

DECEMBER 1, 1977

AN ECOLOGICAL DESCRIPTION OF FOREST
COMMUNITIES ON THE NORTH RIM OF GRAND CANYON NATIONAL PARK
ARIZONA

FOR: NATIONAL PARK SERVICE
RESOURCE MANAGEMENT
NORTH RIM, GRAND CANYON
NATIONAL PARK, ARIZONA

BY: MELINDA HURST
RESEARCH, RESOURCE
MANAGEMENT

I M P E T U S

Few studies have been conducted on the vegetation and ecological position of the North Rim mixed coniferous forests. Community types were sampled in 1965 by Merkle. Earlier, Rasmussen (1941) conducted a biotic survey of the entire Kaibab Plateau. Other studies involving different objectives have been completed within the last decade. This study is exclusive in its objectives, methods, and results. The findings were much more conclusive than were expected at the commencement of the study. The collected data yielded maximum information to the parametric values.

The basis of inventory and resource management will most likely extrapolate on the findings of this study and thus applied management will be aided.

I N T R O D U C T I O N

Assumptions in classifying the forest community of the North Rim have been many. Some researchers state that vegetation can be assumed solely on altitudinal contour interval in relation to slope aspect in the higher elevations (Rand, 1957). Merkle (1954) modified the vegetation constants formerly set by Rasmussen (1941) to a more flexible altitude-vegetation relationship. The flexibility lies in that too numerous environmental aspects are correlated to evident phytosociological features. Physical aspects of slope, aspect, elevation, soils, precipitation and growing season obviously determine species presence at a given site. Other biotic organisms sharing the community exert immeasurable influence in the plant situation.

In the course of ecological topic conversations, many of my coworkers of the NPS, Forest Service Rangers, and professors familiar with the forest structure, all have questioned whether contour interval is the primary determinant of vegetation. Also, the concept of discreet community types with associated dominants was put to question. Are there really community types within Grand Canyon National Park, North Rim? If so, by what indicator should one delineate the discreet communities? I found by methods which I'll expand on later, that there are three "vague" zones of coniferous forest communities. The Pinyon-Juniper-Cowania zone found proximal to the rim, exerts a small yet significant biotype to the zones, much greater in area than the more xeric zone, can usually be typified to selected dominant tree species. However, there are enough intergradations between the Ponderosa pine and Spruce-Fir communities for some ecologists to typify only one coniferous forest biome.

In the classical use of "dominant species" there is definitely a Ponderosa pine zone. The Ponderosas dominate the community, out competing all other species for the physiological needs of water, soil and sunlight. But then by their own massive presence, the Ponderosa seedling reproduction is absent. Instead, one sees that the seedling and sapling density of the shade tolerant white fir is sometimes in excess of four times the numbers of the Ponderosa pines. In this case the community stability is threatened, more so with the continual increase of importance among the white firs. The eventual transition of forest dominants can be attributed to either the natural succession of forest types (Rasmussen, 1941), or to the effects of fire suppression within the National Park (Merkle, 1954).

As is the case of the Kaibab Plateau, with its series of draws and ridges, seeps and outcrops of limestone, microhabitats dot the Plateau, creating exceptions to any established elevation-vegetation constants.

Periodic and thorough vegetational analysis is vital to the inventory of the coniferous forest resource. Climatic fluctuations and time itself will show marked change within the community.

PHYSIOGRAPHY

The North Rim of Grand Canyon National Park is the southernmost extension of the Kaibab Plateau. Elevations run from 7500 feet along portions of the rim, to almost 9000 feet near the North Rim Entrance Station. The area within the park consists of a series of narrow, rounded draws and stoney ridges, mostly running in a north-south direction. Following along the draws are narrow meadows, with the slopes and ridges heavily vegetated by coniferous stands. The entire Kaibab is capped by Permian limestone, with sandy upwellings frequently affecting the overall soil texture. Red mud and clay beds also dot the surface (Mekee, 1938).

SOILS

The soils developed in situ, and are poor due to the high porosity of the parent limestone (McKee, 1938). Soil classification includes the Helmer-Santa-Benewah series of gray podzolic mountain soils (Merkle, 1952). Aside from using the Russian classification system exclusively, the newer American system would place the Kaibab soils collectively as sandy loam, mixed wet-mesic, typic haplustollic argiustoll (U. S. Soil Conservation Service, 1967). The former sentence would translate to a system of soils formed on gentle-to-steep slopes, dry climates with summer rains, a nearly black, organic rich surface with high base accumulations. The Horizon development juvenile, with a shallow layer of clay accumulations. Local variations in the soils would be due to the differing vegetal cover and compositions.

CLIMATE

The climatic regime on the Kaibab classifies as cool and moist, especially at the highest elevations. The weather records are recorded at 8400 feet elevation within the Bright Angel Ranger Station complex at the North Rim headquarters of the Park (see Appendix 10). Record compilations through 1938 showed the maximum July temperature to be 91 degrees F., and a minimum of -25 degrees, with the July average at 61.6. The average January temperature is stable at 21 degrees F. (Greening, 1941). The date of the last vernal killing frost occurs June 14, while the first autumnal frost is September 15; thus the growing season average 93 days. Annual precipitation ranges from 22 - 32 inches, averaging at about 27 inches, and occurring within two seasons. Most of the precipitation is received during July, August, and September, in the form of local convectional afternoon storms. Snowfall constitutes the rest of the precipitation accumulation, occurring from December to March (Merkle, 1954). Rasmussen, 1941, states that a winter snow-pack of 10 - 15 inches has been frequently recorded.

HISTORICAL IMPACT

Little historical exploitation of the Kaibab Plateau was carried out until 1915. Numerous attempts to make money brought just as many failures. Early Indians (475 - 700 AD), used the Kaibab as hunting grounds, as evidenced by artifacts dedicated to their hunting dieties. The first attempts by white man on the Kaibab were the Mormon colonists from southern Utah. Early Mormon settlers of southern Utah and the Arizona Strip ventured into mining, lumbering, agriculture, and grazing. Distance from market and difficulties with procuring these resources left many sites abandoned only after a season or two of exploitation. In 1870 Mormon Cooperatives acquired ranches and herds from the individual members and formed the first extensive grazing enterprise of the Kaibab in 1877 (Crampton, 1965). The church herds were bought by John W. Young, a son of Brigham Young, and the V. T. brand was adopted to mark the herds. John Young also initiated a campaign to attract English aristocracy to the Kaibab as a sporting and hunting ground. Nothing came of this venture because the Kaibab was too hard to reach. John Young then sold out, the LDS church then liquidated their herds. The herds changed hands many times and were finally liquidated in 1919 when Grand Canyon became a National Park (Crampton, 1965).

In 1915, the Kaibab was again opened to lumbering interests, and private companies came in to claim their share of this new wealth. Private grazing interests also reappeared in 1923 and successfully grazed the

Kaibab as a summer range. The Forest Service took over control of half of the Kaibab, (365,500 acres) and opened it to grazing and timber permits. Those permittees are presently continuing this enterprise. The National Park Service presides over the other half with 361,780 acres on the Kaibab Plateau (Rasmussen, 1941). The land set aside by the National Park Service allowed the land to be free of exploitation by cattle, lumber, mining, and sport hunting.

From 1906 to 1923, government hunters were employed in killing predatory animals. Total removal from 1906 to 1939 inclusive has been 816 mountain lions, 30 wolves, 7388 coyotes, and 863 bobcats (Rasmussen, 1941). Subsequently the reduction in competition for forage, energy elimination, and the prevention of killing by man raised an increase in the deer herd on the Kaibab. From an estimated herd size of 4000 head in 1906, the increase totalled over 100,000 by 1924. The range for the animals was totally depleted and thus thousands of deer died of starvation and malnutrition. This massive die-off peaked in the winters of 1924 - 25, and 1925 - 26, and reduced the herd to 40% of the previous total (Rasmussen, 1941).

Since 1926, the slow and frustrating process of forest and meadow recovery has initiated concern as to whether the Kaibab will ever regain its natural climax condition. Presently the areas that are grazed in the Kaibab National Forest by cattle are permanently altered by use and seeding of the range. The meadows and forests of Grand Canyon National Park were left undisturbed and they have optimum potential for full recovery or varied but stable climax conditions.

LITERATURE SEARCH

- Halverson, William L. 1972. Environmental Influence on the Pattern of Plant Communities Along the North Rim of the Grand Canyon. The American Midland Naturalist. 87:(1)222 - 235.
- McKee, E. D. 1938. The Environment and History of the Toroweap and Kaibab Formations of Northern Arizona and Southern Utah. Carnegie Institute of Washington Publication. pp. 492 - 504.
- Merkle, John. 1952. An Ecological Analysis of the Meadows on the Kaibab Plateau, Arizona. Yearbook of the American Philosophical Society, 1953. pp. 157 - 160.
- 1954. Analysis of the Spruce-Fir Community on the Kaibab Plateau, Arizona. Ecology 35:(3)316 - 22.
- 1962. Plant Communities of The Grand Canyon Area, Arizona. Ecology 43:(4)697-710.
- Rasmussen, D. Irvin. 1941. Biotic Communities of the Kaibab Plateau, Arizona. Ecol. Monographs 2:(3)231-274.

METHODS

The first consideration of the 1976-77 North Rim forest study was an effective way to gather data. Many considerations entered into the study plan, and the complexity and demand of the study necessitated precision.

Before deciding on the study design and the methods to apply, an extensive cruise analysis was needed to chart and delineate community types. The fire road system within the Park suited this purpose as ready access to the plots, with hikes taken into the inaccessible areas. A literature search was undertaken to see just how much and of what studies had previously been completed on the North Rim flora. Each researcher attempted a zonation, by elevation and community dominants. Discreet communities were thus established. During the cruise analysis it was determined for the purpose of this study that the densities of tree dominants be used to determine community characteristics. From numbers alone, it was decided that there actually is a ponderosa pine and a mixed conifer* community separate from each other. Within the mixed conifer, as situation would allow, there are small, almost pure stands of aspen, englemann spruce, colorado blue spruce, and sub-alpine fir. A method to survey the forest and avoid these species "islands" within the mixed conifer type had to be devised to glean accurate data that would be representative of the entire forest. After preliminary paper work, it was decided that plot selection would be subjective, whereas plot placement would of course be random. It was determined that a test for quad adequacy would be the "break of the curve" method (Braun-Blanquet 1932, Cain 1938, and others). Six indicator species were selected to measure and plot on a graph necessary for determining plot adequacy. Preliminary plots were selected at random and the frequencies for the following were recorded:

ponderosa pine	(<u>Pinus ponderosa</u>)
white fir	(<u>Abies concolor</u>)
mutton grass	(<u>Poa fendleriana</u>)
<u>Collinsia</u>	(<u>Collinsia parviflora</u>)
biscuitroot	(<u>Lomatium leptocarpon</u>)
deer vetch	(<u>Lotus utahensis</u>)

The above species were selected for community dominants because of their high frequencies. Three species representing the ponderosa pine community, including ponderosa pine, Collinsia, and biscuit root

* Mixed conifer will be used as a collective term for a community of combined spruce, fir, aspen, and ponderosa pine individuals.

all had high frequencies, though the latter two are small plants. For the mixed conifer, white fir, deer vetch, and mutton grass. Two of the above species are shared with different densities between the two communities, those are Collinsia and muttongrass. The graph on the following page will illustrate the tests of the species for sample adequacy.

After the necessary number of quads needed was determined, the placement was next. Totally random selection of the quads was necessary, and since subjective placement would include a bias, a system to cover the forest for complete sampling had to be devised sight unseen. A map on the area with the fire roads drawn on it was used to select the quads. Priorities for sampling were set, the plots would be proximal to the fire roads, and all meadow systems avoided. Each map section, with appropriate township and range that had a fire road running through it was recorded on separate pieces of paper. Known areas of ponderosa pine, as well as mixed conifer areas were separated. Random drawing of four plot locations for the ponderosa pine, and 16 for the mixed conifer completed the plot selection. Before arriving at the plots, a compass direction and pacing distance was determined and carried out. Red-flagged stakes were driven at the four corners of the plot after a tape was used to measure each dimension. Part of plant sampling is a count of the total individuals contained in the study area or plot, which is a representation of the whole stand. It would be impossible to count each individual plant in the vast area of the stand, so an estimation of the population is obtained by sampling. Taking into account the variability within the population, some general inferences about the community can be made. In characterizing a population as a whole, parameters (certain constants) are used. The objective of sampling is to draw estimates on certain parameters of community function. Permanence of plots is desirable for long range studies and precision of site.

The sample plot size was set at one-tenth acre area (20 meters by 20 meters), or 66 feet by 66 feet. This size quadrat is considered adequate to measure stands containing large trees (Kershaw, 1973). To sample the trees or canopy species, each tree individual was counted, its diameter at breast height (dbh), and vertical height were recorded. To aid in the tally, a rope was dragged across the quad with a person on each end, one counted and one recorded. Species reproduction was always counted from this method too. As the rope snagged on a tree, it was thus counted.

In most areas of the forest the shrub layer was absent, but where it existed, it merited measurement. Kershaw (1973), considered five-to-ten 2 meter by 2 meter square plots as adequate for sampling this type of forest shrub profile.

A shrub has lower and upper size limits by which it is defined by. If the diameter at the widest point of the stem is less than one-half inch thick and the height less than one foot, the plant was counted as a perennial. See the appendix for the standard on shrub height. The upper limits of the shrub is set at 4 inches diameter at ground level to 6 feet in height. Any measurements exceeding either of these threw the plant into arborescent (tree) limits. Height classes were assigned to the shrubs, and random placement of the 2 m x 2 m quadrats was undertaken. Five quadrats were laid, and the height and cover within the quadrat was recorded.

The ground cover is a mixture of all or only one of the following: grasses, sedges, and forbs (herbaceous non-grass). The lowest profile, which is the ground cover is the most time consuming to sample. Twenty-five quadrats within the tenth-acre plot were to be randomly laid. The dimensions of this quad were one-half meter by one-half meter square, totaling an area of one-quarter of a meter square. A cover class frame (Daubenmire, 1956), was used for the lowlying vegetation. Selection was random, and to assure this, the Schultz random numbers table was used. The statistically determined random numbers came in series of four, so the sum of the first two numbers gave the pacing distance, as did the next two. If the sum was an even number, the first direction was north, if odd, then south. The second two numbers gave east and west directions in the same manner. Numerical values determined pacing distances in two directions. Random placement assures that each plant has an equal chance with each other plant of being selected. Since the ground vegetation is contagious, or the species aggregated within the plots, regular interval placement of the quadrats would have constituted over sampling of some species, and undersampling of others. Besides, seasonal and yearly reconnaissance of the ground cover was the intent, so randomness would assure that seasonal flushes of species presence would be more accurately sampled.

The recorded data ideally would yield an accurate assessment of the community structure, a complete list of species presence, a permanent standard by which to compare ecological trend, and inventory of the forest resource.

Environmental parameters were the variables in this analysis which served as useful classification discriminators for the study. To obtain confidence levels of the data, three parameters are necessary for quantitative measurement: relative frequency, relative density,

Cover composition is a description of total ground cover of the forest. Each square inch of ground surface can be categorized and summed as to its value, and a percent assigned to describe what is actually found. The sum living cover, plus the sum non-living cover includes the basal area of each tree bole, the reproduction, grasses, and forbs. The non-living will include dead-fall of the tree species, litter, rock, and bare soil. Mosses and lichens will be stated by frequency only, their collective term given is cryptogams. Total cover must include the entire profile strata. Any cover value over 100% indicated a high degree of vegetation cover, and always more than one stratum. If a plumb-bob on a string were dropped from above the tree canopy to the ground, there are three possible vegetation layers which it would traverse: the tree crown, then the next hit would be the shrub, and finally the herbaceous species on the ground. The sum cover would be 300%, since each stratum returned a positive hit. Suppose the plumb-bob fell through an opening in the canopy, bypassed a shrub, and grounded on a rock, a zero percent cover value would be reported.

For the rest of this paper, consistency in using common names of the plants for discussion purposes will be used. The species list, page will give the corresponding generic name. When the underscored genus is given as the plant name, it is because there is no common name given to that specific species.

RESULTS AND DISCUSSION

There are two definite community types within the forests of the North Rim which are subject to this study: the ponderosa pine type and the spruce-fir. However, the two former communities are small in comparison to the mixed conifer ecotype which was discovered to constitute most of the North Rim forests. Since the ponderosa pine type is distinctive in environmental specifications, it will form one type of forest association. Pure stands of spruce-fir are found within the mixed conifer type, and by their small size they will for classification purposes be included in the mixed conifer forest climax type. Mixed conifer refers to a community type with a presence of spruce, fir, and ponderosa pine species. Douglas fir though present, was in so few numbers and tended to aggregate their populations into almost homogenous stands. Quaking aspen, though not a conifer, is an important member of the mixed conifer type. The appearance of ponderosa pine has been established as a positive component of the mixed conifer stand. If, within an acre area the number of mature ponderosa pines exceeds the frequency of mature white fir individuals, the stand classification change to one of ponderosa pine. Other environmental characters indicate a ponderosa pine community other than that species frequency, and will be discussed later in the paper.

The fixed plot concept was used to measure the mature trees with subsequent reproduction rates. This concept is effective for inventories in that it has a predetermined size (66 by 66 feet), or one-tenth of an acre, and can thus be blown-up to represent an acre with a factor of ten. Every tree in the plot was counted and measured so that estimations are kept low. For subsequent discussions each community value will be given; numerical and ecological compositions having been taken from the study data. One objective was to measure the living plants in the community, applied especially to the tree and shrub strata. Decadent trees were counted for their cover value only, and since decadence is represented by a plant with 25% or more dead parts, these plants are not among the producers in the community.

The areas sampled represented study proportions of 16% ponderosa pine, and 84% mixed conifer. This frequency value could set these same numbers as representative of the entire North Rim forested region. Sixteen percent of the forest was of the ponderosa pine association, this community was the most homogenous in species composition of any other type measured. The internal similarity of the ponderosa pine stand was calculated by repeated frequencies of plant species occurring similarly in all ponderosa pine plots.

Twelve species, each with a frequency of over 30%, indicated an indice for similarity of the stand thus the homogeneity factor. Dominance can either be a measure of plant size or plant numbers and is therefore an ambiguous parameter. For example, needle and thread grass attain sizes of up to 3 times that of silver-top sedge, but the sedge plants may outnumber needle and thread grass 10 to 1 within the plot. The importance of a species in a stand is dependent upon size, since the largest plants exert control over all other plants in the community. Dominance is exerted as plant size for the purpose in this paper.

PONDEROSA PINE

The ponderosa pine forms fairly even-aged stands on the North Rim. Uneven aged stands appear to result from disturbances as caused by man, diseases, fires, and reproduction repression. Ponderosa pine is a light demanding species which cannot regenerate under low light intensity and cannot tolerate heavy root competition. Thus, pine seedlings do not establish themselves in adequate numbers under dense stands of timber or in dense forb and grass cover. Natural regeneration depends on an ample seed supply and adequate moisture for germination. Adequate seed crops are reported to occur only once in 4 or 5 years, although favorable moisture conditions occur at about the same frequency, these conditions do not usually coincide (Forest Service #153, 1973). Springs are usually very dry and summer rains come too late to be effective. Therefore, long intervals between good seedling years are the general rule. Reproduction for the North Rim ponderosa pine is quite low. Organic accumulations are deep at the soil surface, understory vegetation dense, and deficient sunlight reaching the ground account for the low reproduction rate. Reproduction averaged in the ponderosa pine plots at .04% for the seedlings, and 3% saplings. No pure ponderosa pine stands were encountered. Frequency for white fir was 26%, with the reproduction at 11% of the rate of ponderosa pine reproduction. The ratio of white fir seedlings to white fir saplings was 7 to 1, and white fir density in the ponderosa pine community was set at 56 individuals per acre. Indications are that white fir is positively establishing itself as a codominant species within the ponderosa pine ecotype on the North Rim. Aspens appeared in the more open spaces, with a frequency of 50%, density of 24 trees per acre was recorded. Page gives a detailed rundown of the community situation for the ponderosa pine type.

The shrub layer is present, but diverse in species representation in the community. The dominant shrub type is Arizona rose, with a frequency of 23%. Arizona rose constitutes 26% stratus cover in the

plots that it was measured, and compares at 52% frequency among other shrub species. New Mexico locust has a frequency of 20%, stratum cover 22%, and constituted 34% of the community shrub presence. Ceanothus had a frequency of 8.5%, a stratum cover of .35%, and its presence totaled 2% of all shrub species found. Over half of the ponderosa pine ecotype lacked a shrub layer. Manzanita presence is confined primarily to parts of the ponderosa pine forest on the Walhalla Plateau, and on some fringes near Tiyo point. None of these plants fell into my plots, so they were not counted, but they do make up a formidable portion of the shrub understory. Arizona rose preferred the drier areas of the ponderosa pine type, and New Mexico locust the more moist. The rose and locust stands are distributed throughout the ponderosa pine community, though they are more aggregated and more numerous in the western portions of the park stands. The understory of the ponderosa pine includes many species of grasses and forbs, which have a ground cover value of 31%. Part of the community stability is bound-up in the less obvious components such as litter, deadfall and cryptogams (mosses and lichens). Soil moisture retention and nutrient recycling depends on organic matter that deters evaporation of water from the ground. The rate of erosion is lessened with increased cover. The sum ground cover indicates that 91.1% of the ground is covered by dead or living material, thus leaving 8.9% as bare soil and rock. Study indications are that the ponderosa pine is presently in dynamic equilibrium as a community dominant. A positive invasion of white fir due to fire suppression, has out competed the ponderosa pine for reproductive establishment. Indications preclude this specie's decline on a large scale in the near future. A total community count of 5 tree species, 9 shrub species, 9 grasses, and 40 species of forbs were present within the bounds of the study plots. Abundance for almost all of these species ranged between occasional and frequent (see page).

- also on
telephone
road
near
Pikes
Lake

Mixed Conifer Association:

The mixed conifer association varies greatly among its species composition. White fir, sub-alpine fir, douglas fir, englemann spruce, Colorado blue spruce, and aspen all grow together in some stands, others are dominated exclusively by any one of the above. Most mixed conifer associations seem to have been initiated by wildfires where conifer invasion is usually high. Established grasses usually slow the invasion of conifers for centuries (Jones, 1958). When an adequate seed source for conifers is available, conifers successfully pioneer and establish as community dominants. Where seeds are sparse, the early establishment of grasses to aspens to conifers is the usual route. In the absence of a coniferous seed supply, aspen may persist for centuries.

Shade tolerance is a character of many mixed conifer species. The approximate descending species order in shade tolerance is thus: englemann spruce, white fir, sub-alpine fir, douglas fir, colorado blue spruce, ponderosa pine, and aspen. The higher the competitive plant density of a stand, the higher the frequency of shade tolerant species. Due to this fact, frequent pine stands of englemann spruce and sub-alpine fir, with individuals of douglas fir can be located within environmental niches in the North Rim Park forest. White fir is the first conifer to pioneer the mixed conifer community, but seldom establishes itself as a climax type (Jones, 1958). Observations on the Kaibab deem the high number of invading white fir individuals to the absence of recent fires. White fir establishes itself and allows invasions of douglas fir. Next, as the two former species change the micro-habitat, englemann spruce is introduced and develops a probably climax. Seed crops vary immensely in the mixed conifer forest; ponderosa pine produces the lightest crop with blue spruce the heaviest—all other conifers are intermediate (Jones, 1958). Aspens reproduce vegetatively by suckers, with self-competition being the limiting factor. Heavy sunlight destroys the germinating seeds of all trees except the ponderosa pine, which is dependent on it for life. Rodents live mainly on the ponderosa seeds, but eat substantial numbers of those of the spruces and firs. Spring is usually a dry season on the Kaibab, so most conifers do not germinate until summer rains begin. White fir however germinates only in the spring mainly on the moisture from snowmelt (Jones, 1958). These newly germinated seedlings are exposed almost at once to the spring dry season, and is an especially difficult period for shallow rooted firs. Frost heaving and washing can virtually eliminate a fir seedling crop when unprotected and in the open. Frequently white fir is observed growing at the northeast base of mature ponderosa pines, hovering in the automatic protection during its entire life span. When the fir grows into the crown of the ponderosa pine, fir deformation is usually the case, and the ponderosa pine reacts with the selfpruning effect of branch die-off.

Early growth of the spruces is very slow, a yearly increment of two and one-half inches is the standard root elongation. Douglas fir does a little better, with white fir root growth set at an annual four inches (Jones, 1958). Since most conifer stands have a preponderance of shade tolerant or moderately tolerant species, they tend to form uneven-aged stands as they mature. This condition assures a continuation of the climax, since decadent individuals give way to younger, already established trees. Eventual elimination of ponderosa pine within the mixed conifer stands increases since the pine reproduction is almost nil. White fir and aspen invade and form isolated pure stands as they pioneer the plot, and "nurse" the spruce seedlings to successful establishment.

Aspen grows as deciduous islands within the mixed conifer forest on the North Rim. Thick aspen seedling establishment is noted at the forest-meadow ecotone. The aspen establishment on the North Rim is believed to be fairly recent; within the last 350 years (Merkle, 1963). Though it never established as a climax species it has certainly formed a fire sub-climax. The topography lends itself to heavy aspen invasion, but the stability of the spruces inhibit its predominance. Aspen stands do quite well and form even aged groves among the ponderosa pine, but snow-pack, disease, insects, and foragers keep their numbers in check. Aspen are highly intolerant of shade, and where the site is well suited to invasion by conifers, and a substantial coniferous seed source exists, aspen stands may last only through a single generation. Generally where the site is ill-suited to conifer invasion, aspen last indefinitely. Near the North Rim entrance station, crooked, bent aspens form pure stands at this high altitude (9000 ft.). The disfigurement arises from the formation of very dense sucker-shoots that compete for space, opting plant vigor for height. As a result, uneven-aged stands give into differential stresses that cause this twisting. Juvenile growth of aspens is fast, and on many sites, growth exceeds that of the associated conifers for decades. Clones on good sites reach maximum heights of 100 feet and survive for 150 years or more barring fire interference. An interesting aspen character predicted by Rasmussen in 1941, elaborated on by Merkle in 1952, and positively observed in 1976 is the absence of one full aspen class in the forest. Tree counts measuring from 6 to 8 inches (diameter at breast height) are very low and in some areas of the forest, totally absent. Reasons for this low is due to the Kaibab deer herd problem of the 1930's (Rasmussen, 1941). Starving deer ravaged the forest and ate the not-so-palatable aspen reproduction, the woody portion of the seedlings and saplings. Older trees that escaped death had enduring scars from being topped and sided as forage for the deer. Injury rings can be observed in some trees at a height of six to eight feet on the aspen.

Management for aspen dominance recommends mechanical thinning of competitor species, this will increase the numbers of root suckers. Aspen are heavily browsed by deer, and repeated heavy browsing can eliminate total aspen regeneration in an area. Aspen should be protected because they are aesthetic, and are best forage for wild animals. They regenerate after stresses of injury and fire immediately. Aspen form a "nurse crop" for the slower growing spruces.

The distribution of the trees in the mixed conifer forest follow varying frequencies due to individual site preferences. Tables presented later in this paper will illustrate elevation and aspect as important controlling factors to species presence.

The shrub strata in this forest is restricted to moderate densities of dwarf juniper, snowberry, Utah serviceberry, New Mexico locust, and Arizona rose. Frequency values are highest for locust and dwarf juniper. Shrub presence increases with diminishing canopy cover, as well as on southwest aspects. Plots on level ground showed aggregated individuals amidst the forest openings. There was also a positive correlation between heightened species diversity and shrub cover. Shrubs dominating the middle profile position in pure stands were negligible, with dwarf juniper showing a .5% frequency, and with a relative cover percent of .07%. With positive mixtures of at least three tree species, dwarf juniper had an increase in frequency of 6.5% and a cover increase of 13.3% for combined plots. Other shrub species increased likewise with decreasing canopy cover. A cruise analysis of the North Rim forest resource would reveal a definite specificity of the shrubs to geographic location. The frequency of New Mexico locust was 11%, Ceanothus 1%, and Arizona rose .8% for plots established on the Walhalla Plateau, or eastern portion of the park. Values listed for the western and northern mixed conifer areas were locust 3, Ceanothus 4, and Arizona rose at 3.2 percents respectively. Usually in most coniferous forests, the shrub layer is much less developed as it is in deciduous stands (Oosting, 1965).

The understory or ground cover consists of herbaceous forbs and grasses. As was the case with the shrubs, the higher the density and canopy cover of the plot, the lower the ground cover values. Overstory species homogeneity also reduced the densities of understory species. In pure stands the canopy forms a dense overstory that restricts light so as to almost eliminate any herbaceous ground cover. The more heterogeneous the stand, the greater the variety, usually the density of the grasses and forbs. The total herbaceous ground cover of the mixed conifer community is at 68%. The percent non-living cover is set at 32%. Within the understory there are three divisions of plant types: the forbs have the greatest number, with a density of 79%, grasses next with a 13% density, and that of the sedges (Carex) was 8%. The ground cover in the mixed conifer forest was divided as such: the fringed brome grass had the highest frequency at 62%. Mutton blue grass, squirrel tail, and june grass ran evenly with respective values of 45%, 40%, and 37%. The forbs were dominated by: (%)

Biscuit root	45
Pussytoes	45
Yarrow	66
Wallflower	45
Lupine	40

Starwort	72
Geranium	50
Bracken fern	38
Lotus	35

The aggregation rates for the above species increased with lowered canopycover values. Pussytoes, starwort, geranium bracken fern and yarrow showed the highest aggregation values while the others were randomly dispersed. Shade tolerance and intolerance is mirrored in the contained species, and the pattern of sunlight penetration is manifested by the understory plant distribution.

PATHOLOGY

Next to man's impact on a forest stand, infections by various agents upon the plants contribute most to altering the ecology of the stand. Disease and insect infestations are a natural step in succession and are necessary in maintaining the community climax. In a balanced community, most pathogens constitute a low-grade infection; that is they maintain their population in the midst of abundant food, disease agents, and natural resistance to them by the plant itself. Usually when there is a fluctuation either to lower or higher numbers of pathogens, it is a result of a modified environment. Man's activities, fire, weather patterns, abrupt temperature changes, pollution, winds, and merely the natural successional changes within the plant community serve to alter the specific habitats that each pathogen requires for survival. The environment that man has created for his economic and aesthetic interests call for the elimination of all pests. Usually within a given time span the pathogen adapts to the extermination program reappears or is replaced by one or more new disease agents to the forest. In areas that are not protected against mass infections for economic or recreational purposes, the disease will usually run its course by destroying its own food source and thus itself. Woody trees and shrubs make great hosts for all classes of pathogens. More often than not an individual tree can harbor various disease symptoms, and the physical susceptibility to many more. Each plant species contains built-in vigor and immunity to certain pathogens. Couple this with site factors, eliminate physiological competition, and the plant has a chance to arrive at maturity. Many pathogens are species specific; that is, they can parasitize, live and reproduce on only one host species. Other pathogens depend on an individual plant genus or family. The major diseases encountered on North Rim tree species are specific to that host, and quite inflexible to any change which may occur.

The four classes of pathogens which were measured in my study were: 1) higher plant parasites, 2) fungal, 3) bacterial, 4) insect. Bacterial infections are usually responsible for limb deformations in the form of galls. On the cytogenic level, the bacterial agents usually cause the cellular DNA of the plant to code for growth befitting the bacteria. The contagious aspect of bacterial infection is the oozing of millions of bacteria from an open lesion or infected wound. Water, insects, and birds are dispersment agents for the bacteria. Nothing rots the heartwood of a tree faster than bacteria will, and symptoms are always a green ooze when fresh, brown when dried. A rotten tree is subject to topple easily, especially since most bacteria prefer mature individuals. Even-aged timber stands can be wiped out toally in a short time. The other microscopic pathogen that was noticed, but not measured are the viral pathogens. A virus infection mimics nutrient depiciency symptoms and are thus difficult to call by name. The damages caused usually show up on the leaves or needles, and cause premature leaf-fall of the plant. The virus, like the bacterium alters the genetic code, and reproduces inter-cellular. The virus finds its way to the reproductive parts of the plant so that each seed is infected before it is even fully formed.

Fungal infection causes most trees to die eventually. Fungi are plants that cannot produce their own food, and must obtain it from those that can. Usually by the time the symptoms are obvious, the tree is doomed, since a fine network of fungal mucelium is interconnected throughout the whole tree. The fruiting bodies of the fungus usually appear on the branches of the host as the physical manifestation of the disease. Conspicuous symptoms are branch proliferations called witches brooms, which produce annual crops of yellow needles. Other symptoms are branch and trunk swellings and cankers. Broom rust of spruce is caused by Chrysomyxa arctostaphyli, a fungus that completes its life cycle on the alternate host of Arctostaphylos species (manzanita). A black rust found on the true firs, especially white fir is caused by Melampsorella caryophyllacearum, and alternates to the herb Stellaria, which we have a rather high density of on the North Rim. Spruces and firs growing on wet sites are more susceptible to the fungi, and the moisture aids the progression of the disease. The broom and rust infections reduce growth and eventually cause death to the trees through strangulation or starvation. Dead reddish, but remaining needles; black coated, swollen branches signify the fir malady of Melampsorella. Mortality due to snow and wind breakage at the point of the fungal cankers is the expected fate of the infected firs. Aside from fungicide applications, control of the alternate

host of Stellaria would be the recommended control of this disease. On the north rim both treatments are not feasible due to the high frequency of occurrence for Stellaria, and the questioned role of the white fir on the North Rim. Broom rust of spruce reduces vigor greatly causing the tree to die from the crown downwards. Spike topped and borken spruces, tree deformation, malnutrition are all effects of the rust disease. In evaluating the damage, time since infection appear more important than number of infections per tree (Petersen, 1963).

Insect infections appear to be aggregated due to the mobility and abundant food supply of the insect. the spruce stands on the North Rim showed activity by the western spruce budworm (Choristoneura occidentalis, Freeman). According to Honing (1972), the spruce budworm is the most widely distributed and destructive defoliator in western North America. Common hosts include douglas fir, white fir, sub-alpine fir, blue spruce, and englemann spruce. Ponderosa pine is an occassional host. The budworm destroys practically all new growth on the tree, and are severely defoliated following an attack. Absence of needles on year old shoots indicate recent feeding activity. The budworm is usually held in check by a combination of several natural control factors, such as parasites, predators, and adverse climatic conditions. Sustained cool weather of only 48 hours can retard the development of the insect resulting in frozen eggs. Insecticide application of Zectran is the only management alternative to just ignoring the insect. Natural control is the effective method to protect against die off. The spruce beetle, Dendroctomus rufipennis caused extensive damage to spruce stands by mining into the heartwood to weaken the structure of the tree. Also, needle-cast is evidenced by the beetle's activity. The infections of the beetle are low on the North Rim, and since the beetle prefers the more mature stands, the mortality is evidenced as deadfall or windthrow. The mountain pine beetle attacks the ponderosa pines by boring into the base, feeding on the phloem (nutrient passageway tissues) of the tree. Usually the trees die a slow death since the beetle spirals and tunnels the length of the tree. Occassionally the tree gets girdled, and mortality is immediate.

By a long shot, the most wide spread and obvious insect attack is from the western tent caterpillar, Malacosma californicum. Since our forests are above 8000 feet elevation, and the frequency of quaking aspen is so high, the caterpillar has found a formidable ecotype to dwell in. The main concern in our area is from the aesthetic standpoint. Public concern for the beautiful aspen is frequently voiced. The

aspen is a vigorous tree, and though totally denuded during its spring leafing out, it can form a second leafing out in mid-July to synthesize its necessary food. This recovery takes energy, and is surely a stress to the tree. Conceivably after three or four seasons of caterpillar attacks, the tree will die. The caterpillar restricts its feeding to the leaves, reducing plant vigor. This situation is a means for a secondary attack by a fungal pathogen. The ecological impact of the caterpillar activity is of course reduced numbers of the tree. Establishment of seedlings is hindered and some less vigorous trees are killed. Thus a sort of "natural pruning" occurs among the aspen. A noticed effect on the trees in the study plots in the increased elimination of sexual reproduction. Catkin formation this spring was very low, attesting to the increased dependence on asexual reproduction by suckers.

The final category of measured pathogens occur among the higher plants. The angiosperms or seed producing plants contribute to parasite activity in their own highly evolved way. Some researchers treat the mistletoes as among the highest evolved plants around. They substantiate by valuing an organism's ability to parasitize and adapt as a specialization. Other researchers consider the mistletoe a genetic throwback to earlier plant survival schemes. Whatever the classification is, it is successful in establishing itself as the prime and most widespread infection we have on the north rim. All of the coniferous tree species on the North Rim are afflicted to various degrees with their own specific mistletoe. Ponderosa pine has the species of mistletoe, Arceuthobium vaginatum, which is the most prolific of the infections. Arceuthobium vaginatum is commonly called dwarf mistletoe, and has the highest frequency, with the most advanced development of any of the other mistletoes. The seeds for dwarf mistletoe are carried by wind, water, insects, and birds to great distances. The infection usually begins on the lower branches of the tree first, since it is quite shade tolerant. This mistletoe is restricted to the conifers, and is fairly specific to ponderosa pine. The first effect is a general weakening of the tree by robbing it of both water and food. As the infection progresses, witches brooms (branch proliferation), or die off in general is noticed in the upper crown of the tree. Slowly the mistletoe moves down to the bottom until it saps its host of all nutrient energy. Physiologically the mistletoe intercepts the sugars as they are formed before the plant can. The parasite also sends haustoria down into the xylem or water conducting tissues to utilize the plant's supply for its own growth. Final tree mortality depends on how many mistletoe plants there are in the tree, how vigorous the tree is, and how old the tree

aspen is a vigorous tree, and though totally denuded during its spring leafing out, it can form a second leafing out in mid-July to synthesize its necessary food. This recovery takes energy, and is surely a stress to the tree. Conceivably after three or four seasons of caterpillar attacks, the tree will die. The caterpillar restricts its feeding to the leaves, reducing plant vigor. This situation is a means for a secondary attack by a fungal pathogen. The ecological impact of the caterpillar activity is of course reduced numbers of the tree. Establishment of seedlings is hindered and some less vigorous trees are killed. Thus a sort of "natural pruning" occurs among the aspen. A noticed effect on the trees in the study plots in the increased elimination of sexual reproduction. Catkin formation this spring was very low, attesting to the increased dependence on asexual reproduction by suckers.

The final category of measured pathogens occur among the higher plants. The angiosperms or seed producing plants contribute to parasite activity in their own highly evolved way. Some researchers treat the mistletoes as among the highest evolved plants around. They substantiate by valuing an organism's ability to parasitize and adapt as a specialization. Other researchers consider the mistletoe a genetic throwback to earlier plant survival schemes. Whatever the classification is, it is successful in establishing itself as the prime and most widespread infection we have on the north rim. All of the coniferous tree species on the North Rim are afflicted to various degrees with their own specific mistletoe. Ponderosa pine has the species of mistletoe, Arceuthobium vaginatum, which is the most prolific of the infections. Arceuthobium vaginatum is commonly called dwarf mistletoe, and has the highest frequency, with the most advanced development of any of the other mistletoes. The seeds for dwarf mistletoe are carried by wind, water, insects, and birds to great distances. The infection usually begins on the lower branches of the tree first, since it is quite shade tolerant. This mistletoe is restricted to the conifers, and is fairly specific to ponderosa pine. The first effect is a general weakening of the tree by robbing it of both water and food. As the infection progresses, witches brooms (branch proliferation), or die off in general is noticed in the upper crown of the tree. Slowly the mistletoe moves down to the bottom until it saps its host of all nutrient energy. Physiologically the mistletoe intercepts the sugars as they are formed before the plant can. The parasite also sends haustoria down into the xylem or water conducting tissues to utilize the plant's supply for its own growth. Final tree mortality depends on how many mistletoe plants there are in the tree, how vigorous the tree is, and how old the tree

was when it first became infected. New establishment for the parasite is very effective since birds, butterflies and thrips feed on the berries and thus distribute the seeds far and wide. Slope and aspect can enhance their distribution also. Hawksworth (1968) found that the greatest infection was on the ridge tops, with the cooler sites on the north and east aspects favoring their growth. Management schemes for dwarf mistletoe infected areas is to prune the affected branches, or in advanced stages to remove the entire tree. The best defense is to manage your forest so as to maintain a healthy stand capable of avoiding serious or widespread infections.

Part of the plot survey included gathering data that would give an accurate assessment of the pathological situation on the North Rim. The data sheets, (appendix) included an area to record the data to be analyzed with the rest of the stand ecology. The importance of knowing about the numbers and extent of your infections gives an idea of the stability of the community, the degree of management needs to eliminate tree mortality. The ultimate goal of the management program should be to preserve the forest resource so as to have a continued supply of representative age class individuals. A diseased tree is not aesthetic, much less safe for recreation areas. Trees in the advanced stages of infection need to be removed immediately.

MISTLETOE

The purer the stand of ponderosa pine, the lower the incidence of infection. Frequency of infection was 8% density of infection figured to an average of 13 individuals per acre, or .07% had some degree of infection. Among the ponderosa pines, the deadfall that evidenced mistletoe as the cause for mortality was .002% of the .07% infection density. Trees that were in the advanced stages of infection usually showed at least 25% of the crown dead, some .02% of the sighted trees showed this character. The number of infections rose logarithmically with the age of the trees, and thus the age of the stands. The most advanced mistletoe infection was found in the 24 - 30 inch diameter at breast height (dbh) trees, with heights from 60 feet and above. Infections were also found in saplings, but merited in presence only. The older stands thus had the highest infection rates. The frequency of infection rose with the greater species heterogeneity of the stand, that is the more varied the stand in species composition, the greater the incidence of infection. Mistletoe infection in the colorado blue spruce was figured at .04% frequency, mostly occurring within the 14 inch dbh, 40 foot height size class. Englemann spruce was surprisingly high in mistletoe infection frequency,

with a .04% of all trees over 12 inches dbh affected. The density for infection was 15 individuals per acre. White fir registered a low .01 infection frequency for mistletoe, a density of 6 individuals per acre was the standard in the white fir. The infections were not specific to age on the white fir. Sub-alpine fir did not show measurable infection rates, since no infected trees fell within my plots, but mistletoe infection was observed among the species. Douglas fir had mistletoe infections on the decadent individuals, as well as the trees averaging 18 inches dbh, and a corresponding height of 70 feet. Infection frequency was set at 18%, with 44 individuals per acre infected.

INSECT INFECTIONS:

Rates of Infection per Pathogen Species Observed Path

Pathogen	% Freq.	Density/acre	ave. dbh	Height	% mortality
Spruce beetle	.001	6	16	52	---
Western spruce budworm	.08	14	12	43	19
Mountain pine beetle	.07	22	26	65	.04
Tent caterpillar	69.0	27	15	60	.09

For density counts of the above table, all individuals regardless of age class were counted. Infection, whether it be one observation on the tree or countless attacks, were all tallied.

FUNGAL

The white fir was the only species that was identified and measured for fungal attack on. The frequency of attack was highest on the individuals in the mixed conifer stands. Ponderosa pine stand white firs showed lower attack, infestation, and mortality rates of the tree as compared to the mixed conifer community. Decreased environmental exposure and increased water relations fostered the establishment of the fungus. The frequency of attack of the fungus Melampsorella caryophyllacearum on the white fir was 14% with the density at 2 individuals per acre. Tree over 24 inches dbh and 80 feet tall accounted for 80% of the infections.

BACTERIA INFECTIONS

Bacterial oozes on the ponderosa pine and aspen were usually a secondary infection. The aspen that exhibited lesions were heavily infected with tent caterpillar activity. Ponderosa pine infection was

secondary to advanced mistletoe infection. The frequency for bacterial infection among the ponderosa pine was .04%, with a density of .06 individuals per acre. For the aspens, the frequency was 14%, with a density of 13 individuals per acre. Bacterial oozes were directly correlated to the general weakening of the individual tree from repeated attacks by the tent caterpillar. In summation, the stability and succession of the North Rim forested region is not immediately in danger of pathological interference. Rates of infection for all pathogens excepting the tent caterpillar and the dwarf mistletoe are so low that any silviculturalist would consider them too low to count. We have a problem with the tent caterpillar, but that infection will run its course, destroying the aesthetic beauty of the species, but actually benefiting the forest community since aspen is considered a disclimax or invader species, and a decrease in their numbers need not cause alarm. The long range problem with dwarf mistletoe lies in that the ponderosa pine will continue to diminish in number, as from decreased reproduction to higher mortalities, the former a result of dwarf mistletoe. Infected mature individuals serve to hold the mistletoe within the tree, and only upon removal will the threat of infection to the reproduction be eliminated.

If the trend of such a high reproduction and invasion rate for the white firs continues, the altering of the ponderosa pine climax will encourage a more dense per individual tree infection. This would be a very influential element towards total community change on the North Rim.

Fire Suppression:

Rasmussen (1941) wrote that the frequency of white fir had increased markedly in the ponderosa pine forest since an active program of fire suppression had been applied. Merkle (1954) also noted an increase in densities of white fir due to fire suppression. His quadrats gave higher presence values than did those of Rasmussen. From data comparisons the apparent trend notes an increase of white fir throughout the entire forest in the Park. Halvorson (1972) speculated that heavy litter accumulation in the North Rim forests was responsible for the reduction of reproduction among the ponderosa pine. Halvorson also predicted that a continuous heavy layer of litter reduces the densities of the ground cover herbaceous species.

A management program that would allow natural fires which presented no immediate danger to burn would be most feasible in manipulating the North Rim forest. This is especially true for the maintenance of the climax community.

The role of natural fires in the forest community*:

- 1) To reduce fuel volume that reduces chance of wildfires.
- 2) Kill or weaken undesirable hardwoods.
- 3) Reduce grass and shrub competition.
- 4) To facilitate the establishment of pine reproduction by removing thick litter and competing plants.
- 5) To control disease, especially insect populations.
- 6) To normalize habitat for wildlife.
- 7) To remove debris and other impediments.
- 8) Affects soils biologically, chemically, and physically
- 9) Maintains the predominance of ponderosa pine.

* Taken from the U.S. Forest Service "Timber Appraisal Handbook," #216, 1974.

CONCLUSION

The following charts and graphs were constructed to detail the dynamics and inventory of the forest resource in tabular form. Again, when reviewing these tables, frequency always refers to presence within the plot. A species individual need only appear once in the plot to be recognized. Density is an actual count of the plant numbers located in the plot. Since individual sizes of the different species vary greatly, as well as intra-species variance, the cover parameter is important in total community assessment. Cover refers to the actual area covered by that individual.

The directional movement of a community depends upon environment, disturbance, stress, and species fluctuation. When the community is seemingly static, it is in the state of a climax or disclimax situation. The concept of "climax" is disputed as to its existence among many ecologists, who recognize continual dynamic and cyclic progression in the plant community structure. Quantitative analysis captures the state of the vegetation at a given point in time. Frequent reconnaissance of the forest, when applied over the years is not only the standard by which the community is charted, but also is the means to compare change.

The first chart gives a comprehensive community analysis. These figures were taken from the plot data and represents a community mean for the given parameters. The densities of mature trees by plot (page) is the individual plant count of mature trees only. The summation at the base of the columns gives the overall inventory for each species regardless of community type. The horizontal shows the counts by plot number. These figures can be expanded to per acre analysis by multiplying each number by ten. The dominant community composition chart (page) refers to the dominant plants of the community being the mature trees. This chart gives numbers on the standing timber resource by computing from the average plot tallies, the board feet per acre per species. Total density per species is given for each community, along with the basal area of these same trees. Basal area in square feet sums the actual area occupied by the butt of the tree.

The chart on species frequency and cover per acre (page) is a rundown of the total community, profile included. On the extreme left, an abundance value is given each species. Abundance is a qualitative observation to show exactly how frequent each species is. Number 1 indicates dominance of that species within its profile, number 5 states that the species occurrence is rare, and that it only needs to appear once to be recognized. Two, 3, and 4 are assigned intermediate values. Both forest community types are represented with vertical columns showing frequency percent and percent cover. In the ponderosa pine

in the higher elevations of the Park. Douglas fir has a high association with sub-alpine fir and englemann spruce. Sub-alpine fir prefers the north-easterly slopes at the higher elevations.

The predominant shrub of the mixed conifer community is dwarf juniper at 20% frequency. New Mexico locust at 14%, forms a dense strata in some stands for short distances. Cover values for the former two species are about equal.

Fringed brome grass with a frequency of 62% does well in this community. Mutton blue grass at 45%, squirreltail 40%, and junegrass 37%, and all aggregate in the small openings in the canopy.

Again, comparing Merkle's 1962 study for the understory forbs, one finds some noteworthy variances:

Species	1962(%)	1976(%)
Biscuit root	53	45
Deer vetch	20	35
Pussytoes	22	45
Western wallflower	--	45
Silver-top sedge	18	29
Gayophytum	47	40
Hills lupine	--	33
Starwort	31	72
Sedge	20	25
False solomons seal	23	33
Richardsons geranium	--	50
Bracken fern	28	38

From close examination of the compared values, there is a definite trend toward establishment of perennial plants. Frequencies and diversities are higher, with wet-mesic forms having the greatest increases.

Reproductive stability (page) is the sole indicator by which forest composition can be charted. The reproduction rate stabilizes when each mature tree has a formidable replacement for it upon death. Compensations for death by disease or mechanical means, and competition must be allotted for. Community direction is also obvious from these rates.

Page gives the Forest Service's adjusted rates of necessary reproduction for forest maintenance. Where these standard rates are compared to the North Rim reproductive situation, the surplus and deficit rates are seen. Community change increases with number increase or decrease on either side of the norm. Ponderosa pine represents the sole decreaser

in the forest with a 38% reproductive deficit to the community. White fir, an increaser, is 147% over the required replacement mean. The two former figures are most diagnostic toward community direction. Aspen, not of long-range concern, is 26% higher than normal, but aspen sensitivity to the environment negates any concern over the number increases. Douglas fir and englemann spruce run about the same in number requirements and in replacements, though they are showing an increase of 270%. Both of these species indicates germination factors are ideal presently, or that the climate is affording a moister and cooler summer condition overall for immediate species response. Colorado blue spruce has stabilized, probably this is due to the required environmental specifications for that species. Sub-alpine fir, giving an 82% increase, in all probability a result of the same effects on the douglas fir and englemann spruce. The increases in these more boreal species are affected by climatic change, vegetational fluctuations, or from fire suppression.

The chart on densities of mature trees by plot, page , is merely a ratio of composition by species for the entire forest. All species are plotted against each other in the sum column. For instance, for every 80 ponderosa pines counted, there were likewise 73 white firs observed, and so on with the other five species.

The following graphs were plotted for concise observation of plant ecological trends over a given time, elevation or aspect. Species densities in relation to elevation gives the number of tree per acre to a corresponding elevation. The graph is self-explanatory, and shows the density responses of each species to each 100 foot rise in elevation. The density to aspect graph likewise illustrates species niche locations to the direction that the slope is facing. The key here is exposure, and just how much each species can tolerate and successfully exist in. Vegetation density greatly influences aspect, ultimately, aspect determines species composition.

The last two graphs were constructed to show seasonal growth amplitudes giving two parabolic species situations. Plant counts were taken within quads and increased to fit acre dimensions. On the horizontal axis, observation dates supplies the parametric measurements. The species selected were similar in density, but parabolic to each other in soil moisture requirements. Soil moisture is indicated fairly well by density, and is measured thus. The meso-hydric species showed a rise in numbers with increasing soil moisture, whereas mesoxeric plants increased with drier soils. From the middle of June, to the first of July, the soils are relatively dry. Monsoonal thunder showers from mid-July to the first of August show an increase in plant growth. The latter half of summer indicates a drying trend that mimics the June condition fairly closely.

It is the expressed purpose of this paper to familiarize the reader with the dynamics of the North Rim forest resource. Community descriptions detail the composition and numbers of the different plant species in the forest. Familiarization with the specifics, no matter how seemingly trivial, gives a base to work from in applying a resource management scheme. The charts and graphs are to increase the understanding of the descriptive analysis of the communities on a comparative basis.

CHARTED COMMUNITY ANALYSIS

Taken From a Comprehensive Plot Study for Each Community

Environmental and Plant Parameters:	Ponderosa pine	Mixed conifer
Percent average slope	15	8
General aspect	NW	E
Litter accumulation	10 cm.	7.5 cm.
Directional discontinuities of vegetation*	S	N
Percent canopy closure	26	84
Average shrub height (inches)	21.5	37.7
Average shrub cover by percent	12.9	11.3
Percent average cover by grasses and forbs	28	67
Percent frequency of cryptogamic species	14	87
Percent rock cover	4	3.7
Percent litter cover	45.4	21
Percent bare soil	3.4	6.2
Sum percent cover (actual surface covered by living & non-living matter)	91	99
Sum percent profile cover (tree canopy, shrubs, grasses, and forbs)	88	113
Sum percent living (metabolizing plants in quad)	46	68
Sum percent non-living (of surface area)	54	32

*This is the direction of slope or aspect face which exhibits the greatest departure from stand homogeneity within the shortest distance.

DOMINANT COMMUNITY COMPOSITION

Taken From Counts and Measurements of Stand Individuals

Species	Ponderosa pine			Mixed conifer		
Ponderosa pine	45	1455	207	16	685	132
White fir	37	330	24	22	717	61
Aspen	18	770	52	27	788	65
Englemann spruce	--	--	--	17	472	42
Colorado blue spruce	-	--	--	6	111	12
Sub-alpine fir	--	--	--	10	160	18
Douglas fir	--	--	--	2	32	6

% Relative Density

Board feet/acre

Basal area/acre
(feet²)

% Relative density

Board feet/acre

Basal area/acre
(feet²)

Species Percent Frequencies and Percent Cover Per Acre.*

(-) = Presence Only

Abund.	Trees: (mature & reproduction)	Freq. %	Cover %	Freq. %	Cover %
		Ponderosa	Pine	Mixed conifer	
1	<i>Pinus ponderosa</i>	100	27	79	11
1	<i>Abies concolor</i>	98	12	74	10
1	<i>Populus tremuloides</i>	47	12	63	7
1	<i>Picea englemanni</i>	10	.5	93	17
2	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>	2	.08	9	2.3
2	<i>Picea pungens</i>	--	--	28	7
3	<i>Abies lasiocarpa</i>	--	--	6	.3
<u>Shrubs:</u>					
1	<i>Berberis repens</i>	42	.01	.08	.01
1	<i>Rosa arizonica</i>	18	10	4	.5
3	<i>Ceanothus martini</i>	6	.01	5	.01
3	<i>Ceanothus fendleri</i>	3	.01	2	.01
4	<i>Symphoricarpos oreophyllos</i>	3	1.0	4	.5
5	<i>Sambucus glauca</i>	2	.5	--	--
3	<i>Robinia neomexicana</i>	1	.5	14	6
5	<i>Ribes inerme</i>	1	.5	--	--
5	<i>Quercus gambelli</i>	1	1.0	--	--
3	<i>Juniperus communis</i>	--	---	20	5
5	<i>Amelanchier utahensis</i>	--	---	1	1
<u>Grasses:</u>					
1	<i>Poa fendleriana</i>	74	6	45	3.5
1	<i>Blephaneuron tricholepsis</i>	45	3	3	.01
2	<i>Sitanion hystrix</i>	33	5	40	6
2	<i>Muhlenbergia montana</i>	32	2	12	.5
2	<i>Bromus ciliatus</i>	18	7	62	14.
3	<i>Stipa comata</i>	6	.01	6	.01
3	<i>Koeleria cristata</i>	4	.5	37	6
4	<i>Stipa columbiana</i>	3	.01	10	.5
4	<i>Poa longiligula</i>	3	.01	10	.5
<u>Forbs:</u>					
1	<i>Lomatium leptocarpum</i>	62	1	45	1
1	<i>Pedicularis centranthera</i>	45	.15	16	.5
1	<i>Collinsia parviflora</i>	38	2		.01
1	<i>Antennaria aprica</i>	32	2	45	3

Abund.	Forbs (continued)	Ponderosa Pine		Mixed conifer	
		Freq. %	Cover %	Freq. %	Cover %
2	Carex rossii	27	2	29	2
3	Agoseris glauca	24	.5	14	.3
2	Achillea lanulosa	20	1.0	66	4
3	Delphinium nelsoni	20	1.0	1	1
4	Chrysopsis villosa	19	.5	4	.3
2	Lotus utahensis	19	1.0	35	2
2	Carex occidentalis	15	.01	14	1
5	Lithophragma tenellum	15	.01	--	--
3	Eriogonum racemosum	15	.5	30	1
3	Saxifraga rhomboidea	14	.5	1	.01
4	Chrysopsis fulcrata	12	.5	8	.5
4	Euphorbia palmeri	10	.5	14	.5
3	Solidago nana	10	.5	10	.5
4	Taraxacum laevigatum	8	.5	2	.01
3	Solidago sparsiflora	8	.5	14	1
4	Viguiera multiflora	8	.1	5	.5
2	Erysimum capitatum	8	.5	45	2
3	Erigeron divergens	7	.5	12	.5
3	Frageria ovalis	7	.01	31	1
4	Gayophytum nuttallii	6	.5	2	.01
2	Cryptantha setosissima	6	.5	14	1
2	Lupinus hillii	5	.5	40	3
2	Thlaspi fendleri	5	.01	9	.01
4	Pseudocymopterus montanus	5	1	4	1
4	Draba asperella	4	.1	12	.5
4	Senecio uintahensis	3	.5	12	1
4	Chenopodium album	3	.1	7	.1
4	Thalictrum fendleri	3	.01	33	1
2	Stellaria jamesiana	2	.01	72	3
3	Castilleja confusa	2	.01	5	.1
3	Hymenoxys subintegra	2	.01	28	1
3	Arenaria fendleri	2	.01	18	.5
3	Cirsium drummondii	2	.5	3	.5
3	Carex siccata	1	.01	35	2.5
4	Phacelia magellanica	1	.1	5	.5
4	Swertia radiata	1	.1	20	2
5	Pyrola virens	--	--	2	.01
4	Smilacina stellata	--	--	30	2
4	Geranium richardsoni	--	--	50	2
4	Aster biglovii	--	--	4	.01
3	Pteridium aquilinum	--	--	38	5
4	Penstemon virgatus	--	--	1	.01

* The species frequency is listed by ponderosa pine values for systematic evaluation.

* Abundance indicates just exactly "how" frequent each species is in each 20 x 20 meter plot (one-tenth acre, or 66 feet x 66 feet)

Abundance classes:

1-Dominant
2-Abundant
3-Frequent

4-Occasional
5-Rare

REPRODUCTIVE STABILITY

Community Reproduction Per Dominant Species.*
Reproduction Rates Per Mature Tree Per Plot.**

Plot #	Pnd. pine	Wht. fir	Aspen	Doug. fir	Englm. spruce	Colo. bl. spruce	Sub-alp. fir
1	7						
2	1	9	.5				
3	.5	5	2	10	4		
4	2	22	2				
5	1	38	13		3	1	
6		45	5		6	6	
7	1	15	39		5	2	6
8	4	9	4		27		
9	.08	26	2				7
10	13	11	41		3		1
11	5						
12	2	21	16		10		
13	3	2	4				
14	.5	3	15		2		1
15			14	3	10	2	6
16	5	8	4	39	4	3	25
17	1.5	6	2	3	6	7	4
18	.5		1	15			22
19	2		1		21	2	
20	7		15				
Sum	3.12	18.3	19	14.3	14.1	3.2	9.1

Reproductive stability

* Plots number 2, 4, 11, and 20 are the ponderosa pine stands, all others are of the mixed conifer type.

** To maintain the climax condition of the forest, the reproduction rate per mature individual should adjust by species: (U.S. Forest Service, 1974).

Ponderosa pine	5
White fir	8
Aspen	14
Douglas fir	6
Englemann spruce	6
Colorado blue spruce	3
Sub-alpine fir	5

The differing amounts are calculated on the average condition of death by disease or mechanical means, natural mortality, and competition.

DENSITIES OF MATURE TREES BY PLOT *

# Plot	Pond. pn.	Wht. fir	Aspen	Doug. fir	Engl. spr.	Colo. b.s.	Sub-al. f.
1	6						
2	2	11	19				
3	6	14	34	1	16		
4	3	22	2				
5	5		5		7		
6	2		15		8		
7	2	7		3		10	33
8	3	8			1		
9	12	6	14	2			2
10	2	6	14		7		1
11	24				6		
12	6	1	9		4		
13	18	11					
14	1	2	7		12		1
15		3	5	17	13	8	2
16	1	3	24	5	9	3	4
17	34	11	6	17	11	4	16
18	7		5	7			9
19	4		29		5	3	
20	5		6				
Sum	80	73	90	31	50	19	30

* Relative density per species for combined plots in the North Rim forest.
(each plot one-tenth acre or 20 meters by 20 meters.)

B I B L I O G R A P H Y

- Buol, Hole, McCracken. 1973. Soil Genesis and Classification. Iowa State Univ. Press, Ames, Iowa.
- Cottam, Curtis, Catana. 1957. "Some Sampling Characteristics of a Series of Aggregated Populations." Ecology 38(4):1047-1049.
- Cottam, Curtis, Hale. 1954. "Sampling Characteristics of Random Populations." Ecology 34(4):22 pps.
- Crampton, C. Gregory. 1965. Mormon Colonization In Southern Utah and in Adjacent Parts of Arizona and Nevada: 1851-1900. Univ. of Utah Pub., Salt Lake City, Utah pp. 181-197.
- Curtis and McIntosh. 1950. "The Interpolations of Certain Analytic and Synthetic Phytosociological Characters." Ecology 54(3):1207-33.
- Edelmann, Remmenga, Ward. 1968. "An Evaluation of Plot Methods For Alpine Vegetation." The Bulletin of the Torrey Botanical Club. Vol. 91, No. 6, pp. 439-450.
- Gould, Frank W., 1968. Grass Systematics. McGraw-Hill Co. 142-315.
- Haring, Inez. 1941. "Mosses of the Grand Canyon National Park." The Bryologist, vol. 44, pp. 124-126.
- Hawksworth, Stewart, Bailey. 1968. "You Can Save Your Pines From Dwarf Mistletoe." U.S. Forest Service Research Paper. RM - 35. pp. 1-22.
- Hitchcock. 1971. Manual of the Grasses of the United States. Vol. 1 and Vol. 2.
- Jones, John, and Trujillo. 1975. "Development of Some Young Aspen Stands in Arizona." USDA Forest Service. Research Paper. RM - 151. 9 pp.
- Kearney and Peebles. 1969. Arizona Flora. Univ. of Calif. Press, Berkeley, Calif. pp. 1085.
- Kershaw, 1973. Quantitative and Dynamic Plant Ecology, 2nd edition. American Elsevier Publishing Co., Inc. New York. pp. 249.
- Lightle, Paul C. 1974. "Dwarf Mistletoe of Ponderosa Pine in the South West." USDA. Forest Service. Forest Pest Leaflet #19. pp. 7.

- McCambridge, William F. 1972. "The Mountain Pine Beetle." USDA. Forest Service. Forest Pest Leaflet #2. pp. 7.
- McDougall, Walter B. 1973. Seed Plants of Northern Arizona. Museum of Northern Arizona, Flagstaff, Arizona. pp. 596.
- Merkle, John. 1962. "Plant Communities of the Grand Canyon Area, Arizona." Ecol. 43:(4) 698-710.
- 1954. "An Analysis of the Spruce-Fir Community on the Kaibab Plateau." Ecology 35:(3) 316-332.
- Oosting, H. J. 1958. The Study of Plant Communities. 3rd edition. W. H. Freeman and Company, San Francisco. pp. 33-74.
- Payne, Richard. 1976. "Practical Point Sampling For Foresters." USDA. Forest Service, Region 4. pp. 16.
- Peterson, Roger S. 1963. "Effects of Broom Rusts on Spruce and Fir Stands." USDA. Forest Service Research Paper INT - 7. pp. 11.
- Rand, Patricia. 1957. "The Plant Communities of Grand Canyon National Park, Arizona." Minnesota Academy of Science. Vol. 25. pp. 87-90.
- Rasmussen, D. Irvin. 1941. "Biotic Communities of the Kaibab Plateau, Arizona." Ecological Monographs 2:(3) 231-274.
- Rice, Elroy L. 1959. "A Statistical Method for Determining Quadrat Size and Adequacy of Sampling." Ecol. 48:(5) 987-1011.
- Schmid, J. M. 1975. "The Spruce Beetle." USDA Forest Service. Forest Pest Leaflet #127. pp. 7.
- Schultz, Gibbons, Defana, Dervin. 1961. "Artificial Populations for Teaching and Testing Range Techniques." Journal of Range Management 14:(5) 8.
- Stelzer, Milton J. 1971. "Western Tent Caterpillar." USDA Forest Service. Forest Service Pest Leaflet #119. pp. 8.
- USDA Forest Service. 1973. Silvicultural Systems for the Major Forest Types of the United States. pp. 45-167.
- United States Forest Service. 1974. Timber Appraisal Handbook, #R-4. Ammendment #216. Scribner Rule. 11.1 — 2 to 11.10 — 29.

PLANT SPECIES LIST -- North Rim, GCNP

The following list of species was obtained by observation and/or collection. Keying of the species was done with the aid of a dissecting scope and the necessary taxonomic keys. Persons classifying were Melinda Hurst, Kathy Keliher, and Betty Strack. Determinations as to the correctness of the nomenclature were made by Dr. Stanley Welsh, Herbarium Curator and Professor of Taxonomy at Brigham Young University.

Listings are entered by taxonomic classification in the left hand column, with the common names on the right. One asterix (*) designates that that specimen is filed in the North Rim Herbarium, Resource Management Office. Two asterix' (**) indicate that the plant is an invader on disturbed sites.

TREES:

* Abies concolor	white fir
* Abies lasiocarpa	sub-alpine fir
* Juniperus scopulorum	rocky mountain juniper
* Picea engelmanni	engelmann spruce
* Picea pungens	Colorado blue spruce
* Pinus ponderosa	ponderosa pine
* Populus tremuloides	quaking aspen
* Pseudotsuga menziesii var. glauca	douglas fir

SHRUBS:

Amelanchier polycarpa	serviceberry
* Amelanchier utahensis	utah serviceberry
* Arctostaphylos patula	roundleaf manzanita
* Berberis repens	mahonia
* Ceanothus fendleri	buckbrush
* Ceanothus martini	mountain lilac
* Cercocarpus ledifolius	curleaf mountain mahogany
Cercocarpus filiformis	fine-leaf mountain mahogany
* Cowania mexicana	cliffrose
* Chrysothamnus parryi	rabbitbrush
Ephedra viridis	mormon tea
* Juniperus communis	dwarf juniper
* Quercus gambelli	gambel oak
* Ribes inerme	gooseberry
* Ribes leptanthum	trumpet gooseberry
* Ribes cardiophyllum	gooseberry

- * *Rhus trilobata*
- * *Robinia neomexicana*
- * *Rosa Arizonica*
Rosa neomexicana
- * *Sambucus racemosa*
- * *Symphoricarpos oreophyllous*

wild raspberry
new mexico locust
arizona rose
new mexico rose
elderberry
snowberry

GRASSES

- * *Agrophyron cristatum*
- * *A. desertorum*
- A. intermedium*
- * *A. riparium*
- A. repens*
- * *A. subsecundum*
- * *A. trachycaulum*
- * *Agrostis alba*
- * *A. scabra*
- ** *Agrostis thurberiana*
- * *Anterrhinum kingii*
- * *Arrehenatherum elatius*
- * *Beckmania syzganhe*
- * *Blepharoneuron tricholepsis*
- ** *Boutelous gracilis*
- * *Bromus ciliatus*
- * *B. inermis*
- ** *Dactylis glomerata*
- * *Danthonia intermedia*
- * *Deschampsia elongata*
- Echinochloa crusgalli*
- Elymus glaucus*
- ** *Erogrostis pectinaceae*
- * *E. cilianensis*
- * *Festuca arizonica*
- * *F. ovina*
- * *Glyceria borealis*
- * *Hordeum jubatum*
- * *Koeleria cristata*
- ** *Lolium multiflorum*
- ** *L. perenne*
- ** *L. tenulentum*
- * *Muhlenburgia montanus*
- * *Oryzopsis hymenoides*
- ** *Phleum alpinum*
- ** *Phleum pratense*

wheatgrass, crested
wheatgrass
meadow wheatgrass
Quackgrass
wheatgrass
slender wheatgrass
white bentgrass
hairy bentgrass
bentgrass
tall oat grass
tall oat grass
american slough grass
pine drop-seed
blue grama grass
fringed brome
smooth brome
orchard grass
timber oatgrass
slender hairgrass
cock-spur
wild rye
love grass
hairy lovegrass
Arizona fescue
meadow fescue
manna grass
foxtail
june grass
wild rye
"
"
mountain muhly
indian rice grass
alpine timothy
timothy

* <i>Poa compressa</i>	blue grass
* <i>P. fendleriana</i>	mutton blue grass
** <i>P. cusickii</i>	cusick bluegrass
<i>P. interior</i>	interior bluegrass
* <i>P. longiligula</i>	long-tougue bluegrass
** <i>P. pratensis</i>	kentucky bluegrass
<i>P. pupicola</i>	rip-gut grass
** <i>Panicum capillare</i>	switch grass
* <i>Sitanion hystrix</i>	squirrel tail
** <i>Sporobolus cryptandrous</i>	drop seed
* <i>Stipa columbina</i>	needle and thread grass
* <i>S. comata</i>	long needle and thread grass

FORBS:

* <i>Achillea lanulosa</i>	yarrow
** <i>Agastache pallidiflora</i>	giant hyssop
* <i>Agoseris arizonica</i>	arizona dandelion
* <i>Agoseris glauca</i>	mountain dandelion
* <i>Aletes macdougali</i>	alates
* <i>Allium palmeri</i>	wild onion
* <i>Arabis drummondii</i>	rockcress
* <i>Antennaria aprica</i>	pussytoes
* <i>A. marginata</i>	pussytoes
* <i>Arenaria fendleri</i>	sandwort
* <i>Asclepias speciosa</i>	antelope horns
* <i>Aster adscendens</i>	white aster
* <i>A. biglovii</i>	bigelow aster
* <i>A. canescens</i>	aster
<i>A. foliaceus</i>	leafy bract aster
* <i>Arnica foliosa</i>	arnica
<i>Astragalus castaneaeformis</i>	milkweed
* <i>A. lentiginansus</i>	"
* <i>Campanula parryi</i>	bellflower
* <i>Carex occidentalis</i>	sedge
* <i>C. rossii</i>	Rag-top sedge
* <i>C. siccata</i>	silver-top sedge
* <i>Castilleja confusa</i>	indian paint brush
* <i>Chrysopsis fulcrata</i>	gold aster
* <i>Chrysothamnus viscidiflorus</i>	rabbitbrush
* <i>Cirsium drummondii</i>	thistle
* <i>C. wheeleri</i>	thistle
* <i>Chenopodium album</i>	lambs quarters
* <i>Chrysopsis villosa</i>	gold aster
* <i>Claytonia rosea</i>	spring beauty
* <i>Clematis hirsutissima</i>	virgins bower
* <i>Collomia linearis</i>	collomia
* <i>Corallorhiza maculata</i>	spotted coral root

* Collinsia parviflora	blue eye grass
* Cryptantha setosissima	fiddleneck
* Delphinium nelsoni	larkspur
* Draba asperella	bladderpod
* Epilobium angustifolium	fireweed
* E. halleanum	fireweed
* Equisetum laevigatum	horsetail
* Erigeron divergens	spreading fleabane
* E. flagellaris	fleabane
* E. formosissimus	tall fleabane
* E. macranthus	fleabane daisy
E. simplex	mountain daisy
E. ursinus	fleabane
* Eriogonum racemosum	red-root buckwheat
* Erysimum capitatum	wall flower
* Euphorbia lurida	spurge
* E. palmeri	palmer spurge
* Fritillaria atropurpurea	fritillary
* Frageria ovalis	strawberry
Galium spp.	galium
* Gayophytum nuttalli	gayophytum
Gentiana affinis	gentian
* Geranium caespitosum	cranesbill geranium
* G. richardsoni	richardsons geranium
* Gilia aggregata	skyrocket
** Gilia longiflora	skyrocket
** G. tenuituba	pink skyrocket
* Goodyeara oblongifolium	rattlesnake-plantain
* Hieracium fendleri	hawkweed
* Hymenopappus lugens	hymenopappus
** Hymenoxys subintegra	hymenoxys
* Lepidium denseflorum	hedge mustard
* Lewesia pygmaea	spring beauty
* Liguisticum porteri	lovage
* Linum lewesii	blue flax
* Lithophragma tenellum	woodland star
* Lithospermum cobrense	puccoon
Lithospermum multiflorum	puccoon
* Lomatium leptocarpum	biscuit root
* Lupinus hillii	hills lupine
* L. kingii	kings lupine
* L. palmeri	lupine
* Lotus utahensis	deervetch
** Melilotus alba	white sweetclover
** M. officianalis	sweetclover
* Mimulus suksdorfi	monkey flower

* Mertensia macdougalii	bluebells
** Oenothera hookeri	hooker evening primrose
* Pedicularis centranthera	wood betony
** Penstemon barbatus	beardtongue penstemon
* P. linearoides	toadflax penstemon
* P. virgatum	wandbloom beardtongue
* Phacelia magellanica	phacelia
* Phlox diffusa	spreading phlox
* Phlox grayi	phlox
* Polygonum sawatchense	knotweed
* Potentilla hippiana	cinquefoil
* Prunella vulgaris	selfheal
* Pseudocymopterus montanum	pseudocymopterus
* Pteridium aquilinum	bracken fern
* Pterospora andromedea	pinedrops
* Pyrola picta	wintergreen
P. virens	wintergreen
* Ranunculus cardiophyllus	buttercup
* Saxifraga rhomboidea	diamond leaf
* Senecio uintahensis	groundsel
* Silene mensiesii	silene
Silene scouleri	"
* Sisymbrium linearifolium	sysimbrium
* Smilacina racemosus	solomons seal
* Smilacina stellata	solomons seal
* Solidago nana	goldenrod
* S. sparsiflora	few-flower goldenrod
* Stellaria jamesiana	tuber starwort
* Swertia radiata	deers ears
** Taraxacum laevigatum	dandelion
* Thalictrum fendleri	meadow rue
* Thlaspi fendleri	thlaspi
* Townsendia excapa	townsendia
* Viguiera multiflora	showy goldeneye
* Viola canadensis	canadian violet
* Xanthocephalum sarothrae	snakeweed
* Zygadenus elegans	death camas

PERMANENT RECORD OF PERMANENT QUADRAT LOCATIONS: Forest quadrats of 1976 plant surveys

Quadrat #	Veg. type	Location;	Cairns built unless stated otherwise.
Permanent quads			
1	Ponderosa Pine	T 32 N - R 4 E; sec. 10; Walhalla plateau, E-6, 3.1 miles from E-6 source, east side of road, 50 paces.	
2	Mixed conifer	T 32 N - R 4 E, sec. 3; Walhalla plateau, E-6, .1 miles from E-6 source, west side of road, 25 paces.	
3	Mixed Conifer	T 32 N- R 2 E, sec. 14; 3.3 miles west of WLD to tiyo point, south side of road, 50 paces.	
4	Ponderosa Pine	T 33 N - R 4 E, sec. 28; On cape royal road, 5.4 miles south of junction to Pt. Imperial, east side of road, 50 paces.	
5	Mixed Conifer	T 33 N - R 3 E, sec. 7; Point Imperial road, .6 miles from junction of Cape Royal road. North side of road, 50 paces.	
6	Mixed Conifer	T 32 N - R 2 E, sec. 23; Point sublime road, 2 miles southeast from Az. alt. #67, north side, 50 paces.	
7	Mixed Conifer	T 34 N - R2 E, sec. 33; 5.2 miles from Az. alt. #67 on Pt. Sublime road, east side of road, 25 paces.	
8	Mixed Conifer	T 33 N - R 3 E, sec. 21; Wlc road, .35 miles on Wlo, left side of road, (east), 50 paces.	
9	Mixed Conifer	T 33 N - R 3 E, sec. 28; no cairn, but a log across a log. On WLC 1 mile past #8 1.35 miles in east side, 50 paces.	
10	Mixed Conifer	T 33 N - R3 E, sec. 30; WLD 3 miles in from source, left side of road (east), 50 paces.	
11	Ponderosa Pine	T 32 N - R 3 E, sec. 6, WLD, 3 miles south of #10, or 6 miles in from source of WLD, 50 paces east.	
12	Mixed Conifer	T 33 N - R 3 E, sec. 21; WI, 1.8 miles west of WIA turnoff, south side, to 50 paces.	
13	Mixed Conifer	T 33 N - R 3 E, sec. 22; WIA 1 mile north-west from WI, 25 paces on left (south) side.	
14	Mixed conifer	T 33 N - R 3 E, sec. 11; E-I one mile in (on foot), northeast, then south of road 100 paces up slope.	
15	Mixed Conifer	T34 N - R 3 E, sec. 29; 1.5 miles south of north entrance, south side of Az. alt. #67, 50 paces up over the embankment.	

Quadrat # Veg. type Location;

Permanent quads		
16	Mixed Conifer	T 34 N - R 4 E, sec. 20; to North Rim lookout tower, 1 mile east of N. entrance station, right (south) side, 50 paces.
17	Mixed Conifer	T 33 N - R 2 E, sec. 1; 1.2 miles west on WIE, off of WI, north side, 25 paces.
18	Mixed Conifer	T 33 N - R 2 E, sec. 30; W-4, 12 miles north of road, W-4 junction, west side of road, 25 paces.
19	Mixed Conifer	T 32 N - R 2 E, sec. 18; W-4 2 miles from #18A (2.2 miles from W-4 junct. NW, 100 paces east, across shallow meadow.
20	Ponderosa Pine	T 33 N - R 2 E, sec. 7; .4 miles from W6A junct., left (south) side of road, 25 paces, near Galahad point.
Non-permanent quads - For the 1976 study only. - no stakes -		
1	Pinyon	T 32 N - R 4 E, sec. 34; 200 paces off path-west 50 paces.
2	Pinyon	T 33 N - R 3 E, sec. 5; widforss point, right (west) side of trail terminus, no markers.
3	Pinyon	T 32 N - R 1 E, sec. 2, point sublime, .5 miles from road end.
4	Pinyon	T 32 N - R 4 E, sec. 24; cape final, north of road end, 200 paces.
5	Pinyon	T 32 N - R 4 E, sec. 34; cape royal, SE of Angels window.

CANOPY COVER VALUES BY INDIVIDUAL SPECIES HEIGHTS

(From Kershaw)

<u>Height in Ft.</u>	<u>Species</u>	<u>ES</u>	<u>CBS</u>	<u>WF</u>	<u>SAF</u>	<u>DF</u>	<u>PP</u>	<u>A</u>
20		20	25	30	30	20	10	5
30		40	50	50	50	35	25	15
50		70	100	100	100	50	45	20
70		100	150	200	150	100	75	30
90		150	200	300	250	150	100	40
100		200	250	400	350	200	150	50

Factors altering the above norms:**

- 1) Inter and intra species competition
- 2) Slope
- 3) Aspect
- 4) Individual plant vigor
- 5) Micro-habitats

** The standard value system is an accurate assessment of the shaded ground surface as projected by the canopy of each species, measured at 12 noon. The ecology for each species is standardized barring microhabitat extremes.

SHRUB HEIGHT CLASSES

- 1 - Less than one foot height.
- 2 - One to 3-1/2 feet high.
- 3 - 3-1/2 to 6 feet high.
- 4 - More than 6 feet high, but less than 1 inch diameter at breast height.
- 5 - Over 6 feet high but between 1-4 inches diameter at breast height.
- 6 - Is arborescent to the extent that it is a tree.

C O V E R C L A S S E S

- 0 - None
- T - 1.0%
- 1 - 1-5%
- 2 - 5-10%
- 3 - 10-25%
- 4 - 25-50%
- 5 - 50-75%
- 6 - 75-95%
- 7 - 95-100%