2.1	1603	15	6	32	14	6-25	14	13	8	0.54	14
ELK1	**1748**	**7**	**12**	**44**	**22**	**9-38**	**23**	**19**	**13**	**0.55**	**6**
4	1616	14	6	31	14	6-25	14	13	8	0.54	13
ELK2	**1672**	**12**	**5**	**32**	**16**	**6-28**	**17**	**13**	**9**	**0.56**	**11**
19	1542	17	2	31	12	5-23	13	12	7	0.54	16
STC1	**1603**	**17**	**2**	**33**	**11**	**3-24**	**13**	**11**	**9**	**0.69**	**16**
7.1	1454	20	4	23	11	5-19	11	11	6	0.50	19
STC2	**1602**	**13**	**1**	**35**	**15**	**4-33**	**17**	**17**	**11**	**0.65**	**12**
6.6	1592	16	5	30	15	6-26	16	14	8	0.52	15
DUG1	**1589**	**14**	**2**	**43**	**14**	**4-31**	**16**	**13**	**11**	**0.69**	**13**
9.2	1454	16	5	30	14	6-24	14	12	7	0.51	15
RSP1	**1579**	**9**	**1**	**25**	**16**	**7-27**	**17**	**18**	**8**	**0.45**	**8**
11.4	1656	10	5	49	21	6-45	24	23	16	0.68	9
LCC1	**1539**	**7**	**11**	**57**	**32**	**14-54**	**34**	**36**	**17**	**0.51**	**6**
9	1619	16	2	34	13	4-28	15	12	10	0.65	15
LCC2	**1712**	**6**	**7**	**65**	**27**	**8-58**	**31**	**25**	**23**	**0.74**	**5**
7	1506	16	7	29	14	6-23	14	12	7	0.47	15
WTC1	**1345**	**20**	**3**	**25**	**11**	**4-21**	**12**	**8**	**7**	**0.61**	**19**
10	1454	20	3	25	11	4-20	12	10	6	0.55	19
BRC1	**1762**	**3**	**19**	**30**	**--**	**--**	**25**	**--**	**--**	**--**	**2**
14	1528	19	4	25	12	6-19	13	13	5	0.42	18
BRC2	**1424**	**14**	**5**	**34**	**11**	**4-22**	**12**	**10**	**8**	**0.65**	**13**
13	1625	22	3	25	9	3-17	9	8	6	0.64	21
BRC3	**1360**	**17**	**3**	**30**	**12**	**4-25**	**13**	**11**	**9**	**0.67**	**16**
12	1592	23	2	30	9	3-20	11	9	8	0.75	22

Table 7. Baker plot statistics (1650-1900), entire riparian plots (bold, this study) paired with closest upslope site (Heyerdahl 1997). A "--" indicates there is not enough data to calculate the value.

Plot ID	Oldest tree ring record	Number of fires	Interval						Std. Dev.	Coeff. of Var.	Deg. Freedom
			Min.	Max.	WMPI	80% CI	Mean	Median			
MAR1	**1808**	**3**	**30**	**53**	**--**	**--**	**42**	**--**	**--**	**--**	**2**
4.5	1636	9	12	43	24	12-37	24	23	10	0.42	8
MAR2	**1638**	**12**	**11**	**28**	**19**	**12-27**	**19**	**22**	**6**	**0.33**	**11**
2.8	1633	12	3	25	9	3-20	10	7	8	0.73	11
MAR3	**1580**	**13**	**4**	**30**	**14**	**6-25**	**15**	**13**	**8**	**0.51**	**12**
4.7	1516	15	6	24	11	5-19	12	11	5	0.47	14
MAR4	**1624**	**18**	**3**	**25**	**11**	**4-21**	**12**	**10**	**7**	**0.61**	**17**
2.9	1694	13	7	31	13	6-22	14	11	7	0.49	12
MAR5	**1551**	**6**	**32**	**64**	**48**	**32-62**	**47**	**43**	**13**	**0.27**	**5**
4.6	1622	10	6	34	17	7-31	18	18	10	0.55	9
MAR6	**1799**	**3**	**6**	**10**	**--**	**--**	**8**	**--**	**--**	**--**	**2**
5.6	1610	5	15	104	42	12-94	49	38	39	0.81	4
MIL1	**1697**	**7**	**9**	**45**	**20**	**8-39**	**22**	**18**	**14**	**0.63**	**6**
3	1675	19	3	23	9	4-16	10	10	5	0.50	18
MIL2	**1794**	**2**	**11**	**11**	**--**	**--**	**--**	**--**	**--**	**--**	**1**
3	1675	19	3	23	9	4-16	10	10	5	0.50	18
SAL1	**1808**	**0**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
1	1584	11	7	43	21	8-37	22	24	12	0.54	10
SAL2	**1799**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
8.8	1622	6	12	56	38	20-59	39	43	10	0.45	5
SAL3	**1796**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
8.8	1622	6	12	56	38	20-59	39	43	10	0.45	5
ECR1	**1617**	**9**	**5**	**31**	**20**	**11-29**	**20**	**23**	**8**	**0.38**	**8**
8	1463	18	5	23	11	5-17	11	10	5	0.41	17
ECR2	**1577**	**5**	**5**	**56**	**32**	**10-65**	**36**	**42**	**23**	**0.63**	**4**
8	1463	18	5	23	11	5-17	11	10	5	0.41	17
ECR3	**1329**	**14**	**5**	**38**	**16**	**6-28**	**16**	**14**	**9**	**0.55**	**13**
8	1463	18	5	23	11	5-17	11	10	5	0.41	17
ECR4	**1510**	**20**	**2**	**27**	**10**	**4-20**	**11**	**10**	**7**	**0.58**	**19**
9	1482	20	3	27	10	4-17	10	10	5	0.48	19
WSH1	**1496**	**9**	**5**	**95**	**22**	**5-58**	**27**	**19**	**28**	**1.04**	**8**
7	1580	27	3	20	8	3-14	8	8	4	0.51	26

Table 8. Baker plot statistics (1650-1900), riparian plots (bold, this study) split by aspect, paired with closest upslope site that has a similar aspect (Heyerdahl 1997). A "--" indicates there is not enough data to calculate the value.

Plot	Oldest	Number	Interval						Std.	Coeff.	deg.
ID	tree ring record	of fires	Min.	Max.	WMPI	80% CI	Mean	Median	Dev.	of Var.	freedom
MAR1N	**1808**	**3**	**30**	**53**	**--**	**--**	**42**	**--**	**--**	**--**	**2**
5.5	1791	--	--	--	--	--	--	--	--	--	--
MAR1SE	**1865**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
4.5	1636	9	12	43	24	12-37	24	23	10	0.42	8
MAR2N	**1868**	**2**	**14**	**14**	**--**	**--**	**--**	**--**	**--**	**--**	**1**
3.9	1645	12	5	110	13	2-46	20	12	30	1.53	11
MAR2SE	**1638**	**10**	**11**	**28**	**20**	**12-27**	**19**	**22**	**7**	**0.34**	**9**
2.8	1633	12	3	25	9	3-20	10	7	8	0.73	11
MAR3N	**1580**	**4**	**13**	**88**	**45**	**14-94**	**50**	**50**	**38**	**0.75**	**3**
4.8	1729	4	12	46	24	9-45	25	18	18	0.72	3
MAR3SE	**1711**	**10**	**4**	**30**	**17**	**7-29**	**18**	**19**	**9**	**0.50**	**9**
4.7	1516	15	6	24	11	5-19	12	11	5	0.47	14
MAR4NE	**1639**	**5**	**22**	**39**	**30**	**20-38**	**29**	**28**	**8**	**0.27**	**4**
2.10	1669	22	2	17	9	4-14	9	9	4	0.43	21
MAR4SE	**1625**	**17**	**3**	**25**	**11**	**4-22**	**12**	**12**	**7**	**0.59**	**16**
2.9	1694	13	7	31	13	6-22	14	11	7	0.49	12
MAR5N	**1809**	**2**	**73**	**73**	**--**	**--**	**--**	**--**	**--**	**--**	**1**
5.7	1558	6	8	88	40	12-86	46	43	33	0.72	4
MAR5SE	**1551**	**4**	**43**	**105**	**68**	**35-104**	**68**	**57**	**33**	**0.48**	**3**
4.6	1622	10	6	34	17	7-31	18	18	10	0.55	9
MAR6N	**1802**	**2**	**10**	**10**	**--**	**--**	**--**	**--**	**--**	**--**	**1**
6.6	1893	--	--	--	--	--	--	--	--	--	--
MAR6SE	**1799**	**2**	**16**	**16**	**--**	**--**	**--**	**--**	**--**	**--**	**1**
5.6	1610	5	15	104	42	12-94	49	38	39	0.81	4
MIL1NE	**1714**	**4**	**9**	**63**	**24**	**6-62**	**30**	**17**	**29**	**0.98**	**3**
N/A	--	--	--	--	--	--	--	--	--	--	--
MIL1SE	**1697**	**6**	**17**	**45**	**26**	**13-41**	**26**	**20**	**12**	**0.45**	**5**
3	1675	19	3	23	9	4-16	10	10	5	0.50	18
MIL2NW	**1831**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
3.4	1793	--	--	--	--	--	--	--	--	--	--
MIL2SE	**1794**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
N/A	--	--	--	--	--	--	--	--	--	--	--

Table 8 (continued). Baker plot statistics (1650-1900), riparian plots (bold, this study) split by aspect, paired with closest upslope site that has a similar aspect (Heyerdahl 1997). A "--" indicates there is not enough data to calculate the value.

Plot ID	Oldest tree ring record	Number of fires	Interval Min.	Max.	WMPI	80% CI	Mean	Median	Std. Dev.	Coeff. of Var.	deg. freedom
SAL1NW	**1822**	**0**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
N/A	--	--	--	--	--	--	--	--	--	--	--
SAL1E	**1808**	**0**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
1	1584	11	7	43	21	8-37	22	24	12	0.54	10
SAL2NW	**1806**	**0**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
N/A	--	--	--	--	--	--	--	--	--	--	--
SAL2E	**1799**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
N/A	--	--	--	--	--	--	--	--	--	--	--
SAL3N	**1804**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
N/A	--	--	--	--	--	--	--	--	--	--	--
SAL3SE	**1796**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
8.8	1622	6	12	56	38	20-59	39	43	10	0.45	5
ECR1NE	**1617**	**7**	**22**	**38**	**27**	**18-35**	**27**	**24**	**6**	**0.24**	**6**
N/A	--	--	--	--	--	--	--	--	--	--	--
ECR1SW	**1707**	**6**	**5**	**70**	**27**	**7-65**	**32**	**23**	**26**	**0.80**	**5**
8	1463	18	5	23	11	5-17	11	10	5	0.41	17
ECR2E	**1767**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
N/A	--	--	--	--	--	--	--	--	--	--	--
ECR2SW	**1577**	**5**	**5**	**56**	**32**	**10-65**	**36**	**42**	**23**	**0.63**	**4**
8	1463	18	5	23	11	5-17	11	10	5	0.41	17
ECR3E	**1840**	**0**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
N/A	--	--	--	--	--	--	--	--	--	--	--
ECR3SW	**1329**	**14**	**5**	**38**	**16**	**6-28**	**16**	**14**	**9**	**0.55**	**13**
8	1463	18	5	23	11	5-17	11	10	5	0.41	17
ECR4NE	**1661**	**12**	**7**	**27**	**16**	**8-24**	**16**	**15**	**7**	**0.41**	**11**
N/A	--	--	--	--	--	--	--	--	--	--	--
ECR4S	**1510**	**16**	**5**	**27**	**13**	**5-23**	**13**	**12**	**7**	**0.54**	**15**
9	1482	20	3	27	10	4-17	10	10	5	0.48	19
WSH1N	**1496**	**7**	**16**	**95**	**31**	**9-70**	**35**	**26**	**30**	**0.85**	**6**
11	1552	20	5	27	11	5-19	11	10	6	0.49	19
WSH1S	**1828**	**2**	**27**	**27**	**--**	**--**	**--**	**--**	**--**	**--**	**1**
7	1580	27	3	20	8	3-14	8	8	4	0.51	26

Table 9. Steamboat plot statistics (1650-1900), riparian plots (bold) paired with closest upslope site. A "--" indicates there is not enough data to calculate the value.

Plot	Earliest	Number	Interval						Std.	Coeff.	Deg.
ID	date[1]	of fires	Min.	Max.	WMPI	80% CI	Mean	Median	Dev.	of Var.	Freedom
HHC1	**(1553)**	**2**	**106**	**106**	**--**	**--**	**--**	**--**	**--**	**--**	**1**
HHC1.5	**1234**	**4**	**4**	**131**	**48**	**6-171**	**72**	**81**	**64**	**0.89**	**3**
HHC2	1648	2	25	25	--	--	--	--	--	--	1
HHC3	**1574**	**4**	**18**	**48**	**37**	**21-53**	**37**	**44**	**16**	**0.44**	**3**
HHC4	1579	3	17	110	--	--	64	--	--	--	2
HHC5	**1497**	**3**	**24**	**167**	**--**	**--**	**96**	**--**	**--**	**--**	**2**
HHC6	(1569)	3	21	106	--	--	64	--	--	--	2
HHC7	**1496**	**5**	**46**	**61**	**55**	**46-61**	**54**	**55**	**7**	**0.13**	**4**
HHC8	1498	8	3	61	28	7-68	34	40	24	0.69	7
CCR1	**1736**	**3**	**24**	**56**	**--**	**--**	**40**	**--**	**--**	**--**	**2**
CCR2	1725	5	23	41	31	20-40	30	29	8	0.28	4
CCR7	**1520**	**7**	**23**	**57**	**36**	**21-52**	**36**	**37**	**12**	**0.34**	**6**
CCR3	**1817**	**0**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
CCR4	1821	1	--	--	--	--	--	--	--	--	0
CCR5	**(1710)**	**3**	**43**	**53**	**--**	**--**	**48**	**--**	**--**	**--**	**2**
CCR6	1693	4	29	53	38	22-52	37	30	14	0.36	3
LRC1	**(1765)**	**1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0**
LRC2	1838	2	2	2	--	--	--	--	--	--	1
LRC3	**1664**	**3**	**8**	**82**	**--**	**--**	**45**	**--**	**--**	**--**	**2**
LRC4	1661	3	8	61	--	--	35	--	--	--	2
LRC5	**(1537)**	**3**	**32**	**60**	**--**	**--**	**46**	**--**	**--**	**--**	**2**
LRC6	1705	5	18	34	27	19-33	27	27	7	0.25	4
LRC7	**1707**	**3**	**14**	**38**	**--**	**--**	**26**	**--**	**--**	**--**	**2**
LRC8	1735	3	11	102	--	--	57	--	--	--	2
LRC9	**1667**	**6**	**13**	**61**	**34**	**15-58**	**35**	**37**	**19**	**0.53**	**5**
LRC10	1389	6	6	61	30	11-58	33	37	20	0.61	5
STB1	**(1630)**	**6**	**7**	**57**	**21**	**6-49**	**25**	**18**	**20**	**0.82**	**5**
STB2	1612	8	5	74	20	4-54	25	22	24	0.93	7
STB3	**(1572)**	**3**	**49**	**110**	**--**	**--**	**80**	**--**	**--**	**--**	**2**
STB4	1670	3	49	106	--	--	155	--	--	--	2
STB5	**1576**	**3**	**13**	**91**	**--**	**--**	**52**	**--**	**--**	**--**	**2**
STB6	1572	2	110	110	--	--	--	--	--	--	1

[1] Earliest establishment date (extrapolated from a pith date) from the samples at that plot. If the year is in parentheses, then the date represents the oldest ring sampled at that site, but the ring was not close enough to the pith of the tree to determine an establishment date.

APPENDIX C. Statistical test tables by study area.

As mentioned in the Data Analysis section, only non-parametric statistical test were used in this study. These tables summarize all of the statistics done for each category of plots. The Mann-Whitney U-Test for unmatched samples was the most common statistical test used. Use of other tests is mentioned for each table whenever applicable.

Table 10. Dugout statistical tests for differences between fire interval lengths grouped by different categories of plot types, 1650-1900. Tests are the two-tailed Mann-Whitney U-Test for unmatched samples, unless otherwise noted.

			Fire Intervals								
					Distribution Type:						
	Number of:				Normal			Weibull			
plot category	**plots**	**intervals**	**min.**	**max.**	**mean**	**median**	**Fit**[1]	**mean**	**median**	**CI**[2]	**Fit**[3]
all plots	38	529	1	65	14	12	0.89	14	13	5-26	<.001
combined riparian	20	237	1	65	15	13	0.88	15	14	5-29	0.18
combined upslope	18	292	1	49	13	11	0.90	13	12	5-24	<.001
statistics	riparian > upslope, **p = 0.01**										
large stream, riparian	8	110	3	54	14	13	0.88	14	13	6-24	0.06
large stream, upslope	6	95	4	39	14	12	0.90	14	12	6-24	<.001
statistics	riparian = upslope, p = 0.33										
small stream, riparian	12	127	1	65	16	14	0.89	16	14	4-32	0.10
small stream, upslope	12	197	1	49	13	11	0.90	13	12	4-24	<.001
statistics	riparian > upslope, **p = 0.03**										
large stream, riparian	8	110	3	54	14	13	0.88	14	13	6-24	0.06
small stream, riparian	12	127	1	65	16	14	0.89	16	14	4-32	0.10
statistics	small = large, p = 0.75										

[1] Wilk-Shapiro normality statistic: a value less than 0.95 accepts the hypothesis that the data does not fit a normal distribution.

[2] 80% Confidence Interval: the range between the 10th and 90th percentile values of the Weibull distribution.

[3] P-value from a Chi-square analysis of how well the data fits the predicted data in a Weibull distribution: a value greater than 0.05 accepts the hypothesis that the actual distribution fits a Weibull distribution.

Table 11. Dugout statistical tests for differences between composite Weibull median probability fire return interval lengths (calculated for each plot), grouped by different categories of plot types, 1650-1900. Tests are the two-tailed Mann-Whitney U-Test for unmatched samples, unless otherwise noted.

		Composite Weibull Median Probability Fire Intervals									
				Distribution Type:							
	Number			Normal			Weibull				
plot category	of plots	min.	max.	mean	median	Fit[1]	mean	median	CI[2]	Fit[3]
all plots	36	9	32	14	13	0.74	14	14	10-20	0.003
combined riparian	19	11	32	16	14	0.76	16	14	11-23	0.42
combined upslope	17	9	21	13	13	0.85	13	13	10-17	0.01
statistics	riparian = upslope, p = 0.14									
large stream, riparian	8	12	17	14	13	0.89	14	14	12-17	0.02
large stream, upslope	6	12	15	13	13	0.93	13	13	12-15	0.047
statistics	riparian = upslope, p = 0.41[4]									
small stream, riparian	11	11	32	17	15	0.82	17	14	11-28	0.26
small stream, upslope	11	9	21	13	13	0.88	13	12	9-18	0.03
statistics	riparian = upslope, p = 0.13									
large stream, riparian	8	12	17	14	13	0.89	14	14	12-17	0.02
small stream, riparian	11	11	32	17	15	0.82	17	14	11-28	0.26
statistics	small = large, p = 0.85[4]									

[1] Wilk-Shapiro normality statistic: a value less than 0.95 accepts the hypothesis that the data does not fit a normal distribution.
[2] 80% Confidence Interval: the range between the 10th and 90th percentile values of the Weibull distribution.
[3] P-value from a Chi-square analysis of how well the data fits the predicted data in a Weibull distribution: a value greater than 0.05 accepts the hypothesis that the actual distribution fits a Weibull distribution.
[4] One-tailed Mann-Whitney U-Test for unmatched samples.

Table 12. Dugout statistical tests for differences between the number of fires per plot, grouped by different categories of plot types, 1650-1900. Tests are the two-tailed Mann-Whitney U-Test for unmatched samples, unless otherwise noted.

		Number of Fires Per Plot									
				Distribution Type:							
	Number			Normal			Weibull				
plot category	**of plots**	**min.**	**max.**	**mean**	**median**	**Fit[1]**	**mean**	**median**	**CI[2]**	**Fit[3]**
all plots	38	3	23	15	16	0.95	15	15	9-20	0.10
combined riparian	20	3	20	13	14	0.95	13	13	7-18	0.07
combined upslope	18	10	23	17	17	0.96	17	17	13-21	0.12
statistics	riparian < upslope, **p = 0.002**									
large stream, riparian	8	12	19	15	15	0.93	15	14	12-18	0.18
large stream, upslope	6	15	19	17	17	0.93	17	16	15-20	0.18
statistics	riparian < upslope, **p = 0.04**[4]									
small stream, riparian	12	3	20	12	13	0.97	11	11	5-19	0.25
small stream, upslope	12	10	23	17	17	0.96	17	17	12-22	0.03
statistics	riparian < upslope, **p = 0.01**									
large stream, riparian	8	12	19	15	15	0.93	15	14	12-18	0.18
small stream, riparian	12	3	20	12	13	0.97	11	11	5-19	0.25
statistics	small = large, p = 0.13[4]									

[1] Wilk-Shapiro normality statistic: a value less than 0.95 accepts the hypothesis that the data does not fit a normal distribution.
[2] 80% Confidence Interval: the range between the 10th and 90th percentile values of the Weibull distribution.
[3] P-value from a Chi-square analysis of how well the data fits the predicted data in a Weibull distribution: a value greater than 0.05 accepts the hypothesis that the actual distribution fits a Weibull distribution.
[4] One-tailed Mann-Whitney U-Test for unmatched samples.

Table 13. Baker statistical tests for differences between fire interval lengths grouped by different categories of plot types, 1650-1900. Tests are the nonparametric two-tailed Mann-Whitney U-Test for unmatched samples, unless otherwise noted.

			Fire Intervals								
					Distribution Type:						
	Number of:				**Normal**			**Weibull**			
plot category	**plots**	**intervals**	**min.**	**max.**	**mean**	**median**	**Fit**[1]	**mean**	**median**	**CI**[2]	**Fit**[3]
all plots	27	246	2	104	15	12	0.71	15	13	4-31	<.001
combined riparian	15	108	2	95	19	14	0.80	19	15	5-37	0.001
combined upslope	12	138	3	104	13	11	0.60	13	11	4-25	<.001
statistics					riparian > upslope, **p = 0.001**						
large stream, riparian	3	40	3	30	15	12	0.94	15	13	6-25	0.003
large stream, upslope	3	37	3	31	12	11	0.83	12	10	5-20	0.002
statistics					riparian = upslope, p = 0.10						
small stream, riparian	15	68	2	95	13	11	0.81	21	17	5-43	0.03
small stream, upslope	9	101	3	104	21	16	0.58	13	10	4-26	<.001
statistics					riparian > upslope, **p = 0.0002**						
large stream, riparian	3	40	3	30	15	12	0.94	15	13	6-25	0.003
small stream, riparian	15	68	2	95	13	11	0.81	21	17	5-43	0.03
statistics					small = large, p = 0.15						
dry forest, riparian	4	57	2	38	14	12	0.93	14	12	5-25	0.02
mesic forest, riparian	11	51	4	95	24	21	0.84	24	19	7-49	0.07
statistics					dry < mesic, **p = 0.01**						
north aspects, riparian	15	36	7	95	28	23	0.76	28	21	9-55	0.09
south aspects, riparian	15	64	3	105	20	17	0.72	20	16	5-40	0.002
statistics					north > south, **p = 0.02**						

[1] Wilk-Shapiro normality statistic: a value less than 0.95 accepts the hypothesis that the data does not fit a normal distribution

[2] 80% Confidence Interval: the range between the 10th and 90th percentile values of the Weibull distribution

[3] P-value from a Chi-square analysis of how well the data fits the predicted data in a Weibull distribution: a value greater than 0.05 accepts the hypothesis that the actual distribution fits a Weibull distribution.

Table 14. Baker statistical tests for differences between the number of fires per plot, grouped by different categories of plot types, 1650-1900. Tests are the nonparametric two-tailed Mann-Whitney U-Test for unmatched samples, unless otherwise noted.

plot category	Number of plots	Number of Fires Per Plot: min.	max.	Distribution Type: Normal mean	Normal median	Weibull mean	Weibull median	Weibull CI[1]	Weibull Fit[2]
all plots	28	0	27	10	10	11	9	3-20	0.66
combined riparian	16	0	20	8	7	9	5	1-22	0.18
combined upslope	12	5	27	14	13	14	12	6-23	0.49
statistics	riparian < upslope, **p = 0.03**								
large stream, riparian	3	12	18	14	13	not enough data			
large stream, upslope	3	12	15	13	13	not enough data			
statistics	riparian = upslope, p = 0.35[3]								
small stream, riparian	16	0	20	6	5	8	3	1-19	0.05
small stream, upslope	9	5	27	14	11	14	10	5-29	0.05
statistics	riparian < upslope, **p = 0.02**								
large stream, riparian	3	12	18	14	13	not enough data			
small stream, riparian	16	0	20	6	5	8	3	1-19	0.05
statistics	small < large, **p = 0.03**[3]								
dry forest types, riparian	4	9	20	15	16	not enough data			
mesic forest types, riparian	12	0	13	5	4	7	3	1-16	0.16
statistics	dry > mesic, **p = 0.002**[3]								
north aspects, riparian	16	0	12	3	2	5	2	1-11	0.06
south aspects, riparian	16	0	17	6	5	9	3	1-21	0.01
statistics	north < south, **p = 0.02**[4]								

[1] 80% Confidence Interval: the range between the 10th and 90th percentile values of the Weibull distribution

[2] P-value from a Chi-square analysis of how well the data fits the predicted data in a Weibull distribution: a value greater than 0.05 accepts the hypothesis that the actual distribution fits a Weibull distribution.

[3] One-tailed Mann-Whitney U-Test for unmatched samples

[4] One-tailed Wilcoxon Signed Rank Test (for matched samples)

Table 15. Baker statistical tests for differences between fire interval lengths in the Marble Creek drainage, grouped by different categories of plot types, 1650-1900. Tests are the nonparametric two-tailed Mann-Whitney U-Test for unmatched samples, unless otherwise noted.

	Number of:		Fire Intervals		Distribution Type: Normal			Weibull			
plot category	**plots**	**intervals**	**min.**	**max.**	**mean**	**median**	**Fit[1]**	**mean**	**median**	**CI[2]**	**Fit[3]**
north riparian	6	12	10	88	37	31	0.92	38	26	11-81	0.16
north upslope	7	57	2	112	23	12	0.69	23	15	4-52	<.001
statistics	riparian > upslope, **p = 0.01**										
south riparian	5	38	3	105	20	16	0.66	20	15	5-41	0.004
south upslope	9	75	3	104	19	12	0.63	20	15	5-41	<.001
statistics	riparian = upslope, p = 0.53										
north riparian	6	12	10	88	37	31	0.92	38	26	11-81	0.16
south riparian	5	38	3	105	20	16	0.66	20	15	5-41	0.004
statistics	north > south, **p = 0.01**										
north upslope	7	57	2	112	23	12	0.69	23	15	4-52	<.001
south upslope	9	75	3	104	19	12	0.63	20	15	5-41	<.001
statistics	north = south, p = 0.78										
mid elev. north riparian	2	4	13	88	56	62	not enough data				
mid elev. north upslope	2	7	8	88	37	43	0.88	43	20	8-103	0.15
statistics	riparian = upslope, p = 0.12[4]										
mid elev. south riparian	2	12	4	105	30	22	0.77	31	19	5-73	0.25
mid elev. south upslope	2	23	6	34	14	11	0.85	14	12	6-25	0.01
statistics	riparian > upslope, **p = 0.03**										
mid elev. north riparian	2	4	13	88	56	62	not enough data				
mid elev. south riparian	2	12	4	105	30	22	0.77	31	19	5-73	0.25
statistics	north = south, p = 0.08[4]										
mid elev. north upslope	2	7	8	88	37	43	0.88	43	20	8-103	0.15
mid elev. south upslope	2	23	6	34	14	11	0.85	14	12	6-25	0.01
statistics	north > south, **p = 0.02**										

[1] Wilk-Shapiro normality statistic: a value less than 0.95 accepts the hypothesis that the data does not fit a normal distribution

[2] 80% Confidence Interval: the range between the 10th and 90th percentile values of the Weibull distribution

[3] P-value from a Chi-square analysis of how well the data fits the predicted data in a Weibull distribution: a value greater than 0.05 accepts the hypothesis that the actual distribution fits a Weibull distribution.

[4] One-tailed Mann-Whitney U-Test for unmatched samples

Table 16. Steamboat statistical tests for differences between fire interval lengths grouped by different categories of plot types, 1650-1900. Tests are the two-tailed Mann-Whitney U-Test for unmatched samples, unless otherwise noted.

			Fire Intervals								
					Distribution Type:						
	Number of:				Normal			Weibull			
plot category	**plots**	**intervals**	**min.**	**max.**	**mean**	**median**	**Fit[1]**	**mean**	**median**	**CI[2]**	**Fit[3]**
all plots	28	86	2	167	43	37	0.88	43	34	9-88	0.10
combined riparian	15	43	4	167	47	43	0.87	47	38	11-95	0.23
combined upslope	13	43	2	110	38	29	0.87	38	29	7-82	0.05
statistics	riparian = upslope, p = 0.15										
large riparian	8	29	4	131	41	38	0.88	41	35	11-77	0.08
large upslope	8	33	3	102	32	27	0.90	32	27	8-63	0.005
statistics	riparian = upslope, p = 0.13										
small riparian	7	14	8	167	60	49	0.91	62	39	11-141	0.62
small upslope	7	14	8	110	52	37	0.84	53	36	11-119	0.05
statistics	riparian = upslope, p = 0.80										
large riparian	8	29	4	131	41	38	0.88	41	35	11-77	0.08
small riparian	7	14	8	167	60	49	0.91	62	39	11-141	0.62
statistics	small = large, p = 0.27										
combined large	8	49	3	106	30	27	0.90	30	23	11-41	0.04
combined small	5	16	4	106	44	34	0.89	45	29	13-58	0.05
statistics	small = large, p = 0.28										

[1] Wilk-Shapiro normality statistic: a value less than 0.95 accepts the hypothesis that the data does not fit a normal distribution.
[2] 80% Confidence Interval: the range between the 10th and 90th percentile values of the Weibull distribution.
[3] P-value from a Chi-square analysis of how well the data fits the predicted data in a Weibull distribution: a value greater than 0.05 accepts the hypothesis that the actual distribution fits a
[4] One-tailed Mann-Whitney U-Test for unmatched samples.
[5] Kruskal-Wallis One-Way Nonparametric Analysis of Variance.

Table 17. Steamboat statistical tests for differences between fire interval lengths grouped by aspect and plot type, 1650-1900. Unless otherwise noted, tests are the two-tailed Mann-Whitney U-Test for unmatched samples. If a comparison is not listed, there were no significant differences between the category types (e.g., north aspect riparian plots = north aspect upslope plots, p = 0.90).

			Fire Intervals								
					Distribution Type:						
	Number of:				**Normal**			**Weibull**			
plot category	**plots**	**intervals**	**min.**	**max.**	**mean**	**median**	**Fit[1]**	**mean**	**median**	**CI[2]**	**Fit[3]**
north aspect	12	38	5	167	41	28	0.84	42	27	8-94	0.28
east aspect	5	23	3	61	38	40	0.95	37	36	15-61	0.13
south aspect	2	4	11	102	41	26	not enough data				
west aspect	9	20	4	131	53	46	0.89	53	45	13-103	0.02
statistics	no significant differences according to aspect, p = .34[5]										
north riparian	6	19	7	167	42	30	0.78	43	26	9-97	0.20
north upslope	6	19	5	110	41	25	0.85	43	24	6-101	0.27
east riparian	3	12	23	61	43	44	0.93	42	42	24-61	0.16
east upslope	2	11	3	61	33	33	0.97	32	28	8-61	0.047
south riparian	1	2	14	38	26	26	not enough data				
south upslope	1	2	11	102	57	57	not enough data				
west riparian	5	10	4	131	67	57	0.97	65	56	15-127	0.18
west upslope	4	10	18	106	40	30	0.70	41	30	19-75	0.02
statistics	west riparian > west upslope, **p = 0.02**[4]										

[1] Wilk-Shapiro normality statistic: a value less than 0.95 accepts the hypothesis that the data does not fit a normal distribution.

[2] 80% Confidence Interval: the range between the 10th and 90th percentile values of the Weibull distribution.

[3] P-value from a Chi-square analysis of how well the data fits the predicted data in a Weibull distribution: a value greater than 0.05 accepts the hypothesis that the actual distribution fits a

[4] One-tailed Mann-Whitney U-Test for unmatched samples.

[5] Kruskall-Wallis One-Way Nonparametric Analysis of Variance.

APPENDIX D. Dugout study area fire maps.

Fire years were mapped for every year there was clear evidence of fire scarring. The Dugout fire maps show the fire scar data from this study (black) superimposed onto the fire scar data from Heyerdahl (gray, 1997). The intra-annular position of the scar is shown for both data sets. "No record for this year" indicates that there were no trees sampled that were recording during that year. "No evidence of fire" indicates that at least one tree at the plot was recording during that year, but there was no evidence of fire in any of the samples within that plot for that year. "Probable evidence of fire" indicates that there was some sort of disruption in the rings of a sample at that site for that year (e.g., an abrupt increase or decrease in ring widths), but it could not definitely be attributed to fire scarring. The fire boundaries are based on those determined by Heyerdahl (1997, see the Methods section). If data from this study indicated a different fire boundary, the fire boundaries were adjusted accordingly.