AN ABSTRACT OF THE THESIS OF

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Michael Newton

Four brushfield reclamation methods were compared on a 28 hectare area supporting a dense overstory of red alder and a thick understory of deciduous brush species. Tractor scarification, aerial application of 2, 4, 5-T and picloram followed by broadcast burning or tractor crushing, and aerial application of glyphosate were performed during the summer and early fall of 1976, after salvage logging. Prior to disturbance, permanent sampling points were established throughout the area, and vegetation characteristics assessed. The season after site preparation, points were revisited and treatment effects on vegetation, brush species response, and operational planting characteristics observed. Additional information on treatment effectiveness, soil disturbance, and animal habitat was also recorded.

All methods successfully reduced competitive woody cover. Canopies supporting 50 to 100 percent cover were typically reduced

to near-zero levels after site treatment. Few plant species, either woody or herbaceous, were eliminated by any of the treatments. Species found in the original brushfield community were clearly present one season after logging and site preparation, although the relative dominance of those plants appears to have been lowered because of an increase in the abundance of a few invading and residual species.

Few woody plants escaped undamaged. Plant response was not equal among treatments. Many of the woody plants in the scarified area were removed completely. Shrubs in the herbicide-burn-crush combinations were generally effectively top-killed, but often produced basal sprouts. Deciduous woody plants not mechanically injured prior to glyphosate application died, or exhibited symptoms interpreted as precursors to mortality, without basal sprouting. Viable woody root systems were still present in all areas, however.

Abundant and well distributed planting environments were created by all four treatments. Difficulty of planting was rated least in the scarified area.

Coniferous tree seedlings planted in all treatment areas should be subject to environments conducive to survival and growth desired in a commercial plantation. The vegetation following site treatment is important in determining the rate at which competitive effects return to the site. Woody plant development from existing root systems in the herbicide-burn-crush combinations, and moisture demanding herbaceous vegetation appearing after scarification suggests that seedlings planted in those areas may be faced with serious competition within a few seasons. Woody plant development from weakened residual root systems may occur in the glyphosate treated areas also, but because plants injured by this herbicide generally do not sprout, the rate of development should be slower, allowing seedlings a greater time period for unrestricted growth.

Comparative Effects of Chemical, Fire, and Machine Site Preparation in an Oregon Coastal Brushfield

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COMPARATIVE EFFECTS OF CHEMICAL, FIRE, AND MACHINE SITE PREPARATION IN AN OREGON COASTAL BRUSHFIELD

INTRODUCTION

The forests of the Pacific Northwest are some of the most productive in the nation. Yet today, almost 2.5 million acres of high site forest land in both the Coast Range of Oregon, and the Coast Range and western Cascade foothills of Washington are producing brush and low value hardwoods (Gratkowski _et al_. 1973). Much of this was once covered with conifers, falling into brushfield conditions after repeated wildfires or poor forest management.

Reclamation of these areas, however, has proceeded very slowly. Serious brushland rehabilitation efforts have taken place only after the mid-1950's in the Northwest (Dimock _et al_. 1976). Recently, increased land and timber values have made brushfield conversion to conifers more attractive for many timberland owners, and as a result, these areas are probably being reclaimed at a greater pace today than ever before.

Establishing conifers on these lands typically requires some type of site preparation. Traditionally, tractor scarification has been the treatment relied upon most heavily, although newer and less intensive methods such as fire and herbicides are playing an increasingly important role (Dimock _et al_. 1976). Sound knowledge of the effects of site preparation on vegetation succession, animal habitat, and tree seedling environments is needed, however, before any site can be rehabilitated successfully.

This study attempts to contribute to that knowledge by comparing four types of site preparation treatments in a red alder (*Alnus rubra* Bong.) dominated brushfield located in the central Oregon Coast Range. The methods included tractor scarification, herbicides followed by tractor crushing, herbicides followed by burning, and herbicides alone. Specifically, the following objectives were established: (1) document the vegetational changes brought about by these four treatments, (2) determine the existence of sprouting brush species before disturbance, and evaluate damage sustained by them as a result, and (3) estimate the number, distribution, and difficulty of planting spots created by these methods. In addition, treatment effects on wildlife habitat were examined, along with other information valuable in evaluating site preparation effectiveness.

The study approach consisted of first obtaining baseline vegetation data around permanent sampling points prior to disturbance, and subsequently re-evaluating the conditions surrounding those points the season after site treatment. By comparing conditions before and after preparation, insight into the initial environments created by these methods for seedling establishment should be gained, and their costs and benefits estimated.

LITERATURE REVIEW

The Brush Problem in a Seedling Context

Brushfield site preparation efforts are generally applied so that an acceptable tree seedling environment (in terms of survival and growth) is produced from an unacceptable one. This typically translates into removing the constraints on site resources imposed by brush species and making these freed resources available for seedling use. The extent to which this is required depends upon how tightly these resources are controlled by brushy vegetation, and also on the environmental tolerances or requirements of the tree seedlings being placed in those conditions. It appears pertinent, therefore, to briefly review the environmental requirements of conifer seedlings, as well as the influence of competing vegetation on seedling development.

Light plays a critical role in seedling survival and growth, and is also one site resource severely competed for by brushy vegetation. Hodges and Scott (1968) observed six species of conifer seedlings growing in a range of environments from dense conifer shade, to completely open sites. They found that at low light levels, (below 1400 ft-c) rates of photosynthesis of grand fir (*Abies grandis* (Dougl.) Forbes) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) were generally greater than either Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) or noble fir (*Abies procera* Rehder).

Emmingham and Waring (1973) observed the effects of shade on a variety of coniferous species growing in the Siskiyou Mountains of Oregon. They reported that Douglas-fir establishment was normally restricted to areas receiving at least 10 percent relative light (full sun in the open during summer), while the more tolerant true fir species, white fir (*Abies concolor* (Gord. & Glend.) Lindl.) and Shasta red fir (*Abies magnifica* var. *Shastensis* Lemm.), were abundant down to 2.5 percent relative light (R.L.). They also noted that Douglas-fir had greater elongation than the true firs between 10-40 percent R.L. and at 100 percent R.L. All species grew best, however, at 100 percent relative light. Isaac (1943) reported that of the three shade frame densities used in his study in western Washington, the "light" shade frame (20% of full sun) produced the best survival and growth for Douglas-fir seedlings and transplants. He indicates, however, that at least 50 percent of full overhead light is necessary for survival and reasonable growth in field conditions.

A number of workers have observed reduced survival and growth of conifer seedlings of all shade tolerance levels because of light competition by brush species. Zavitkovski *et al*. (1969) mention the effects of snowbush (*Ceanothus velutinus* Dougl.), a slow growing bush type, on the development of four species of coniferous seedlings in the Oregon Cascades. They found that height growth of all species, including Douglas-fir and western hemlock, declined when planted in snowbrush over ten years old. They also noted height growth reductions of 50 percent in six species of naturally occurring conifer seedlings under suppression of this shrub. Allen (1969) examined the effects of a fast growing shrub, salmonberry (Rubus spectabilis Pursh), on Douglas-fir growth in the Coast Range of Oregon. He observed trees fully or partially overtopped by this brush species grew considerably less than those with the terminal of the seedling fully exposed. He also noted that trees at least partially suppressed were weak and spindly in their physical stature. Ruth (1956) presented convincing evidence concerning the suppressive effects of brush on conifer seedlings in two coastal plantations. He reported average annual height growth five years after planting as 63.5 cm (25 in) for unshaded Douglas-fir in contrast to 20.3 cm (8 in) for shaded seedlings. Average yearly growth for species of mixed tolerance showed similar results (68.6 vs. 15.2 cm). Survival was also dramatically reduced for trees growing in overtopped environments.

One factor allowing brush species to become such fierce competitors for light is their growth rate. Apsey (1961) as cited by Smith (1968) mentioned that on good sites red alder can reach breast height in one year. On poor sites three years were required to attain this level. Douglas-fir, in contrast, required eight years to grow to this height on medium sites (Williamson 1968). Roberts (1975) found that in the Oregon Coast Range, sprouts from root stools of woody species burned four months earlier had grown substantially. She reports basal sprouts of bigleaf maple (Acer macrophyllum Pursh) 1.4 meters (4.6 ft) in height and bitter cherry (Prunus emarginata (Dougl.) Walp.) sprouts approaching 1 m (3.3 ft). Newton (1973) uses the term dominance potential to describe the ability of a species to assume dominance, over a specified length of time, in a limited system. In moist environments, such as many coastal areas, the ability of a species to outgrow its competitors (for light) strongly enhances its dominance potential.

Seedling responses to moisture, a second site resource, have also been demonstrated. For example, Cleary (1970) has reported differences in photosynthetic response of two conifers subjected to varying amounts of moisture stress. He found that Douglas-fir showed a nearly linear decline in photosynthesis when plant moisture stress rose from eight atmospheres to 22 atmospheres. Ponderosa pine, in contrast, demonstrated little reduction in photosynthesis until 15 atmospheres, which then occurred abruptly with no measurable photosynthesis after 20 atmospheres plant moisture stress.

The effects of vegetation competing for moisture on seedling development has been described by a number of workers. Chetock (1976) observed that grass-dominated communities were the most moisture demanding when compared to brushy communities, a finding observed by Newton (1964) also. Newton (1964) found that 92 percent of the total soil moisture depletion in the top 91 cm (36 in) of soil in his study area was related to use by vegetation, primarily grasses. After weed control in the area, which had been unsuccessfully planted with conifers several times, he observed greater survival and signs of lammas growth on tree seedlings. Preest (1975) has reported significant favorable effects of weed control on height and diameter growth of Douglas-fir for four subsequent years in bent grass (*Agrostis tenuis* Sibth.) dominated areas in the Oregon Coast Range.

Tolerance to physical damage by falling litter and debris is another requirement of tree seedlings being placed in a brushfield environment. For instance, Zavitkovski *et al.* (1971) found that red alder up to five years of age can produce almost 5000 kg per hectare of litter annually. Riech (1966) observed the effects of static bending stress on Douglas-fir height growth. He found that as stress increased, leader growth decreased in nearly a linear fashion. Newton (1978) has observed that western hemlock is better at readjusting after deflection than Douglas-fir, with less loss of growth.

Damage by animals is a final factor influencing the development of seedlings in brush areas. Several workers have observed the effects of rabbit (*Sylvilageus* spp.) or hare (*Lepus* spp.) clipping of planted conifers in brushy habitats (Allen 1969, Minore 1971, Zavitkovski *et al.* 1969). Ruth (1956) noted that deer (*Odocoileus* spp.), mountain beaver (*Aplodontia rufa* Raf.), and rabbits all had considerable effects on the height growth of trees in two Oregon coastal plantations threatened by brush. He observed that Douglas-fir not browsed by the end of their fifth season averaged nearly 142 cm (56 in) tall, while those browsed three times averaged only 21 cm (8.3 in) in height. Ruth also noted differences in animal preferences, Douglas-fir sustaining the most damage, hemlock intermediate, and cedar (Thuja plicata Donn.) and spruce (Picea sitchensis (Bong.) Carr.) the least. He mentions that browsing seldom killed trees directly, but that reduced height growth and loss of vigor allowed competing brush species to outgrow and suppress them, greatly reducing their chances for survival. Edgren and Stein (1974) comment that suppression by brush can reduce seedling growth, allowing more seasons of browsing opportunity to vulnerable seedlings. Thus it appears from these observations that a strong relationship exists between brush species and animals; ultimately acting to the detriment of the planted seedling.

Brushfield Site Preparation Implications and Constraints

In order to convert brushfield communities into environments suitable for coniferous seedlings, some type of site preparation is normally required. Three primary methods are commonly employed in the Pacific Northwest. These include the use of machines, fire, and chemicals; either singly or in combination. Each method has specific attributes which make it valuable as a reclamation measure. Understanding both the advantages and disadvantages of each treatment is critical if short and long term goals are to be realized.

Mechanical methods have been the most widely used site preparation measure in the past, and they continue to play a large role today (Dimock et al. 1976). Scarification by bulldozers equipped with toothed blades (brush blades) comprises the bulk of these methods, although chopper-flailing machines, disc plows, and various other machines are also used. High-lead scarification, a more recent development, involves the use of a cable yarding machine pulling massive weights or scarifying tools up and down a slope. All these measures, with the exception of high-lead scarification, have the operational constraint of being restricted to slopes of less than 30 percent (Gratkowski 1974). Of the three basic methods focused on here, they are also the most expensive to use, although this may be offset somewhat because of easier planting and reduced planting costs (Gratkowski et al. 1973).

Since these methods generally involve soil disturbance and exposure, some concern over soil loss and damage is warranted. However, Froelich (1973, 1974) notes that soil compaction appears to be a serious problem when soils are in the mid-range of wetness, and under normal, dry operating conditions should pose only a slight hazard. Soil erosion may become a problem, however, particularly on steep slopes (Stewart 1978). Because these methods extensively clear a site, temperature extremes are often maximized (Cochran 1969), possibly enhancing frost problems. Slash or brush free areas created by these techniques also allow greater, unrestricted movement of some animals, providing access to planted seedlings, although they also remove cover for small mammals potentially injurious to conifers. In addition, slash piles or windrows typically formed by these measures and left unburned may harbor animals that damage planted seedlings nearby (Gratkowski and Anderson 1968).

Mechanical methods are effective in initially reducing vegetative competition, but offer no control over surviving plants. They can be effective in areas supporting herbicide resistant brush, however (Stewart 1978). Plant succession after mechanical treatment is not well documented. Observations by Dyrness (1973) indicate that on unburned but disturbed areas in Oregon Cascade clearcuts, herbaceous vegetation, including some species of grasses, initially follows disturbance. Malavasi (1977) has reported similar findings. Stewart (1978) comments that mechanical treatment of brush often stimulates the development of herbaceous vegetation, possibly requiring follow-up control treatments.

A final consideration for mechanical site preparation is that although these methods may be the only viable alternative in areas with smoke management problems, or where herbicide use is unacceptable, much of the land suitable for mechanical measures will soon be reclaimed (Dimock et al. 1976), placing emphasis on lands better suited to other methods.

The use of fire has many characteristics that differ from mechanical site preparation, and much has been written on its use. For example, burning can be done on all types of terrain, with associated costs normally lower than mechanical methods (Gratkowski et al. 1973). The escape hazard and high manpower requirements may negate these advantages, however. Like mechanical methods, burning can physically remove slash and brush from a site, and thereby reduce planting costs. Vyse and Muraro (1973) reported that after burning, 93 percent of their study area in British Columbia was rated as having no planting difficulty, whereas before treatment nearly 85 percent was described as moderate to great in difficulty. They estimated cost savings for bare root planting at $71 per hectare ($30 per ac). Although reduced debris decreases planting costs, soil burned bare on steep slopes can also be susceptible to erosion (Gratkowski 1974). Compounding this hazard are soil-wettability factors. DeBano and Rice (1973) mention that prescribed burning can produce a water repellent layer, either at the soil surface or several centimeters below, that reduces infiltration. Without a protective litter layer, overland flow leading to surface erosion may occur, especially on severely burned areas. However, several investigators have reported that broadcast burning is usually severe on less than 10 percent of the treated area (Morris 1970, Dyrness and Youngberg 1959, Tarrant 1956), suggesting that highly repellent soils may be only a localized, concentrated problem.

Open areas created by burning, like mechanical site preparation, allows greater animal access to the new plantation. Gockerell (1966) found that deer and elk (Cervus spp.) damage on plantations in western Washington was greatest in slash-burned areas as compared to unburned areas. In addition to animal damage, he notes that few natural seedlings were found in the burned areas, suggesting that fire was a nonselective site preparation measure in that instance, removing competing vegetation as well as any existing stocking.

Several investigators have commented on vegetation after fire. Morris (1970) reported that shrub cover is reduced for three years in coastal environments after slash burning, but that herbaceous cover did not differ significantly from burned to unburned areas. However, overall, it increased gradually until shrubs became competitive. He suggests that slash burning is an effective tool to reduce brush competition where Ceanothus species are not present. Dyrness (1973) recorded vegetation information before logging, and followed successional trends after logging and slash burning. He found that invading herbaceous species dominated from the second to fourth growing seasons after burning, but that by the fifth year, residual herbaceous species (species present before logging or fire) had regained dominance. He also notes that in many cases, herbaceous vegetation was not followed by a shrub stage and speculates that this layer may be bypassed altogether, leading directly to tree dominance.

Chemical site preparation, the third primary brushland reclamation measure is becoming increasingly important in the Pacific Northwest. It offers application to all types of topography, and is also the least expensive of the methods discussed here. In addition, relatively large areas can be treated with a low-labor requirement (Gratkowski et al. 1973). Because slash and brush are not physically removed from the site, soil compaction and accelerated erosion do not occur. However, planting in these areas can be more difficult and costly (Stewart 1978). Small animals potentially injurious to planted seedlings may also be protected from predators by standing residues (Dimock 1974, Gratkowski 1974). Chemical site preparation can profoundly influence animal habitats. Lawrence (1967) reviewed the effects of chemical vegetation management on wildlife, and concluded that animal populations can be helped or hindered by their use, depending on their habitat requirements. For example, Keith et al. (1959) found that forb production reduced by herbicides in Colorado resulted in an 87 percent decrease in pocket gopher (Thomomys spp.) populations in his study plots. In contrast, Borrecco et al. (1972) reported an increase in deer activity during the growing season in chemically treated areas in Oregon.

Herbicide resistant vegetation poses another problem in the use of chemicals as a brushland reclamation measure. Applications of herbicides in areas with a significant makeup of these species may lead to suppression of sensitive plants with a corresponding increase in the resistant component (Newton 1967). This selectivity, however, is a major feature of chemical use and can be used to advantage on sites supporting existing conifer stocking.

Plant successional studies after chemical application are not well represented in the literature. Work done after right-of-way spraying in the East is perhaps the most complete. Niering and Goodwin (1974) found that repeated removal of tree species by basal chemical application resulted in stable shrub dominated communities in Connecticut. Bramble and Byrnes (1974) reported broadcast spraying of 2, 4, 5-T and 2, 4-D resulted in a replacement of a woody community with an herbaceous one composed of grass and sedge dominants in Pennsylvania. The woody component gradually returned to these communities, eventually progressing to the original pre-spray vegetation. Malavasi (1977) followed biomass trends after chemical site preparation in the Oregon Coast Range. He observed that herbaceous biomass increased steadily up to the sixth season after disturbance. He speculates that low shrub biomass in these units provided little competition for site resources, allowing herbaceous development.

Combinations of methods offer the flexibility needed to accommodate diverse goals in varied topography and vegetation. Herbicides are often used with mechanical methods or fire to combine control with removal of physical barriers created by slash and brush (Stewart 1978). Herbicides in conjunction with burning involve the use of translocated or contact chemicals (spray and burn or brown and burn), to desiccate or kill brush prior to burning. Fire in these areas builds up and spreads more rapidly and uniformly than in unsprayed areas (Stewart 1978). Translocated herbicides also allow some degree of sprout control. Chemical site preparation with mechanical measures also provide some advantages. Spraying before tractor crushing of brush reduces sprouting and allows the stems to dry and become brittle. Residues left after logging and crushing may also restrict deer use and provide protection for planted seedlings (Wallmo 1969, Grisex 1960), while providing vegetation control.

STUDY AREA

The study area is located in the central section of the Oregon Coast Range approximately 40 km (25 miles) northwest of Corvallis (Sec. 23, T. 10 S., R. 8 W.). The site has a history of repeated logging entry, removing merchantable conifers each time. The last entry was made about 20 years ago, leaving the site stocked with a few scattered conifers and dominated by red alder and mixed shrub species 20 to 80 years old (Figures 1 and 2). Twenty-eight hectares (70 ac) of this type were dedicated by Starker Forests of Corvallis, the present owner, for a cooperative study in brushland reclamation adjacent to previous research plots.

Site Characteristics

The moist and mild climate of the area is typical of many coastal mountain locations. Precipitation averages 165 to 180 cm (65-70 in) annually, with the majority falling during the winter months, mainly in the form of rain. A summer drought occurs, however, with approximately 5 cm (2 in) falling during the combined months of July and August. Temperatures are mild, the mean January temperatures approaching 4.4°C (40°F) and July temperatures averaging 18°C (65°F) (Sternes, 1960).

The topography is north to north-east facing, marked by numerous benches and gentle to moderate slopes. Elevations generally vary

Figure 1. Alder overstory and mixed brush understory characteristic of the study site.

Figure 2. Brush structure underneath the alder canopy.

from 152 to 305 m (500 to 1000 ft). Soils are deep, of a clay loam texture, and belong to the Bohannon-Slickrock association.

Franklin and Dyrness (1973) put the area in the transition between their Picea sitchensis and Tsuga heterophylla zones. The common vegetation in these zones include Douglas-fir, western hemlock, Sitka spruce, and on disturbed sites, red alder as overstory trees. Shrub composition is characterized by vine maple (Acer circinatum Pursh), salmonberry, red huckleberry (Vaccinium parvifolium Smith), elderberry (Sambucus spp. L.), and Oregon grape (Berberis spp. L.). Typical herbaceous vegetation is composed of sword fern (Polystichum munitum (Kaulf.) Presl.), oxalis (Oxalis oregana Nutt.), wild-lily-of-the-valley (Maianthemum dilatatum (Wood) Nels. & Macbr.), miners lettuce (Montia sibirica (L.) Howell), and lady fern (Athyrium felix-femina (L.) Roth). Franklin and Pechanic (1968) and Henderson (1970) have described the vegetation of red alder stands in the Picea sitchensis zone. Their descriptions as well as those by Franklin and Dyrness appear similar to the present study site, and will be discussed in more detail later.

Treatments

Four treatments involving mechanical methods, fire, and herbicides were applied to the study area during the summer and early fall of 1976. All treatments took place after salvage logging during the same summer. Mechanical methods were represented by tractor scarification, and a spray and crush treatment (herbicides followed by tractor crushing). Scarification involved the use of a bulldozer equipped with a blade fitted with large tines extending down approximately 46 cm (18 in). The area was treated during the first week in September by running the tractor back and forth over an area with the blade positioned so that the tines were run through the ground. Most trees, shrubs, and herbaceous vegetation were uprooted, broken off, or plowed under, leaving bare soil. Residues were pushed into long piles and left unburned.

The spray and crush treatment utilized both the application of herbicides and mechanical measures. Areas designated for this method were first sprayed by helicopter with a mixture of 2, 4, 5-T low volatile ester and picloram (as the potassium salt), on July 30. Application rates were 2.2 kg per hectare (2 lb per ac) of 2, 4, 5-T, and 1.1 kg per hectare (1 lb per ac) of picloram. Water was used as a carrier, and 94 l of spray formulation were applied per hectare (10 gal per ac). Sprayed brush and logging slash was crushed by running a bulldozer over these areas with its blade held above the ground, and "walking" over most slash and brush, crushing it under its weight. Standing trees were normally pushed over but not piled. Crushing was done the second week in September.

The treatment involving fire was also used in conjunction with herbicides (spray and burn). Areas designated for this treatment were sprayed on the same day, using the same herbicidal mixture and rates, as the spray and crush treatment. During the following month, any standing residual trees were felled by a two man crew using chain saws. An attempt was made to burn these areas during the first week in October by a crew with drip torches. The success of the burn was less than desired, and is discussed in more detail in a later section.

The sole use of herbicides was the basis for the fourth method in this study. Areas marked for this treatment were sprayed by helicopter with 1.7 kg of glyphosate per hectare (1.5 lbs acid per ac) on September 26. Water was used as a carrier, and 94 l of spray formulation were applied per hectare (10 gal per ac). No other treatments were performed, other than the disturbance from logging activities.

METHODS

Plot Design and Point Layout

Prior to salvage logging, the entire area was divided into six, square, 4-hectare (10 ac) plots, and one irregularly shaped plot of the same size, for a total of seven basic investigative units. These provided replicate areas for three treatments (spray and burn, spray and crush, chemical alone), but only one irregular plot for the scarification method. Because of the topographical constraints involved with the mechanical treatments, and the escape hazard with fire, plots were assigned treatments randomly among the choices of operational suitability.

In each plot, 16 permanent sampling points were established on a 40 by 40 meter (two by two chain) grid, oriented in cardinal directions for a total of 112 points. With this spacing, four rows of points with four points in each row were positioned in every square plot, leaving a 40 m (two chain) buffer strip between plot boundaries and the nearest point. Distances between points were measured with a steel tape to avoid bias and to ensure relatively accurate relocation in subsequent sampling. At times, the spacing between points was altered to 20 m (one chain) to avoid roads, heavy logging disturbances, and to fit into the confines of plot boundaries, as in the irregularly shaped scarified plot. Because of the great difficulty in foot travel through the area, and to ensure reasonable placement of the grid system in the plot, the grid was started at exterior surveyed boundaries. Points were marked with heavy wire stakes 61 cm (2 ft) long, pushed into the ground leaving 20 cm (8 in) exposed. Plastic flagging and aluminum tags were attached to the tops.

Pre-disturbance Data Collection

Vegetation

Before site preparation, and typically before logging, a variety of baseline vegetation data were gathered around each point, attempting to portray the conditions before disturbance. Occasionally, logging activities moved into an area before the environment around a point could be fully evaluated. In these cases a subjective decision was made as to whether there was enough information available to warrant evaluation, or to relocate the point. Normally, the condition of the herbaceous vegetation determined this decision. Shrub and tree species were much less affected and pre-disturbance conditions were easily reconstructed.

Canopy coverage was estimated by a method similar to one used by Iverson (1976) for determining the amount of overtopping vegetation influencing a seedling. At each point, an imaginary inverted cone was constructed, with its apex 20 cm (8 in) from the ground surface, and its sides extending outward at a 45 degree angle from the horizontal (see Figure 3). This method was intended to portray canopy coverage conditions as a 20 cm (8 in) seedling "perceives" them. Within this cone three strata were delineated in which canopy coverage was visually estimated. The first layer extended from the cone apex to 1.5 m (5 ft) in height and sampled ground cover vegetation. Shrub coverage was estimated between 1.5 and 6 m (5 to 20 ft) in height in the second layer. Vegetation greater than 6 m was sampled in a third layer, extending to the tallest canopy level. Cover was estimated as a percentage of the area hidden by vegetation, and was placed into one of six cover classes similar to Daubenmire's (1959). These were: 0, 1-5, 5-25, 25-50, 50-75, and 75-100 percent. In addition to the cover estimates, the dominant species making up the majority of the cover were also recorded.

In order to sample ground cover composition and determine species frequency, a circular plot with a radius of 2.27 m (7.45 ft) was established around each point. All herbaceous species, and low or rhizomatous shrubs were included in this classification. The three species contributing the greatest amount of cover were recorded along with cover estimates for each one. Total cover (less than 1.5 m in height) over the entire plot was also estimated. Cover classes previously outlined were used for all estimates. The percentage of sample plots in each treatment area in which a species was recorded

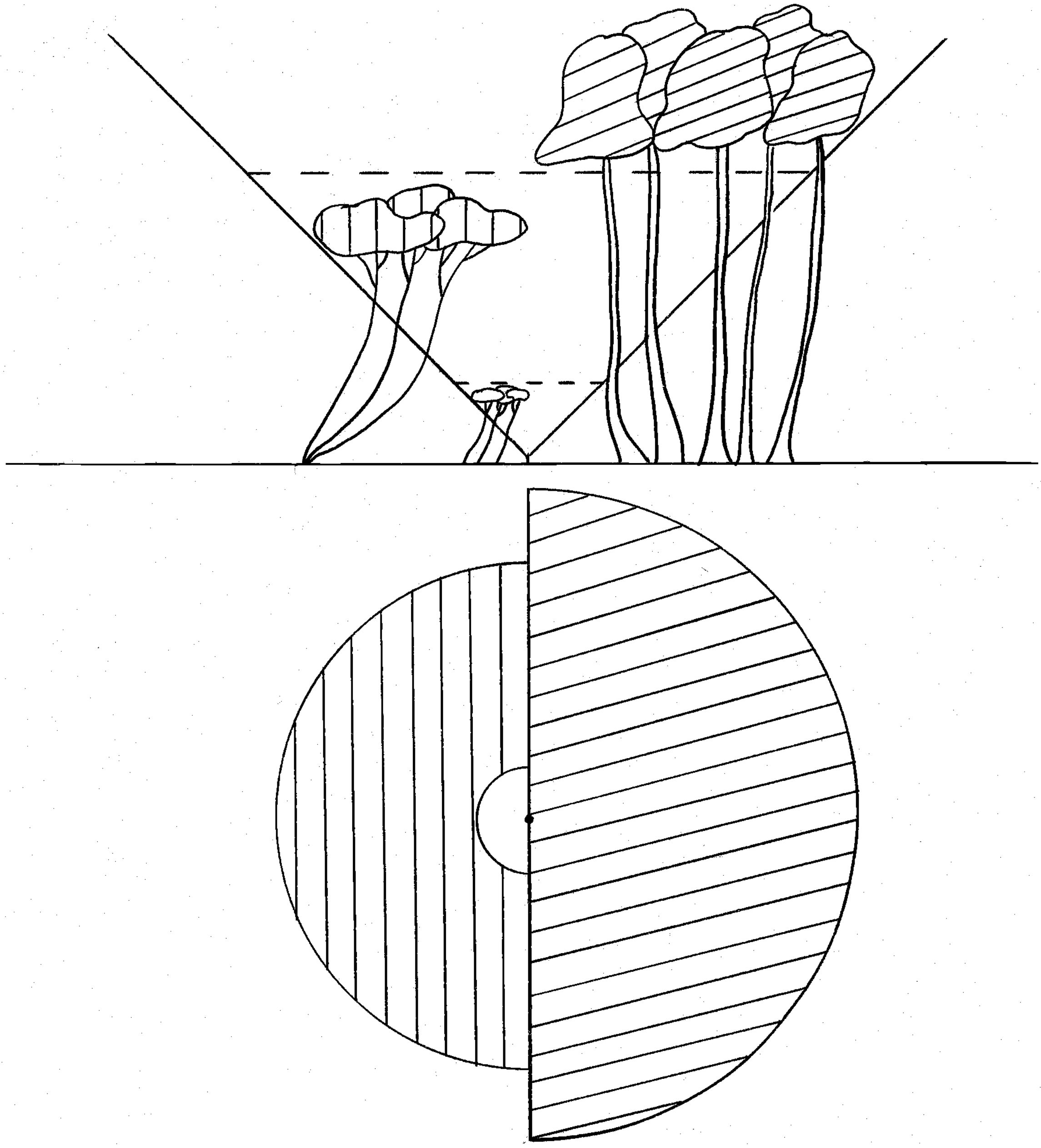

Figure 3. Cone projection used to estimate canopy coverage in three layers. Top diagram illustrates cross-section of cone. Bottom figure depicts an aerial view of the cone looking down. Each stratum is occupied by 50 percent cover.

was used to determine its frequency.

Tree and shrub information was gathered using a plotless technique. A list of the important woody species in the area was compiled before sampling. The area around each point was searched for the nearest individual of each species up to a maximum radial distance of 10 m (33 ft). As each species was located, the distance and bearing from the point was recorded. This allowed the same individuals to be re-examined in subsequent sampling after site preparation.

Post-disturbance Data Collection

Vegetation

During the winter after site preparation and logging, points were relocated and remarked as necessary. Wooden stakes were placed in the ground to permanently mark their location. The following June, each point was revisited, and a variety of post-site preparation information collected.

Canopy coverage values were again estimated in three strata. The methods and cover classes were the same as those used in the initial sampling.

Ground cover vegetation was also estimated in the same manner as predisturbance methods, but with some modifications. The six species contributing the greatest cover were recorded rather than three in order to accommodate any increase in diversity. Cover values of each were also noted. In addition, the three shrub species supplying the greatest amount of cover (less than 1.5 m in height) were noted and their cover recorded. Total herbaceous cover and total cover (less than 1.5 m) were estimated also.

Woody Plant Damage and Response

Tree and shrub species measured previously were re-evaluated and damage and plant response recorded. A two or three digit code was assigned to each individual, based on the following definitions in Table 1. An individual plant with damage of more than one cause was normally assigned two or more damage numbers. Because a plant can respond in only one pattern, however, a single plant response symbol described how the plant reacted. With the assignment of symbols to whole-plant responses, the flexibility needed to describe a wide range of damage and responses was achieved.

Planting Characteristics

In order to estimate planting information, a circular plot with a radius of 5.08 m (16.68 ft) was outlined around each point with a steel tape. An imaginary grid on a 3 by 3 m (10 by 10 ft) spacing was positioned over this area, simulating potentially plantable spots. With this spacing, nine possible spots were present at every point. Each spot was rated as either plantable or not plantable within a 61 cm (2 ft)

Table 1. Plant damage and response codes used to describe the effects of treatments on individual woody plants.

Code	Damage
1	untouched-slightly damaged
2	standing- injured by herbicide
3	bent or crushed
4	buried by slash
5	buried by soil
6	burned
7	broken or cut off at ground
8	completely removed
	Plant Response
A	crown leafed out greater than 50%
B	crown leafed out 5 to 50%
C	crown leafed out less than 5%
D	crown leafed out less than 5%, basal sprouts
E	crown dead, sprouts along stems only
F	crown dead, sprouts from stems and base
G	crown dead, enlarged buds on stems or base
H	top dead, basal sprouts only
I	totally dead
J	viability not determinable

radius of the actual grid point.

To determine the distribution of spots around each point, the large sample plot (5.08 m radius) was divided into four quadrants. Two or three plantable spots in a quadrant indicated it was fully stockable, while one spot implied partial stocking. No plantable spots indicated prospective non-stocked conditions. An increase in quadrants with partial or non-stocked conditions was interpreted as a decrease in the uniformity of micro-environments over an area, and an indication of future patchy distributions.

In addition, each plantable spot was rated according to difficulty of planting. Three classifications were used: easy, medium, and hard. Spots rated as easy were defined as those in which a tree planter had no access problems, slash was sparse and low to the ground, and little hindrance in tool movement would occur. Medium difficulty meant a planter would have slash to step over, but none to go under, access would be decreased, and tool movement would be slightly hindered. Hard spots were those which possessed conditions causing a planter to crawl under or over slash, with limited access, and greatly hampered tool positioning.

Additional Treatment Effects

Additional information concerning the effectiveness of treatments was also collected. The amount of plot area (5.08 m radius) affected by the site preparation prescription was noted, and the amounts subjected to treatment expressed as a percentage of the total plot area, using the same intervals as cover classes for estimation.

Soil disturbance in the small sample (2.27 m radius) plot was also recorded on a scale of one to five. One indicated undisturbed soil, and five denoted heavily disturbed or scarified soil. In addition, these subplots were noted as having either been burned or unburned.

Animal habitat conditions were evaluated over the large plot. Deer access through the plot was estimated as well as abundance of preferred food, such as leafy shoots or sprouts of vine maple, huckleberry, hazel, and particularly Rubus species, as well as various herbaceous plants (Crouch 1964). Mountain beaver habitat was also noted. The presence of slash concentrations, old logs, stumps, or tangles of dense brush and preferred foods such as sword fern, salmonberry, vine maple, and miners lettuce indicated ideal habitat (Hooven 1977). Both deer and mountain beaver evaluations were subjectively rated as excellent, medium, or poor.

RESULTS

Pre-disturbance Characteristics

Vegetation

Canopy coverage before site preparation is presented in Figures 4, 5 and 6. Ground vegetation coverage in layer one (Figure 4) was typically concentrated between 5 and 50 percent in most treatment areas, although the chemical plots had 25 percent of their points containing no cover. The scarification plot, because of a more recent disturbance history on part of the area, shows some divergence from this pattern, with one fourth of its points occurring in the 75 to 100 percent class. This anomaly also manifests itself in other community characteristics discussed below. Figure 5 demonstrates the distribution of shrub canopy coverage in layer two. The greatest percentage of points in most treatments fell into the two cover classes representing 50 to 100 percent cover. The scarification plot, however, again exhibited a departure from this pattern, with all cover classes being represented. Canopy coverage in the tree stratum is portrayed in Figure 6. A distribution similar to the shrub layer is apparent, with most points falling between 50 and 100 percent cover. The area designated for the scarification treatment was found to have the majority of its points containing 5 to 50 percent canopy coverage.

The dominant species contributing cover in each layer is shown

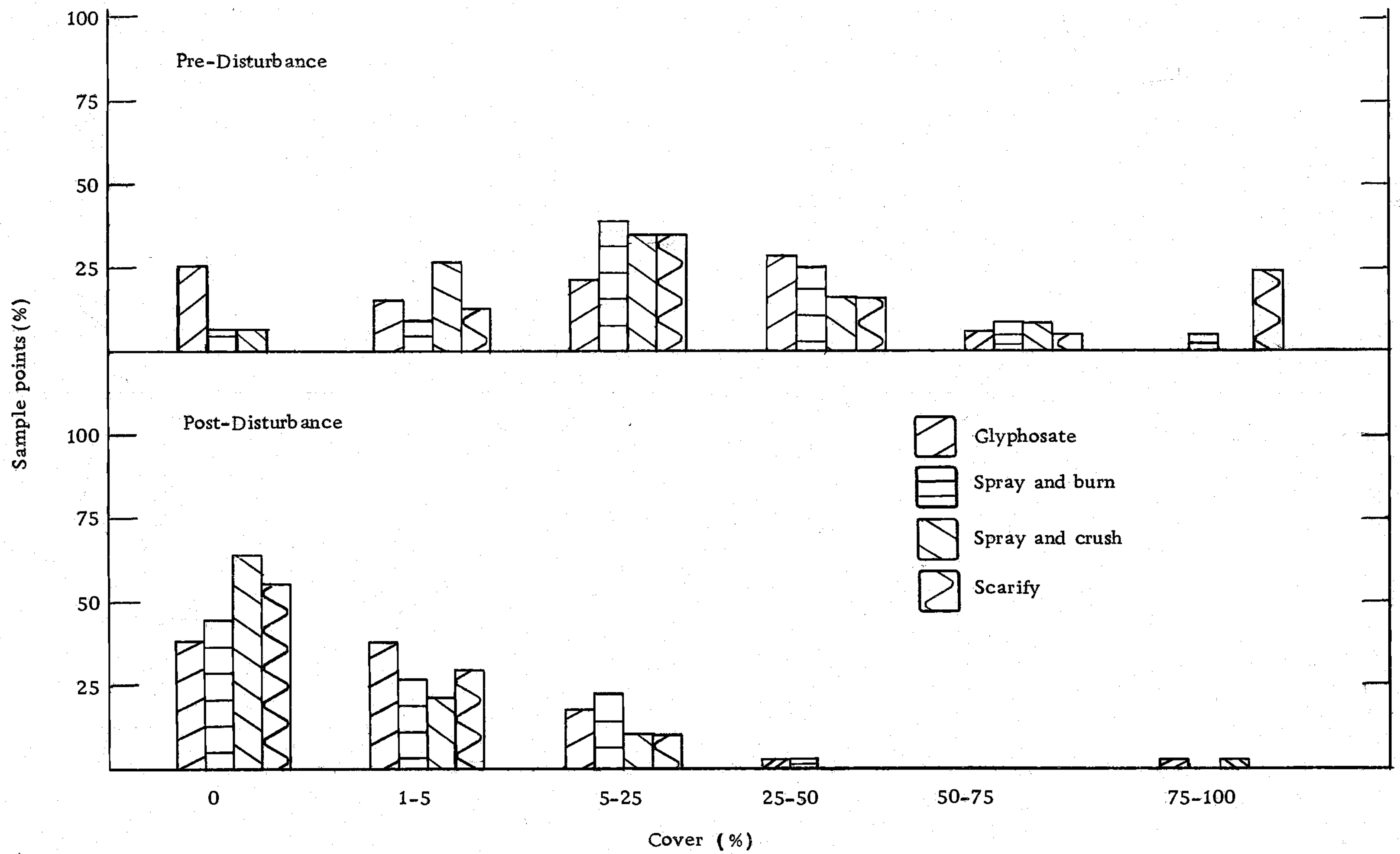

Figure 4. Canopy coverage in layer one (ground layer) before and after disturbance.

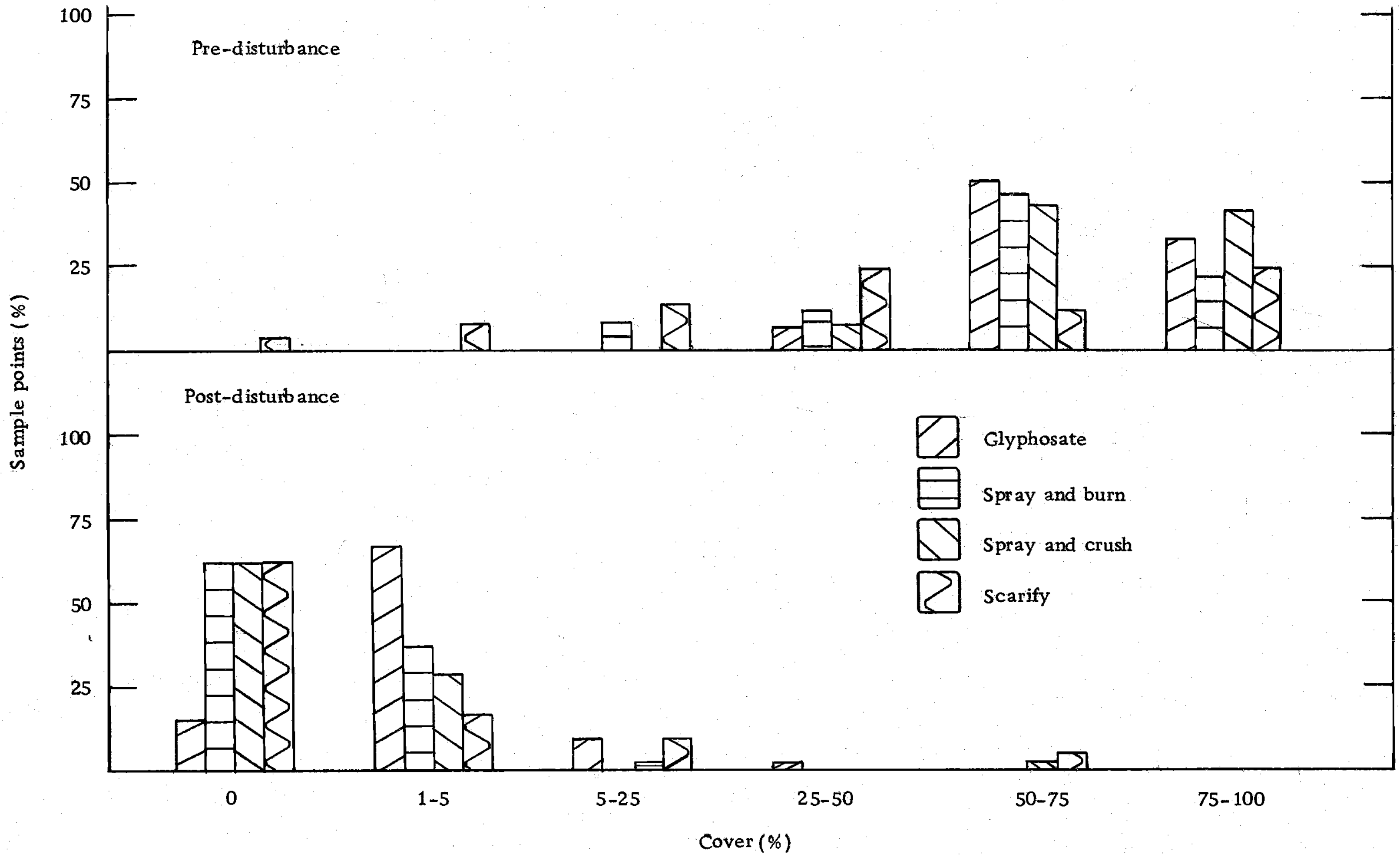

Figure 5. Canopy coverage in layer two (shrub layer) before and after disturbance.

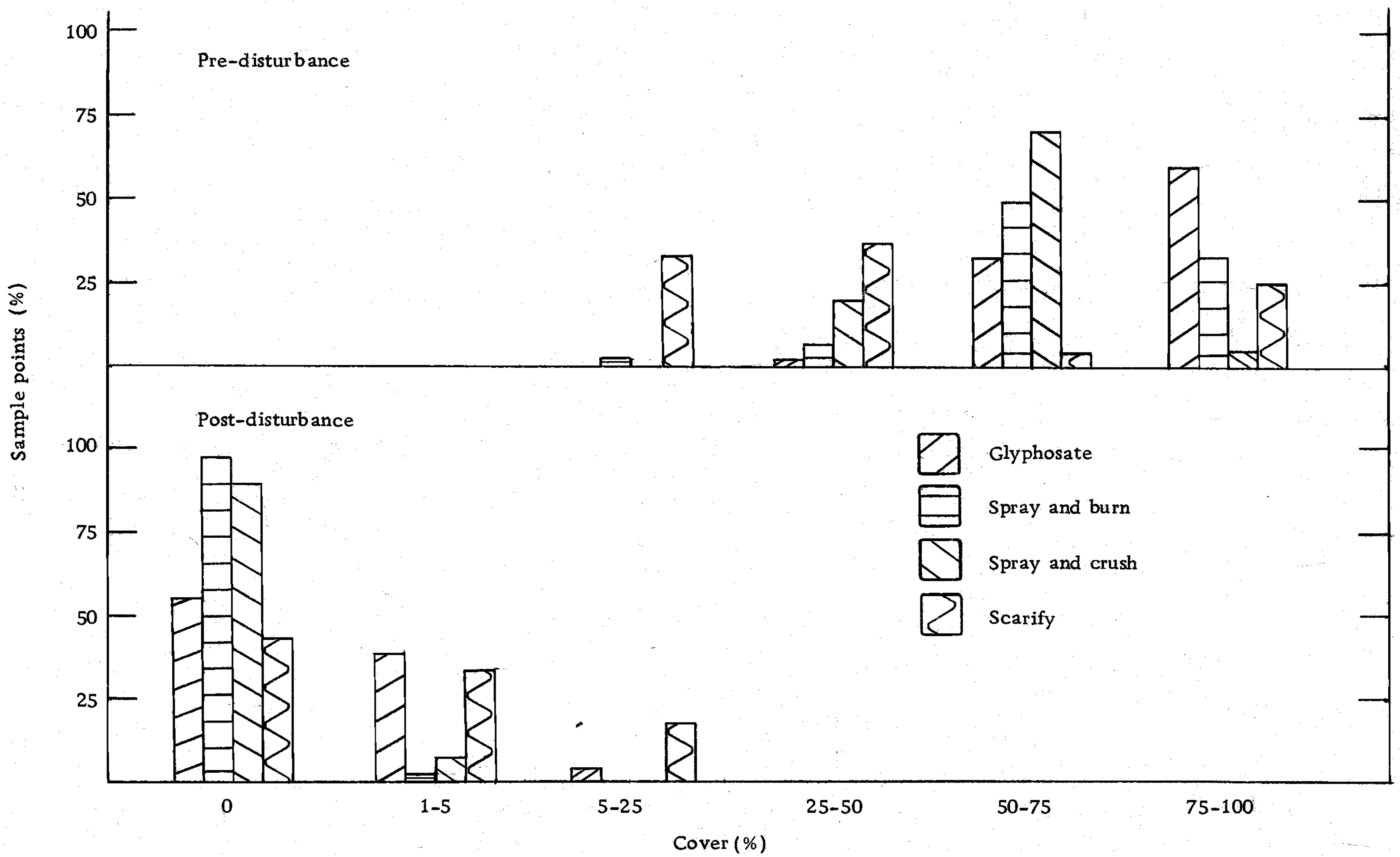

Figure 6. Canopy coverage in layer three (tree layer) before and after disturbance.

in Figures 7, 8, 9 and 10. In layer one (Figures 7 and 8), sword fern and salmonberry were the major species supplying cover in all treatment areas. In addition, trailing blackberry (Rubus ursinus Cham. & Schlecht.) comprised a large fraction of the cover in the scarification plot. In the shrub stratum (Figure 9), vine maple, hazel (Corylus cornuta Marsh), red elderberry (Sambucus racemosa L.), and salmonberry were important contributors over the entire area. Young red alder was also an important species in the scarification site, indicating the more recent disturbance on part of this area. Species contributing large amounts of cover in the third layer include mainly red alder, but bigleaf maple, bitter cherry, and Douglas-fir also play minor roles (Figure 10).

Ground vegetation composition and frequencies are shown in Appendix I, and graphically in Figure 11 for some selected species. Sword fern was the most frequently occurring species in all areas except the scarification plot, producing frequency values of 88 percent or higher. It was, however, still a high ranking species in the scarified area, with a frequency of 44 percent. Salmonberry was also abundant in all treatment areas, having frequency values ranging between 53 percent in the chemical areas to 63 percent in the spray and burn plots. Miners lettuce was consistently represented throughout the study area, although not overly abundant, with frequencies ranging from 28 to 13 percent. Other important species comprising

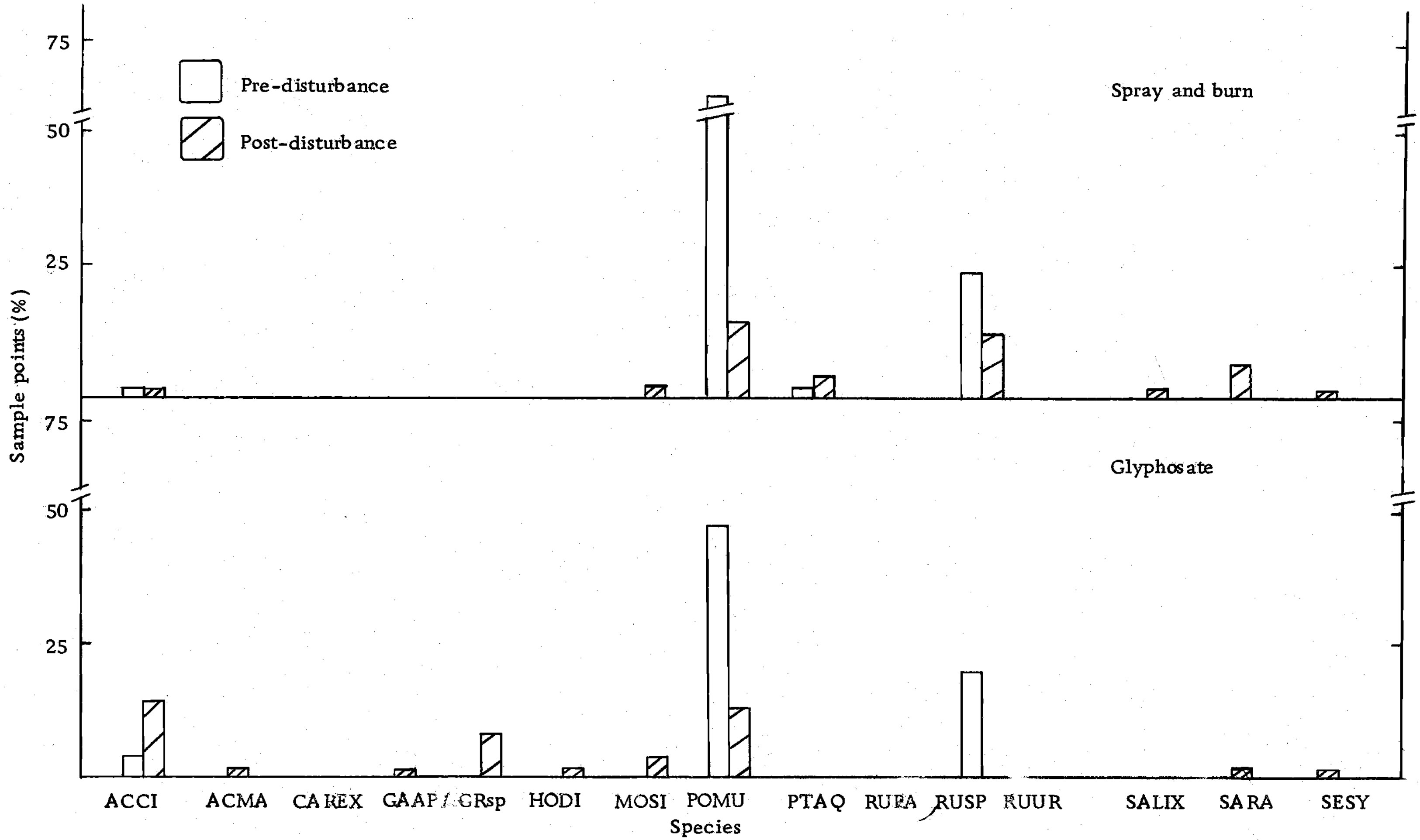

Figure 7. Dominant species providing cover in layer one (ground layer) before and after disturbance, in the spray and crush and glyphosate areas. Species codes are defined in Appendix II.

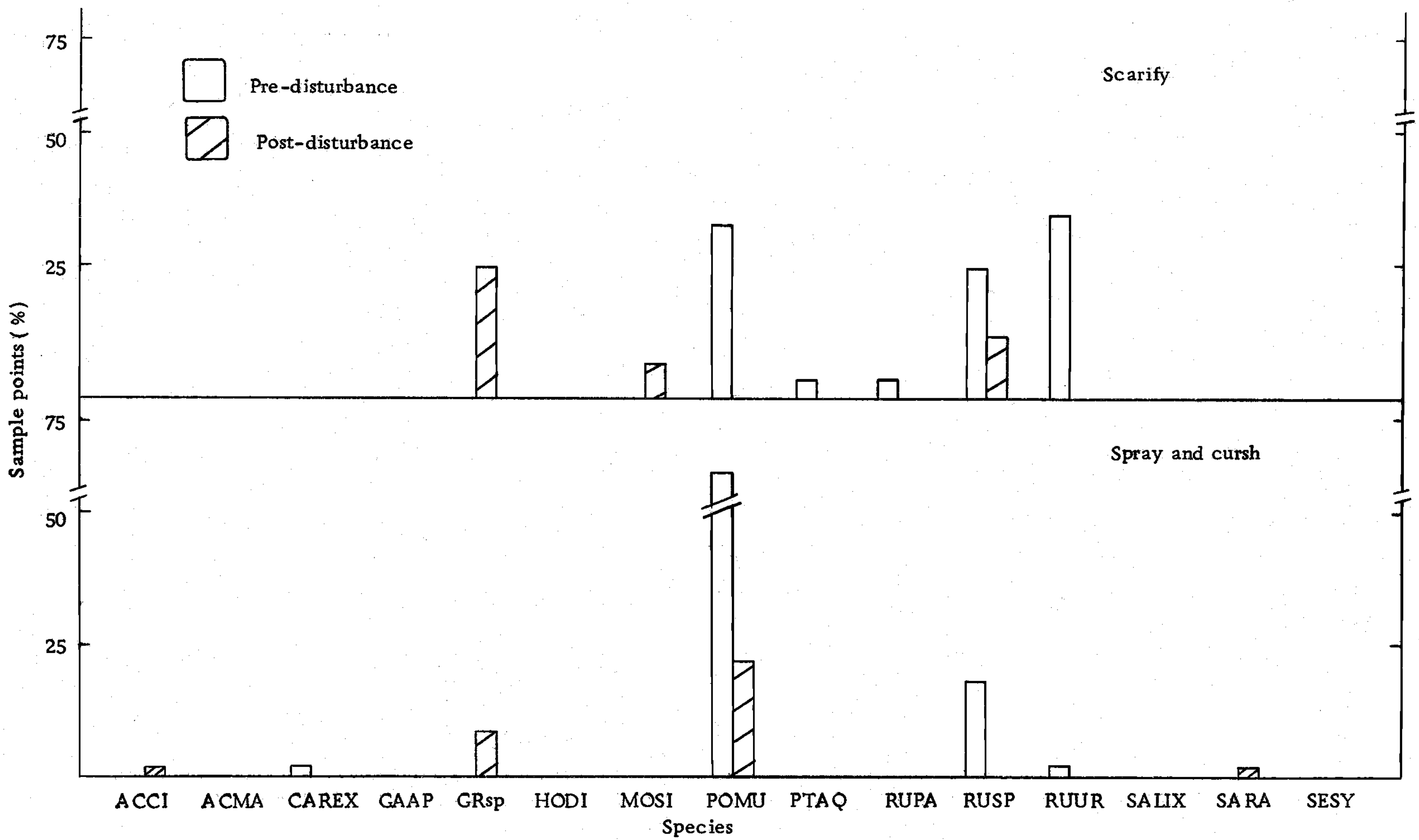

Figure 8. Dominant species providing cover in layer one (ground layer) before and after disturbance, in the spray and crush and scarify areas. Species codes are defined in Appendix II.

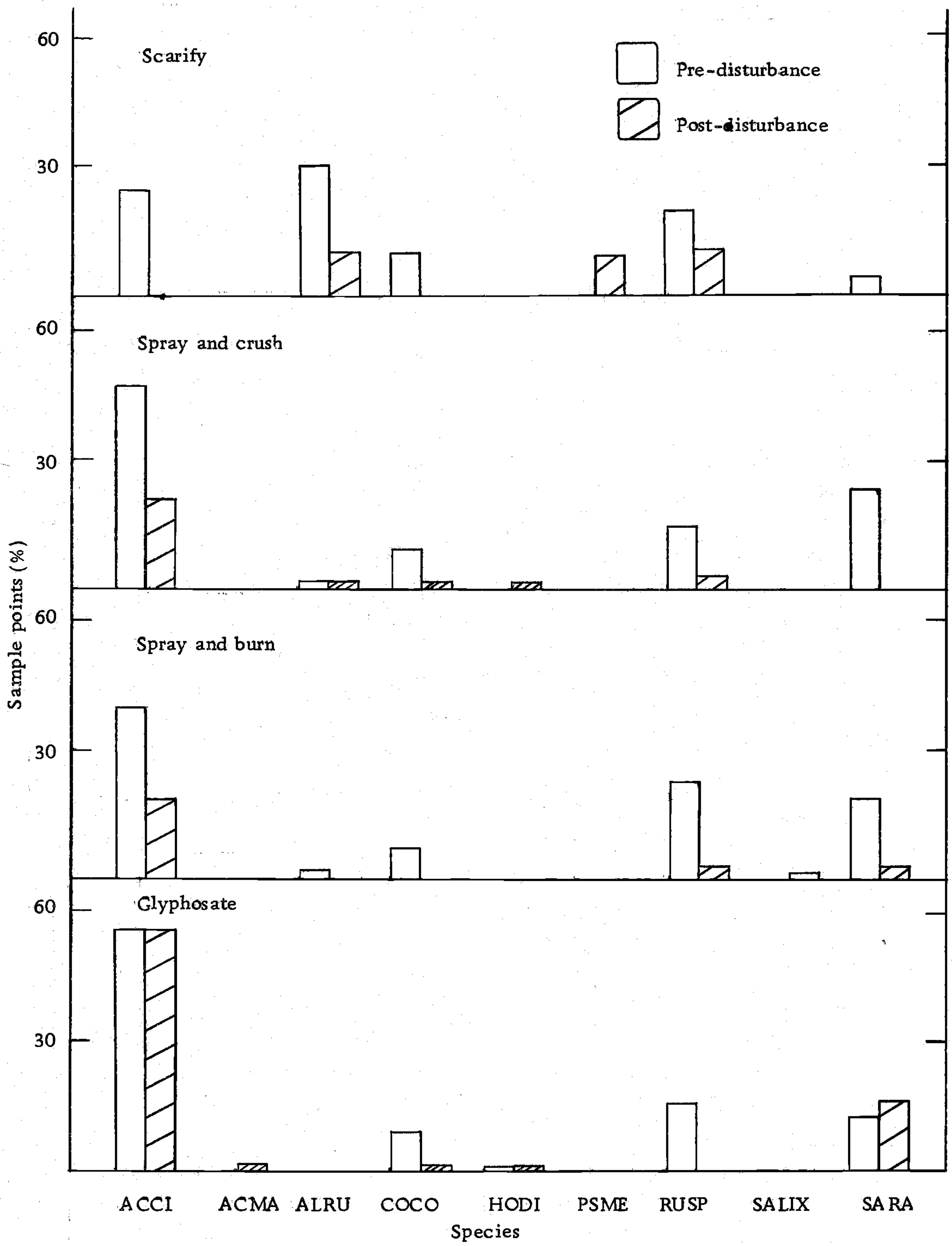

Figure 9. Dominant species providing cover in layer two (shrub layer) before and after disturbance. Species codes are defined in Appendix II.

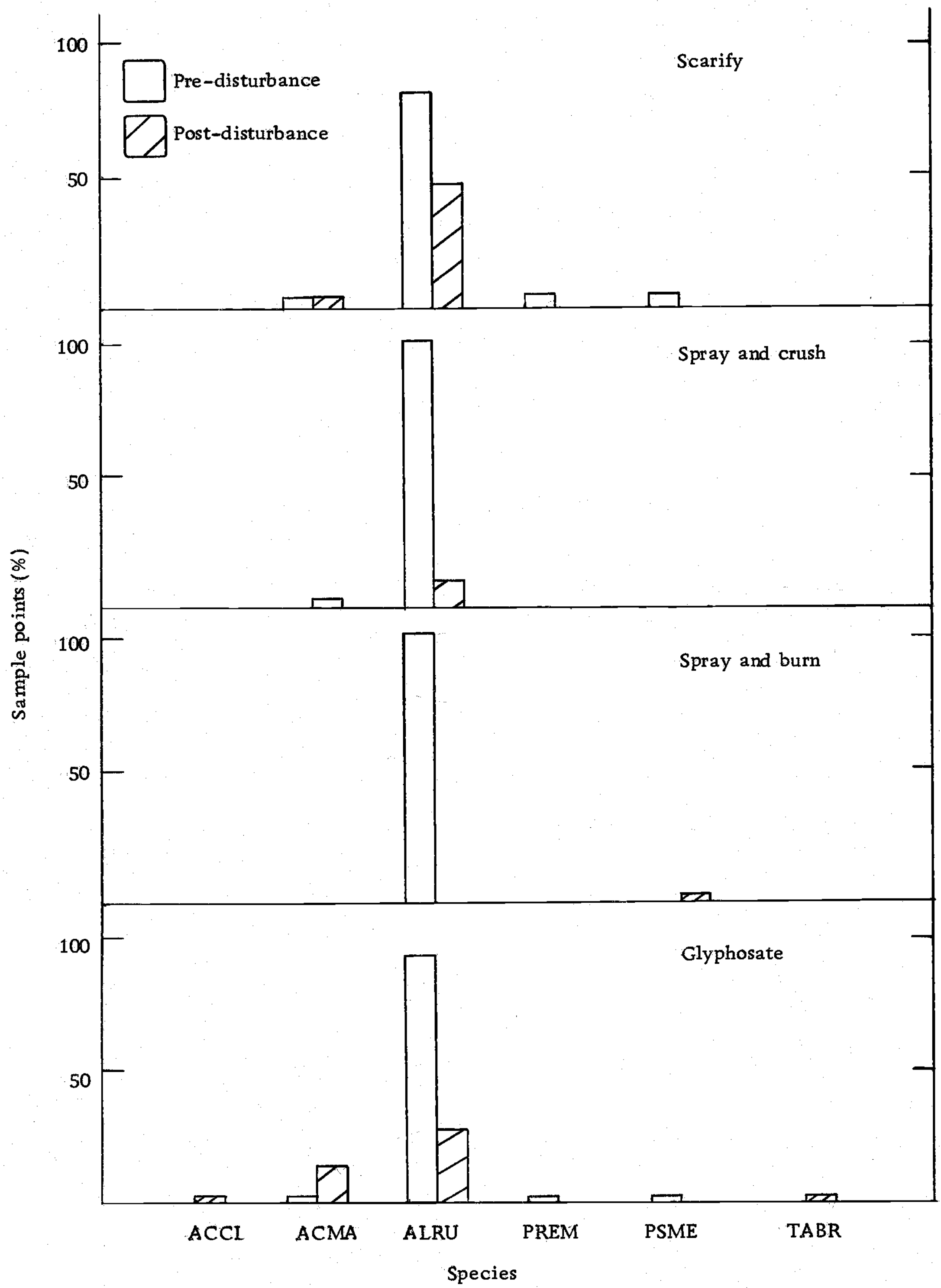

Figure 10. Dominant species providing cover in layer three (tree layer) before and after disturbance. Species codes are defined in Appendix II.

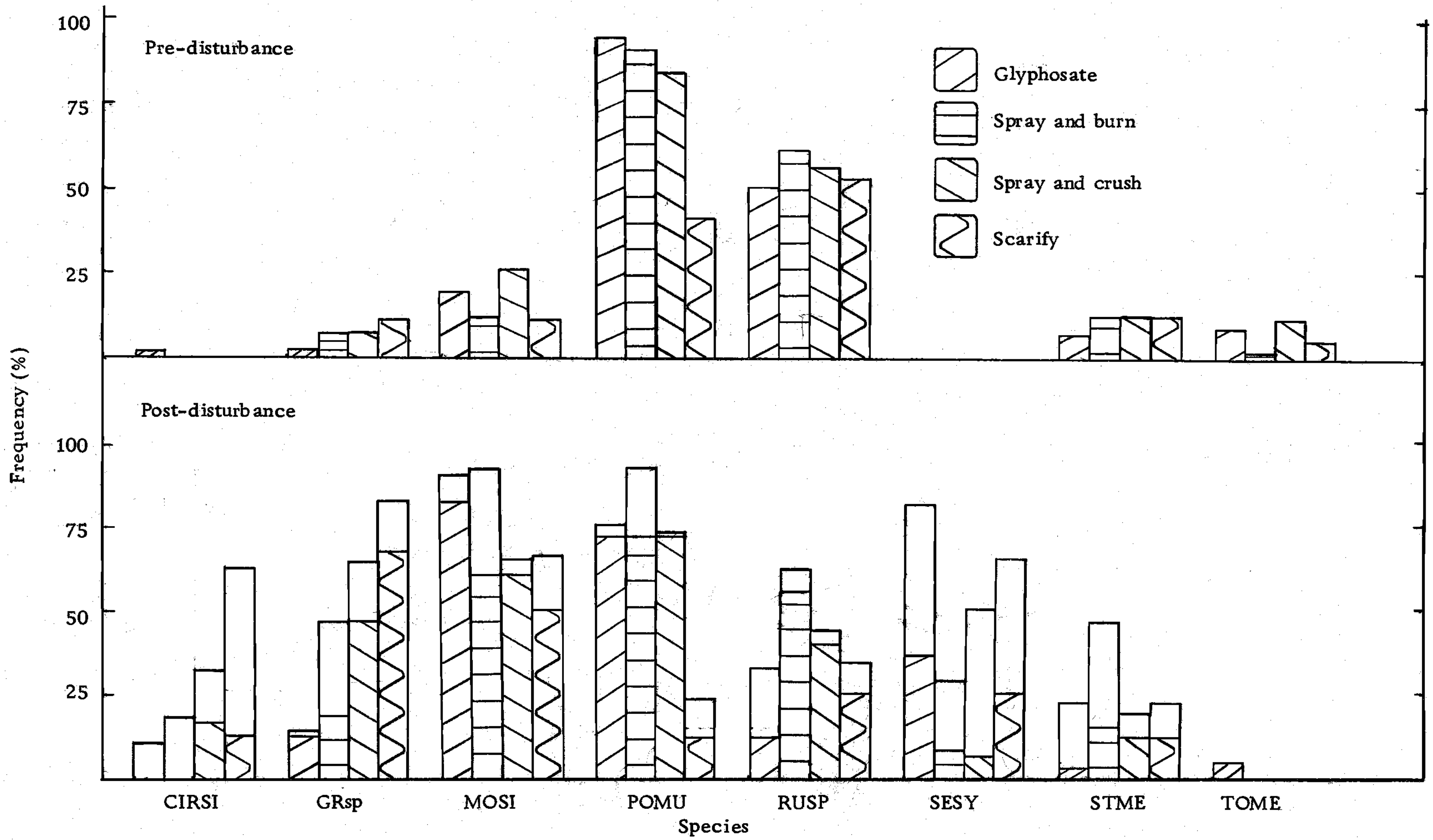

Figure 11. Frequency of some selected ground vegetation species before and after disturbance. Frequencies are based on the three most widely covering plants in each sample plot before disturbance, and both three (shaded) and six (unshaded) species after disturbance. Species codes are defined in Appendix II.

pre-disturbance vegetation include bleeding heart (Dicentra formosa (Andr.) Walp.), waterleaf (Hydrophyllum tenuipes Heller), soft nettle (Stachys mexicana Benth.), wild cucumber (Marah oreganus (T. & G.) Howell), bracken fern (Pteridium aquilinum (L.) Kuhn.), and in the scarification plot, trailing blackberry.

Total ground vegetation cover in each sample plot is presented in Figure 12. Most plots in all treatment areas contained at least 25 percent cover, with over half of the points in each area supporting more than 50 percent total cover. The scarification plot had the largest number of points above 75 percent cover, with 81 percent of its points falling into this category.

Table 2 presents frequency values for most shrub and tree species encountered within a 10 m (33 ft) radius of the sample point prior to disturbance. Red alder, vine maple, and salmonberry were extremely abundant, having frequency values ranging between 81 and 100 percent over all treatment areas. Elderberry was also frequently encountered, occurring on 78 to 88 percent of the sample plots in all treatment areas. Other species occurring frequently were hazel, red huckleberry, bitter cherry, and to a lesser extent, ocean spray (Holodiscus discolor (Pursh) Maxim). Douglas-fir was not abundant except in the scarified site, where it had a frequency of 56 percent. Its presence there was at least partly due to natural seeding after relatively recent disturbance.

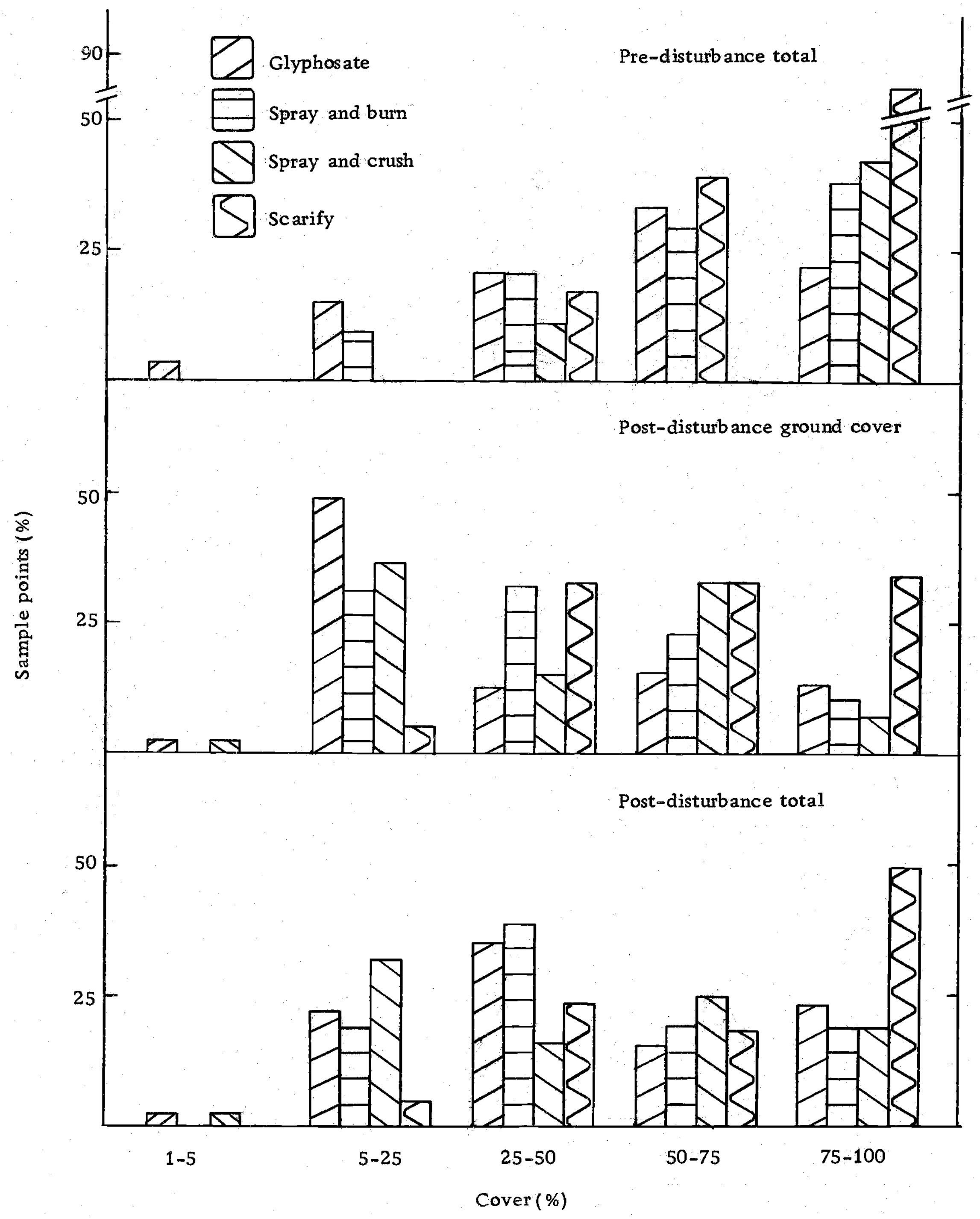

Figure 12. Total cover (less than 1.5 m) distribution in the 2.27 m radius sample plot, before and after disturbance.

Table 2. Frequency of woody species before disturbance. Values are based on the percentage of points where each species was found within a 10 meter radius. Species codes are defined in Appendix II.

Species	Glyphosate	Treatment Area Spray & Crush	Spray & Burn	Scarify
ACCI	97	81	97	86
ACMA	19	3	9	13
ALRU	88	97	88	100
BENE	13	13	9	--
COCO	31	69	84	50
HODI	3	31	9	13
PREM	25	9	25	56
PSME	6	13	3	56
RUSP	97	94	88	81
SALIX	3	3	--	--
SARA	78	88	84	56
TABR	3	--	--	--
TSHE	--	--	--	6
VAPA	53	72	63	44

Post-disturbance Characteristics

Vegetation

Post-disturbance canopy coverage is depicted in Figures 4, 5 and 6. In layer one (Figure 4), canopy coverage in all treatment areas generally ranged between zero and 25 percent, with a large percentage of the points in each treatment falling into the zero percent category. Few points in any treatment were occupied by cover values greater than 25 percent. In the shrub stratum, canopy coverage in all areas was concentrated between 0 and 5 percent (Figure 5). Sixty-two percent of the points in all treatments, except the chemical, were completely void of cover. In the glyphosate areas, 16 percent of the points were void of cover, while 69 percent were covered to an extent of 1 to 5 percent. A small percentage of points in all treatments, especially the glyphosate, were scattered in cover classes greater than 5 percent. Cover values in the third layer demonstrated a distribution pattern similar to the shrub stratum (Figure 6). A high percentage of points in the spray and crush, and spray and burn treatments (88 and 97%) were contained in the zero percent cover category, while the chemical and scarification treatments contributed 53 and 44 percent of their points to this class. The remaining points in these two treatment areas were generally contained in the 1 to 5 percent class, and to a lesser extent, in the 5 to 25 percent category.

The dominant species contributing post-disturbance cover in each canopy level are presented in Figures 7, 8, 9 and 10. Sword fern was a large contributor in all but the scarification plot in layer one, while salmonberry supplied a large portion of the cover in the scarification and spray and burn areas, but was absent in the glyphosate and spray and crush plots. Grass species were also contributors in the crush, glyphosate, and in particular, the scarification plot, where 25 percent of the points were dominated by these species. Vine maple was an important species in the chemical plot, as were elderberry and bracken in the burn areas.

Figure 9 illustrates the dominant species contributing post-disturbance cover in layer two. Vine maple was a major species in the burn and crush areas, but especially so in the chemical plot where 56 percent of its points were occupied by this species. Salmonberry, red alder, and Douglas-fir were the major cover contributors in the scarified area, but these species were absent or minor in other treatment areas. Elderberry played a large role in the chemical plots, but was minor or absent in other treatments.

The dominant species supplying cover in the tree layer are presented in Figure 10. Red alder was the major contributor in the scarified plot (50% of its points) as well as the crush and chemically treated areas. Bigleaf maple added additional cover at a small percentage of points in the scarify, crush, and especially the chemical-only plots, but was absent in the burned areas.

Post-disturbance ground vegetation composition and frequencies are presented in Appendix I, and in Figure 11 for some selected species. Frequencies shown are derived from either the top three or top six species recorded (in terms of their cover) at each point. Miners lettuce was among the most frequently occurring species in all treatment areas, having values ranging from 50 to 81 percent (based on top three species) and frequencies between 69 percent in the scarify plot and 93 percent in the spray and burn areas based on top six species. Sword fern was also abundant in all but the scarification areas, having a frequency of 75 percent based on the top three species, and as high as 94 percent using the upper six species at each point. Salmonberry was present over all areas also, having frequency values ranging from 13 to 56 percent (top three) and values varying between 35 percent in the glyphosate plots to 62 percent in the spray and burn areas (top six species). Frequencies of grass species were generally the highest in the scarification plot and lowest in the chemical only areas. A similar pattern is presented by Cirsium based on the six uppermost species at each point. Woodland groundsel (Senecio sylvaticus L.) had moderate to low frequency values over all treatments using three species (6 to 35%), but considerably higher frequencies if the upper six species are considered (28-84%).

Post-disturbance shrub species frequencies and composition are presented in Table 3. Elderberry was the most abundant shrub in all treatment areas after disturbance ten months later. Vine maple, thimbleberry (Rubus parviflorus Nutt.), and bitter cherry were also major contributors over all areas.

Figure 12 depicts post-disturbance total cover in the 2.27 m radius sample plot. Total ground vegetation cover (herbs, rhizomotous shrubs) was evenly distributed over all cover classes in all treatments, except the 1 to 5 percent category. The scarified plot showed a slightly greater percentage of points in the higher cover classes with respect to the other treatment areas, while the glyphosate plots presented the reverse trend. Total cover (herbs, all shrubs) in the plot is shown in the bottom figure, where a trend similar to total ground vegetation is exhibited. The scarification plot contained one half of its points in the highest cover class, while other treatment areas were uniformly distributed over all classes, except the 1 to 5 percent category.

Woody Plant Damage and Response

Damage to individually recorded woody plants is presented in Figure 13. Because a single plant was often recorded as having more than one type of damage inflicted on it, the bars representing percentage of woody plants recorded do not necessarily add to 100 percent within a given treatment. This is most noticeable in the spray and

Table 3. Frequency of woody species less than 1.5 meters tall after disturbance. Values are based on the percentage of points where a species was rated among the three most dominant shrubs within a 2.27 meter radius. Species codes are defined in Appendix II.

Species	Treatment Area Glyphosate	Spray & Burn	Spray & Crush	Scarify
ACCI*	63	44	44	31
ACMA	3	--	3	--
ALRU	6	16	13	13
BENE	--	3	--	--
COCO	13	22	6	3
GASH	3	3	--	--
HODI	3	3	--	--
PREM	31	41	66	69
PSME	--	--	--	6
RUPA	47	38	25	75
SALIX	--	3	--	--
SARA	75	91	100	69
VAPA	3	6	--	--

*Because vine maple propagates by layering, bent or crushed tops lying in the plot but not necessarily rooted were used to determine its frequency in some plots.

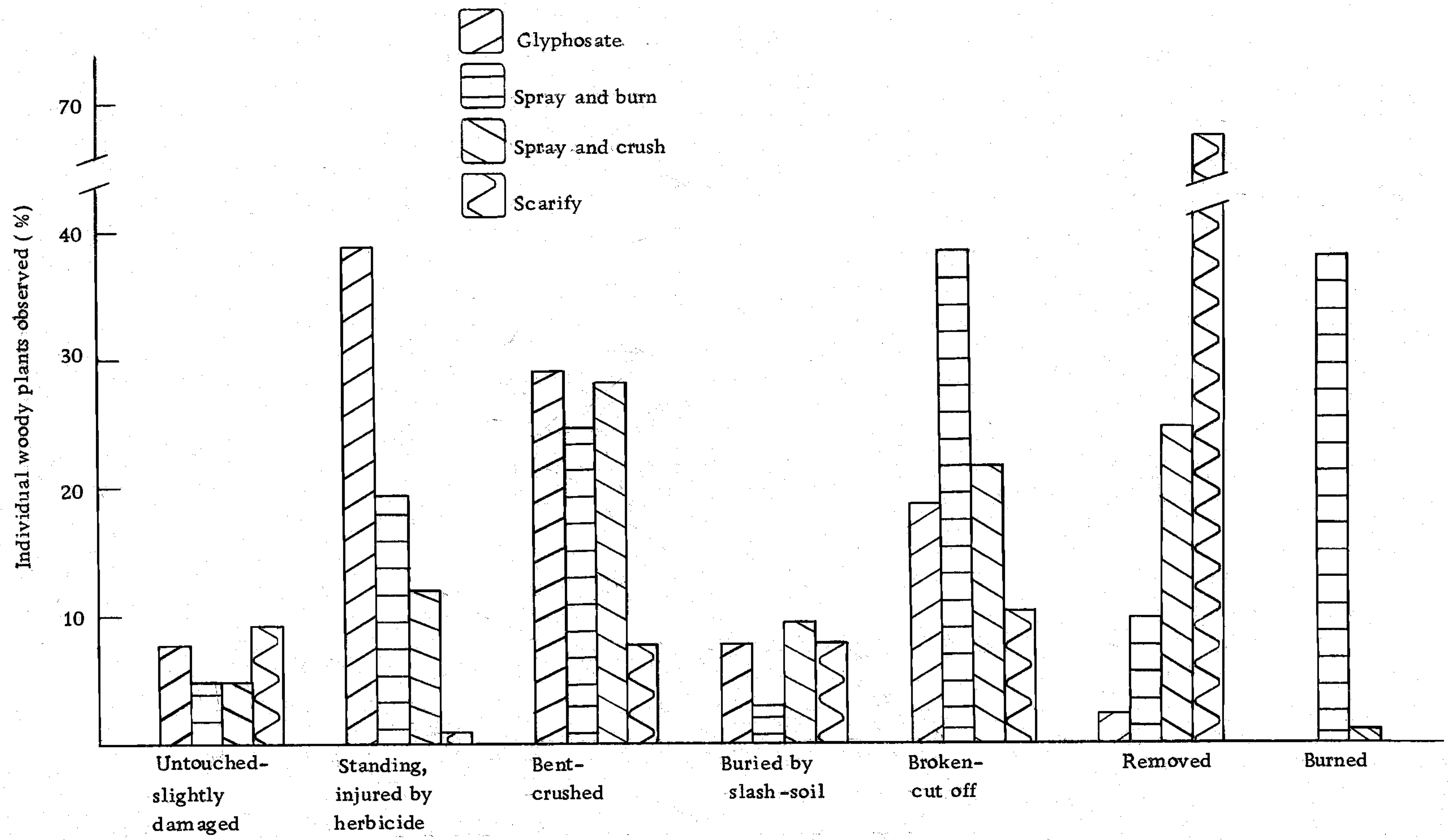

Figure 13. Woody plant damage resulting from logging and site preparation.

burn treatment, but very minor in the others. Within a given damage class, however, the percentages are helpful in comparing differences between treatments.

Very few plants in any of the treatment areas were left undamaged as a result of logging or site preparation activity. The glyphosate treatment contained a high percentage of plants that were standing and injured by herbicide (38%), and also a large number that were either bent-crushed (29%), or broken-cut off (19%). In the spray and burn area, 39 percent of the plants were burned to some extent, but the same amount were also broken-cut off. In addition, one fourth were bent-crushed and 19 percent were injured by herbicide alone. In the spray and crush plots, 28 percent of the recorded woody plants were bent-crushed, while a large percentage (27%) were totally removed from the site. A large fraction were also broken-cut off (23%). The scarification treatment contained the highest percentage of plants in a single damage class in any treatment area, with 66 percent of the recorded individuals being completely removed from the plots. Eleven percent were broken-cut off, while 7 percent were bent-crushed, and buried by soil or slash. Nine percent were untouched or slightly damaged.

Plant response to damage is illustrated in Figure 14 for each treatment. Response classes have been condensed into dead, top dead with basal sprouts, and "other," which includes all other response

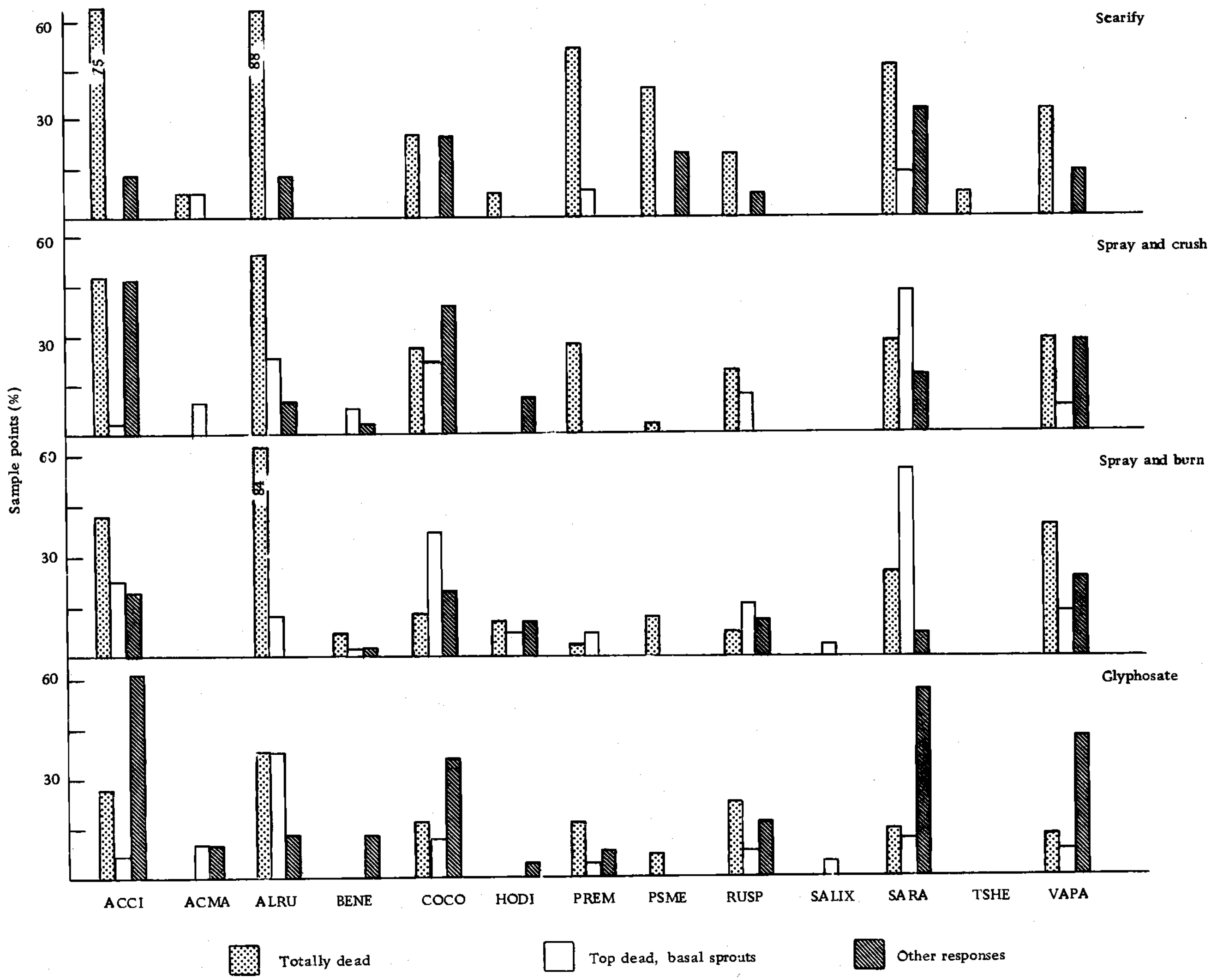

Figure 14. Plant response after logging and site preparation. Species codes are defined in Appendix II.

categories listed in Table 1. Among the more important species, vine maple shows some differences in its response in the four treatment areas. In the glyphosate treated areas, a large portion of the plants remained alive, with most of these in the "other" category, and few with basal sprouts. In the spray and burn areas, more vine maple were dead than with basal sprouts, or other responses. The plants in the spray and crush plots generally had the same number of individuals that died, as those that responded differently, with few individuals producing only basal sprouts. The scarified area contained a large percentage of plants that died, with no plants having basal sprouts and relatively few with other responses.

Alder responses in the spray and burn, spray and crush and scarification plots were similar to each other, but departed from this trend in the chemical only areas. In the first three treatment areas, a large percentage of the alder died as a result of the treatments occurring in those areas. In the chemical only plots, an equal number of plants both died and produced basal sprouts.

Hazel, another important species, demonstrated a high percentage of plants alive in the chemical (glyphosate) plots, with most of these falling into the "other" category. In the spray and burn areas, a large percentage of the plants demonstrated basal sprouting, with slightly fewer showing other viable responses. Hazel in the spray and crush areas also showed a large number of viable plants, but had fewer basal sprouters than other responses. In the scarified plot, an equal number of hazel plants died and remained alive (without basal sprouts).

Elderberry plants in the chemically treated areas demonstrated a large response in categories other than dead or basal sprouts. In the spray and burn areas, a large fraction of the viable plants produced basal sprouts, but few responded in other ways. A similar trend is exhibited by plants in the spray and crush areas. Elderberry responses in the scarification plot show that many of these plants died, but that an equal number remained alive, most of which were in categories other than basal sprouts only.

Figure 15 graphically presents the percentage of woody plants (other than Douglas-fir and western hemlock) remaining alive in each treatment area. In the glyphosate plots, 71 percent of the individual recorded woody plants exhibited signs of viability nine months after the last act of disturbance. In the spray and crush, and spray and burn areas, 54 percent of the observed plants remained alive, and in the scarified area, 30 percent survived.

Planting Characteristics

Planting spot results are depicted in Figures 16 and 17. All treatments prepared abundant plantable environments (Figure 16). Assuming a maximum density of 1112 potential plantable areas per

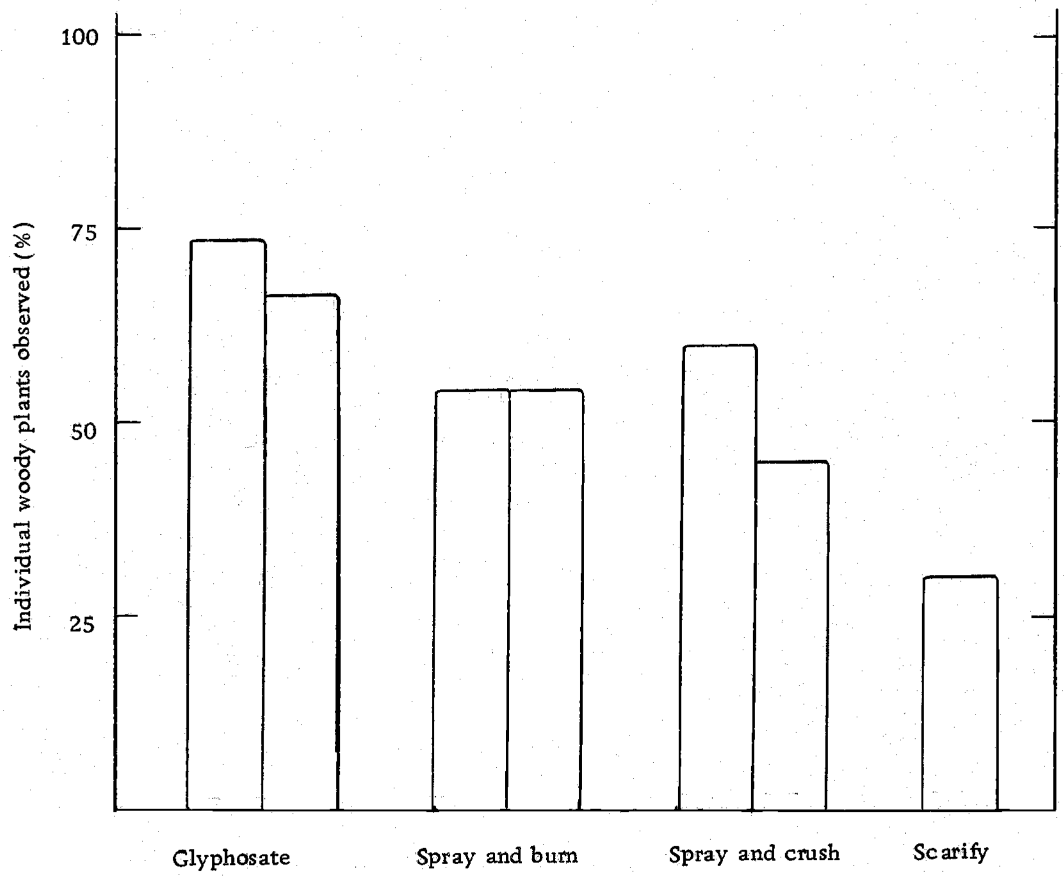

Figure 15. Woody plants showing signs of viability one season after logging and site preparation.

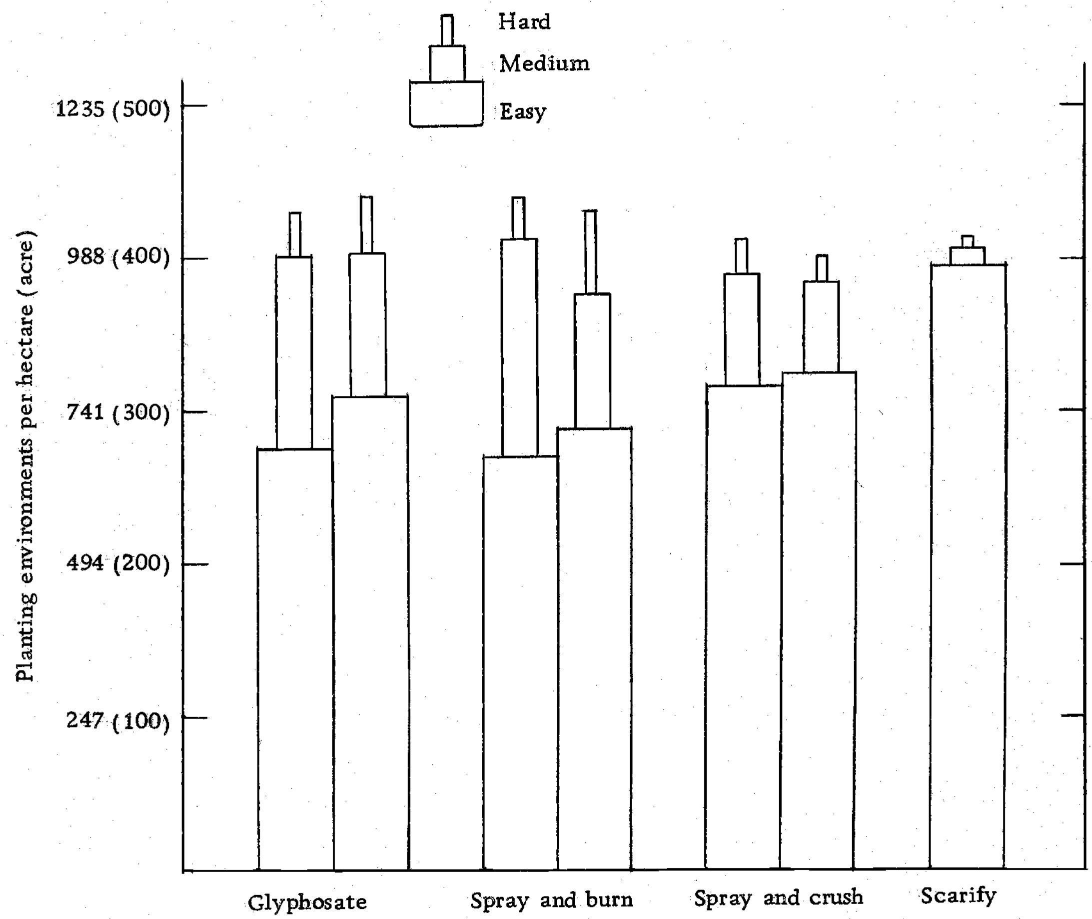

Figure 16. Number and difficulty of planting spots created by site preparation.

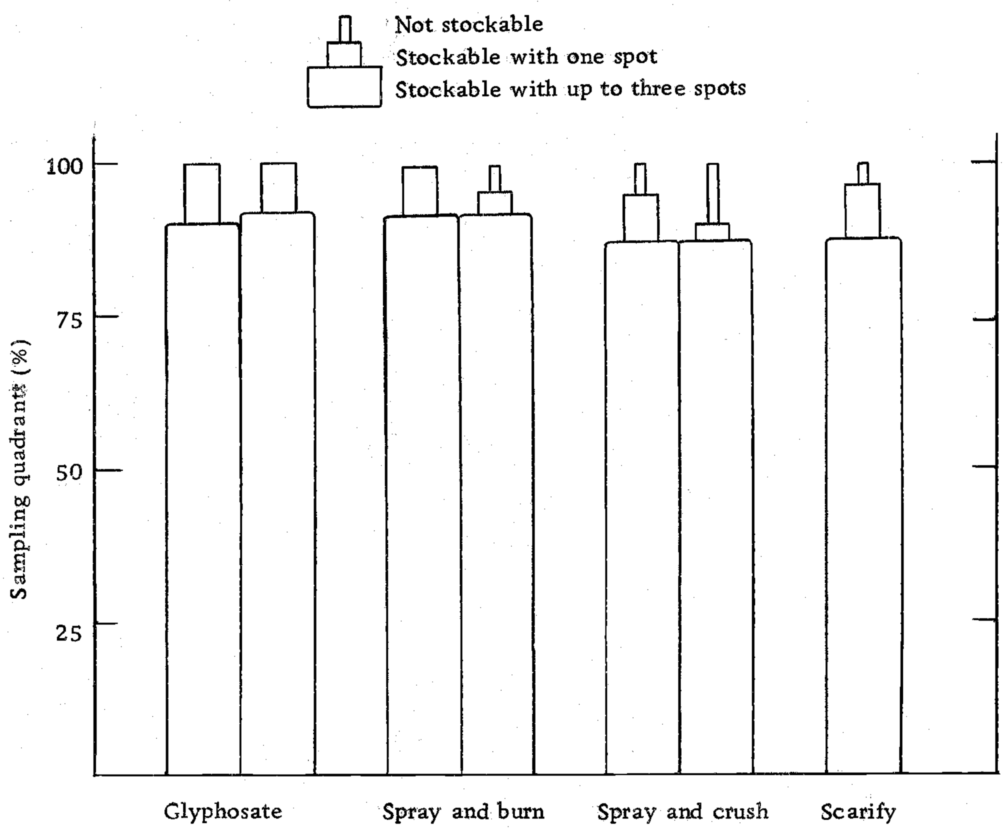

Figure 17. Stockability of sampling quadrants.

hectare (450 per ac) each treatment in every plot produced at least 90 percent of this maximum. The two glyphosate plots, as well as the two spray and burn areas, produced the highest estimate of plantable spots per hectare (1065 and 1079). The number of potential areas in the spray and crush plots were slightly lower (1003 and 1028), while the scarified area created an estimated 1035 plantable environments per hectare.

In terms of planting difficulty, the scarified area produced the greatest percentage of easily plantable spots, with 95 percent rated so (Figure 16). Difficulty in plots of other treatments varied between 61 and 65 percent easy in the spray and burn areas to 74 and 78 percent in the spray and crush plots. The glyphosate treated areas were rated as having 64 and 70 percent of their potential plantable spots in the "easy" category. Most plots had a relatively small percentage of planting environments that were rated as hard. The scarification area created only 1 percent hard spots. In the spray and burn plots, the percentage of hard areas were 6 and 12 percent, while the spots in the spray and crush treatment areas had 6 and 5 percent rated hard. The chemical only planting spots were rated as 7 and 8 percent hard.

Sampling quadrant stockability is presented in Figure 17. All plots in each treatment produced a high percentage of fully stockable quadrants. Percentages varied from 88 percent in both spray and crush plots, and the scarified area, to 94 percent in both the spray and burn plots, and one glyphosate area. A number of quadrants in all treatments were rated as having either one, or no planting spots. Percentages of quadrants with one spot ranged from 3 percent in one spray and burn, and spray and crush plot, to 9 percent in the scarified area and one glyphosate plot. In terms of quadrants with no spots, the extremes were 3 percent in the scarified plot and one spray and burn area, to 9 percent in one spray and crush plot. One spray and burn area and both glyphosate plots had all quadrants at least partially stockable.

Additional Treatment Effects

The amount of the 5.08 m (16.68 ft) radius sample plot prepared according to the prescribed treatment is illustrated in Figure 18. Results are for the physical aspect of each treatment (burn, crush, scarify), except for the glyphosate treatment, which is for the effects of the spray application only. In the spray and burn plots, a large fraction of the points were poorly treated (burned). Forty-one percent of the points were prepared to an extent of 5 percent or less, while 57 percent were treated to a degree of 25 percent or less. Sample plots covered with an intensity of 25 to 75 percent amounted to only 19 percent of the observed points. In addition, one fourth of the points were treated to an extent of 75 to 100 percent.

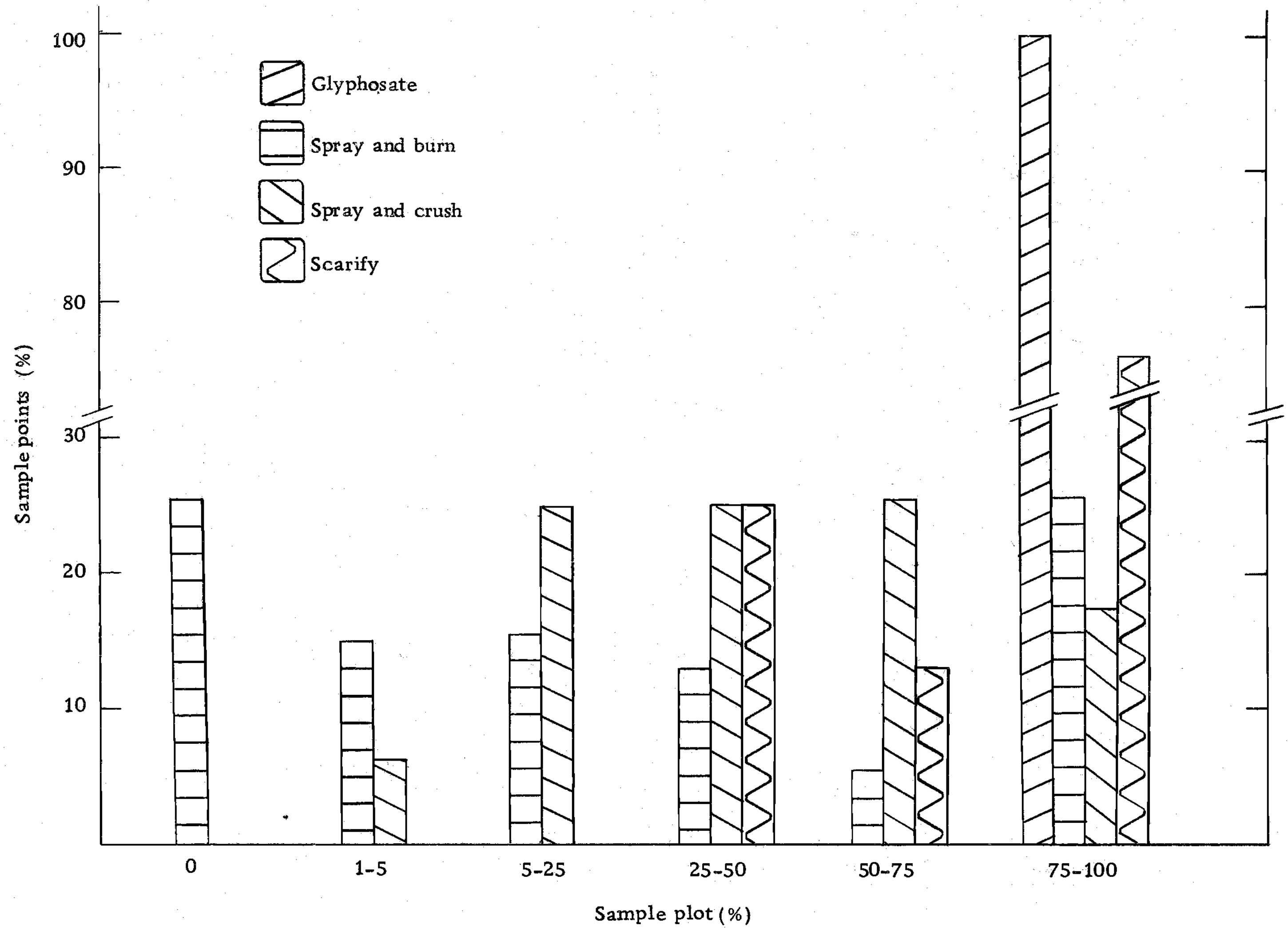

Figure 18. Sample area prepared according to site preparation prescription.

The spray and crush treatment prepared 31 percent of the sample plots with an intensity of one fourth or less. However, no points were rated as being completely untreated. In each class above 25 percent this treatment produced nearly an equal number of points in each one (25, 25, 19 percent respectively). The scarification treatment prepared all points with an intensity of 25 percent or greater. One fourth of the sample points were prepared to a degree of 25 to 50 percent, and 13 percent were scarified over 50 to 75 percent of the sample area. Sixty-three percent of the points were treated to an extent of 75 percent or greater. In the glyphosate plots, all of the sample points were prepared to the full extent or slightly less by the prescribed treatment (75 to 100%).

Soil disturbance in the small sample subplot demonstrates some differences between treatments. The glyphosate treatments produced most of their points in the bottom two (less intensive) soil disturbance categories (63%), and 18 percent in the top two classes (Figure 19). In the spray and burn areas, soil disturbance presented a similar trend, with 60 percent of the points classified into the two lowest categories, and one fourth in the two most heavily disturbed classes. Soil disturbance in the spray and crush was generally distributed throughout the range of classes. However, 53 percent of the sample plots were contained in the upper two soil disturbance categories. The scarification treatment produced the highest

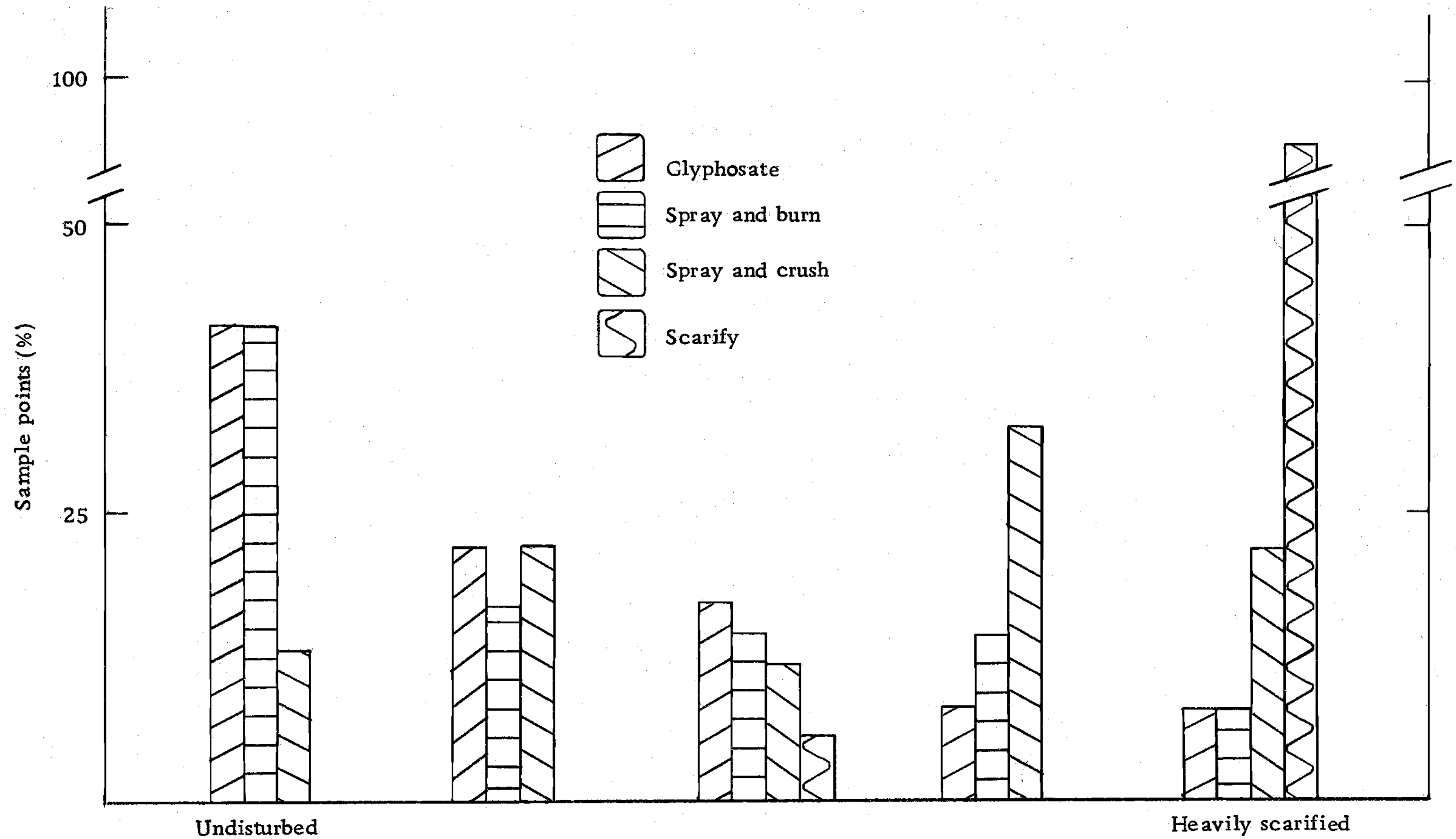

Figure 19. Soil disturbance resulting from site preparation and logging.

percentage of points with highly disturbed soil. Ninety-four percent of the points were rated as heavily scarified, while the remaining sample plots were classed as intermediate in disturbance.

Treatment effects on animal habitat are seen in Figure 20. All methods typically produced the same general distribution of points in the poor, medium, and excellent deer access categories. However, the scarified plot produced no poor access points, and a large number of excellent-rated sample plots (75%). Abundance of preferred deer forage in relation to treatment is shown in the middle figure. The glyphosate points were equally distributed among the three classes, while the spray and burn points were rated as 13, 28, and 59 percent for each respective category. In the spray and crush areas, the greatest percentage of points (50%) were classed as moderate in preferred forage with each of the remaining classes supporting one fourth of the points. The scarification plot followed the same trend as the spray and burn treatment, with few of its points falling into the poor class (6%), and a large fraction being rated as excellent (56%). The moderate class claimed the remaining number of sample plots in the scarification area (38%).

The top figure presents the relationship between mountain beaver habitat and methods. In the chemical-only treatments, most of the points were rated as excellent habitat (81%), while 13 percent were classed as moderate and 6 percent as poor. The spray and burn

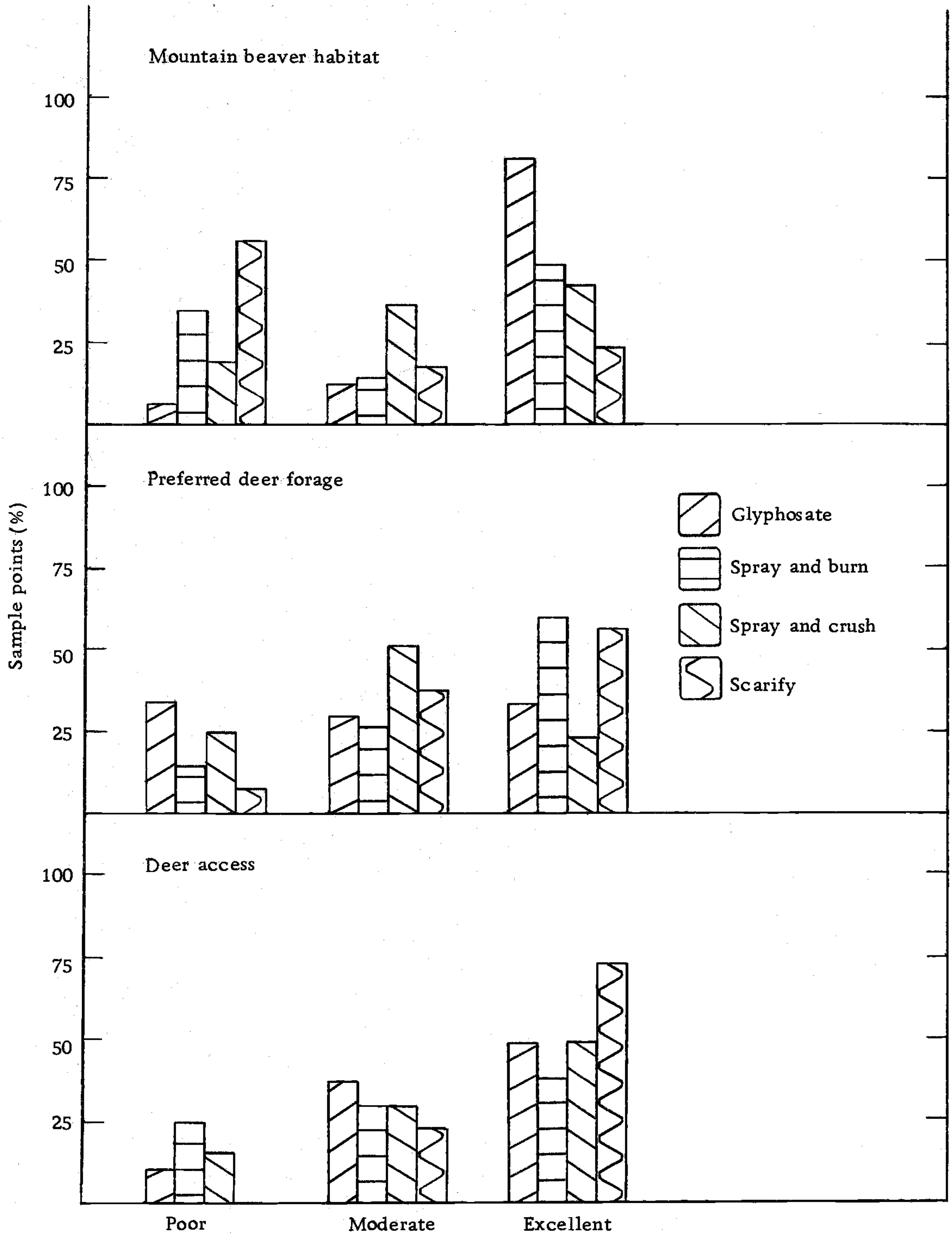

Figure 20. Animal habitat characteristics after site preparation.

method produced 34 percent of the points in those areas under the poor category, and one half as excellent. Most of the points in the spray and crush plots were rated as either moderate or excellent (38 and 44% respectively), while 19 percent were classified as poor. In the scarified area, 56 percent of the sample plots were categorized as poor, with the remaining points classed as moderate (19%), and excellent (25%).

DISCUSSION

Vegetation Changes

The effectiveness of all treatments in reducing heavy brushfield cover can be witnessed by comparing Figures 5, 6 and 21. All methods succeeded in shifting cover from the higher classes before logging and site preparation, to the lower categories afterward. Logging activities played a large role in this reduction. Had these site preparation treatments been applied without prior removal of the overstory, slightly different (greater) cover distribution patterns may have occurred, particularly in the glyphosate treated areas. It is doubtful, however, that this amount of cover would have reduced light to levels below those tolerated by Douglas-fir seedlings. The implications of this cover reduction are important with respect to the introduction of coniferous tree seedlings. Site resources such as light, water, and nutrients, formerly utilized by the old brushfield community, have become available to planted seedlings, as well as surviving and invading plant species. How successful these tree seedlings are in establishing themselves on this site depends in part, on the competitive ability of surrounding vegetation in ensuing years, rather than the influence of residual plant species at this point in time.

Changes in the relative dominance of species supplying cover

Figure 21. Heavy alder and brush cover (background) was successfully reduced by all treatments, including the spray and crush, shown here.

are also noteworthy (Figures 7, 8, 9 and 10). The deep uprooting action of the scarification treatment appears responsible for the absence of sword fern cover in layer one, and vine maple, hazel, and elderberry cover in layer two. The other treatment areas typically contained points supporting most of these species. The high percentage of points with alder in the tree layer, however, does not reflect this theory. Two realistic explanations for this observation are that these trees may have been growing on ground unsuitable for this type of treatment, or that sample points were placed too close to the plot boundary, thus having trees along the edges influencing the point. Within the prescribed area, and on suitable topography, few trees remained standing. The heavy mechanical action responsible for the removal of the previously mentioned species appears to also be related to the development of grass cover in layer one. In the scarified plot, and in skid trails or other areas of heavy traffic, these species, especially velvet grass (Holcus lanatus L.) developed into a rank herbaceous cover (Figure 22). This was also noticeable in the spray and crush, and glyphosate plots.

In the glyphosate treated areas, the lack of salmonberry cover in both layers one and two is probably in great part, a function of this species sensitivity to this chemical. Other treatments in both layers contained at least a small percentage of points where salmonberry was the dominant vegetation contributing cover (spray and crush in

Figure 22. Herbaceous development after scarification.

layer one was an exception). Although sensitive to glyphosate, vine maple remained in its pre-disturbance position as one of the dominant species supplying cover in layer two. These results, however, must be tempered by the fact that this species may require two years before expiring. Therefore the presence of this species at this time does not necessarily indicate a treatment shortcoming. The impacts of glyphosate, and the other treatments on plant succession are discussed in a later section.

On all but the scarified plot, the appearance of many woody species (vine maple, bigleaf maple, willow (Salix Spp. L.), elderberry, ocean spray), contributing cover in the lowest vegetation layer (layer one) suggests that the effective height of the woody component of this community has been reduced, and is now represented by basal sprouts and crushed or layered stems. The lower a competing canopy can be made, the shorter the time required by a conifer seedling to endure in a less than optimum environment, and the greater expectation of reasonable survival and growth.

A close comparison of ground cover species composition and frequency values before and after disturbance reveals that very few species were severely reduced or eliminated by any of the treatments (Figure 11 and in Appendix I). For example, sword fern frequencies remained nearly unchanged after site preparation, except perhaps in the scarification plot. This appears consistent with the cover reduction of this species in that area. Salmonberry frequency values decreased slightly, but unexpectedly, it was still a common species in all treatment area, including the glyphosate plots. Judging by this species extreme sensitivity to this herbicide, frequencies would have been expected to decrease. Although the data hints at this, plants injured by logging activities (which appear to be less sensitive as uninjured plants), or seriously injured but still viable individuals probably mask the impact of the chemical on this plant. Piggyback (Tolmiea menziesii (Pursh) T. & G.) was among the most severely affected species, determined solely on the basis of its decreased frequency in all areas. Although it never reached a high level of importance before disturbance, after site preparation it was only recorded in the glyphosate treated areas. Nonetheless, at most points in every treatment, remnants of the pre-disturbance plant community were clearly evident after site preparation, ten months later. Dyrness (1973) has reported similar results in Cascade clearcuts.

Many species, having been among the three dominant species before disturbance, appear to have been displaced into a lower level of dominance afterwards. The displacement of these species from dominant to codominant or subordinate positions appears to have been caused by a marked increase in the relative positions of a few invading species, and residual species that increased in abundance after treatment. In particular, miners lettuce and woodland groundsel in all areas, and grass and thistle species in the scarify and spray and crush plots seem to share this responsibility (Figure 11). Apparently, the environmental conditions conducive to the development of these species have been fulfilled, such as increased light, temperature, and soil disturbance.

Soil disturbance, especially, seems to have encouraged grass and thistle colonization, although miners lettuce and woodland groundsel appear to have benefitted from this also, especially where there was surface heat. West and Chilcote (1968) correlated the appearance of woodland groundsel in Coast Range clearcuts with available soil nutrients after slash burning, and also with a successional stage in which a nitrogen fixing species became abundant. Although groundsel appeared in burned areas in this study, it also occurred in large amounts in plots not containing fire as a treatment. Since this site was dominated by red alder, which is nitrogen fixing, the availability of nutrients after site preparation may have influenced the development of this plant.

The future growth and survival of the planted seedlings on this site may be compromised because of shrub colonization. Early in the growing season following disturbance, great quantities of elderberry germinants appeared, covering the ground surface in many areas. This species has the capability of germinating on nearly pure organic substrates, such as crushed rotten logs, where little else was found growing. It was expected that a large fraction of these germinants would succumb to summer heat and moisture stress, but many survived and developed rapidly. Deer browsing kept many in check in exposed areas, but where germinants were protected by slash, or in otherwise inaccessible areas, they were nearly as tall as the 2-1 planting stock used to regenerate the site. Besides elderberry, other species produced germinants throughout all treatment areas. Bitter cherry and thimbleberry in particular had high post-disturbance frequency values (Table 3).

The summation of these vegetation changes indicate that although tall living cover has been substantially reduced in all areas, the foundation for competitive shrub development still exists. In addition, the appearance of herbaceous species such as grasses in the scarified area, may have important impacts on the future growth of coniferous tree seedlings introduced into these sites. The type of disturbance responsible for the observed vegetation changes can determine in part, the successional trajectory of the area subjected to them.

Woody Plant Damage and Response

An analysis of the damage sustained by woody plants in each treatment shows that few plants in any area escaped unharmed. The damage inflicted on them, however, was not always representative of the prescribed site preparation treatment. Logging activities often damaged many individuals before site preparation methods took place, accounting for the large numbers of individuals in the crushed and broken classes, regardless of treatment. As a result, plants in some treatments, such as the glyphosate or spray and burn plots received more mechanical damage than they would have had logging activities not taken place. However, a rather definite pattern of expected damage on plants from corresponding treatments exists (Figure 13). For example, in the "standing, injured by herbicide" category, the highest percentage of injured plants were those from the glyphosate plots. Similarly, in the "completely removed" class, the scarification method contributed the highest percentage of individuals occupying this category.

These results indicate that although logging activities can have a large impact on "non-target" plant species in an area, the site preparation methods utilized here influenced many individuals escaping logging. Ordinarily, this damage supplemented the prescribed mechanical treatments to a certain extent. However, in the glyphosate plots, this injury before herbicide application appeared to reduce the treatment effectiveness. Had the treatment been applied before logging, the herbicide would have damaged or killed shrubs rendered unresponsive by breakage.

Individual species response to damage reveals some very basic differences among treatments. Considering the more important species (vine maple, alder, hazel, elderberry, salmonberry, and red huckleberry), the scarification treatment produced plants that either died, or were in other non-basal sprouting categories (Figure 14). This essentially means that plants were completely uprooted and removed, or they were not affected at all. In the spray and crush, and spray and burn areas, a moderate amount of plants died as a result of the treatments, and a moderate amount responded in other ways. However, a large number also reacted by producing basal sprouts after they had been top-killed. The characteristic feature of the plant responses in these two treatments--top-kill with basal sprouting--is most likely attributable to a combination of physical damages (logging, crushing, burning, slashing) and the nature of the herbicides used, especially 2, 4, 5-T.

In the glyphosate-treated plots injured plants responded in different ways. The emphasis on basal sprouting shifted to emphasis on the "other" category, and on extremely sensitive species, such as salmonberry, to the dead class. Many of the plants in the "other" response class reacted by producing small amounts of non-competitive, deformed (miniature) foliage, small deformed buds, or sprouts on the upper stems. Vine maple, hazel, and salmonberry were especially found exhibiting these symptoms (Figure 23). These signs, without basal sprouting are all typical of glyphosate injury, and are

Figure 23. Salmonberry shoot exhibiting symptoms of glyphosate injury.

almost inevitably precursors to mortality.

Interpreting the plant responses described above can give an indication of the future shrub development and successional patterns in these areas. In the scarification plot, the high percentage of plants that died because of complete removal, in addition to the grass and other herbaceous species occupying the area, indicate that this site will initially be dominated by herbaceous species, with scattered residual shrubs not affected by the treatment. Future shrub development will most likely depend on germination from seed, or by the broken and scattered root systems of various rhizomatous shrubs. A decrease in the herbaceous cover will come about only after a sufficient shrub (or conifer) canopy has developed to shade out these species. The plant responses in both the spray and crush and spray and burn treatments give an indication of a different developmental scheme. Although these treatments both produced a moderate amount of dead plants, nearly half showed signs of viability. Evidence from other areas treated with mechanical methods, or by phenoxy herbicides (Hamer Lake Study, M. Newton 1976, Forest Research Lab, unpublished data) indicate that individuals not killed by these treatments are likely to become serious competitors in relatively short periods of time (two years). In addition, the lower frequencies of grass species in these areas and also total cover (particularly in the burn plots), suggest that shrub colonization by seed will probably be more successful because of less intense competition by herbaceous vegetation. Thus, in these areas, a rapid return to shrub dominance is expected to arise from sprouts, followed by a second wave derived from seed.

The plots treated with glyphosate will probably not respond in the same manner as the other treatment areas. The large amount of viable woody plants in these plots gives some indication of this. However, signs of viability exhibited by many plants in these areas cannot be interpreted in the same fashion as those found in other treatments. Available evidence indicates that plants responding to this chemical are often mortally injured, but take as long as two years to completely die (Billie Creek Study, M. Newton 1977, Forest Research Lab, unpublished data). Therefore, many of the individuals recorded in the "other" category will most likely decline rather than increase in vigor. An exception are those plants which were mechanically injured prior to chemical application. Data also indicates that these plants are less sensitive, or non-sensitive to glyphosate, and respond by basal sprouting or producing a near normal complement of foliage. Taking these effects into consideration, the initial woody plant development on these plots will most likely take place in the form of mechanically damaged plants, shrub germinants, or evergreen species (which are resistant to glyphosate). The rate of this development, however, should not be as great as shrubs in the burn and crush plots, because it will generally be derived from shrub germinants, and to a lesser extent, from sprouting plants.

The characteristics of shrub reinvasion and development are important when introducing tree seedlings into these sites. Seedlings planted in the scarified area are expected to be exposed to substantial moisture stress from grass. As a result, survival and growth may suffer. Depending on the rate of shrub colonization from seeds and animal browsing on shrubs or conifers, herbaceous vegetation may form a relatively stable community for some time.

In the burn and crush plots, rapidly developing residual woody species will probably influence the planted seedlings in these areas within a few seasons. The ability of these seedlings to evade serious competition will depend on how rapidly they can grow to a size where competition becomes minimal. Proximity to vigorously growing shrubs, and types and amounts of animal damage should play a large role in this struggle. In areas of heavy disturbance (particularly in the crush plot), seedling development will most likely be influenced by grass and other herbaceous species as well.

Seedlings in the glyphosate treated areas will probably be subjected to the same type of shrub development as the burn and crush plots, although not as rapid and extensive. Therefore the requirement for prompt height growth is not as critical, but still an important feature in evading shrub encroachment and animal damage. The longer period of time before woody competition becomes serious suggests that these seedlings may have a better chance at unrestricted growth than seedlings growing in the crush, burn, or scarified plots. Had treatment effectiveness not been compromised by mechanical injury prior to herbicide application, this time period would have most likely been increased. Standing dead material, however, will have the potential for causing substantial seedling injury in future years unless felled deliberately, or unless hemlock is used to complement Douglas-fir (Newton 1978).

Planting Characteristics

The high number of potential plantable spots created by all treatments suggests that heavy concentrations of slash and debris were kept to a minimum. Because of the physically disturbing effect of the crush treatment, less planting spots were expected in these plots. Although this occurred, the difference was negligible, with all plots still containing at least 988 planting spots per hectare (400 per ac).

Differences in the difficulty of planting between treatments were not as great as they were expected to be. Logging disturbances such as skidding logs, crushing and removing slash or brush before site preparation helped open up the matrix of debris and create a uniform physical layer over all except the scarified plot. The complete clearing inherent in this treatment accounted for the highest rating of easily planted areas. The other treatments varied very closely to each other in all three difficulty categories. Had the spray and burn plots actually burned according to prescription, the difficulty in these areas would most likely have been similar to the study by Vyse and Muraro (1973), and approached that of the scarified plot. Interestingly, it was a burn plot that had the highest percentage of hard rated spots among all treatments, due to a slashed area that escaped treatment, either mechanically or by fire. The relatively low percentage of points rated as hard in all treatments indicate that much of the slash and debris was low enough to step over, or the site open enough to move about. Had either of these factors increased, more spots would have been rated as hard.

The pattern of stockable quadrants suggests that all treatments created planting spots with good potential distribution. The glyphosate plots may have had slightly better distribution than the other treatments, based on the observation that neither plot contained completely unstockable quadrants. The absence of slash concentrations probably account for this observation.

Additional Treatment Effects

An examination of treatment effectiveness (Figure 18) confirms what has been observed throughout the study. The great majority of the spray and burn plots were generally poorly burned, or not burned at all. Periods of rain prior to the burning date, coupled with the north aspect of the site resulted in poor drying of the logging residue. Areas that did burn were those on flat ground, or where conifer slash was a component of the fuel mixture. Although slightly better, the spray and crush plots were still treated with medium intensity. Some areas of the plots were too steep for the machine to work effectively, and others had little or no residue to crush because of prior logging disturbance.

Unlike the burn and crush plots, most points in the scarification plot were prepared to the full extent. Areas partially prepared were those where the topography became too steep to operate, where existing stocking occurred, or where slash piles covered the surface. All points in the glyphosate plots were treated to the full extent. Only one noticeable skip in the spray pattern was found, and was not extensive. Because the chemical was aerially applied, topography was no restriction. Although not closely scrutinized, points in the spray and crush and burn areas appeared to have been adequately covered by the spray pattern also, with a few minor skips observed. Thus, even though these plots received poor to moderate physical preparation, the entire area was sufficiently treated by chemical means.

Soil disturbance as a result of logging and site preparation was distributed in an expected pattern (Figure 19). Both the glyphosate and spray and burn plots demonstrated disturbance patterns in the lowest categories, reflecting the use of machinery only during the logging process. The spray and crush plots, as a result of logging and site preparation, contained more points in the higher disturbance classes. The scarified plots, obviously, contained the highest percentage of points in the heavy disturbance class, reflecting the deep plowing action of this treatment.

Animal habitat characteristics influenced by site preparation reveal some differences between treatments. Deer access through sample plots appears to follow a trend established by planting difficulty data (Figure 20). Most treatments were generally close to each other in each category, except the scarified plot, where no points were rated as poor, and three-fourths were rated as excellent. Had the spray and burn plots actually burned, a higher percentage of excellent rated points would have been expected there also. These results suggest that planted seedlings in all treatments, but especially the scarified area, will not be substantially protected from deer damage by logging or site preparation residues.

The abundance of preferred deer forage after site preparation was not equally distributed between treatment areas. The glyphosate plots presented low to moderate abundance, possibly due to decreased salmonberry sprouts and leaves, and also a decrease in sprouts from other species. Both the spray and burn, and the scarified areas had high proportions of their points rated as excellent. Sprouts from burned or mechanically injured shrubs most likely account for this rating. The moderate response by the spray and crush plots is not well understood, since a point distribution similar to the spray and burn plots would be expected.

The removal or decrease of preferred food species by glyphosate indicates that this treatment can have considerable effects on the wildlife populations in the treated areas. A decrease in the forage supply may result in deer migrating to other areas of a richer supply, thus reducing associated damage to planted seedlings. However, the possibility also exists for heavier than normal browsing activity to take place because other preferred foods are no longer available. Empirical evidence suggests that in the case of mountain beaver, the latter alternative initially holds true.

The range of site preparation treatments used in this area also indicate that mountain beaver habitat may be influenced. The scarification treatment, because of its complete clearing nature, contained the highest percentage of poor rated points. Little slash or debris was left for animals to tunnel next to or under, and sword fern, which is a preferred food, was normally reduced. The spray and burn, and spray and crush areas were moderate in providing habitat for this animal. The array of physical disturbances on these sites, in addition to partial removal of sword fern help explain this observation. The glyphosate plots produced the best mountain beaver habitat among all treatments. In reality, this method disturbed the existing habitat the least, often leaving islands of undisturbed layered vine maple stems, old logs, and other debris, which appear to be sought out for tunneling. Sword fern was also abundant on these plots, making them particularly attractive.

CONCLUSIONS

The evidence accumulated on each of the four site preparation treatments utilized in this study indicates that all can have a large impact on the brushfield communities they are applied to. Woody canopies, often totally covering their respective strata, were nearly devoid of cover after logging and site treatment. Site resources, formerly used by the old plant community, now appear available to coniferous tree seedlings planted in those areas.

Although vegetative cover dramatically declined, few species, either woody or herbaceous, were eliminated by any of the treatments used. In fact, many species of the original plant community were clearly evident ten months after site preparation treatment. Because of a large increase in the numbers of a few invading and residual plant species, however, the relative dominance of many plants present before disturbance has been reduced.

The presence of viable woody root systems in all treated areas suggests that the potential for competitive shrub development still exists. This development, however, is not expected to proceed at the same pace on all treatment sites. The most rapid resurgence of shrubs is expected to occur in the spray and crush and spray and burn areas, originating from sprouts on root crowns, or continuing from partially injured tops. In the scarified area, redevelopment is also expected to occur quickly, but from untreated individuals and scattered root systems of rhizomatous shrubs. However, because many woody plants were uprooted and removed in this area, herbaceous species, particularly grasses, may influence this site for a relatively long period of time. It is held that shrubs in the glyphosate treated areas will respond the least after site preparation. Evidence from this and other studies indicate that plants injured by this chemical decline, rather than increase in vigor. Only plants mechanically damaged prior to herbicide application are expected to develop in a competitive manner.

Since all methods were initially effective in reducing competing vegetation, as well as producing abundant and well distributed planting spots, the decision to choose one method over another must be made by weighing other important factors. Cost, operational feasibility, effects on soils, vegetation, and animals, policies, and other variables may all play a large role. Based on this research, a number of points have been identified which may assist land managers in correctly choosing and applying each of these site preparation treatments:

1. The development of grasses and other herbaceous vegetation after scarification suggests that seedlings planted in these environments will be subjected to substantial moisture stress. The use of this treatment therefore, should be avoided on droughty sites unless

herbaceous plant control is anticipated.

2. The scarification treatment, and to a lesser extent, the spray and crush method, produced the greatest amount of soil disturbance. Where soils are wet or easily erodable, discretion in use may be advisable.

3. The protection of preferred browse species by slash suggests that tree seedlings may benefit from this also. If an effective, uniform layer of logging and site preparation residues is desired to protect seedlings from deer, logging activities should be directed toward that goal. There was often little residue left to crush because of prior processing by logging.

4. Relatively rapid shrub development is expected to occur in areas treated by the spray and crush and spray and burn methods and on shrubs mechanically injured prior to glyphosate application. In order to ensure conifer dominance in those areas, follow-up treatments with selective herbicides may be necessary.

5. Although the areas to be burned received poor treatment, the use of translocated herbicides before burning has produced a large degree of vegetation suppression. The use of mass ignition, or other ignition methods, might have resulted in full rather than partial treatment of the area.

6. The use of glyphosate shows promise in controlling deciduous brush species of the type observed in this study, without rapid

development of sprouts. This is particularly true of salmonberry. However, injury to target species prior to application of the chemical should be avoided in order to fully enhance treatment effectiveness.

7. Because no method completely removed the woody plant component on these sites, and because of the animal damage expected to occur on seedlings planted in these areas, the use of planting stock specially adapted to these problems may be needed to complement the site preparation procedures. In particular, the use of large stock may help seedlings stay ahead of shrub development, as well as make them less susceptible to animal damage. Western hemlock and grand fir, because of their low palatability, appear especially suited in this regard.

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APPENDICES

Appendix I. Frequency of ground vegetation species before and after disturbance. Values are based on the percentage of points where a species was rated among the three dominant (Pre_3, $Post_3$) or six dominant ($Post_6$) plants within a 2.27 meter radius. Species codes are defined in Appendix II.

Species	Glyphosate			Spray & Burn			Spray & Crush			Scarify		
	Pre_3	$Post_3$	$Post_6$	Pre_3	$Post_3$	$Post_6$	Pre_3	$Post_3$	$Post_6$	Pre_3	$Post_3$	$Post_6$
ANMA	--	--	--	--	--	--	--	--	--	6	--	6
ATFI	6	--	--	--	--	3	3	3	9	--	--	6
CAOL	--	3	--	--	--	--	--	--	--	--	--	--
CAREX	--	--	6	--	--	3	6	3	16	6	--	--
CEVI	--	--	--	--	--	--	--	--	3	--	--	--
CIRSI	3	--	9	--	--	19	--	16	32	--	13	63
DIFO	6	31	40	44	6	37	16	3	9	6	6	19
DRAU	9	--	6	3	--	--	3	--	--	--	--	--
EPGL	--	--	6	--	--	--	--	--	--	--	--	--
ERMI	--	--	--	--	--	--	--	--	3	--	--	--
GAAP	--	25	57	--	--	6	3	--	16	--	6	12
GASH*	3	--	--	--	--	--	--	--	--	--	--	--
GATR	--	--	22	--	--	--	--	--	6	--	--	--
GRsp	3	13	16	9	19	47	9	47	66	13	69	82
HYRA	--	--	--	--	--	--	--	3	--	--	--	6
HYTE	19	6	22	6	6	--	16	9	15	6	--	6
JUNCU	--	--	--	--	--	--	--	--	--	6	--	13
MADI	3	--	3	6	--	6	--	--	--	--	--	--
MOSI	22	81	90	16	59	93	28	59	67	13	50	69
NEPA	--	--	--	--	--	--	--	3	9	--	--	--
OXOR	6	--	3	9	--	6	3	--	6	--	--	--

Appendix I. (Continued)

Species	Glyphosate			Spray & Burn			Spray & Crush			Scarify		
	Pre_3	$Post_3$	$Post_6$	Pre_3	$Post_3$	$Post_6$	Pre_3	$Post_3$	$Post_6$	Pre_3	$Post_3$	$Post_6$
POMU	97	75	81	94	75	94	88	75	78	44	13	26
PTAQ	--	--	6	16	22	41	--	--	9	19	19	--
RUAC	--	--	--	--	--	3	--	6	12	--	6	25
RUCR	--	--	3	--	--	--	--	--	3	--	--	--
RUDI	--	--	--	--	--	--	--	--	--	6	13	--
RUPA*	--	--	--	--	--	--	--	--	--	31	--	--
RUSP	53	13	35	63	56	62	59	38	47	56	25	38
RUUR	3	--	--	--	--	--	--	--	3	56	38	52
SARA*	9	--	--	--	--	--	3	--	--	--	--	--
SEJA	--	--	3	--	--	--	--	--	3	6	--	6
SESY	--	34	84	--	9	28	--	6	50	--	25	69
SEVU	--	--	--	--	--	3	--	--	3	--	--	--
STCR	--	3	28	3	3	25	--	6	37	--	--	6
STME	6	3	25	13	16	47	13	13	22	13	13	26
THOC	3	3	--	9	3	9	6	3	--	--	--	--
TOME	9	--	9	3	--	--	13	--	--	6	--	--
TRCH	--	--	3	3	3	--	--	--	3	--	--	--
TRLA	--	--	--	--	3	--	--	--	--	--	--	--
URDI	3	--	3	--	--	3	3	--	3	--	6	--
VIOLA	--	--	--	--	--	--	3	--	3	--	--	--

*Post-disturbance frequencies of these species are described in Table 3.

Appendix II. Plant species codes, common and scientific names. Nomenclature follows Hitchcock and Cronquist (1973) and Garrison et al. (1976).

Species Code	Common Name	Scientific Name
ACCI	Vine Maple	Acer circinatum
ACMA	Big-leaf Maple	Acer macrophyllum
ALRU	Red Alder	Alnus rubra
ANMA	Pearly Everlasting	Anaphalis margaritacea
ATFI	Lady Fern	Athyrium felix-femina
BENE	Oregon Grape	Berberis nervosa
CAOL	Little Western Bittercress	Cardamine oligosperma
CAREX	Sedge Species	Carex spp.
CEVI	Sticky Chickweed	Cerastium viscosum
CIRSI	Thistle Species	Cirsium spp.
COCO	California Hazel	Corylus cornuta
DIFO	Bleeding Heart	Dicentra formosa
DIPU	Foxglove	Digitalis purpurea
DRAU	Mountain Woodfern	Dryopteris austriaca
EPGL	Common Willow-herb	Epilobium glandulosum
ERMI	Australian Fireweed	Erechtites minima
GAAP	Goose-grass	Galium aparine
GASH	Salal	Gaultheria shallon
GATR	Fragrant Bedstraw	Galium triflorum
GRsp	Grass Species	Gramineae
HODI	Ocean Spray	Holodiscus discolor
HYRA	False Dandelion	Hypochaeris radicata
HYTE	Pacific Waterleaf	Hydrophyllum tenuipes
JUNCU	Rush Species	Juncus spp.
MADI	Wild Lily-of-the-valley	Maianthemum dilatatum
MAOR	Wild Cucumber	Marah oreganus
MOSI	Miners Lettuce	Montia sibirica
NEPA	Small-flowered Nemophila	Nemophila parviflora
OXOR	Oregon Oxalis	Oxalis oregana
PHNE	Woodland Phacelia	Phacelia nemoralis
POMU	Sword Fern	Polystichum munitum

Appendix II. (Continued)

Species Code	Common Name	Scientific Name
PREM	Bitter Cherry	Prunus emarginata
PSME	Douglas-fir	Pseudotsuga menziesii
PTAQ	Bracken Fern	Pteridium aquilinum
RUAC	Sheep Sorrel	Rumex acetosella
RUCR	Curly Dock	Rumex crispus
RUDI	Himalaya Blackberry	Rubus discolor
RUPA	Thimbleberry	Rubus parviflorus
RUSP	Salmonberry	Rubus spectabilis
RUUR	Trailing Blackberry	Rubus ursinus
SALIX	Willow Species	Salix spp.
SARA	Red Elderberry	Sambucus racemosa
SEJA	Tansy Ragwort	Senecio jacobaea
SESY	Woodland Groundsel	Senecio sylvaticus
SEVU	Common Groundsel	Senecio vulgaris
STCR	Crisped Stellaria	Stellaria crispa
STME	Soft Nettle	Stachys mexicana
TABR	Pacific Yew	Taxus brevifolia
THOC	Western Meadowrue	Thalictrum occidentale
TOME	Piggyback	Tolmiea menziesii
TRCH	Trillium	Trillium chloropetalum
TRLA	Western Starflower	Trientalis latifolia
TSHE	Western Hemlock	Tsuga heterophylla
URDI	Stinging Nettle	Urtica dioica
VAPA	Red Huckleberry	Vaccinium parvifolium
VIOLA	Violet species	Viola spp.