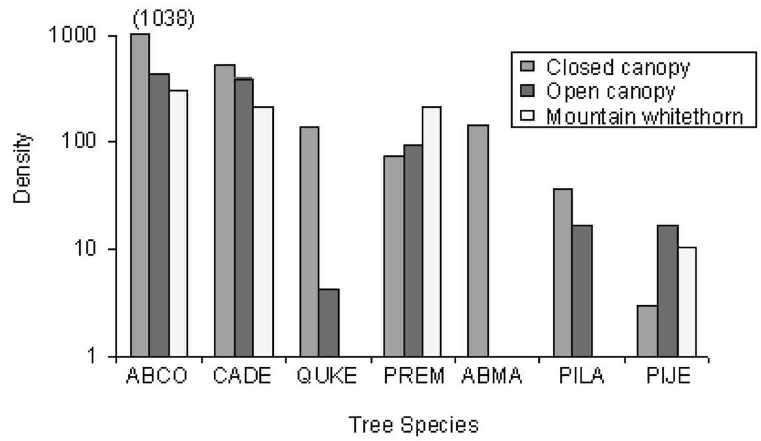

Figure 37—Density of tree seedlings and saplings (>5 cm tall and <5 cm dbh) per hectare by species and patch type. Note that the y-axis is logarithmic. Tree species acronyms on the x-axis are listed in *appendix B*.

Tree Seedlings and Soil Moisture

To date, tree seedlings and saplings (trees >5 cm tall and <5 cm DBH) were systematically surveyed in 25 m^2 plots established at 268 of the 402 gridpoints. The survey found the following species in declining order of abundance: white fir, incense cedar, black oak, bitter cherry, red fir, sugar pine, and Jeffrey pine. Regeneration varies by patch type: most species were most abundant in closed-canopy forest and had fewer individuals in gaps and the least in mountain whitethorn patches *(fig. 37).* The exceptions were bitter cherry, which was most abundant in snowberry patches; Jeffrey pine, which was most abundant in open areas; and black oak, which was most abundant in bedrock-dominated areas (not shown).

Monthly snow-free measurements of soil moisture have been collected for two years at the 402 gridpoints within the 18 plots of the Teakettle Experiment *(appendix A),* using time-domain reflectometry (Gray and Spies 1995). Soil moisture is measured in the upper soil layer (0-15 cm) at all gridpoints, and additionally between 0-45 cm at nine points in each plot. Pre-treatment measurements of soil moisture found a constant rate of drying of soils in the upper 45 cm during the growing season. Volumetric moisture values soon after snowmelt (mid-May) average 18 percent (with a range of 12-33 percent), and decline to 14 percent (6-47 percent) by early July, and to 10 percent (5-28 percent) by October. The high variability of moisture is likely caused by differences in topography and depth to bedrock and is probably important in determining the location and speed of vegetation response to disturbance.

Summary

The Teakettle Experimental Forest encompasses several forest communities typical of the western slopes of the Sierra Nevada. Forest composition appears to be strongly influenced by elevation, topography and soil depth. Between 1,900 and 2,300 m, mixed-conifer forest predominates, although red fir is locally common along riparian corridors that may be cold air drainages. Jeffrey pine is dominant on ridge tops with shallow soil. Red and white fir dominate tree density and basal area at Teakettle, but Jeffrey and sugar pine are often the largest individuals and are good indicators of drier and warmer mixed-conifer conditions. Mixed conifer is a forest of high contrast with open patches having high soil surface temperatures and low soil moisture, and closed-canopy forest with a relatively deep litter layer and lower understory light levels. Distinct shrub patches are common and the most dominant shrub, mountain whitethorn, may be an important resource island of available nitrogen in these forests.

Although Teakettle's mixed conifer is old growth, tree and snag basal area and log volume are low compared to other western old-growth forests. This is probably due to the patchy nature of mixed-conifer ecosystems in the southern Sierra Nevada. Sample plots that fell entirely within a tree group have a basal area and density typical of productive Pacific Northwest old growth, while gap plots may have few if any trees. These gaps have remained at Teakettle despite decades of fire suppression. This gap persistence is unusual in productive forests where trees often colonize available growing space and strongly influence microclimate conditions. The lack of snags and tree regeneration in most of the gaps indicates they have probably been gaps for several decades and do not appear to be shrinking. We do not know what mechanism is maintaining these gaps but suspect that shallow, coarse-textured soils, and high soil surface temperatures are important influences. Soil moisture holding capacity probably significantly influences the location and growth of trees because summer survival largely depends on a site's water reservoirs from the winter snowpack. Some of the forest's gap pattern appears to result from the geomorphic template (i.e., shallow depth to bedrock). Some of the larger gaps, however, have deep soils. Plant colonization in these openings may be limited by the high surface temperatures and lack of shade.

Growing conditions in Sierra forests have high temporal variability with strong seasonal and annual weather changes that affect plant establishment and growth. Almost all precipitation occurs in the winter; and soil moisture available to plants is determined by snow pack depth, the speed at which it melts, and substrate water-holding capacity. Plants with shallow roots may experience drought conditions within a month of being uncovered from the winter snow pack. El Niño and La Niña events produce extreme annual fluctuations in snow conditions. In 1998 after an El Niño winter, snow melted out of Teakettle 8 weeks later than the previous year, and even through October many soil moisture samples did not drop below 20 percent that year. Within the brief 30-year record from nearby Cliff Camp, annual snow depth varied by up to tenfold.

The transition from mixed-conifer to red fir forest produces a fundamental change in forest structure and pattern. On average, red fir forests have higher tree and snag basal area and greater log volume than mixed conifer. Red fir forests are less variable than mixed conifer with fewer gaps, lower tree species richness, and higher canopy cover. The shift from mixed conifer to red fir includes the loss of Jeffrey pine, sugar pine, and incense cedar, but the main transition is from white fir to red fir dominance. The transition may correspond to tree response to snow pack conditions. Several studies found white fir and red fir seedlings have similar ecophysiological requirements during the growing season but that the transition to red fir dominance may relate to snowpack tolerance (Barbour and others 1990, 1991; Pavlik and Barbour 1991). The ecotone between the forests corresponds to the mean freezing level during December to March storms, which is the elevation at which snow pack depth substantially increases over small elevation increases. Royce and Barbour (2001a, b) have suggested that the red fir ecotone can be modeled based on timing of snow pack melt, slope aspect, and soil water storage capacity. The higher number of red fir that we found in cool riparian areas relative to other mixed-conifer forests may be a reflection of these factors. Teakettle's riparian areas have a much deeper snow pack than adjacent upland forest, and during the spring melt, snow often persists for 2 to 3 weeks longer.

As a relatively pristine old-growth forest, Teakettle may serve as a useful standard to gauge the effects of forest management practices in other areas. For example, there has been considerable debate about the number of large trees per acre that would classify a stand as old growth, and whether a stand could have a "surplus" of large trees that could be thinned (USDA 2001). The size criteria often used is 30" dbh (76.2 cm). The density of these trees at Teakettle is fairly high, averaging 39 and 43 stems/ha in mixed conifer and red fir, respectively. These densities suggest big trees are underrepresented by current stand conditions in most Sierra forests. Furthermore, the scale at which stand structures are measured can skew estimates of basal area and density. Measurements taken in tree clusters will overestimate the number of large trees present across the matrix of gaps and tree groups that characterize mixed conifer.

Much of the information from the Teakettle Experiment studies is preliminary, but all of the research to date indicates high species richness and a complex community that is influenced by patch structure, composition, microclimate, and nutrient conditions.

Plants are the building blocks of terrestrial ecosystems, and their composition establishes a scaffold of structure that influences many ecological processes. The Teakettle Experiment will continue to explore the connection between composition, structure, and function through long-term measurements of the cascading effects of fire and thinning restoration treatments on ecosystem processes in Sierra mixed conifer.