Determining the Disturbance Effect on Forest Development for Use in Park Management Plans

Bruce Larson, Faculty of Forestry, University of British Columbia, 2329 West Mall, Vancouver, BC V6T 1Z4, Canada; bruce.larson@ubc.ca
Regina Rochefort, North Cascades National Park Service Complex, 810 State Route 20, Sedro-Woolley, WA 98284; regina_rochefort@nps.gov
Mariano Amoroso, Faculty of Forestry, University of British Columbia, 2329 West Mall, Vancouver, BC V6T 1Z4, Canada

Introduction

On San Juan Island, Washington, forests are an important component not only of the landscape of the island but also of San Juan Island National Historical Park. Although the forests of the island were manipulated during the historic military time period (1853 to 1871), significant and widespread alterations occurred during the post historic period of 1872 to 1966 (Agee 1984). During that time, patches of forest were cleared for agriculture in both the American and English Camps. Following the park's establishment in 1966, many of these fields were abandoned and dense Douglas fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*) stands became established. In addition, the island has a history of fires and windstorms that impact the forest stand development.

Objectives

An important part of any monitoring plan is proper stratification of the area. Earlier work on San Juan divided the forests into nine community types (Peterson 2002). Our early analysis showed that there was great variation within type, at least in the Douglas fir types which included approximately 80% of the stands in the park. In order to develop management and monitoring plans in an efficient and cost effective manner the stand types must be stratified in order to reduce the coefficient of variation among measurement plots.

Our objective of this study was to determine if "forensic silviculture" techniques could be used to better understand the history and development of the forest stands in order to better stratify the forest stand types. "Forensic silviculture" is the term used for a variety of tools that can be used to quantify the role of disturbance on forest stand development. Past patterns of tree growth and mortality are related to disturbance history and competitive interaction between trees.

Three stands were selected that represented different disturbance regimes that had affected the park.

Research objectives by stand. One stand (EC-SL) was chosen because it presents signs of past selective logging. The objective here was to study and analyze the effect past selective logging had on the present diameter distribution and to determine the nature of the cutting.

A second stand (EO-WD) was chosen because we hypothesized that the major disturbance regime was windstorms. We wanted to analyse the impact of wind damage on the structure (vertical arrangement and spatial distribution of individuals) of the stand, and to determine whether the fallen trees were the consequence of a single event.

The third stand at American Camp (AC-ND) was chosen because during the initial reconnaissance because there was no evidence of recent major disturbances. The objective here was to reconstruct the stand development patterns and to compare the age distribution with the other two stands at English Camp which have been impacted by disturbances after stand initiation.

Methods

Basic techniques in stand reconstruction were used. The purpose of reconstruction is to determine what the stand looked like in past times. Quantitative measure are used, such as diameter distribution and number of stems per hectare. After the reconstruction is complete, patterns such as how the diameter distribution has changed in time are used to better understand the stand development trajectories. This information can then be used to better understand the future and incorporated into management and monitoring plans.

The goal of reconstruction is to understand the impact of certain disturbances. Evidence of disturbance (such as stumps or windthrown trees) is used to separate the stands into groups that have different disturbance regimes. Then the most efficient methodology can be used in each group to reconstruct the development patterns. For this reason different techniques were used in different stands.

EC-SL. A 10m x 14m grid was laid out in the stand into which a total of 26 circular plots (0.02 ha each) were fit. Plot size was determined after a preliminary survey where stand and stump density were assessed in order to determine the variability within the stand. Since the objective was to study the effect of a considerable selective logging, we decided to define two populations: uncut and cut. For the "cut population" the baseline were all plots that included at least two stumps while the "uncut population" included plots with no stumps.

In each plot, diameter at breast height (DBH), species, and crown class were determined for all trees. Tree cores for age determination were taken at breast height, and three of the cored trees were randomly chosen to measure total height and height of the live crown (no trees with broken tops were measured).

EC-WD. In order to have a better understanding of the vertical and spatial arrangement of trees and the nature of the wind damage (different wind events, trees affected and wind direction) we stem mapped all individuals contained in a representative area of the stand representing severe wind damage. We laid out a 0.25 ha-square plot (50m x 50m) and stem mapped the individual location of each standing and fallen tree. For this, horizontal distances and bearings for each tree were taken from a reference point. For the fallen trees, the direction (bearing) of the tree on the ground was also recorded. Other measurements in the plot included: species, diameter at breast height and crown class for all trees; total height and height to live crown were recorded and cores for age determination were taken on a subsample of trees (one-fifth and one-third of the trees, respectively).

AC-ND. The sampling approach in this stand consisted of two transects run along the stand where plots were laid down systematically every 24 meters. The first transect was initially located following (parallel) the ridge line, and the second one 24 meters downhill from this one. Plots were circular and 0.02 ha each (7.98 m radius). Measurements in all plots included species, diameter at breast height and crown class for all trees; total height and height to live crown were recorded and cores for age determination were taken on a subsample of trees (one-quarter and one-third of the trees, respectively).

For the three stands, a total of 795 trees were measured and 250 tree cores taken.

Analysis

In this paper we demonstrate examples of the types of analyses that were conducted as part of the stand reconstruction. The total analyses were much more complete than what is presented here. These examples will demonstrate the usefulness of reconstruction to stratify stands into groups following similar patters of development.

The EC-SL stand had an average age at breast height of 84 years with a range of tree ages varying between 53 and 94 years. Most trees were in the 85- and 95-year age classes. On average it took 2.8 years (differences varied between 1 and 5 years) for trees to reach the age at breast height determined from the cores taken at ground level.

The diameter distribution for the stand as a whole ranged between 6 and 66 cm and presented a mean diameter value of 29 cm. While comparing both "cut" and "uncut" populations, diameter distributions exhibited different patterns as well as mean values. The uncut population had an arithmetic mean of 31.9 and its diameter distribution can be described as a bell-shaped curve. The cut population, on the other hand, had an arithmetic mean of 33.8 cm and seems to present a bimodal diameter distribution. Although different by almost 2 cm, differences were not statistically significant.

Diameter distributions were compared by fitting two-parametric Weibull curves to assess whether both follow a sigmoidal (bell-shaped) distribution. The results showed that uncut population could be assumed to follow a single-peaked distribution. Different from the cut population, plots with stumps were more widely distributed (lower γ value) and seemed to have a second peak in the 55–60 cm class. However, tests showed that although two peaks were noticeable, it could not be considered non single peaked; furthermore, the second peak resulted insignificant. CHI-square tests between both distributions showed significant difference at an α-level of 0.05 (p-value 0.03).

The EC-WD stand tree ages were between 51 and 90 years with an average of 78 years. Most tree ages ranged between 70 and 90 years. The age distribution is normal but is skewed to the left (skewness coefficient of –1.96).

The diameter distribution of the EC-WD stand exhibited a wide range of diameters ranging from 12 and 74 cm, and a mean diameter of 37 cm. The distribution seems to be skewed to the right, but it is important to note that the distribution is only represented by living trees, windthrown trees were not included and this might have resulted in some missing trees in the intermediate-high diameter classes.

In order to reconstruct the storm history of the stand, the direction (bearing) of the fallen trees was mapped. A combined detailed analysis of the direction, tree condition and relation to other fallen trees (whether a stem was above or below its neighbor) suggested patterns of different winds events. Based on the direction in which the trees fell and the diameter of the trees, we assume that the two major clumps fell during the same wind storm event. Most of these trees had diameters greater than 45 cm, and where the diameter was smaller, the trees were below them (probably due to the impact of the previous ones). This type of analysis was used throughout the plot and it was hypothesized that three separate wind events influenced the development of this stand.

Tree ages ranged from 23 and 105 years. However, it is important to note that the youngest age classes (30 and 35) were only represented by three trees, and two of them corresponded to suppressed trees that have recently died.

Discussion

The age distribution of both stands at English Camp suggests that these stands were established after a major or stand-replacing disturbance. The majority of trees at both stands varied by less than 20 years of age. This narrow age pattern is typical for stand establishment after stand-replacing disturbances such as fires or clearcuts (Oliver and Larson 1996). Considering the time the trees needed to grow to breast height (around four years on average), we deduced that the establishment of the stands occurred between 1907 and 1920 for the EC-SL stand, and 1915 and 1920 for the EC-WD stand. The presence of large old stumps covered with charcoal in some areas of these stands indicates that there was logging activity in the site before the current stand got established. Remaining older trees in the proximity of these stands had charcoal on the bark as well, while this could not be observed in any of the living trees in the stands. This strongly suggests that a fire had gone through the area before the stand was established. The age class distributions of both stands, as well as the previously mentioned observations on the site lead to the conclusion that the stands established after an intensive harvesting and subsequent fire in the beginning of the 20th century (around 1905). This coincides with observations made by Agee (1984), reporting that in the period from 1905 to 1915 most of the forest in English Camp was cut and often burned shortly after.

The EC-SL stand exhibits signs of past logging activity evidenced by the presence of stumps. Based on the radial growth of the trees growing close to the stumps and the age of stumps, Hetsch (2005) indicates that this partial cutting took place around 1960. Based on the reconstruction of the DBH of the cut trees, we could say that the cutting did not follow the common logging practice known as high grading where usually large diameter and high quality timber are harvested (Smith et al. 1997). A detailed reconstruction of the event done by Hetsch (2005) indicates the cutting was done at a low intensity where 86 intermediate size trees per hectare (20 cm diameter) were removed. Since this event, there seems to be no other disturbances but the fall of few intermediate and suppressed trees. This may have been a combined event of trees weakened by competition that probably fell by the action of wind events.

The EC-WD stand, on the other hand, showed evidence of past wind storm events. Based on the analyses we hypothesize that more than one wind storm took place. The first wind storm, where almost all trees fell down, may have been of important intensity since most of the windthrown trees were large in diameter. Some of the remaining fallen trees may have fallen down later as a consequence of a less intense wind event. Although the exact date of these events was not determined, we hypothesize that these events took place not long ago. The overall condition of the fallen trees was good (no indication of external rot).

There is no evidence of any other partial disturbances of importance since the time of the past described disturbances. Both the windthrow damage and the partial cutting have resulted in the development of variable-size gaps and the release of growing space (sensu Oliver and Larson 1996). However, due to the poor establishment of new individuals in most of the situations, we assumed that most of it was re-occupied by the remaining overstory trees.

The age distribution of the stand studied at the English Camp follows also that one of stands initiated after stand-replacing disturbances. The majority of the trees in this case established in a period of between 30 and 40 years. This wider age distribution could be explained by the drier site conditions where the stand grew, thus delaying the establishment. Additionally, and according to the variability found in age across the sampled trees, we could also hypothesize that part of another stand established earlier may have been sampled. Considering the time the trees needed to grow to breast height, we can predict for this stand a time of establishment around 1905 and 1940. The presence of old stumps in almost all sampled plots indicates the existence of logging activity preceding the establishment of the stand. Neither these sumps nor the older trees in the proximity of the stand presented signs of past intense fires (scars, charcoal). In summary, the currently stand got established after the previous stand was harvested at the beginning of the 20th century (around 1905). Whether fire was used after logging or naturally occurred remains unknown.

Conclusion

This study represents a collaborative work between the National Park Service and the University of British Columbia. Three stands at the English and American Camps at San Juan Nation Historic Park were selected for study. Different field techniques and sampling approaches were used in the three stands in order to determine stand development patterns through the reconstruction of present and past stand structures. These studies showed that although the average tree age and average diameter of stands may be similar, very different distributions of these statistics may have resulted from different disturbance regimes. In order to reduce the coefficient of variation between plots in the creation of a monitoring plan stands should be stratified by disturbance regime. Reduction of the variation through stratification will increase the efficiency and effectiveness of the plan.

References

Agee, J.K. 1984. *Historical Landscapes of San Juan Island National Historic Park.* Seattle, Wash.: University of Washington.

Hetsch, S. 2005. Reconstruction of stand development—A case study on San Juan Island, Washington, USA. Diploma Thesis, Albert-Ludwigs-Universität, Freiburg, Germany.

Oliver, C.D., and B.C. Larson. 1996. *Forest Stand Dynamics*. 2nd ed. New York: John Wiley & Sons.

Peterson, D.L. 2002. *Developing a Vegetation and Fuels Data Base for San Juan Island National Historical Park.* Seattle: U.S. Geological Survey Forest and Rangeland Ecosystem Science Center, Cascadia Field Station.

Smith, D.M., B.C. Larson, M.J. Kelty, and P.M.S. Ashton. 1997. *The Practice of Silviculture*. 9th ed. New York: John Wiley & Sons.