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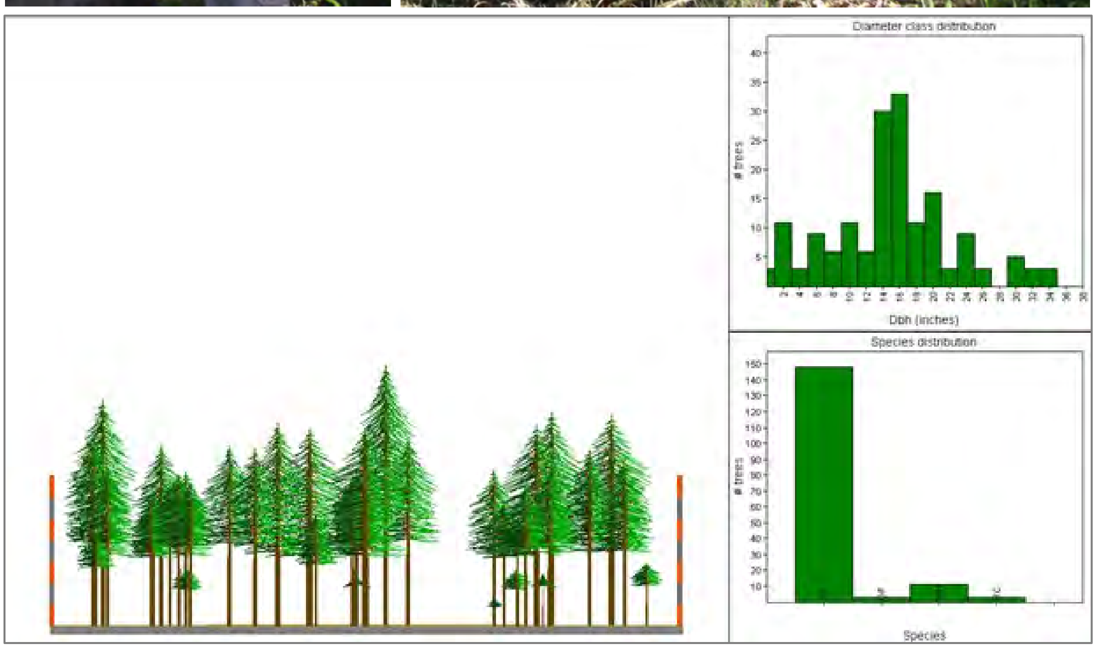
Natural Resource Stewardship and Science

Modeling Future Forest Conditions at San Juan Island National Historical Park

A Planning Tool for Park Managers and Scientists

Natural Resource Report NPS/NOCA/NRR—2020/2107



ON THIS PAGE

Top photo: Mariano Amoroso in front of a tree toppled by windthrow in English Camp; Bottom photo illustrates a windthrow disturbed stand in English Camp.
Photographs courtesy of University of British Columbia

ON THE COVER

Clockwise from top: Mariano Amoroso coring a tree to determine age; American Camp stand AC-6; visualization of American Camp stand AC-6 in 2008.
Photographs and diagrams courtesy of University of British Columbia.

Modeling Future Forest Conditions at San Juan Island National Historical Park

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Mariano Amoroso and Bruce Larson

Department of Forest Resources Management
Faculty of Forestry
University of British Columbia
Vancouver, BC, Canada

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Abstract

Coniferous forests cover almost half of San Juan Island National Historical Park's (SAJH) landscape today as they did during the park's historical period of 1853-1871. However, during the posthistoric period (1872 to 1966), large patches of forest were cleared for agriculture in both American and English Camps (Agee, 1984). Following the park's establishment in 1966, many of these fields were not managed and dense forest stands established after the fields were released from agriculture. By 1983, tree densities in some areas ranged from 2,000 to 8,900 stems/acre (Rolph and Agee, 1993). These anthropogenic changes altered the historic landscape and increased fired danger in the wildland-urban interface between the park and adjacent development. In the early 1990s the park worked with Dr. James Agee at the UW CPSU to develop a Vegetation Management Plan for the Park (Rolph and Agee, 1994). Following plan recommendations, the OLYM Fire crew initiated a program of forest thinning to reduce fire hazards and accelerate the development of healthy forest stands.

Between 2005 and 2008, stands in field surveys were conducted at American and English Camp to describe the structure of forest stands and to project future development. Surveys were conducted to assist in the future development of silvicultural prescriptions and long-term monitoring programs. Stands were stratified into forest cover classes using aerial photos. Following field reconnaissance, initial stand delineations were refined to 33 forest stands; 15 at American Camp and 18 at English Camp. Field surveys were conducted to quantify species composition, tree size (diameter and height), and forest age. Data were entered into the Landscape Management System (LMS) database to project stand composition in 60 years. Stand ages ranged from 20 – 165 years indicating that most stands had been manipulated following the park's period of historic significance (i.e., more than 133 years ago).

The projections of what forest stands will likely look like in the future presented in this study will assist managers in developing silvicultural recommendations and tracking of the efficacy of forest management. In addition, this documentation of current conditions combined with the future projections will facilitate development of an effective long-term monitoring strategy.

Acknowledgements

We would like to thank the staff of San Juan Island National Historical Park for supporting our field surveys, Lise Grace for formatting this report, and Anne Braaten and Natalya Antonova for developing the maps in this report. We would also like to thank Dr. Steven Acker and Dr. Catharine Copass for their reviews of this report. This project was funded by the National Park Service Pacific West Region through the Small Park Natural Resource Preservation Program; funding was obligated to University of British Columbia by the Pacific Northwest Cooperative Ecosystem Studies Unit Cooperative Agreement No. CA9088A0008 and managed by Regina M. Rochefort, PhD.

1. Introduction

Coniferous forests are an important component of the landscape in San Juan Island National Historical Park (SAJH). Although the forests were manipulated during the historic military time period (1853 to 1871), significant and widespread alterations occurred during the posthistoric period of 1872 to 1966 (Agee, 1984). At that time, patches of forest were cleared for agriculture in both American and English Camps. Following the park's establishment in 1966, many of these fields were not managed and dense Douglas fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*) stands became established. By1983, tree densities ranged from 2,000 to 8,900 stems/acre (Rolph and Agee 1993). In the early 1990s the park worked with Dr. James Agee at the University of Washington (UW) National Park Service Cooperative Studies Unit (NPS CPSU) to develop a Vegetation Management Plan for the Park (Rolph and Agee 1993). The plan recommended the management of historically forested areas in such a manner as to accelerate forest development to a produce in healthy, dynamic forest.

Over the next decade, the Olympic National Park (OLYM) fire crew thinned the dense forest stands in American Camp and removed down and dead trees along road edges in English Camp. Some of the densest stands were thinned from 8,900 stems/acre to 300 stems/acre. Monitoring of these activities was limited to reporting required by the NPS Fire Management Program (i.e., location and dates of operations, number of stems removed, volumes of chipped trees, burn piles). Often, the Fire Crew coordinated with the North Coast and Cascades Exotic Plant Management Team (NCCN EPMT) to control Canada thistle (*Cirsium arvense*) that invaded bare ground resulting from burned slash piles.

By 2004, SAJH park staff and OLYM fire crew felt that stands in both camps needed to be assessed with respect to current composition, stand densities, species composition, and fuel loads to determine how close they were to the park's desired future condition for these communities. Silvicultural prescriptions were needed to guide future forest management to attain management goals for these stands. Additionally, the evaluation would aid the park in developing a long-term monitoring program to evaluate the coniferous forests with respect to short-term management goals and long-term ecological status of the park. Both SAJH and OLYM Fire staff felt that permanent plots were needed to effectively monitor and guide future management actions. Although the North Coast and Cascades Network (NCCN) had identified SAJH forest monitoring as a need for long-term monitoring, it was not identified as a funding priority within the NCCN Long-term Monitoring Program (Weber et al. 2009).

In 2004, Dr. Regina Rochefort (Science Advisor, North Cascades National Park Service Complex (NOCA)), Dr. Bruce Larson (Silviculturist, University of British Columbia (UBC)), Bill Gleason (Chief of Resource Management, SAJH), and OLYM Fire Managers Larry Nickey and Todd Rankin developed this project to address the park's need for an assessment of forest conditions and to provide a baseline for management prescriptions. The project was submitted and received funding through the NPS Pacific West Region's Small Park funding program. The goals of this project were to assess the status of dense, coniferous forests in San Juan Island National Historical Park, provide insights to guide future forest management plans, and to communicate information about the forests and their management to the park staff.

2. Methods

2.1 Study Area

San Juan Island National Historical Park is located on San Juan Island, the second largest island in the San Juan archipelago. The San Juan Islands are located off the northwest coast of Washington state (US) and south of Vancouver Island (Canada). This group of islands, and their Canadian counterpart known as ‘Gulf Islands”, represent a unique ecosystem since they are located in the rain shadow of the Olympic Mountains and Vancouver Island. These geographic barriers generate a dry climate that supports a landscape characterized by open woodlands and forests mainly composed by Douglas-fir (*Pseudotsuga menziesii*), Pacific madrone or Arbutus (*Arbutus menziesii*), and Garry Oak (*Quercus garryana*) (Franklin and Dyrness 1988, Meidinger and Pojar 1991).

San Juan National Historical Park is composed of American Camp on the south end of the island and English Camp on the north tip (Figure 1). Mean annual precipitation ranges from 737 mm in the northern end of the island (English Camp) to 508 mm in the southern end (American Camp). About 70 percent of the annual precipitation falls between October and April (US National Park Service 2009). The mean annual temperature is 9.5 °C, with means of 3.3 and 15.5 °C for the months of January and July respectively (Western Regional Climate Center 2007). Soils are mainly glacial in origin and contain a group of series that range from poorly drained to excessively-drained soils (Agee 1987).

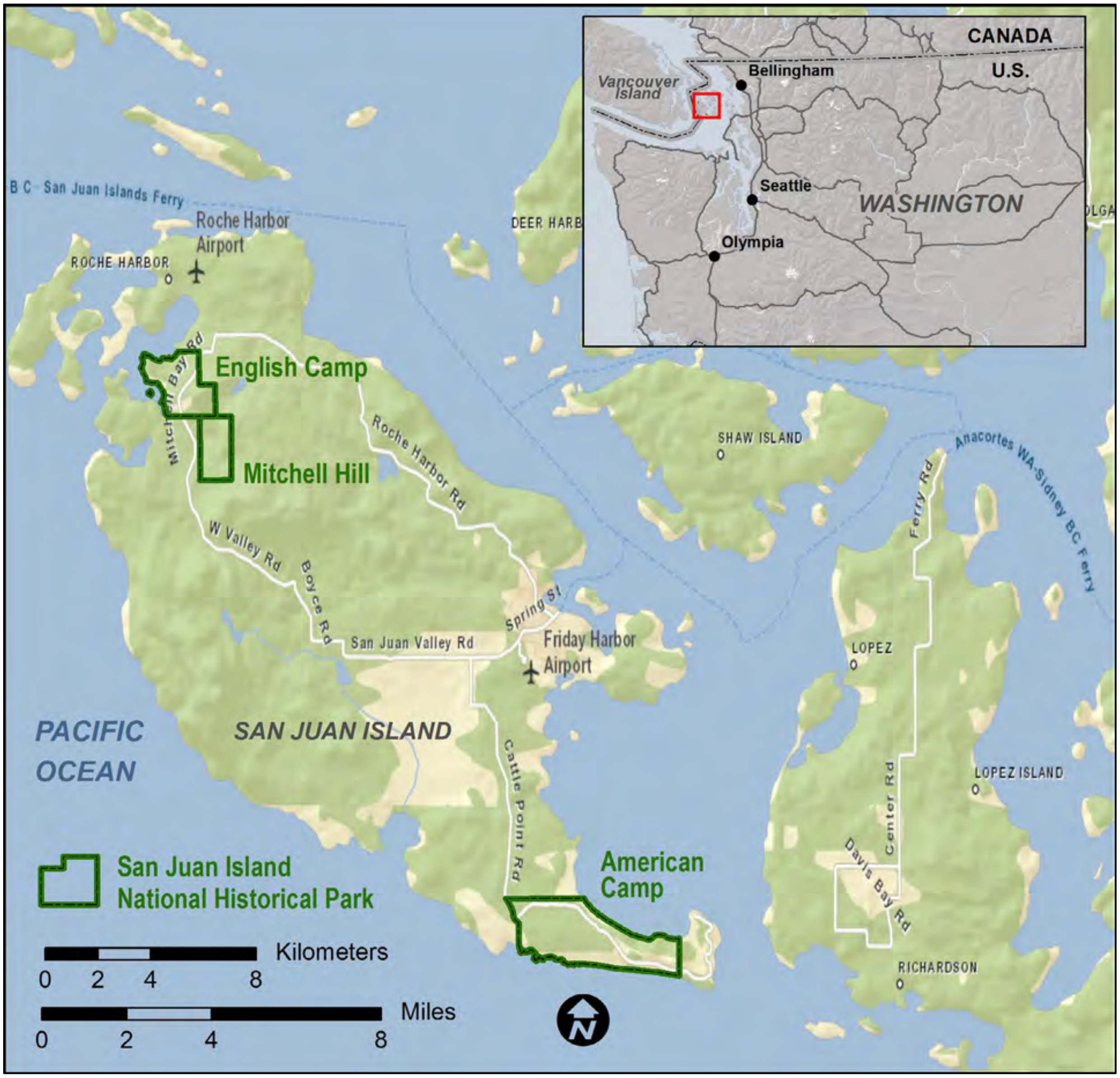


Figure 1. San Juan Island and San Juan National Island Historical Park. English Camp is at the north-western end of the island American Camp is at the southern end.

Disturbances, both natural and anthropogenic, have been important factors in the development of the structure of forest stands within the Park (Agee 1984, 1987; Hetsch 2005; Amoroso and Larson 2006). Fire has a long history beginning with low intensity fires used by the native peoples to maintain open woodlands (Agee 1984). After the arrival of European settlers, in the mid 1800's (Hetsch 2005), logging became the predominant anthropogenic influence on park forests until the mid 1960s.

2.2 Sampling Overview

Prior to conducting field surveys, forests were stratified based on their stand characteristics (species composition, tree size, and stand density) in a two step process. First, we used high-definition photos in combination with soil maps of the park (NRCS 2006) to delineate broad groups of forest stands.

This stratification yielded 45 stands, 19 at American Camp and 26 at English Camp. The second step consisted of extensive field verification of the preliminary stand delineations. We surveyed transects across all preliminary stands in both Camps, recording stand characteristics systematically every 100 meters. As a result, some of the initial stand delineations were revised, combining stands with similar dominant species composition, age, and structure. Following field review, the forests across both areas were stratified into 33 stand-types (Figure 2). Stratification by stand type was performed to reduce the number of plots needed to later accurately depict the forest types and to account for variability, making sampling more efficient and effective.

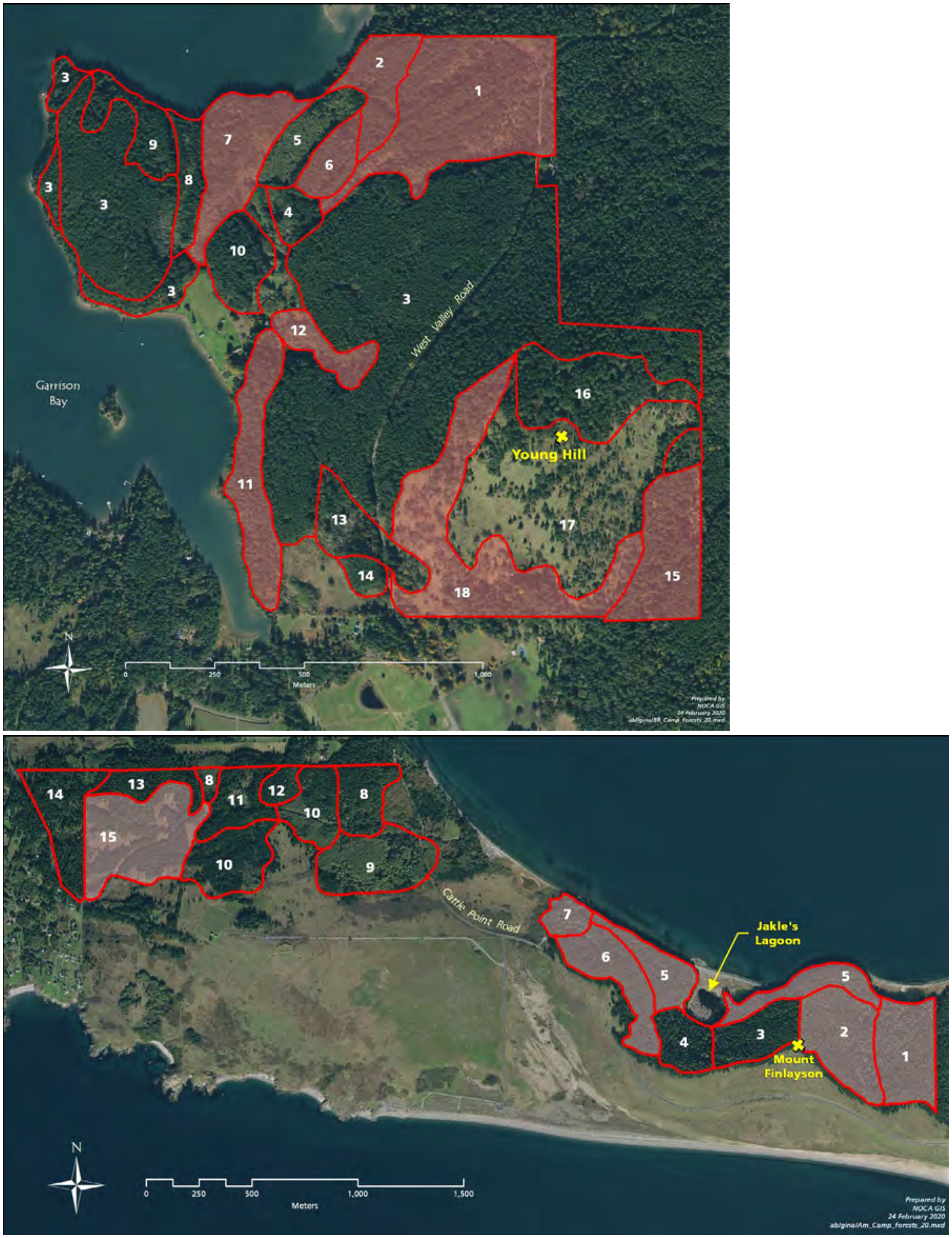


Figure 2. Stand delineations for English (top) and American Camp (bottom). Shading denotes stands that are at least 100 years old.

2.3 Field Surveys

A total of 269 plots was established across all stands in the Park. The number of plots used to sample each stand was determined based on stand size and variability of vegetation within stands. The number of plots ranged from 5 to 20 per stand but was generally in the range of 6 to 9 (Table 1).

Table 1. Number of plots sampled at each stand, stand and site characteristics.

Stand	Plots	Site Index	Age (years)	Slope %	Aspect°
A-1	8	75	162	13	295
A-2	8	71	154	16	60
A-3	7	99	75	18	324
A-4	6	65	77	12	30
A-5	8	68	151	10	10
A-6	7	88	112	11	98
A-7	5	84	160	10	42
A-8	8	100	87	0	360
A-9	7	82	81	0	360
A-10	8	87	20	0	360
A-11	8	95	28	2	146
A-12	6	88	88	2	110
A-13	7	83	90	0	360
A-14	8	79	101	1	330
A-15	10	110	27	0	360
E-1	17	91	106	4	296
E-2	10	90	102	7	280
E-3	20	88	95	11	257
E-4	5	109	46	1	268
E-5	9	94	48	1	294
E-6	6	91	103	7	305
E-7	8	92	110	4	97
E-8	6	108	46	0	360
E-9	6	91	95	8	66
E-10	5	99	90	6	269
E-11	7	83	134	12	256

Table 1 (continued). Number of plots sampled at each stand, stand and site characteristics.

Stand	Plots	Site Index	Age (years)	Slope %	Aspect°
E-12	7	81	106	4	300
E-13	5	94	64	5	230
E-14	4	93	91	8	253
E-15	8	80	165	13	100
E-16	10	89	77	13	211
E-17	15	77	77	18	203
E-18	10	82	165	12	227

Plots were systematically located using a 32-m sampling grid. Plots were first located on a map, and later established in the field. Plots were circular and 0.02 ha. in size (7.98 meters radius). At each plot all trees taller than 1.3 m. (breast height) were sampled. The following information was recorded for each tree: species, diameter at breast height (DBH), strata (A-emergent, B-main dominant canopy, C-mid strata, D-lower strata), and crown class (D-dominant, C-co-dominant, I-intermediate, S-suppressed). Strata and crown class were assigned using the classification described by Oliver and Larson (1996). Up to 5 trees per plot were cored using increment borers at a height of 30 cm from the ground. Cores were used to estimate age of the stands and site index (SI). (Site index is a term used to describe the productivity or quality of a site for tree growth.) Generally, 1 to 3 cores in each plot were used to determine the site index. For this, where available, dominant, healthy Douglas-fir trees were selected. To determine the lower age-class limit, 1 to 2 young and small or suppressed trees were also cored. Finally, a healthy individual of each prominent species in the stand was selected and cored, to obtain an estimate of the ages of the various species. All cores were mounted and sanded, and age was estimated by counting the rings. The heights of the site index trees were measured using a digital hypsometer.

2.4 Data Analysis - Stand Modeling

Forest growth models can be important tools used to support management decisions and answer research questions. They can forecast future forest conditions under different scenarios, and therefore, help to predict outcomes of management practices and test hypotheses. We used the Landscape Management System (LMS) for all data analysis. It is a modular system that coordinates the activities of other programs (projection models, visualization tools, etc.) as a way of making growth estimates and producing output in visual, graphical, and tabular forms (McCarter et al. 1998). LMS was designed to assist in landscape level analysis and planning of forest management alternatives as it facilitates data manipulation and inventory update simulation (McCarter et al. 1998).

The age of each stand was estimated using tree age data from all plots assuming that the trees regenerated following a stand replacement disturbance. Within stands, minor differences in age between plots were ignored, because tree ages do not actually influence how the growth model predicts tree growth (Dixon 2007). Where data was available, the site index of each plot was calculated using TIPSY v.4.1 (Table

Interpolation Program for Stand Yields, BC Ministry of Forests and Range 2007), using the ages and heights of the dominant Douglas-fir trees. For plots without site index data, the average stand site index was used in stands with little variation between plots; in stands with more variation between plots, the site index from the most similar plot (with regards to species composition, stand density, slope and aspect) was used.

All the stand level and inventory information was entered in MS Excel and later imported into the Landscape Management System (McCarter et al. 1998). The Landscape Management System (LMS) is, in essence, a framework that coordinates separate programs, such as forest growth models and visualization tools, as a way of making growth estimates and producing output in visual, graphical, and tabular forms (McCarter et al. 1998). Due to the location of the study area, the Pacific Northwest variant was chosen for the growth model in LMS. Once all the information (stand level, site index, tree inventory) was imported into LMS, new portfolios were created, and the inventory was restored. In this last step, the growth model predicts tree level information necessary to grow trees in the future and additionally generates the stand level information. MLS was run as a 'plot-by-plot' and later on the information was averaged at the 'stand' level. For this, each plot per stand was entered into LMS as though it were a complete stand. Variation between plots with regards to site conditions such as slope and SI, and variation in stand conditions such as density and species composition were therefore retained. Stands were projected 60 years to predict future stand conditions. Once the plots had been projected, all of the plots in each stand were averaged together, to obtain entire stand estimates. Stands were also visualized in LMS using Stand Visualization System (SVS) (McGaughey 1997), a stand visualization tool, to aid in identifying the key differences**.**

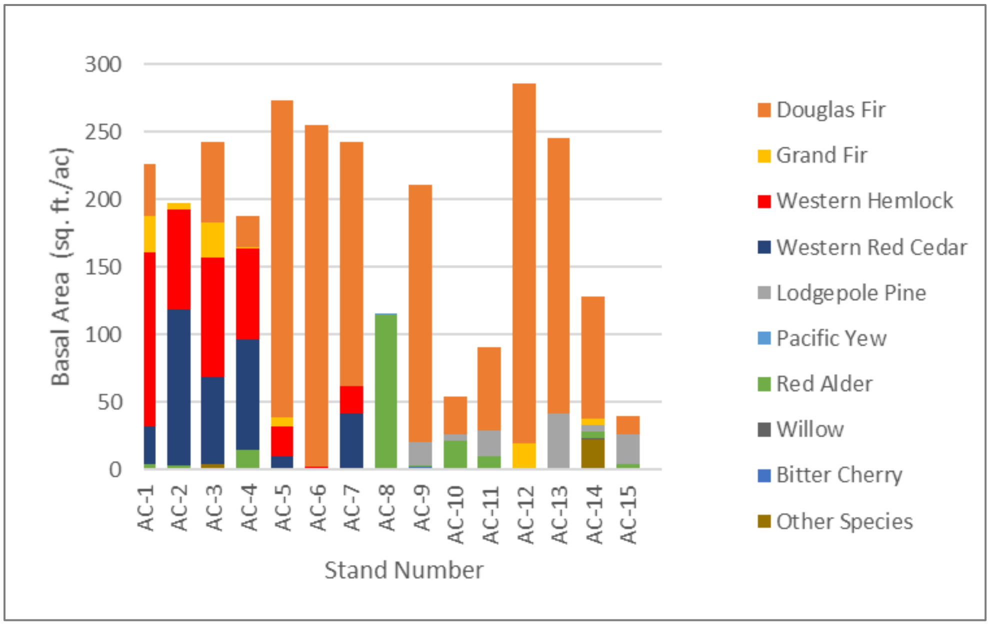
3. Results

3.1 Overall stand composition and average stand statistics

Douglas-fir (*Pseudotsuga menziesii*) is the dominant species in the Park and is present in nearly all stands (Figure 3). Red alder (*Alnus rubra*) grand fir (*Abies grandis*), and western red cedar (*Thuja plicata*) were also found at both camps, but several species were restricted to American or English Camp. Western hemlock (*Tsuga heterophylla*) and lodgepole pine (*Pinus contorta*) were only documented in American Camp. Western hemlock was common in stands near Mount Finlayson and lodgepole pine was found primarily on dry, flat sites at the interface between the forest and grasslands. Pacific madrone (*Arbutus menziesii*), big leaf maple (*Acer macrophyllum*), and Garry oak (*Quercus garryana*) only grew in English Camp. Pacific madrone was only present in small proportions, but it was present in most stands in English Camp.

Overall, stands at both Camps exhibit a wide range of ages, ranging from 27 to 165 years (Table 2). According to our estimates, almost one half of the stands in the Park are at least 100 years old. These stand ages should be considered slight underestimates since we did not adjust them for the number of years it took for trees to grow to coring height (~ 30-40 cm). Therefore, we expect these stands to be several years older than the ages presented here. Additionally, the stand age was estimated assuming stand-replacement origin; therefore, ages do not represent the average age of the sampled trees but refers to the onset of the establishment following a major disturbance.

Densities, expressed as trees per acre (TPA), ranged from 21 to 664 reflecting variability in site quality, the wide array of ages, and stand composition. As shown in previous studies (e.g. Oliver 1981), mean diameter did not provide a good representation of a stand age as for similar diameters (i.e. 15 inches) trees can present dissimilar ages and/or stand density.



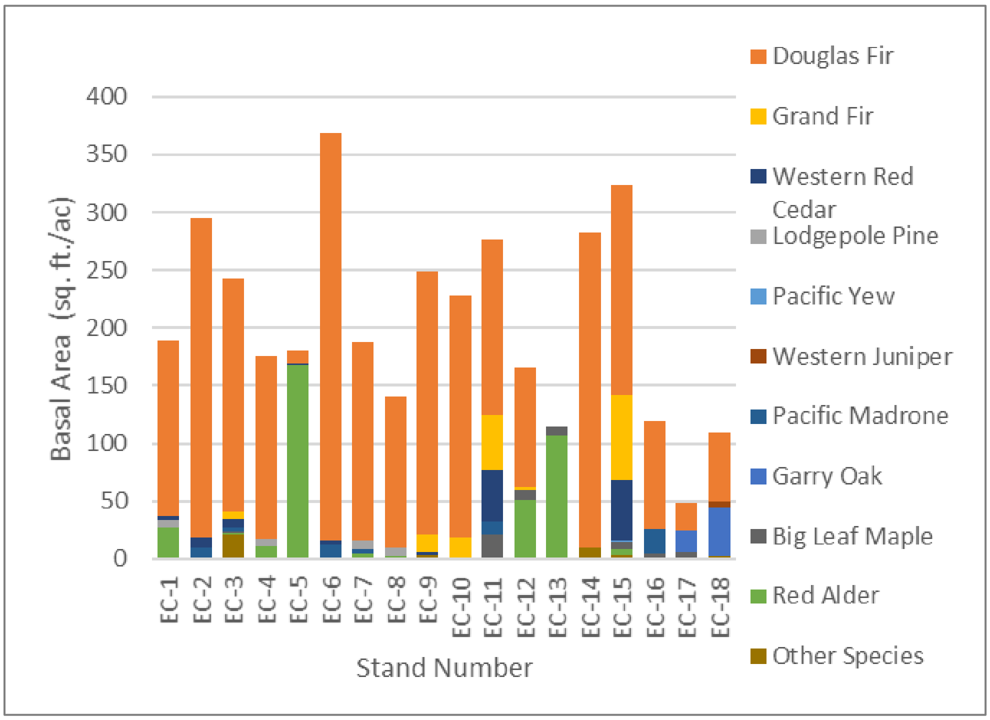


Figure 3. Stand composition and total basal area per acre the sampled stands at (top) American and (bottom) English Camp.

Table 2. Descriptive statistics for the sampled stands at the American and English Camp.

Stand	Age	Density (trees/ acre)	Mean Diameter (inches)	Basal Area (square feet/acre)	Mean Height (feet)
A-1	162	262.5	9.2	225.8	52.9
A-2	154	312.5	10.3	259.1	55.1
A-3	75	237.4	11.6	242.3	65.9
A-4	77	193.1	10.1	187.2	54.2
A-5	151	470.0	6.5	274.3	33.6
A-6	112	163.0	15.1	254.0	66.8
A-7	160	164.0	12.6	243.3	54.1
A-8	87	230.0	8.2	114.6	56.5
A-9	81	128.7	15.9	210.2	79.6
A-10	20	542.5	3.3	53.9	15.7
A-11	28	215.0	6.2	90.1	30.2
A-12	88	176.5	14.6	285.3	64.8
A-13	90	172.7	14.7	244.8	69.1
A-14	101	205.0	8.5	127.8	46.0
A-15	27	532.0	2.6	39.2	15.8
E-1	106	476.7	6.7	188.8	34.6
E-2	102	278.0	12.2	295.4	67.5
E-3	95	247.0	11.6	242.2	62.9
E-4	46	664.0	5.9	174.9	27.1
E-5	48	401.8	8.0	179.8	59.1
E-6	103	279.7	13.8	368.3	73.6
E-7	110	375.0	6.5	187.5	29.8
E-8	46	356.3	7.2	141.1	37.2
E-9	95	206.5	12.7	248.4	60.3
E-10	90	280.0	9.1	227.5	47.7
E-11	134	205.9	12.8	276.0	65.4
E-12	106	143.0	12.7	165.4	73.9
E-13	64	92.0	14.5	113.8	83.5
E-14	91	225.0	14.5	283.2	82.8
E-15	165	177.5	15.1	323.0	71.4

Table 2 (continued). Descriptive statistics for the sampled stands at the American and English Camp.

Stand	Age	Density (trees/ acre)	Mean Diameter (inches)	Basal Area (square feet/acre)	Mean Height (feet)
E-16	77	122.0	10.6	119.9	44.9
E-17	77	21.3	12.7	47.6	52.2
E-18	165	54.0	12.3	108.8	44.3

3.2 Stand composition and stand development

Stand AC-1

The large scattered Douglas-fir trees in the overstory reflect the stand establishment more than 160 years ago (Table 3). Other species form part of a second stratum mainly composed of western hemlock, western red cedar, and grand fir.

Table 3. Stand AC-1 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas fir	7.5	27.1	37.6	16.7
Grand fir	40.0	9.5	27.5	12.2
Pacific yew	2.5	3.3	0.2	0.1
Red alder	5.0	12.7	4.4	2.0
Western red cedar	35.0	9.4	27.9	12.4
Western hemlock	172.5	8.3	128.2	56.8
TOTAL	262.5	9.2	225.8	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

The growth model predicts no major changes in the species composition over the next sixty years. However, there will be some mortality and reduced growth rates of some Douglas-fir trees in the upper part of the canopy allowing for faster growth of trees in the smaller diameter classes. The visualization depicts a stand with fewer small diameter trees in the lower canopy in 2068 than in 2008 (Figure 4).

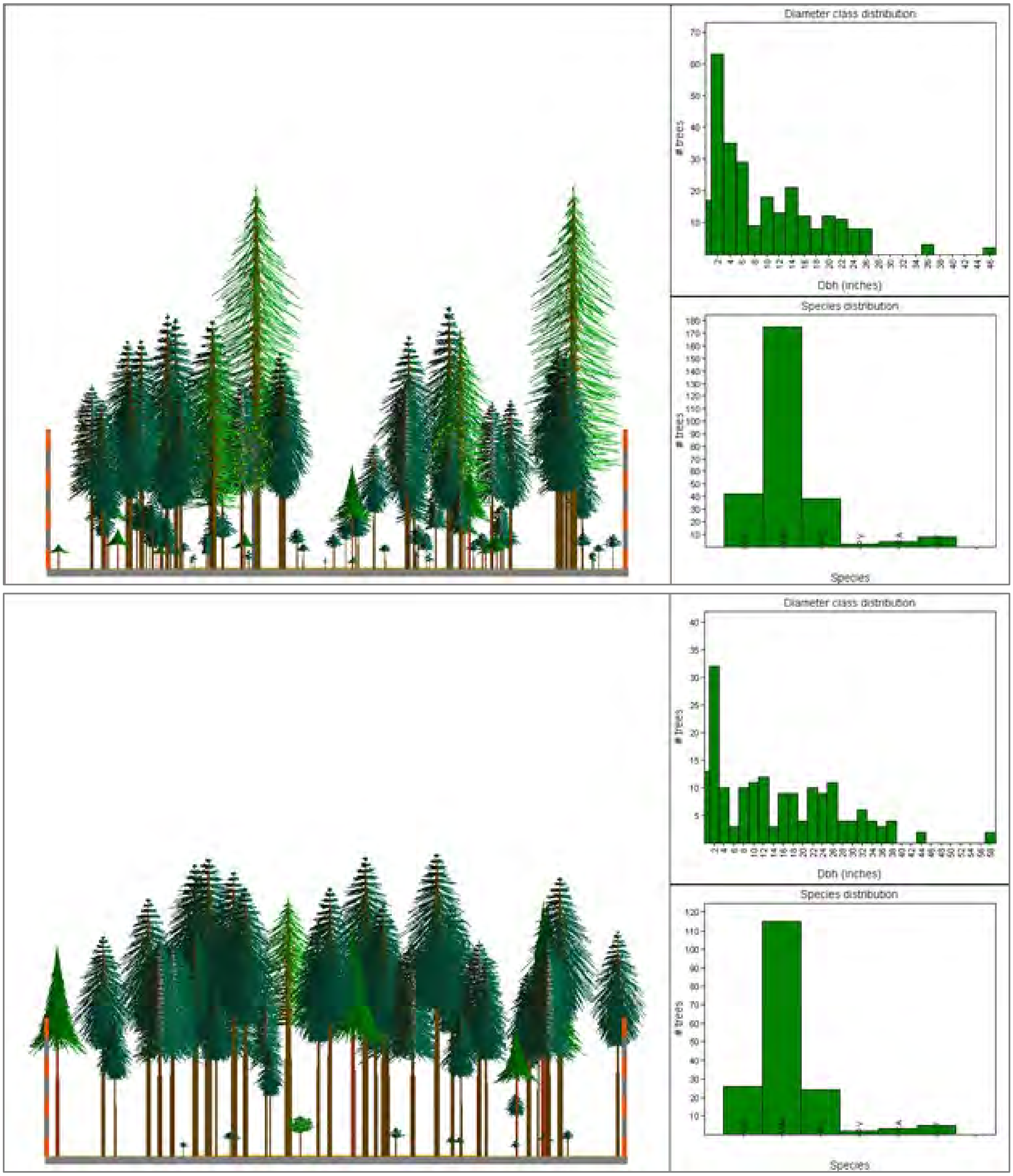


Figure 4. Stand AC-1 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-2

Stand AC-2 originated at the same time stand AC-1 did but the site is moister resulting in higher tree density and stand basal area (Table 4). Site differences also resulted in different species composition leading to an overstory mainly composed by the western red cedar and western hemlock. While there were some scattered Douglas fir trees in the stand, none were located in the sampling plots.

Table 4. Stand AC-2 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Grand fir	5.0	13.4	4.9	1.9
Red alder	5.0	10.4	3.0	1.1
Western red cedar	187.5	8.7	115.5	44.5
Western hemlock	90.0	10.6	73.8	28.5
TOTAL	312.5	10.3	259.1	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Future predictions depict a gradual movement of the trees into larger diameter classes and perhaps less stratified canopy as some species reduce their height growth rates (Figure 5).

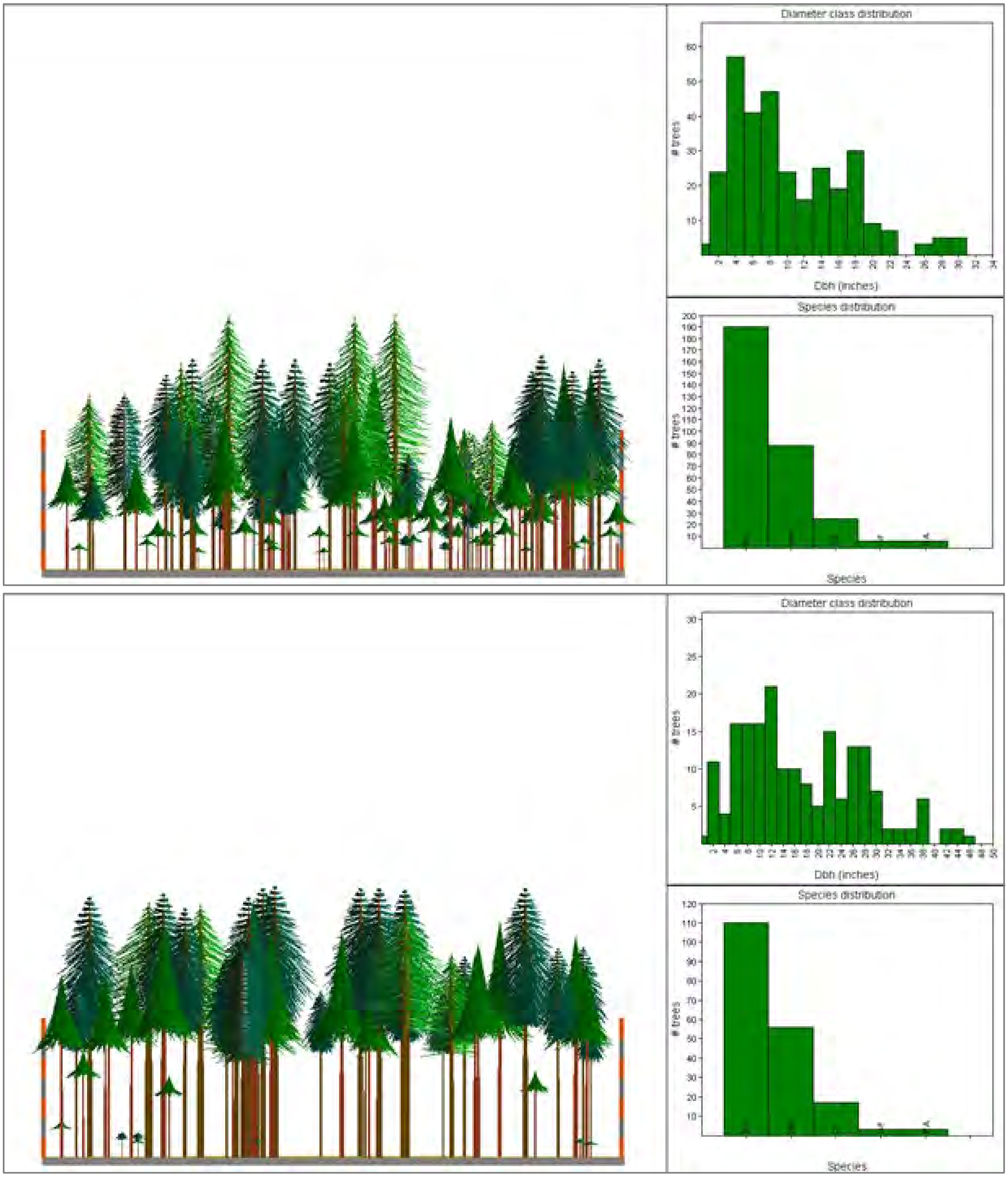


Figure 5. Stand AC-2 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-3

Stand A-3 differs from stand AC-1 and AC-2 in that originated about 80 years ago. The overstory of this stand is dominated by Douglas-fir and western red cedar with scattered presence of grand fir trees (Table 5). Nevertheless, much of the density and BA in this stand is represented by western hemlock which occupies lower positions in the canopy.

Table 5. Stand AC-3 species composition and stand characteristics.

Species	TPA [1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas fir	37.2	16.6	59.3	24.5
Grand fir	14.3	17.4	26.2	10.8
Other species	11.4	8.0	4.3	1.8
Western red cedar	31.5	14.9	64.1	26.4
Western hemlock	143.0	9.2	88.5	36.5
TOTAL	237.4	11.6	242.3	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

The complex structure of this mixed species stand will undergo significant changes in the future reflected by the changes in diameter classes. Species such as grand fir, for example, will move into upper positions in the canopy. Nevertheless, the outcomes are uncertain as the growth of each species will heavily be influenced by its immediate neighbors (Figure 6).

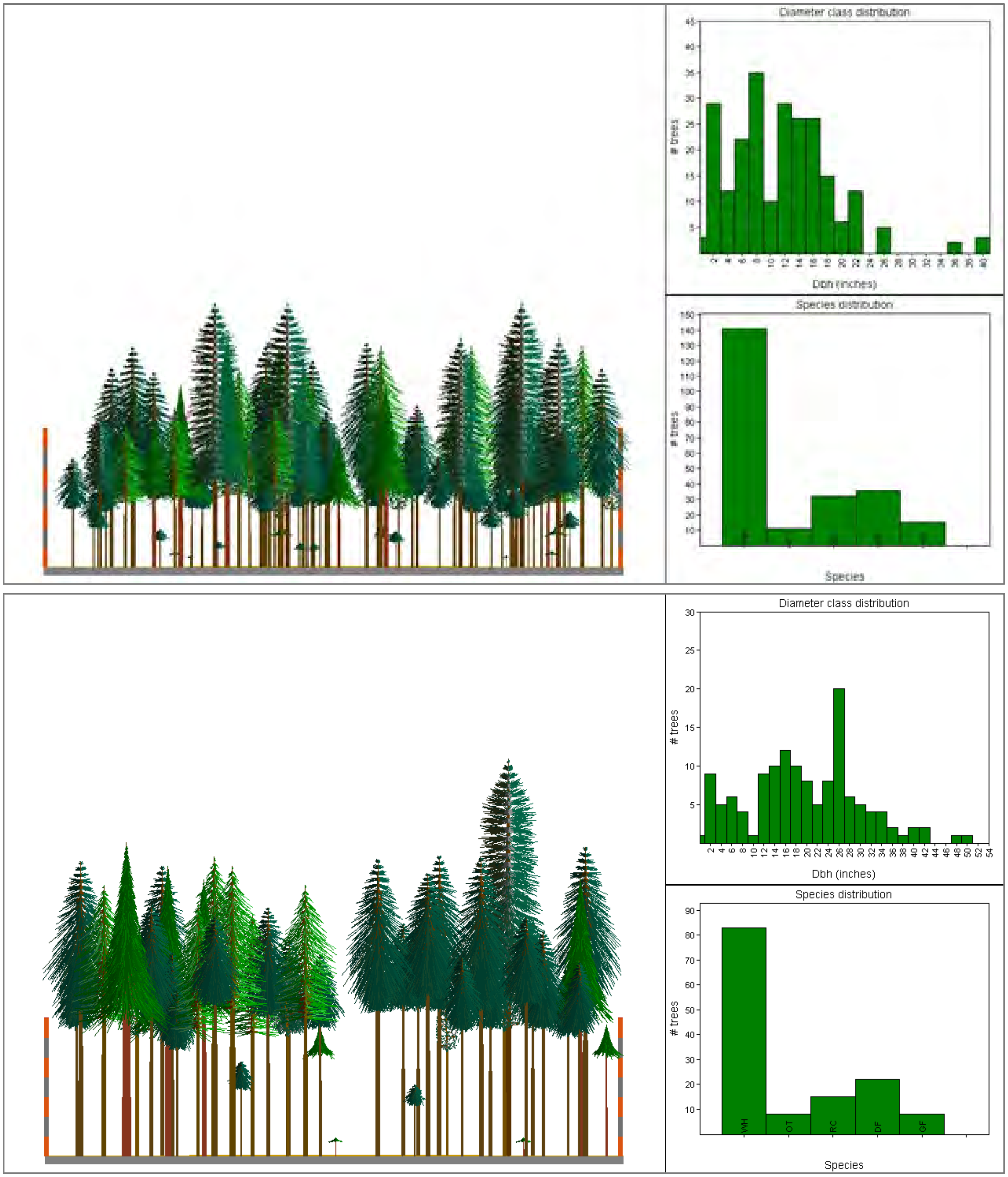


Figure 6. Stand AC-3 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-4

Stand AC-4 originated in the same fire as stand AC-3, but the lower site quality has resulted in lower densities and BA values (Table 6).

Table 6. Stand AC-4 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	16.7	11.8	22.8	12.2
Grand fir	10.0	3.1	0.5	0.3
Other species	10.0	2.1	0.3	0.2
Red alder	33.3	8.1	13.9	7.4
Western red cedar	33.3	17.1	81.8	43.7
Western hemlock	89.9	9.5	68.0	36.3
TOTAL	193.1	10.1	187.2	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

While no major changes in the forest composition for this stand are expected in the future, recruitment in the understory will continue as well as the growth of trees into larger diameter classes. This will represent a clear change in the future diameter distribution (Figure 7).

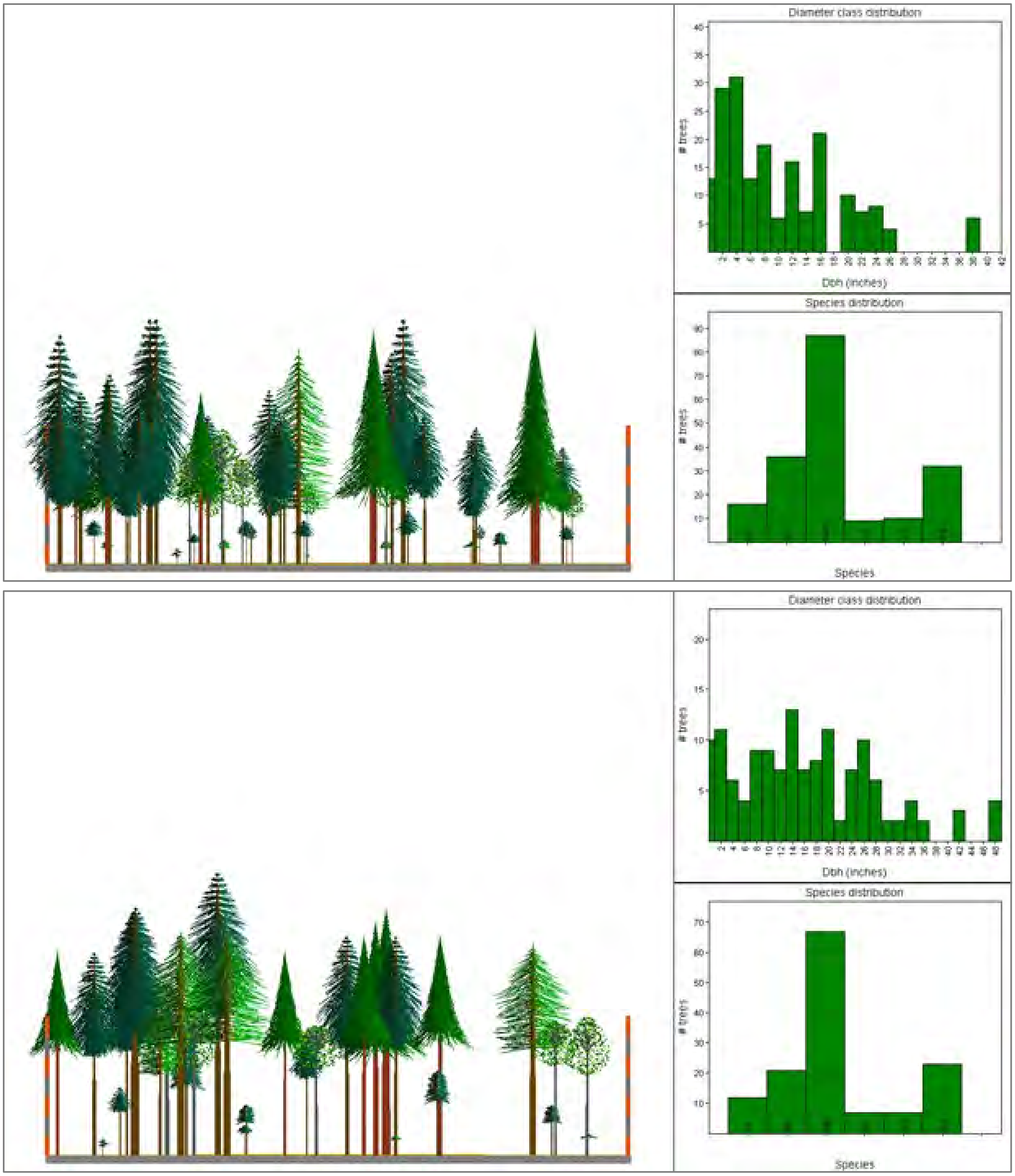


Figure 7. Stand AC-4 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-5

Stand AC-5 had its origin at the same time as stands AC-1 and AC-2 and escaped the most recent fire in the adjacent stands. This elongated stand contours the northern beaches of the American Camp being interrupted only at the Jake's Lagoon. It presents an irregular Douglas-fir overstory with several more shade tolerant species such as grand fir, western red cedar, and western hemlock in subcanopy positions (Table 7).

Table 7. Stand AC-6 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	145.0	15.9	234.8	85.6
Grand fir	240.0	1.0	6.2	2.3
Other species	20.0	2.7	1.3	0.5
Pacific yew	7.5	5.5	1.3	0.5
Western red cedar	32.5	6.2	8.2	3.0
Western hemlock	25.0	8.9	22.5	8.2
TOTAL	470.0	6.5	274.3	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

While the model did not predict major changes in the composition and structure of this stand, the spatial arrangement of some species may lead to stratified clumps of trees as the shade tolerant species grow (Figure 8).

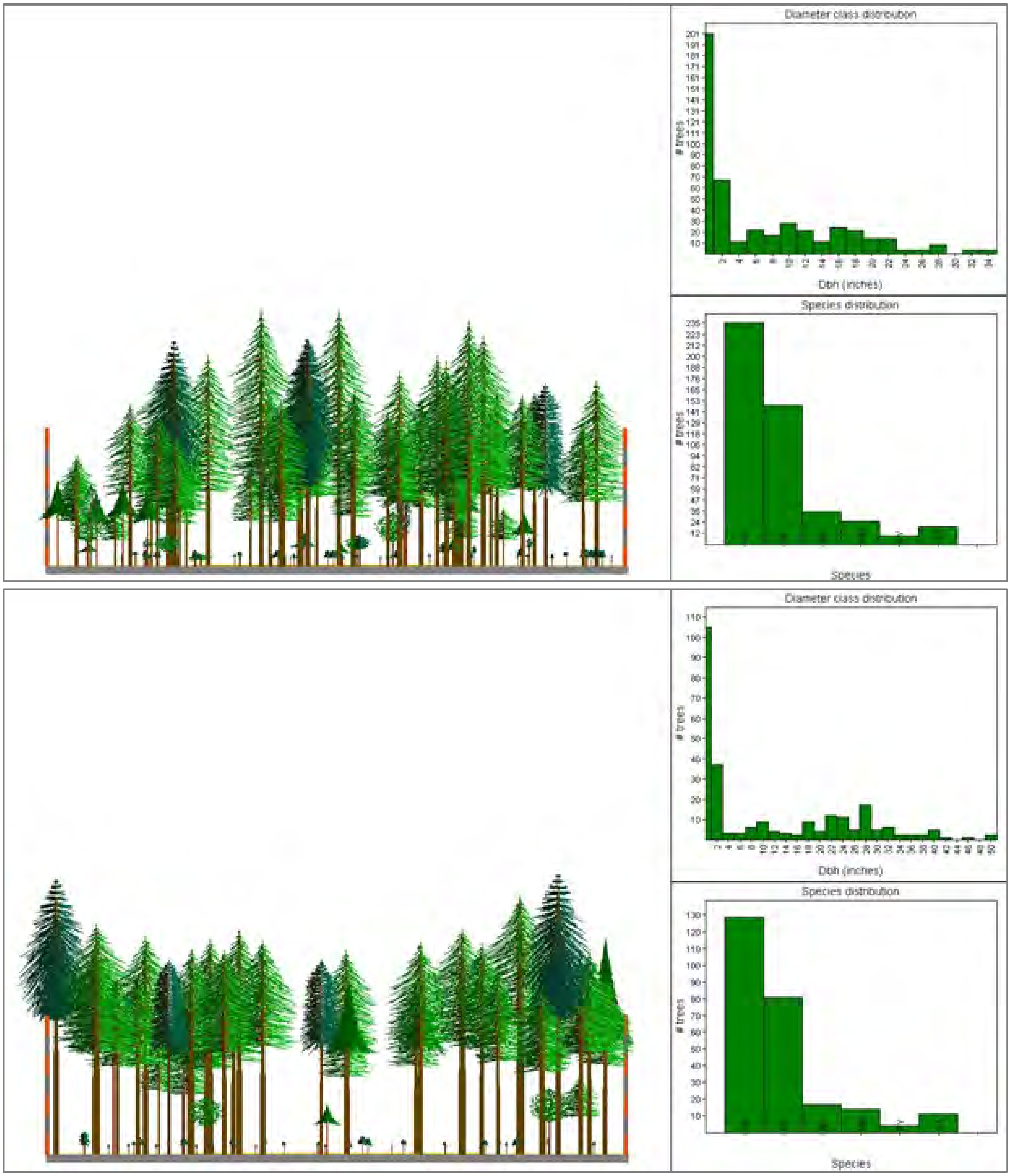


Figure 8. Stand AC-5 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-6

Stand AC-6 is a Douglas-fir-dominated forest of medium-to-low density with few sub-canopy trees (Table 8). Some small trees of more shade tolerant species are present in the edge with stand AC-5.

As most of the stands in this part of the American Camp, its uniform composition typifies even-aged stands originating after stand replacing fires.

Table 8. Stand AC-6species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	145.9	16.7	253.5	99.8
Grand fir	2.9	0.2	0.0	0.0
Western red cedar	2.9	4.5	0.3	0.1
Western hemlock	11.4	1.8	0.2	0.1
TOTAL	163.0	15.1	254.0	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

As most density-dependent mortality has occurred already in this mature stand (> 110 years), we expect the stand to remain dominated by Douglas-fir, but we expect a doubling of the median tree diameter over the next sixty years (Figure 9).

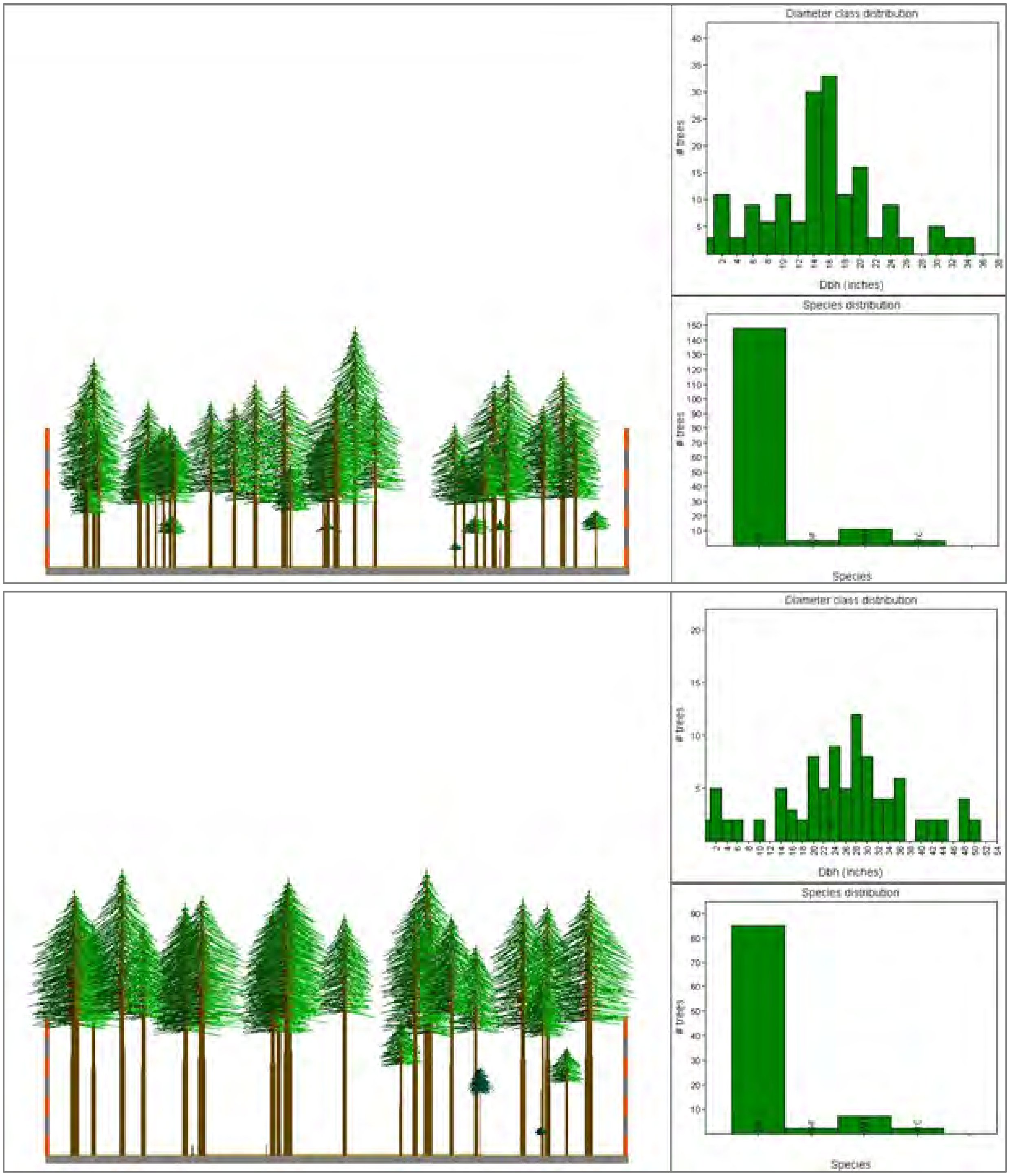


Figure 9. Stand AC-6 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-7

This 160-year stand is one of the smallest units in the American Camp. It presents a unique composition and structure with older western red cedar trees emerging above a Douglas-fir dominated canopy and a lower stratum of western hemlock trees (Table 9).

Table 9. Stand AC-7 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	92.0	16.5	180.1	74.0
Other species	12.0	4.0	1.2	0.5
Pacific yew	8.0	5.7	1.4	0.6
Western red cedar	8.0	22.9	40.2	16.5
Western hemlock	44.0	6.0	20.4	8.4
TOTAL	164.0	12.6	243.3	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Some important stand structure changes are expected in the future as species that are currently in the lower strata competing with others (such as western hemlock) will growth faster and start attaining larger sizes and reaching the upper canopy (Figure 10).

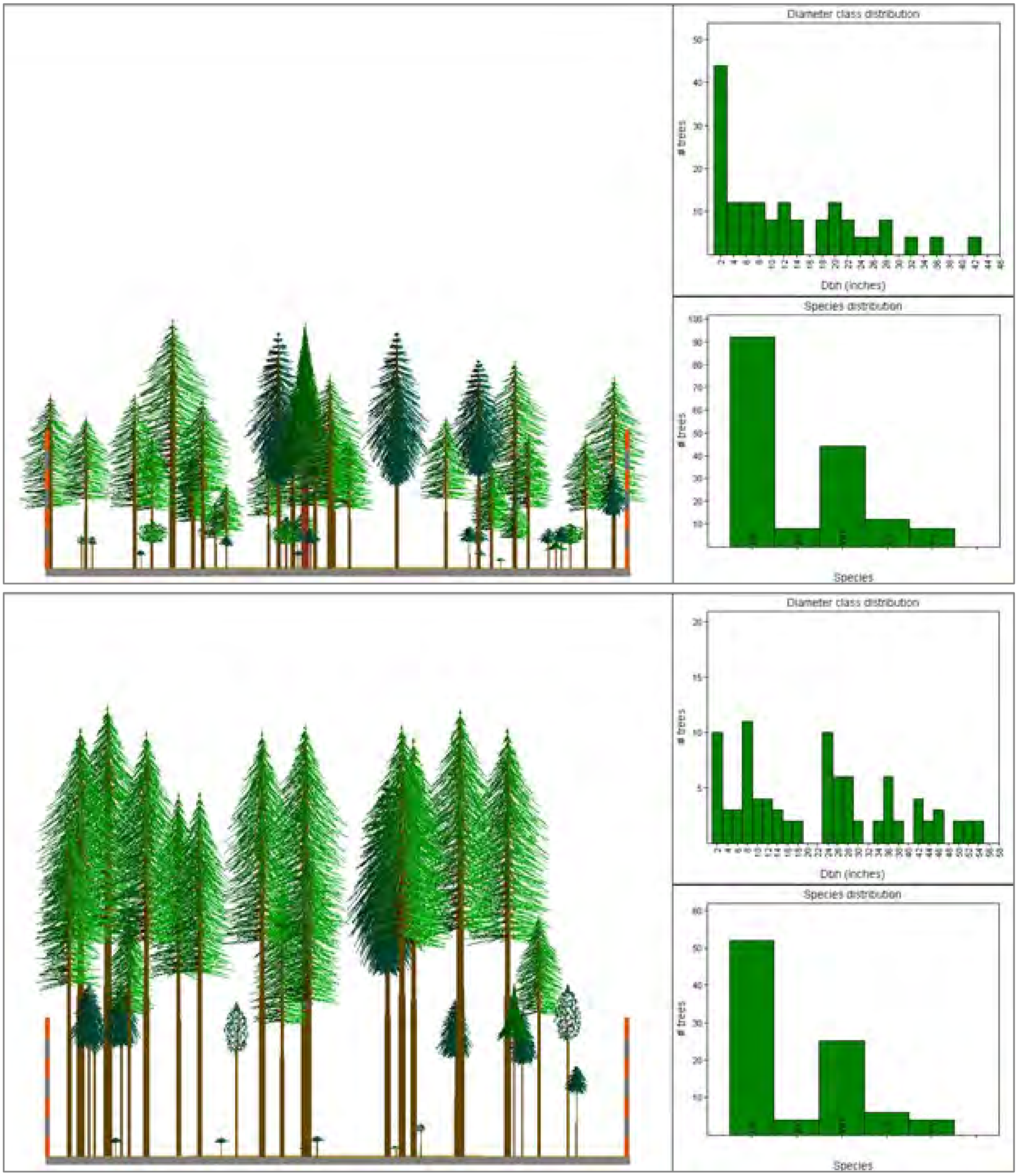


Figure 10. Stand AC-7 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-8

Unlike most of the stands in the western part of the American Camp, stand AC-8 has an overstory composed purely of red alder (Table 10). This medium density stand originated about 90 years ago.

This stand type also includes a small portion of forest between stands A-11 and A-13 (see map in Figure 2).

Table 10. Stand AC-8 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	2.5	0.6	0.0	0.0
Red alder	227.5	8.3	114.6	100.0
TOTAL	230.0	8.2	114.6	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Over the next sixty years, density-dependent mortality is predicted to continue resulting in a stand with a more homogenous canopy and diameter distribution (Figure 11).

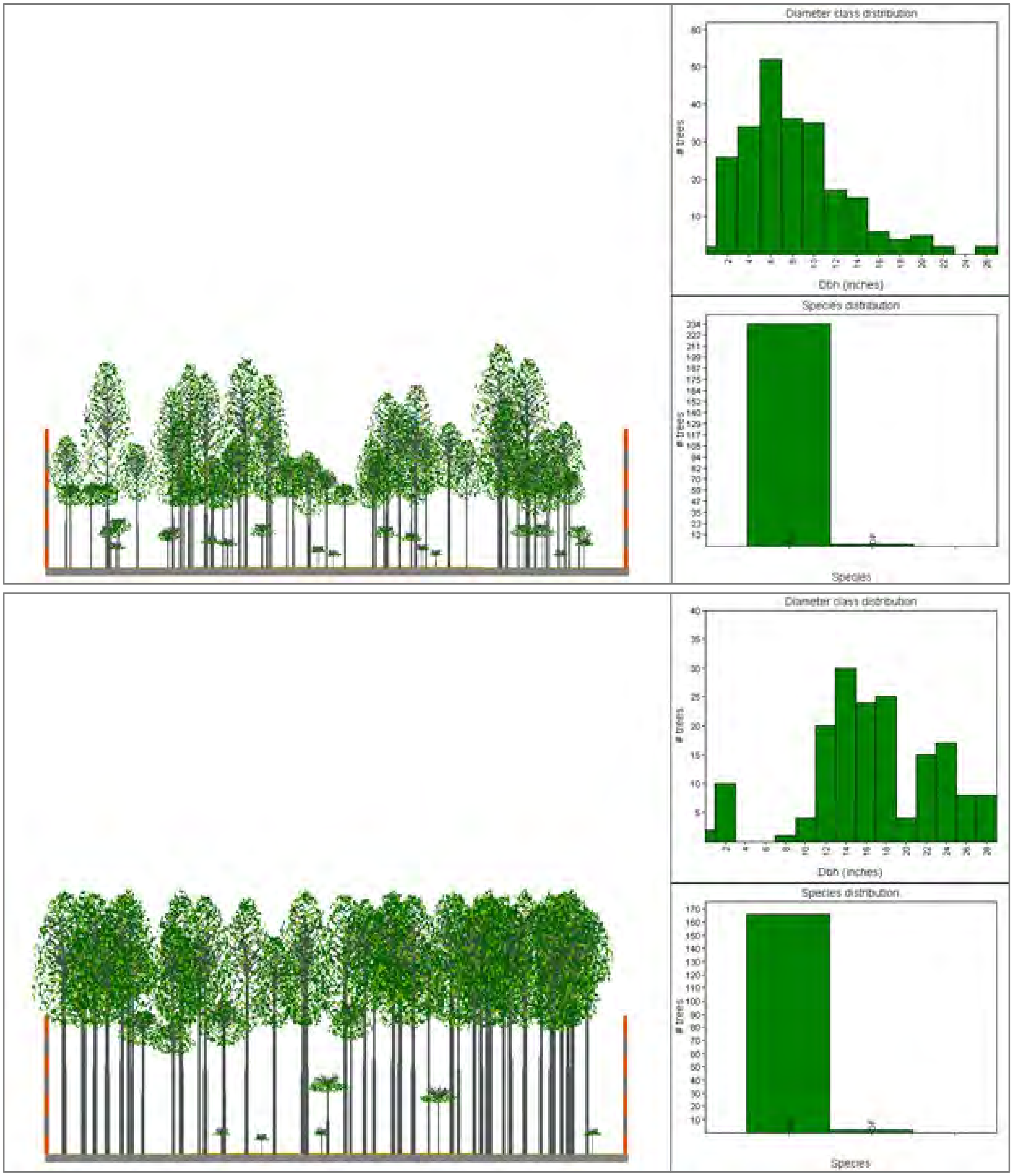


Figure 11. Stand AC-8 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-9

Stand AC-9 originated approximately at the same time stand as stand AC-8 but developed into a mixed Douglas-fir dominated forest (Table 11). These differences might be partially explained by the fact that this stand has been subject of selective harvesting over the past years, as well as soil differences. Along with Douglas-fir, some lodgepole pine trees are in the overstory and species such as red alder or bitter cherry can be found in the understory.

Table 11. Stand AC-9 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Bitter cherry	5.7	8.1	2.1	1.0
Douglas-fir	103.0	17.2	189.8	90.3
Grand fir	2.9	2.8	0.1	0.1
Lodgepole pine	11.4	15.9	16.8	8.0
Red alder	5.7	6.7	1.4	0.7
TOTAL	128.7	15.9	210.2	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

No major changes in species composition over the next 60 years are expected (Figure 12).

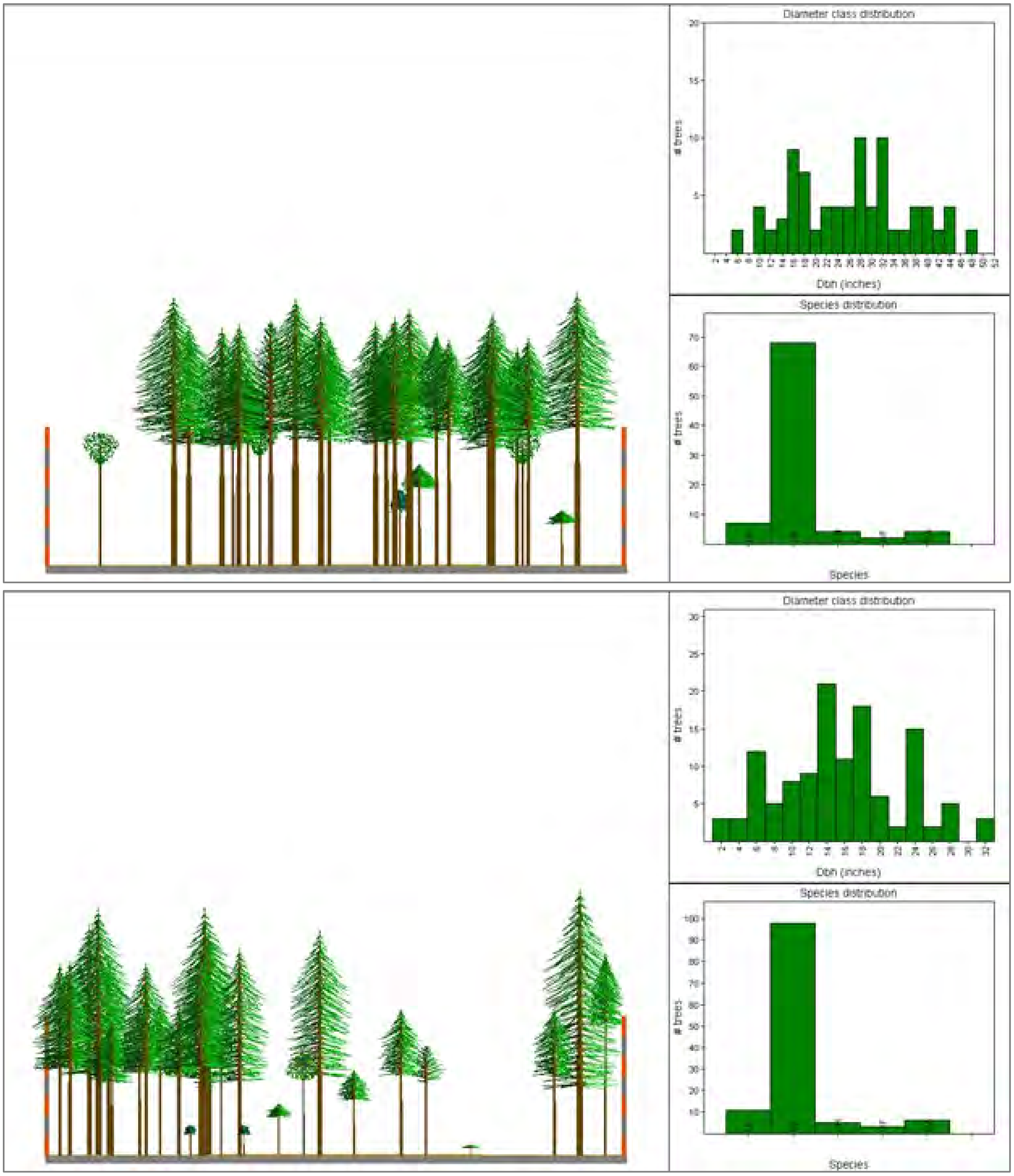


Figure 12. Stand AC-9 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-10

Stand AC-10 is a large stand composed of two units. This young and dense stand is about twenty years old and dominated by a red alder overstory with Douglas-fir and lodgepole pine beneath (Table 12).

Table 12. Stand AC-10 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	360.0	2.8	28.0	51.9
Lodgepole pine	77.5	2.4	4.1	7.7
Red alder	105.0	5.7	21.8	40.4
TOTAL	542.5	3.3	53.9	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Currently there are differences in height and size among species. However, these differences will become less pronounced in the future as red alder reduces its height growth and Douglas-fir and lodgepole pine reach the upper canopy (Figure 13).

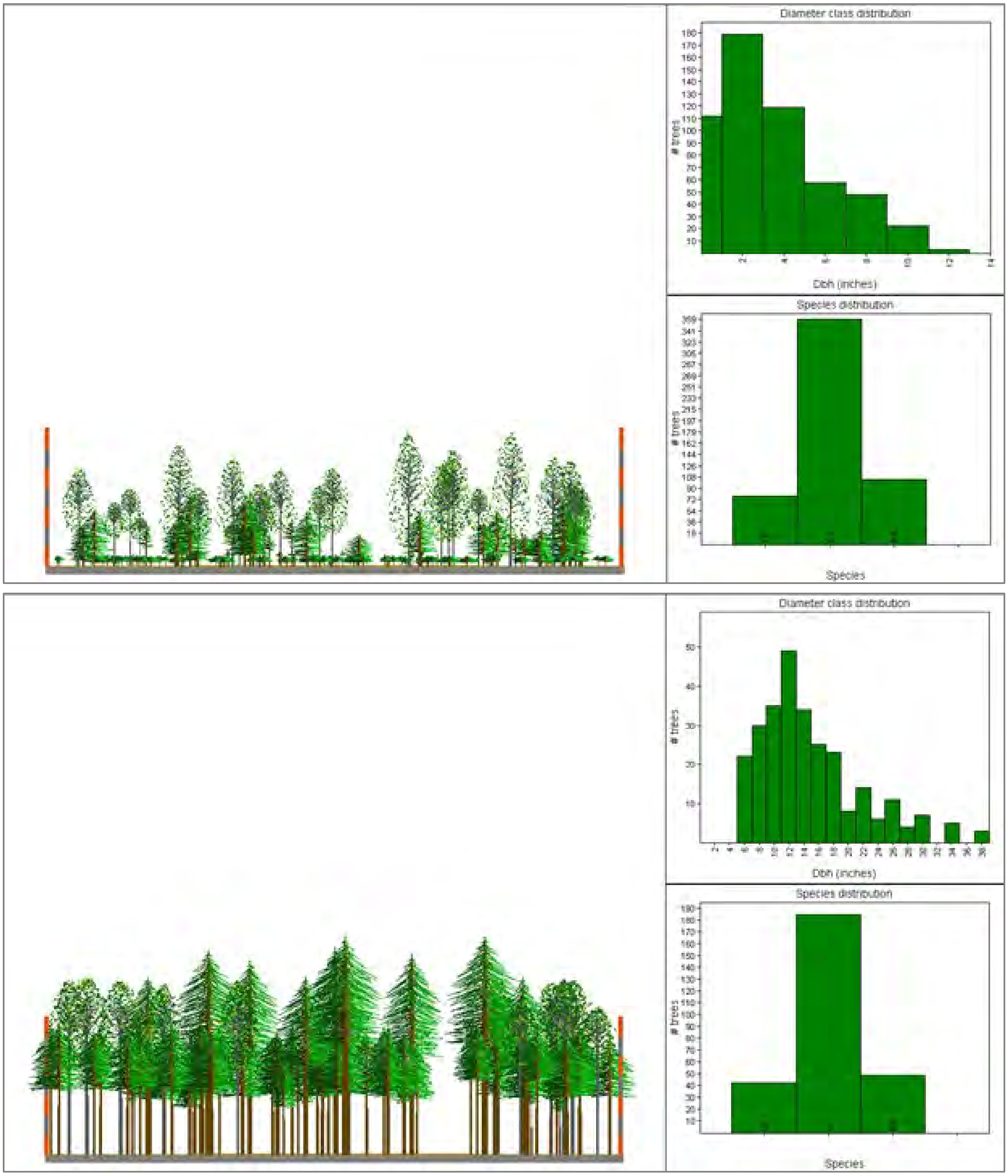


Figure 13. Stand AC-10 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-11

This young (~ 30 years), irregular stand varies from dense Douglas-fir – lodgepole pine forests on the edges to open grasslands with scattered small trees towards the center (Table 13). Red alder occurs with Douglas fir and lodgepole pine in areas extending south from the road resulting in a denser canopy.

Table 13. Stand AC-11 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Bitter cherry	7.5	2.6	0.3	0.3
Douglas-fir	77.5	7.7	61.6	68.3
Lodgepole pine	72.5	5.7	18.4	20.4
Red alder	57.5	5.4	9.9	10.9
TOTAL	215.0	6.2	90.1	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

In spatially irregular stands, such as these, average predictions have limited usefulness. Nevertheless, the model predictions may accurately predict future conditions for the dense parts of the stand. These areas will likely undergo some degree of density-dependent mortality and height stratification patterns in the future (Figure 14).

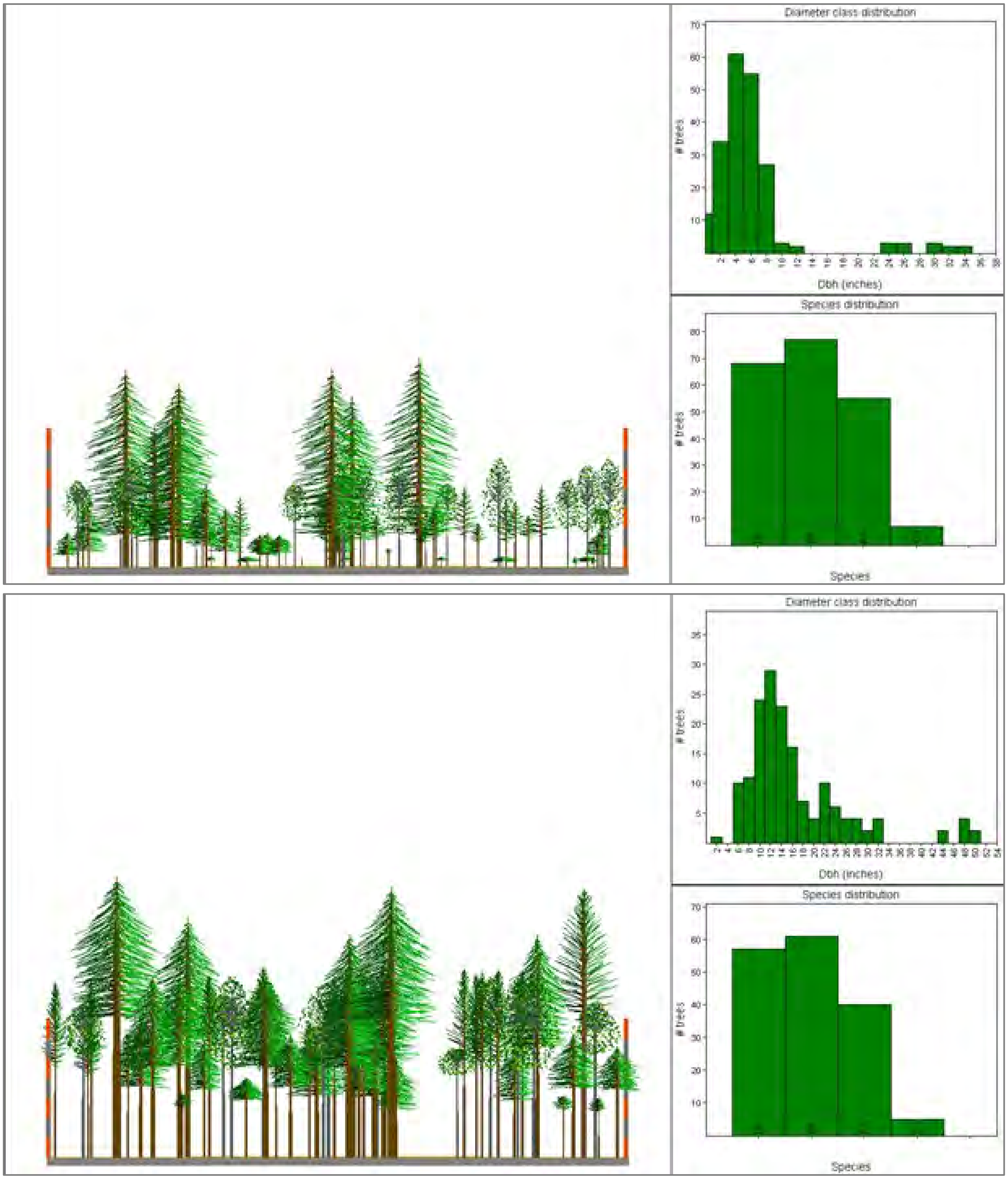


Figure 14. Stand AC-11 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-12

This is the smallest stand at American Camp and its overstory is dominated by mature, spaced Douglas-fir trees with some grand fir trees in the lower strata (Table 14). While it might appear that this stand is as an extension of the stand AC-11, but there are important differences in stand age and species composition. Stand 12 is almost 60 years older than stand 11, and lodgepole and red alder are not important components of this stand.

Table 14. Stand AC-12 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	139.9	17.0	266.3	93.3
Grand fir	36.6	5.5	19.0	6.6
TOTAL	176.5	14.6	285.3	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

As the composition of this stand will remain unaffected, the different growth patterns of the two species will result in a reduction of the size and height differences as grand fir moves into the upper canopy (Figure 15).

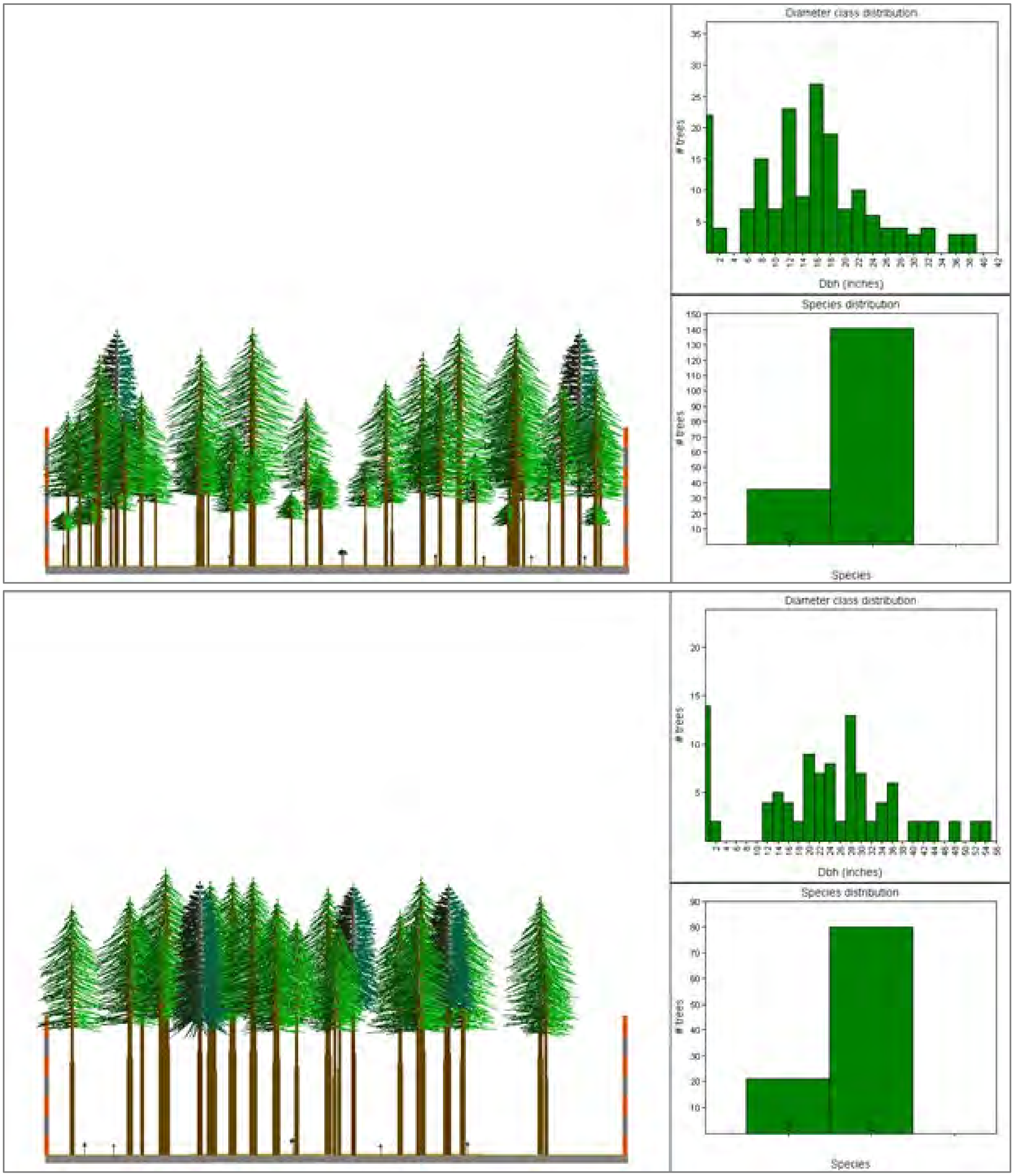


Figure 15. Stand AC-12 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-13

Stand AC-13 is composed of a medium-to-low density Douglas-fir overstory with some lodgepole pine (Table 15). Although this stand is fairly uniform in the overstory, some changes in understory occur as one moves from the northern Park boundary toward stand AC-15.

Table 15. Stand AC-13 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	126.1	15.7	203.5	83.1
Lodgepole pine	43.3	12.5	40.9	16.7
Other species	3.3	4.7	0.4	0.2
TOTAL	172.7	14.7	244.8	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

The model predicted this spatially homogeneous stand will not undergo substantial structure changes in the next 60 years. Nevertheless, as the younger stand AC-15 develops, new trees may colonize the stand's southern boundary providing some structural complexity (Figure 16).

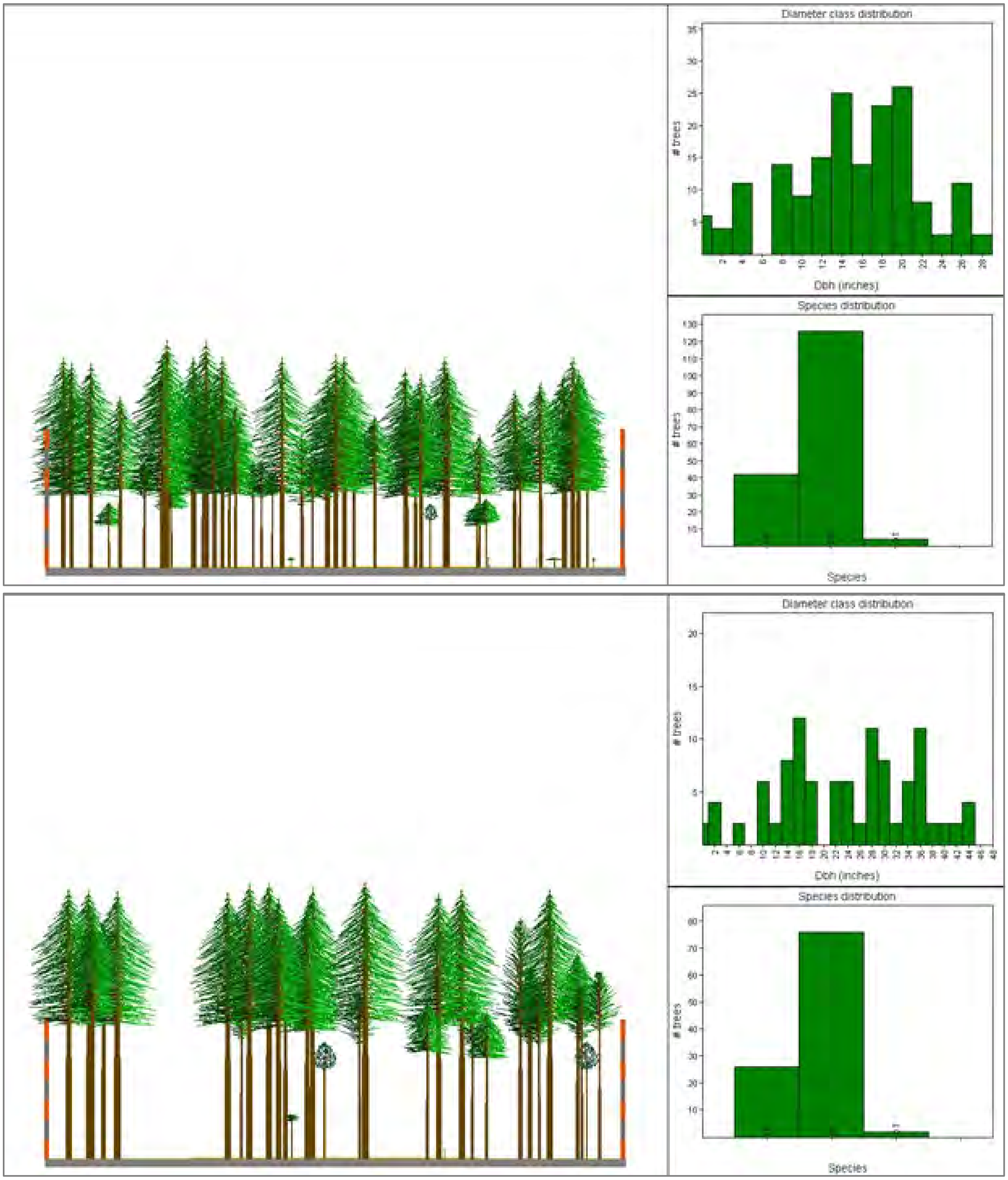


Figure 16. Stand AC-13 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-14

This stand represents the western boundary of the American Camp and is perhaps the stand with the most anthropogenic influence as it surrounded by multiple neighbors. This stand has substantial spatial variation in terms of structure and species composition (Table 16). Old Douglas-fir trees (> 100 years) dominate the overstory. Most of the diversity of this stand is in the lower strata and the understory is composed of several broadleaf species of small trees.

Table 16. Stand AC-14 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	55.0	16.3	90.1	70.5
Grand fir	10.0	7.1	4.7	3.7
Lodgepole pine	2.5	19.4	5.1	4.0
Other species	97.5	5.7	22.5	17.6
Red alder	27.5	4.7	4.2	3.3
Willow	12.5	4.0	1.2	0.9
TOTAL	205.0	8.5	127.8	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Since this stand includes great spatial variability, future stand development will vary significantly and will depend on the spatial arrangement and the life span of the species in the understory (Figure 17).

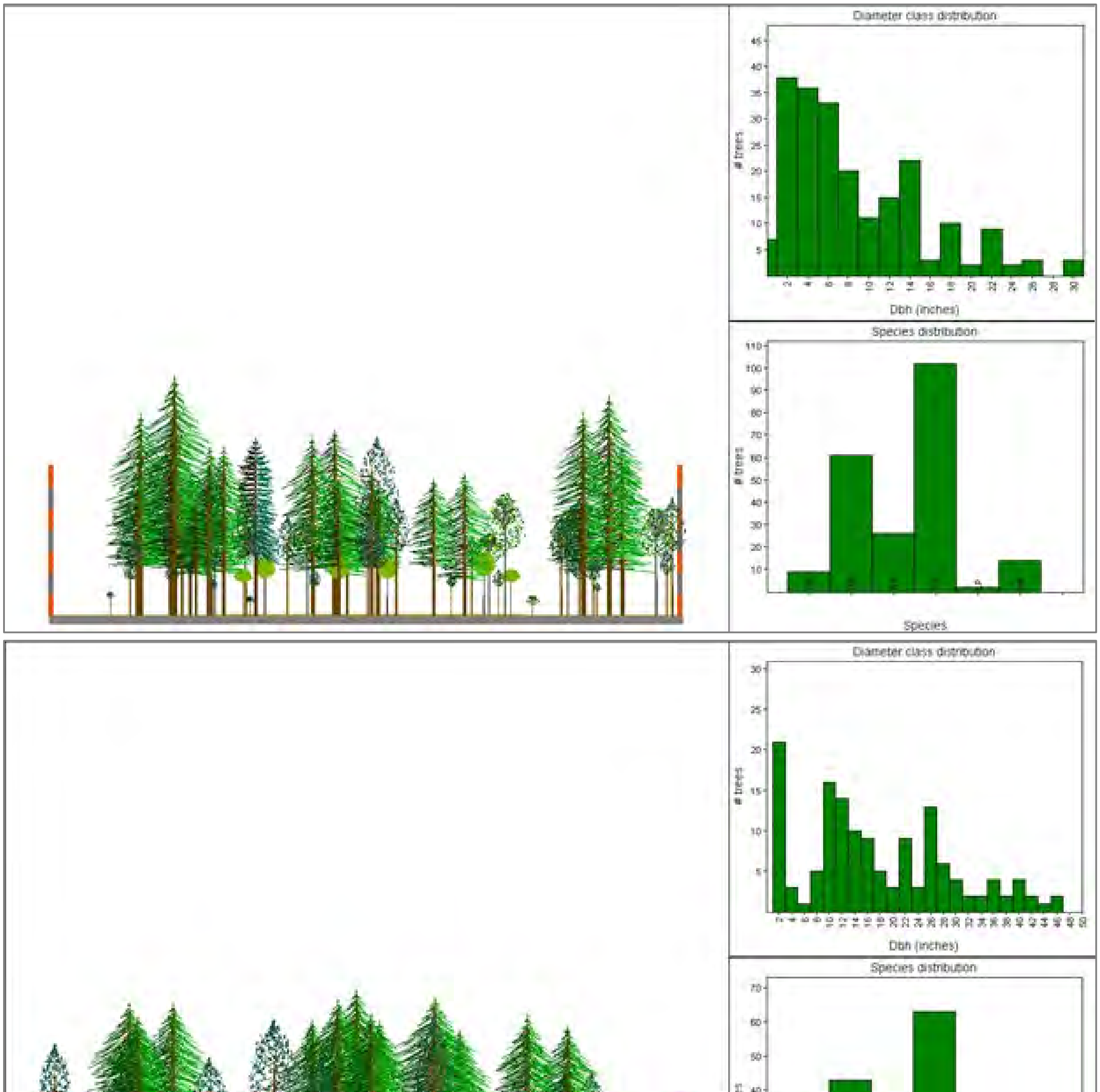


Figure 17. Stand AC-14 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand AC-15

Stand AC-15 represents the interface of the forest and the grasslands in the western part of the American Camp. In this stand, young (~30 years old) lodgepole pine and Douglas-fir are colonizing the grassland with an irregular spatial pattern (Table 17).

Table 17. Stand AC-15 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	220.0	2.5	13.5	34.3
Lodgepole pine	296.0	2.4	21.3	54.4
Red alder	16.0	6.7	4.5	11.4
TOTAL	532.0	2.6	39.2	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Over the next sixty years, older tree clumps will continue to grow and recruitment of new trees will continue resulting in more trees in the larger diameter classes, but no substantial changes in species composition (Figure 18).

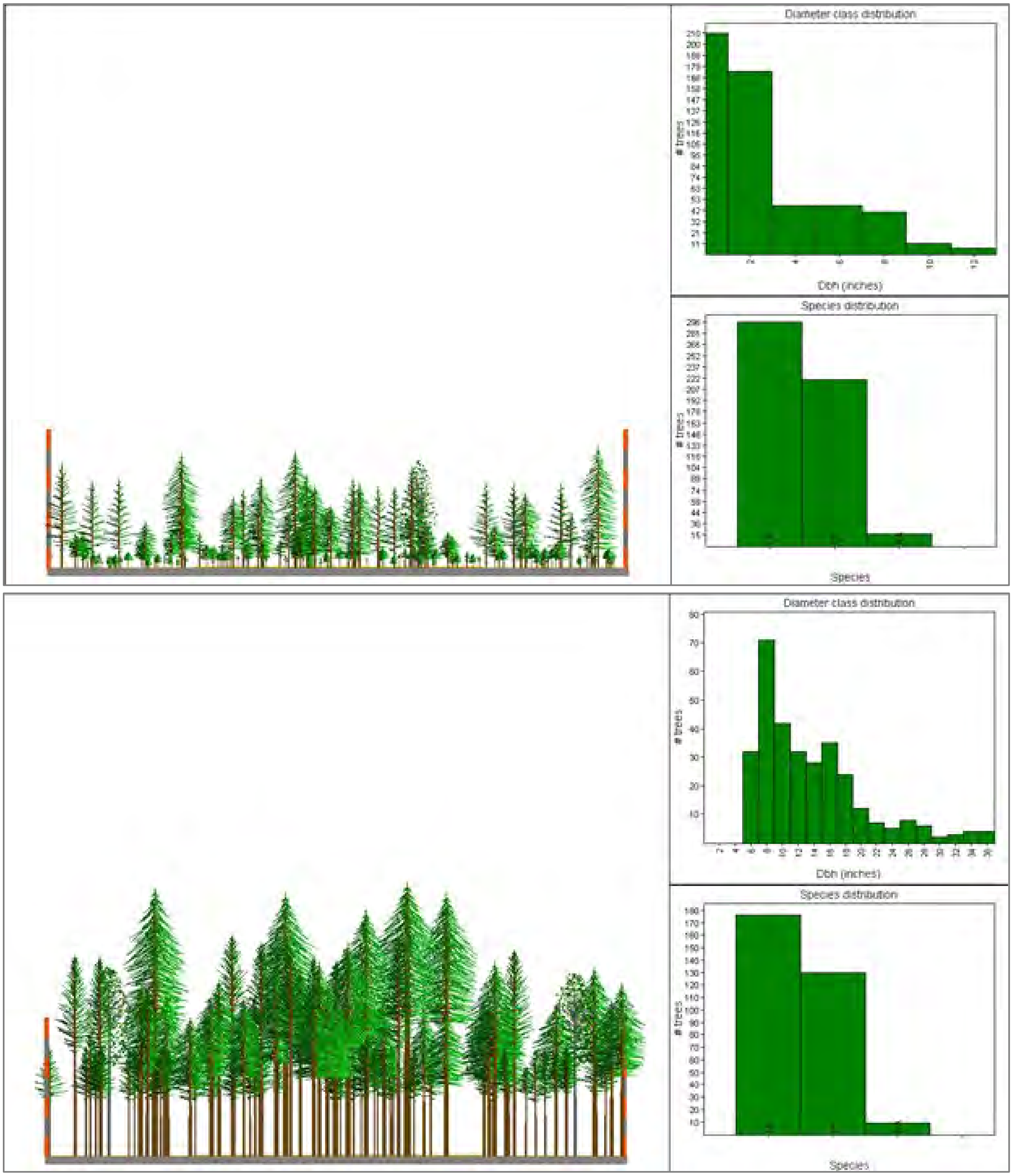


Figure 18. Stand AC-15 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-1

Stand EC-1 represents the most heterogeneous stand in the Park both in terms of species composition and spatial distribution. The average stand composition, summarized in the Table 18, provides a good representation of the general matrix, an overstory mainly composed by Douglas-fir with groups of red alder trees. Nevertheless, proportions and sizes varied greatly among plots as did the importance of other species. While the establishment date of this stand might have been more than 100 years ago, a wide distribution in ages exists.

Table 18. Stand EC-1 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	2.4	4.2	0.2	0.1
Black cottonwood	1.2	1.7	0.0	0.0
Douglas-fir	356.4	7.1	151.1	80.0
Grand fir	7.1	2.2	0.2	0.1
Lodgepole pine	4.7	14.5	5.7	3.0
Pacific yew	1.2	5.9	0.2	0.1
Red alder	88.5	6.1	27.3	14.4
Western red cedar	15.3	3.4	4.1	2.2
TOTAL	476.7	6.7	188.8	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

The model predicts an important change in the structure of the stand. In 60 years, although there will still be recruitment as seen in in the large number of trees in the 2” diameter class, a large number of trees will have moved from the 4-10” diameter into the 12-26” diameter and canopy structure will become more uniform and closed (Figure 19).

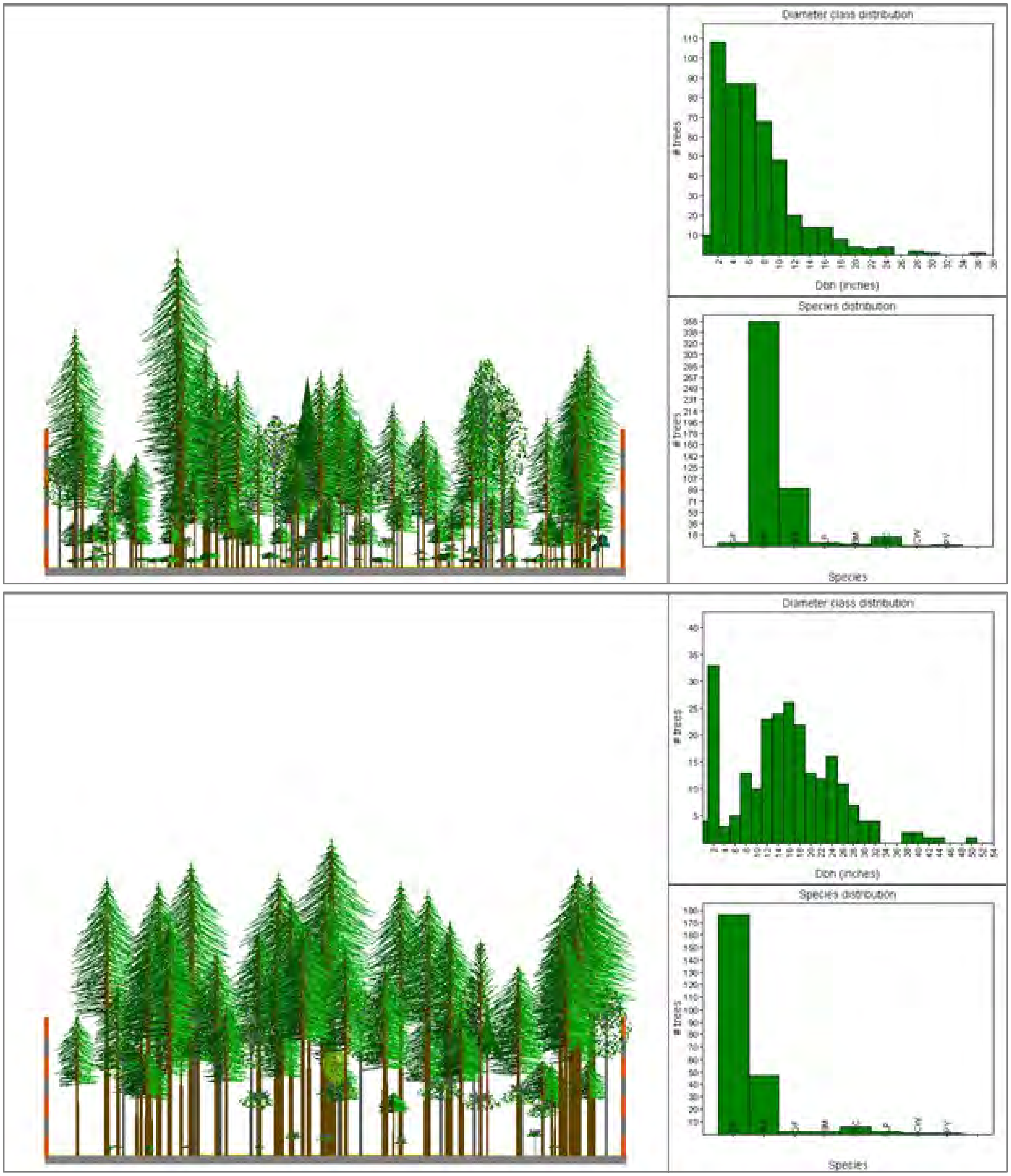


Figure 19. Stand EC-1 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-2

Although stand EC-2 originated at the same time stand EC-1 did and has similar site conditions, it developed very uniformly and has a pure Douglas-fir overstory and a modal diameter distribution (Table 19).

Table 19. Stand EC-2 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	2.0	11.1	1.3	0.5
Douglas-fir	234.0	13.2	276.7	93.7
Grand fir	6.0	2.4	0.2	0.1
Pacific yew	2.0	1.7	0.0	0.0
Western red cedar	24.0	6.4	9.0	3.0
Pacific madrone	10.0	12.0	8.1	2.8
TOTAL	278.0	12.2	295.4	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

No major changes in composition and structure are expected for the next 60 years, but a gradual growth of the trees to larger diameter classes (Figure 20).

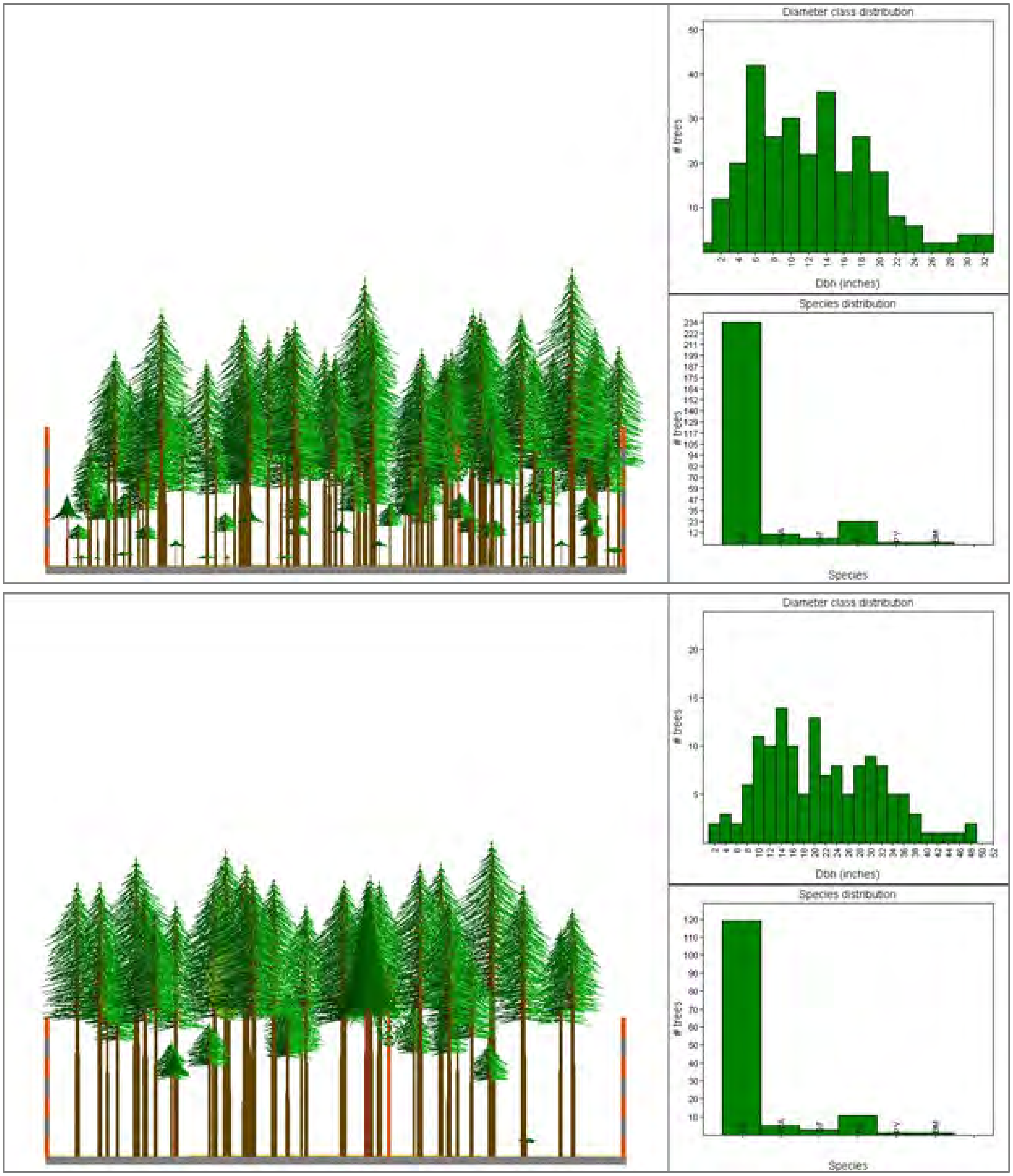


Figure 20. Stand EC-2 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-3

Stand EC-3 represents the largest stand type in the English Camp. It consists of a medium-to-low density Douglas-fir overstory with scattered red alder and pacific madrone trees, and some grand fir and western red cedar trees in lower diameter classes (Table 20). It is distributed in several areas of English Camp including Bell Point and part of the interface with the Garry oak ecosystem.

Table 20. Stand EC-3 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	4.0	4.8	0.8	0.3
Douglas-fir	172.0	13.1	201.9	83.4
Grand fir	21.0	5.4	5.2	2.2
Other species	17.0	14.6	21.3	8.8
Pacific yew	1.0	2.5	0.0	0.0
Red alder	1.0	14.3	1.1	0.5
Western red cedar	26.0	6.0	8.1	3.3
Pacific madrone	5.0	11.5	3.9	1.6
TOTAL	247.0	11.6	242.2	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

As this stand type has a large geographic distribution, modeling future conditions is more complicated. In general, the model predicts that the current stand structure will become more homogenous as some of the smaller trees grow into the upper canopy. This will represent a moderate change in the diameter distribution (Figure 21).

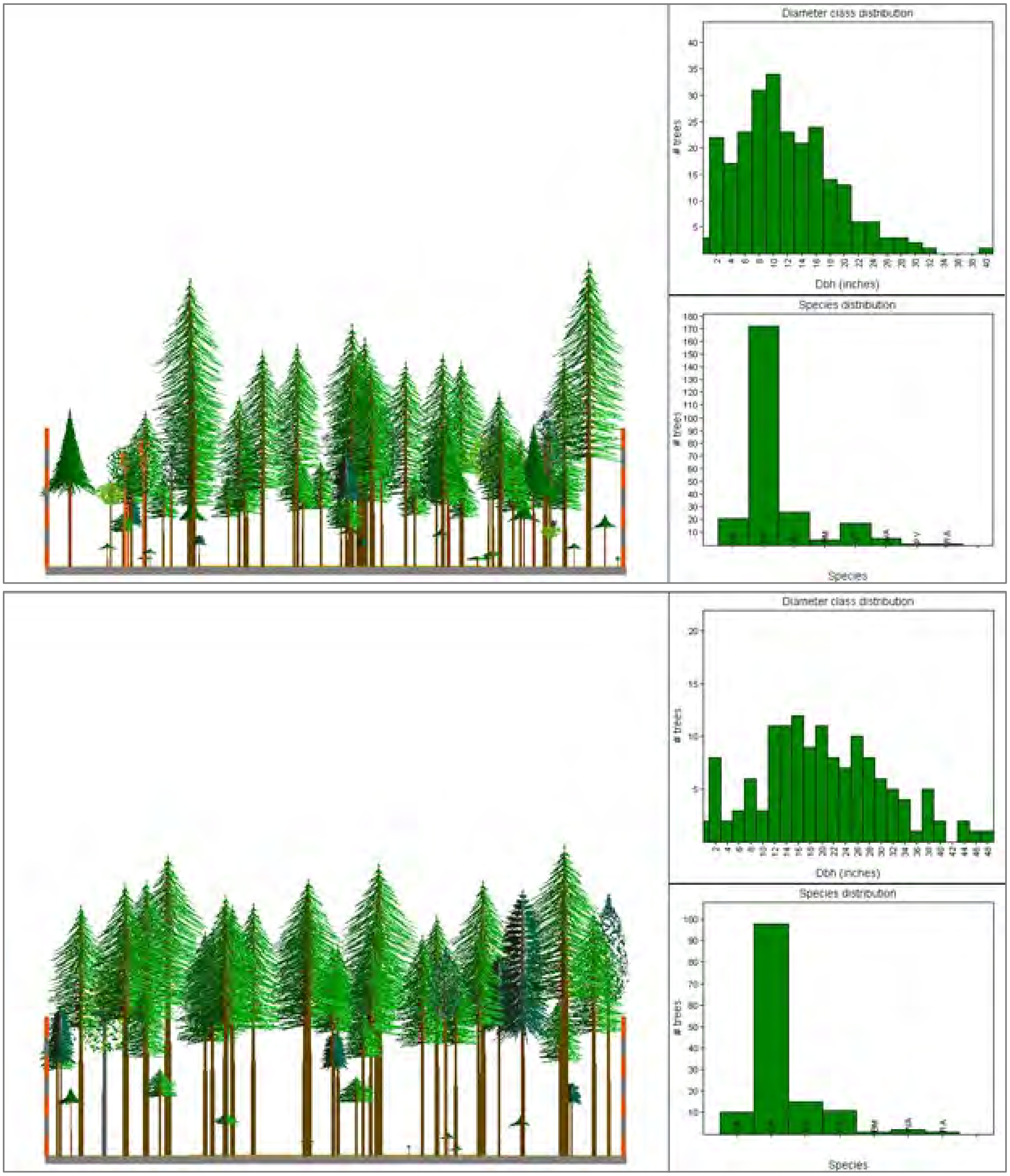


Figure 21. Stand EC-3 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-4

This is a very small and dense stand composed of young Douglas-fir trees (~ 50 years old) with some scattered red alder and lodgepole pine trees in the upper stratum (Table 21). This stand differs from older adjacent stands (i.e., EC-10 and 6) with larger diameter trees and this may reflect recent activity in the Park such as logging or land clearing.

Table 21. Stand EC-4 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	644.0	5.8	158.0	90.3
Grand fir	8.0	0.6	0.0	0.0
Lodgepole pine	4.0	16.3	5.8	3.3
Red alder	8.0	15.8	11.1	6.4
TOTAL	664.0	5.9	174.9	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

The model predicts a gradual movement of Douglas-fir into larger diameter classes and a decrease in density as the stand undergoes density-dependent mortality. Additionally, it is expected that red alder will lose its importance in the upper part of the canopy (Figure 22).

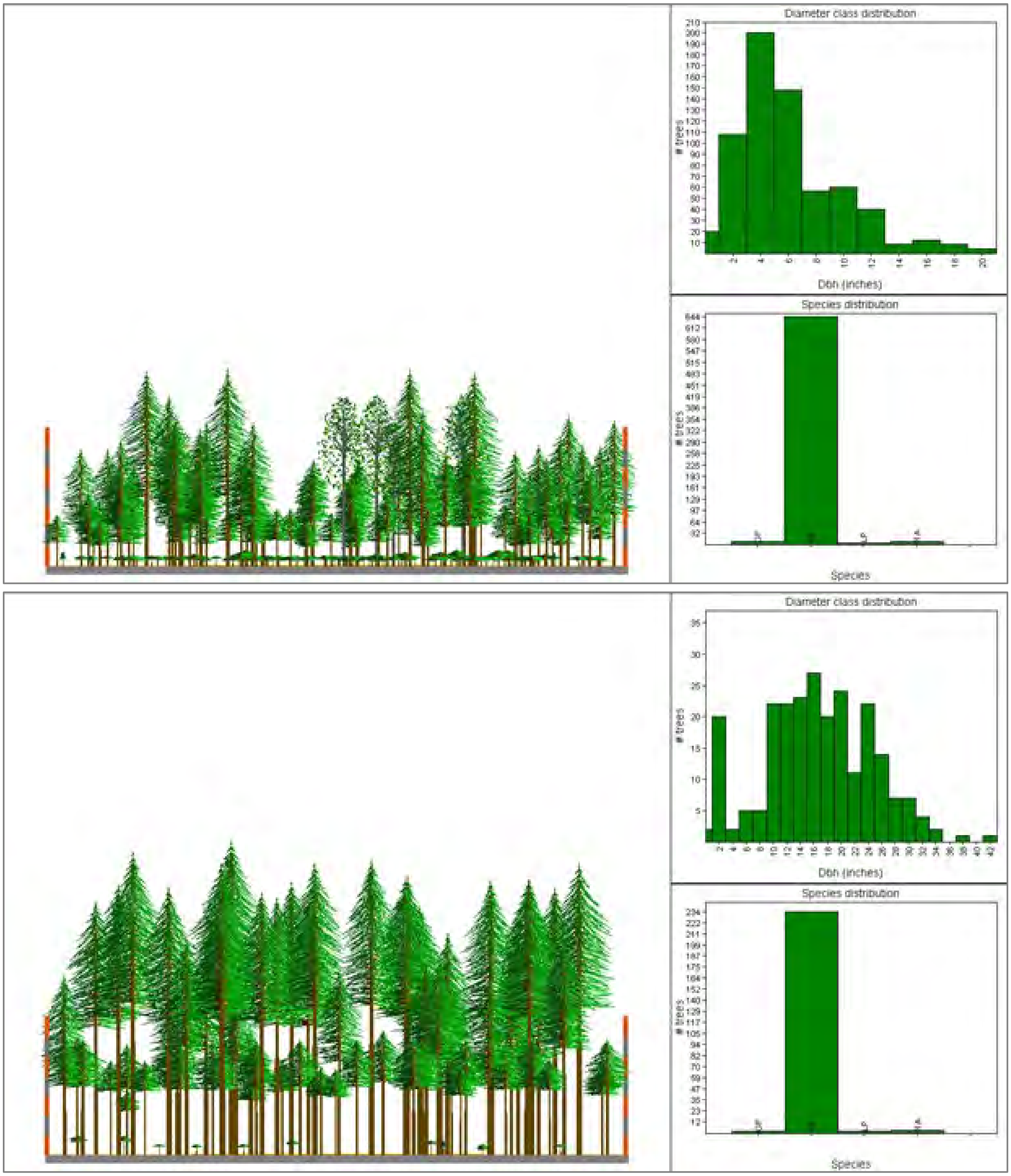


Figure 22. Stand EC-4 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-5

Stand EC-5 originated at the same time stand as EC-4 and might have been subject to the same disturbance or anthropogenic activity. However, EC-5 differs from EC-4 in that its overstory is composed purely of red alder and it has lower overall tree density (Table 22). While this stand has numerous Douglas-fir, due to their small they do not comprise much of the basal area.

Table 22. Stand EC-5 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	106.6	3.4	10.6	5.9
Grand fir	13.3	1.2	0.2	0.1
Other species	2.2	3.7	0.2	0.1
Red alder	262.0	10.6	167.8	93.3
Western red cedar	17.8	2.6	1.1	0.6
TOTAL	401.8	8.0	179.8	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

While some mortality is expected for the next 60 years as the stand develops, it will not be as pronounced as that in stand EC-4 (Figure 23).

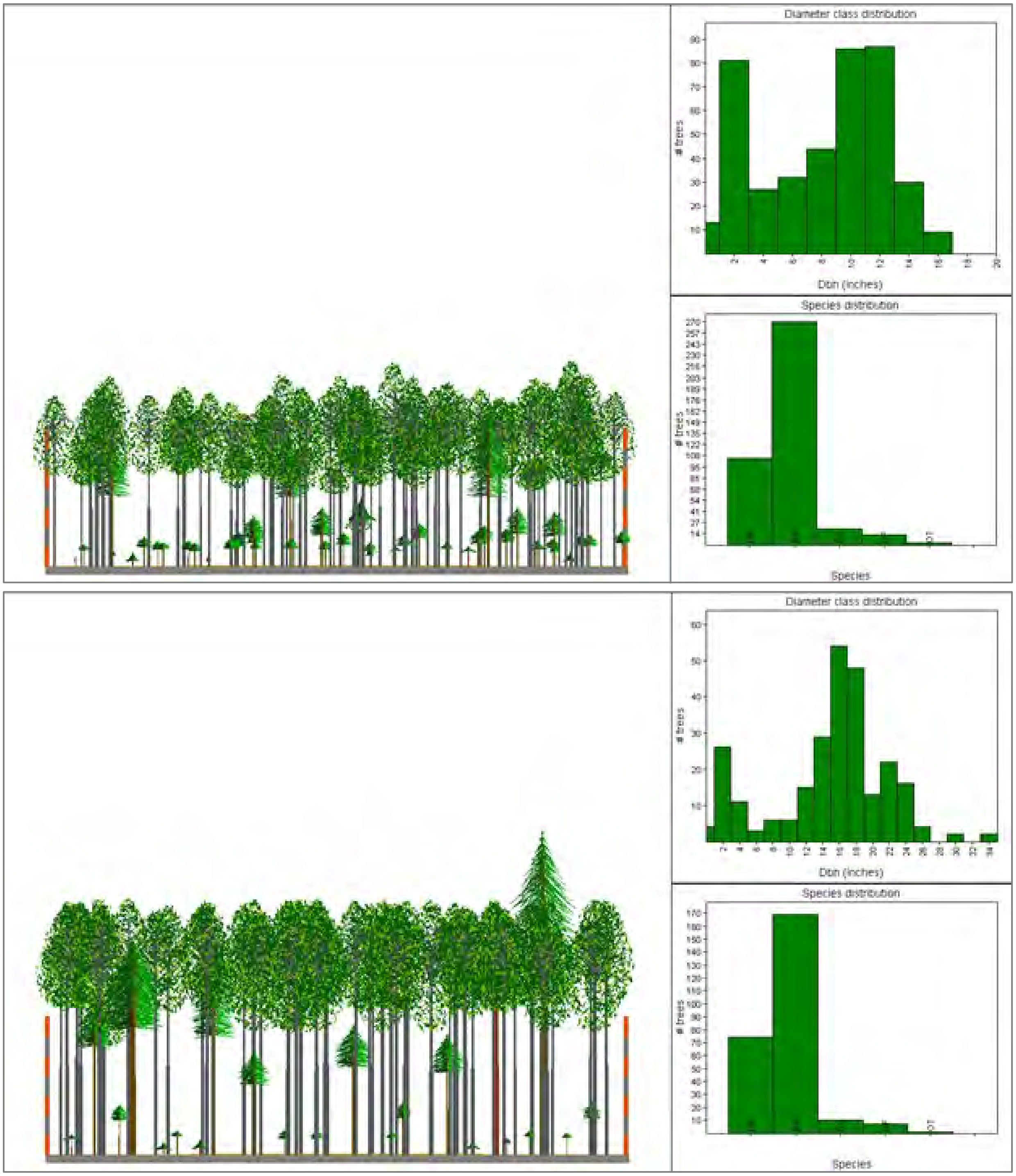


Figure 23. Stand EC-5 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-6

Stand EC-6 is another small stand at English Camp composed of large and mature Douglas-fir trees (Table 23). Pacific madrone trees are mixed in the overstory in some areas as well as small subcanopy western red cedar trees.

Table 23. Stand EC-6 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	243.1	14.8	351.9	95.5
Grand fir	3.3	5.0	0.5	0.1
Western red cedar	26.6	4.5	3.2	0.9
Pacific madrone	6.7	17.2	12.8	3.5
TOTAL	279.7	13.8	368.3	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Predictions for the next 60 years suggest height differentiation among species as the range of diameters will increase; no significant recruitment is forecast (Figure 24).

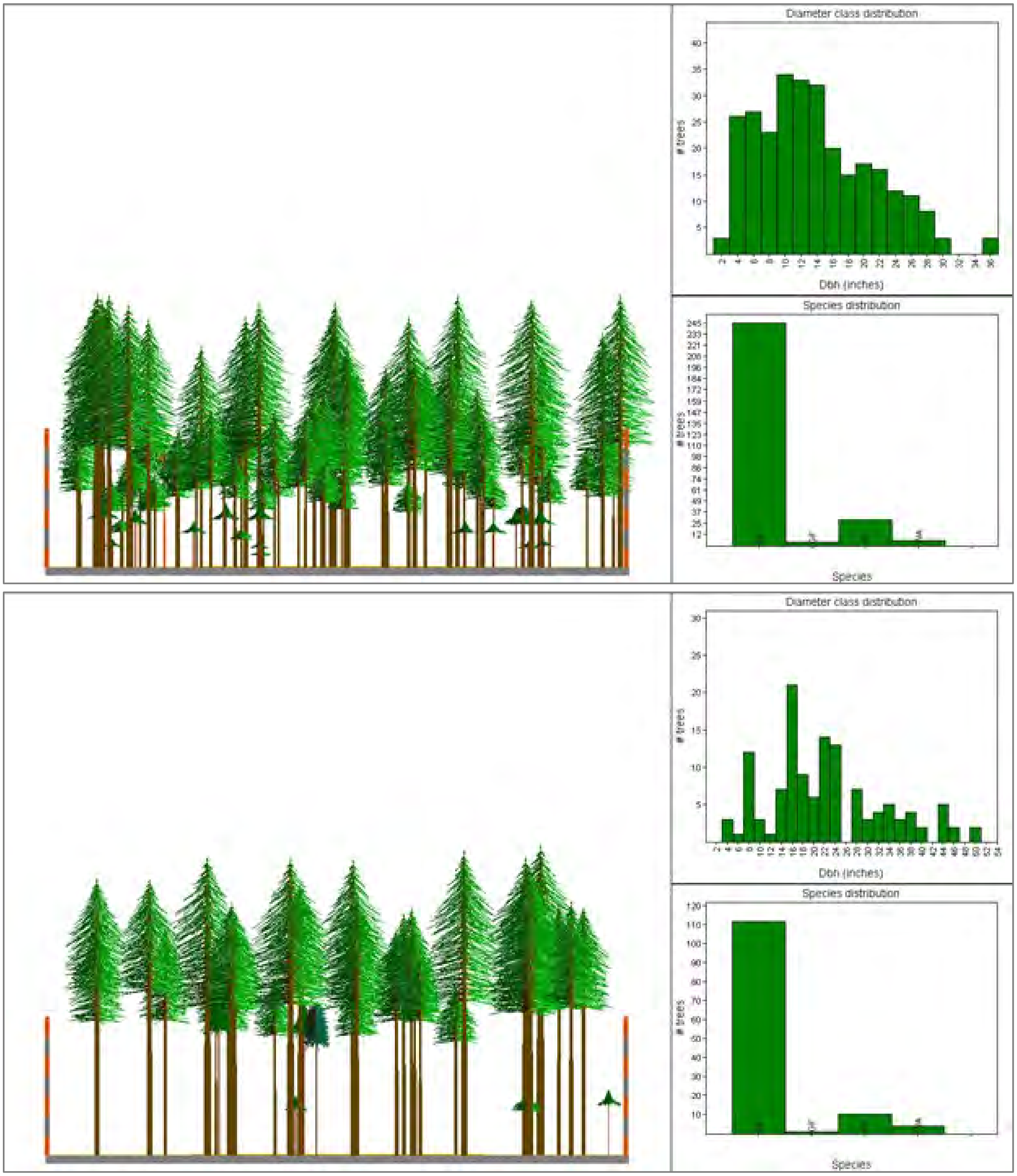


Figure 24. Stand EC-6 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-7

Stand EC-7 originated at the same time as stand EC-6with the resulting same overstory dominance (Douglas-fir), but there are more species richness in the lower canopy (Table 24). However, it regenerated at a higher density having presently 34% more trees and 50% of the basal area of stand

EC-6. The overstory of this stand is uniform in terms of species composition but there is a significant variability in the size of the trees. There are also minor components of other species both in the overstory and understory.

Table 24. Stand EC-7 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	315.0	6.9	171.1	91.2
Grand fir	32.5	0.7	0.1	0.1
Lodgepole pine	7.5	11.2	7.5	4.0
Red alder	15.0	7.3	5.1	2.7
Pacific madrone	2.5	16.6	3.8	2.0
Western juniper	2.5	0.9	0.0	0.0
TOTAL	375.0	6.5	187.5	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Future stand development will include more vertical stratification and a reduction in the number of trees in the smaller diameter classes (Figure 25).

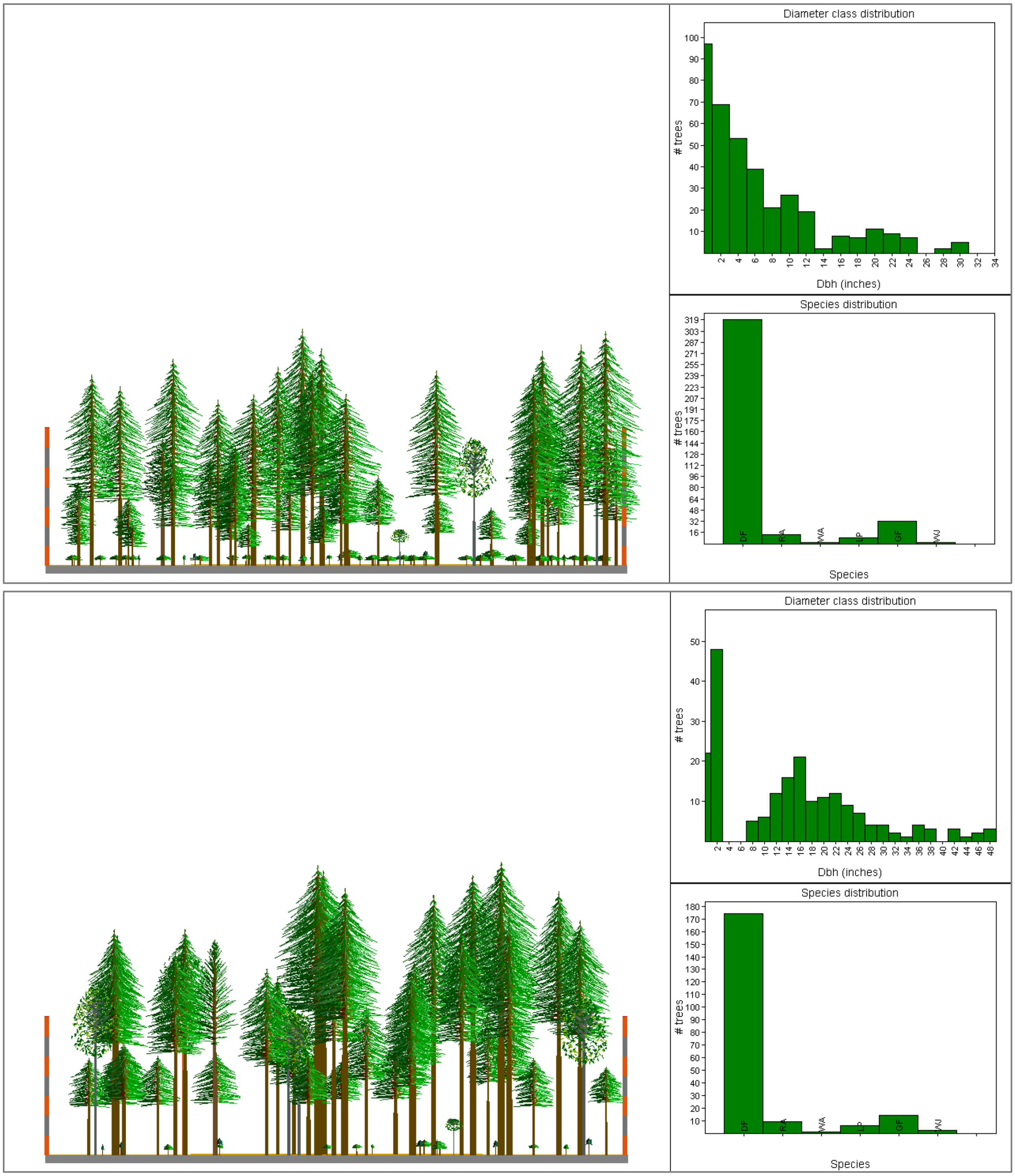


Figure 25. Stand EC-7 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-8

Stand EC-8 is a long strip of young forest that could have originated at the same time as stands EC-4 and EC-5. It is mainly composed by an overstory of Douglas-fir with a small proportion of grand fir in the understory (Table 25). This stand has a considerable spatial variation with higher densities in its northern part of the stand.

Table 25. Stand EC-8 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	313.0	7.6	130.9	92.8
Grand fir	33.3	1.8	0.8	0.6
Lodgepole pine	6.7	10.9	6.6	4.7
Red alder	3.3	12.4	2.8	2.0
TOTAL	356.3	7.2	141.1	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Similar to the other young stands at English Camp, it is expected that the diameter distribution will change to a more uniform, unimodal distribution as the stand develops and density-dependent mortality occurs (Figure 26).

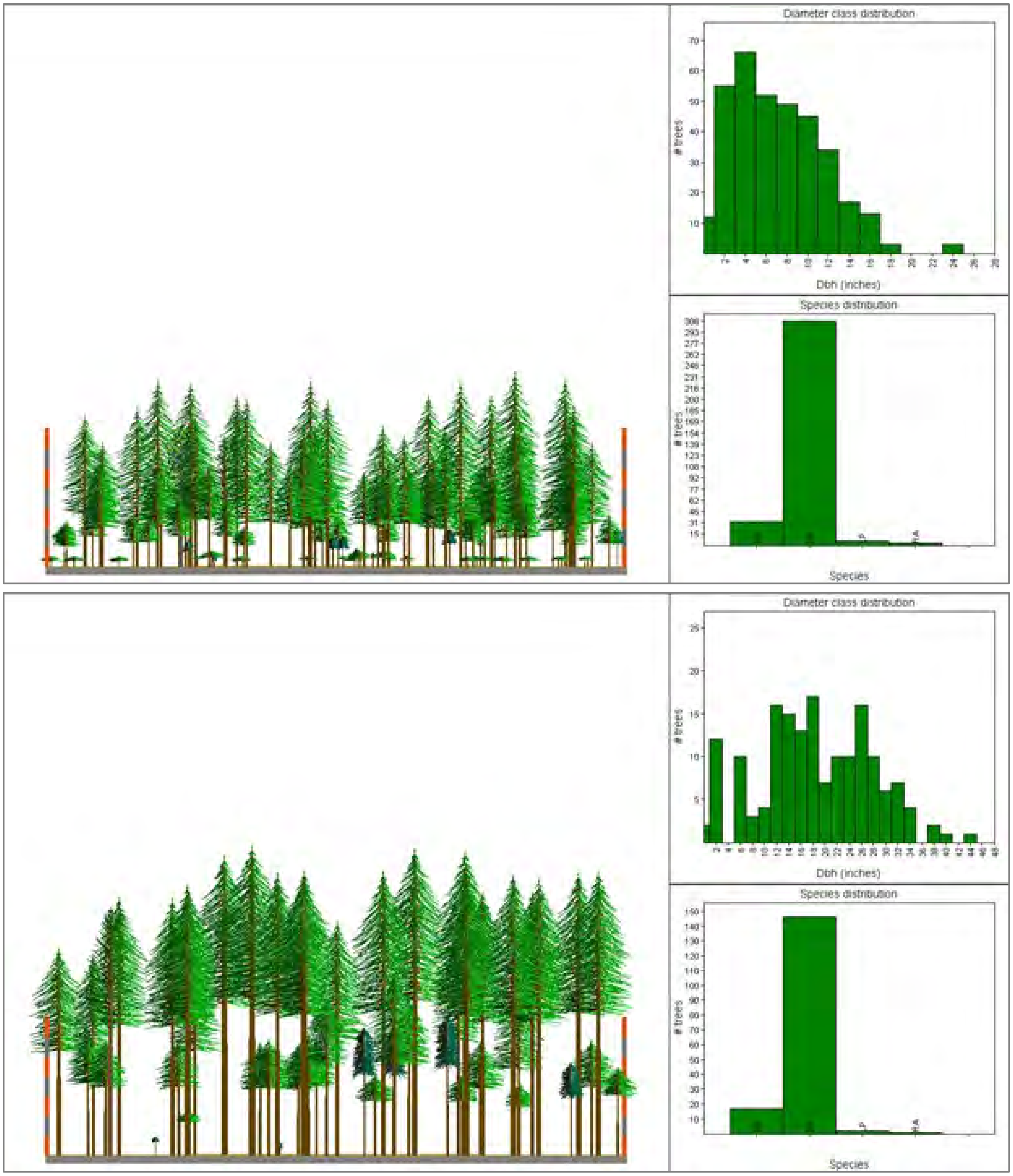


Figure 26. Stand EC-8 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-9

Stand EC-9 is very similar in composition and structure to stand EC-7 with the only difference that has developed into a more open forest (Table 26). More shade tolerant species such as grand are present in smaller proportions occupying lower position in the canopy.

Table 26. Stand EC-9 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	163.2	13.9	227.3	91.6
Grand fir	23.3	9.4	15.7	5.5
Other species	13.3	6.1	3.5	1.2
Western red cedar	6.7	7.4	2.0	0.7
TOTAL	206.5	12.7	248.4	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

No major changes were forecast for this stand, but a gradual growth of the trees into larger diameter classes (Figure 27).

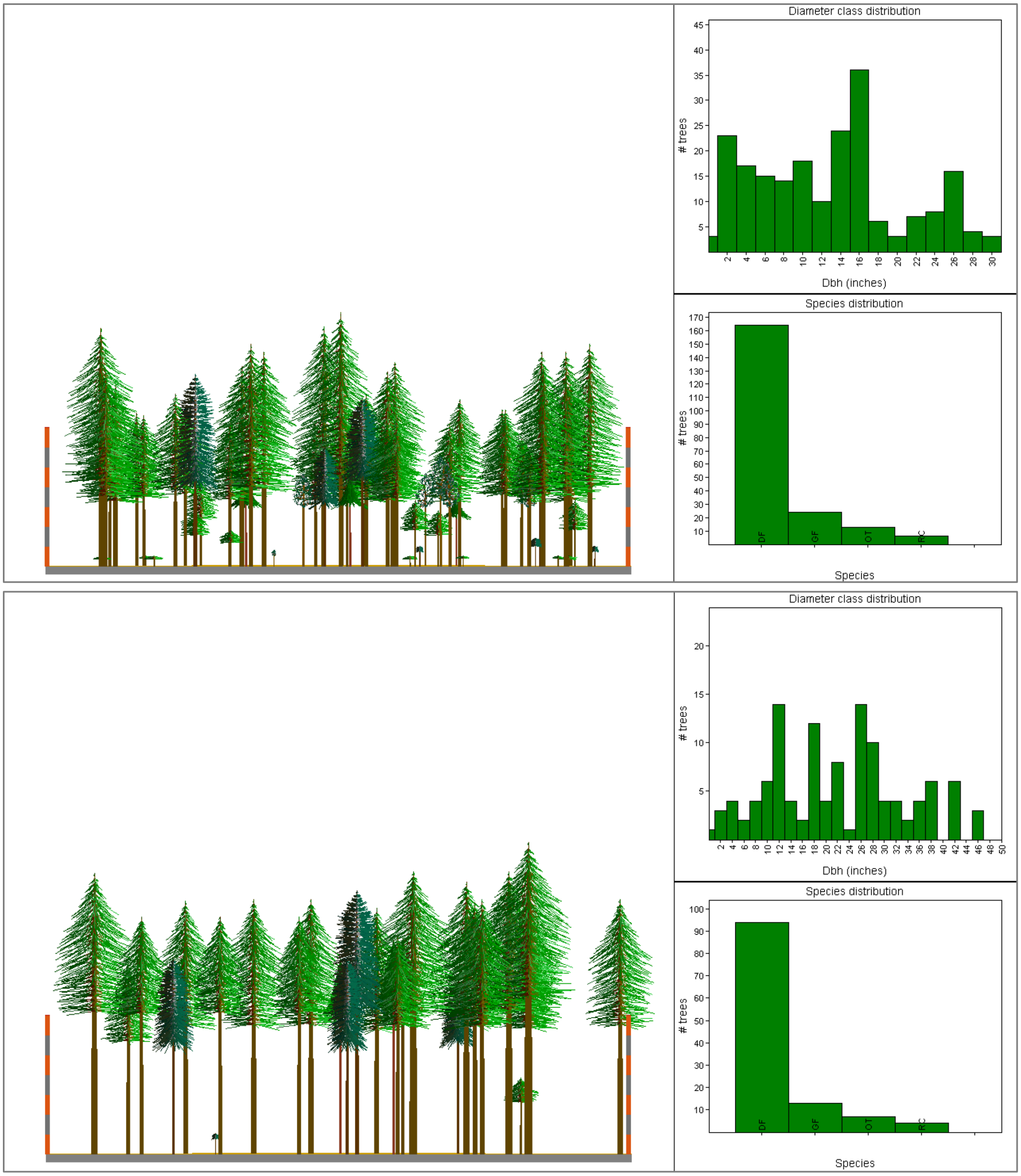


Figure 27. Stand EC-9 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-10

Stand EC-10 originated about 100 years ago and is dominated by Douglas-fir in the overstory and Grand fir in the understory (Table 27). Today, both species vary considerably in diameter and height.

Table 27. Stand EC-10 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	148.0	13.6	209.4	92.1
Grand fir	132.0	4.1	18.1	7.9
TOTAL	280.0	9.1	227.5	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

The model predicted that while the stand will maintain a stratified structure, some smaller trees will start reaching the overstory and increase in size as reflected by the changes in the diameter distribution (Figure 28).

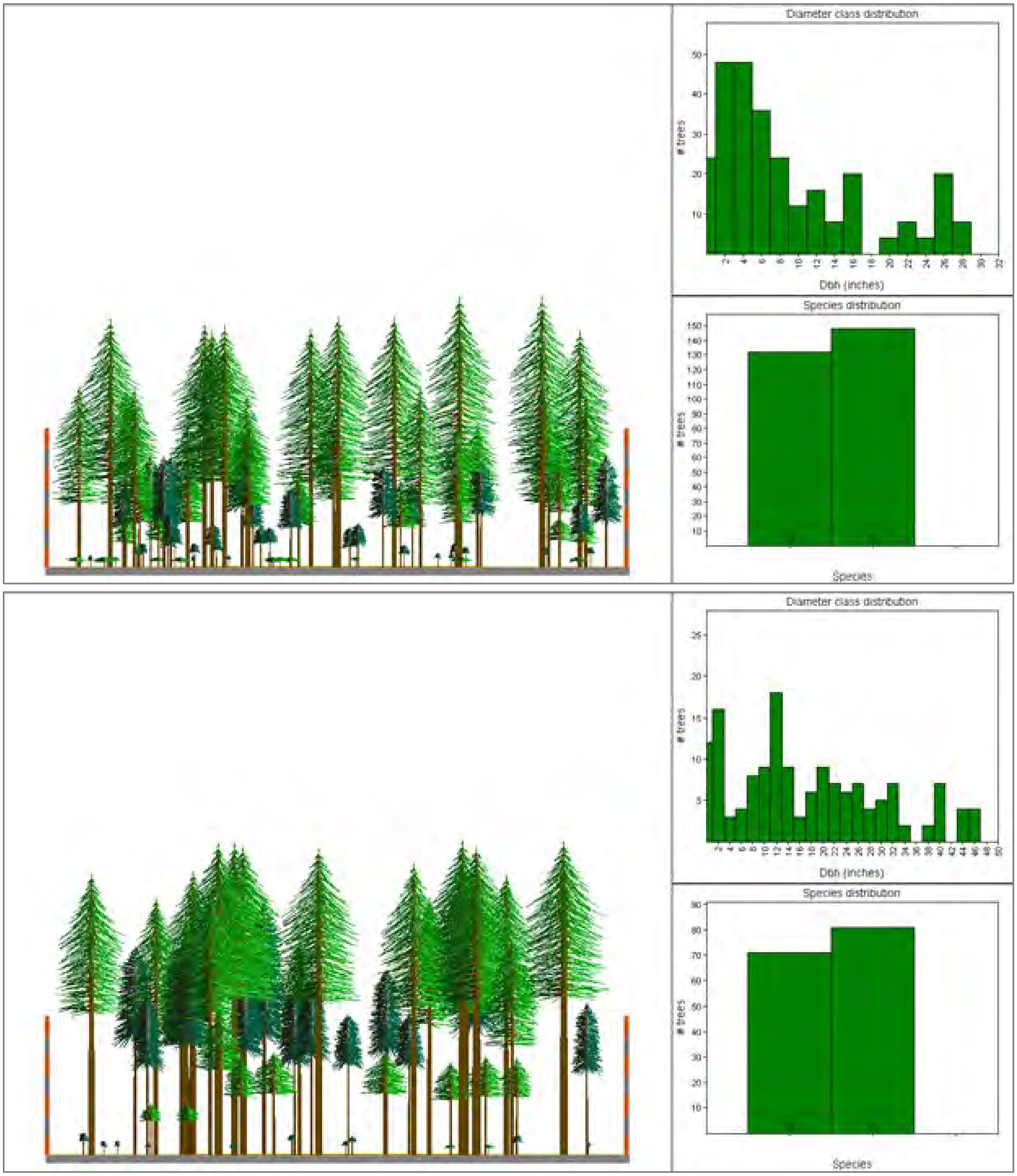


Figure 28. Stand EC-10 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-11

This narrow strip of forest differs from the surrounding stands due to its variability in species composition and stand structure (Table 28). While in some parts of this stand Douglas-fir is the dominant species in the overstory, in other areas, big leaf maple and pacific madrone occur in the overstory. More shade tolerant species such as grand fir and western red cedar, while smaller in size, are also present in subcanopy positions and dominate the lower diameter classes.

Table 28. Stand EC-11 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	17.2	13.3	20.3	7.3
Douglas-fir	68.6	18.5	151.7	55.0
Grand fir	77.2	8.8	47.8	17.3
Western red cedar	37.2	9.7	44.6	16.2
Pacific madrone	5.7	18.1	11.8	4.3
TOTAL	205.9	12.8	276.0	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

The model predicted that as species continue stratifying in height in this forest, no major changes are expected in the composition and structure. Nevertheless, there is important spatial variation that could lead to diverse patterns of development within the stand (Figure 29).

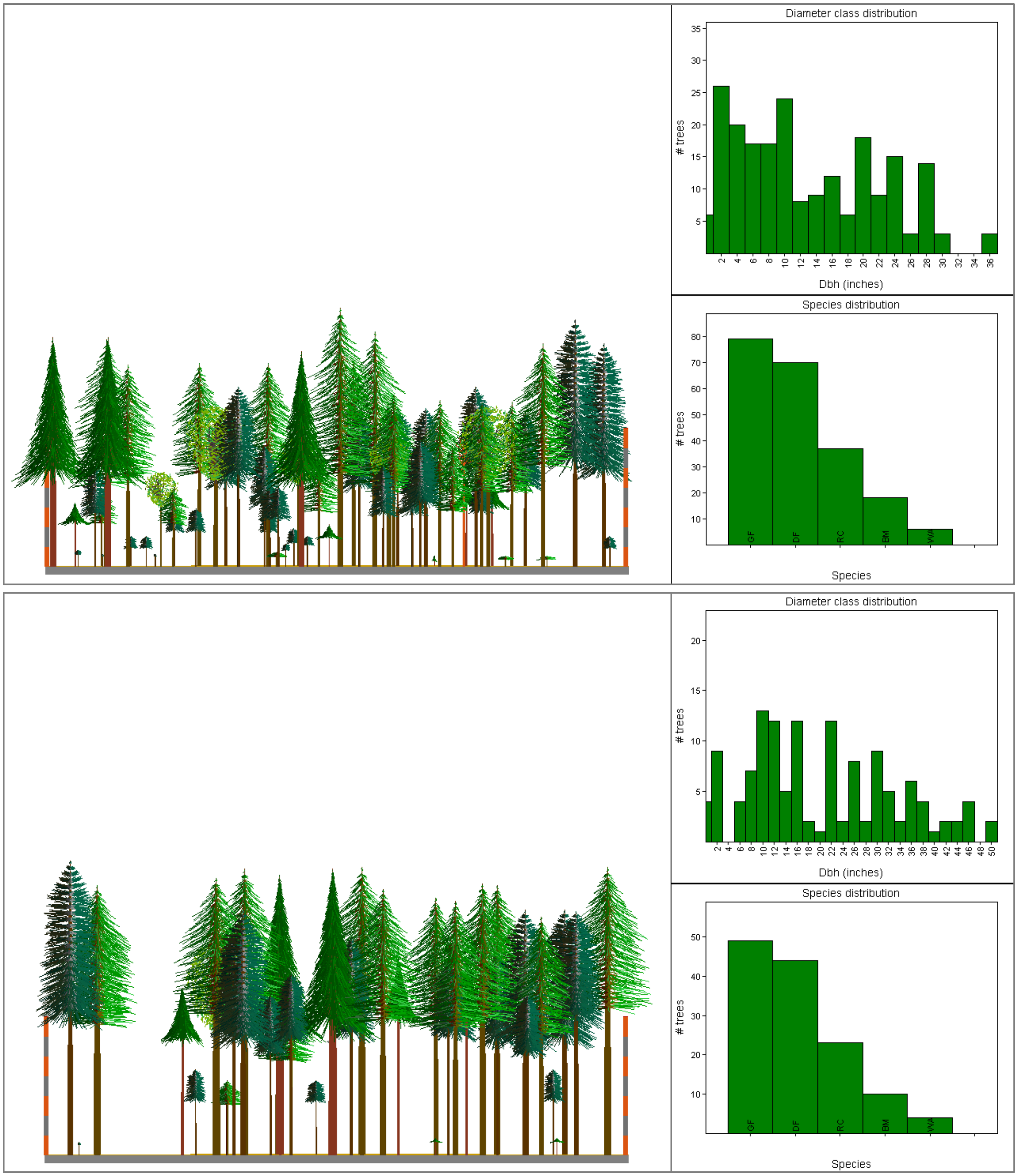


Figure 29. Stand EC-11 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-12

This stand has the lowest density among the stands at English Camp (Table 29). Douglas-fir shares the overstory with lesser amounts of red alder and big leaf maple. Due to the proximity to the original encampment, this stand might have been subject to logging or other human activity resulting in the variable current structure.

Table 29. Stand EC-12 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	5.7	13.7	9.4	5.7
Douglas-fir	71.5	14.1	103.4	62.5
Grand fir	11.4	4.8	1.9	1.2
Red alder	54.3	12.4	50.6	30.6
TOTAL	143.0	12.7	165.4	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

The outcomes of the model indicate that while some species will grow into upper parts of the canopy, this will not result in major changes in the stand structure (Figure 30).

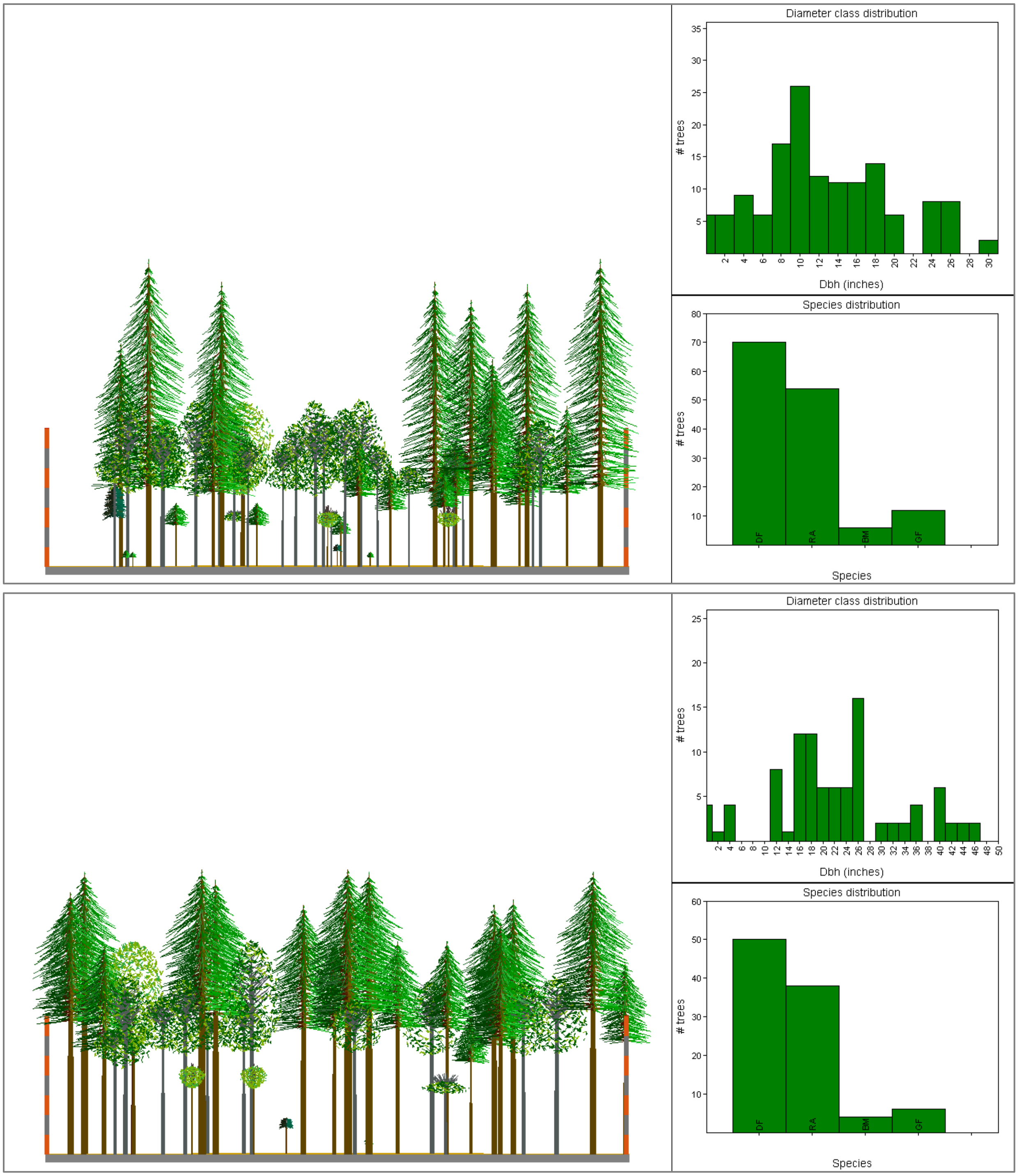


Figure 30. Stand EC-12 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-13

Stand EC-13 originated about 65-70 years ago and is characterized by a very low density (Table 30). The overstory is dominated by red alder with a few scattered big leaf maple trees. Stands EC-13, AC-8, and EC-5 are the only stands dominated by red alder in the Park.

Table 30. Stand EC-13 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	4.0	18.4	7.4	6.5
Red alder	88.0	14.3	106.4	93.5
TOTAL	92.0	14.5	113.8	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

While no major changes are be expected for this stand, the predictions for 60 years reveal an increase in the number of trees in the larger diameter classes (Figure 31).

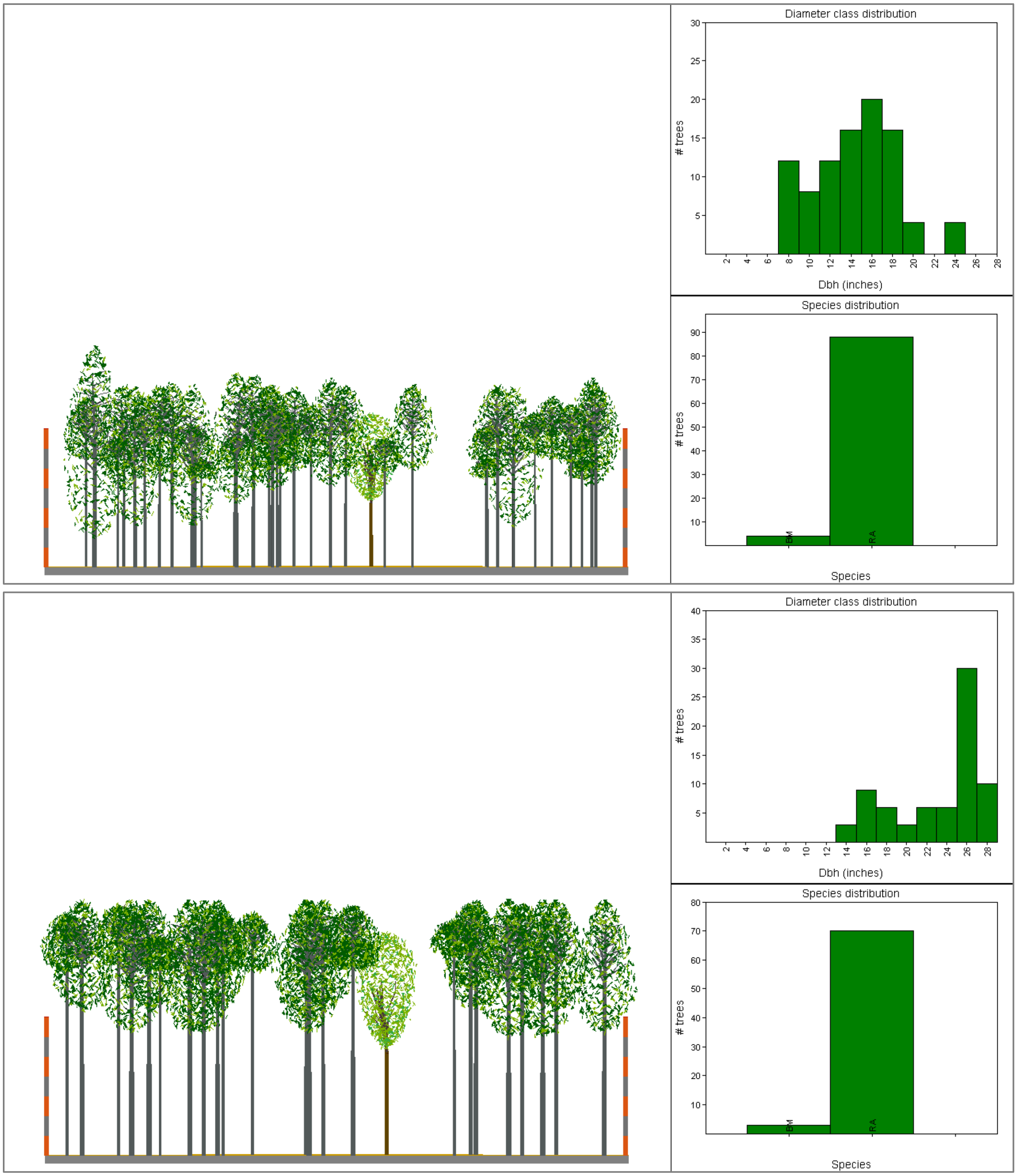


Figure 31. Stand EC-13 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-14

Stand EC-14 is the smallest stand at English Camp and it is located at the interface with the Garry oak ecosystem. It is composed of mature, well-spaced Douglas-fir trees and, as most stands in this area, originated more than 90 years ago (Table 31).

Table 31. Stand EC-14 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	215.0	14.5	273.0	96.4
Other species	10.0	13.5	10.1	3.6
TOTAL	225.0	14.5	283.2	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

No major changes in the stand structure are predicted as the stand develops (Figure 32).

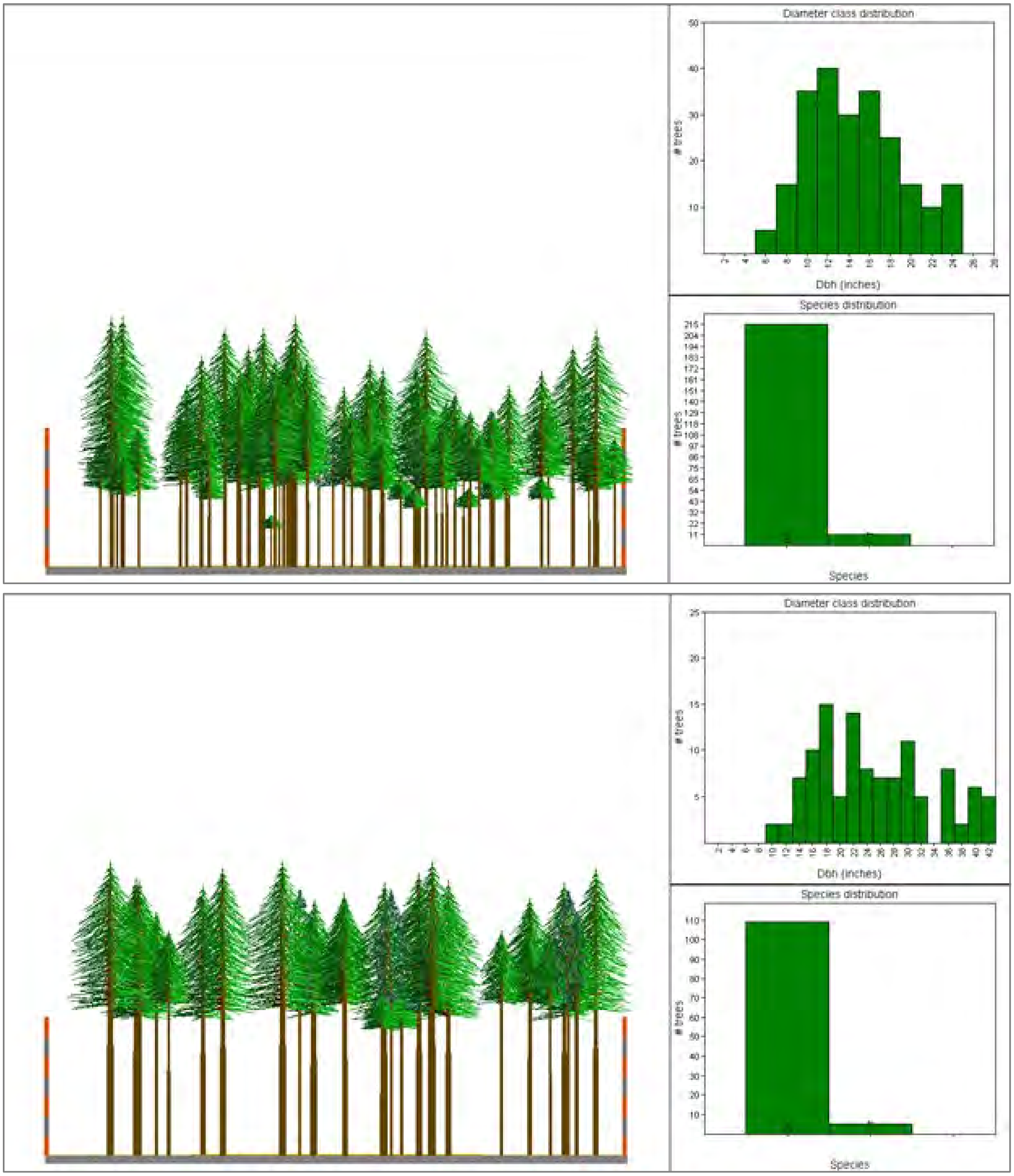


Figure 32. Stand EC-14 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-15

Stand EC-15, along with EC-11, is one of the most diverse stands in terms of species composition at English Camp (Table 32). Its old overstory (> 170 years) is dominated primarily by Douglas-fir but also contains grand fir and western red cedar trees in smaller proportions.

Table 32. Stand EC-15 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	5.0	15.3	6.7	2.1
Douglas-fir	85.0	17.4	181.2	56.1
Grand fir	35.0	16.1	73.7	22.8
Other species	15.0	6.2	3.1	1.0
Pacific yew	7.5	4.0	0.7	0.2
Red alder	7.5	11.2	5.3	1.6
Western red cedar	22.5	15.9	52.3	16.2
TOTAL	177.5	15.1	323.0	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

As vertical stratification in the canopy will continue over the next sixty years, the model also predicted a gradual increase in the number of trees in larger diameter classes and less recruitment (Figure 33).

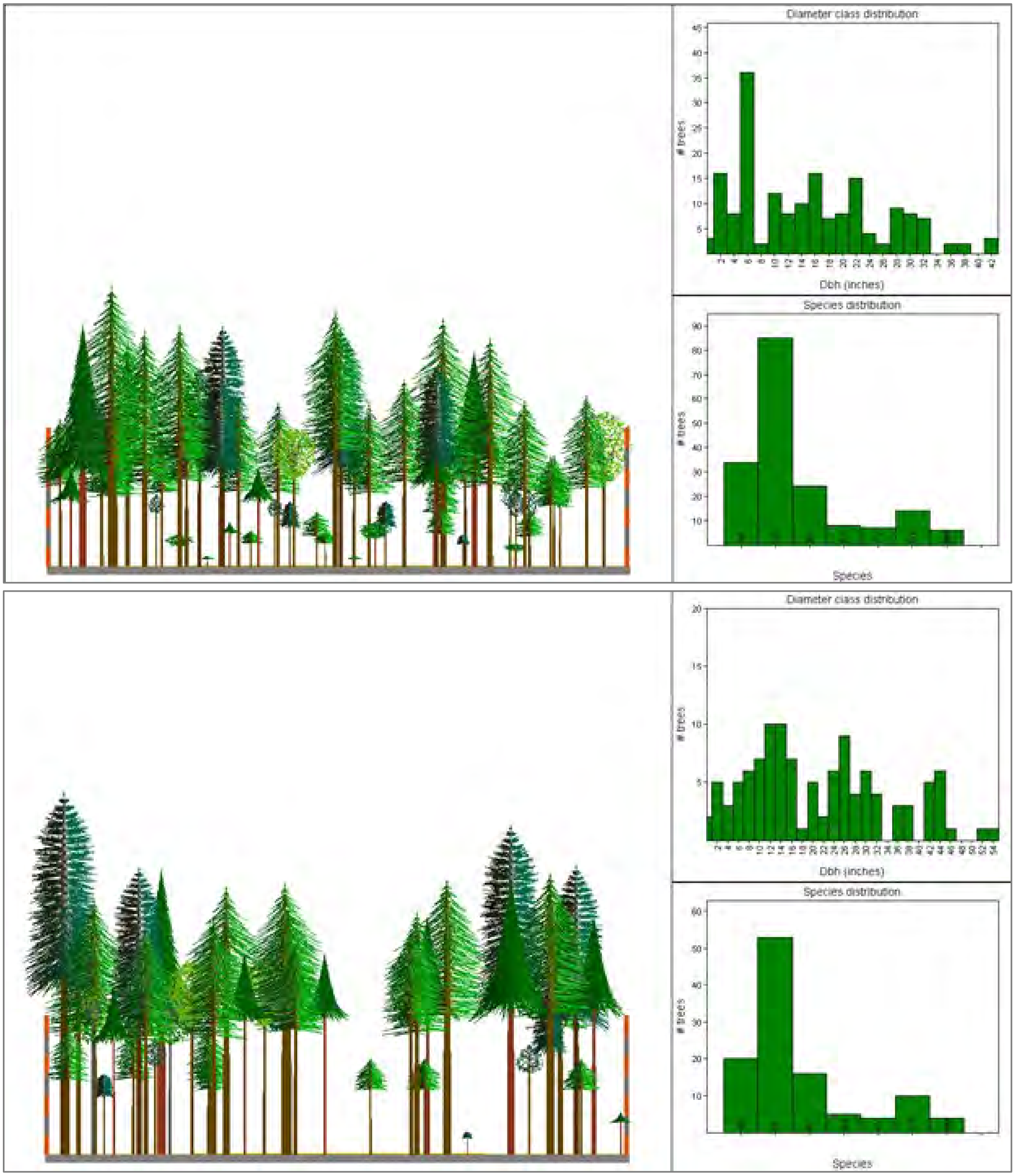


Figure 33. Stand EC-15 visualizations, diameter distribution and species composition in 2008 (top)and 2068 (bottom).

Stand EC-16

Stand EC-16 represents the northern boundary of the Garry oak ecosystem and the interface with the pure Douglas-fir forests. While oak was not present in our sampling plots, some scattered trees are found in the overstory along with the dominant Douglas-fir and pacific madrone (Table 33).

Table 33. Stand EC-16 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	8.0	9.3	4.1	3.4
Douglas-fir	90.0	10.8	93.6	78.1
Pacific madrone	20.0	12.4	22.2	18.5
Western red cedar	4.0	0.7	0.0	0.0
TOTAL	122.0	10.6	119.9	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

As this relatively mature stand (~ 80 years) develops, fewer trees will recruit in the understory and stratified patterns in height within the canopy will emerge (Figure 34).

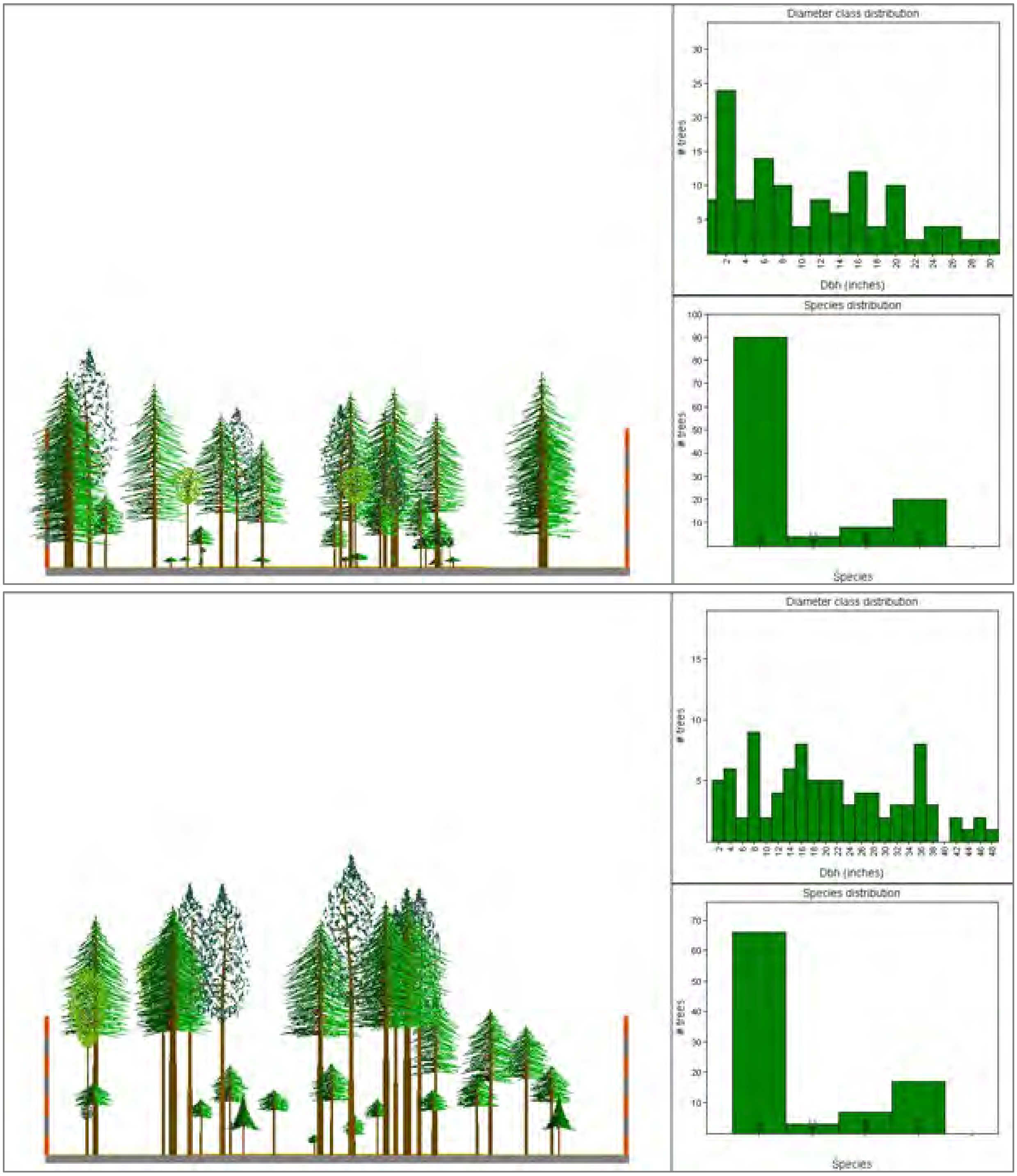


Figure 34. Stand EC-16 visualizations, diameter distribution and species composition in 2008 (top)and 2068 (bottom).

Stand EC-17

Stand EC-17 represents the Garry Oak ecosystem and is located at the driest site in the Park at mid and high elevations of Young Hill. This stand is an open mixed Garry oak – Douglas-fir forest resembling a parkland (Table 34). While these two species are the largest trees in the area, Douglas-fir along with other small trees represents most small individuals.

Table 34. Stand EC-17 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Big leaf maple	1.3	27.4	5.5	11.4
Douglas-fir	13.3	11.4	22.5	47.3
Other species	5.3	2.5	0.2	0.5
Garry Oak	1.3	51.8	19.5	40.9
TOTAL	21.3	12.7	47.6	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

In this type of ecosystem, recruitment is a very low probability event so no recruitment is expected. No other major changes are likely to occur either in the near future (Figure 35).

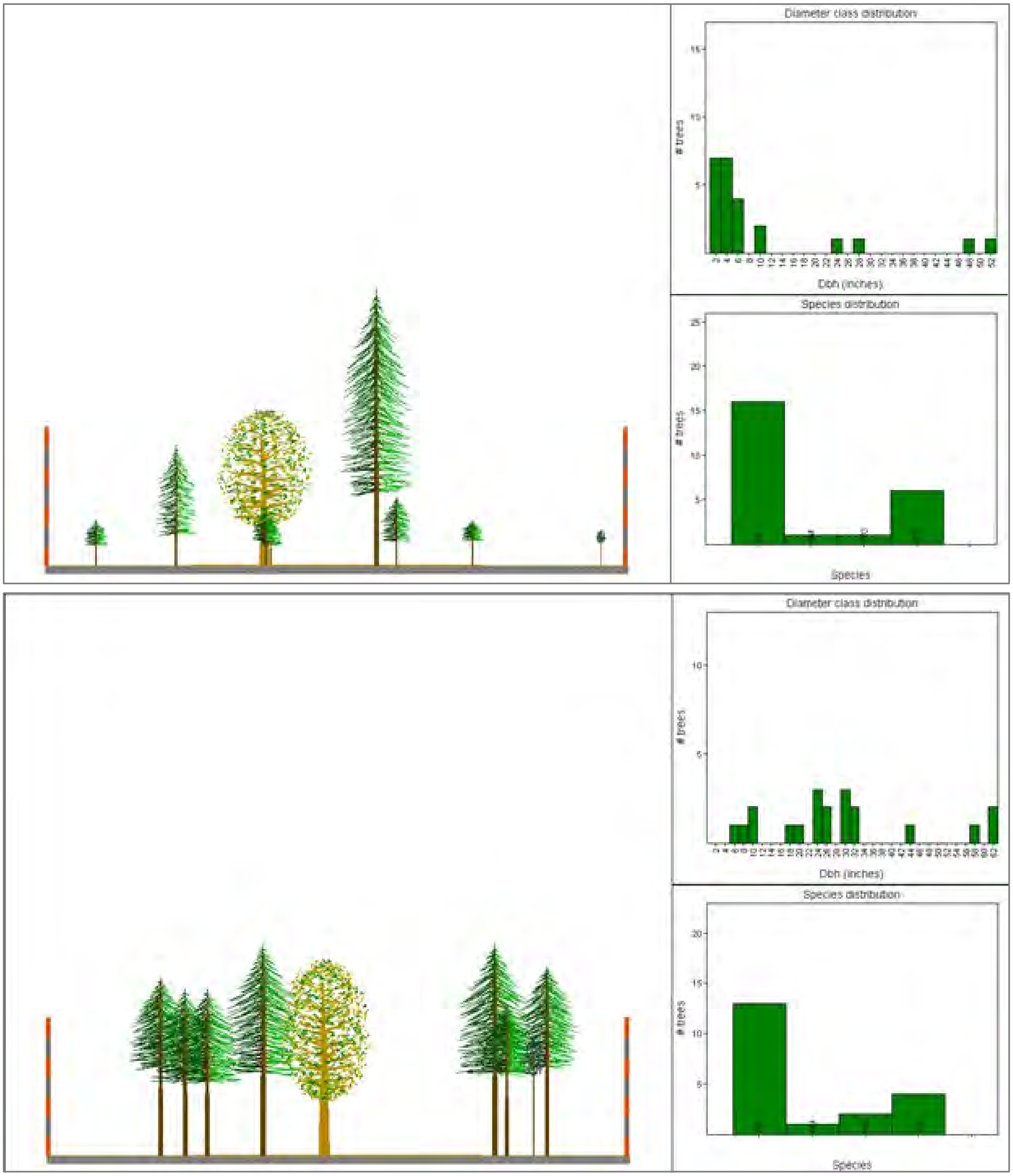


Figure 35. Stand EC-17 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

Stand EC-18

Stand EC-18 represents, on the other hand, the southern boundary of the Park and the Garry oak ecosystem. This stand is the continuation of the Garry oak ecosystem at lower positions in the landscape. Similar to EC-17, it is dominated by Douglas-fir and Garry Oak, but tree density and basal area are higher (Table 35).

Table 35. Stand EC-18 species composition and stand characteristics.

Species	TPA[1]	Mean Diameter [2]	Basal Area [3]	Relative Basal Area (%)
Douglas-fir	18.0	13.7	59.8	55.0
Other species	20.0	3.8	2.0	1.8
Western juniper	6.0	11.9	4.9	4.5
Garry oak	10.0	27.1	42.1	38.7
TOTAL	54.0	12.3	108.8	100.0

[1] trees per acre

[2] inches

[3] square feet per acre

Future development includes death of some large, old overstory trees and the growth of some Douglas-fir trees into larger diameter classes (Figure 36).

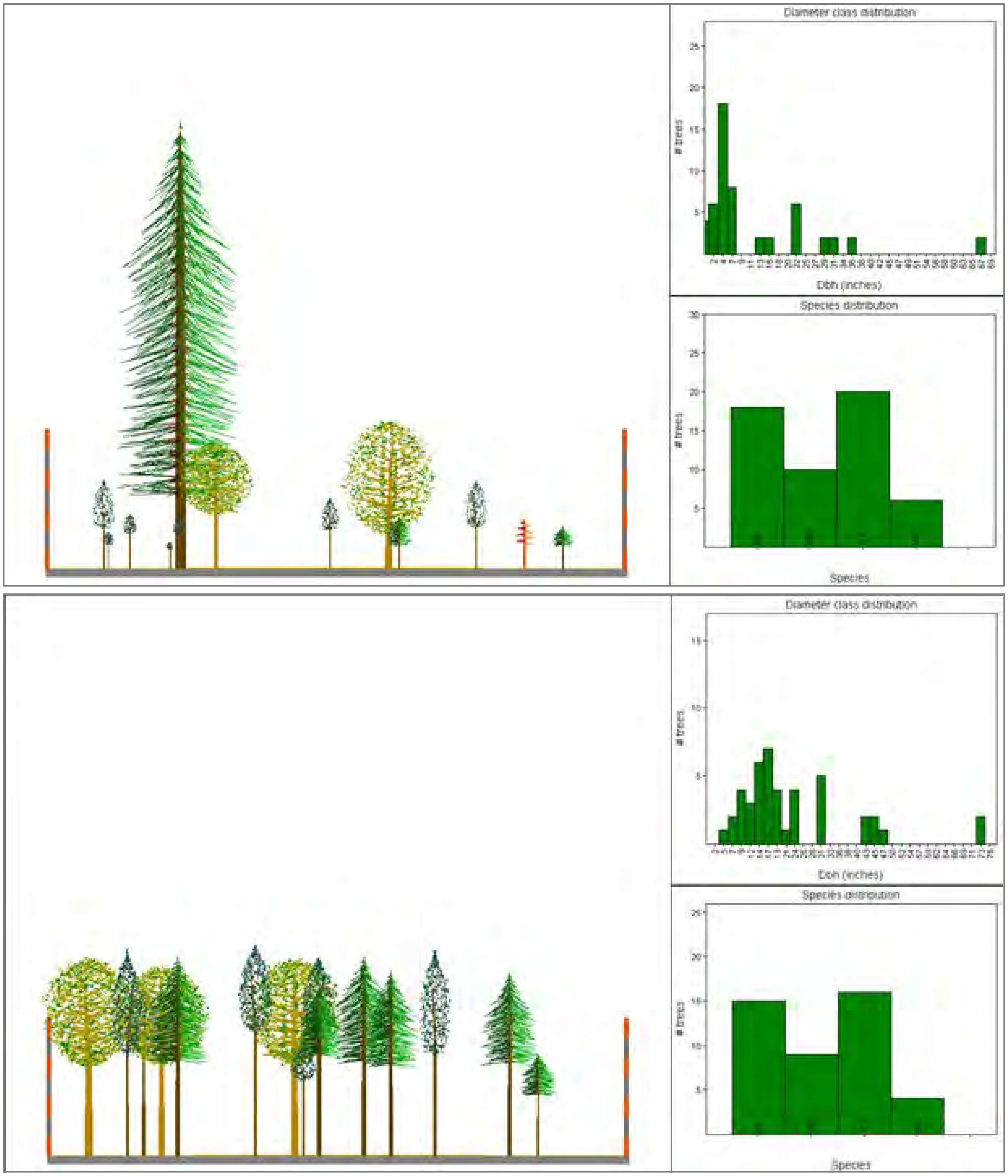


Figure 36. Stand EC-18 visualizations, diameter distribution and species composition in 2008 (top) and 2068 (bottom).

4. Summary

Forests cover approximately 48% of SAJH (McCoy and Dalby 2008) and stands range in age from 20 years old to 165 years. In this study, we grouped forest stands by dominant species to guide sampling. At American Camp, the oldest stands were in the Mount Finlayson area on the eastern and northern boundaries of the park. Stands 1, 2, 5, and 7 established between 150 and 162 years ago, during the historic time period (i.e. 135 - 157 years before this study). These stands have large Douglas fir, Western Hemlock or Western Red Cedar in the canopy with understory species composition reflecting available site moisture. Stand 6 is about 112 years old, but still similar to the older stands in that is dominated by Douglas fir and is fairly uniform in composition reflecting an even age stand that probably established after a fire. Stands 3 and 4 are fairly young – under 80 years old and also originated after a fire. These two young stands will undergo the greatest structural changes in the Mount Finlayson area as individuals increase in height and diameter and some species move into the upper canopy.

The western portion of American Camp is the area where most of the post-historic period agricultural clearing occurred and where the Olympic fire crew conducted forest thinning. Only stand A-14 is over 100 years old, the remainder ranging from 20-87 years in age. Stand A-8 is the most unusual as it is dominated by red alder. These stands are more spatially variable than the stands on Mount Finlayson and as stands develop, the models project increases in tree diameter, some density dependent mortality, and continued colonization into grasslands especially near stand 15.

Eight of the 18 stands in English Camp are older than 100 years old (EC- 1, 2, 6, 7, 11, 12, 15, 18). EC- 4, 5, and 13 are similar to stand AC-8 in that they also have high components of Red Alder and all are young developing stands. Stands 16, 17, and 18 are representative of Garry Oak ecosystems although Oak are sparse throughout EC-16; recruitment of all species are low in these stands. Continued monitoring of tree regeneration is recommended her to determine if the current fire management strategy is encouraging Garry Oak while decreasing recruitment of Douglas fir and other conifers.

We recommend that the park and/or North Coast and Cascades Network establish permanent plots for long-term monitoring of these forest stands to document trends in species composition, growth, and future stand trajectories. Using the current forest stand ages and composition combined with the predicted changes presented in this study will allow for efficient sampling and resources but will also allow the park to develop and track efficacy of management strategies based on forest growth and development.

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Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525